2018

Variable Force Mechanical Stabber and Slasher

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Team 21 - Take a Stab At It
Variable Force Mechanical Stabber and Slasher:
Final Design Review

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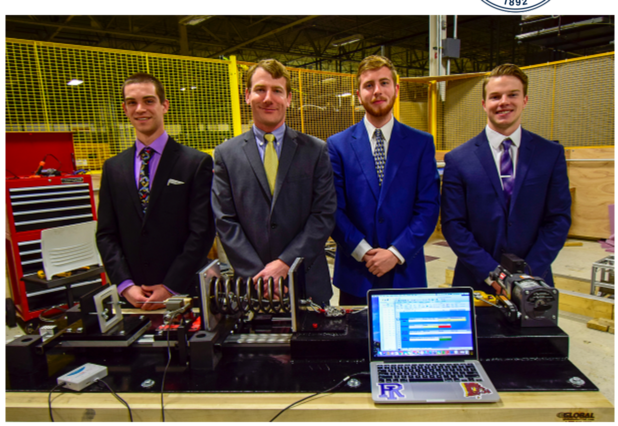
Maxwell Caro - Software Design and Modeling
Alec Svendsen - Manufacturing and Modeling
Brody DiPentima - Material Selection and Manufacturing

Facilitated by Dr. Bahram Nassersharif



May 7, 2018

The University of Rhode Island
Department of Mechanical, Industrial, & Systems Engineering

Abstract

The main focus of the design was to create a variable force mechanical stabber and slasher for Dr. Nassersharif for testing material sample developed by Team 20 and other departments at the University of Rhode Island (URI). The table was designed to deliver impact energies ranging from 0 to 165 Joules (J). The variable force is created through compressing a spring mechanically and measuring the velocity at impact on a test specimen. The spring propels a cart on a track system to constrain the movement of the attack in a specific direction. The system uses software to determine the initial compression based on user inputted impact energy. Velocity and acceleration data is acquired and read by the software to determine the kinetic energy and impact force. Testing of the system was performed and the results analyzed to determine future work and improvements.

Desmark/Amerisewn is a local company that is based in Cranston, Rhode Island and manufactures protective clothing for law enforcement, correctional officers, and mental health professionals. Those industries require workers to wear protective clothing that must be certified through the National Institute of Justice (NIJ). Non-balistic protective clothing is certified through professionally through the NIJ for impact energies ranging from 24 J to 65 J.

The current design achieves several design specifications such as a spring being able to achieve 40000 cycle before failure while the goal was 5000 cycles. The spring can also deliver impacts that achieve the NIJ tests standards. Another main requirement was obtaining impact kinetic energies that could achieve exceed the maximum NIJ test by 2.5 times. The robustness of the spring means that it is not compressed its full length in order to do so. The machine can also simulate a slash with a self centering swivel vice that has the angle of attack adjusted simply if the tester desires. Additionally, a linear relationship between the spring compression and release velocity was established for testing.

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Nomenclature

a:	Constant For Spring Calculations
b:	Constant For Spring Calculations
d:	$\frac{1}{2}$ Of The Spring Diameter (in)
D:	Diameter Of Bar (in)
f:	Fatigue Strength Fraction
k:	Spring Constant (N/m)
k_a:	Spring Surface Factor
k_b:	Spring Size Factor
k_c:	Spring Loading Factor
k_d:	Spring Temperature Factor
k_e:	Spring Reliability factor
KE:	Kinetic Energy (J)
L_b:	Length Of Bar (in)
m:	Mass (g)
N:	Number Of Cycles For Spring Failure
N_t:	Number Of Turns Of The Spring
PE:	Potential Energy (J)
P_{max}:	Maximum Pressure (lbs)
S_e:	Endurance Strength (kpsi)
S_e':	Spring Endurance Limit (kpsi)
S_{ut}:	Ultimate Strength (kpsi)
T:	Torque (lbf ft)
v:	Velocity (m/s)
x:	Displacement (m)
z_a:	Transformation Variate
σ_{rev}:	Stress In Spring (kpsi)
μ :	Coefficient Of Friction
τ_{max}:	Maximum Shear Stress (kpsi)

List of Acronyms

URI:	University Of Rhode Island
BOM:	Bill Of Materials
DRO:	Digital Readout
NIJ:	National Institute Of Justice
UHMWPE:	Ultra High Molecular Weight Polyethylene
MCE:	Mechanical Engineering
ROI:	Return On Investment
GUI:	Graphical User Interface
RAM:	Random Access Memory
VB:	Visual Basic

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1 Introduction

The scope of the project focuses on supporting Dr. Nassersharif's research, Team 20's test specimen, and other materials research URI where test specimens undergo dynamic strike events. There are several sections that will detail the most import aspects of the capstone. The background for the project covers the specimen Team 20 is designing. The motivation for the project is primarily economic. The specific problem definition will be a detailed overview of the variable force stabber and slasher.

1.1 Background

URI has been interested in developing inter department research opportunities as part of it's academic mission. [1] For the 2017 - 2018 capstone, Dr. Nassersharif developed a project that had two groups work together to develop stab and slash resistant material and a variable force mechanical stabber and slasher.

Part of Dr. Nassersharif's project involved some outreach to Desmark/Amerisewn, a Cranston based company that manufactures protective clothing for law enforcement and correctional officers. The company has 35 years of experience in the protective clothing industry. The products are made in Rhode Island for law enforcement, correctional officers, military, and medical personnel. These industries generally require employees to accept some physical risk during their normal work routine. As professionals in the industry, they provided their insight into material development and how their products are certified through the National Institute of Justice (NIJ). The NIJ non-ballistic armor standards provided impact energies for certification to begin the mechanical design of the testing device. [2] Dr. Nassersarif provided constructive feed back on the capabilities of the tester as the project progressed over the year.

1.2 Motivation

The motivation of the project was to create a variable force mechanical stabber and slasher that measured impact energy and force on a material test specimen. Some critical design considerations are the repeatability and accuracy of testing. The group designed the machine that could deliver impact energies with a 5% error from the expected impact energy and recorded impact energy. This provides a reasonable assurance that the test specimen was struck with the desired energy and any data extracted from testing will be accurate and true. Another motivation was developing coordination with Team 20 and designing a system that could hold their material specimen for testing.

1.3 Problem Definition

The primary problem being solved is designing a modular test system that can help URI perform material testing systematically through predicting and measuring the kinetic energy and force delivered on impact to the test specimen. The tester would be important because it can test new materials and designs at a URI facility instead of an outside agency. A good machine will save time and money because the tester receives instant feedback. The system will also help Team 20 design modules because of accurate data acquisition and repeatable testing.

The tester needs to to have positive control based on a desired impact energy set by the tester. Currently the tester produce energies to 165 Joules (J) which is 2.5 times the NIJ maximum energy test for non-ballistic armor. [2] The tester must also be easily operated by a single user which is currently being achieved through an Excel Macro and easy to handle physical controls. A considerable design factor is the wide range of users from Desmark/Amerisewn (non-engineers) to researchers from URI with engineering background or degrees. The goal is to design a system that non-engineers can use with minimal training and researchers can get relevant information.

The most difficult part of the system is what to measure on impact. Desmark/Amerisewn has some easily definable measurements needed due NIJ published standards and provides guidance for materials testing at URI. The essentials are energy dissipation in the specimen and penetration depth if there is any. Currently, testing concerns stabbing and slashing high endurance materials and provide similarities between Desmark/Amerisewn and URI needs.

The tester will be modular in nature to simulate different attacks like stabs, slashes, and blunt force. The first phase of the machine will adhere to the design specifications with the understanding that it will need to perform more than a range of stabs attack specified. It is important that the group keeps the design simple and adaptable so that a range of angles and attacks can be simulated.

An additional requirement is creating energy profiles that simulate a range of attackers. The current NIJ testing only focuses on a pass / fail requirement for armors. Desmark/Amerisewn would like testing to focus on more common threats that law enforcement and correctional officers face. They would like to create common energy profiles that are approximations of sex, weight, and skill level which corresponds to an output energy.

A final consideration of armor design and testing is the wide range of body shapes that the armor has to adhere to as well as the different physical shapes for male and female torsos. An unfortunate reality is the range of fitness levels among law enforcement and correctional officers means that armor design has to be approximated. The same is true for female officers since their bust size and other different dimensions from males affects how the armor contours to their bodies.

2 Project Planning

Project planning was complex for the duration of the project. There was a constant adjustments of deadlines between major milestones due to shipping and fabrication times. A gantt chart was used to organize the general tasks that the team had to accomplish for the semester, but simultaneously allow for flexibility when unexpected challenges arrived.

The plan shown in Fig. 1 had to have the team members working in parallel on several different tasks that complimented each other. The beginning of the project was primarily dominated with research and concept generation of the table design. At the end of the first semester, the team had a proof of concept generated, but needed to fabricate and test the assumptions.

The tasks for second semester focused on three areas:

1. System Modeling
2. Fabrication
3. Software Integration
4. Test Engineering Plan
5. Build Presentation
6. Design Showcase

2.1 System Modeling

System modeling was handled primarily by Maxwell Caro and Nicholas Perry. The primary tasks they had to complete was create a dynamic model of the table that could create a linear relationship between the spring compression and release velocity which is detailed in Sec. 12. The system modeling was important for the test engineering plan because it was important to confirm the assumptions the dynamic model through testing.

2.2 Fabrication

Fabrication was the most complex and detailed task that the group accomplished. All group members participated in fabrication, but the effort was lead primarily by Alec Svendson through his knowledge of machining and Brody DiPentima handling the logistics by placing and tracking the order forms and bill of materials. Since system modeling and fabrication were occurring simultaneously, good coordination between the team was required to work towards the same deadlines.

2.3 Software Integration

The software integration was performed by Maxwell Caro and Brody DiPentima. The integration required research into the optimal software and hardware that could capture velocity readings for impact energies. Another crucial aspect was developing a calculator on Microsoft Excel that could determine spring displacement corresponding to impact energy.

2.4 Test Engineering Plan and Build Presentation

The test engineering plan and build presentation were complementary tasks that the group accomplished collectively. The test plan involved creating a test procedure that ensure safe operation while recording velocity measurements. Another critical aspect was recording the test results to compare the theoretical and measured velocity readings.

2.5 Design Showcase

The final task for the semester was the design showcase which had the group create a larger poster and brochures for an open house presentation that was open to the public and sponsors. The paper work was a summary of the years work that had to reach a wide audience which included engineers, professors, and parents of students. Additionally, the group prepared for live demonstrations of the the completed stabber to show that the systems developed over the semester worked as intended.

ID	Indicators	Task Mode	Task Name	Duration	Start	Finish	Resource Names
1			**FALL SEMESTER**	**74 days**	**Wed 9/6/17**	**Mon 12/18/17**	**Team**
2			**CONCEPT GENERATION**	**23 days**	**Thu 9/21/17**	**Mon 10/23/17**	**Team**
3			Group Assignment 1	3 hrs	Thu 9/21/17	Thu 9/21/17	Team
4			Patent Search	7 days	Thu 9/21/17	Fri 9/29/17	Team
5			Standards Search	7 days	Thu 9/21/17	Fri 9/29/17	Brody,Max
6			Intial Project Plan	3 days	Thu 9/21/17	Mon 9/25/17	Team
7			Finalized Project Plan	6 days	Tue 9/26/17	Tue 10/3/17	Team
8			3D Design Concept	54 days	Thu 9/21/17	Tue 12/5/17	Team
9			**Concept Design Presentation**	**28 days**	**Fri 9/22/17**	**Tue 10/31/17**	
10			**ANALYSIS**	**19 days**	**Thu 9/21/17**	**Tue 10/17/17**	
11			QFD	13 days	Fri 9/29/17	Tue 10/17/17	Team
12			**DESIGN**	**28 days**	**Fri 9/29/17**	**Tue 11/7/17**	
13			Design Specifications	15 days	Fri 9/29/17	Thu 10/19/17	
14			Updated Design Specifications	5 days	Wed 11/1/17	Tue 11/7/17	
15			30 Designs	13 days	Sun 10/1/17	Tue 10/17/17	Team
16			**Weekly Progress Report**	**51 days**	**Mon 9/25/17**	**Mon 12/4/17**	**Team**
17			Weekly Progress Report 1	1 day	Mon 9/25/17	Mon 9/25/17	Nick
18			Weekly Progress Report 2	1 day	Mon 10/2/17	Mon 10/2/17	Alec
19			Weekly Progress Report 3	1 day	Mon 10/9/17	Mon 10/9/17	Max
20			Weekly Progress Report 4	1 day	Mon 10/16/17	Mon 10/16/17	Brody
21			Weekly Progress Report 5	1 day	Mon 10/23/17	Mon 10/23/17	Nick
22			Weekly Progress Report 6	1 day	Mon 10/30/17	Mon 10/30/17	Alec
23			Weekly Progress Report 7	1 day	Mon 11/6/17	Mon 11/6/17	Max
24			Weekly Progress Report 8	1 day	Mon 11/13/17	Mon 11/13/17	Brody
25			Weekly Progress Report 9	1 day	Mon 11/20/17	Mon 11/20/17	Nick
26			Weekly Progress Report 10	1 day	Mon 11/27/17	Mon 11/27/17	Alec
27			Weekly Progress Report 11	1 day	Mon 12/4/17	Mon 12/4/17	Max
28			**Proof of Concept Presentation**	**0 days**	**Tue 12/5/17**	**Tue 12/5/17**	**Team**
29			**Final Report**	**0 days**	**Mon 12/18/17**	**Mon 12/18/17**	**Team**
30			**SPRING SEMESTER**	**76 days**	**Mon 1/22/18**	**Mon 5/7/18**	**Team**
31			**Weekly Progress Report**	**61 days**	**Mon 1/29/18**	**Mon 4/23/18**	**Team**
32			Weekly Progress Report 1	1 day	Mon 1/29/18	Mon 1/29/18	Nick
33			Weekly Progress Report 2	1 day	Mon 2/5/18	Mon 2/5/18	Alec
34			Weekly Progress Report 3	1 day	Mon 2/12/18	Mon 2/12/18	Max
35			Weekly Progress Report 4	1 day	Mon 2/19/18	Mon 2/19/18	Brody
36			Weekly Progress Report 5	1 day	Mon 2/26/18	Mon 2/26/18	Nick
37			Weekly Progress Report 6	1 day	Mon 3/5/18	Mon 3/5/18	Alec
38			Weekly Progress Report 7	1 day	Mon 4/2/18	Mon 4/2/18	Max
39			Weekly Progress Report 8	1 day	Mon 4/9/18	Mon 4/9/18	Brody
40			Weekly Progress Report 9	1 day	Mon 4/16/18	Mon 4/16/18	Nick
41			Weekly Progress Report 10	1 day	Mon 4/23/18	Mon 4/23/18	Alec
42			**DESIGN IMPLEMENTATION**	**50 days**	**Mon 12/18/17**	**Fri 2/23/18**	**Team**
43			Order Material	35 days	Mon 12/18/17	Fri 2/2/18	Brody,Nick
44			Deisgn Analysis	20 days	Mon 1/22/18	Fri 2/16/18	Alec,Nick
45			Create Dimensions	40 days	Mon 12/18/17	Fri 2/9/18	Max,Alec
46			Assemble Machine	50 days	Mon 12/18/17	Fri 2/23/18	Team
47			**TESTING**	**24 days**	**Fri 2/23/18**	**Wed 3/28/18**	**Team**
48			Develop Testing Procedure	16 days	Fri 2/2/18	Fri 2/23/18	Nick
49			Develop Excel Macro	6 days	Wed 2/21/18	Wed 2/28/18	Max
50			Initial Testing	10 days	Mon 3/26/18	Fri 4/6/18	Team
51			Prepare Presentation, Poster, and Brochure	4 days	Fri 3/23/18	Wed 3/28/18	Team
52			**DOCUMENTATION**	**43 days**	**Wed 2/28/18**	**Fri 4/27/18**	**Team**
53			Test Design Report	8 days	Wed 3/14/18	Fri 3/23/18	Team
54			Paper Draft	28 days	Wed 3/7/18	Fri 4/13/18	Alec,Brody
55			**1st Presentation**	**0 days**	**Wed 3/28/18**	**Wed 3/28/18**	**Team**
56			**REDESIGN**	**21 days**	**Wed 3/28/18**	**Wed 4/25/18**	**Team**
57			Analyze Test Reults	11 days	Fri 4/6/18	Fri 4/20/18	Team
58			Target Holder	11 days	Fri 4/6/18	Fri 4/20/18	Team
59			**Design Showcase**	**0 days**	**Fri 4/27/18**	**Fri 4/27/18**	**Team**
60			**Final Report Due**	**0 days**	**Mon 5/7/18**	**Mon 5/7/18**	**Team**
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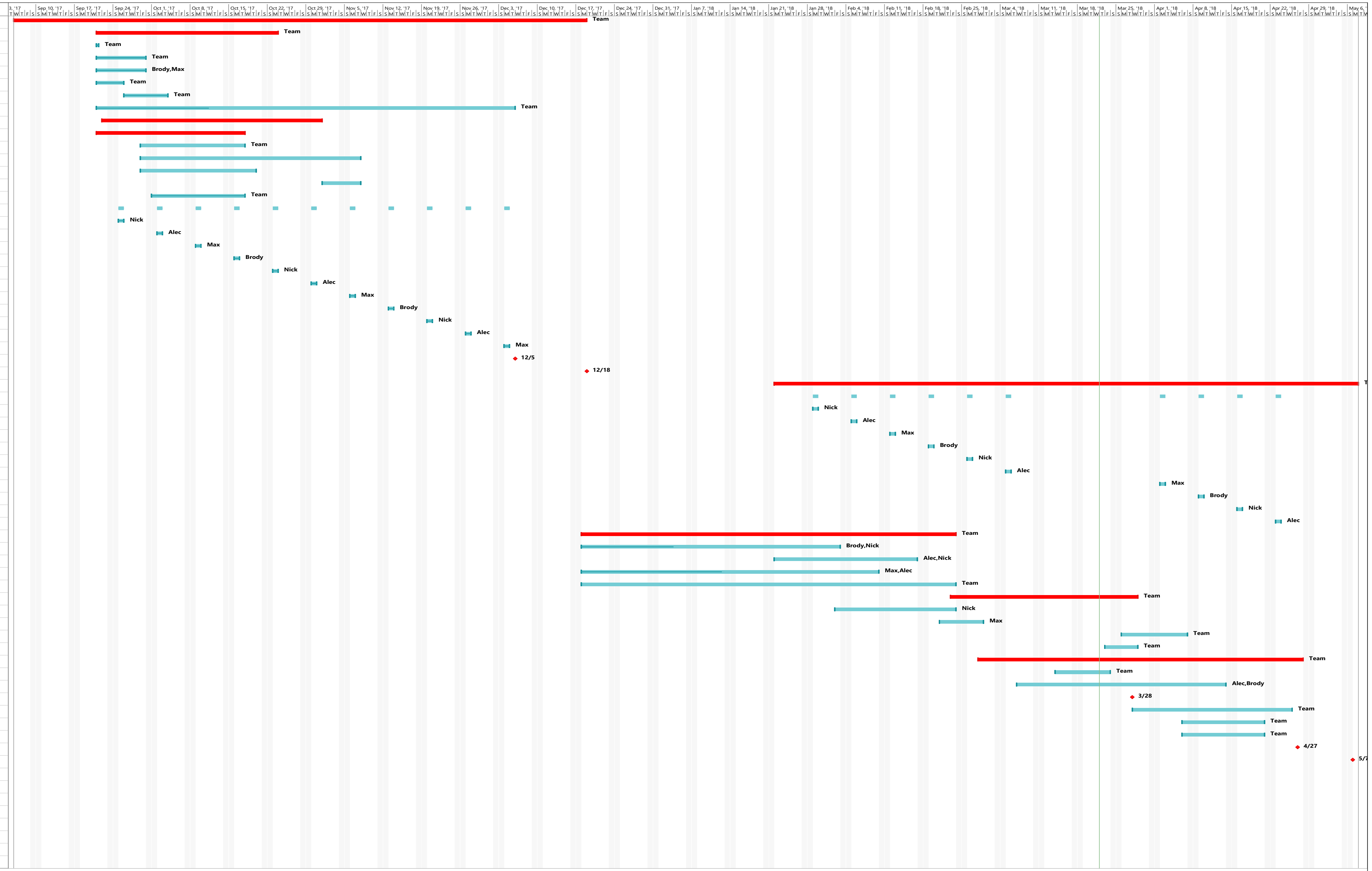


Project: Team 21 Project Plan (0
Date: Thu 3/22/18

Task · Split · Milestone · Summary · Project Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · External Tasks · External Milestone · Deadline · Progress · Manual Progress

Page 1

Figure 1: Team 21 Project Plan (v1.5)

3 Financial Analysis

3.1 Funding

The project is funded by both URI and Desmark/Amerisewn. The team was given no finite number for funding but were requested to keep costs between $2000 - $ 3000. The funding for this project would cover both materials and shipping costs.

3.2 Material Costs

Finding the right parts for this project while also keeping the budget in mind turned out to be quite a challenge for the team. Since the project is fully custom and has very specific requirements, many parts requested were of higher quality and more expensive. Parts like the track system and the quick release shackle are of rated higher than the desired specifications. This was a necessary precaution, because less expensive parts could lead to device failure and potential injury. The table below lists all the parts currently purchased for the project.

Table 1: Purchased Parts

Part	Part Cost	Quantity	Total Cost
Table	$299.95	1	$299.95
Utility Winch	$262.63	1	$262.63
Steel Compression Spring	$33.11	1	$33.11
Integral V Linear Guide (Track)	$128.169	1	$128.16
Rubber stopper	$29.95	4	$119.80
Right Angle Plates	$100.50	1	$100.50
Cart Top Plates	$26.92	2	$53.84
Spring mount plates	$40.06	2	$80.12
Self Centering Vise	$137.81	1	$137.81
Quick Release Shackle	$312.01	1	$312.01
Cart	$271.63	2	$543.26
DRO	$33.19	1	$33.19
Rust Preventing Paint	$23.88	1	$23.88
Table Steel Top	$116.00	1	$116.00
Steel Square Channel	$14.48	1	$14.48
Pulley	$33.26	1	$33.26
C-Channel	$106.65	1	$106.65
U-Bolt	$1.94	1	$1.94
6061 Aluminum for cart stop	$8.21	1	$8.21
Target Right Angle Plate	$29.29	1	$29.29
Cart Stop Knob	$15.87	1	$15.87
Shackles	$10.53	2	$21.06
Wrong U-Bolt	$4.51	1	$4.51
Lanyard	$17.61	1	$17.61
Total			**$2437.25**

Table 2: Purchased Hardware

Part	Part Cost	Quantity	Total Cost
3/8"-16 Thread Size, 1" Long	$9.37	1	$9.37
1/4"-20 Thread Size, 1" Long	$9.09	1	$9.09
5/16"-24 Thread Size, 1-1/4" Long	$9.39	1	$9.39
3/8"-16 Thread Size, 5" Long, Fully Threaded	$8.21	1	$8.21
Extreme-Strength 1/2"-13 Thread Size, 5" Long	$5.69	2	$11.38
Wing-Head Thumb Screw 1/4"-20 Thread Size, 2" Long	$4.48	4	$17.92
Total			**$72.02**

With the total amount spend being $2509.27, the project landed within budget. At the moment, there are no plans for further purchases. A computer will be provided by Amerisewn for their use, as well as the Logger Pro data collection software. The software and computer will be provided by URI while being used at the university.

3.3 Production Costs

Since this project is being built for a very specific purpose, it is never intended to go into mass production. With such a niche market, mass production may not be profitable. This means if the product were to be produced more than once, it would be a custom made. Using Tables 1 and 2, the approximated material cost can be calculated.

There would also be costs in manufacturing and assembling the device. The estimation of these costs can be seen below in Table 3.

Table 3: Total Labor Costs

Task	**Est. Time Required (Hrs)**	**Cost per Hour**	**Total Cost**
Assembly	8	$25.00	$200.00
Machining	5	$30.00	$150.00
Welding	3	$30.00	$90.00
Programing and Calibration	3	$30.00	$90.00
Total			**$530.00**

In order to to manufacture and assemble a single functioning device, the estimated cost is roughly $3039.27. These costs are an approximated and the total time required for this process is between 1-2 working days. This is just over the desired budget, but because the machine isn't going to be reproduced with paid labor, the machine will never be above budget.

3.4 Return on Investment

An important part of this project is making sure the product will save money for the consumer; in this case URI and Amerisewn. Their were many different focuses of this product, one is to simulate NIJ Test Standards and to assist in the design and production of materials in an effective and efficient way. If a new material sample is made, it must shipped off to pass NIJ testing. This takes time and costs money approximately $200 per test. If the material fails, the time and money is completely wasted. This product would not only to able to guarantee a material passes NIJ quality tests within minutes, but also aid in the production for new materials. After materials are tested on site, they can then be sent out o officially pass NIJ quality standards, ultimately saving time and money.

Amerisewn states they send out approximately 15 samples a year to be officially tested with each test taking 3-4 weeks to acruie results. If one makes the assumption that a third of those tests fail, that is 15-20 weeks of loss of production where progress could've been made. That would be approximately $1000.00 lost in testing costs and possibly even more money in labor costs. The use of this product would eliminate the waiting period and allow the user to immediately redesign the sample if it wasn't up to quality standards. Depending on the amount of samples being sent out for quality standard testing and the amount of research and development the using company requires, investment could easily be returned within a few years.

3.5 Human Resource Allocation

Throughout the course of the 2018 spring Semester, the team spent several hours devoted to the Project. One can see the division of hours for each team member listed in the Tables below. The hours are divided up into several different sections for each team member and may vary depending on the tasks the were responsible for.

Table 4: Time Contributed to Project for Spring 2018 Maxwell Caro

Task	**Time (Hours)**
Research	60
Calculations	15
Build	10
Design	25
Proof of Concept and Engineering Analysis	15
Financial Planning	2
SOLIDWORKS Modeling	20
Bill of Materials	3
Total	**150**

Table 5: Time Contributed to Project for Spring 2018 Brody DiPentima

Task	**Time (Hours)**
Research	60
Calculations	20
Build	8
Design	30
Proof of Concept and Engineering Analysis	20
Financial Planning	3
SOLIDWORKS Modeling	0
Bill of Materials	10
Total	**151**

Table 6: Time Contributed to Project for Spring 2018 Nicholas Perry

Task	**Time (Hours)**
Research	60
Calculations	15
Build	6
Design	35
Proof of Concept and Engineering Analysis	15
Financial Planning	5
SOLIDWORKS Modeling	6
Bill of Materials	10
Total	**152**

Table 7: Time Contributed to Project for Spring 2018 Alec Svendsen

Task	**Time (Hours)**
Research	60
Calculations	16
Build	5
Design	40
Proof of Concept and Engineering Analysis	11
Financial Planning	9
SOLIDWORKS Modeling	10
Bill of Materials	2
Total	**153**

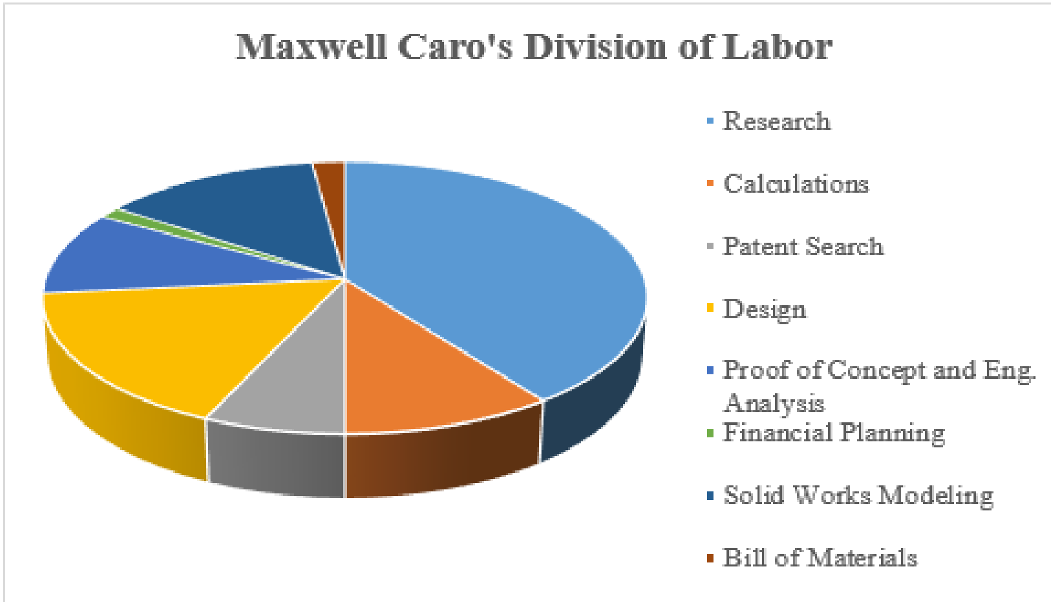


Figure 2: The Time Distribution of Maxwell Caro during the spring 2018 Semester

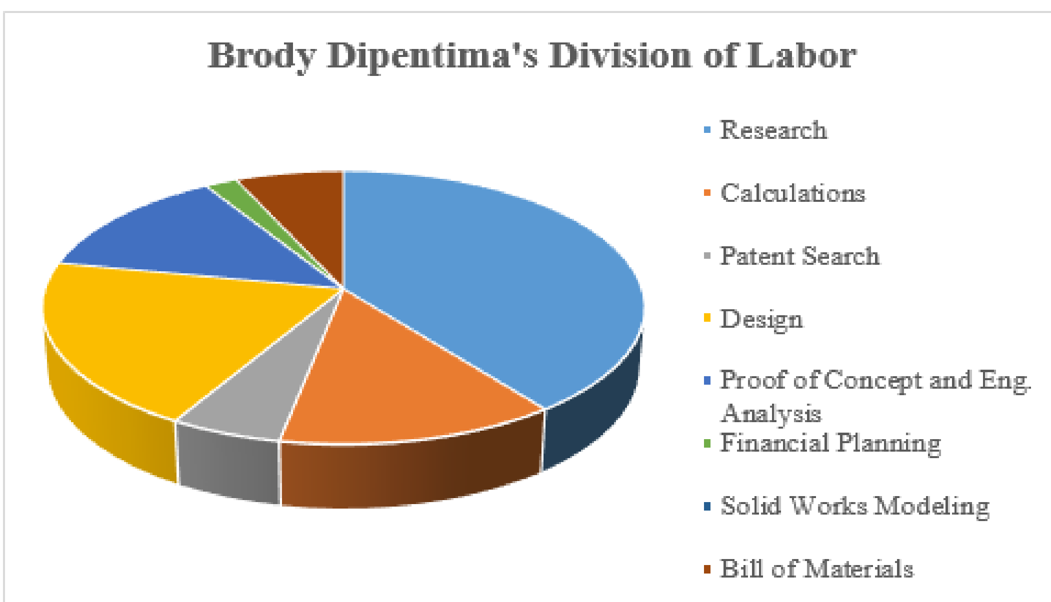


Figure 3: The Time Distribution of Brody DiPentima during the spring 2018 Semester

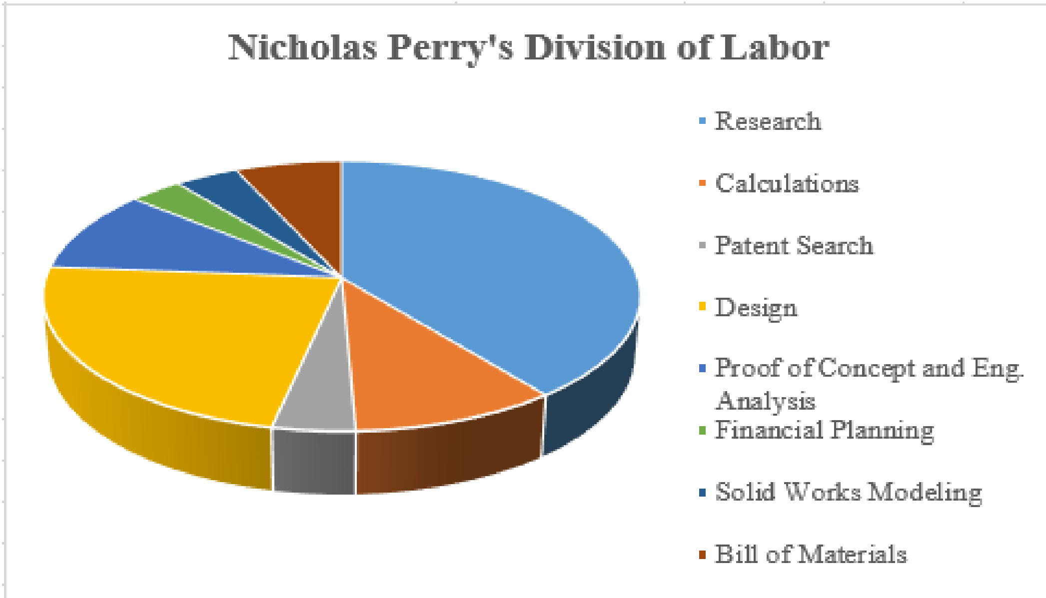


Figure 4: The Time Distribution of Nicholas Perry during the spring 2018 Semester

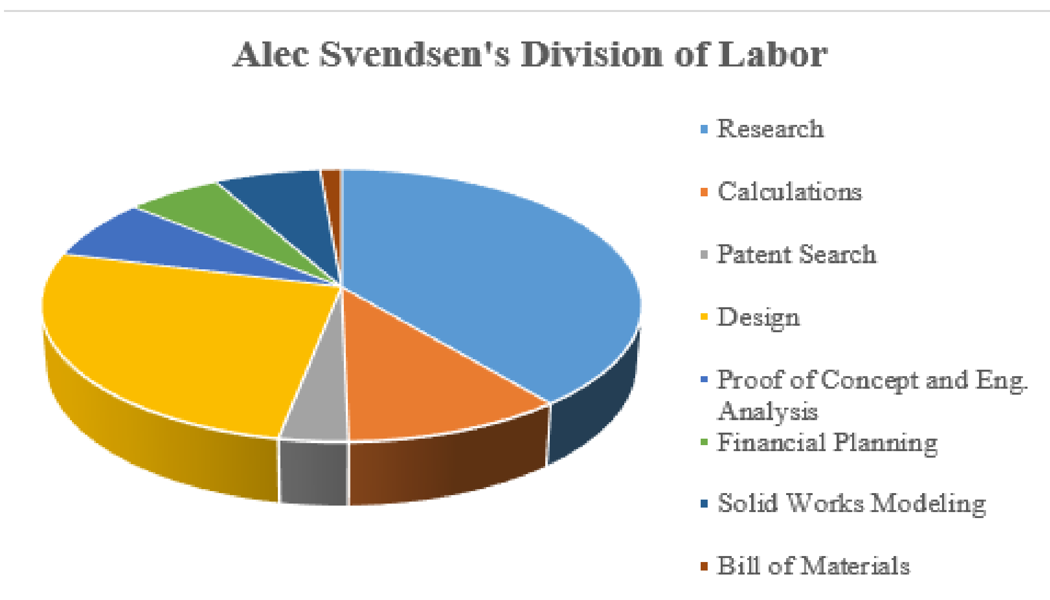


Figure 5: The Time Distribution of Alec Svendsen during the spring 2018 Semester

Table 8: Total Time Spent on Project Spring 2018

Team Member	**Time (Hours)**
Maxwell Caro	150
Brody DiPentima	151
Nicholas Perry	152
Alec Svendsen	153
Total	**606**

Table 9: Total Project Cost due to Engineers and Consultants

Responsible Party	**Time Spent (Hours)**	**Cost per Hour**	**Total Cost**
Team 21 Members	606	$30.00	$ 18,180.00
Dr. Nassersharif	3	$ 75.00	$ 225.00
Amerisewn	3	$ 75.00	$ 225.00
Total			**$18,630.00**

4 Patent Search

One of the first steps in creating a new product is to make sure that whatever is going to be made will not infringe on existing patents. Since overlooking this aspect of a project can ruin a business model, it was stressed to start with this first. Almost instantly after given the project of a mechanical stabber, work was done by each member in attempt to find products that are already on the market and had patents. Since the project is going to be a one-off attempting to only use in house, and not for profit, the patent search turned into finding other products that relate to impact testing and using the patents to reverse engineer a system that can work for Amerisewns' Take a Stab At It team.

Other concepts that were learned in doing the patent search was the classification system. Many of the class numbers were in connection to vibration and impact testing, garments to protect against blows, and analyzing material properties by measuring acceleration and shocks.

4.1 Patent Search

US6523391/Vertical Height Impact Testing Apparatus
Date: February 5, 2003
Rights Owned By: Kenneth A. Knox

Abstract: A vertical impact testing apparatus comprises a rigid frame, an anvil connected to the frame, a dart positioned above the anvil, and a dropped-weight mechanism connected to the frame. The frame is comprised of a vertical column, a base, and a guide rail. The vertical column extends for a sufficient distance to securely support a weight assembly through travel from various heights for testing a specimen. To facilitate downward travel of the dropped-weight mechanism at a proper vertical orientation, a guide block is rigidly attached to the weight assembly and the dropped-weight mechanism is mounted to the guide rail. The dart is stabilized by a braced support arm connected to the frame and a bearing acting cooperatively to ensure impact of the dart with the specimen is in the vertical plane and without tilt. The anvil is a solid structure, fixed in position, which contacts and supports the specimen on a side opposite of the dart as the dart impacts the substrate and forces it downward. [3]

Relevance: This patent has a design very similar to our method of delivering the weapon to the specimen but in a vertical, weight-driven design rather than a horizontal, spring-driven design. The overall structure and track system as well as the interchangeable target system influenced our design.

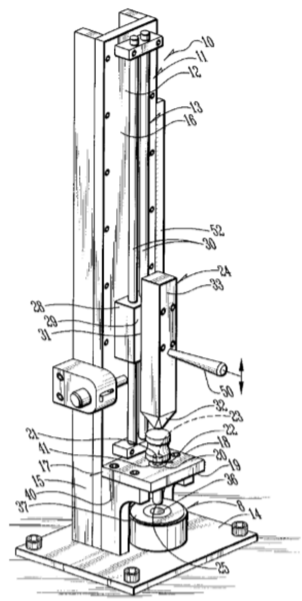


Figure 6: Vertical Height Impact Testing Apparatus

US9395264/Blunt Impact Test Apparatus And Method
Date: July 19, 2016
Rights Owned By: Donald E. Powers

Abstract: A blunt impact test apparatus includes an apparatus frame having track rails for positioning proximate the test structure; a track angle positioning mechanism engaging the track rails to control a slope of the track rails; and an impact cart adapted to roll on the track rails. [4]

Relevance: The track and cart system is very similar to the design we ended up adopting with the help of this patent. An angled track allows gravity to deliver the payload at low energies. Since we needed a higher energy output, a spring was implemented into the design to increase the speed therefore, increasing the energy output.

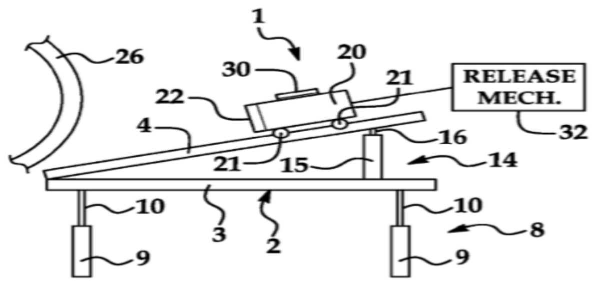


Figure 7: Blunt Impact Test Apparatus And Method

US8667879/Multilayer Backing Materials for Composite Armor
Date: March 11, 2014
Rights Owned By: Julie A. Kidd

Abstract: A multilayer backing composite for armor plate systems. One embodiment provides a ceramic layer and a bonded multilayer backing layer bonded to the ceramic layer. The backing layer can be formed from at least two layers each of alternating elastomeric interstitial layers and UHMWPE layers having an areal density in the range of about 125 to 400 g/m^2. The areal density of the stack can be in the range of about 4 to 15 lbs/ft^2, and specifically about 6.98 lbs/ft^2. In some embodiments, at least one of the at least two UHMWPE layers nearer to the ceramic layer of the stack can have a lower areal density than at least one layer further from the ceramic layer. The ceramic layer can be SiC and 0.280 thick; each rubber layer can be about 0.01; and each UHMWPE layer can be about 0.15. [5]

Relevance: The multilayer backing can be used in our target system behind the specimen.The sturdy composite backing will give the most accurate results without interfering with the results of the specimen in question. Though the target system will be more prominent second semester, we have looked into the backing material for the specimen and the patent has given us many ideas.

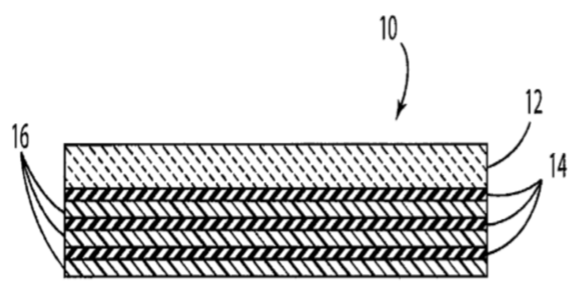


Figure 8: Blunt Impact Test Apparatus And Method

US9719901/Impact Tester Device

Date: August 1, 2017
Rights Owned By: Wade C. Jackson

Abstract: Systems and methods for testing an impact response of a material and/or structure to one or more impacts of known magnitude. The systems and methods include a portable impactor device for imparting an impact force on a surface of an engineered structure, wherein the portable impactor device has an adjustable orientation such that an impact may be delivered as an angle ranging from ± 90 ° relative to a horizontal plane. Additionally, the portable impactor device described may be utilized to test an impact response of one or more surface areas of a full-scale prototype structure. [6]

Relevance: The Spring system to see how much energy was dissipated will likely be implemented into the target to test blunt force and energy dissipation. The compression length of the spring will determine how much energy the body armor dissipated when compared to the compression with no armor.

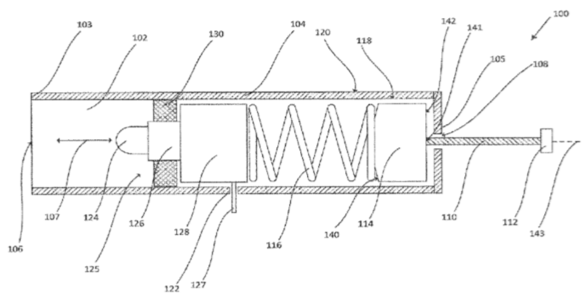


Figure 9: Blunt Impact Test Apparatus And Method

US9562825/Shock Sensor with Latch Mechanism and Method of Shock Detection
Date: February 7, 2017
Rights Owned By: Michael Naumann

Abstract: A micro-mechanical shock sensor includes a proof mass coupled to a surface of a substrate and projection element extending laterally from the proof mas. The shock sensor further include a latch mechanism and retention anchor. The mechanism has a latch spring attached to the surface and latch tip extending from a movable end of the latch spring. The retention anchor is attached to the surface and is located proximate the latch tip. The proof mass is configured for planar movement relative to the substrate when the proof mass is subjected to a force of at least a threshold magnitude. Movement of the proof mass in response to the causes the latch tip to become retained between the projection element and the retention anchor to place the shock sensor in a latched state. The latched state may be detected by optical inspection, probe, or external readout. [7]

Relevance: Measuring the impact of the knife accurately is a key task that the system needs to achieve. There are several outputs to measure over the front and back faces of the armor the groups need to account for in second semester. This system is potentially useful because a threshold force triggers the system which means that the knife impact while be the only factor that triggers the latch.

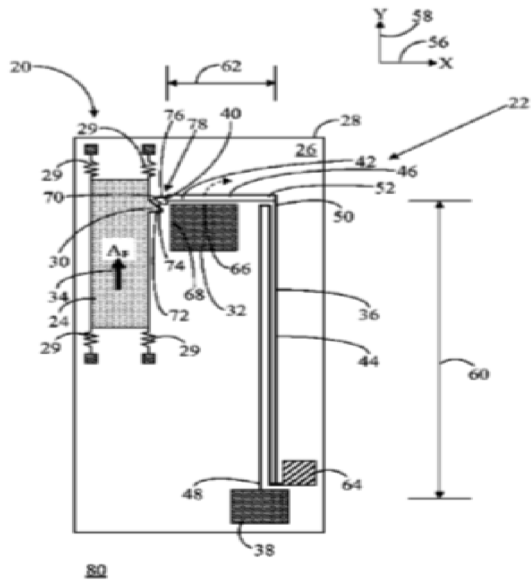


Figure 10: Blunt Impact Test Apparatus And Method

US9243699/Pressure Sensor for Anthropomorphic Dummies
Date: January 26, 2016
Rights Owned By: Phillipe Beillas and Francois Alonzo

Abstract: The present invention relates to a pressure sensor for measuring the pressures experienced by an anthropomorphic dummy in an abdominal or thoracic section of the trunk of said dummy. This sensor comprises at least two fluid-tight flexible pressure-measurement chambers (**4**) arranged in the abdominal or thoracic section of the trunk of said dummy on each side of a sagittal median plane of said abdominal or thoracic section, said pressure-measurement chambers (**4**) being filled with an incompressible fluid and each comprising at least on pressure-measurement cell (**5**) able at output thereof to deliver and electric signal indicative of the pressure of said fluid in said pressure-measurement chambers. [8]

Relevance: Discussions with Amerisewn showed in interest in trying to simulate a human target as closely as possible. This patent details a potential target methodology that can be applied for the target designed second semester. Some drawbacks are the expense of signal conditioning for electric measurements. Using this patent would be most useful for simulating attacks to the chest and their measurements.

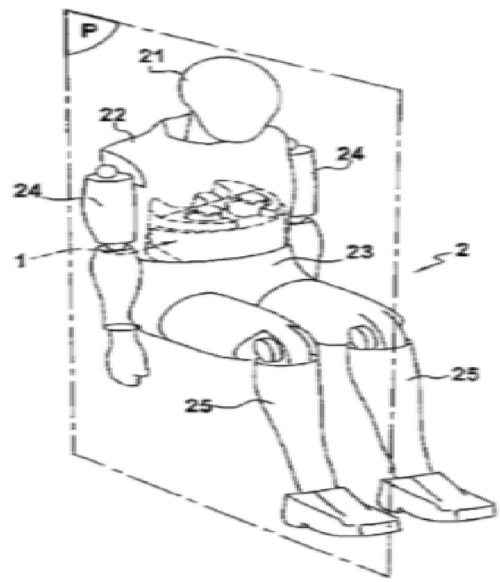


Figure 11: Pressure Sensor for Anthropomorphic Dummies

US9121785/Non-powered Impact Recorder
Date: September 1, 2015
Rights Owned By: Fraser M. Smith

Abstract: A non-powered impact recorder is disclosed. The non-powered impact recorder includes a resonator tuned for a resonant response within a predetermined frequency range. A reduced cross-sectional area portion if formed within the resonator and configured to structurally fail when the resonator experiences the resonant response. Additionally, the non-powered impact recorder includes and electric circuit element disposed about the reduced cross-sectional area portion of the resonator. Upon structural failure of the resonator, the electric circuit element is broken to cause a discontinuity in the electric circuit element. Interrogation of the discontinuous electric circuit element facilitates approximation of impact frequency and/or impact energy. [9]

Relevance: The sensor is relevant because it introduced a non powered measuring system for impact energy. A drawback is that each test is destructive for the sensor which would increase the cost per test. Inputing the frequency range is useful because there is a definite energy threshold that can be met at particular points on the armor specimen.

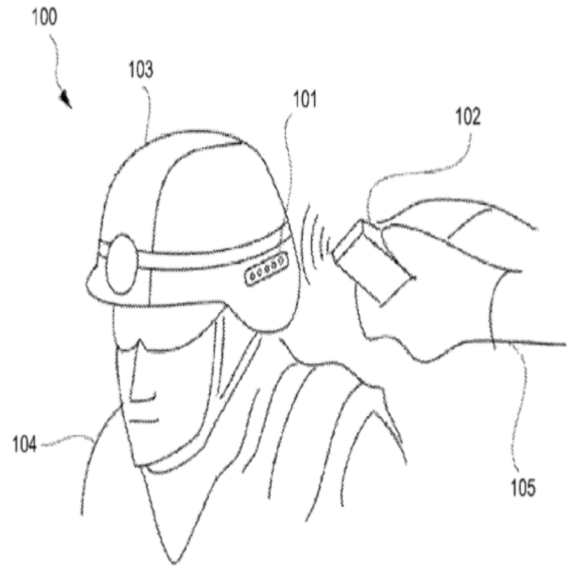


Figure 12: Non-powered Impact Recorder

US9063029/Dummy for Simulating Human Physical Behavior, Method for Simulating Human Physical Behavior
Date: June 23, 2015
Rights Owned By: Patrick Alan Forbes, Robert Marjin Anthony Frank Verschuren, Arjan Pieter Teerhuis, and Lex van Rooij

Abstract: A dummy for simulating human physical behavior during a test, comprising artificial human body elements that are mutually connected, the body elements having deformation properties, wherein a deformation property of a body element is actually variable. The dummy compromises an actuator for varying a deformation property. The actuator may comprise a fluidic driver. [10]

Relevance: Measuring the impact of the knife accurately is a key task that the system needs to achieve. There are several outputs to measure over the front and back faces of the armor the groups need to account for in second semester. This system is potentially useful because a threshold force triggers the system which means that the knife impact while be the only factor that triggers the latch.

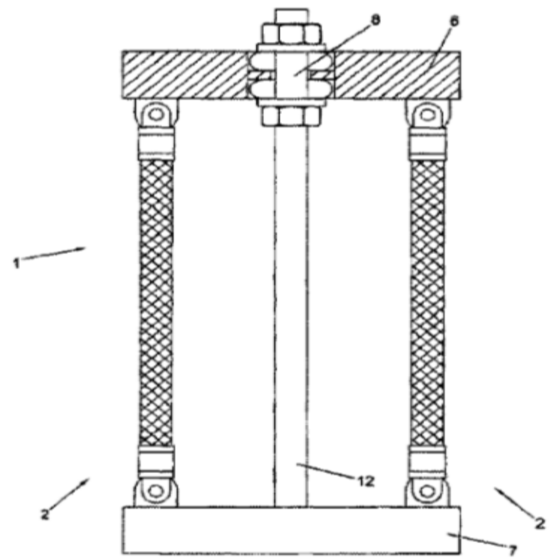


Figure 13: Dummy for Simulating Human Physical Behavior, Method for Simulating Human Physical Behavior

4.2 Literature Searches

Title: Weight, Volume , And Center Of Mass Of Segments Of The Human Body
Date: August, 1969
Author: Charles E. Clauser
Relevance: From the study, it was determined that the human stab motion incorporates the forearm and hand weight into the stab energy. It was also determined that a single forearm and hand make up about 2% of the human body weight. This is used to determine stab energy based on the body weight to replicate a specific stab. [11]

Title: Biomechanics Of Knife Stab Attacks
Date: March, 1999
Author: E.K.J Chadwick, A.C. Nicol, J.V. Lane, and T.G.F. Gray
Relevance: Based on the data collected, the study determined how much energy is delivered in a stab. From the hundreds of trials conducted, the maximum force and energy based on body weight was determined. This can be used to determine the maximum human stab energy based on body weight. [12]

Title: The Effect Of Knife Handle Shape On Stabbing Performance
Date: December, 2004
Author: Ian Horsfall
Relevance: The study included both data from male and females as well as weight and

height. From this, the data was able to back up previous data as well as add more data about female stab force. [13]

Title: An Assessment Of Human Performance In Stabbing
Date: June, 1999
Author: Ian Horsfall
Relevance: The study included male, female, experienced police, and military school students giving a large range of data. Tests were conducted giving the energy of both thrusting and overhand motion. This is the most comprehensive study conducted giving the upper bounds for male, female, as well as different experience/strength levels and stab types. This data was used to create the calculator along with the other data gathered. [14]

5 Evaluation of Competition

The market for the stabber and slasher is singular for URI and Amerisewn. The tester is being designed for a specific purpose in a small market and not intended to replace outside NIJ certification. The closest “competition” would be in Quantico VA where testing is approximately $200 and takes two to fours weeks for feedback. Their tester utilizes a gravity feed drop test onto a test specimen. Impact energy is adjusted by changing the height the stabber is dropped from, but a slash can not be simulated. The drop test also limits the target type to simulate chest armor because industry certification simulates stabs to the torso.

The current design has satisfies more complex attacks the Amersewn wants to test their designs against. In real world scenarios, there are stabs and slashes from several angles to the torso. Additionally, protective clothing is not limited to the chest, but to extremities as well. The current design delivers the required energy, but can simulates slashes to the torso from self centering swivel vise used on the cart. Additionally, future target design is accounting for different forms of protection to be tested with helmets and greaves.

Since the market is very specific and test based, this device will not be mass produced. URI intends to keep the tester on site for different clothing types to be tested as well. The design allows for testers to change the striking object with ease to simulate different testing environments. Amerisewn tests approximately 15 products annually so a test site in RI saves them time and money. While final certification is done by the NIJ, they can approximate the certification test and know when a specimen is sent for certification, it will pass. URI will also gain by having a device on campus that can test various specimens as well.

6 Specification Definition

The primary problem being solved is designing a modular test system that can help URI perform material testing systematically through predicting and measuring the kinetic energy and force delivered on impact to the test specimen. The tester would be important because it can test new materials and designs at a URI facility instead of an outside agency. A good machine will save time and money because the tester receives instant feedback. The system will also help Team 20 design modules because of accurate data acquisition and repeatable testing.

The tester needs to to have positive control based on a desired impact energy set by the tester. Currently the tester produce energies to 165 Joules (J) which is 2.5 times the NIJ maximum energy test for non-ballistic armor. [2] The tester must also be easily operated by a single user which is currently being achieved through an Excel Macro and easy to handle physical controls. A considerable design factor is the wide range of users from Desmark/Amerisewn (non-engineers) to researchers from URI with engineering background or degrees. The goal is to design a system that non-engineers can use with minimal training and researchers can get relevant information.

The most difficult part of the system is what to measure on impact. Desmark/Amerisewn has some easily definable measurements needed due NIJ published standards and provides guidance for materials testing at URI. The essentials are energy dissipation in the specimen and penetration depth if there is any. Currently, testing concerns stabbing and slashing high endurance materials and provide similarities between Desmark/Amerisewn and URI needs.

The tester will be modular in nature to simulate different attacks like stabs, slashes, and blunt force. The first phase of the machine will adhere to the design specifications with the understanding that it will need to perform more than a range of stabs attack specified. It is important that the group keeps the design simple and adaptable so that a range of angles and attacks can be simulated.

An additional requirement is creating energy profiles that simulate a range of attackers. The current NIJ testing only focuses on a pass / fail requirement for armors. Desmark/Amerisewn would like testing to focus on more common threats that law enforcement and correctional officers face. They would like to create common energy profiles that are approximations of sex, weight, and skill level which corresponds to an output energy.

A final consideration of armor design and testing is the wide range of body shapes that the armor has to adhere to as well as the different physical shapes for male and female torsos. An unfortunate reality is the range of fitness levels among law enforcement and correctional officers means that armor design has to be approximated. The same is true for female officers since their bust size and other different dimensions from males affects how the armor contours to their bodies.

7 Conceptual Design

The mechanical design of the Mechanical Stabber and Slasher was originally inspired by the NIJ energy levels of the testing of non-ballistic armor. A reference table of the energy levels the NIJ uses to certify protection levels follows:

Table 10: Stab Resistant Level Strike Energies

Protection Level	**"E1" Strike Energy J**	**ft·lbf**	**"E2" Overtest Strike Energy J**	**ft·lbf**
1	24 ± 0.50	17.7 ± 0.36	36 ± 0.60	26.6 ± 0.44
2	33 ± 0.60	24.3 ± 0.44	50 ± 0.70	26.9 ± 0.51
3	43 ± 0.60	31.7 ± 0.44	65 ± 0.80	47.9 ± 0.59

where the table is capable of achieving impact energies of 2.5 times the "E2" Level 3 test specified in Tbl: 10. The modeling performed (see Sec. 12) and testing conducted (see Sec. 14) are based on Tbl: 10. Having to follow the constraints of Desmark/Amerisewn, the device must have been able to fit on the top of a table.

Following the design specifications, the energy needed to deliver to the target at a high range is 65 J, for the mechanical stabber, the range of delivered energy will be 0-165 J. This allows the operators to be able to go above and beyond the certification levels to have peace of mind that the composite will pass impact testing. Along with energy targets, angle of attack was also desired in the design specifications. Since almost always a stab in real life is not perpendicular to the composite, a vice was used to be able to hold the stabber or slasher as well as being able to give it a precise desired angle.

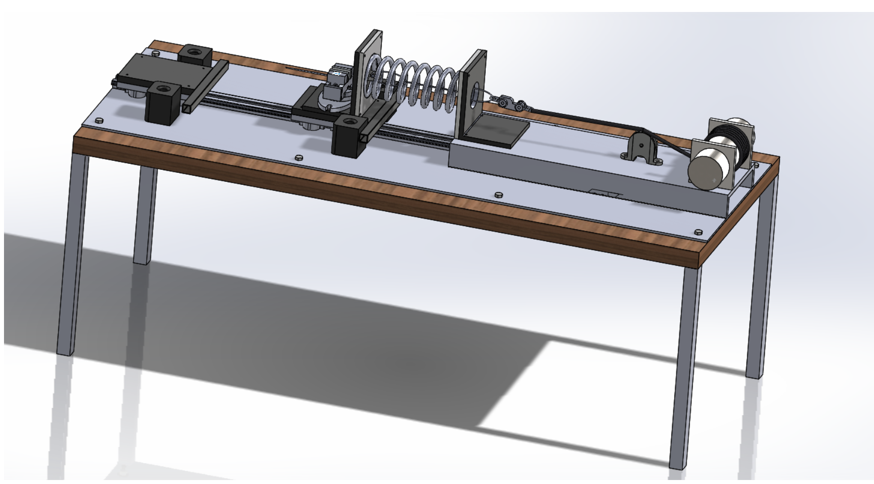


Figure 14: SolidWORKS Rendering of Variable Force Stabber and Slasher

To be able to deliver the large amount of energy into the target, many different designs were created including air cannon, hydraulic and spring power. Due to repeatability and maintenance requirements and ease of computations, spring power was chosen.

The design manufacturing was focused on metal fabrication to make sure the strength of connections was sturdy. Using a combination of welding, drilling, and tapping, the final product is designed with a high factor of safety in structural design. The table was chosen for its high mass and strength, it was then coupled with a quarter inch steel plate for more structural support with eight $\frac{1}{2}$ in bolts. The track was placed on top of the steel plate with sixteen $\frac{5}{16}$ in bolts. Then, the rubber stoppers have four more half inch bolts through all of the layers of the table. The C-channel is was welded on top of the steel plate to hold the winch and pulley system. The winch is bolted onto the C-channel with the standard $\frac{5}{16}$ in bolts. Over design was critical in this system because of the inherently high repeatable forces, to which the design has been created.

7.1 Concept Generation

Each group member created 30 individual designs over the course of a month. They were to increase on the previous designs and conceptualize new ideas

Maxwell Caro Concept List

1. In this design it is the fundamental design system that was conceived. There is a spring that propels the shank at the specimen. The spring is displaced by the winch.

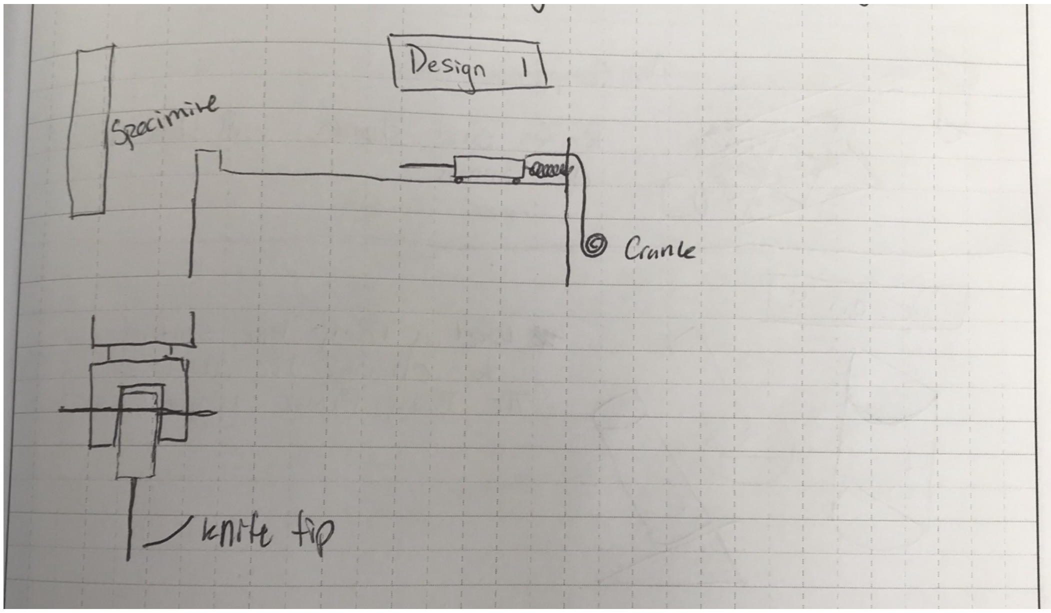


Figure 15: Maxwell Caro Design Concept 1

2. In this design the specimen holder was designed. It has a cylindrical shape to hold a variety of real world shaped riot gear.

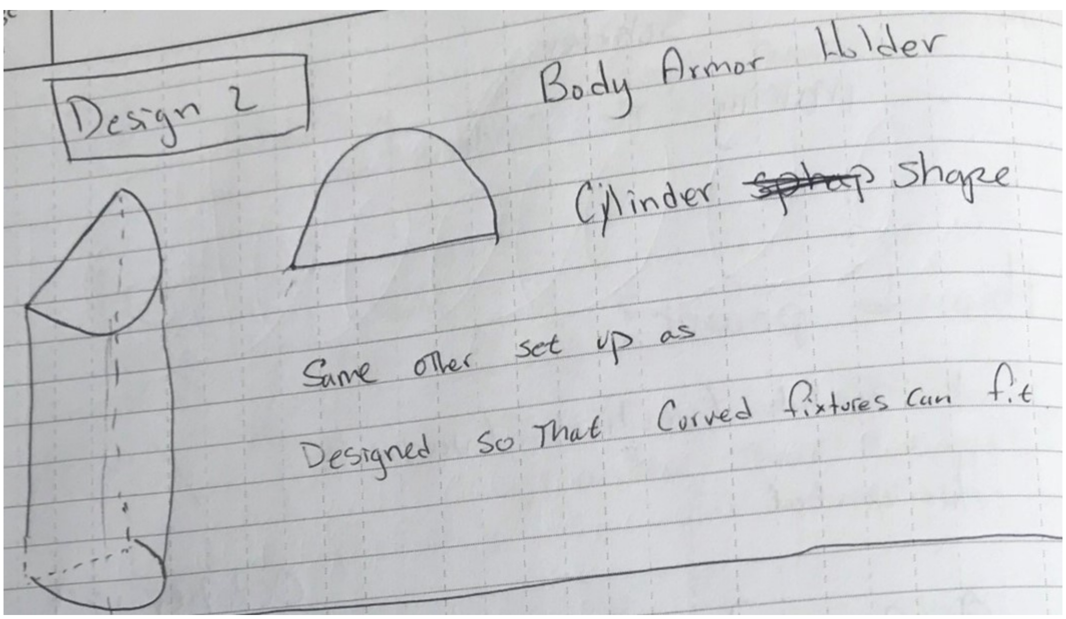


Figure 16: Maxwell Caro Design Concept 2

3. This design is replacing the spring with an air cannon. This design is easier to use but harder for reproducibility and safety. It is a very low volume of parts design.

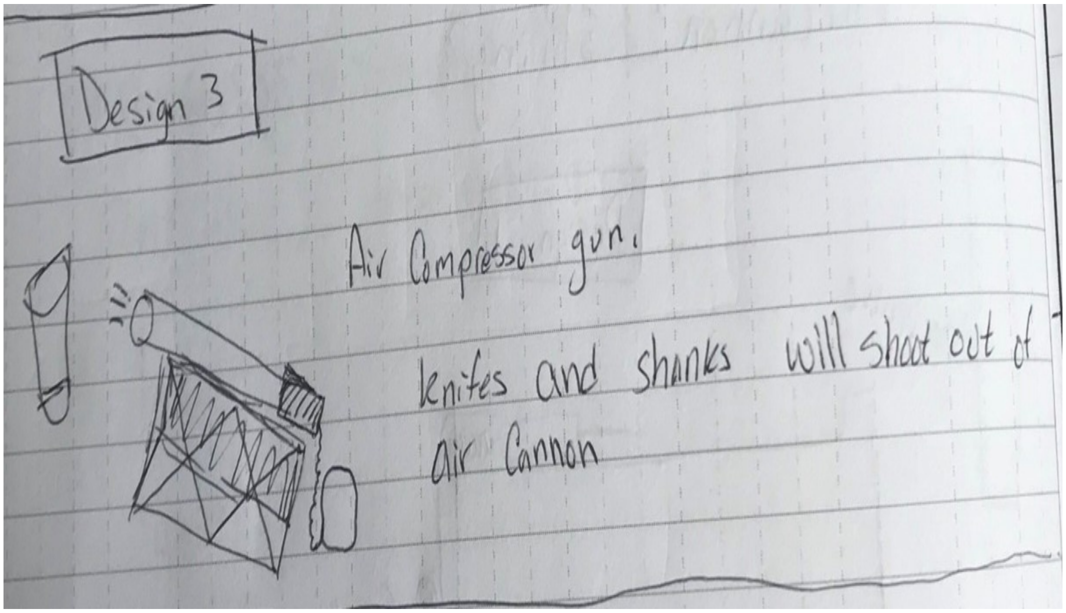


Figure 17: Maxwell Caro Design Concept 3

4. This design works off design 2. It is the same shape but attached to an angle pivot. Using this design, the specimen can be stabbed and slashed at different angles.

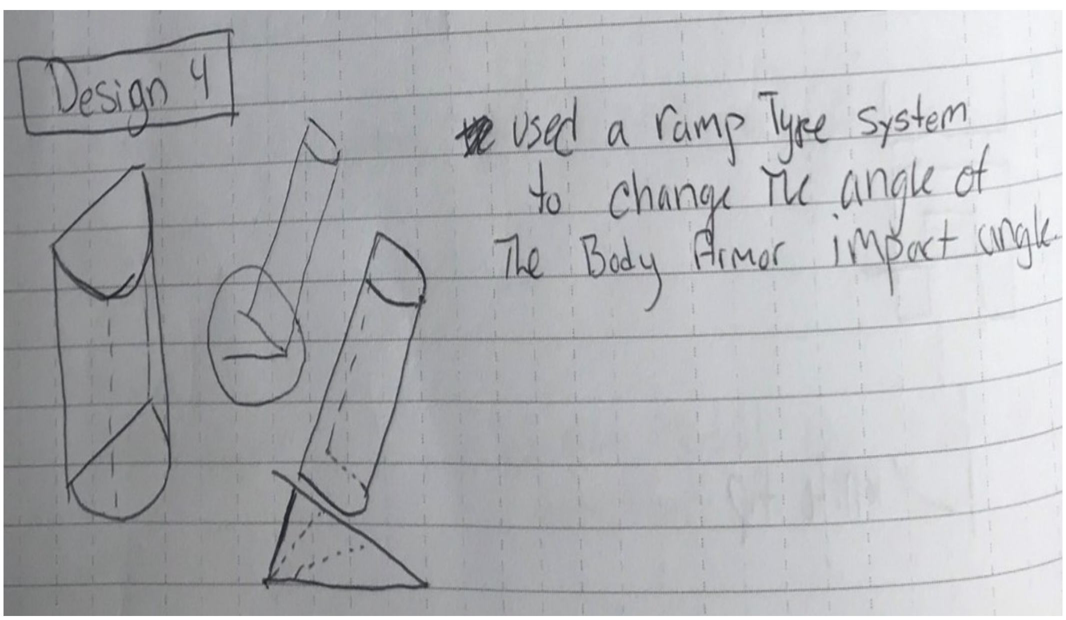


Figure 18: Maxwell Caro Design Concept 4

5. This design is for the cart system. It is an I beam with a linear motion cart attached to

it. These carts have extremely low friction allowing the spring to have to utilize less initial energy to propel at the same end velocity.

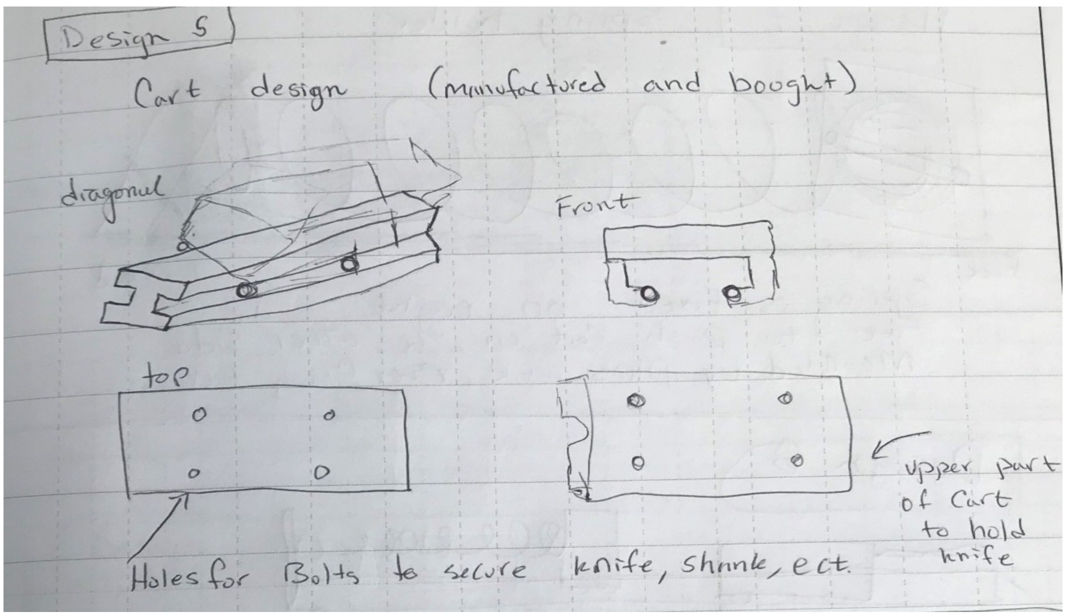


Figure 19: Maxwell Caro Design Concept 5

6. This design is for the spring. This design is the beginning of the math stage for the spring to make sense. The spring will be pulled back to a specific displacement in order to get desired potential energy.

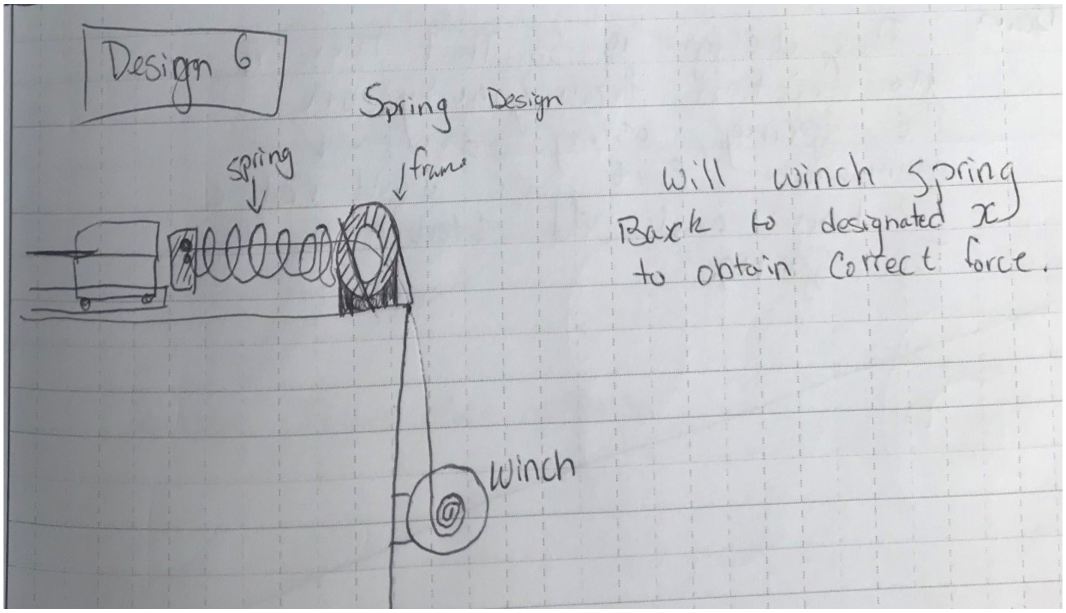


Figure 20: Maxwell Caro Design Concept 6

7. This design fixes the spring in place. On the right side the spring will be fixed and secured with a pin. On the motion side, there is a circular indent and the spring will be secured with a pin.

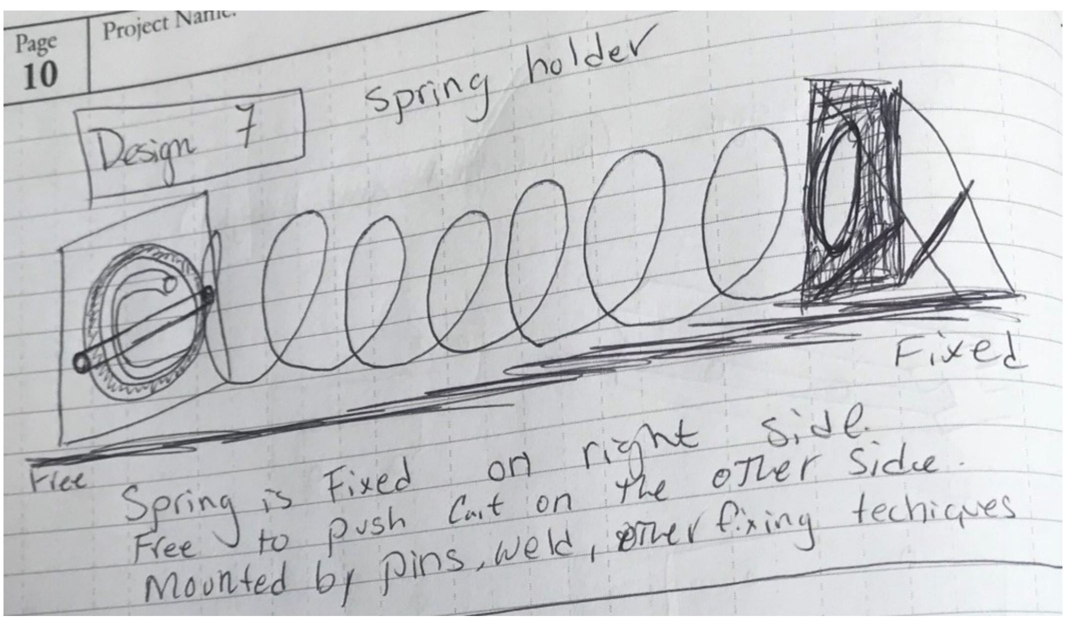


Figure 21: Maxwell Caro Design Concept 7

8. This design works off of design 7. It is the same concept but instead of a plate pushing

the cart it is another cart. This would reduce friction and we would not have to deal with the issue of gravity on the spring hitting the table. It also keeps it in check from x and y vibration.

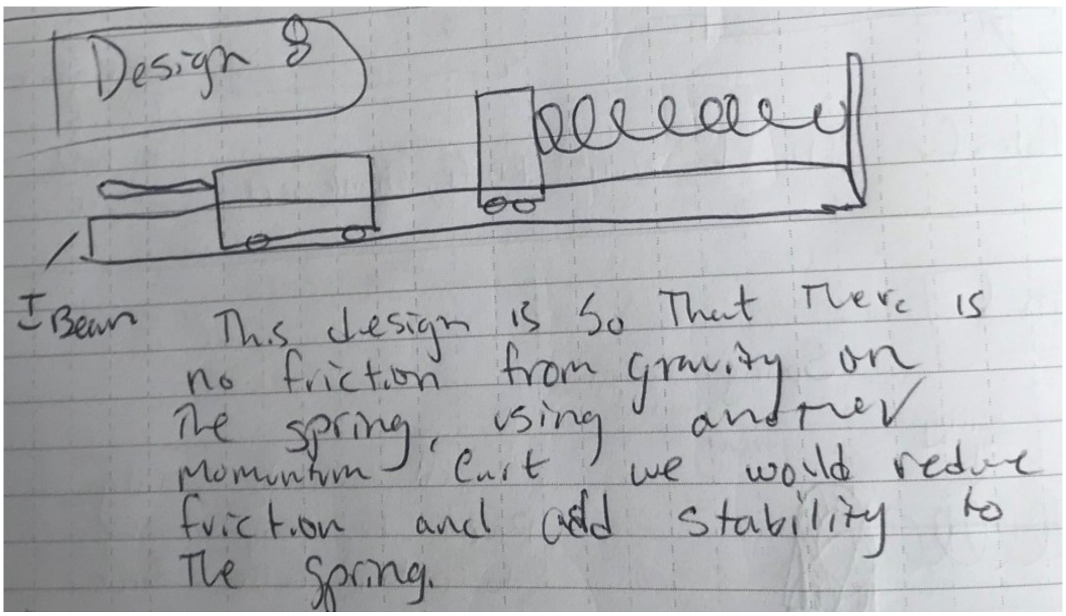


Figure 22: Maxwell Caro Design Concept 8

9. In this design it is a system to accurately get the displacement of the spring. Since force is directly related to the displacement of the spring, this is a very important parameter. It is solved by having a laser sensor to detect the cart to the mm.

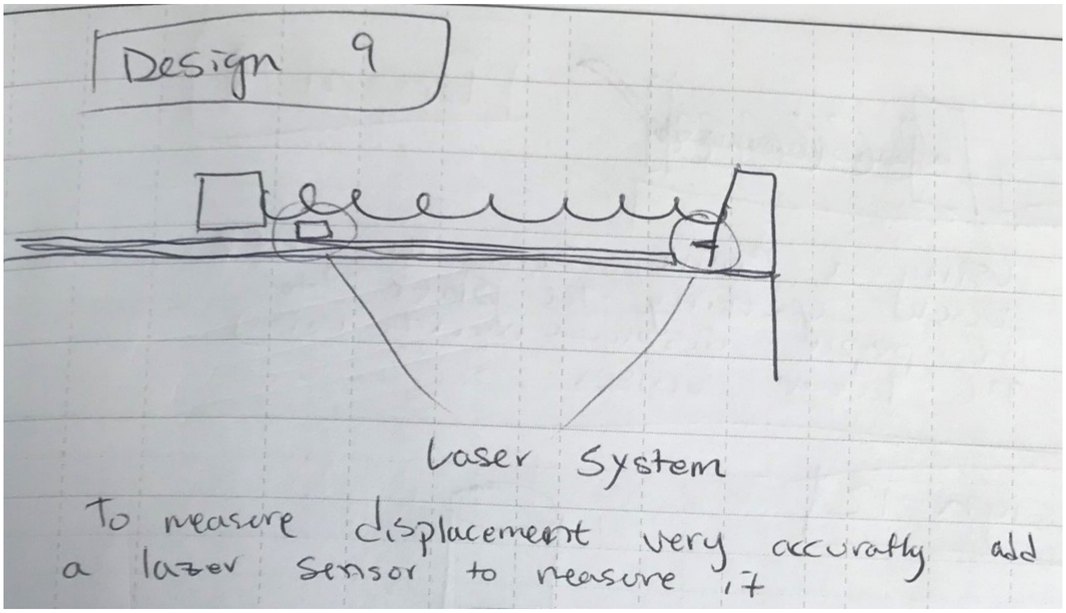


Figure 23: Maxwell Caro Design Concept 9

10. This design is to help the slashing and stabbing angles. Because we want this rig to be as versatile as possible this would allow the operator to change the angles on the knife or shank as well as the specimen for more angles of penetration.

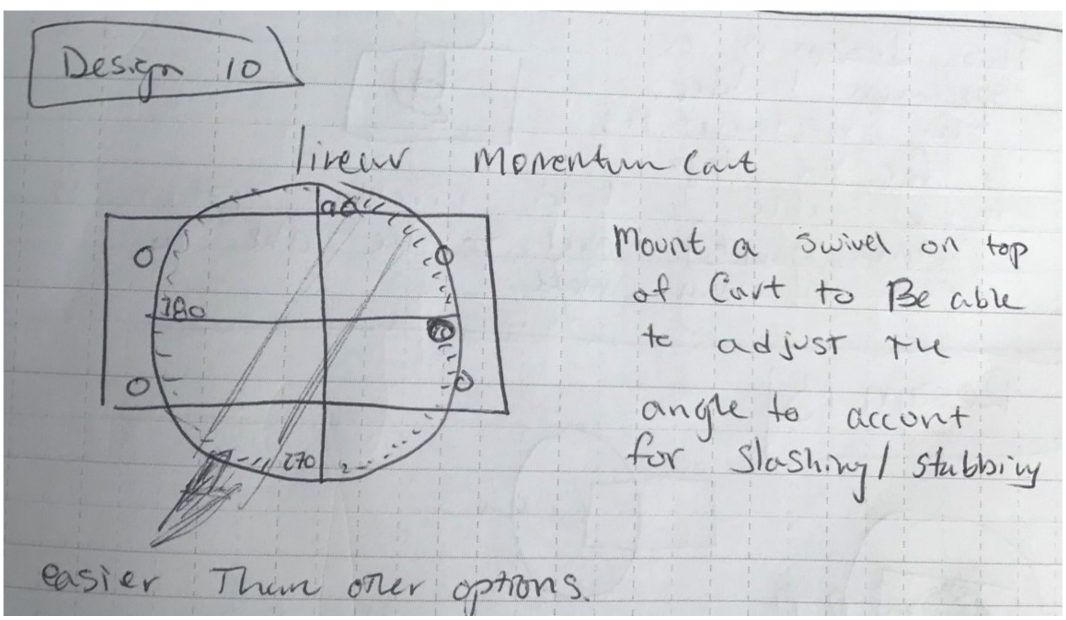


Figure 24: Maxwell Caro Design Concept 10

11. This design is in replacement to the winch. This is a crank system that would allow the

operator to use the screw mechanism to bring back the spring. This is a low power option but there would be more stress on the operator.

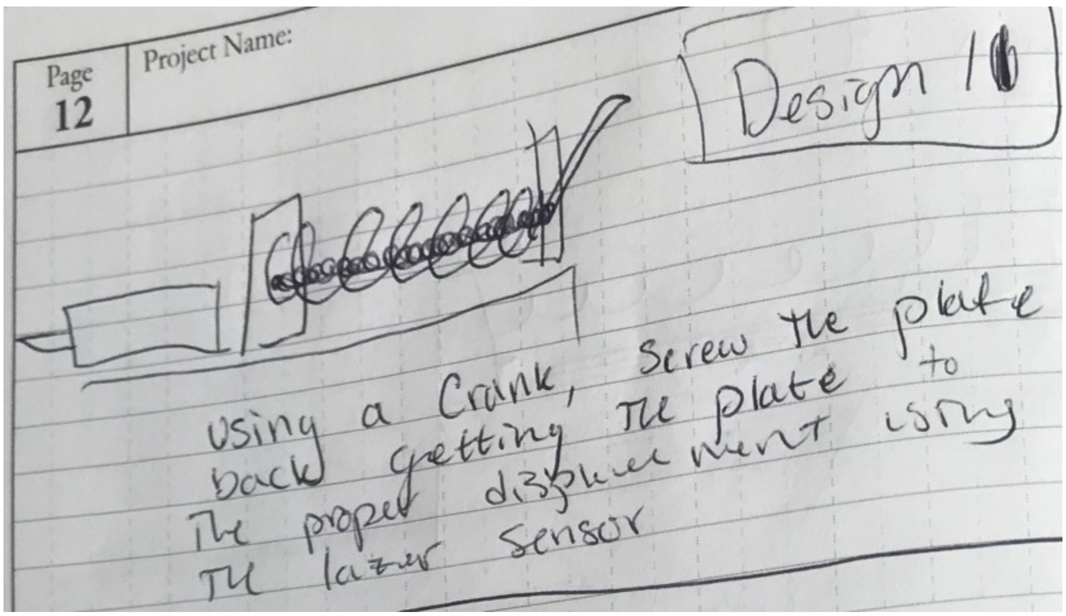


Figure 25: Maxwell Caro Design Concept 11

12. This is a specimen holder. This is a cylinder shaped like a chest. It would mimic the body and would rotate. This gives 360 degree angles to the testing mechanism this would be beneficial for testing under arm or to the side of legs.

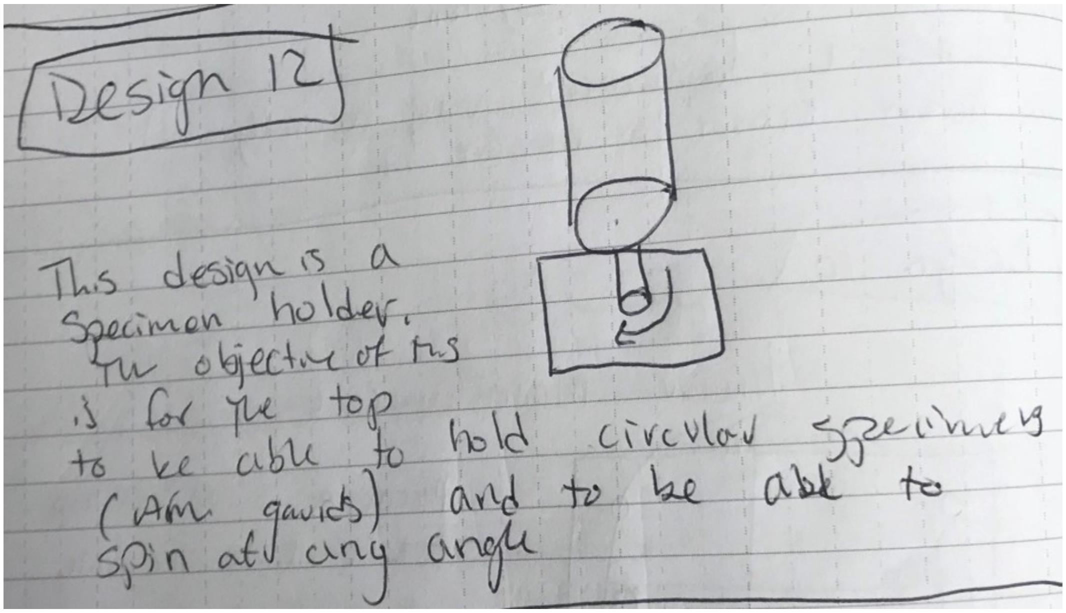


Figure 26: Maxwell Caro Design Concept 12

13. This design is to release the pin to release the energy into the cart from the spring. It is a lanyard system like military applications. It would require some significant force to be pulled and would instantly release.

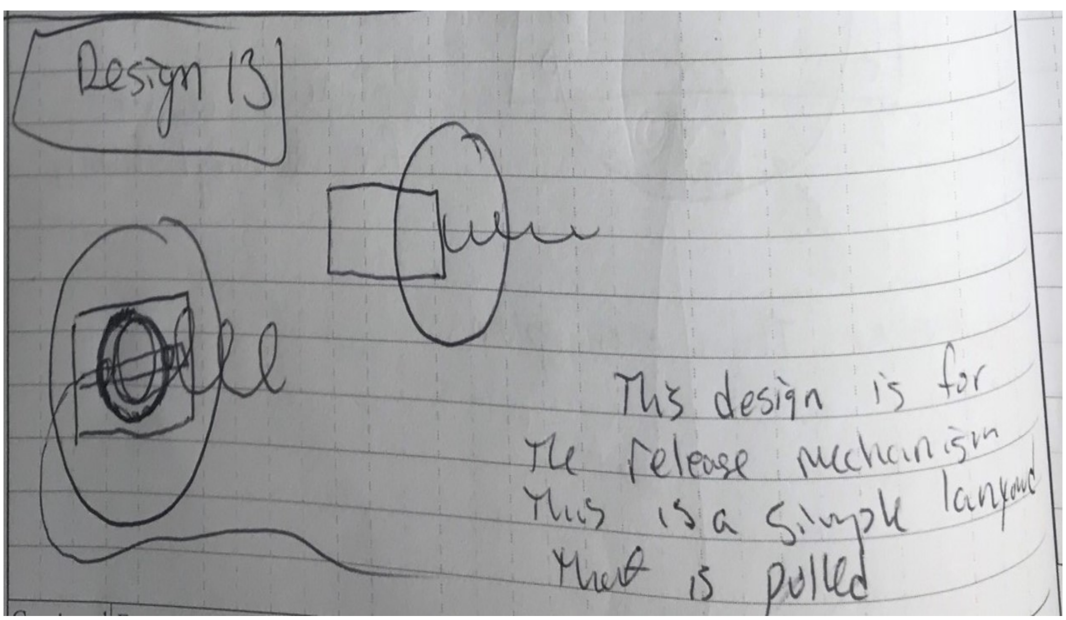


Figure 27: Maxwell Caro Design Concept 13

14. This design is in replacement to the single spring design. This would utilize two springs

instead of one. We would be able to lower the spring constants or would be able to decrease displacement of the springs.

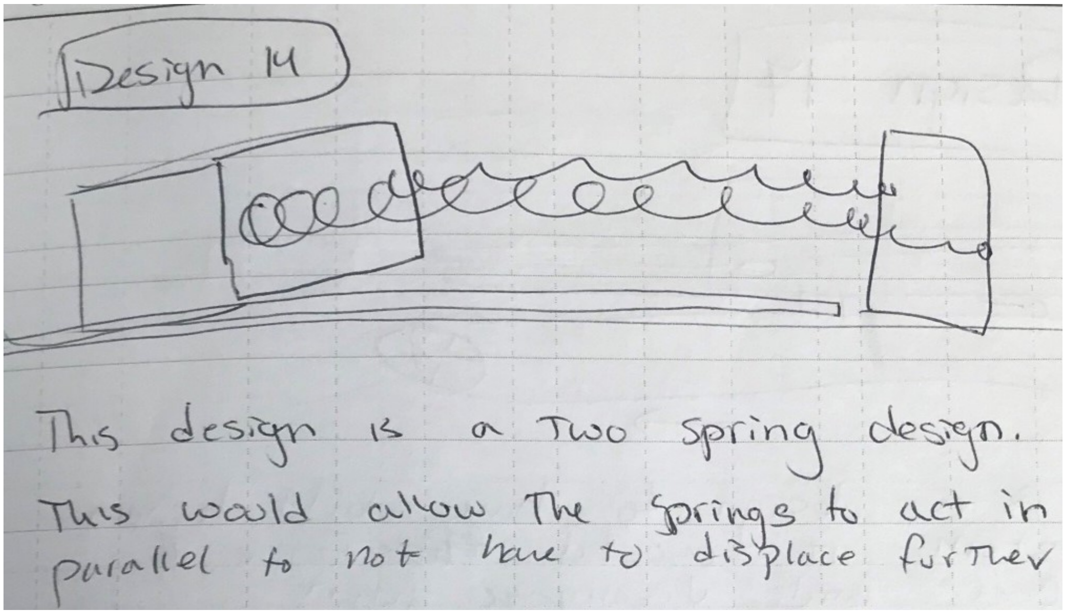


Figure 28: Maxwell Caro Design Concept 14

16. This design is an attempt to recreate the NIJ standard test within a single story building. The NIJ standard is done using gravity as the force and uses 3 stories to let the knife fall.

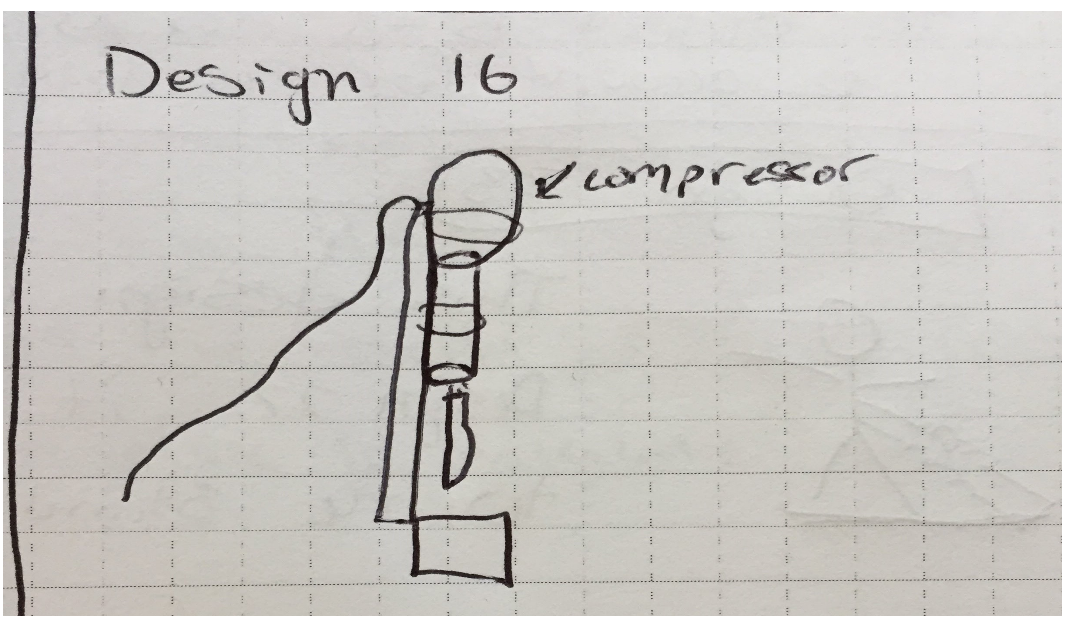


Figure 29: Maxwell Caro Design Concept 16

17. This design replaces the spring. This would be design that is similar to a car impact test. On a track the cart would be propelled by a string and have constant velocity. This would be an easy way to know the exact velocity at impact to obtain energy.

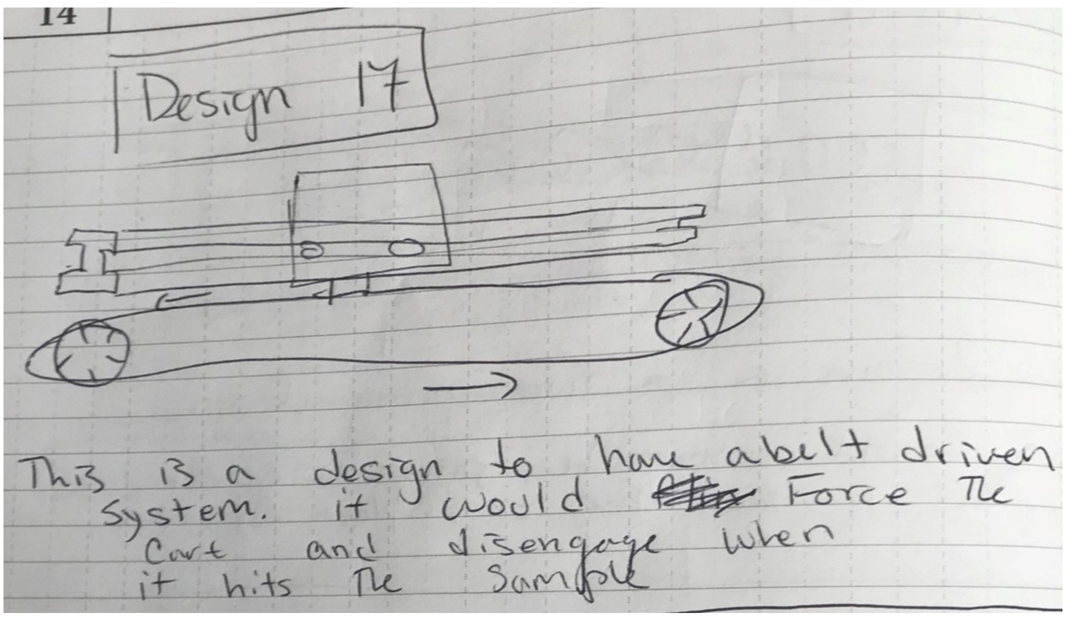


Figure 30: Maxwell Caro Design Concept 17

18. This design replaces the pin. This design is a clamp system that instead of pulling a pin it would release and let the cart go. It would require more moving pieces.

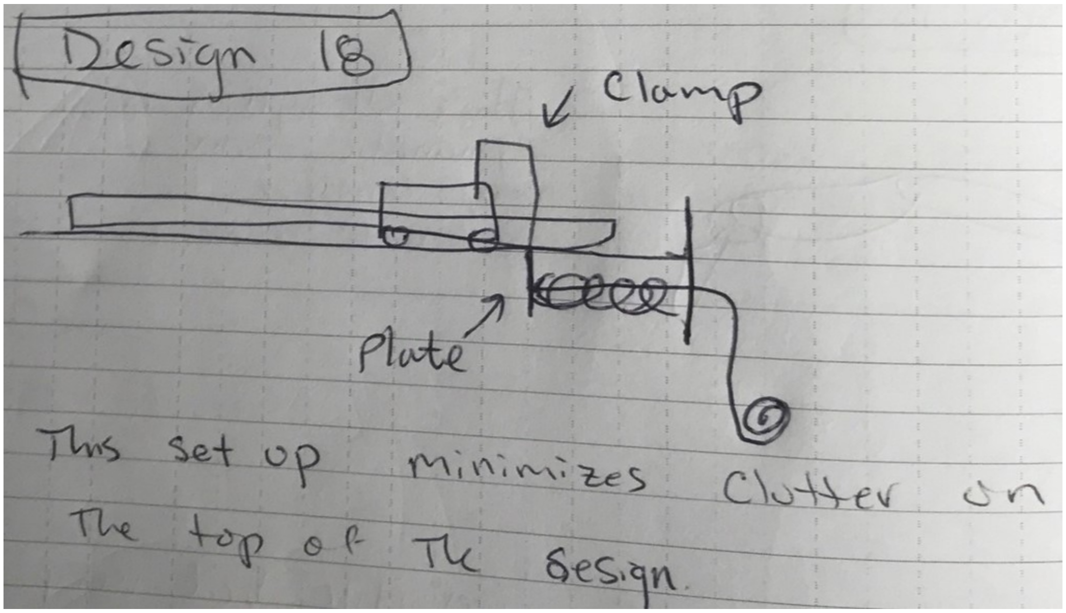


Figure 31: Maxwell Caro Design Concept 18

19. This design changed the track. This is a single wheel system it would reduce the friction but add lots of vibration.

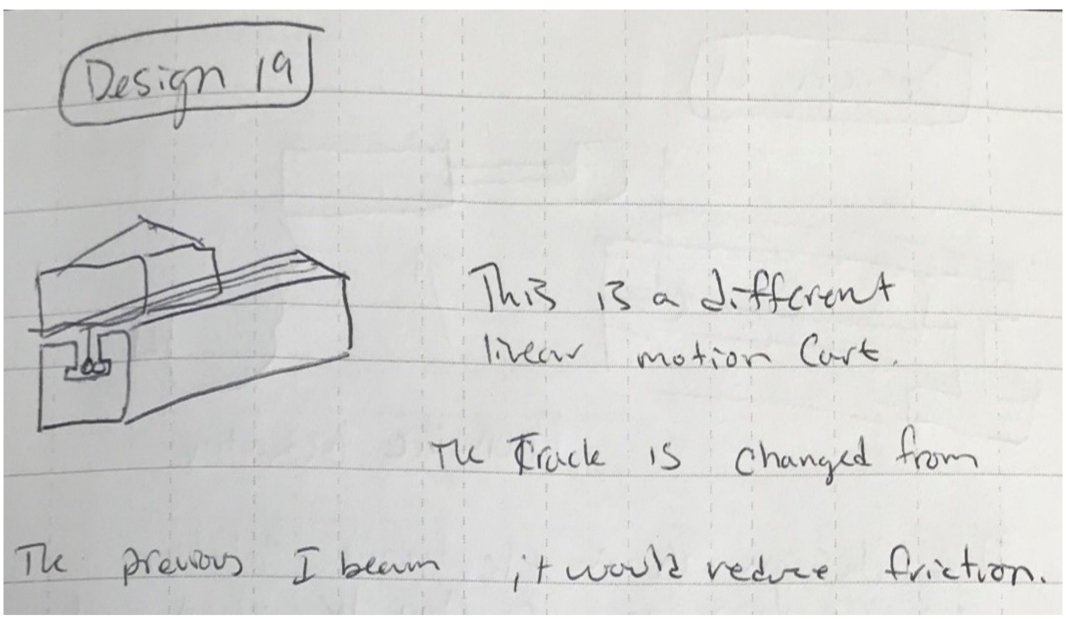


Figure 32: Maxwell Caro Design Concept 19

20. This is the design that the NIJ certified companies use. Since we do not have the immediate height space to obtain the energies needed it seems implausible but the most

repeatable and professional.

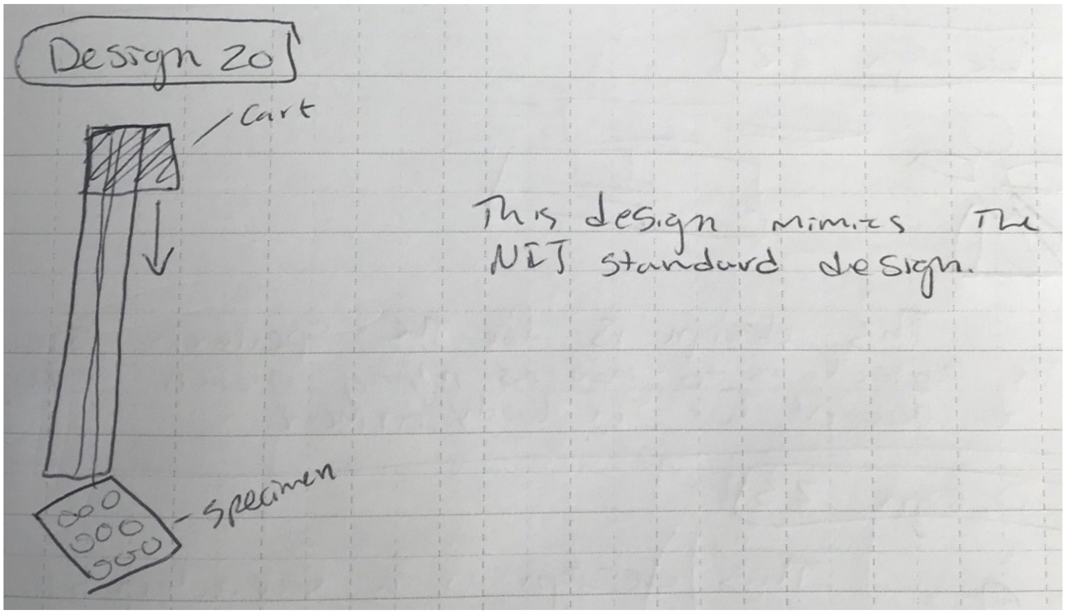


Figure 33: Maxwell Caro Design Concept 20

21. This design is a pneumatic driven system. This would be very repeatable if the actuator was variable. This is a very expensive option. It would require energy to use every test. It would be adjustable and repeatable.

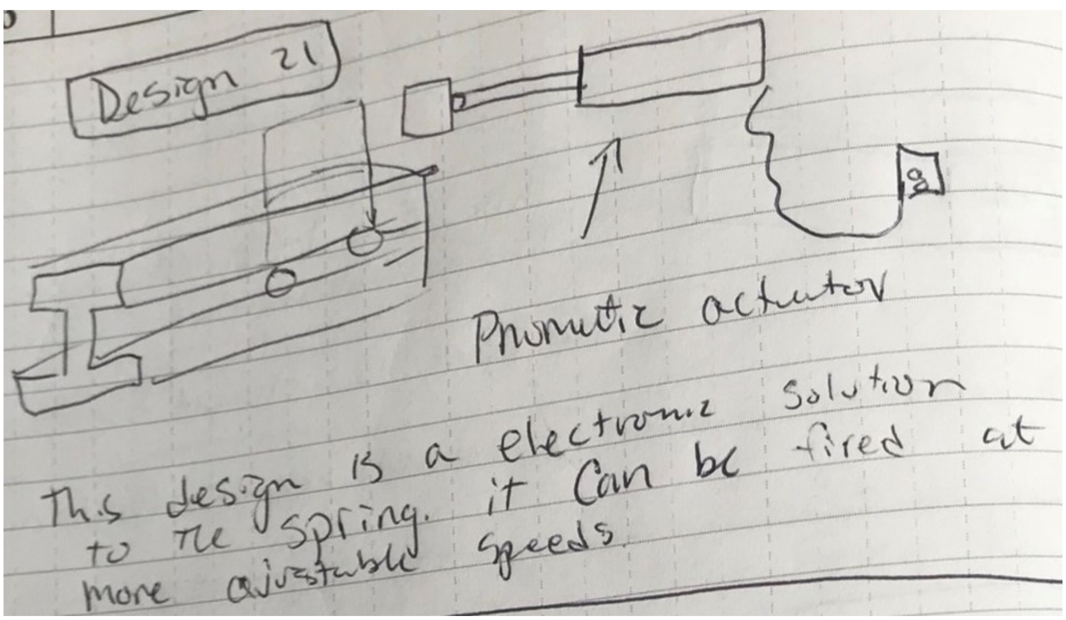


Figure 34: Maxwell Caro Design Concept 21

22. This design is for the specimen holder. It is the shape of a body along with the angle variability makes this a good design.

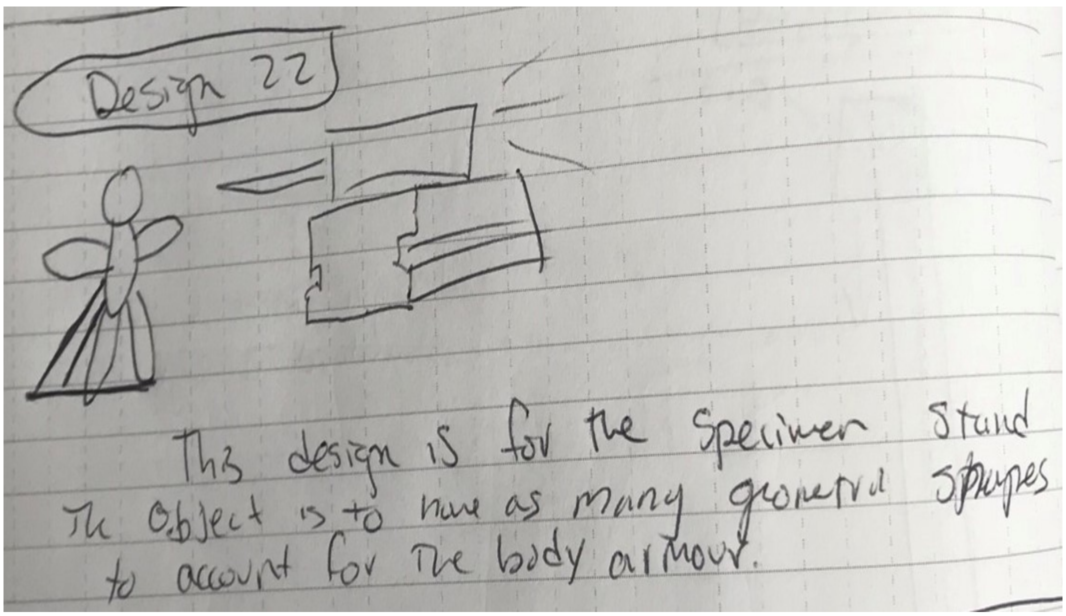


Figure 35: Maxwell Caro Design Concept 22

23. Discussed in the sponsor meeting, the sponsor stated an interest in pushback just like a real human would. Using springs behind the specimen, this would mimic the motion of a human backing up in the event of an attack.

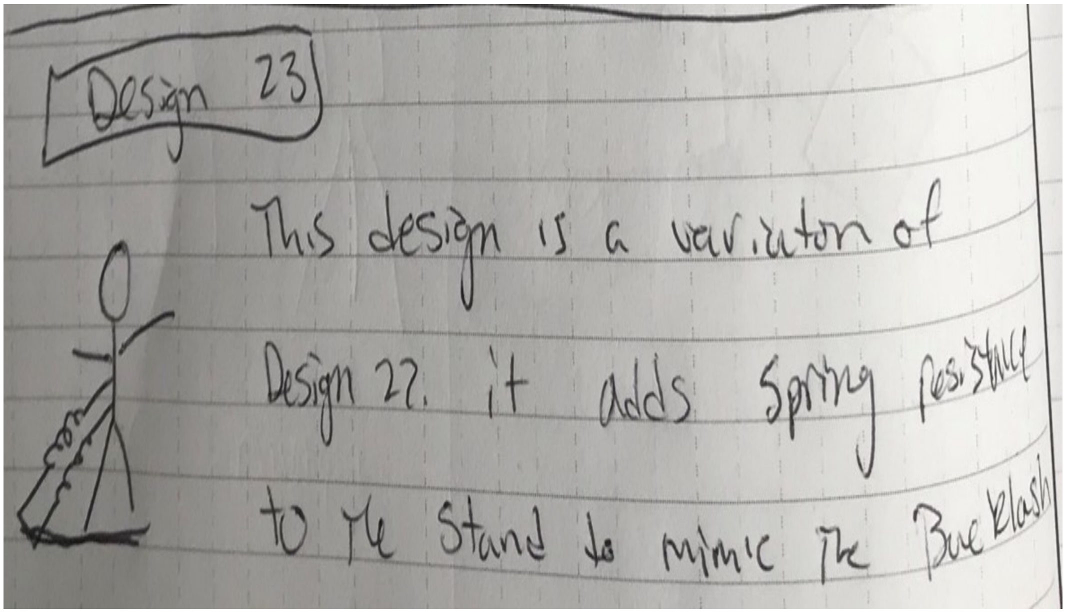


Figure 36: Maxwell Caro Design Concept 23

24. This design is for the stopping mechanism in case of an emergency. If the shank penetrates through the specimen it can smash into the end of the track. This would dissipate some of the energy in catastrophic events.

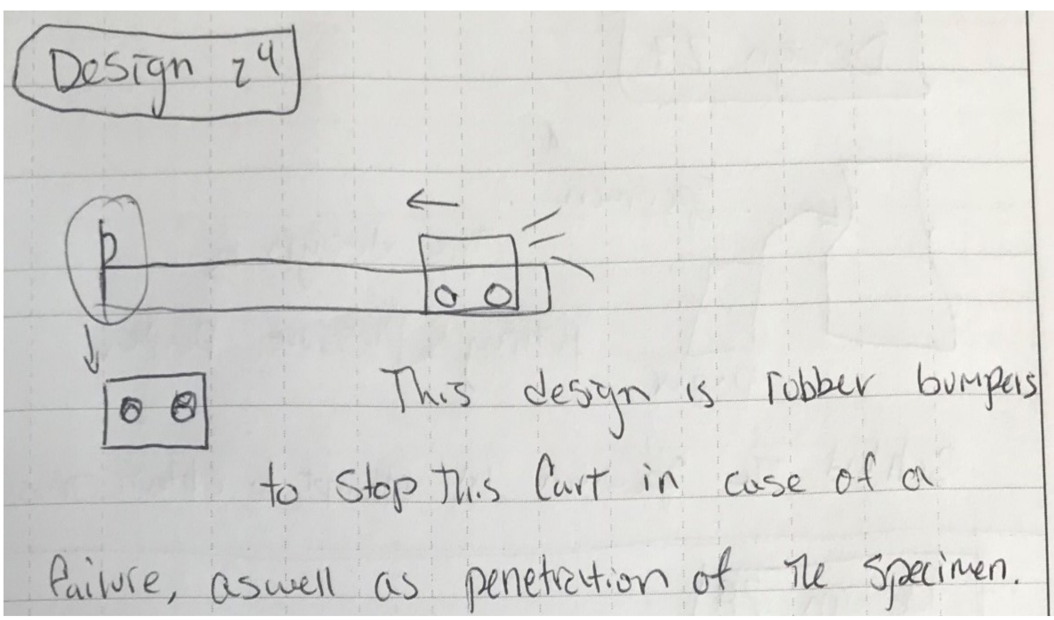


Figure 37: Maxwell Caro Design Concept 24

25. This design is for a coil over to dissipate some of the energy on the back compression.

Since the spring will be wanting to expel the excess energy, this will stop some vibrations and increase the safety of the device.

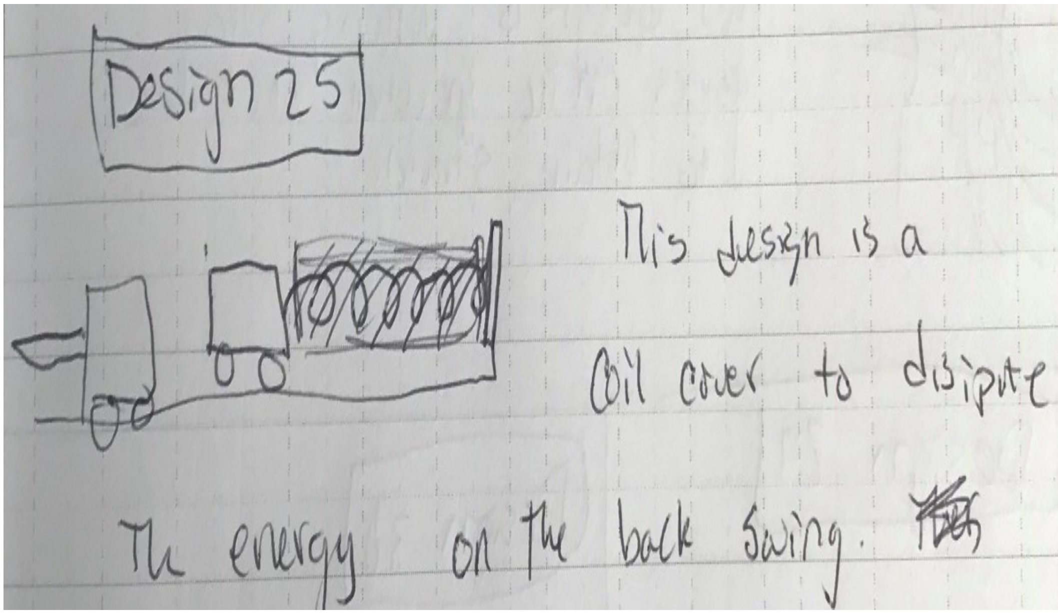


Figure 38: Maxwell Caro Design Concept 25

26. Since we need velocity at the exit to calculate the energy, this is a high speed camera system to capture the velocity.

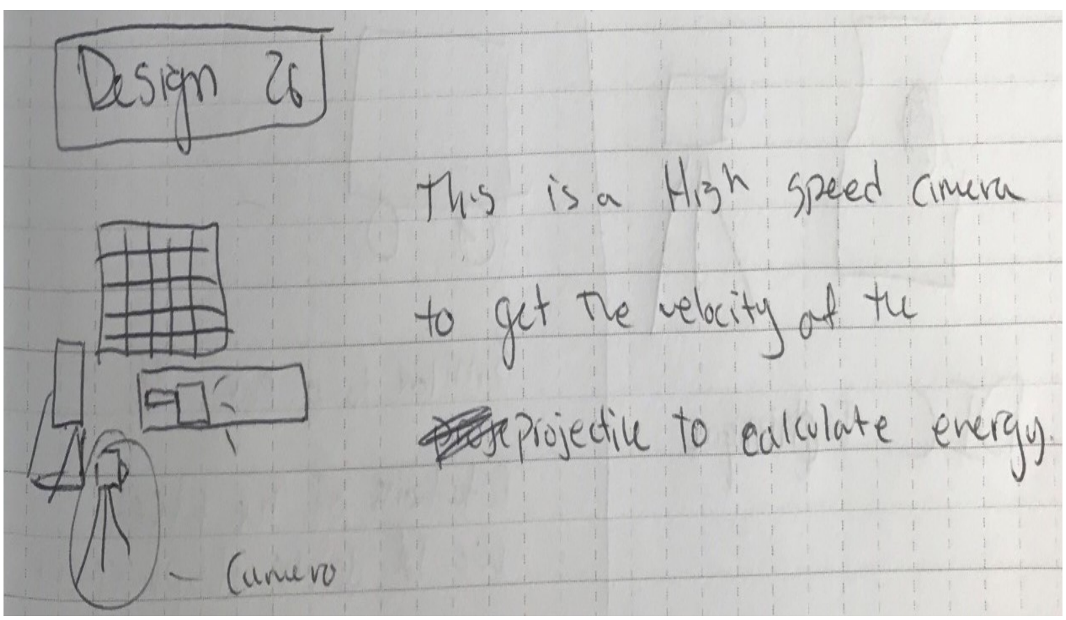


Figure 39: Maxwell Caro Design Concept 26

27. Impact stress paper. Professor Nassersharif obtained some samples of this material. It would be an interesting option if it can react to the impact forces fast enough.

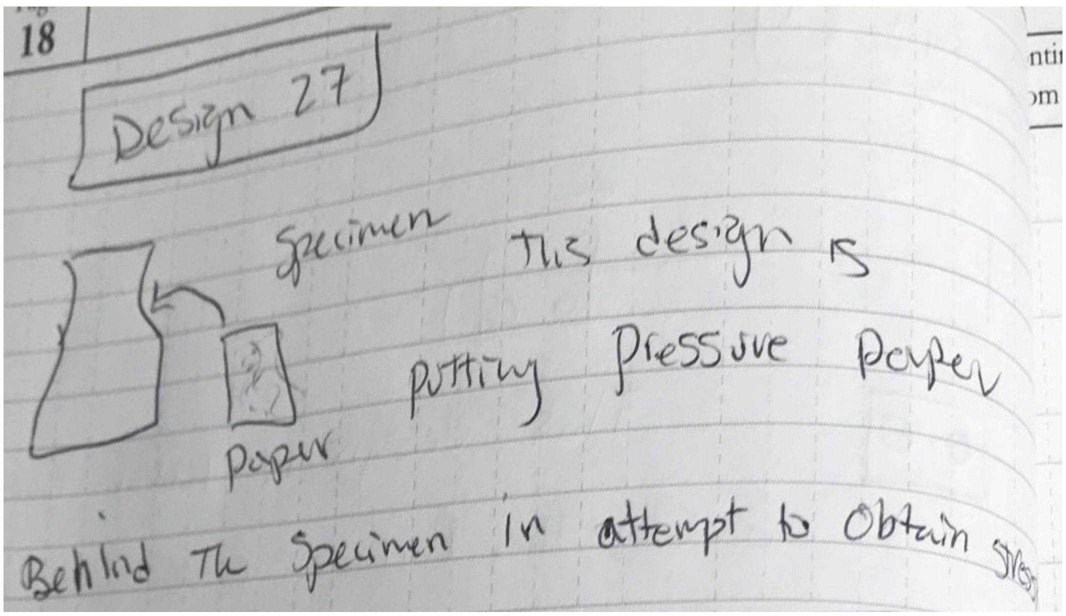


Figure 40: Maxwell Caro Design Concept 27

28. Strain gauges are a good cheap way of measuring the strain on the material. This would be time consuming and destructive but it is an option if others are too expensive or do not have the correct impact time

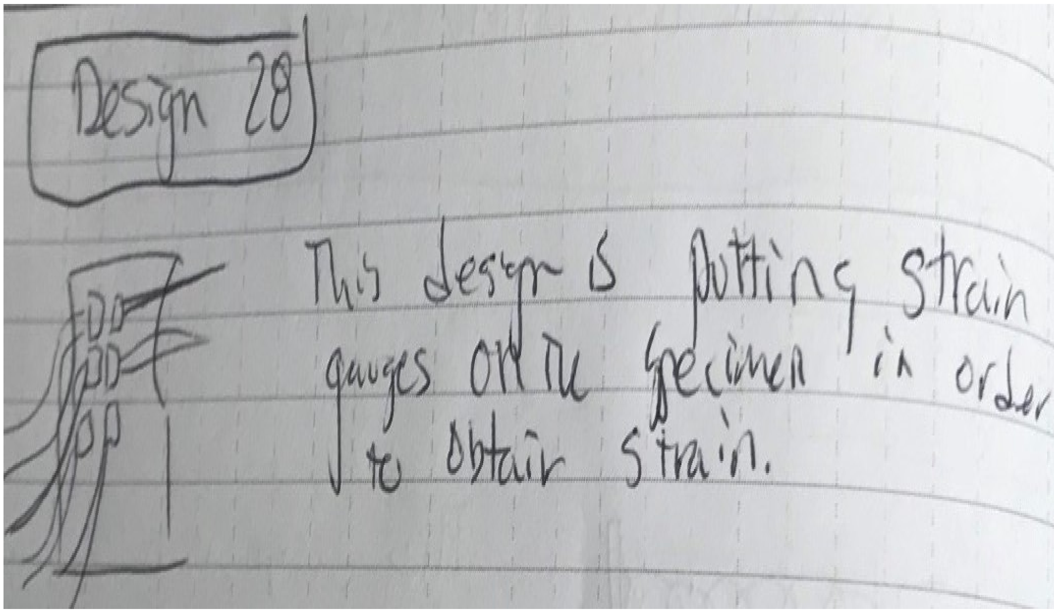


Figure 41: Maxwell Caro Design Concept 28

30. Many systems that measure distance traveled use a system that counts the rotation of the wheel. This would be good to find the displacement of the spring.

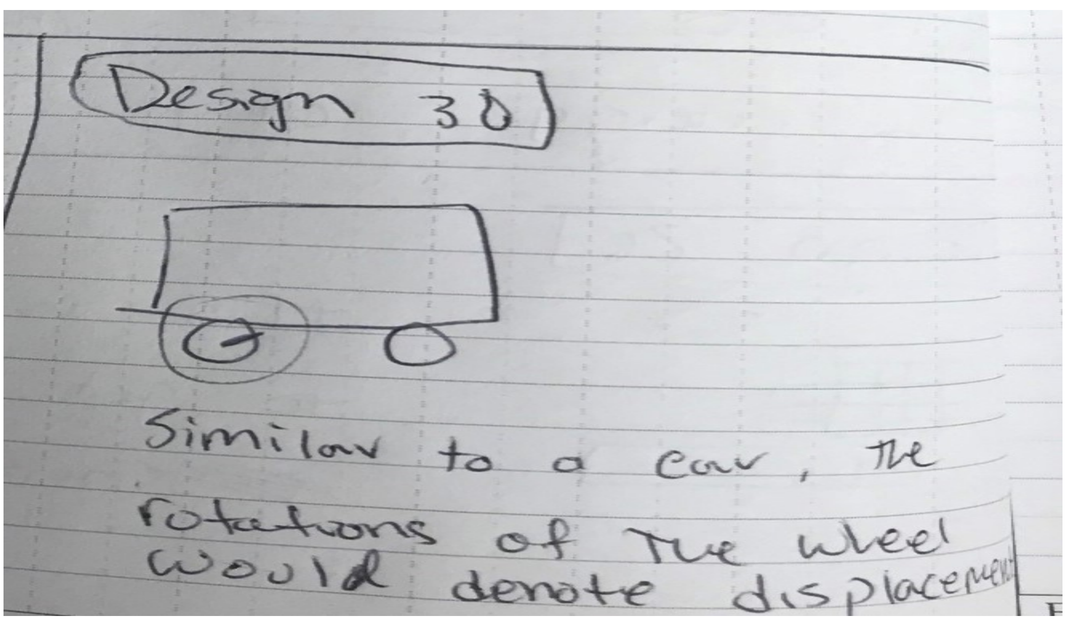


Figure 42: Maxwell Caro Design Concept 30

Brody DiPentima Concept List

1. This design uses a spring to launch a linear motion cart along a track to deliver the weapon to the target. The spring is drawn back by a winch system.

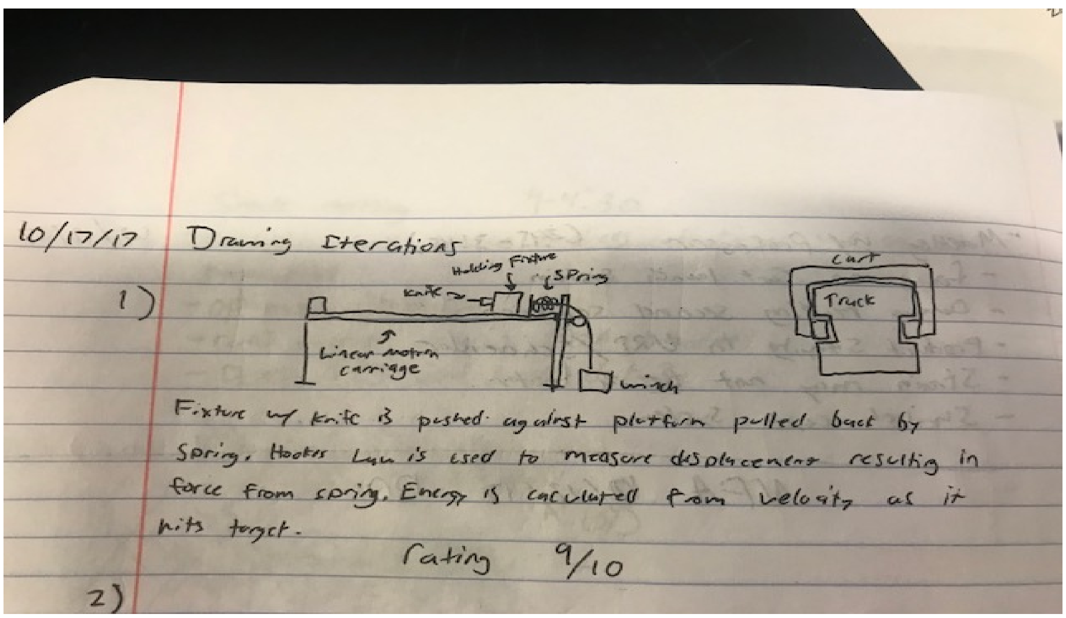


Figure 43: Brody DiPentima Design Concept 1

2. This design is similar to Design 1 but uses a aircraft carrier like launch system where the cart is pushed until a stopper is hit.

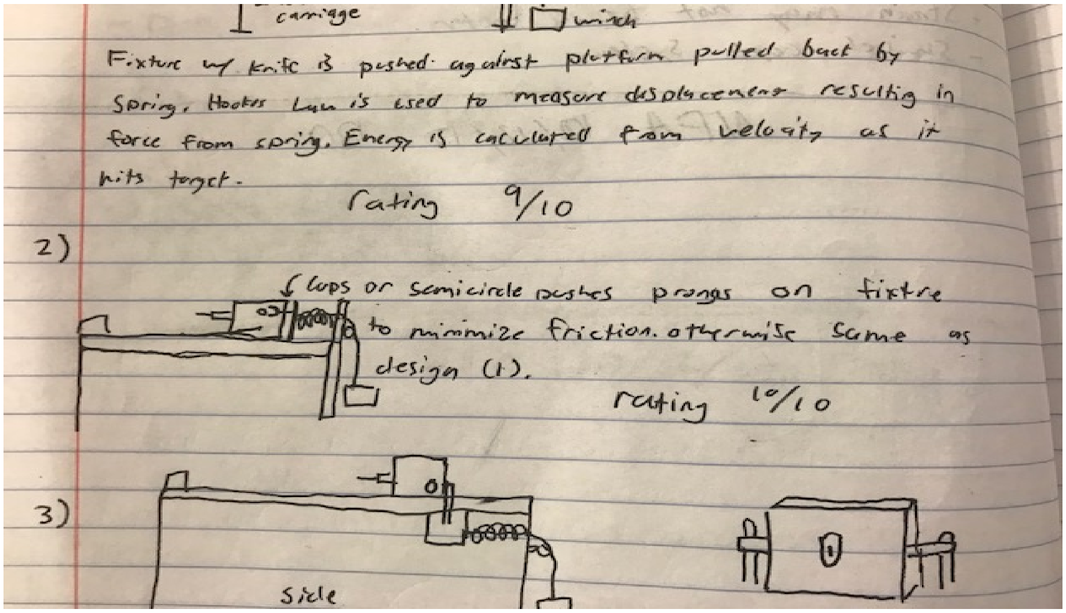


Figure 44: Brody DiPentima Design Concept 2

3. This setup is similar to Design 1 but has the spring pushing the cart from the bottom to maximize space on the tabletop.

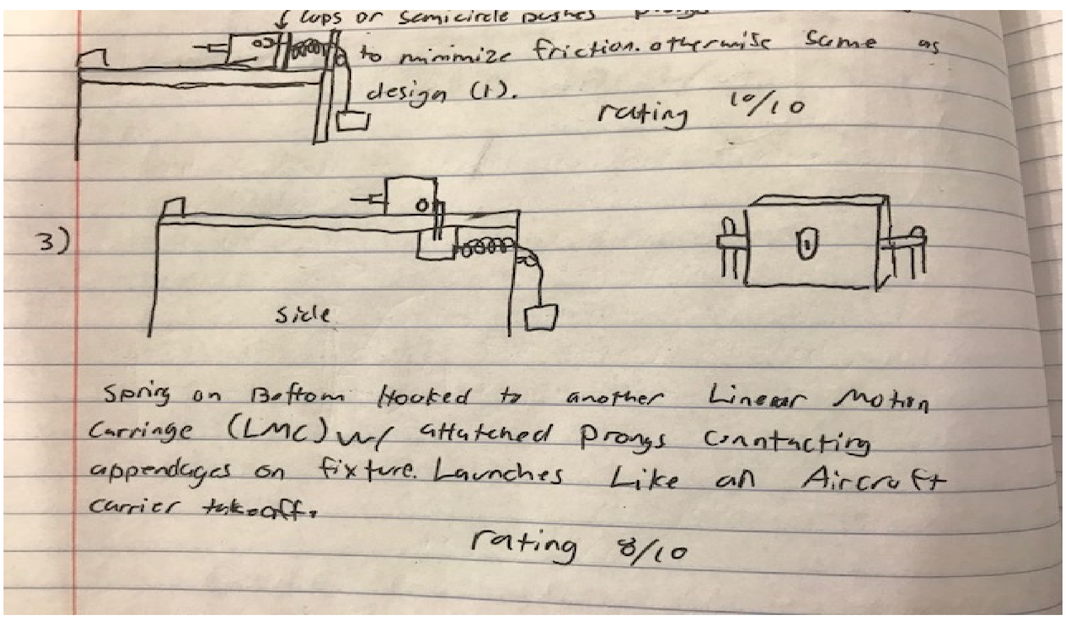


Figure 45: Brody DiPentima Design Concept 3

4. A dummy system with a jointed base and telescopic arms to allow for the knife or spike to be delivered at any angle.

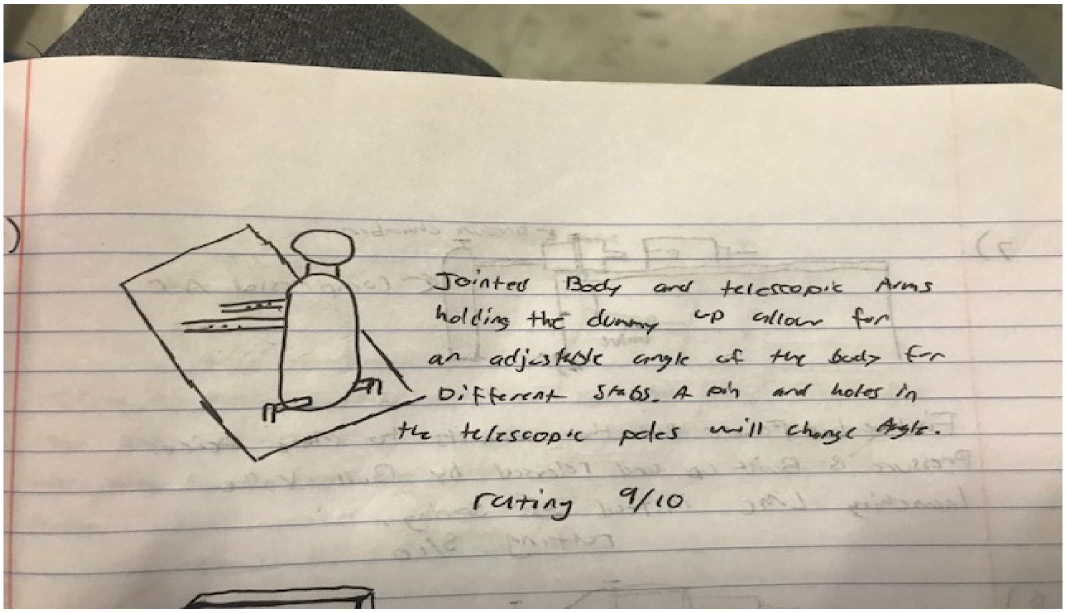


Figure 46: Brody DiPentima Design Concept 4

5. Similar to the dummy but with a swivel base to be able to turn the target allowing for any incident angle.

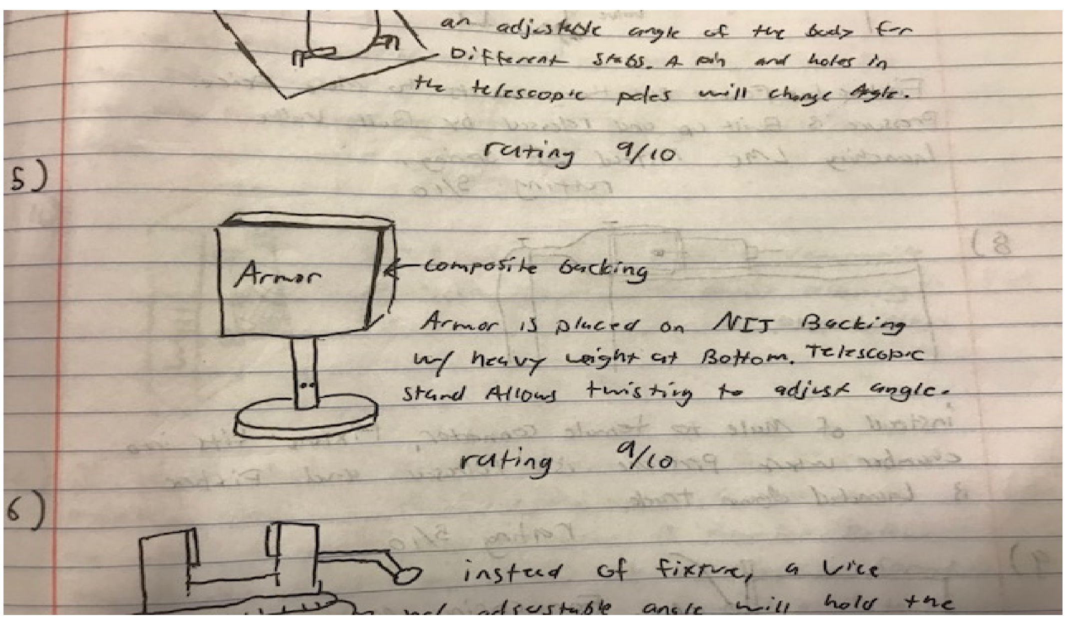


Figure 47: Brody DiPentima Design Concept 5

6. A swivel vice to attach to the top of the cart allowing the knife to be held as well as swivel to any angle with precision.

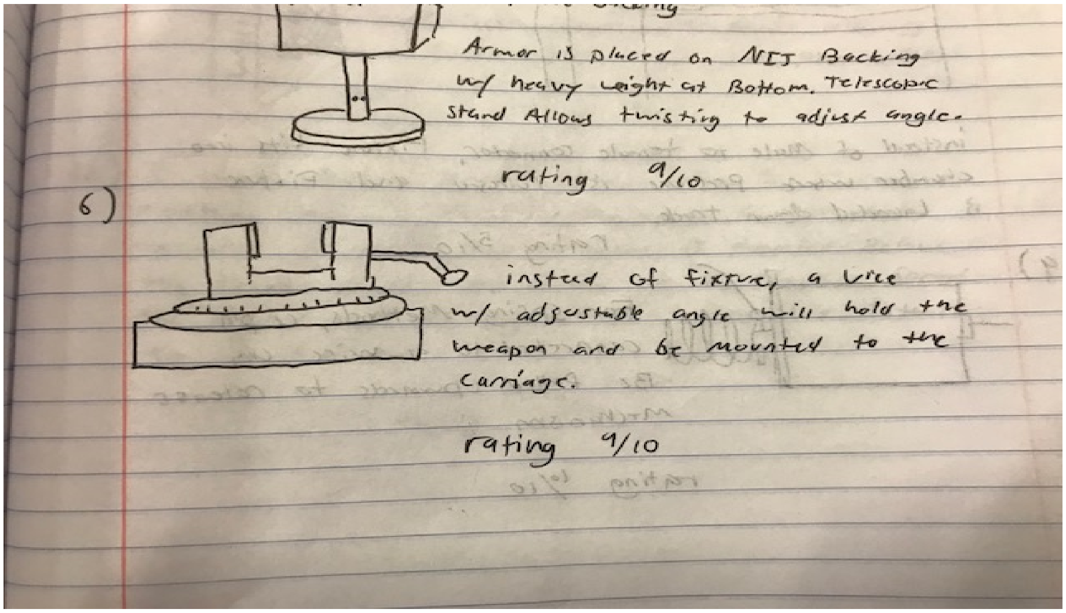


Figure 48: Brody DiPentima Design Concept 6

7. Compressed air with a pressurized chamber and ball valve will launch the cart rather than previous spring designs. A male end from the pressure chamber will fit into a female end on the cart where the air will project the cart down the track.

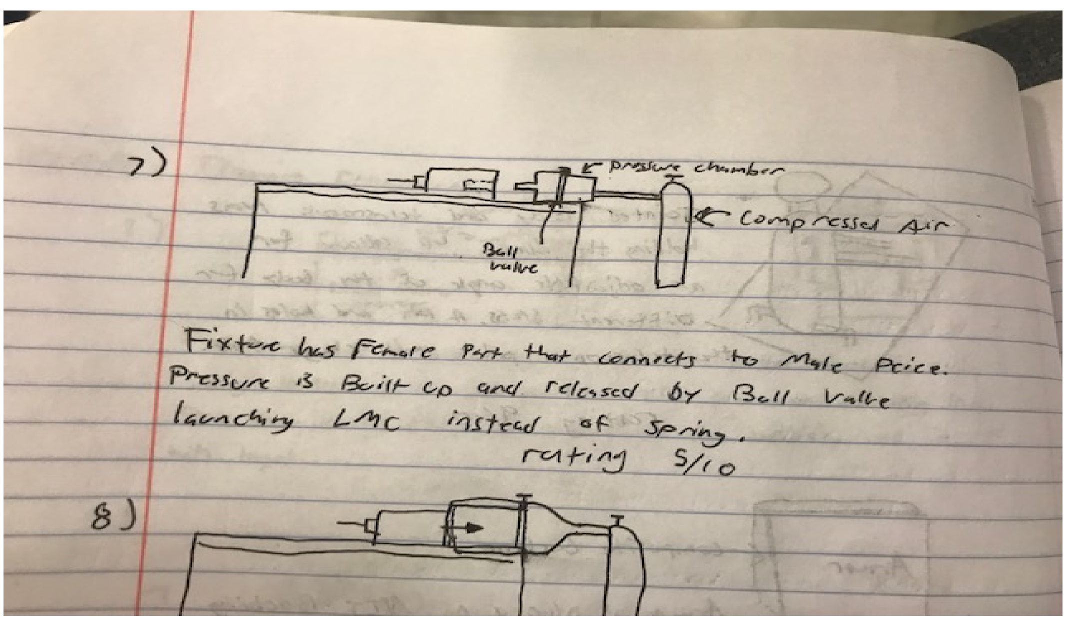


Figure 49: Brody DiPentima Design Concept 7

8. Similar to design 8 but rather than a male and female end, the cart will fit into the

chamber similar to a barrel of a gun, where it will be projected down the track.

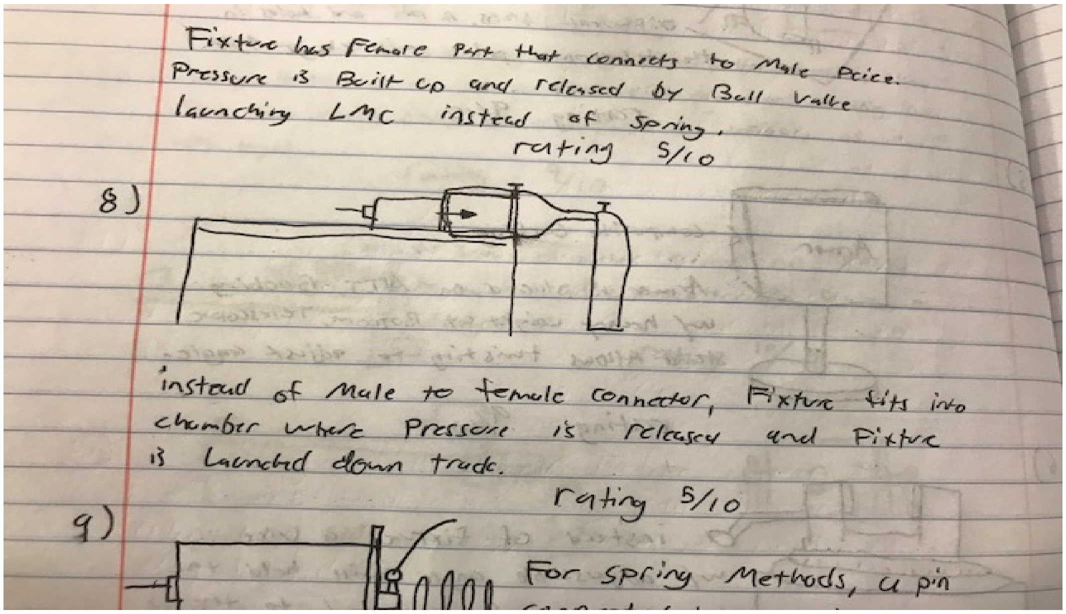


Figure 50: Brody DiPentima Design Concept 8

9. In addition to any spring propelled track, a quick release system can be used for accurate and safe launching. A pin can be pulled from a safe distance through a lanyard.

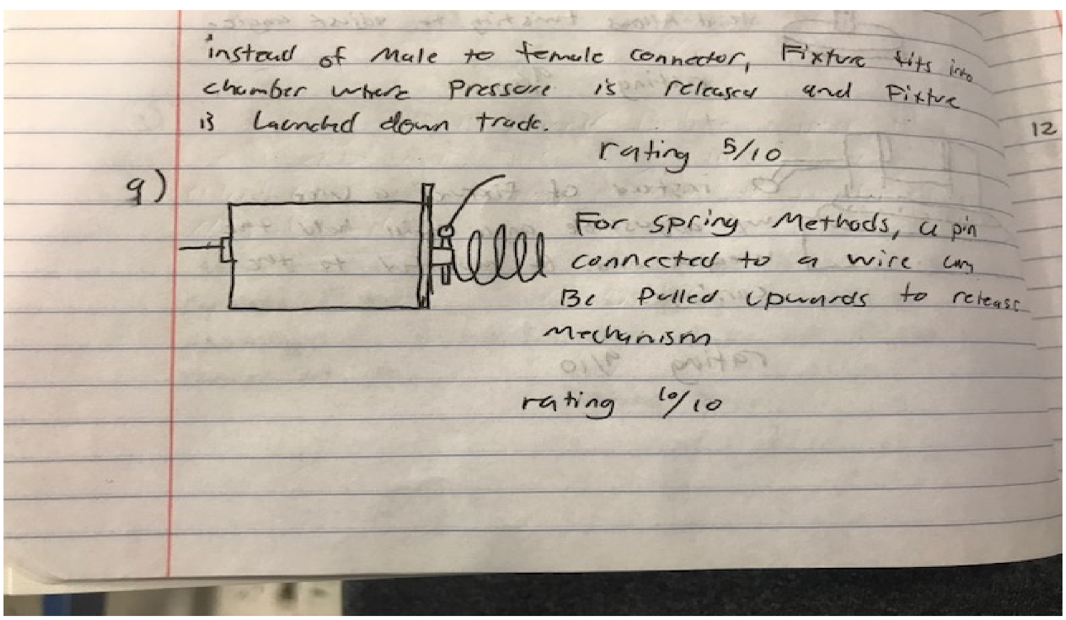


Figure 51: Brody DiPentima Design Concept 9

10. A t-shirt gun like device propelling a fixture holding the weapon into the target.

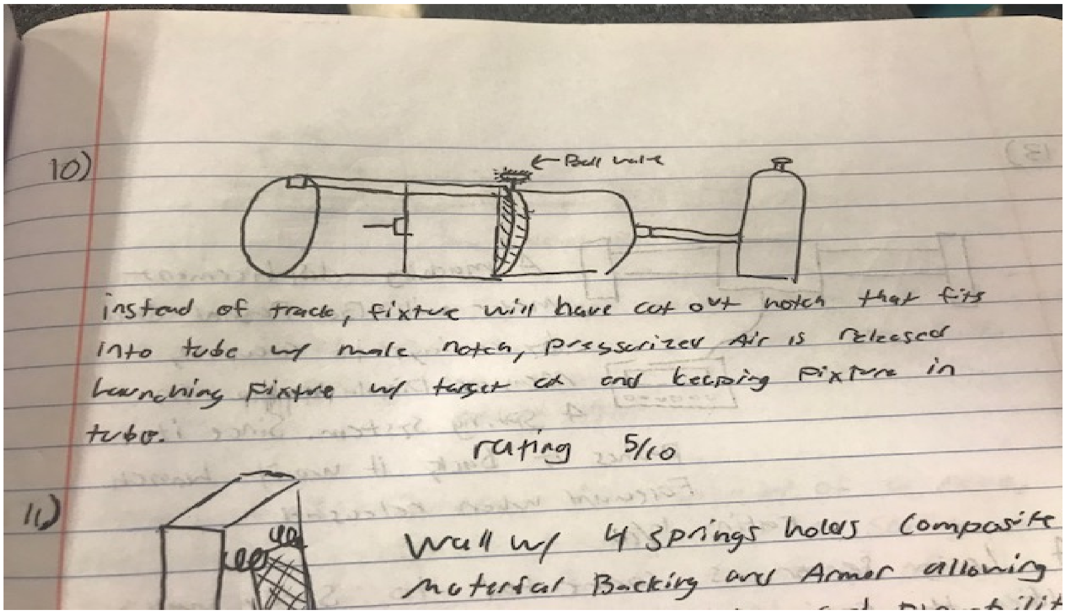


Figure 52: Brody DiPentima Design Concept 10

11. The target can be mounted to four springs allowing for a small amount of give, mimicking a real life situation and causing less fatigue on the target base.

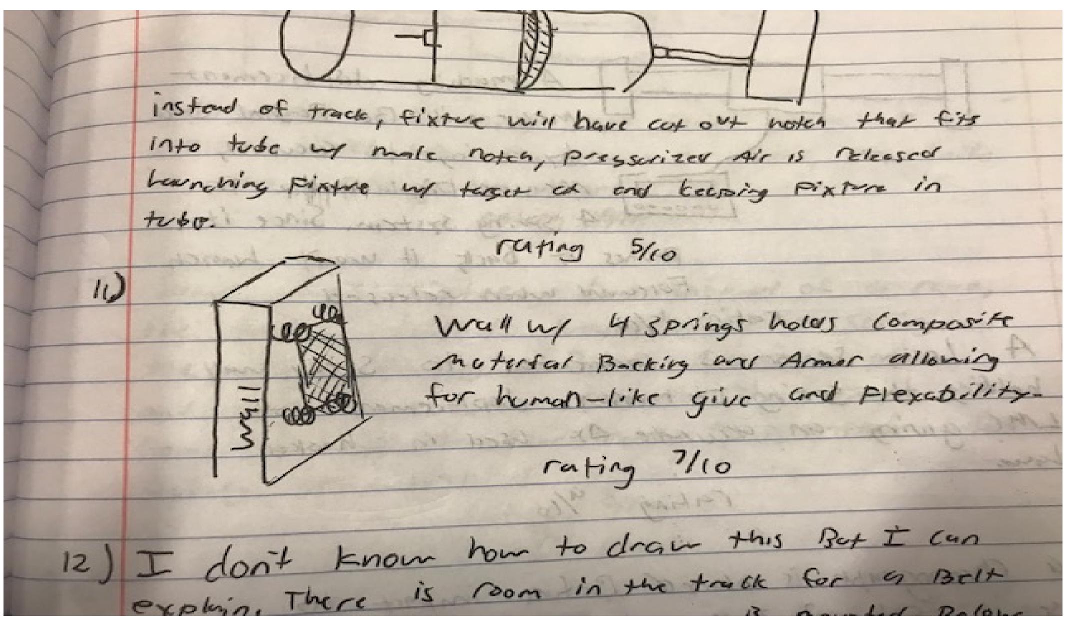


Figure 53: Brody DiPentima Design Concept 11

12. Rather than a spring propelling the cart, a belt and drive system is mounted under the cart, pulling it down the track at a set speed into the target.

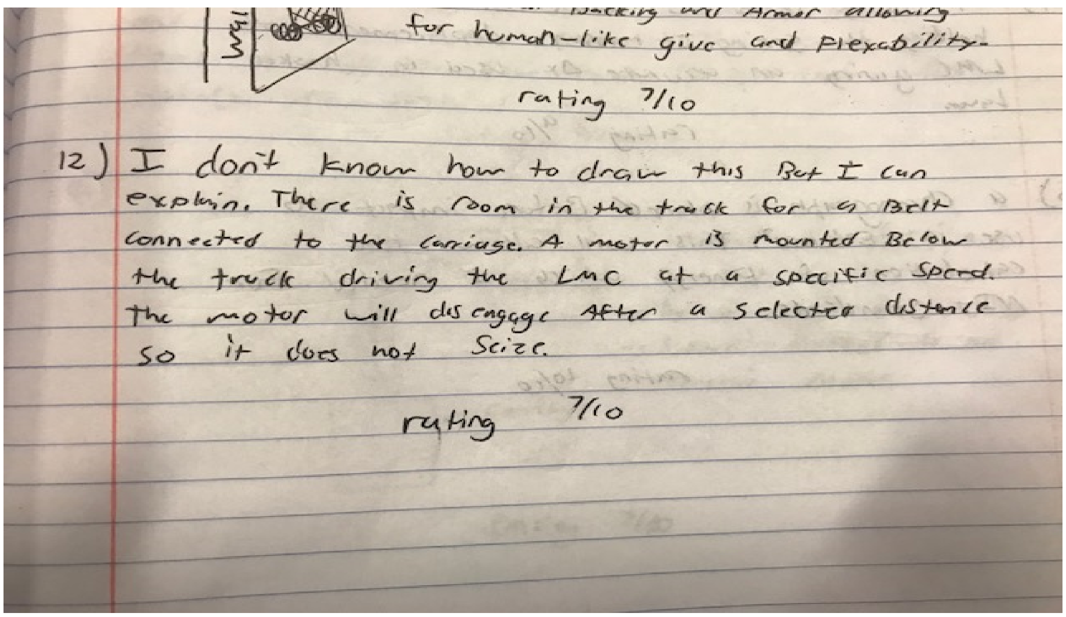


Figure 54: Brody DiPentima Design Concept 12

13. A DRO system can be used when drawing back any spring system to give an accurate measurement of displacement. Mechatronics can be used to stop the winch once a certain displacement is reached.

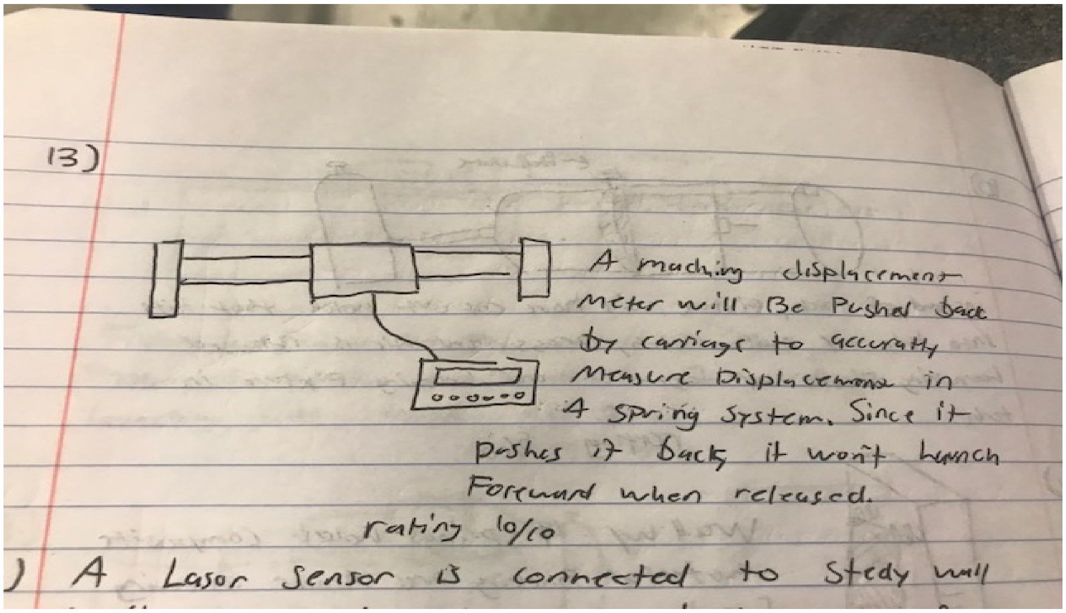


Figure 55: Brody DiPentima Design Concept 13

14. Similar to the DRO system, a laser sensor measuring location can be used to accurately measure the displacement by seeing the change in original location to the displaced location.

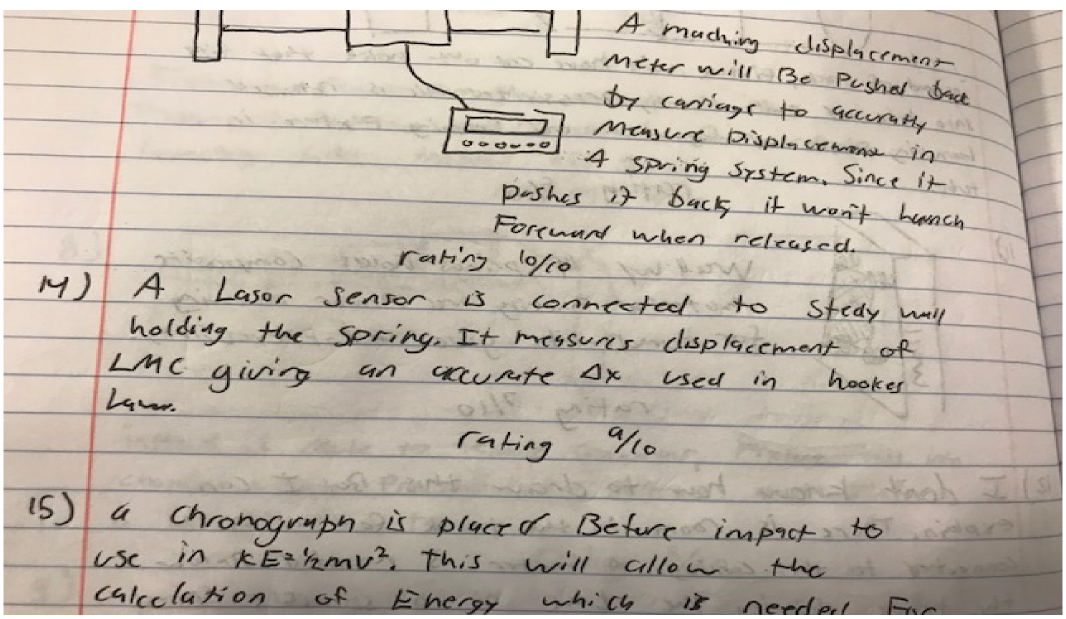


Figure 56: Brody DiPentima Design Concept 14

15. A chronograph can be used at the end of the track to measure the speed of the cart in order for kinetic energy to be calculated.

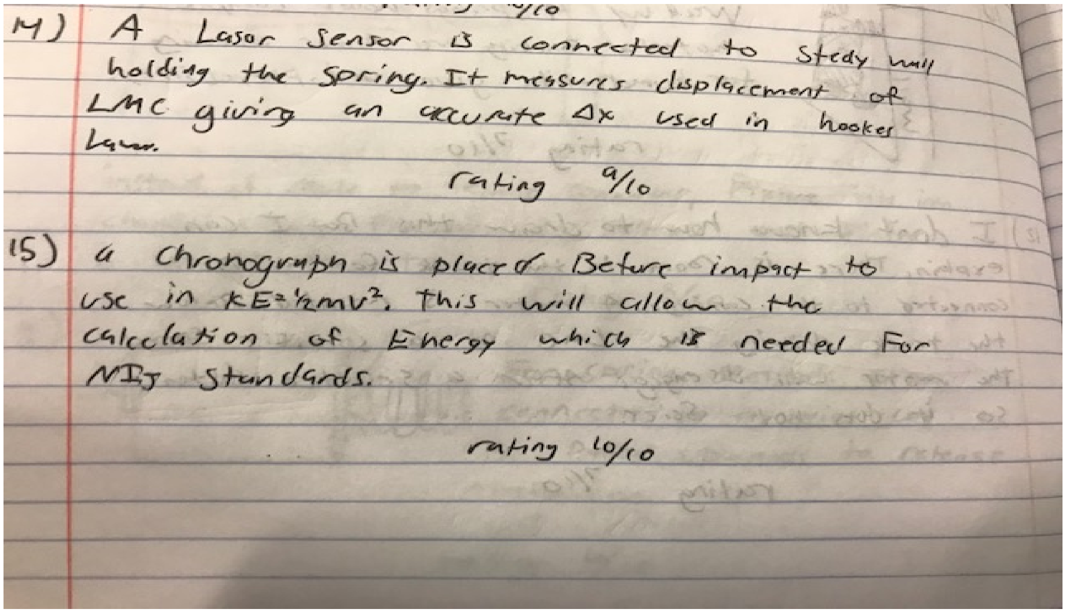


Figure 57: Brody DiPentima Design Concept 15

16. A table allowing the fixture holding the weapon to spin can be connected to a spool. The spool can be pulled at a certain constant speed giving the knife a fixed velocity that it will strike the target at.

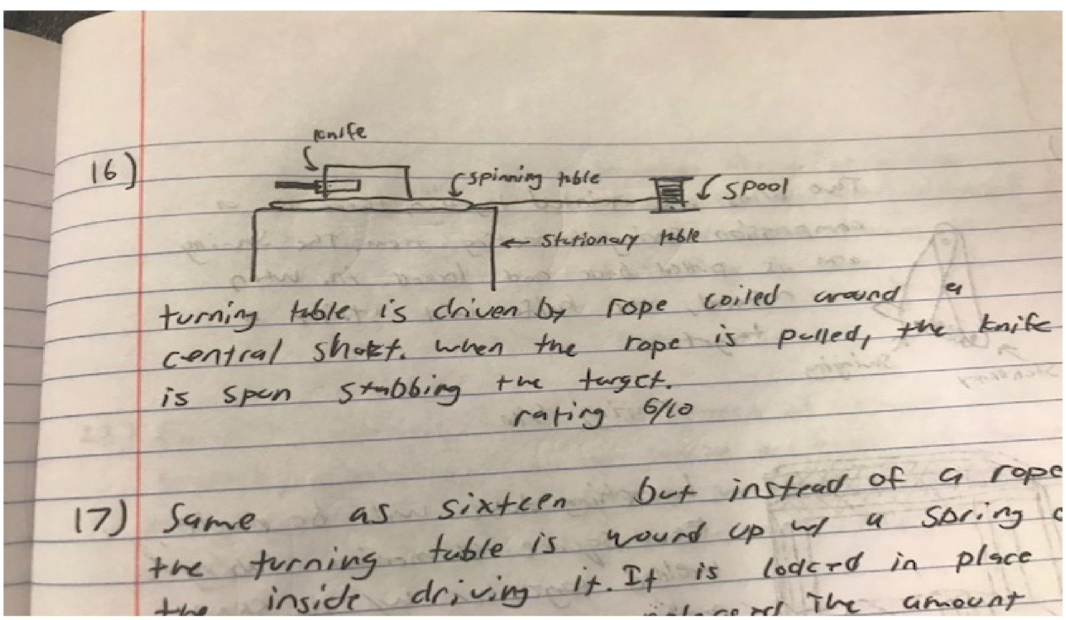


Figure 58: Brody DiPentima Design Concept 16

17. The same as design 16 only a wound spring under the table can be used rather than a

spool and rope system.

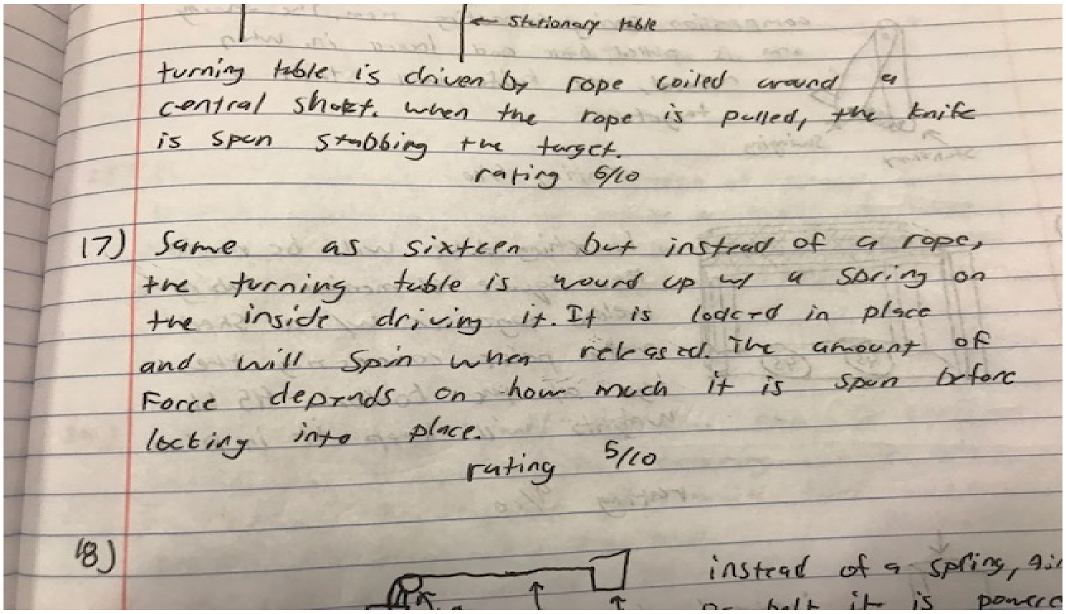


Figure 59: Brody DiPentima Design Concept 17

18. Rather than a spring or compressed air system, a rope and pulley system hooked up to an electric motor can pull the cart down the track at a set speed where it will then strike the target.

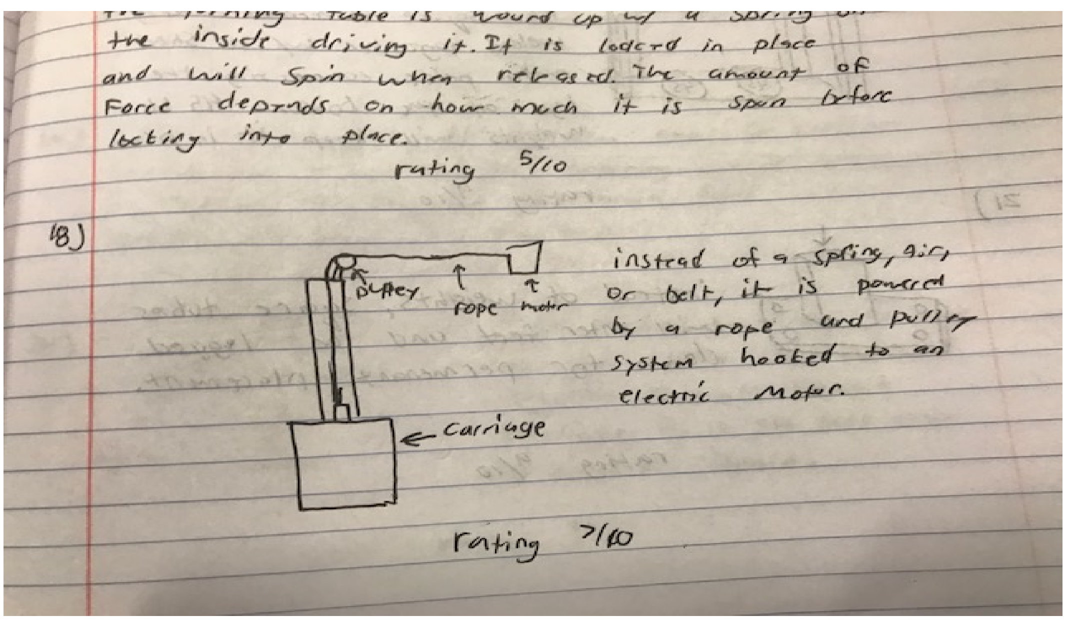


Figure 60: Brody DiPentima Design Concept 18

19. An arm like system can be loaded back with a compressed spring. The amount of compression will determine the energy delivered. A release system will launch the arm, swinging it into the target.

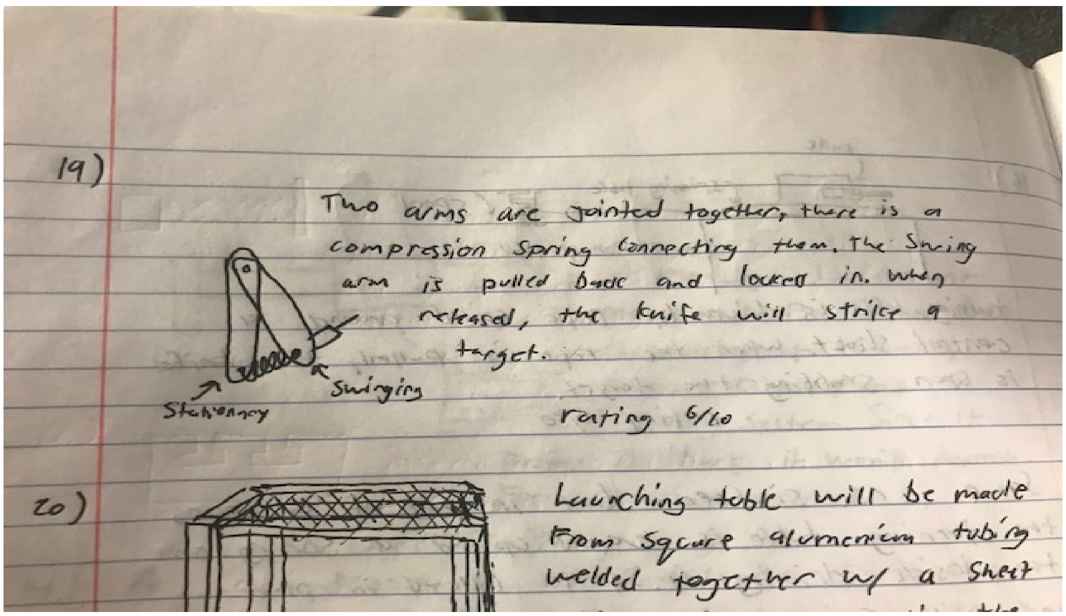


Figure 61: Brody DiPentima Design Concept 19

20. For any design, a weighted table with a heavy metal top can be used when bolting down the track or winch system as well as cause little movement when the energy from the system is released.

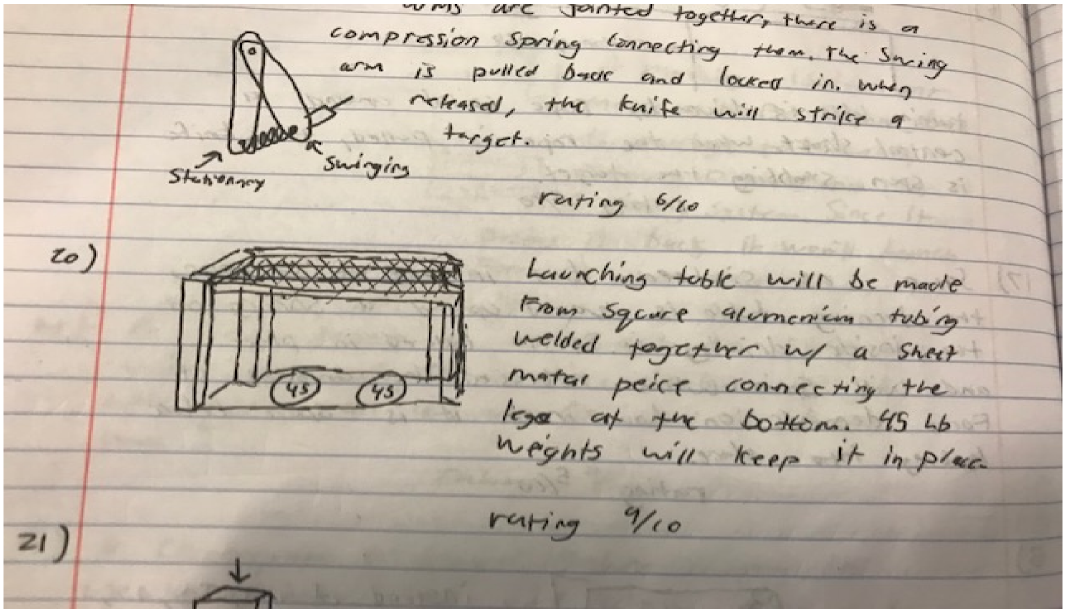


Figure 62: Brody DiPentima Design Concept 20

21. Similar to design 20 but a foot system can be used to lock down the table, giving no movement when the system is launched.

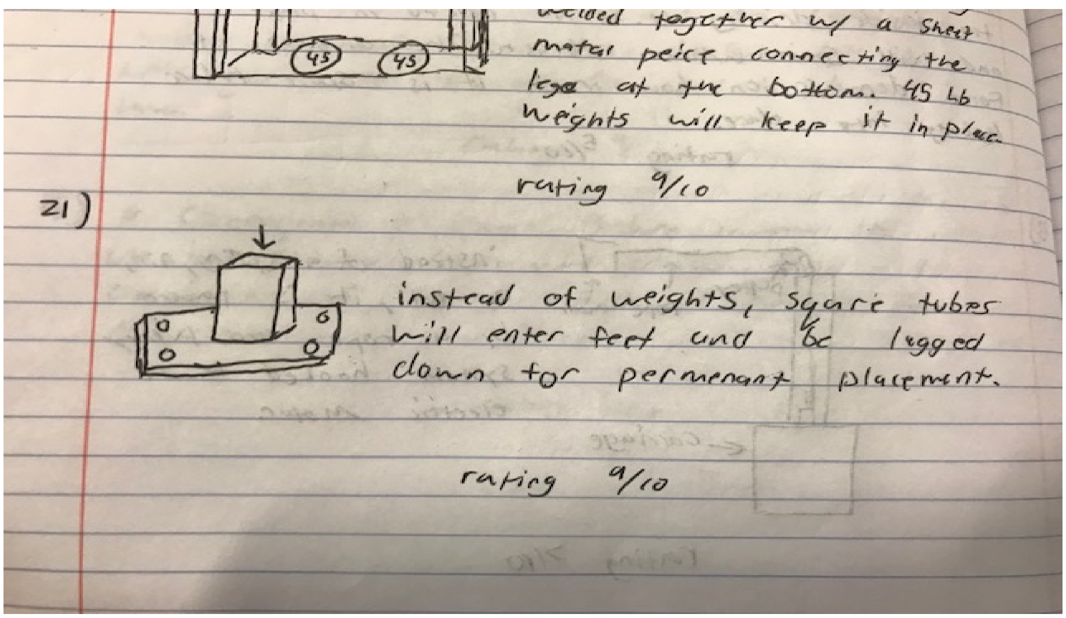


Figure 63: Brody DiPentima Design Concept 21

22. Similar to design 10 but rather than launching the knife fixture, the target will be placed at the end of the chamber so it won't travel through the air.

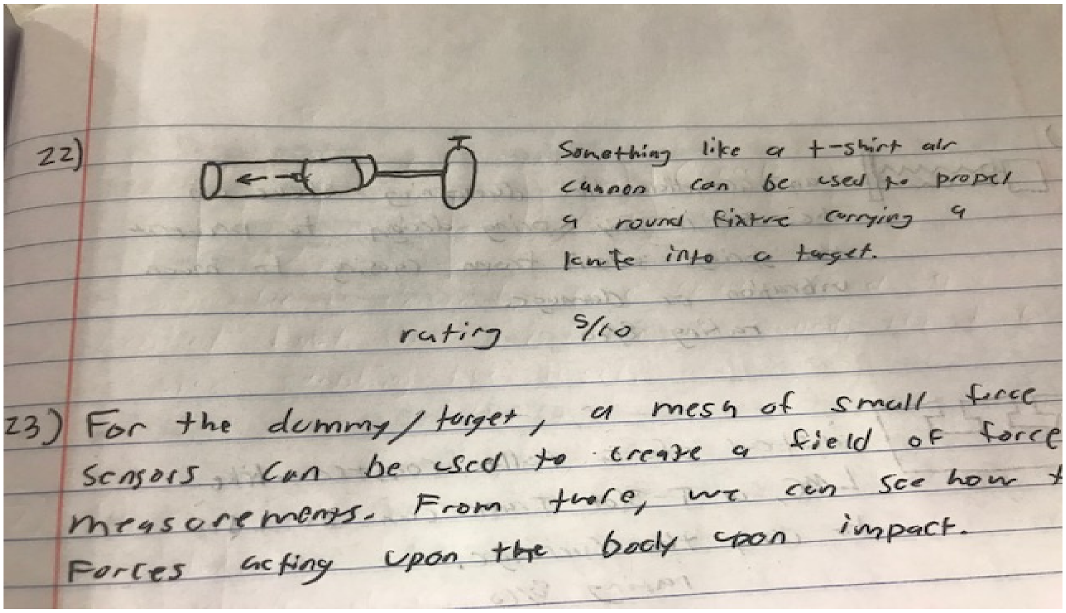


Figure 64: Brody DiPentima Design Concept 22

23. For the target system, a mesh of force sensors can be placed behind the target to give a grid-like feedback system showing where force was dissipated.

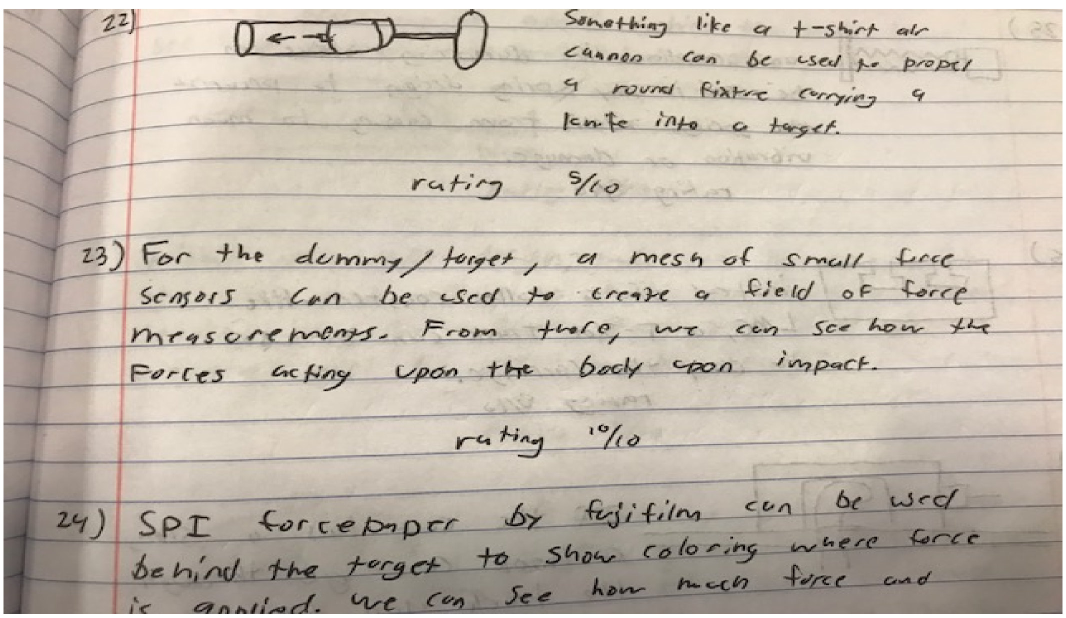


Figure 65: Brody DiPentima Design Concept 23

24. SPI force paper can be placed behind the target instead of a force reading grid in order to show where force was dissipated.

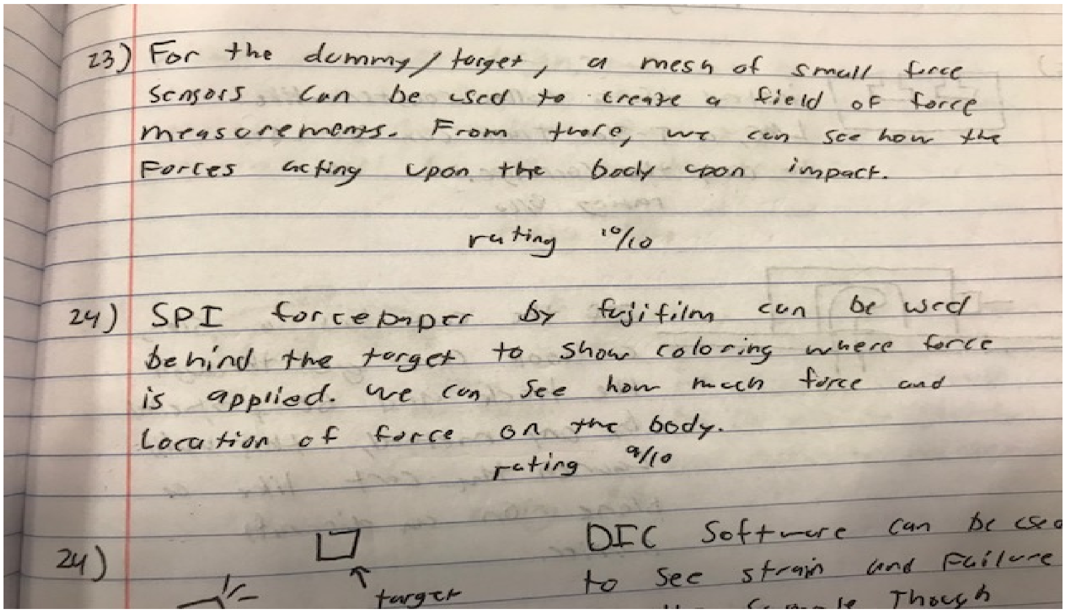


Figure 66: Brody DiPentima Design Concept 24

25. A DIC system can be used to measure strain using slow motion cameras, quality lighting, and a DIC software system.

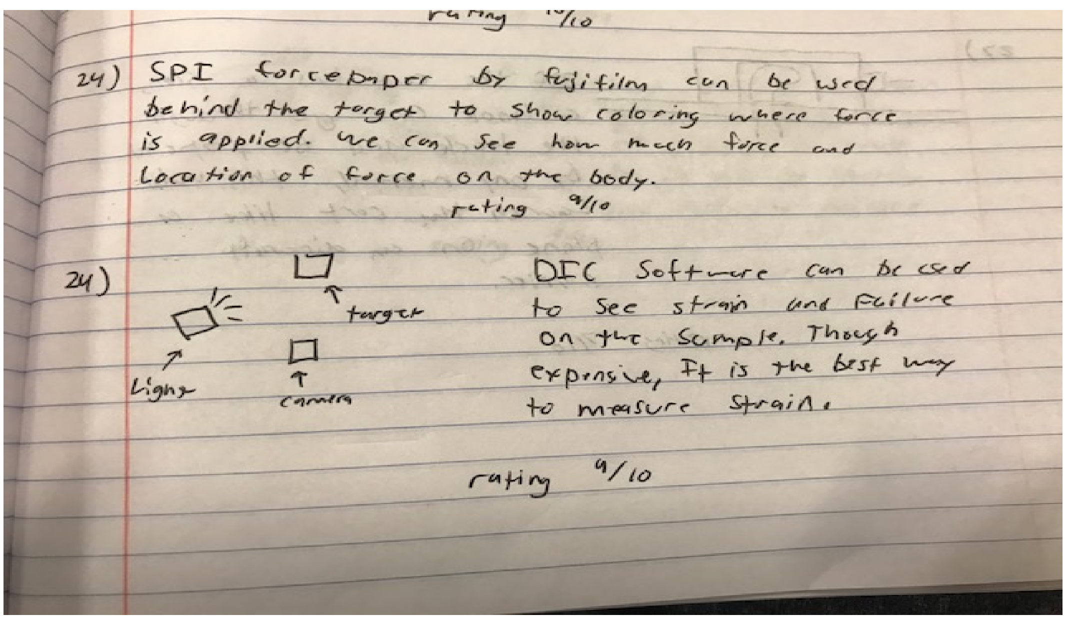


Figure 67: Brody DiPentima Design Concept 25

26. A dampening sleeve can be placed over the spring to contain the leash as well as dampen the spring vibration after release.

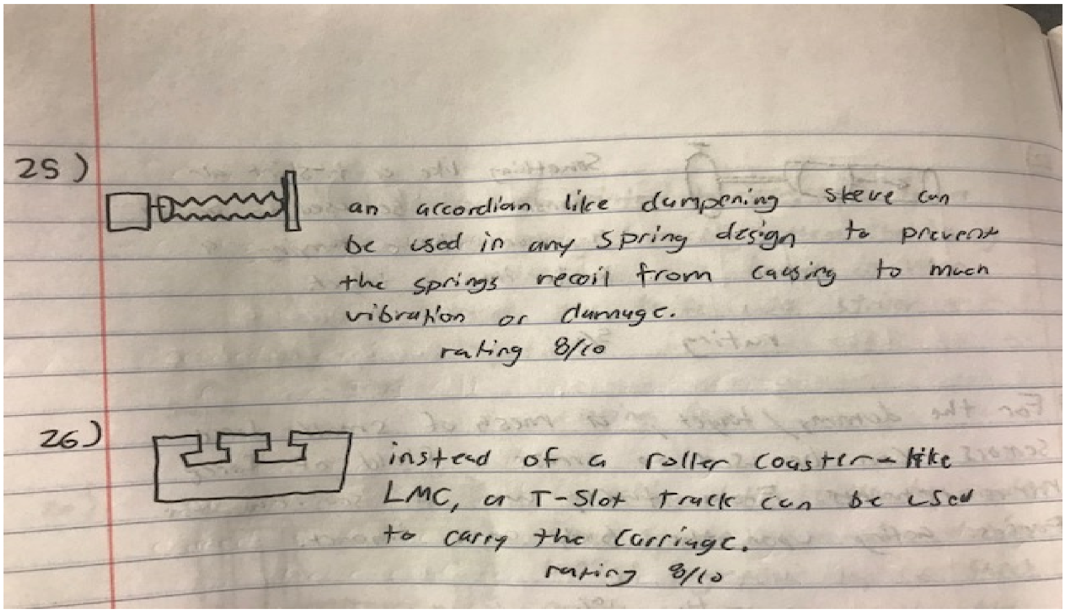


Figure 68: Brody DiPentima Design Concept 26

27. A T-slotted track with lubricant can be used as a track rather than the previous ball bearing or wheeled designs.

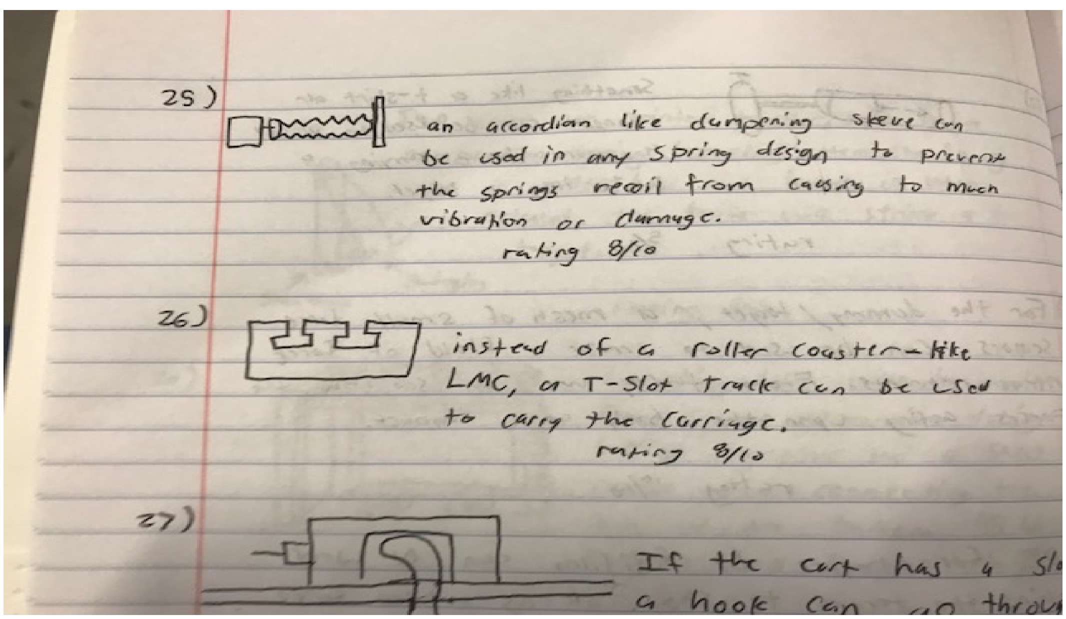


Figure 69: Brody DiPentima Design Concept 27

28. A force plate can be placed behind the knife fixture on the cart to show the impact force. The output reading will show how it is dissipated over time as well as maximum force.

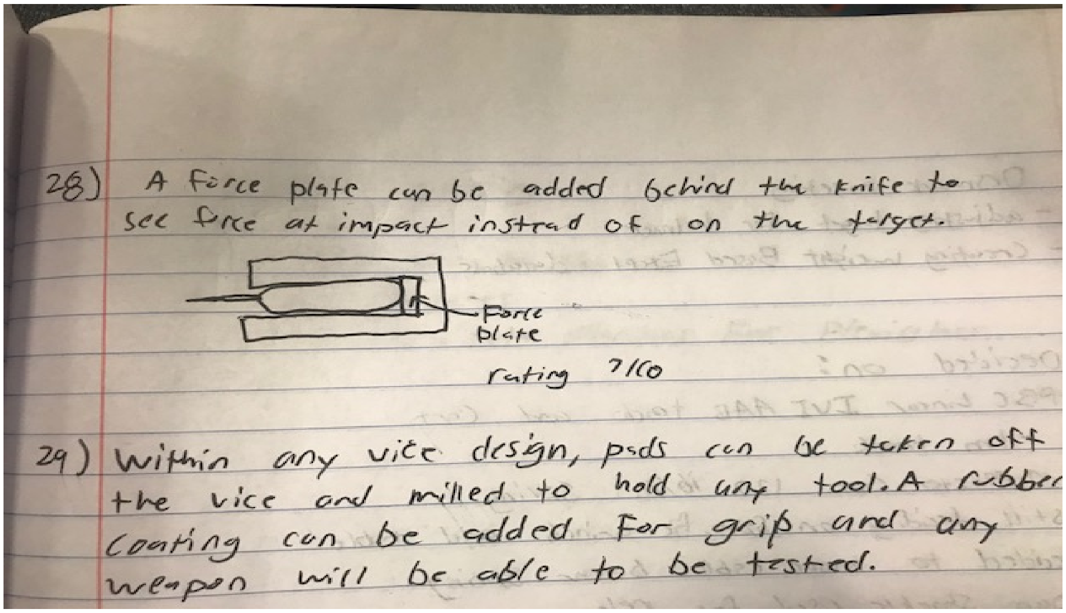


Figure 70: Brody DiPentima Design Concept 28

29. For any design with a vice holding the weapon, the gripping pads can be milled custom to each weapon allowing for a universal system that is easily interchangeable.

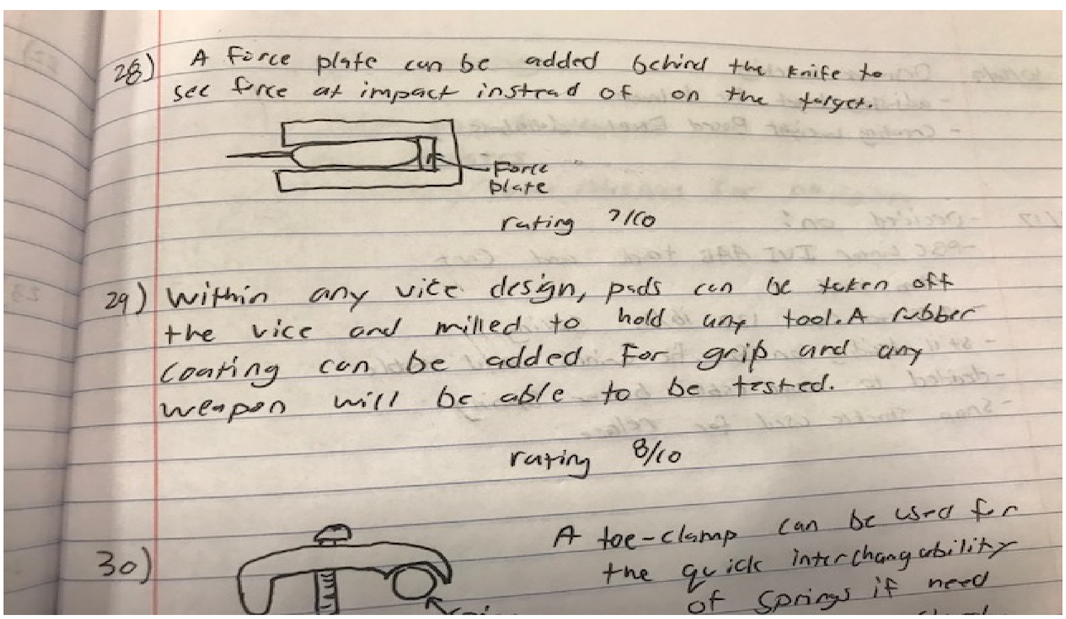


Figure 71: Brody DiPentima Design Concept 29

30. A toe-clamp system can be used to secure down the spring effectively as well as allow quick and easy replacement of the spring if needed.

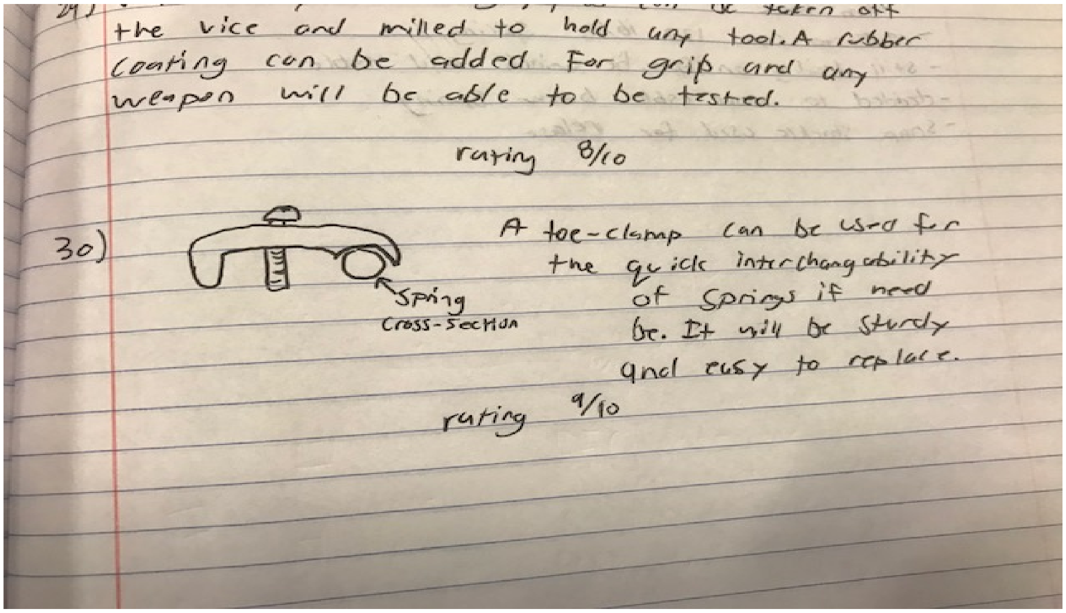


Figure 72: Brody DiPentima Design Concept 30

Nicholas Perry Concept List

1. Cylindrical Stand mimics a crash test dummy. The hollow cylinder is attached to a telescoping support stand that can depress to 45° to simulate the NIJ standards. The stand is connected to a pressure sensor that can map the impact field.

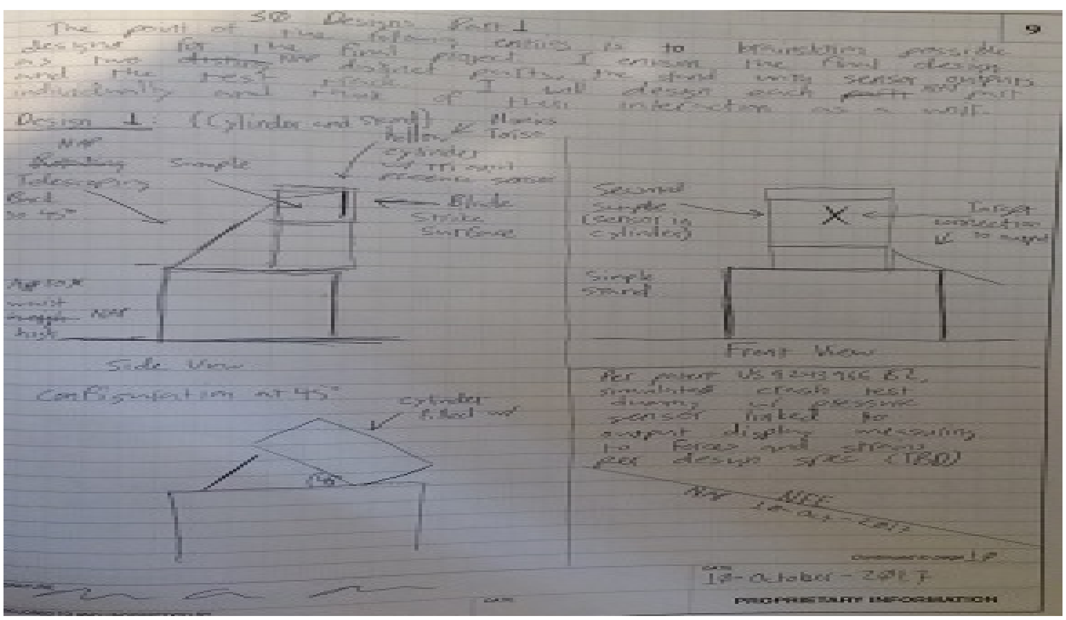


Figure 73: Nicholas Perry Design Concept 1

2. The track system is shown in its entirety. The target is similar to design 1. The most notable aspect of the track is the propulsion system. A spring driven seems to have the advantage of simple construction and modeling, but fatigue needs to be taken into account due to compression and release.

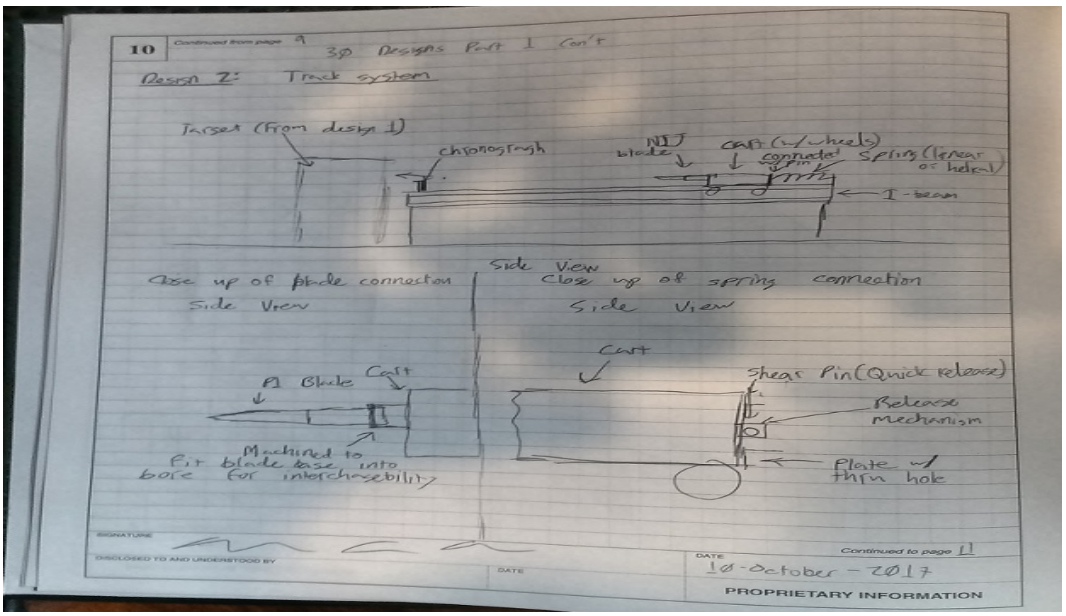


Figure 74: Nicholas Perry Design Concept 2

3. This design is replacing the spring with an air cannon. This design is easier to use but harder for reproducibility and safety. It is a very low volume of parts design.

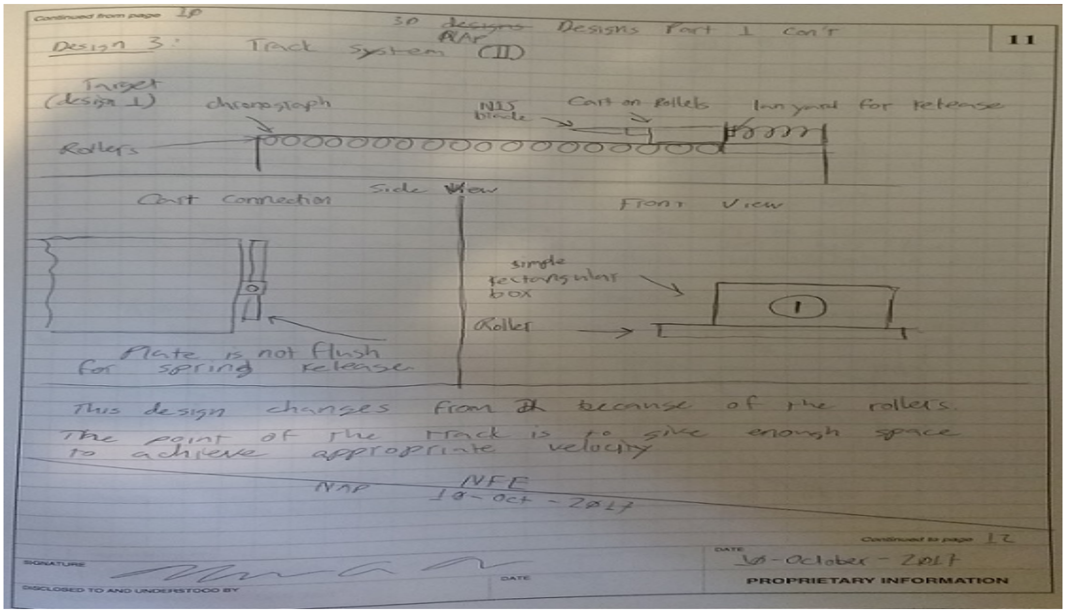


Figure 75: Nicholas Perry Design Concept 3

4. The release mechanism is visualized similar to a lanyard firing an artillery piece. A shear pin is inserted into a through hole that is retained with a safety clip. Mechanically, the pin is holding the spring at the desired compression and when released, should propel the cart in a safe manner.

5. The spring is attached to a plate that is contacting the linear momentum cart with a hook. The thru-hole allows for the shear pin to take the load of the spring while keeping the cart in place.

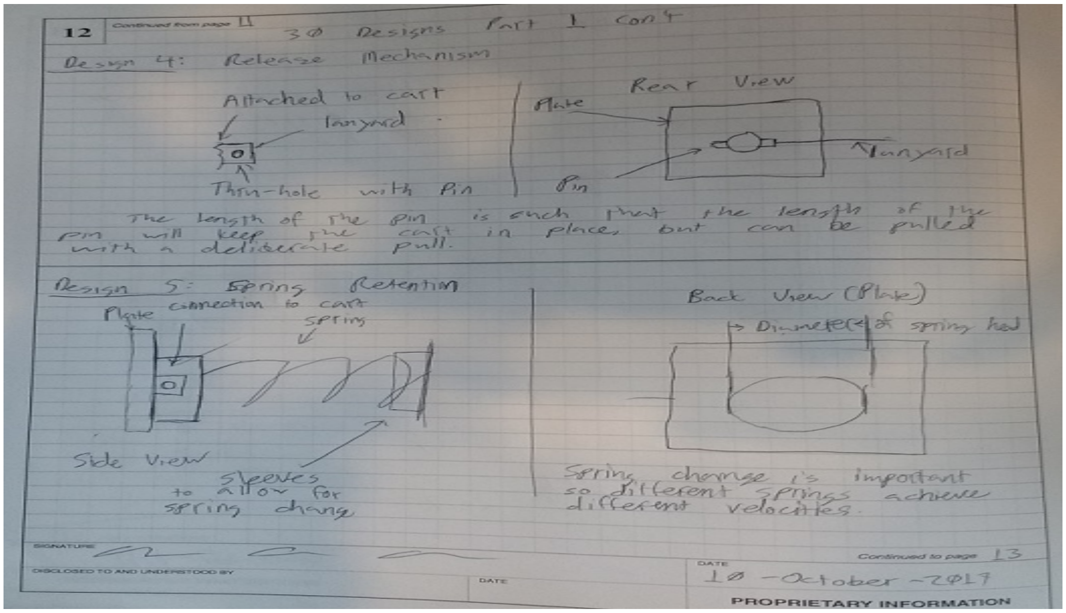


Figure 76: Nicholas Perry Design Concepts 4 through 5

6. A mechanical winch with steel cable is threaded through the spring. A low HP motor will draw the cart to the desired compressed length and held in position with the shear pin. The compression measurement sensor is still being determined.

7. The second concept is have the plate pushing the cart rest in notches along the track that correlate with approximations of the kinetic energy for desired tests. The cart is held in place with the shear pin.

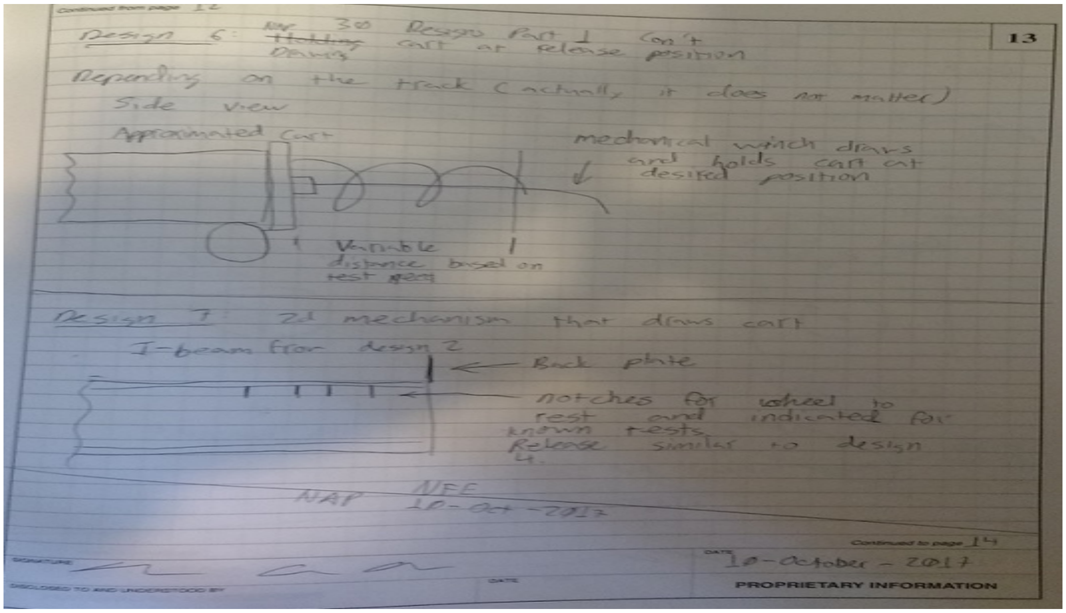


Figure 77: Nicholas Perry Design Concepts 6 through 7

8. For this drawing mechanism, the plate connected to the cart was a one direction spring that prevents rotation so that the cart locks into place. The cart is still drawn mechanically by the winch. The idea is to have a smooth release with a simple mechanism.

9. This concept has the idea that the springs should be easy to change. The constant tension and compression of the spring will lead to eventual fatigue and replacement. Design considerations should be given the eventuality and ease of use should be considered.

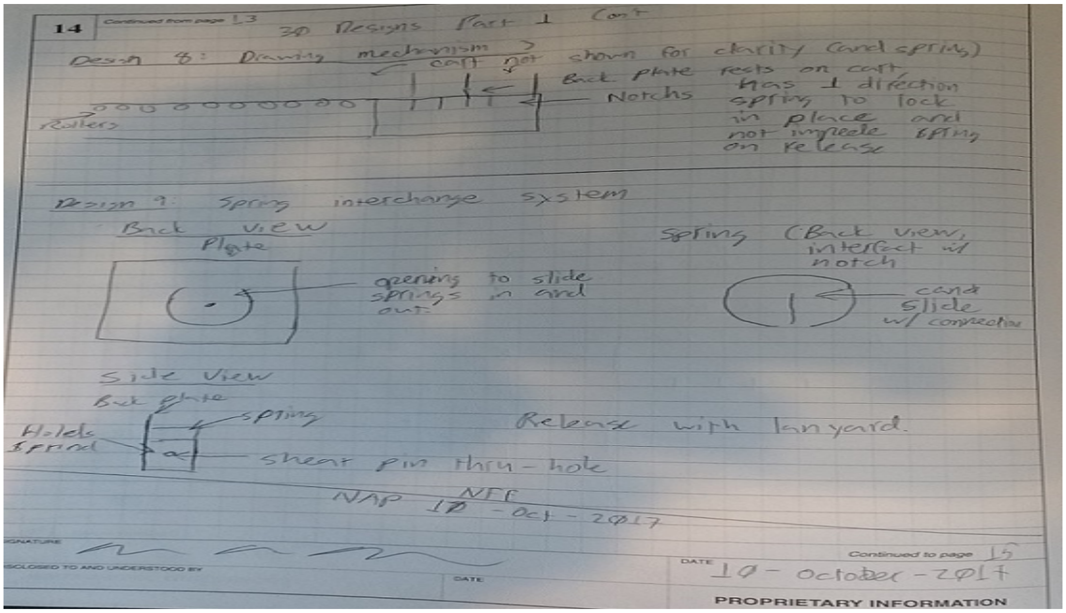


Figure 78: Nicholas Perry Design Concepts 8 through 9

10. The purpose of the dummy is to measure the impact on an approximate human form and map the pressure field. The test material will be placed on NIJ standard backing and the SPI pressure sensor will be draped over the target. Cost is estimated at $10,000.

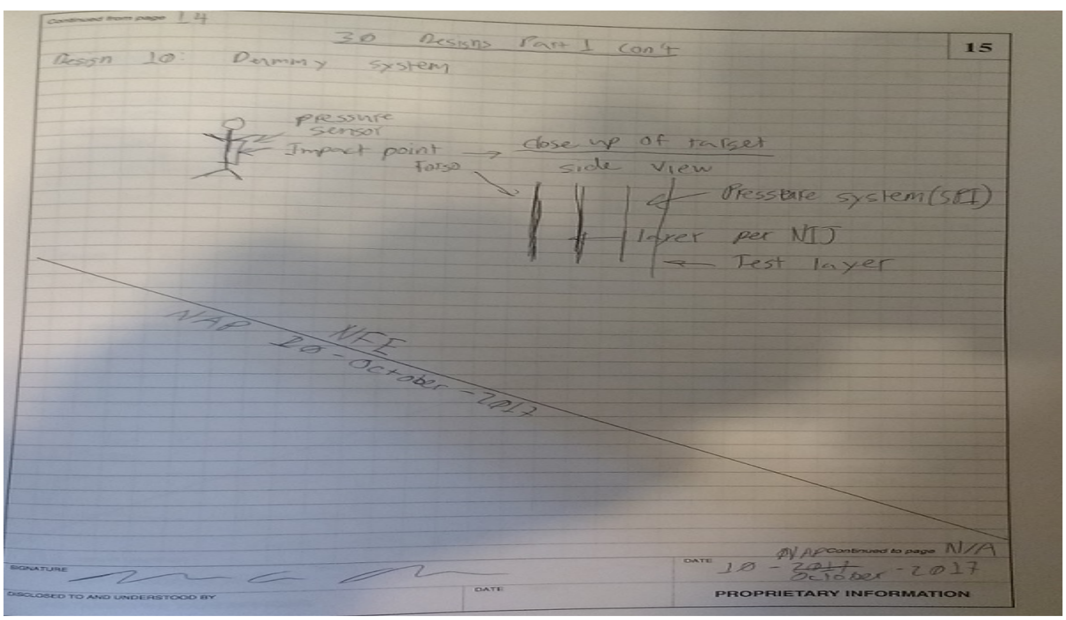


Figure 79: Nicholas Perry Design Concept 10

11. I wanted to look at a different propulsion system and thought compressed air would be

a good alternative. This is a simple breach loading system where the user inputs the desired psi and fires the stabber at the target.

12. The breach loader presents problems in terms of time constraints due to pressure loss and dynamic modeling of the projectile. It is simpler to place the projectile in the rear, but sealing the breach through clamping was chosen for this design.

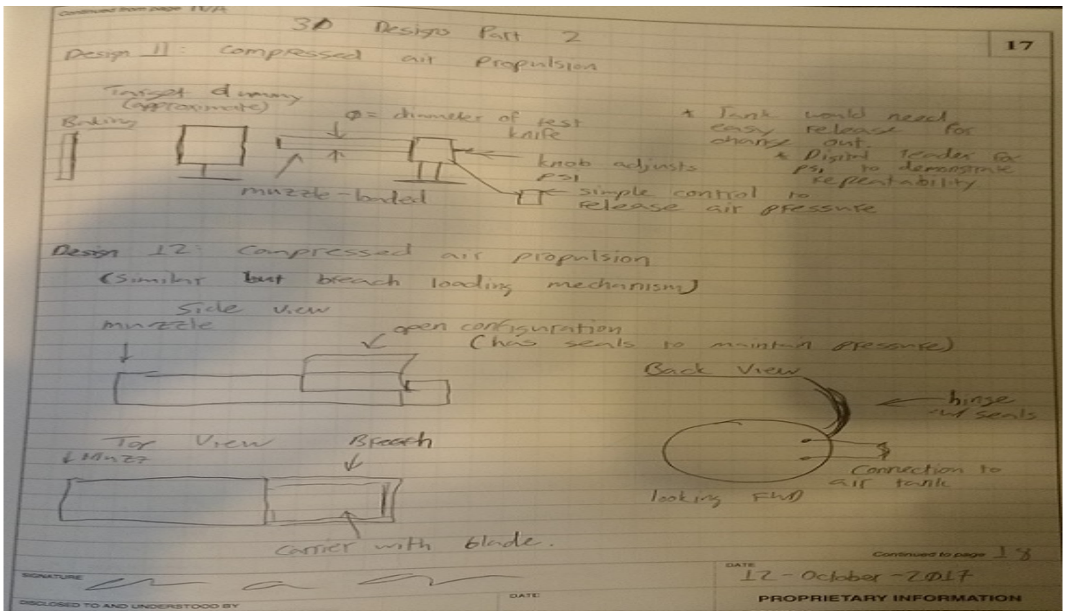


Figure 80: Nicholas Perry Design Concepts 11 through 12

13. An alternative breach sealing mechanism that recoilless rifles utilize. A lever is depressed and the breach is swung open where the projectile can be loaded. When the breach is closed, the seal prevents air from bleeding out of the system.

14. Another method of breach sealing comes from a sliding breach block small artillery pieces use. In this case, a lever opens and closed the breach allowing for the projectile to be loaded. The compressed air is still supplied with a replaceable canister.

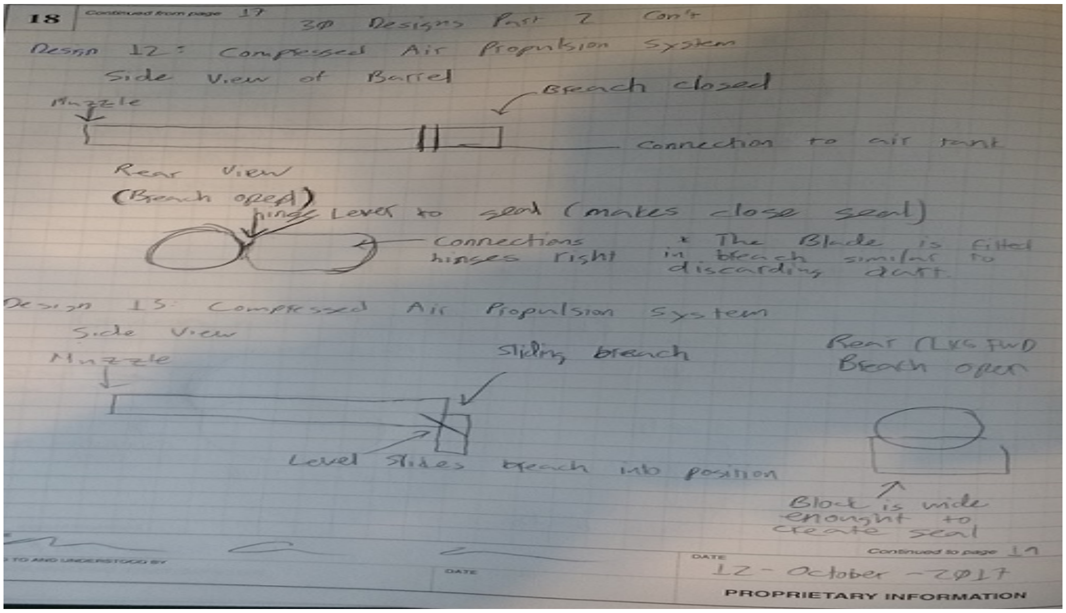


Figure 81: Nicholas Perry Design Concepts 13 through 14

15. All of the air cannon systems needed to have a projectile that fit into the muzzle of the system that did not allow any air to escape and affect the ballistics of the test. The projectile would have a quick release system that allowed for easy changing of blades depending on the test conducted.

16. Another though was to have the cart propelled similar to an aircraft carrier launch system. A guide track would be cut and a hook pushing the cart would be used. The lanyard system would be easier to construct since the hook can extend below the spring.

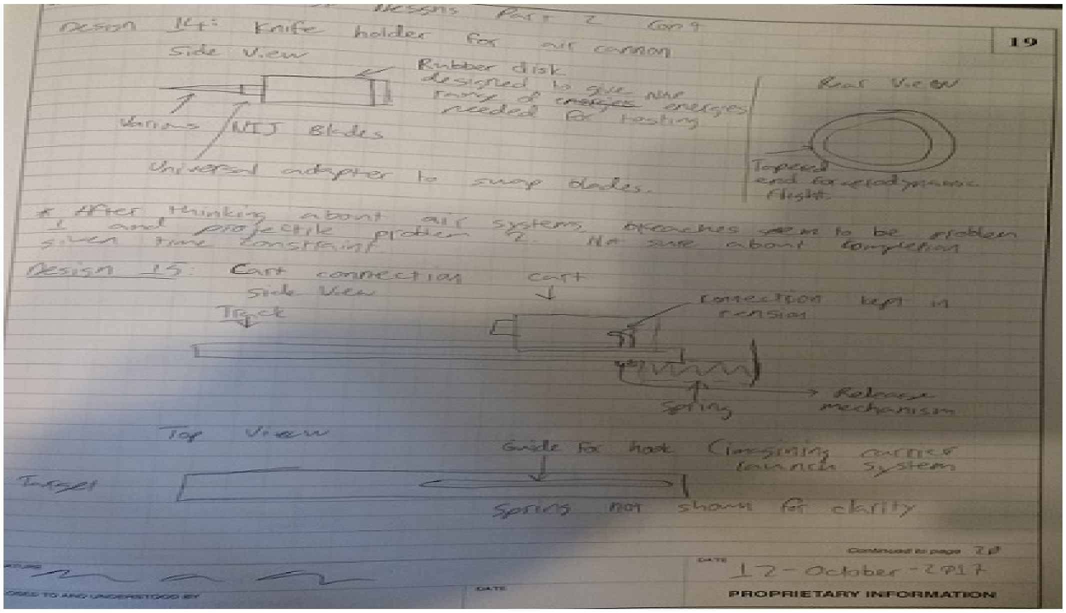


Figure 82: Nicholas Perry Design Concepts 15 through 16

17. The spring is placed on the bottom of the track to save some space. The hook from design 15 works in conjunction with this system so that the cart is only pushed by the hook.

18. This hook system combines a plate pushing the cart connected to a rotating hook. When the shear pin is pulled, the hook rotates out of position allowing the plate to propel the cart down the track.

19. This hook is a little simpler because it does not rotate, but pulled strait down by the lanyard. There is a pulley similar to M777 firing mechanism that translate horizontal pull to vertical release.

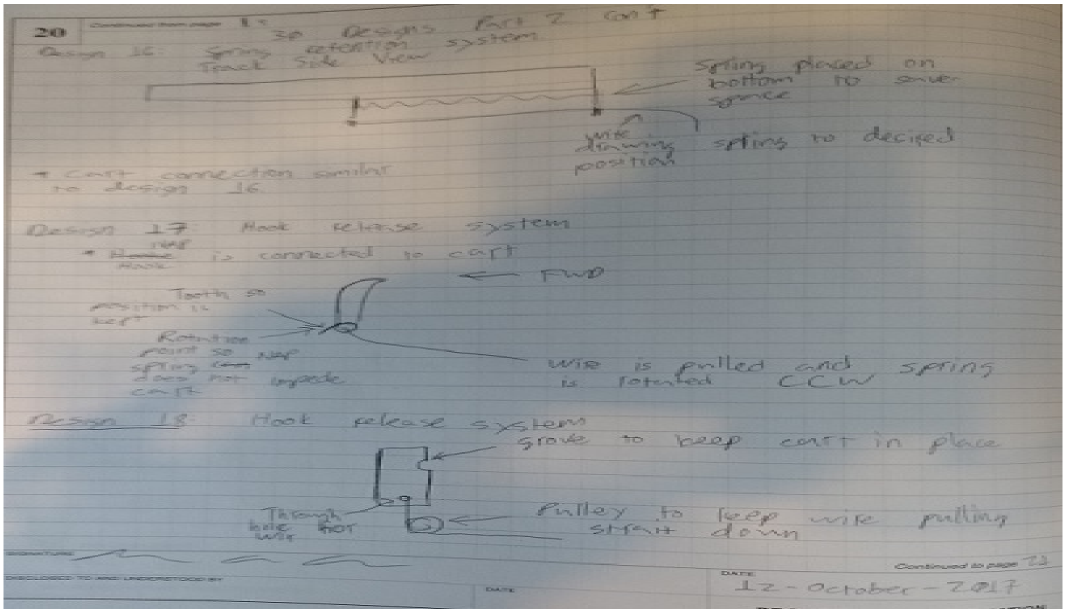


Figure 83: Nicholas Perry Design Concepts 17 through 19

20. Motor pulley system would be a different propulsion system because velocity could be varied with the RPM of the motor. A bike chain would propel the cart down the track until impact.

21. A limitation of the previous system would be acceleration down the track provided by the motor. A spring would assist with getting the required terminal velocity by reducing the amount of acceleration the motor had to produce.

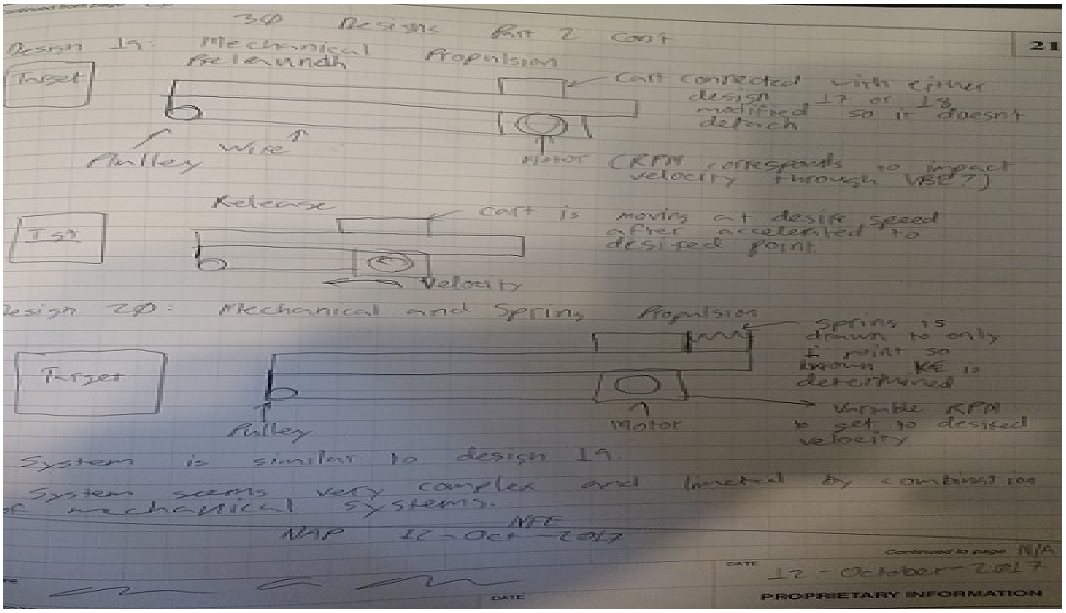


Figure 84: Nicholas Perry Design Concepts 20 through 21

22. The stand with the telescoping support from design 1 is used, but a flat face is used to simplify the target setup. Pressure sensors are attached to the back so that a pressure field can be mapped with the Arduino output.

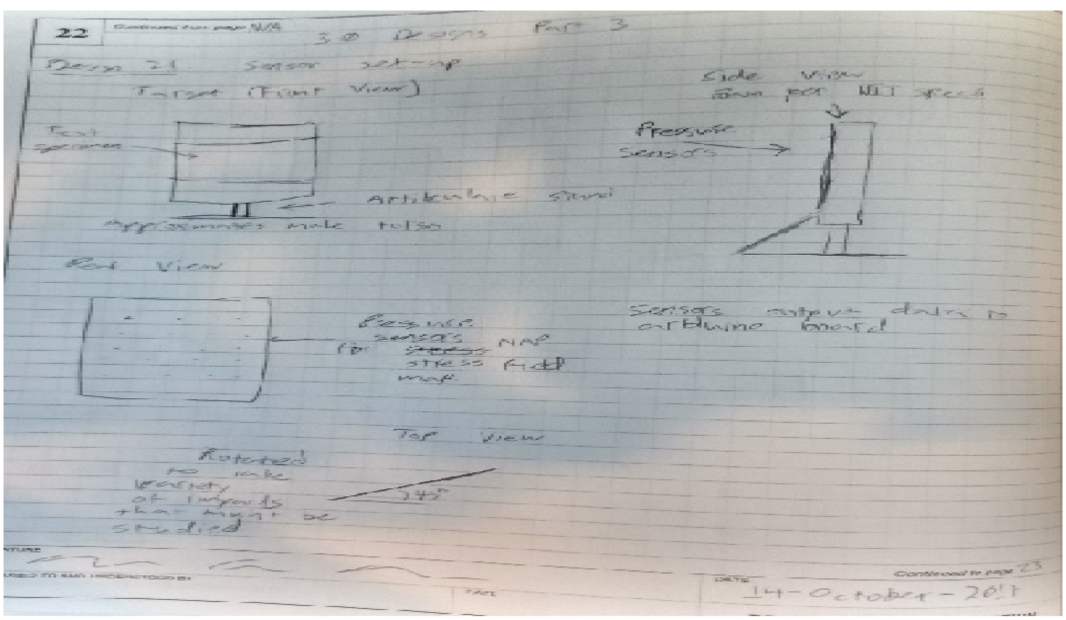


Figure 85: Nicholas Perry Design Concept 22

23. DIC is very useful for mapping the strain experienced at high strain rates which can be

back calculated to determining impact energy when combined with the chronograph. The geometry of the track allows for strikes at angles to be recorded as well.

24. 2-D DIC could be a cheaper alternative since 1 high speed camera is required. The track geometry limits the strike angles that can be correlated. Analysis is simpler and software from URI is already available.

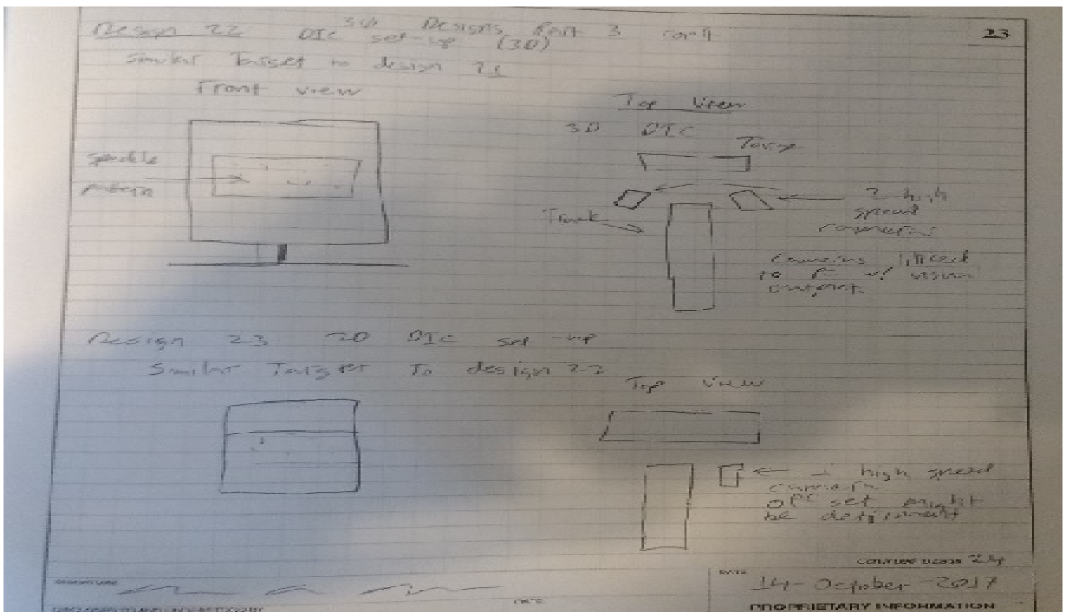


Figure 86: Nicholas Perry Design Concepts 23 through 24

25. VB can be used to display the kinetic outputs of the test. Radio boxes can be used to customize testing and what needs to be measured. Arduino chips can be used to limit cost and enhance endurance.

26. If DIC is pursued, existing software is used to show how the material performs during the test so that visual analysis can be conducted. Very small deflections and strains can be measured.

27. This gage is used in the auto crash test industry to record impact behavior. This gage is placed on a cylinder approximating the average torso so that realistic responses can be measured.

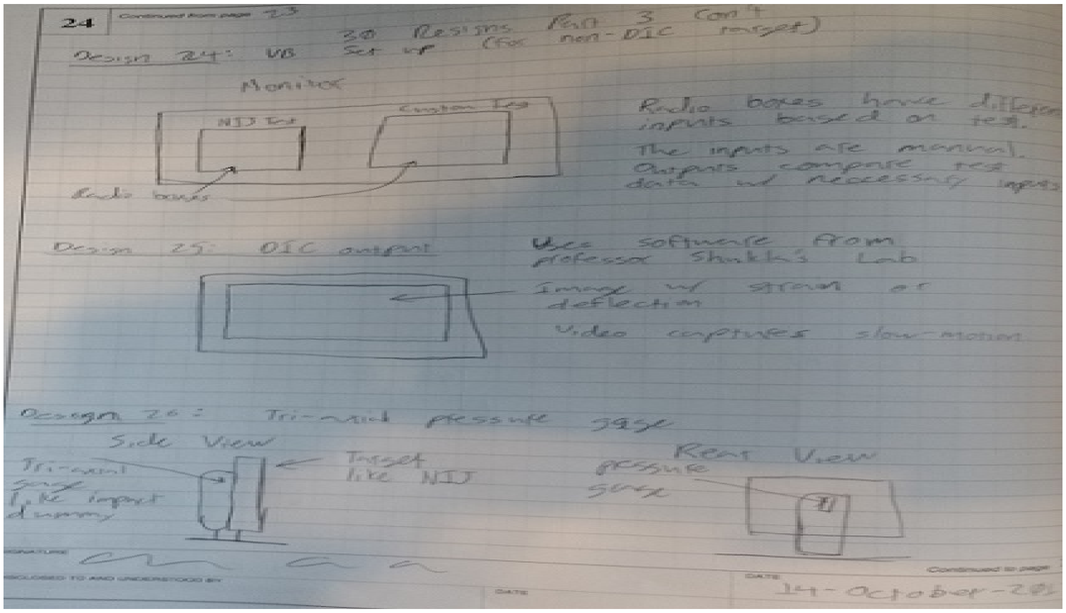


Figure 87: Nicholas Perry Design Concepts 25 through 27

28. The customer requires knife attacks at specific degrees. This design has an articulate arm attached to the car so that specimens can be tested for the effects of different impacts during testing.

29. This design had a clamp attached to the cart so that different angles can be achieved. It is similar in effect to design 27, but articulation is achieved through rotation.

30. The user needs a simple output so that when the spring is compressed, the known compression of energy can be displayed. Fine adjustments are needed so that the spring is only compressed into position for consistent testing.

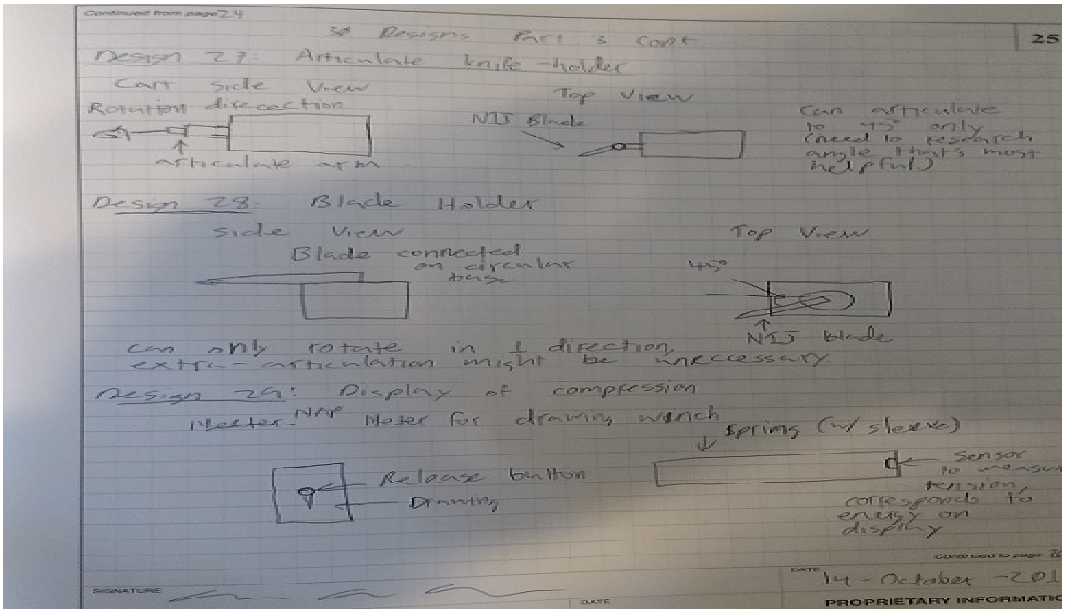


Figure 88: Nicholas Perry Design Concepts 28 through 30

31. Similar to the spring retention on the bottom of the track, a side mount can be utilized so that the system is not cluttered. The main objective was to reduce potential clutter around critical systems.

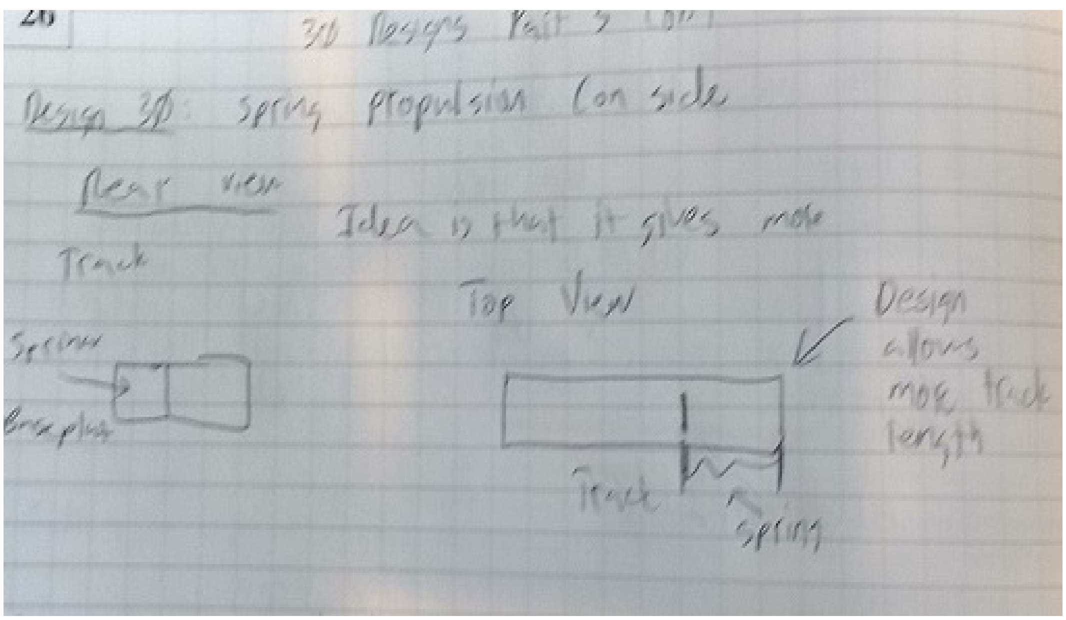


Figure 89: Nicholas Perry Design Concept 31

Alec Svendsen Concept List

1. This design uses an air cannon with a horizontal setup to propel the piercer into the test specimen. Variability with the compressed air allows for a large range of test velocities.

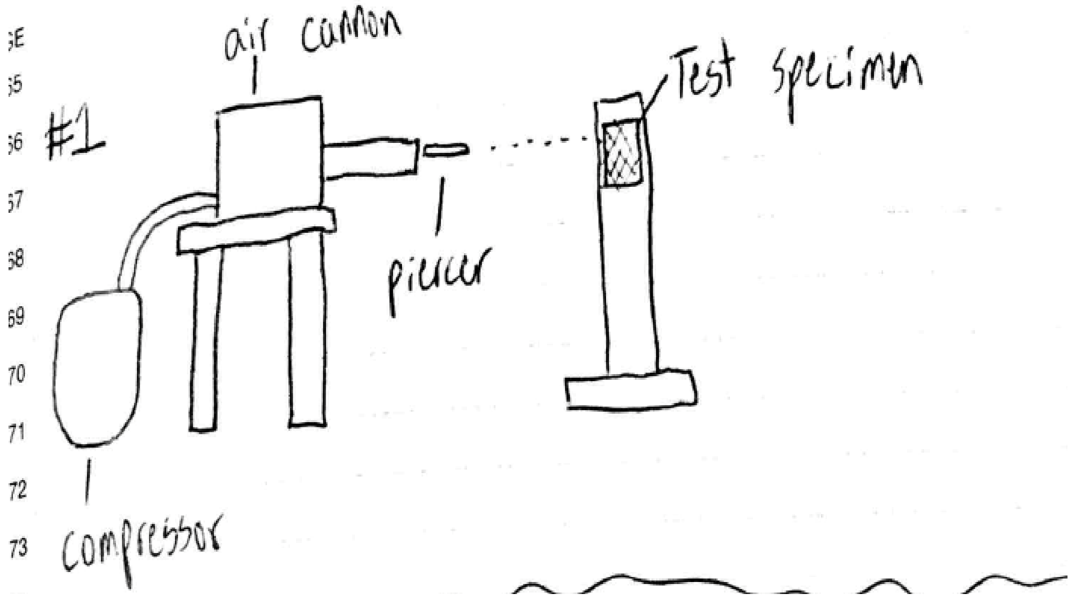


Figure 90: Alec Svendsen Design Concept 1

2. This design is similar to Design 1 but incorporates gravity to hit the test specimen with more energy.

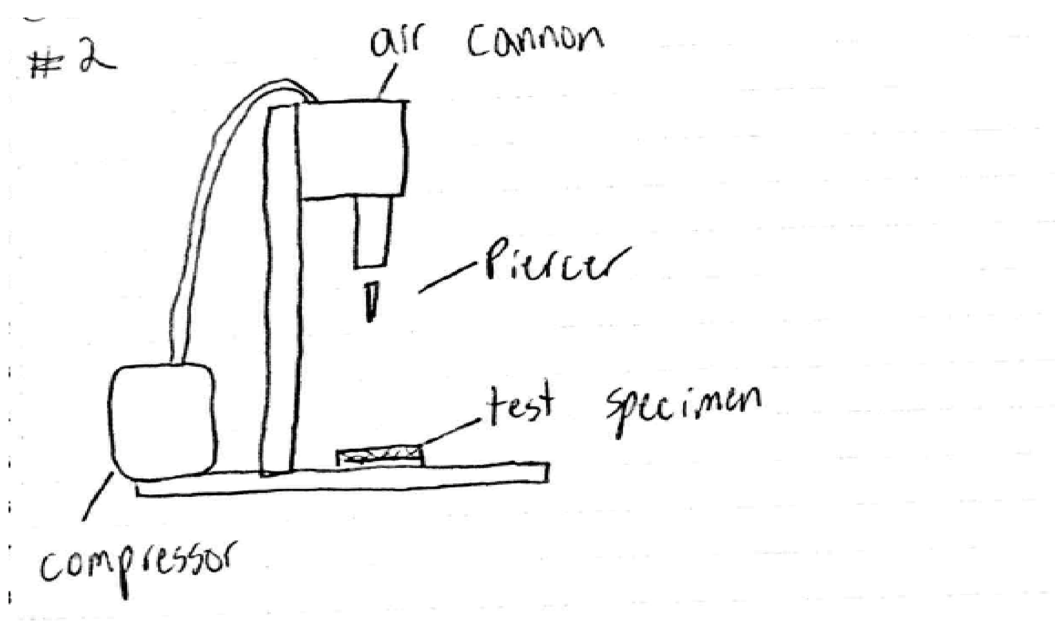


Figure 91: Alec Svendsen Design Concept 2

3. This setup is similar to Design 1 but uses a test dummy to have more versatility with the test subject.

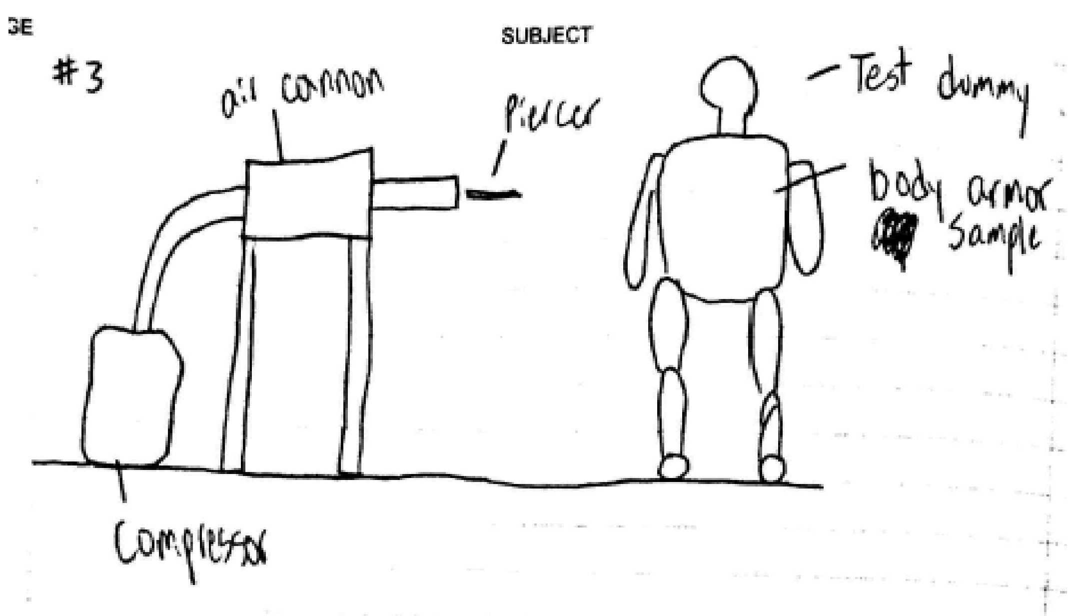


Figure 92: Alec Svendsen Design Concept 3

4. With this Test subject design, one can experiment with arm or leg guards that have already been manufactured.

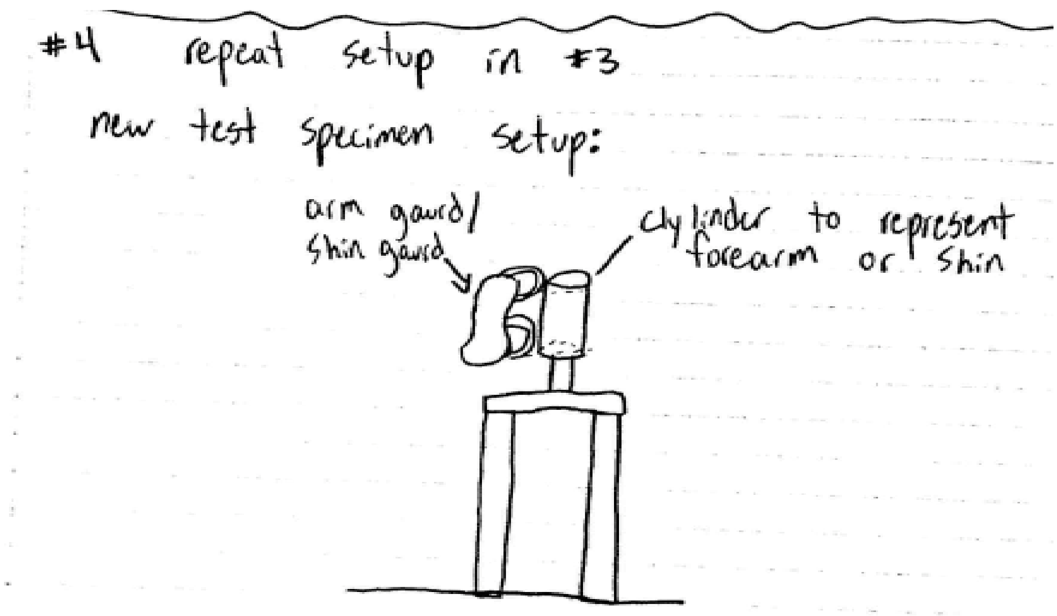


Figure 93: Alec Svendsen Design Concept 4

5. This design allows the user to easily test chest body armor samples.

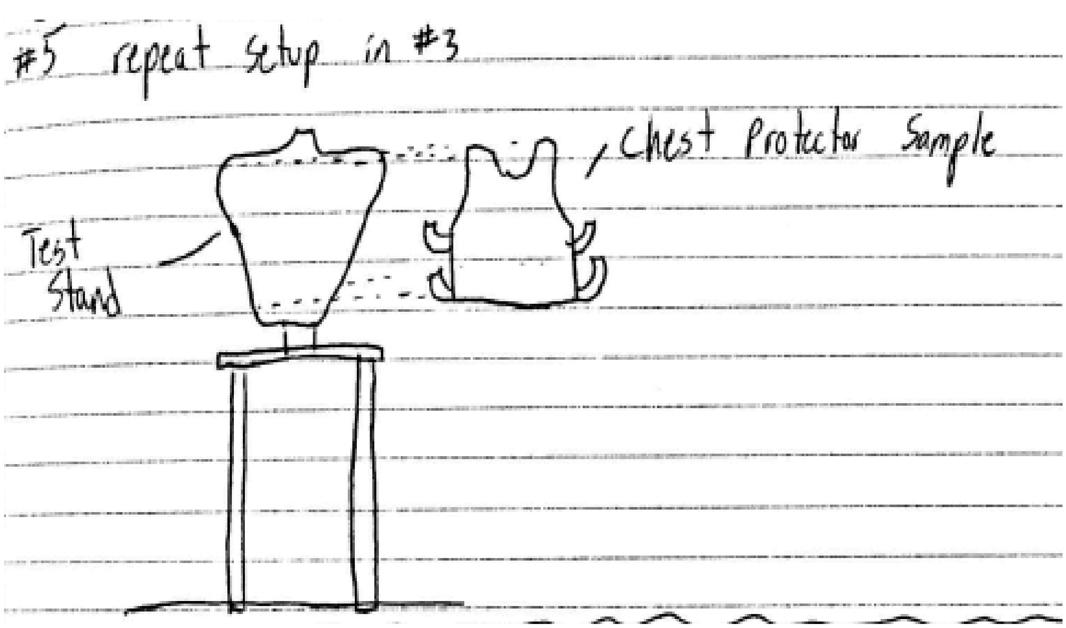


Figure 94: Alec Svendsen Design Concept 5

6. This design easily allows the user to test pre-manufactured gloves.

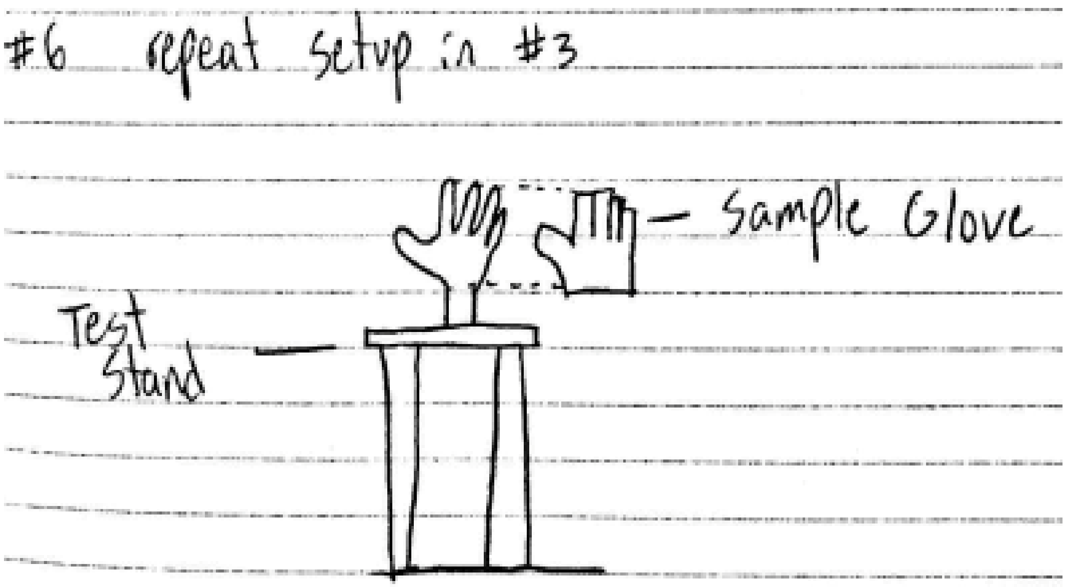


Figure 95: Alec Svendsen Design Concept 6

7. This is a very simple and mechanical design that allows for a wide variety of tests. The simplicity of this design will improve repeatability and make it more modular.

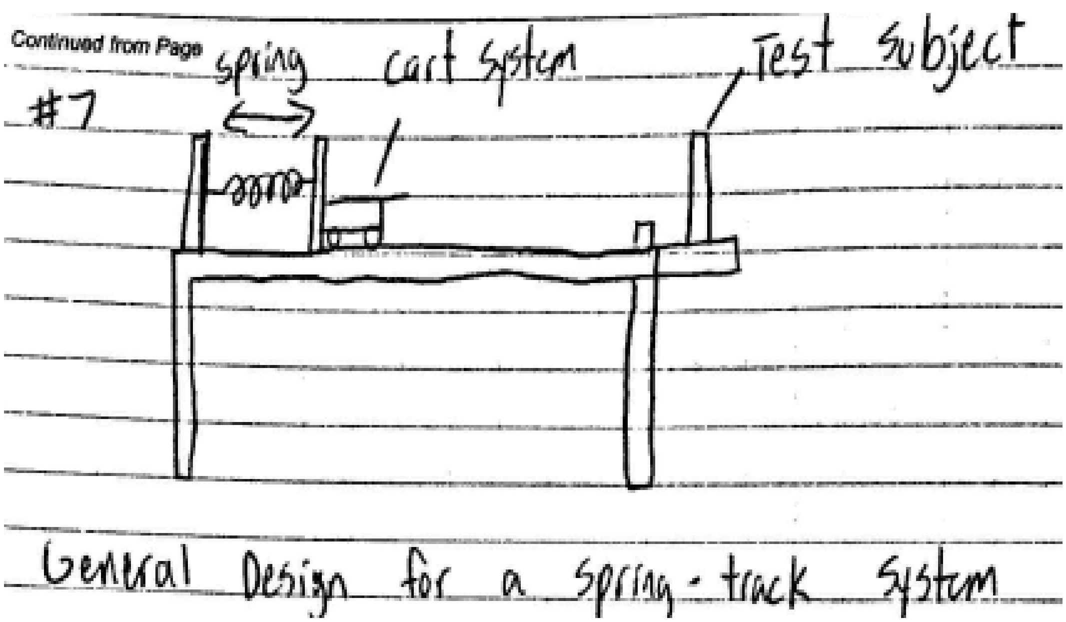


Figure 96: Alec Svendsen Design Concept 7

8. This First track option is the most basic. There are simply slits on the track to guide the cart to the test subject.

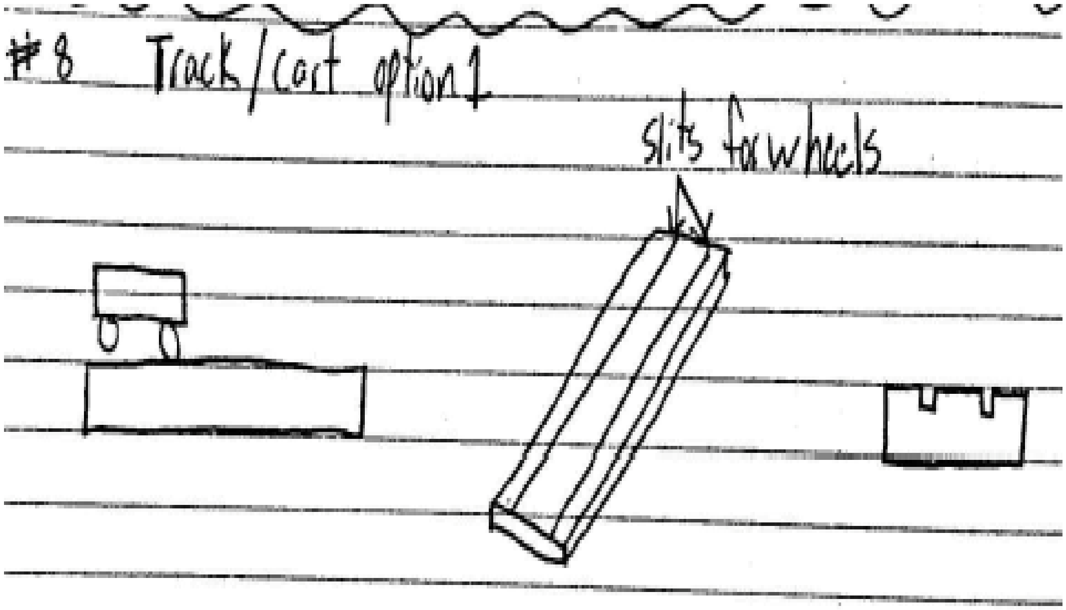


Figure 97: Alec Svendsen Design Concept 8

9. This Track uses an I-Beam setup to guide the cart to the test subject. It also increases safety/reliability since the cart is secured to the track.

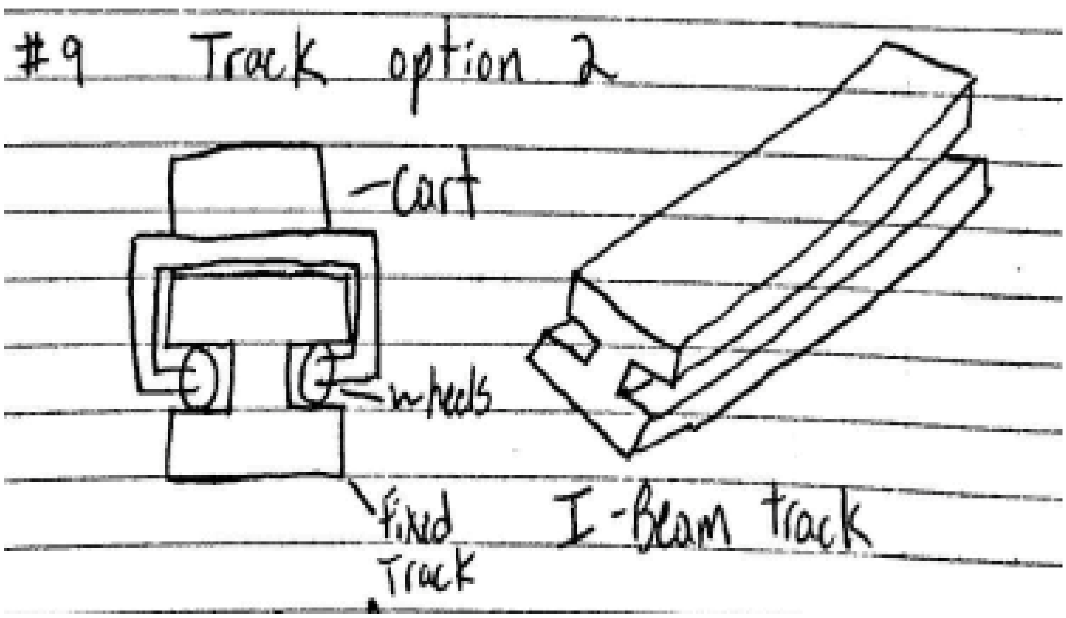


Figure 98: Alec Svendsen Design Concept 9

10. Similar to Design 9, this track is also secured increasing safety and reliability. More research is needed to see which track would have the least friction.

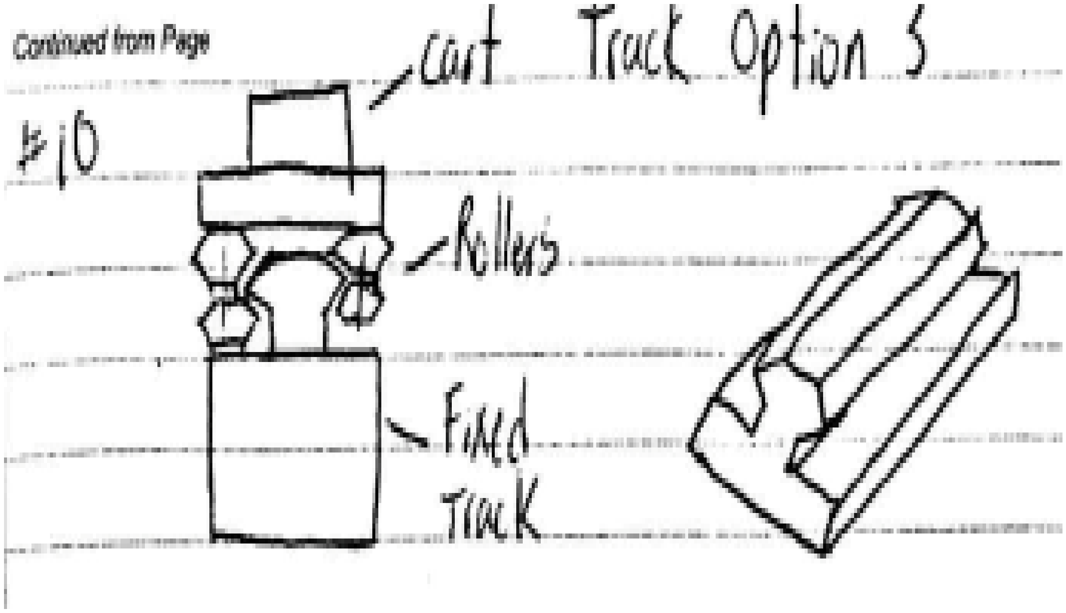


Figure 99: Alec Svendsen Design Concept 10

11. This is another track design that would provide more stability than design 8 but mostly likely not as secure as designs 9 and 10.

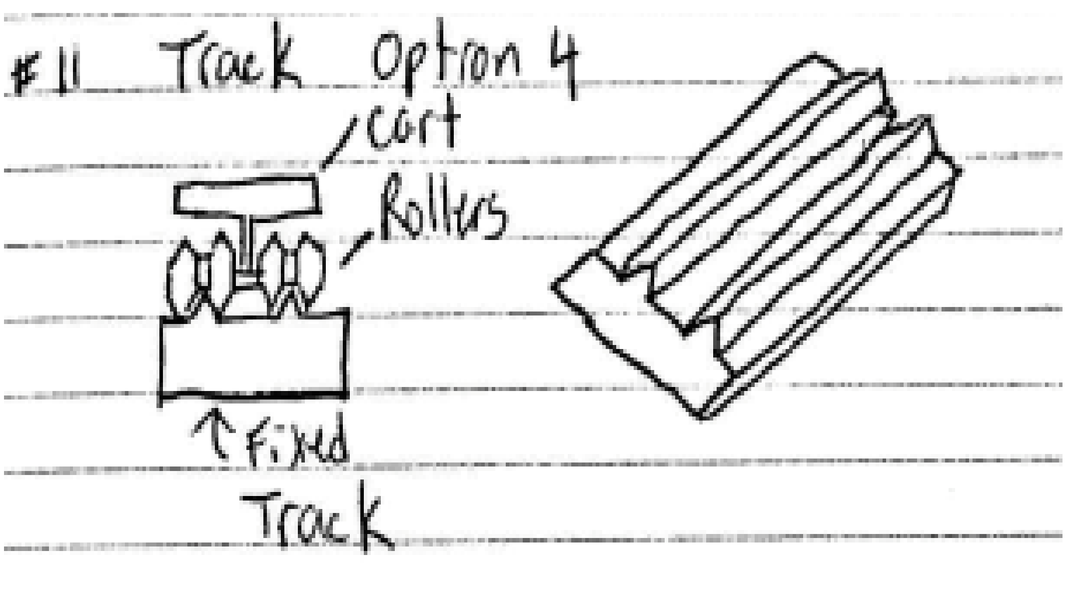


Figure 100: Alec Svendsen Design Concept 11

12. This track design uses air to hover the cart across the track. This setup would have the least friction, but is also the most complicated all making more possibilities for malfunctions.

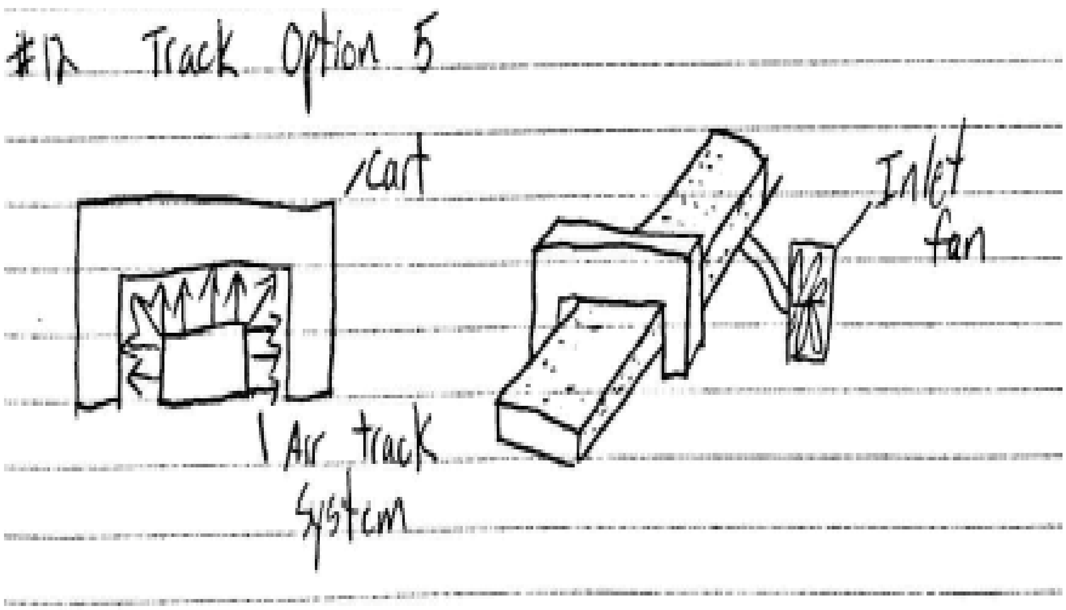


Figure 101: Alec Svendsen Design Concept 12

13. The most basic option for measuring the displacement in our spring would be with a simple ruler. It is very basic but therefore decreases the accuracy of our apparatus.

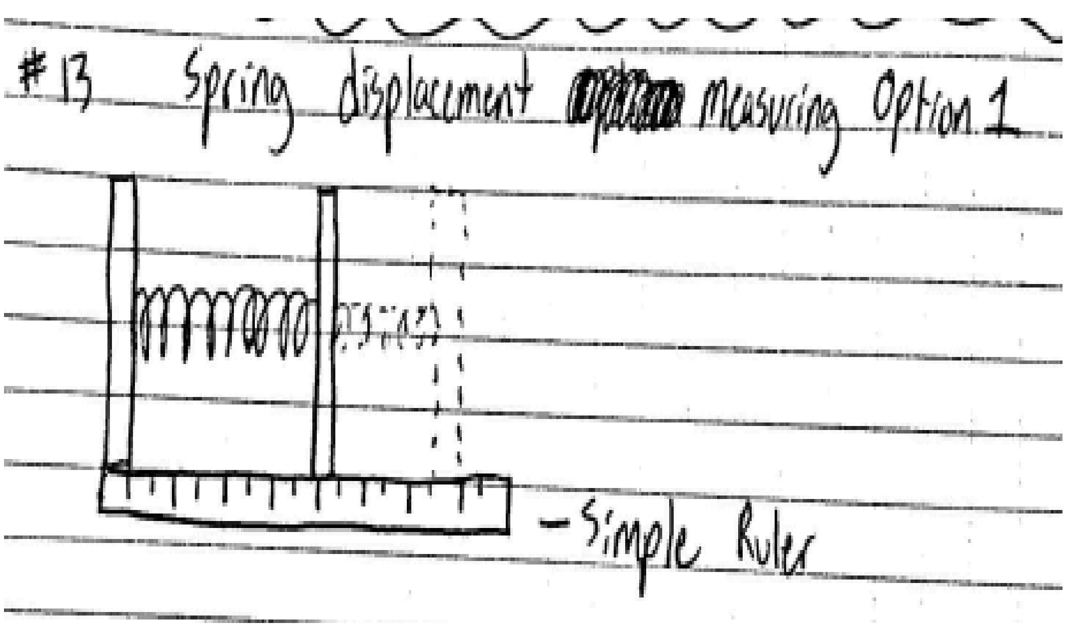


Figure 102: Alec Svendsen Design Concept 13

14. The laser measurement system would be much more accurate and allow for more exact testing with our apparatus.

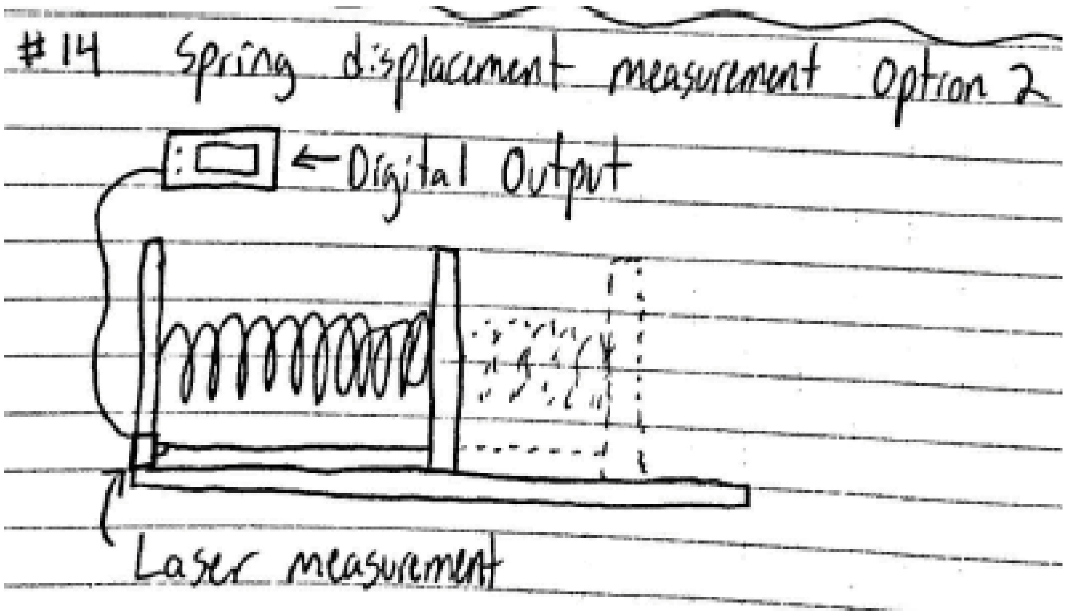


Figure 103: Alec Svendsen Design Concept 14

15. The Single Axis digital Readout System is likely the most feasible with this project. They are cheap, exceptionally accurate, and easy to install.

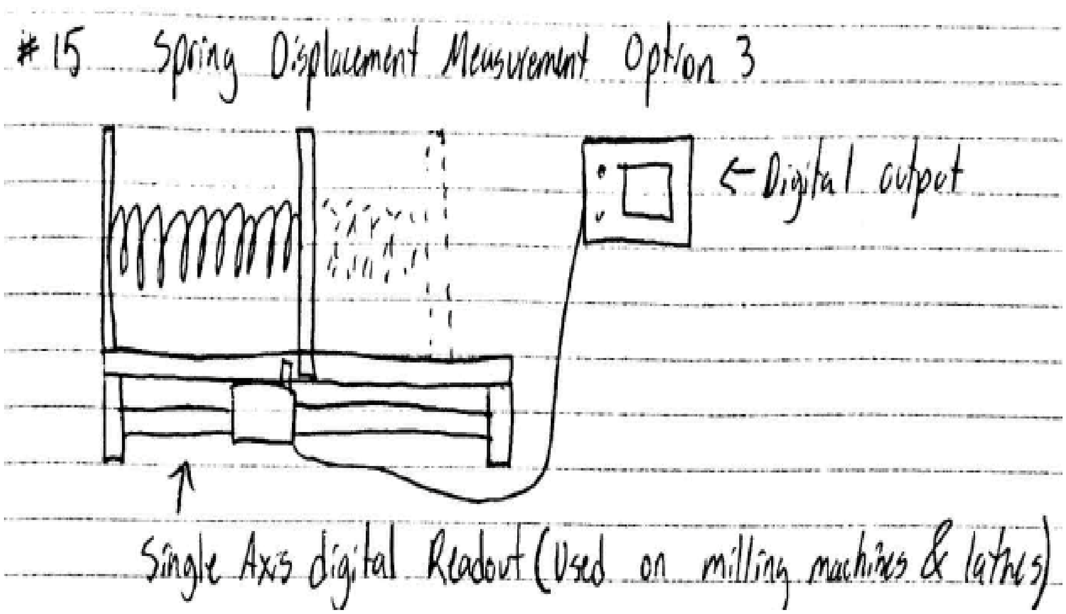


Figure 104: Alec Svendsen Design Concept 15

16. On our cart we would have multiple ports at different angles to bolt down our vise and

piercer/Knife. This would allow the test specimen to be struck at multiple different angles to mimic slashing or stabbing.

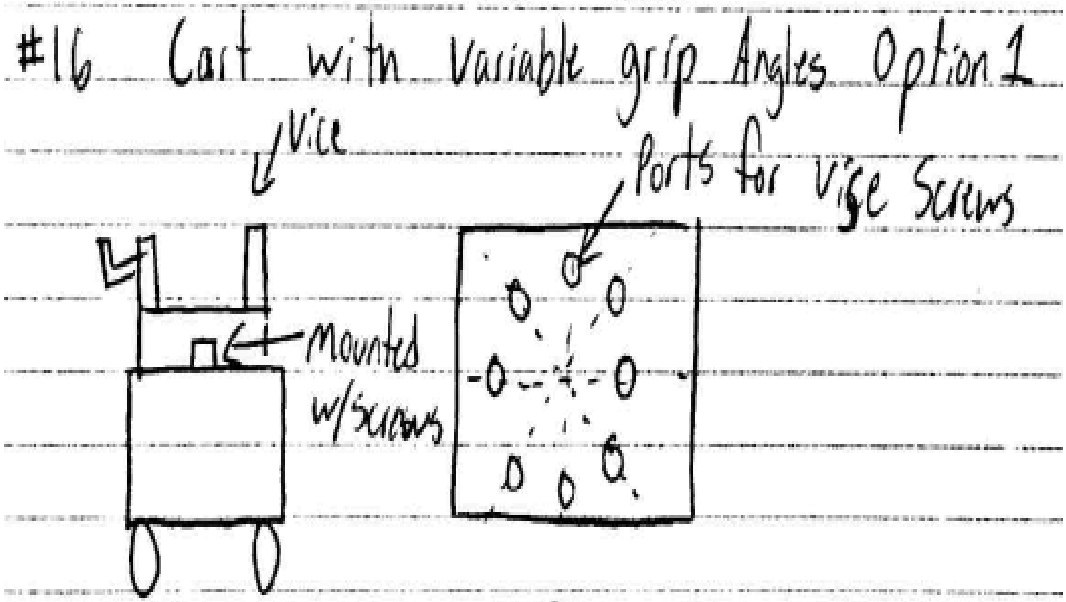


Figure 105: Alec Svendsen Design Concept 16

17. The swivel vise used in this design is more user friendly than Design 16 and also allows the user to set the vise at more angles.

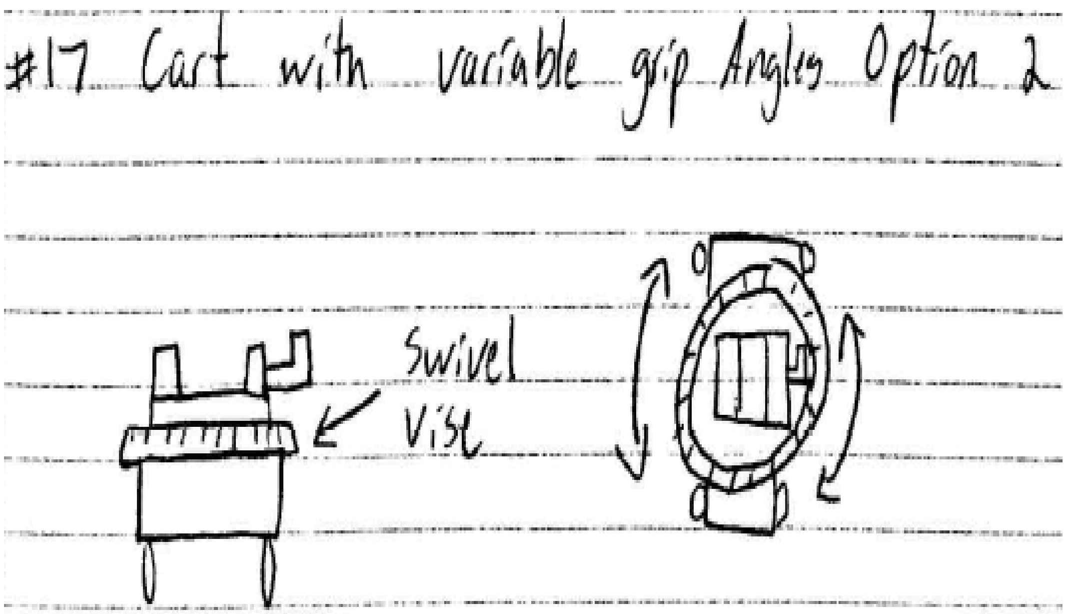


Figure 106: Alec Svendsen Design Concept 17

18. This design uses a simple hand winch to compress our spring system. The downfall to this design is the requirement of manual labor and distance of spring compression is directly based on the tooth sizes in the gear of the winch.

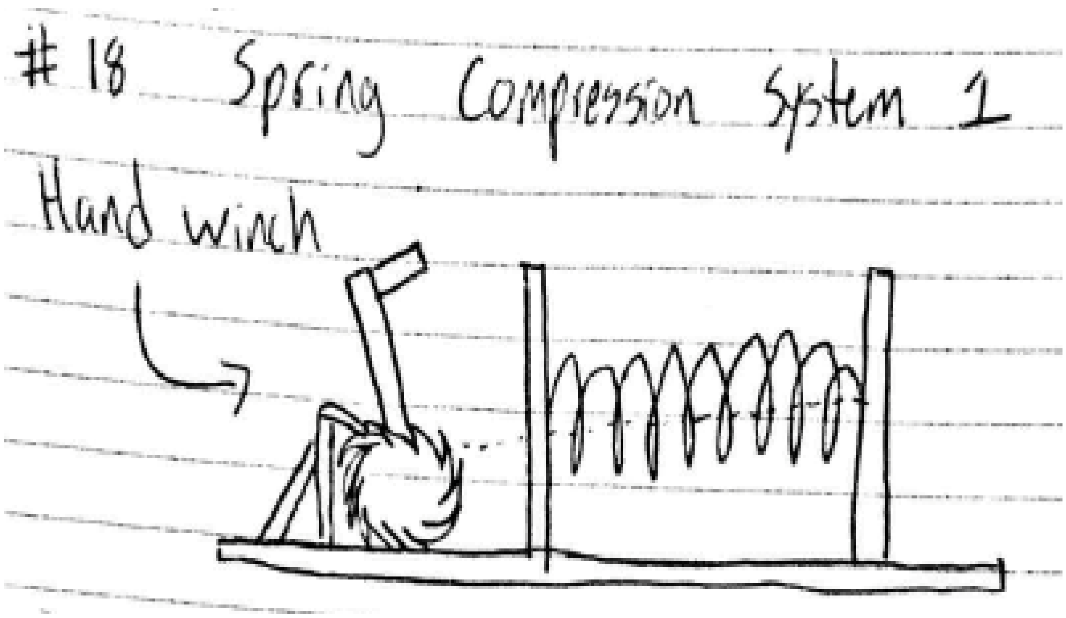


Figure 107: Alec Svendsen Design Concept 18

19. This electric winch design is very user friendly allowing the user to compress the spring with minimal effort over various displacements. This system seems to be the most feasible for our project.

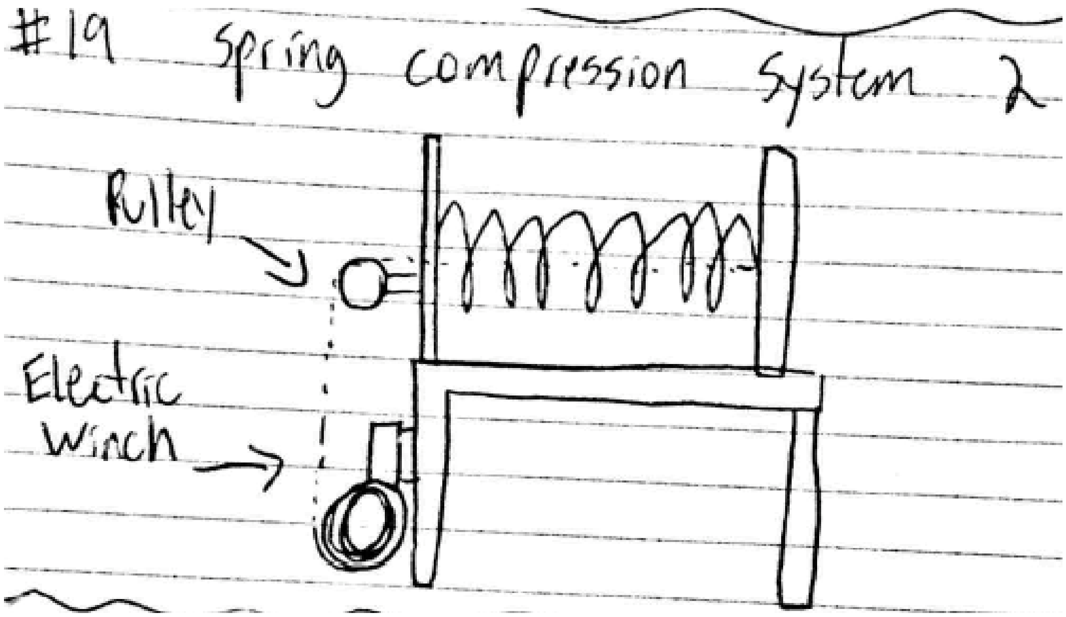


Figure 108: Alec Svendsen Design Concept 19

20. This Design is sturdy and accurate but like Design 18, it requires manual labor. For that reason, there are better methods for this system.

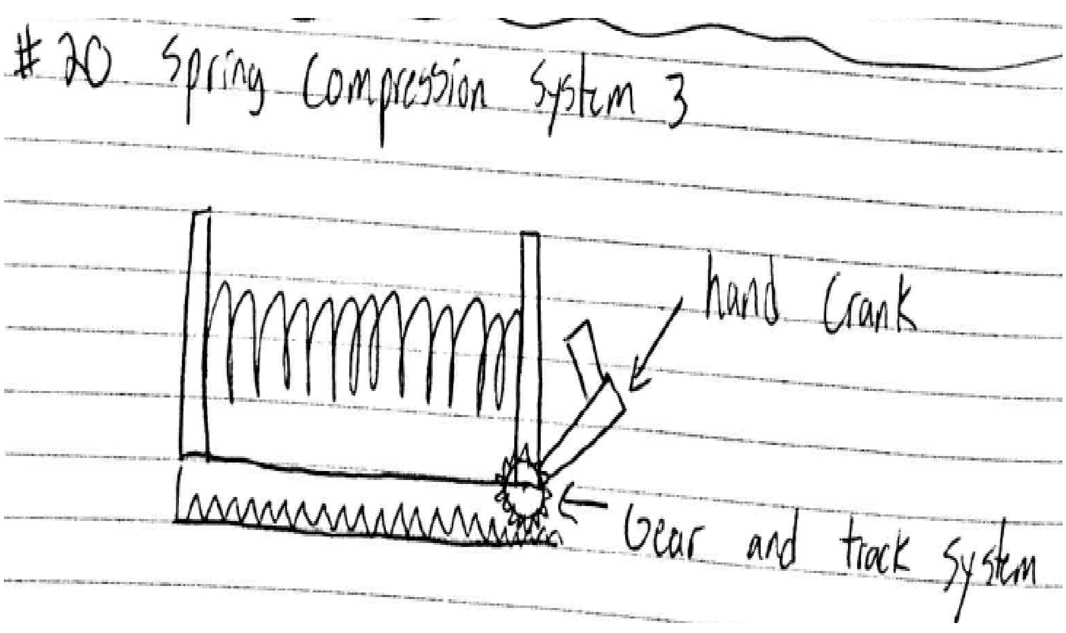


Figure 109: Alec Svendsen Design Concept 20

21. Another possibility for our cart propulsion could be a linear actuator. This method would be dependent on cost and variability of the device.

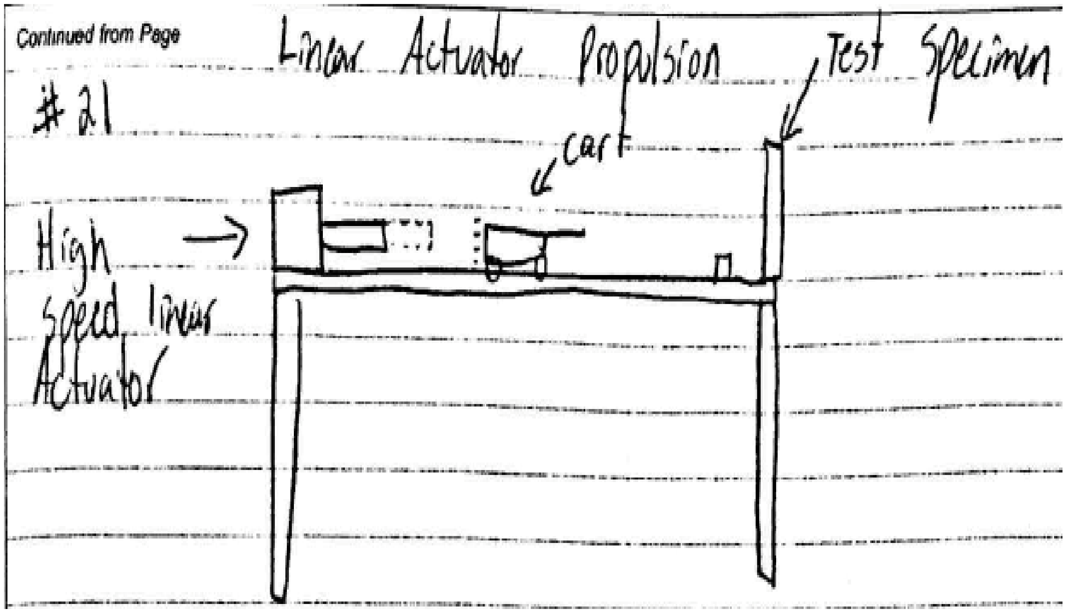


Figure 110: Alec Svendsen Design Concept 21

22. This design incorporates a hand lever with a tension spring located under the track.

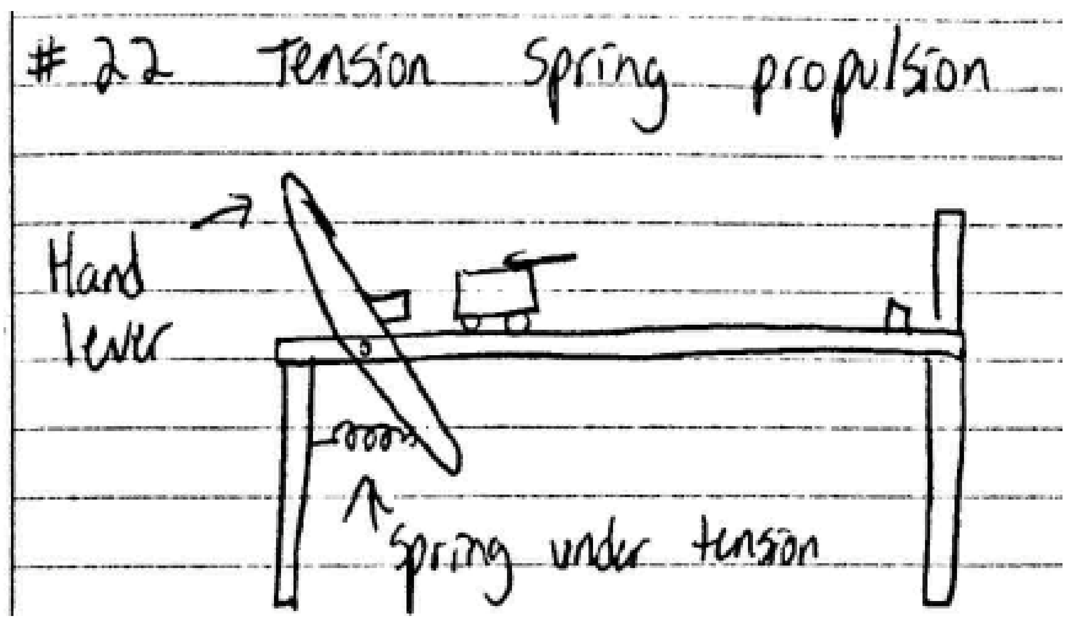


Figure 111: Alec Svendsen Design Concept 22

23. With the lever system the user must manually pull back the spring. It is a very simple and strong design but could require a lot of effort from the user.

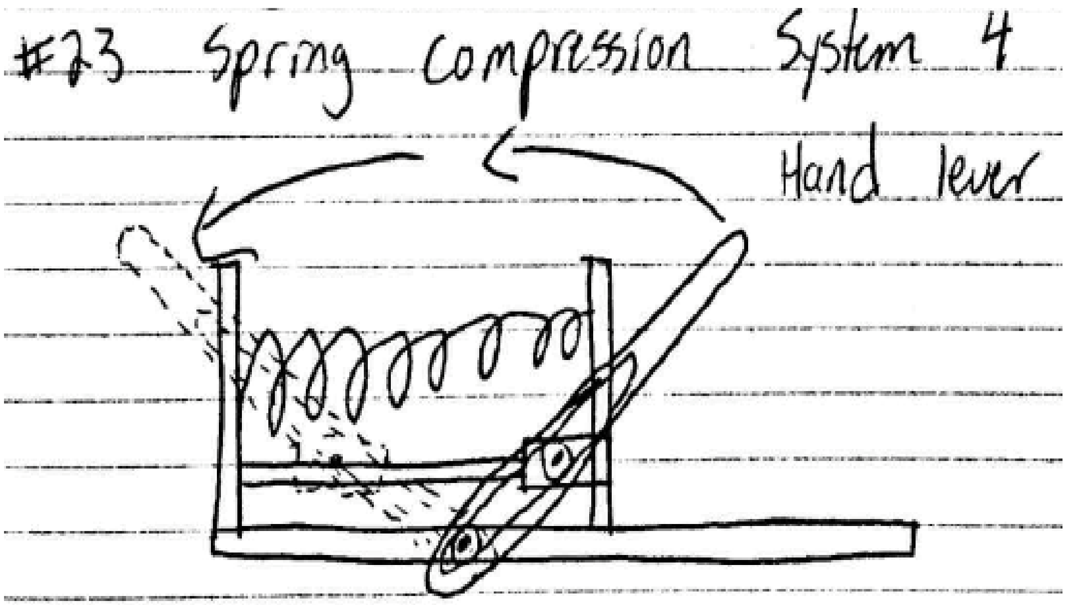


Figure 112: Alec Svendsen Design Concept 23

24. The pressure sensor system would allow us to verify that our theoretical and actual outputs. This data would be extremely important in material impact testing.

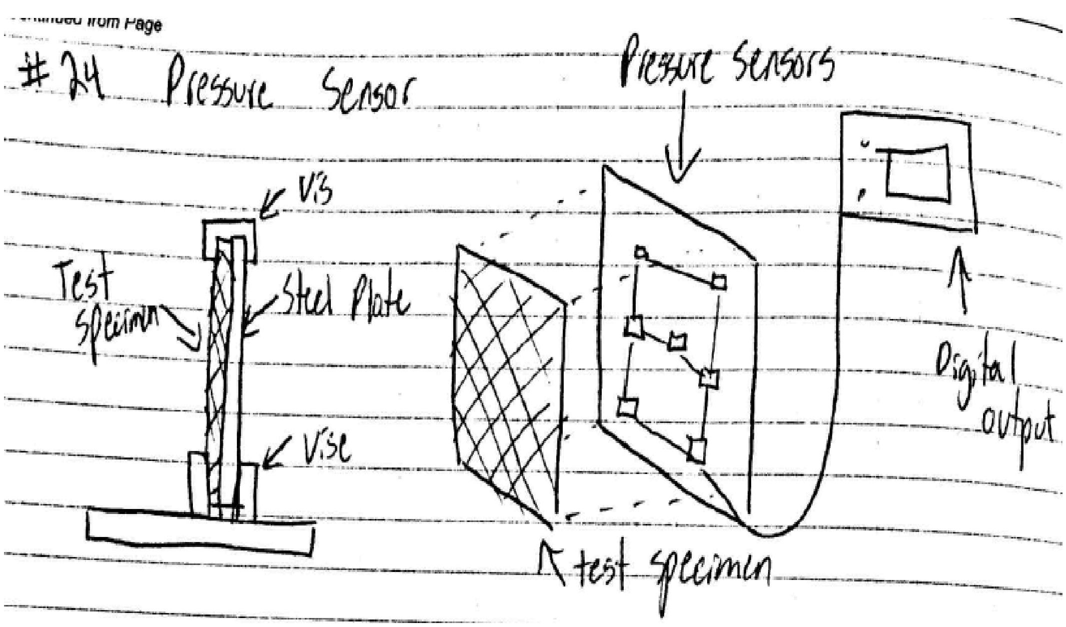


Figure 113: Alec Svendsen Design Concept 24

25. By putting a track perpendicular to the cart track and a swivel vise on that track, there are multiple ways and angles at which the test specimen can be struck.

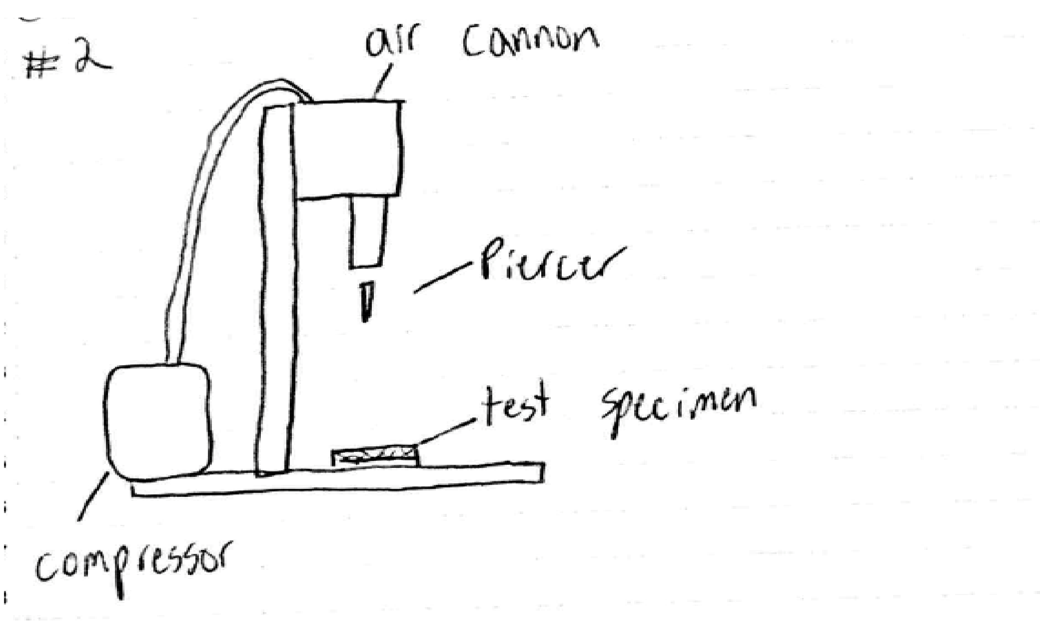


Figure 114: Alec Svendsen Design Concept 25

26. With tracks also set parallel to the cart track, the user can easily simulate a slashing motion. This design allows for a great amount of possibilities when striking the test subject.

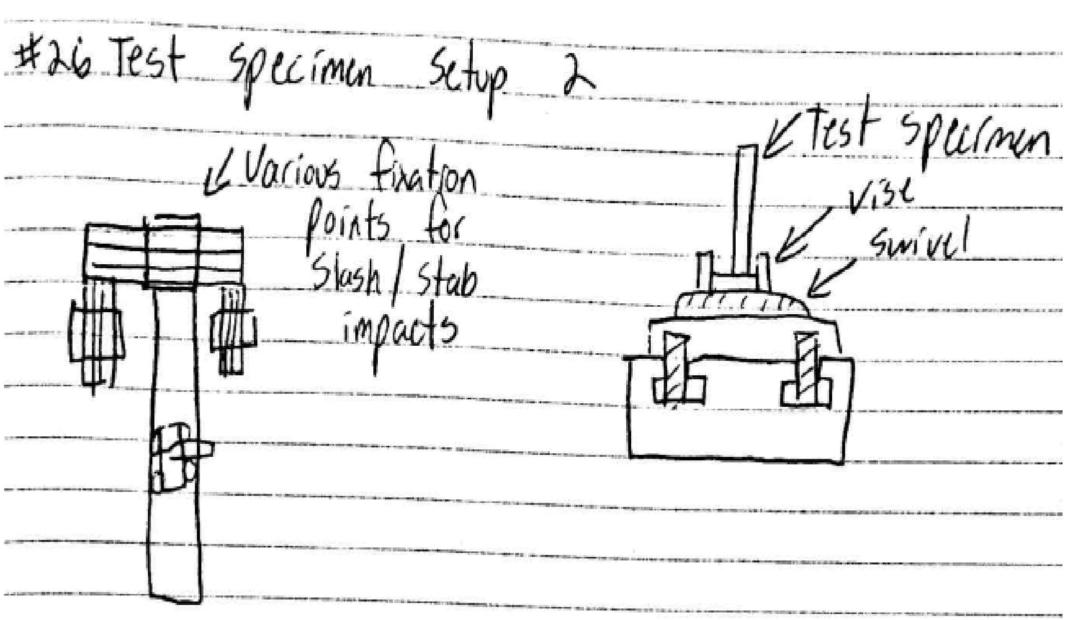


Figure 115: Alec Svendsen Design Concept 26

27. The cart stopper will absorb the impact of the cart protecting the cart and the track. This will make a much more durable design.

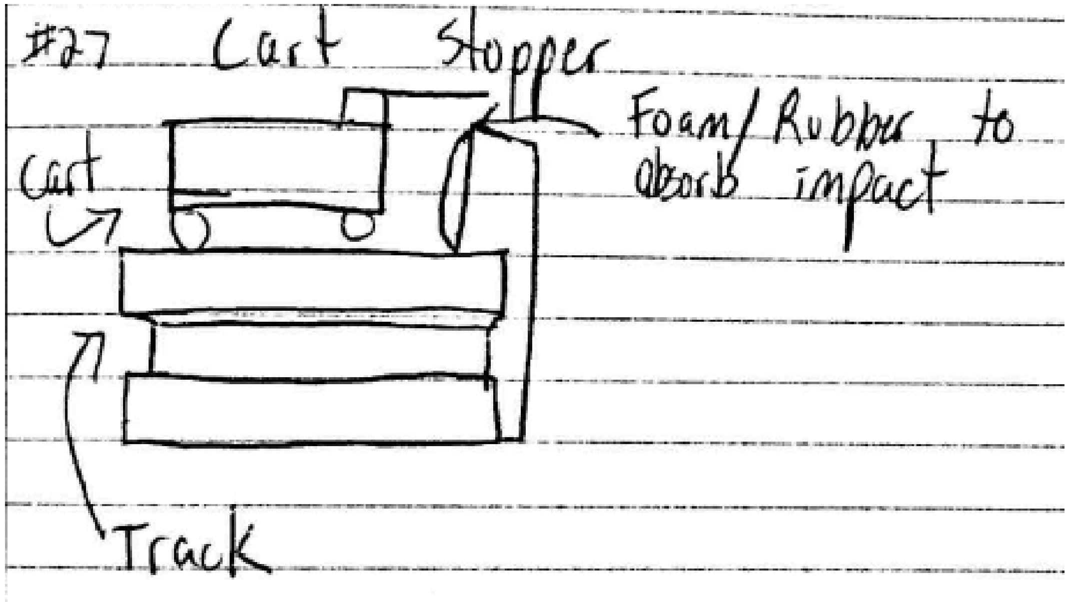


Figure 116: Alec Svendsen Design Concept 27

28. The frame is bolted into the ground in order to withstand the repeated motions of the spring and cart.

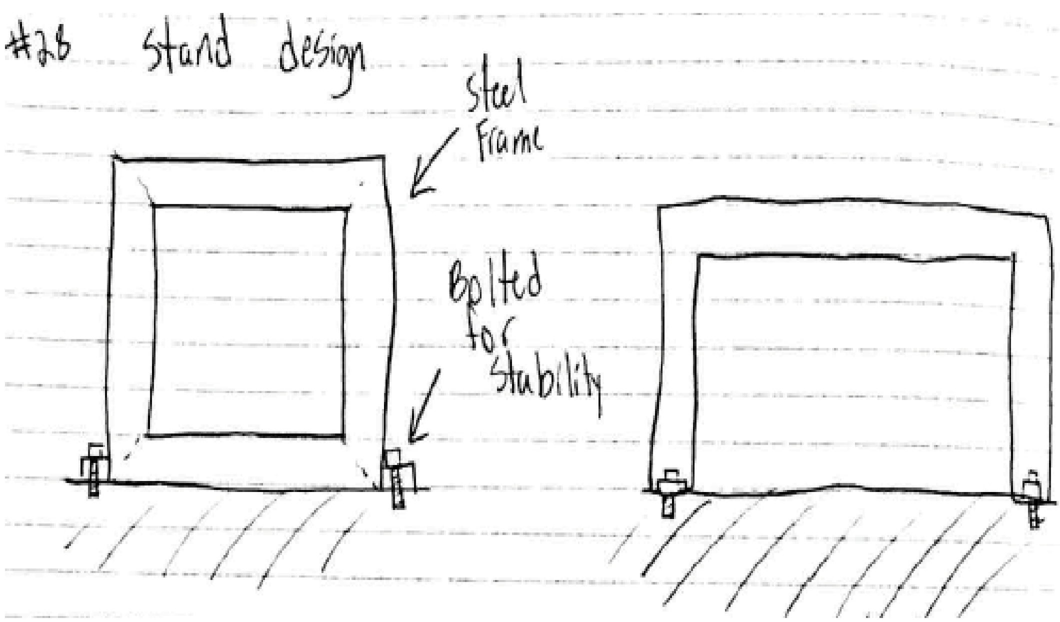


Figure 117: Alec Svendsen Design Concept 28

29. If floor mounting isnt a possibility, this design allows for weights to be stacked in the center of the frame to keep it stable.

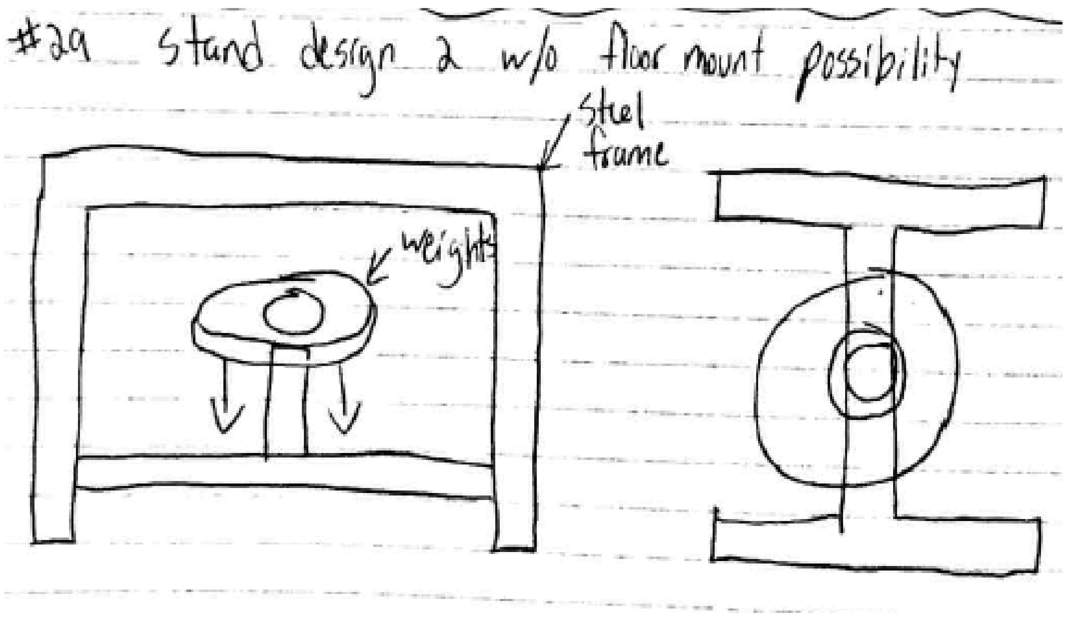


Figure 118: Alec Svendsen Design Concept 29

30. Having the plate mounted to the frame with bearings secures the spring only allowing for linear motion. This would make the design more consistent and accurate.

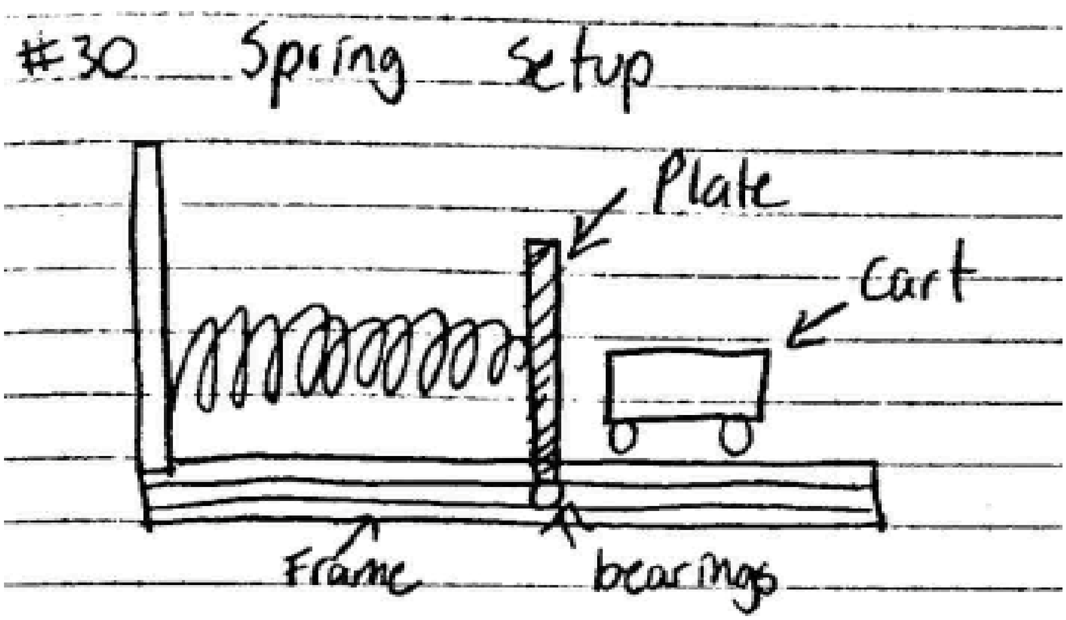


Figure 119: Alec Svendsen Design Concept 30

8 QFD

8.1 Concept Evaluation

Air Cannon

The compressed air powered design will offer a variety of positives, the largest being the easy variability of the launching power and lack of vibration created after launch. The launching power can be changed by the twist of a knob allowing more air to be pressurized. Though this may take longer than displacing the spring, it is much easier and controlled. Since there is much less vibrational forces, there is no need to dampen a any vibrations. This allows for a very controlled environment after launch. Some of the negatives include that compressed air can be very dangerous. The weapon will be connected to a cart fixture that will be driven by compressed air that will be compressed in a chamber behind the weapon. This creates a scenario will be catastrophic. If there pressure chamber can contain the pressure or if it is released with an improper setup, the weapon and cart can turn into a projectile. This may also occur if the release of pressure is obscured. If a female system on the cart is connected to a male system on the pressurized chamber as previously designed, there is a possibility that the cart doesn't eject from the air cannon and then becomes an explosive. For all these reasons, the spring system was chosen

Spring Propulsion System

The spring system offers many positive attributes, the largest being its simplicity. The energy delivery is consistent and easy to calculate. The spring system is driven by the kinetic and potential energy equations. This allows us to guess the energy based off the known spring constant and the displacement of the spring, and know the actual energy based off the mass and velocity. All the variables are easy and cheap to measure. The air system doesn't have this type of simplicity. The spring is easily interchangeable and keeps our system simple allowing for it to be built and tested in much less time. But, as mentioned before, there will be vibrational forces caused after launch. This will require a dampening system to keep the forces from obstructing the results and system as a whole. The spring will also need to eventually be replaced do to fatigue unlike the air system, but this is cheap and easily done. The spring system seems to deliver all the desires of both Amerisewn and URI and if new circumstances arrive, the easy interchangeability of the spring can adapt to new situations. For these reasons, the spring system was chosen over the compressed air.

A compressed air system may be implemented in the future for testing, then possibility permanently, but the spring system more closely correlates to the current time frame. If the spring system works as expected and is repeatable, there may be no need to test the compressed air system. For the time being, the spring system seems to have little flaw and a quick assembly time making it the best choice in the current situation. Other power systems have been explored throughout the design concept phase including and electric motor and belt drive train, a pulley system, and various modified spring and compressed air designs.

These designs may be explored in the future if necessary.The QFD beaks down the two major power systems in question, the spring and compressed air systems showing the positives and negatives of both allowing for the final decision to be made.

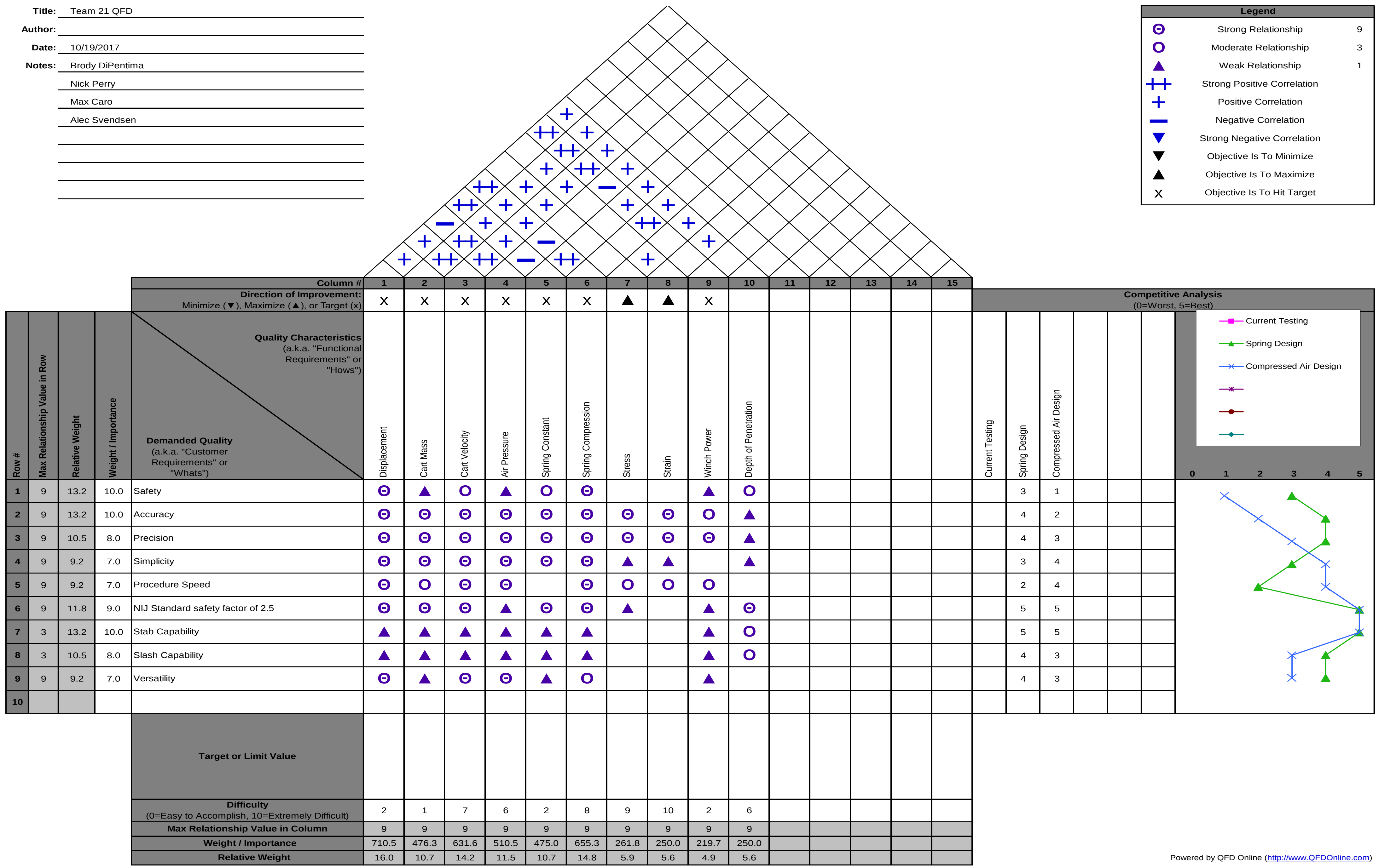


Figure 120: QFD Analysis

Displacement:

The displacement in this scenario is the amount the spring compresses. This is a substantial unit of measurement because this is how we are going to obtain our forces on the cart. F=kx is the equation for the amount of force the spring is transferring into the cart. The only other part of that equation is spring constant and that will be determined in the beginning and be constant until a different spring is swapped in.

Cart Mass:

The mass of the cart is important because this is directly related to the amount of energy that is used in stabbing or slashing the specimen. By changing the mass of the cart one can easily change the amount of energy that is transferred to the specimen. The mass is also translated into the momentum which is another parameter to be considered in the impact testing of the specimen.

Cart Velocity:

The cart velocity is also related to the energy of the cart. Since the energy is velocity squared this parameter can easily change the amount of energy transferred. It is also related to the safety of the rig. Since velocity does increase the energy at the greatest increment, this can create an unsafe environment. The objective would be to create the right function of mass of the cart to velocity of the cart to safety of the entire system.

Air Pressure:

For a compressed air driven design, the air pressure is what will be driving the cart down the track toward the target. The air pressure will determine the speed and therefore, energy delivered to the target. From a tank of compressed air, air can be released into a pressure chamber until the desired pressure is reached and then released to drive the cart.

Spring Constant:

For a spring driven design, the spring constant along with the displacement will determine the force delivered to the cart. The the spring constant will determine the displacement needed to deliver that force. The lower the spring constant, the more displacement needed and therefore, the more recoil coming from the spring. The higher the spring constant, the less displacement needed but the more work the winch needs to do.

Spring Compression:

The more the spring is compressed the more it will transfer energy into the track and table. Connecting the spring to a cart that is mounted on the track will dissipate some x and y vibration if the tracks is following the z axis. The reduction of vibration will allow the rig to last longer and provide more repeatable results with less maintenance.

Stress:

The stress applied on both the armor and composite backing will allow the pass or fail of the armor and the damage the body takes. The measurement of stress will show concentrations in the materials to show the location of failure and how it can be improved. The assessment of the stress on the body will allow us to asses the bodily damage even if there is no penetration through the armor.

Strain:

The strain measures the change in length over the original length, therefore showing displacement. With this, we are able to tell which materials were displaced the most allowing the blade/spike to penetrate. This allows for the analysis of each layer or even the armor as a whole. It also allows the analysis of stitching patterns by showing gaps in materials where the blade or spike was able to enter. From this information, the armor can be adapted and tested then compared to past armors to compare strain.

Winch Power:

The winch power will be a function of the spring constant and displacement of the spring needed for a test. If a low spring constant is needed but there is a high displacement, a low torque winch can be used but if a high spring constant is used to test, a more powerful winch is needed. The winch also needs to be highly accurate. The increments of which the winch is pulling the rope need to be accurate for the displacement to be correct. If the winch is too powerful, it will pull the spring in with too much force causing an inaccurate amount of displacement.

Depth of Penetration:

The depth of penetration measures the blade/spikes penetration into the armor or through the armor into the composite backing. This will allow us to deem the test as either a pass or fail as well as quantify how much the armor failed or passed by. With the layering of the materiel known and the depth of penetration known, we can also find more information about the test such as where spike/blade was stopped and what layers failed to contain the weapon.

9 Design for X

There were numerous aspects taken into consideration when designing the device. Since the project is potentially dangerous, user safety is the first and key design consideration. Following that, the device was also designed for simplicity and durability. The team worked diligently to properly incorporate these aspects into the design.

9.1 Design for Safety

Safety is a key component of every product. The safety of the user was also the main aspect in the design of this product. There were many factors to be taken into account because of all high stresses the device would be enduring. Keeping safety as the key priority, the design was made so the user could not accidentally misfire the device. A step by step process was implemented for the user to follow pre-launch.

In order for the system to function safely and properly, many components had to be either fabricated or purchased with much high specifications than required. For example the Seacatch quick release component is rated to function under a load of 1300 pounds, well beyond maximum force generated by the spring at full compression of about 875 pounds. Finding components that met these specific requirements deemed to be quite a challenge for the team.

Many components of the build were made from steel for its strength and durability. The system was designed so all components that were to be under high stress would be steel and welded. Making these components from steel rather than another materials insured user safety and durability.

9.2 Design for Simplicity

Every successful product focuses on the simplicity for the user. Simpler devices are usually more reliable, durable, and user friendly. This was also a key aspect the team implemented into the design of the system. There are many methods in which a knife can be launched, including air propulsion, high speed linear actuators, or springs, etc.The team acted on a simple linear compression mechanical spring. It is the simplest and has the fewest potential points of failure. When the spring properties eventually begin to fatigue after thousands of compressions, the spring can easily be removed and replaced within minutes.

Other components of the device were also selected for simplicity reasons.The winch for example, only has to be plugged in and has two options, reel in or out. The vice allows to the user to replace the weapon to be launched within seconds. This system also offers extreme and simple weapon variability while also focusing on ease of the user. The target design simply allows the user to test a variety of sized samples in multiple different locations. The user must only insert the sample composite material and fasten it into place using two wing screws. All these areas are key components that make this system user friendly for a single operator.

9.3 Design for Reliability

In order for this product to be of use, It has to function properly and accurately for a long period of time with little to no maintenance. For this reason the team decided to use a larger spring that could generate much more than the maximum energy levels required. After completing simulations on the spring, it was determined to maintain its properties up to 40,000 cycles. The calculations for these values can be seen in sub-section 12.4 This ensures a long, accurate, and reliable life of the spring.

Knowing the spring had such a long life-span, the team focused on ensuring a just as long, if not longer, life span for the table and other components. The base of the table was made of quarter inch thick steel, bolted to the table with eight half-inch bolts. Other components like the steel C-Channel and angle iron pieces were welded into place. This was the strongest possible connection, ensuring permanent fixation and reliability. The weaker components that have a higher chance of failure, were all fixed in a way that allows them to easily be replaced. For example, the Track, carts, winch, DRO, and rubber stoppers are bolted in and can be simply unfastened if needed.

10 Project Specific Details and Analysis

Amerisewn is a local company that supplies a wide variety of protective clothing and equipment. There is a large market for all its products, but market for testing them is quite different. The market is narrowed even further since this project focuses primarily on non-ballistic body armor samples. This device has a very specific purpose that would be difficult to implement in other areas. For this reasoning, the market focus for this product would be almost exclusively towards armor manufacturers or textile companies.

The device could have many potential applications in the industry. It would not only be great for in-house testing before products are officially NIJ tested, but also for research and development of new composites. With such a wide range possible launch energies, strike angles, and weapon possibilities, the device provides an extreme amount of variability for the development of new products. Any body armor company could greatly benefit by implementing this device into its development and testing phases.

This device would also benefit the company financially. With every single sample that is sent out for NIJ testing and fails, precious time and money is lost. This device could non-officially ensure the passing of products for NIJ testing. With the total build costing around \$2500, within just a few years money of initial investment could easy be returned and save the company even more in the future. When a product fails NIJ testing, money is not only lost in the \$200 payment, but also with the time to acquire results.If the company were to purchase this device and prevent 13 products from failing in NIJ testing, the product has already paid for itself.

11 Detailed Product Design

One of the biggest challenges the team faced was making the concept a reality. Many components from the original SolidWorks build would have had to be completely custom manufactured, costing extra time and money. The original concept can be be seen below in Figure 121. The Team then focused on finding pre-manufactured components that could then slightly be altered to meet the design. There were many changes to the original concept as parts were purchased and manufacturing began.

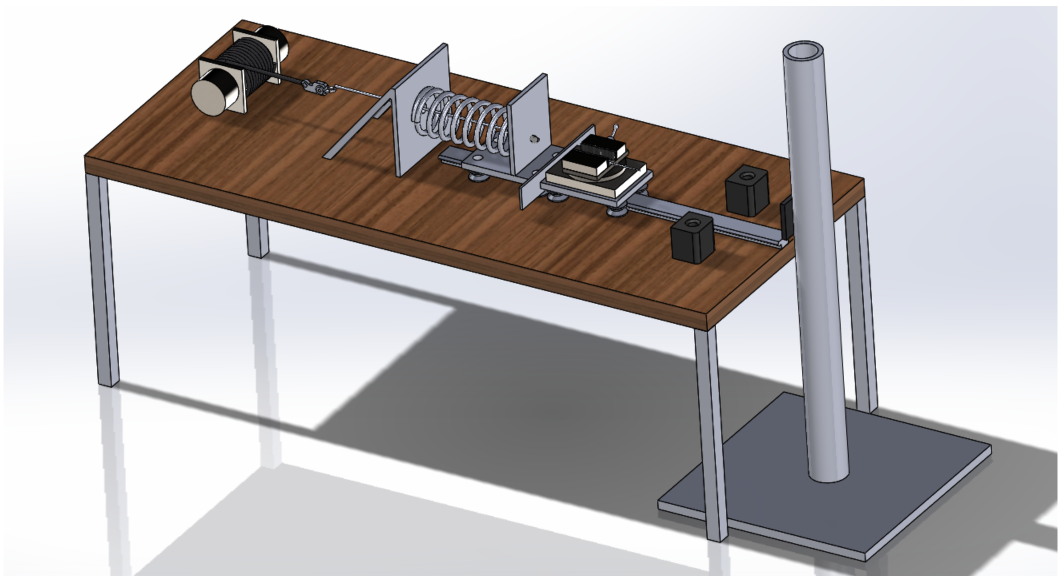


Figure 121: SolidWorks Model of Original Concept Build

After much research on what components were actually available to be integrated into the system, the manufacturing process started with the steel base plate. Due to time restraints, the designing of the final build and the manufacturing processes of determined pieces were occurring simultaneously. Some of the components were set from the start of the build, and the other pieces were designed around them. Components like the cart and track system, Spring, and winch had little to no variability. In order to integrate this parts into the build, custom pieces were manufactured to make sure everything functioned smoothly. For example, in order to modify the carts and weld components to them, a custom steel base plate was fabricated. The drawing for this can be seen in Appendix Figure 176. All other machine drawings and also be found in Appendix 20.5

As the team continued to manufacture components, the final SolidWorks model was produced with many design changes. The details of the redesign can be found in Section 15. The final CAD Assembly can be seen below in Figure 122.

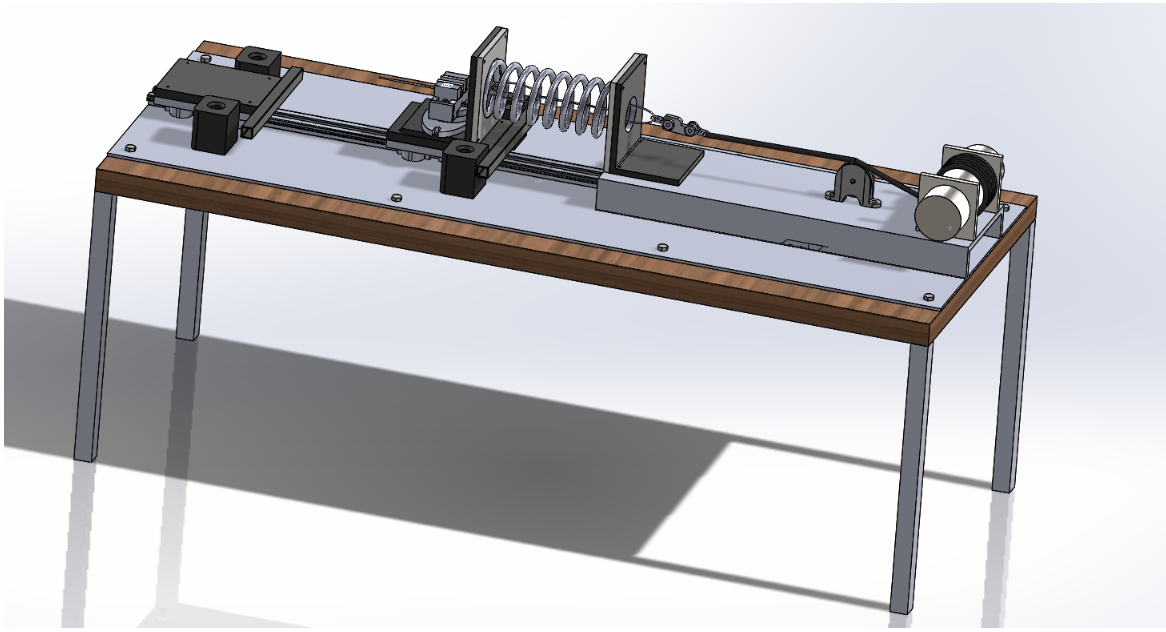


Figure 122: SolidWorks Model of Final Build

All components of the final model were then manufactured and assembled into the final product. The most obvious changes implemented to the final design are the one cart system and c-channel. The Final build can be seen below in Figure 123.

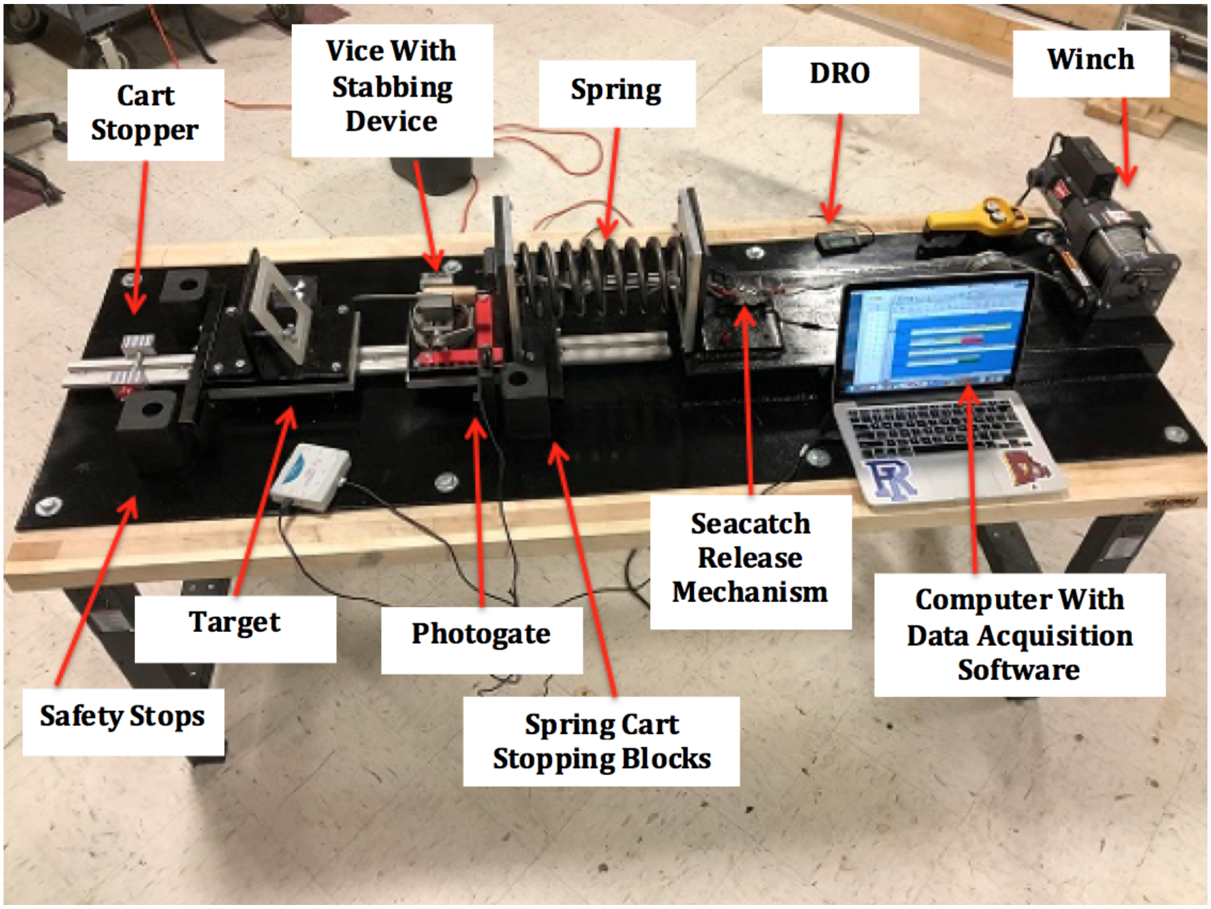


Figure 123: Final Build

12 Engineering Analysis

The engineering analysis of the design is divided into the theoretical modeling and optimization of the system, the energy profiles of stabs, the spring stress, and spring fatigue and detailed in appropriate subsections.

12.1 Theoretical Model and Optimization

The first design iteration of the stabber and slasher had two separate carts with one attached to the propelling spring which pushed another cart that would travel down a track to impact a target. After some initial testing, it was clear that the impacting cart was not moving fast enough to deliver the required energy levels for NIJ testing. The team had to return to the initial equations and determine a solution.

The initial theory was based on energy conservation as well as correlating potential energy of the (KE) spring to the kinetic energy (KE) delivered by the cart:

$$PE = \frac{1}{2}k\Delta x^2 \tag{1}$$

$$KE = \frac{1}{2}m_{Stabber}V_{Release}^2 \tag{2}$$

which was not mechanically accurate for the system that was designed, Eqn. 2 needs to be modified to include the mass of the propelling cart:

$$KE = \frac{1}{2}(m_{Propulsion} + m_{Stabber})V_{Release}^2 \tag{3}$$

Relating Eqns. 2 and 3 and creating an achieved velocity ratio:

$$\frac{V_{Release_2}}{V_{Release_1}} = \sqrt{\frac{m_{Stabber}}{m_{Propulsion} + m_{Stabber}}} \tag{4}$$

Holding the $m_{Stabber}$ 12.4 kg (measured) and varying $m_{Propulsion}$ produces a plot that determines the optimal $m_{Propulsion}$:

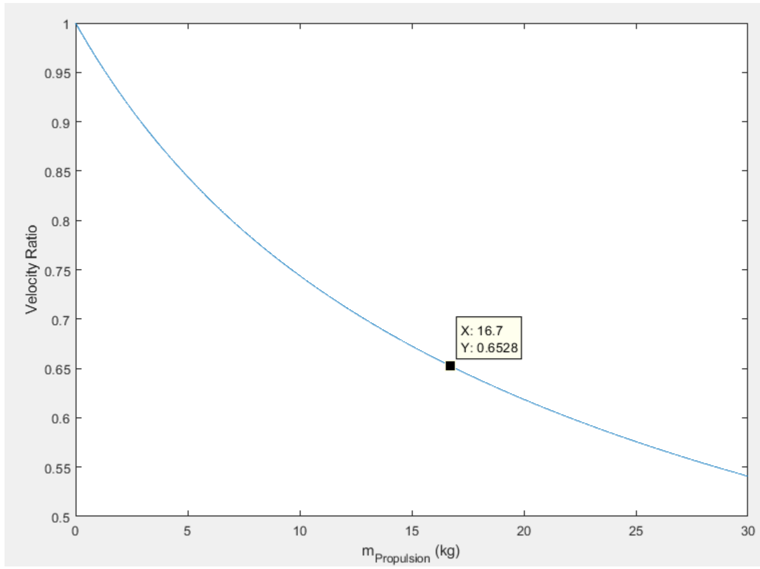


Figure 124: Velocity Ratio for Optimizing Release Velocity

Figure 124 shows the velocity delivered as a percentage of the release velocity when the table was initially fabricated with the stabbing cart moving at 65.3% of the release velocity under ideal circumstances. If $m_{Propulsion}$ was 0 kg, then all of the release velocity would be transfered to the stabber which was the major basis of redesign.

The next step of modeling the system was creating the dynamic model. [15] The system was modeled as a single mass with the propelling spring on one side with the rubber stopper modeled as a spring and dampener on the other. The system is models as:

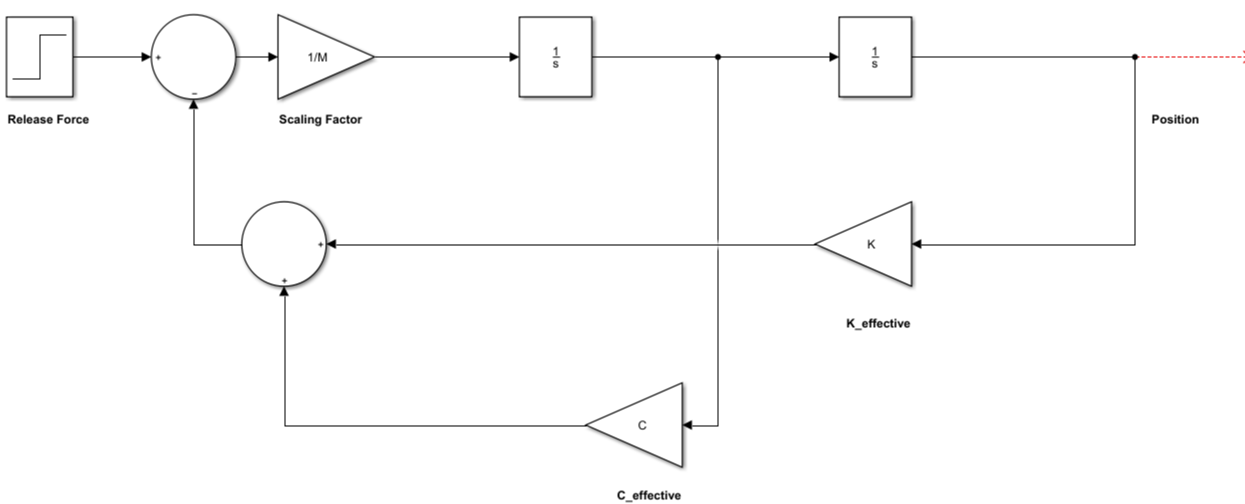


Figure 125: System Model of Redesigned Stabber

The equation of motion describing the single cart system is described mathematically as:

$$\ddot{x} = \frac{1}{m}(c_{stopper})\dot{x} + (k_{effective})x \tag{5}$$

$$k_{effective} = \begin{cases} k_{stopper} - k_{spring} & x \leq 0.5 \\ -k_{spring} & x > 0.5 \end{cases}$$

$$c_{stopper} = \begin{cases} C & x \leq 0.5 \\ 0 & x > 0.5 \end{cases}$$

The position output of Figure 125 and Eqn. 5 can be plotted as:

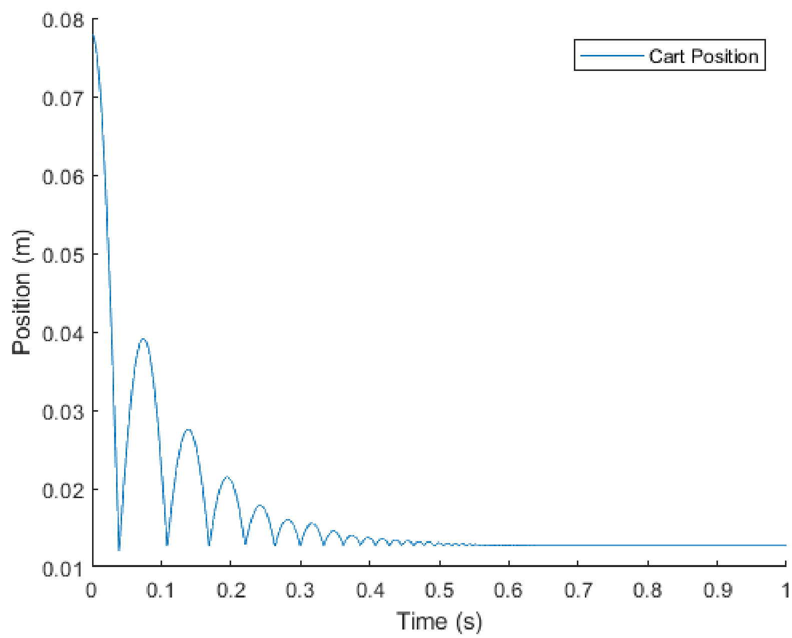


Figure 126: Stabber Cart Position vs. Time

which shows that the system stabilizes after approximately half a second. Further optimization will be discussed in Sec. 19.

12.2 Energy Profiles

In order to replicate a human-like stab, how a human delivers energy from a stab must first be understood. Amerisewn wanted more information on how each person stabs depending on their gender, weight, and strength. With this information, they would be able to replicate the stab of someone specific based on their weight. The forearm and hand weight are taken into account in the energy delivery of a stab. [11] Also, a single human forearm and hand make up about 2% of their body weight. From this, we see that the weapon weight and 2% of the attackers body weight are taken into account when calculating the kinetic energy of the stab.

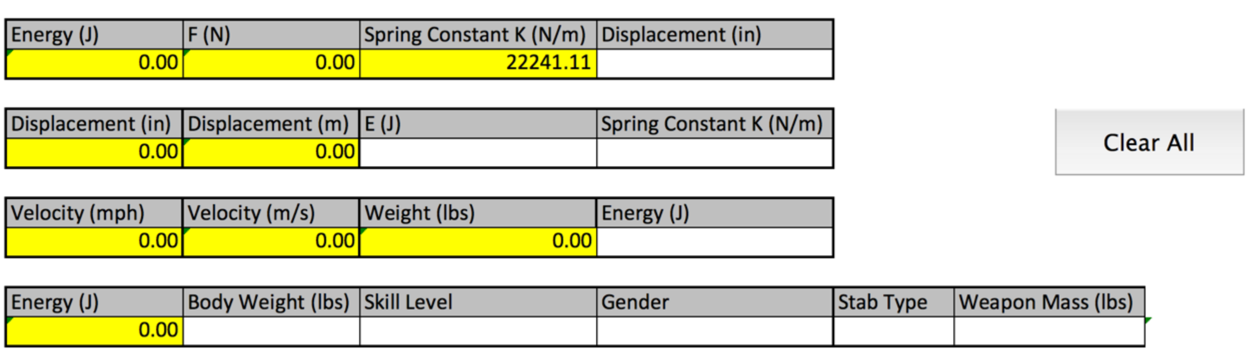
The maximum energy delivered from a stab, from a set of random volunteers, was 103 joules with a velocity of 9.2 m/s. [12] From this, the maximum energy delivered from an average person can be determined. This data was confirmed where is was found that the set of volunteers had a maximum stab energy of 72 J. [13] This will set the higher end of the energy delivery when replicating a human stab. But this is for an average male stabbing in an overhand motion, there is no data separating gender, stab type, or experience level.

Additional studies that had a random set of men and women volunteers with varying skill levels resulted in the following data:

Table 11: Summary Of Performance Data

Group	Number of tests	Mean energy (J)	95% energy (J)	Maximum energy (J)	Mean velocity (ms^{-1})	95% velocity (ms^{-1})	Maximum velocity (ms^{-1})
All underarm	157	26.4	54.4	63.4	5.8	8.2	10.1
All overarm	46	46.1	77.3	114.9	8.5	11.0	11.6
Male, underarm	142	28.1	54.9	63.4	6.0	8.3	10.1
Female, underarm	15	10.8	22.4	30.9	4.6	6.0	7.4
RMCS, underarm	32	26.8	50.9	57.5	6.1	8.3	9.4
Gloucestershire police, underarm	60	31.6	57.0	64.0	6.1	7.8	9.0

This resulting data can be used to create the upper and lower bound for both female, male, and a trained person as well as for overhand and underhand stabs. [14] From all the data gathered throughout all the studies conducted, a calculator was created to measure stab energy based on body weight, weapon weight, gender, stab type, and strength/experience level. With drop down menus for gender, skill level, and stab type, all the user has to do is enter the desired body weight and weapon mass and the energy will be output:



Energy (J)	F (N)	Spring Constant K (N/m)	Displacement (in)
0.00	0.00	22241.11	

Displacement (in)	Displacement (m)	E (J)	Spring Constant K (N/m)
0.00	0.00		

Velocity (mph)	Velocity (m/s)	Weight (lbs)	Energy (J)
0.00	0.00	0.00	

Energy (J)	Body Weight (lbs)	Skill Level	Gender	Stab Type	Weapon Mass (lbs)
0.00					

Figure 127: Pre-Launch Calculator

The machine operator will be able to mimic an approximate energy profile for a specific person that would be the attacker in a scenario where the armor in question would be used. This will allow for the most accurate testing to replicate human scenarios.

12.3 Spring Stress

The spring stress was analyzed using SOLIDWORKS and compressing the spring to produce 165 J for PE. A nonlinear static simulation was created for 4.73 in. compression which correlates to 165 J. The simulation conditions fixed the model so there was only linear motion. The spring material is A 227 cold drawn steel wire with the material properties applied to the model. The results are shown graphically:

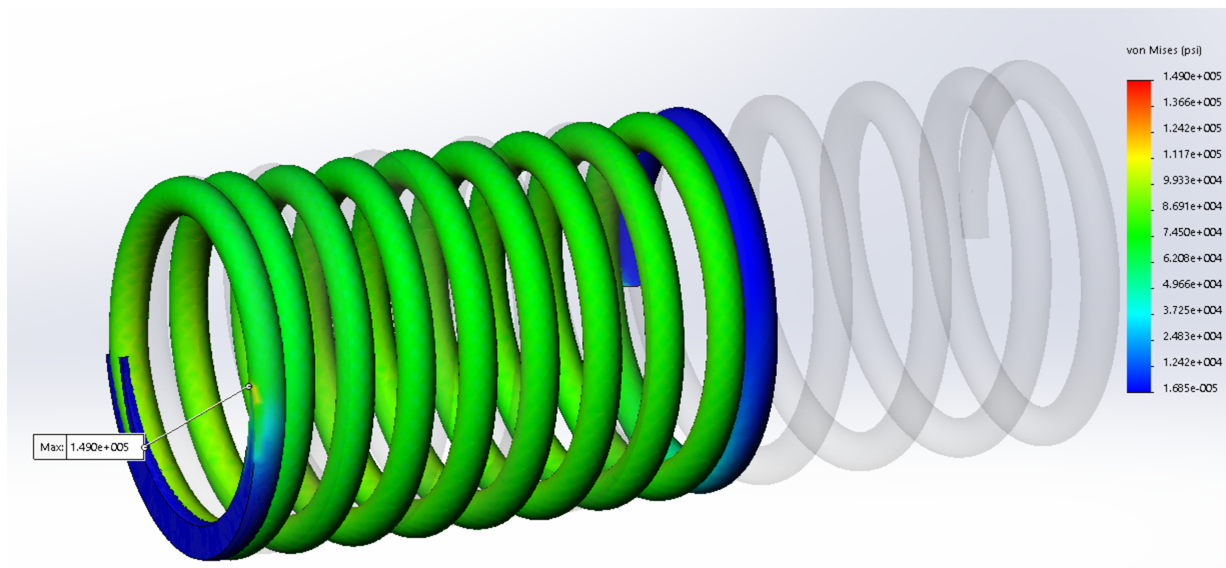


Figure 128: Simulation Of Spring Compressed To 2.5x Maximum NIJ Standards

Where the maximum stress evaluated for Von Mises is 149 KPSI. A 227 has a maximum tensile strength of 283 KPSI leaving a factor of safety of 1.89. The 4.73 in. compression length represents 65% of the maximum compression for the spring. Anticipated testing has the system delivery 2.5 times the NIJ impact test ensuring that the system is not routinely operating at maximum threshold.

12.4 Spring Fatigue

Modeling spring failure is another important component for designing the system. Since the diameter of the wire exceeds $\frac{3}{8}$ in., traditional spring equations can not be applied. [16] Instead, the spring was modeled as a long bar under torsion and apply failure for variable loading. The first step was determining the length of the bar as:

$$L_b = \pi D N_t \tag{6}$$

with $D = 0.5in.$ being the diameter of the wire in in. and $N_t = 10$ as the number of turns in the spring. The next step required finding the torque that the bar is experiencing and written as:

$$T = L_b P_{max} \tag{7}$$

where $P_{max} = 605$ lbs. is is the maximum force the spring experiences for 165 J test with a compression of 4.73 in. The endurance strength of the bar is determined by:

$$S_e = k_a k_b k_c k_d k_e S_e' \tag{8}$$

with k representing various correction factors for design criteria. The surface factor k_a depends on the quality of the spring and defined as:

$$k_a = a S_{ut}^b \tag{9}$$

with $S_{ut} = 283 kpsi$ being the minimum tensile strength of the spring while $a = 2.70$ and $b = -0.265$ are constants based on the surface finish for cold drawn steel. [16]. The size factor k_b for torsional loading and $\frac{1}{2}$ diameter is:

$$k_b = \frac{d}{0.3}^{-0.107} \tag{10}$$

the constants were taken from [16], Table 6-2. The loading factor $k_c = 0.59$ is a constant based solely on loading torsional conditions. The temperature factor $k_d = 1.000$ because the the system is operating at room temperature and not expected to operate in any other temperature range. The reliability factor k_e represents the desired reliability of the spring by:

$$k_e = 1 - 0.08 z_a \tag{11}$$

where $z_a = 4.753$ is the transformation variate corresponding to 99.9999 % reliability. [16]. Lastly, the endurance limit $S_e' = 100$ kpsi because the ultimate strength of A 227 is 283 kpsi. [16]. With all of the factors calculated for Eq. 8, $S_e = 3.3572$ kpsi.

The next step is determining the number of cycles to failure through the following relation:

$$N = \left(\frac{\sigma_{rev}}{a}\right)^{1/b} \tag{12}$$

where σ_{rev} is the replaced by $\tau_{max} = \frac{Tr}{J}$ for the spring and a and b are constants that are further detailed as:

$$a = \frac{f S_{ut})^2}{S_e} \tag{13}$$

with the fatigue strength fraction $f = 0.778$ that is graphically interpreted from [16] and S_e is from Eq. 8. Constant b is:

$$b = -\frac{1}{3} \log \left(\frac{f S_{ut}}{S_e} \right) \tag{14}$$

where the unknown variables are the same as Eq. 13 and giving a value of $N = 40,000$ cycles to failure.

13 Build & Manufacture

When starting the manufacturing process the team had to evaluate which components needed to be purchased from outside sources and which components could be made by the group. Key components like the track and cart system, spring, winch, and quick release were all outsourced. The team then had to custom manufacture the rest of the build to assure smooth integration of all components such as the c-channel, the bolt holes, and the steel cart attachments, spring housing, etc.

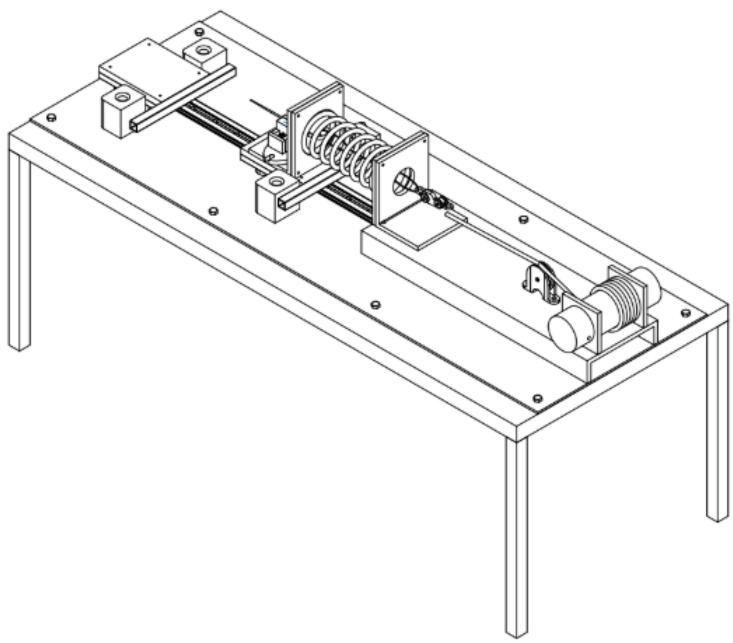


Figure 129: SolidWorks Model of Final Build

In order to comply with the high forces in the system, the base of the build is a 6x2 foot long $\frac{1}{4}$ in. thick steel plate, bolted with eight $\frac{1}{2}$ in. bolts into a wood table. This insures strength and durability of the design with the critical components connect to steel. This also gives the design a more modular design, as the entire assembly and easy be taken off the table and mounted somewhere else.

Multiple processes were used in the manufacturing of the table. Some of the most important processes were CNC milling, manual milling, tapping, and welding. CNC milling was used in order to obtain precisely milled aluminum housings for the spring. CNC was chosen because it allows for the milling of perfect circles in larger diameters. The aluminum plates were milled with a hole just above the outer diameter of the spring in order to keep it in proper position. The machine drawing for this component can be seen in Appendix Figure 159. The actual component can be seen in Figure 130 below.

Figure 130: CNC Milled Aluminum Spring Housing

Many components of the build were manually milled. The steel plates on the carts, the angle iron pieces, the C-channel, and the test sample frame all had to be custom milled. Milling allowed for accurate dimensions and hole placement for tapping. All components were connected through a threaded piece and bolt or welded connections. The machine drawings for these components can be seen in Appendix Figures 160,161,162,164, & 176. An example of a bolted connection are the angle iron and aluminum pieces seen below in Figure 131.

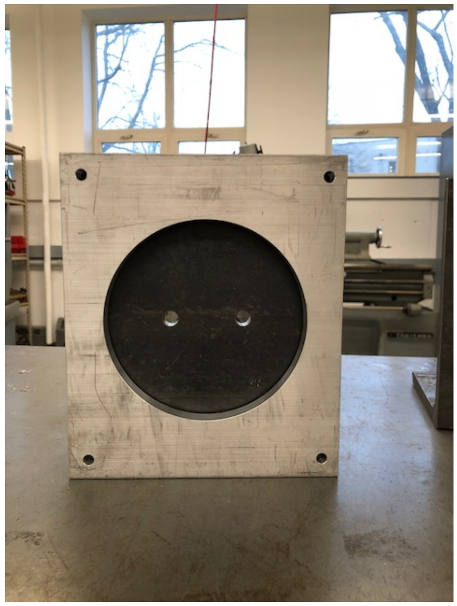


Figure 131: Milled Components with Bolted Connection

The high stress components, like the C-channel and angle iron pieces were welded because it has the highest connection strength. All pieces that did not require a high strength connection were tapped and bolted together. Bolting components together made the build modular and also allowed for easy replacement if a component were to fail in the future. For example, steel plates (Fig:176) were put on the carts and then modified because the steel plate would be much more inexpensive to replace than the custom cart if the part were to fail.

There was also one component of the build which was 3D printed. This was the mount for the bar tape. It was decided to 3D print this piece because of it's unique geometry and because of the quick production time of 3D printing. This component is also bearing a negligible load, so strength is not a priority. The CAD model for this piece can be seen in Appendix Figure 163.

The project was designed and manufactured to be as robust and safe as possible. All of the components in the build have specifications higher than the minimum requirement, insuring a higher factor of safety. All these factors were taken into account when building this project to insure reliability and ease for the user.

14 Testing

Due to loss of energy in the form of friction, the total potential energy of the spring will not transfer into the cart in the form of kinetic energy. This is shown in the form of a loss of velocity. In order to predict an accurate theoretical velocity, we need to account for the loss of energy in the transfer. In order to do so, testing was done to create a velocity trendline in order to accurately predict the cart's velocity on impact.

A MatLab script was created to get a rough estimate of the said trendline. The equation for the trendline was was a function of displacement allowing the DRO output to serve as the displacement when calculating the theoretical velocity. For the first set of tests, the cart was not yet finished, therefore the tests were invalid. They served to prove that the new trendline would drastically reduce error and that velocity is a linear function. 35 tests were conducted ranging from 1 inch to 4 inches of displacement. The MatLab equation resulted in an average error of 16.67% error. The trendline equation from the collected data resulted in an average error of 6.34% error, therefore proving the trendline equation is much more accurate. The collected data below shows the linearity of the data:

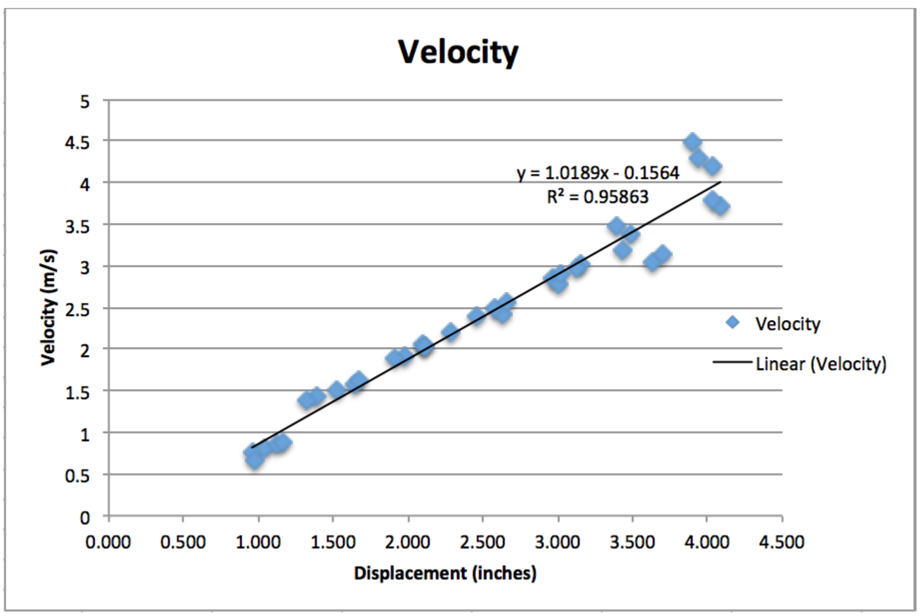


Figure 132: Velocity Trendline of the Preliminary Calibration Testing

Once the cart was completed, a true series of calibration tests could be ran to create an accurate velocity trendline for the pre-launch calculator. A series of 42 tests were ran ranging from 1 inch to 3.5 inches of displacement This resulted in an average error of 1.7 joules and delivered 5-90 joules of energy. The energy deviation was determined to be much more important than the percent error, especially at low energy levels. With a goal of a max energy deviation of 5 joules, the machine proved accurate and repeatable. The trendline shown gives a visual of the linearity of the data:

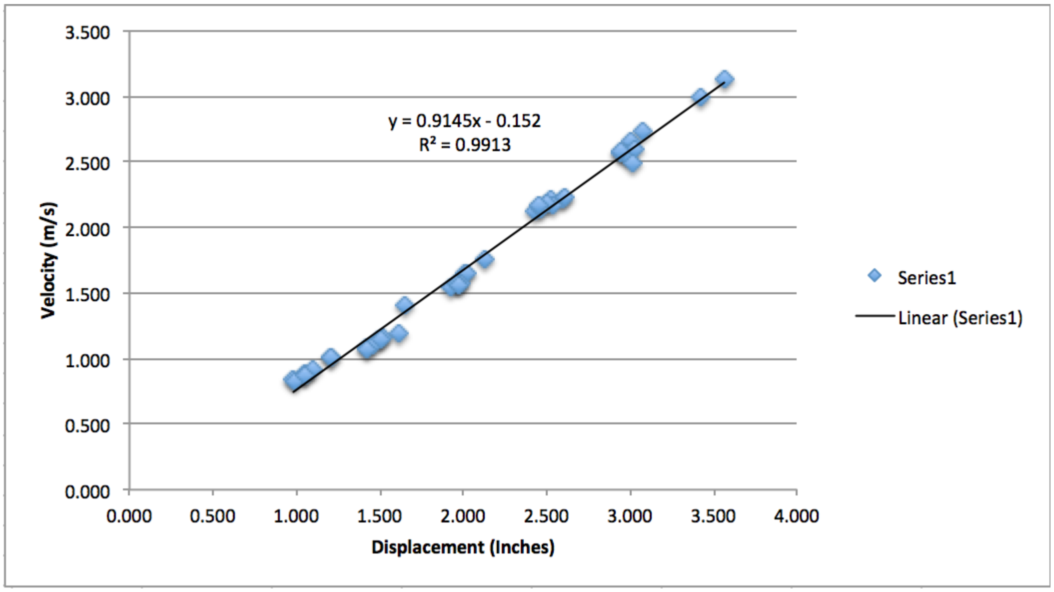


Figure 133: Velocity Trendline of the Final Calibration Testing

With the machine now fully calibrated and the new equation in the pre-launch calculator, actual testing is able to be conducted with confidence in the data. A series of over 40 tests were conducted on a sample of 12 layer carbon fiber with carbon nanotube resin. Energy never deviated from the theoretical by more than 4 joules and averaged around 1.5 joules difference. This is the testing the machine will be doing in the field, therefore this series of tests proved the validity of the machine and gave the customer reassurance.

15 Redesign

Throughout the build phase, the team decided to make some changes to the design in order to increase accuracy and efficiency as problems arose. One problem the team noticed very early on was mounting the spring. The original idea was to mount the spring with clips screwed into the aluminum housing. After reconsidering, the team realize that these clips would be too time consuming to manufacture and also be under extreme stress when put into effect. In order to reduce the likelihood of this clips failing, they were removed all together. Instead, the spring would always be compressed $\frac{1}{2}$ in. similar to a coil spring around a shock absorber in a car. This new system contains the spring perfectly while also allows for easy removal if necessary. Within segment redesign, there also had to be an alteration in theory (see Sec. 12) because the spring is not releasing to a full rest position.

The largest change form the original design was going from a two cart system to a one cart system for the reasons outlined in Sec. 12. After the first round of testing, the theoretical and actual impact energies were very inaccurate. This was due to a large portion of the system energy being lost in the cart to cart transfer. For this reason, a one cart system was implemented, where the stabber would be directly on the spring cart. After testing the new system, actual and theoretical impact energies were very accurate.

Other changes had to be made to the build now that a one cart system is in place. The stabber vice had to be moved as well as the photo gate. A new mount for the bar tape also had to be designed and constructed. The team decided to use the extra cart as the target assembly. This required, more designing and manufacturing. The target assembly will be adjustable along three axis, giving the user much variation in testing. This setup required a brake for the target cart. The brake was also designed and manufactured in this phase.

There were a few other changes away from the cart system that the team aimed to fix during the redesign phase. The first being the rubber stopper bolts. After initial testing, the standard half inch bolts were beginning to warp. The standard bolts are to be replaced with higher rated ones. The resolution of the winch was also an aspect the team aimed to improve. During testing, drawing the system back to the exact position deemed to be a challenge. Reducing the amount of coiled cable in the winch increased the resolution and allowed for more accurate drawings before launch.

16 Operation

Test Procedure

1. Start Excel Macro(Pre Launch Calc), GA4(Bluetooth), LoggerPro(LabQuestMini and photogate).

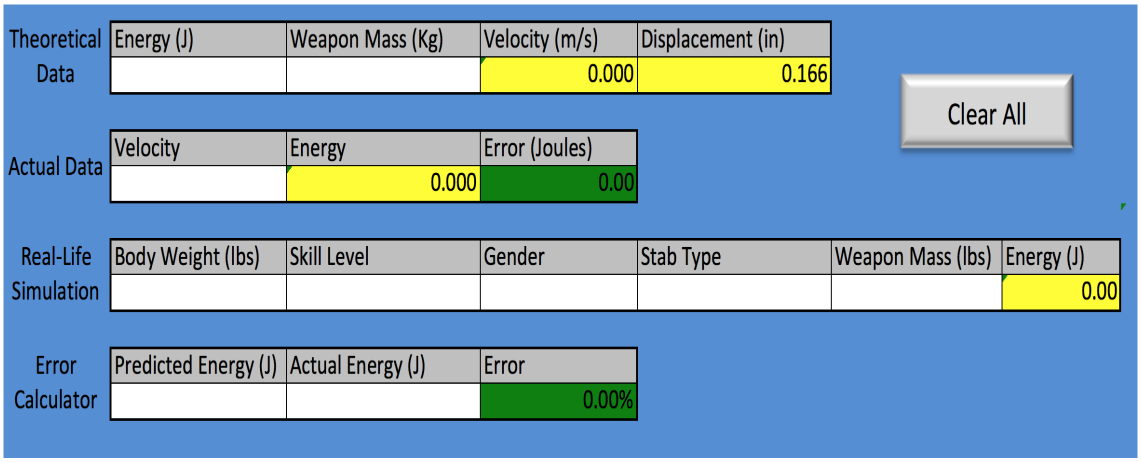


Figure 134: Open Excel File

2. Turn on winch. Do not attach clamp to leash.

Figure 135: Connect winch to power supply

3. Turn on DRO and zero at zeroed position.

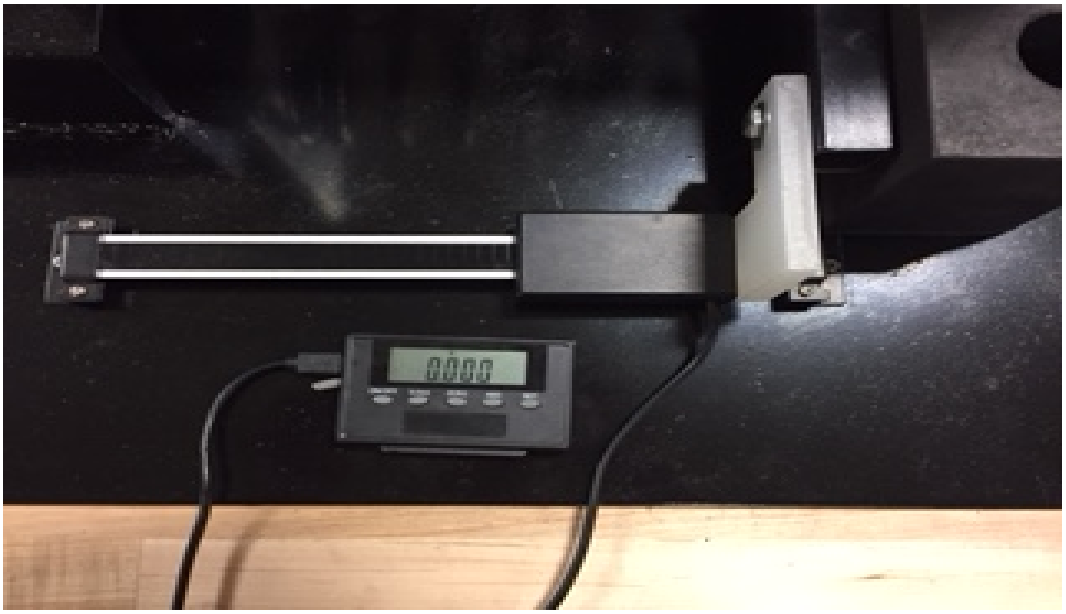


Figure 136: Turn on DRO and zero

4. Determine desired kinetic energy.

5. Use Excel Macro(pre-launch sheet) to find displacement.

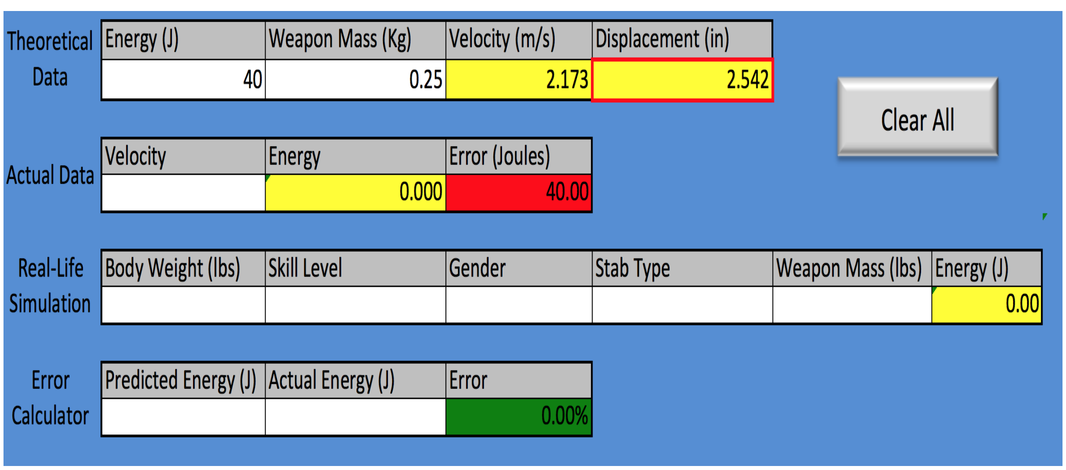


Figure 137: Input Energy value to get displacement

6. Connect clamp to leash

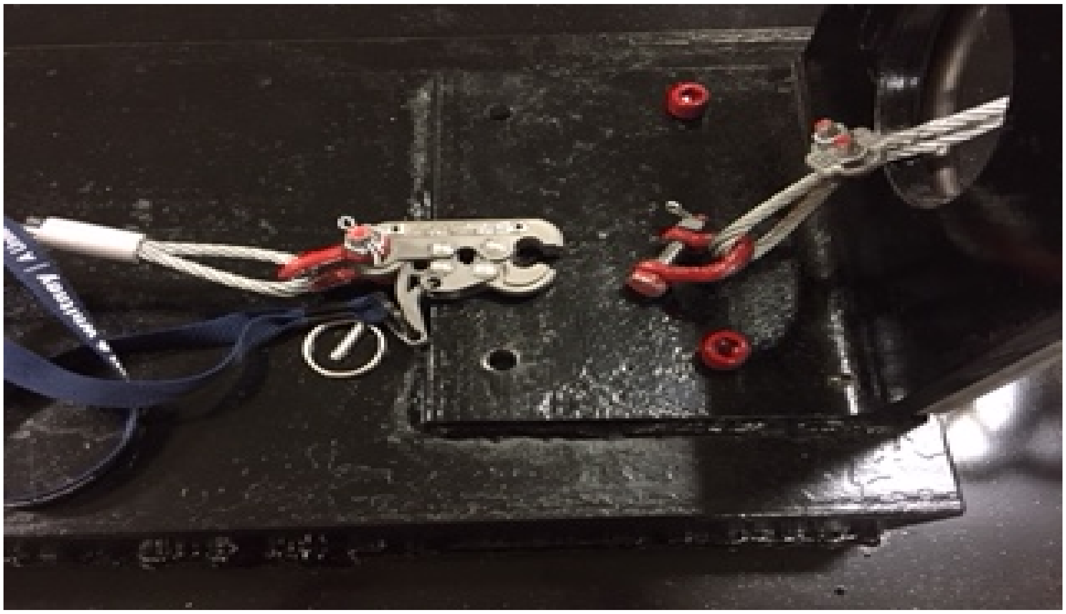


Figure 138: Connect clamp to spring leash

7. Draw the cart to displacement position using DRO and winch.

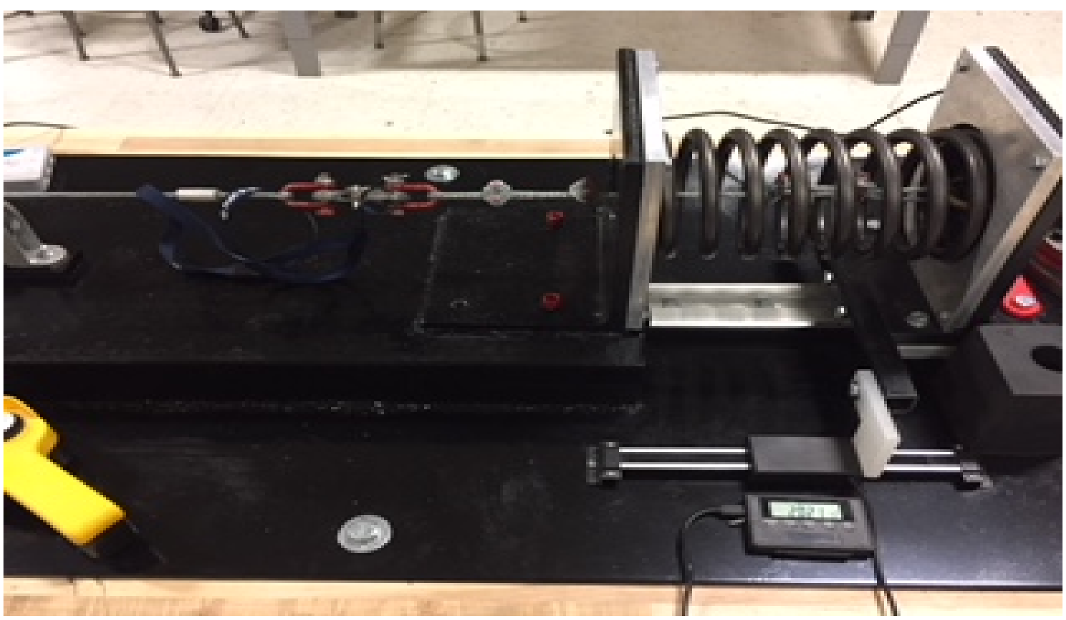


Figure 139: Pull spring to desired displacement shown on DRO

8. Inspect system for any blatant errors. Remove safety pin from clamp.

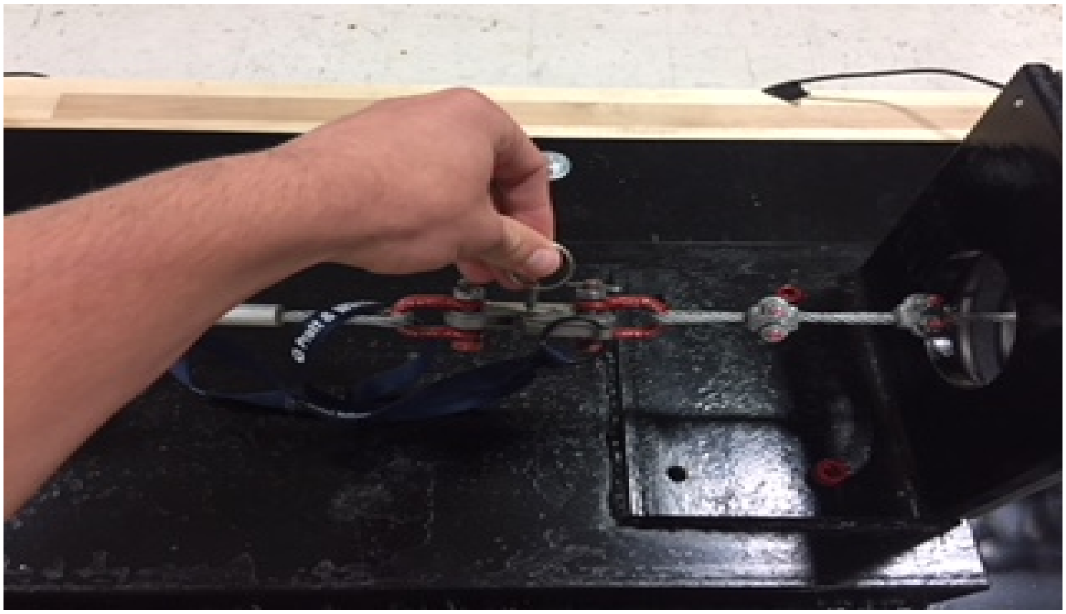


Figure 140: Pull safety pin

9. Start Capture in GA4 and Logger Pro.

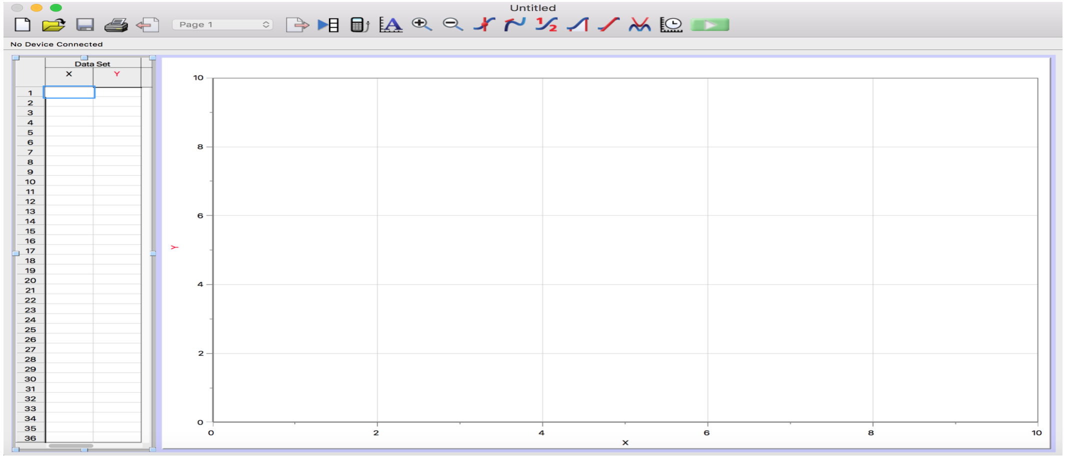


Figure 141: Start Capturing in Logger Pro and GA4

10. Pull lanyard to launch.

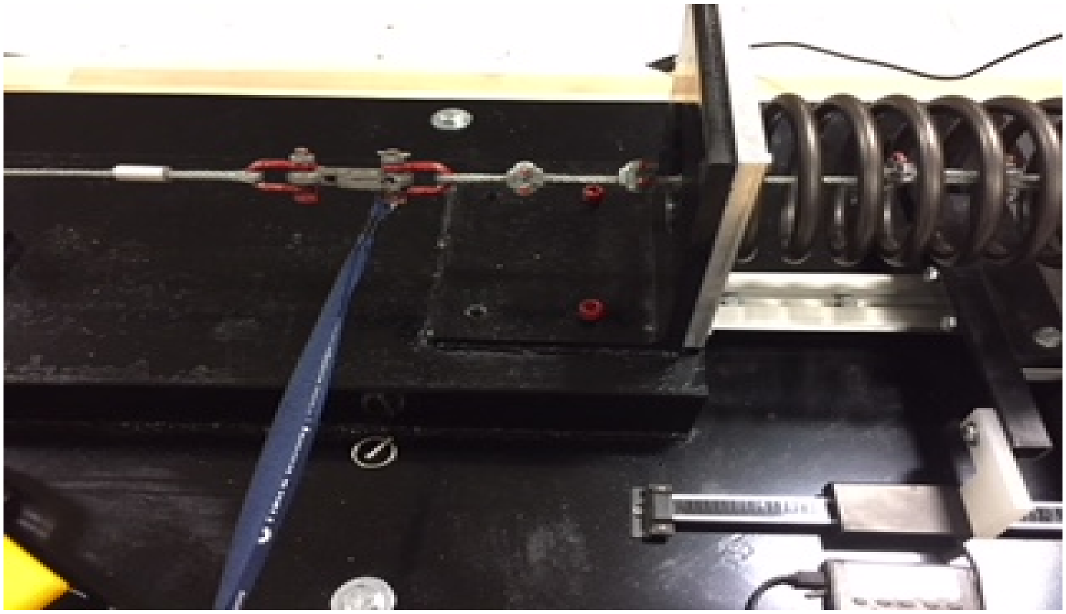


Figure 142: Pull lanyard

11. Stop recording on GA4 and LoggerPro.

12. Turn off Winch.

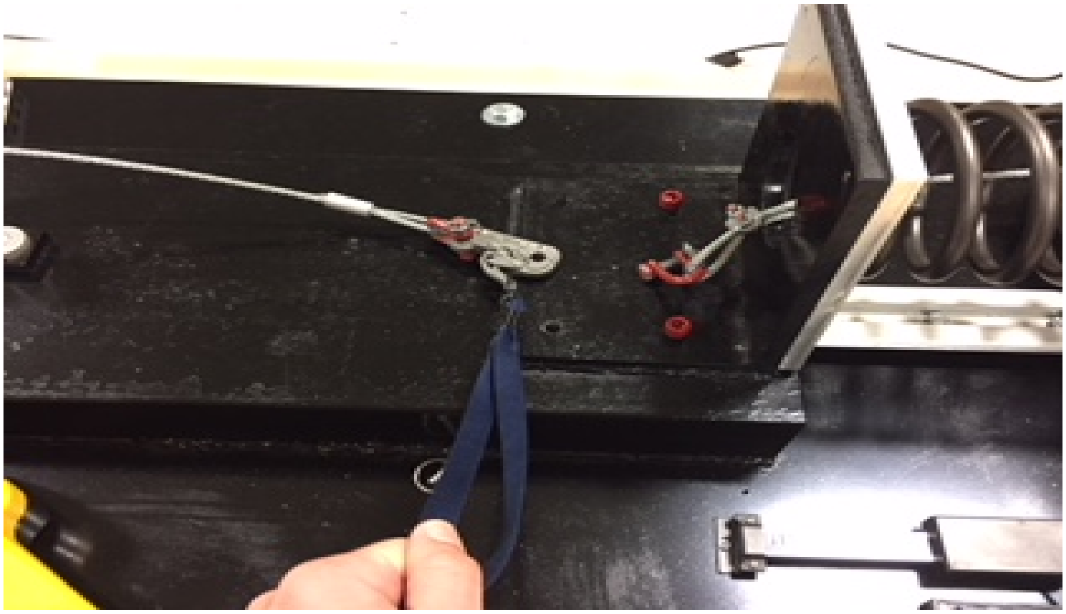


Figure 143: Fired Lanyard

13. Turn off DRO.

Figure 144: Turn off DRO

14. Use Excel to finish Analysis.

Theoretical Data	Energy (J)	Weapon Mass (Kg)	Velocity (m/s)	Displacement (in)
	40	0.25	2.173	2.542

Clear All

Actual Data	Velocity	Energy	Error (Joules)
	2.184	40.782	0.78

Real-Life Simulation	Body Weight (lbs)	Skill Level	Gender	Stab Type	Weapon Mass (lbs)	Energy (J)
						0.00

Error Calculator	Predicted Energy (J)	Actual Energy (J)	Error
	40	40.782	1.95%

Figure 145: Analyze data on Excel

17 Maintenance

The maintenance of this machine was designed to be minimal. Major components that require maintenance are the track, propulsion cart, quick release clamp, and spring. The maintenance period recommended by both PBC Linear (manufacturer of the cart and track) and SeaCatch (manufacturer of the quick release clamp) is six months. [17] [18]

17.1 Track and Cart Maintenance

At the six month interval, maintenance of the track and cart require:

1. Visual inspection of damage from cart motion

2. Corrosion from improper lubrication

The track and cart is designed for a long life cycle in the hundred of thousand of cycles. If their is physical damage to the track, the track loses structural integrity and testing should be halted until the track is replaced since it is a structural failure.

If there is corrosion, it means that the cart, which uses an oil filled polymer lubricator on the wheels, has failed and that the applicator on the cart was broken. This represents another structural failure and a replacement part needs to be ordered. In either case, high endurance parts were ordered for the track, but semi-annual inspection is required to ensure proper operation.

17.2 Quick Release Clamp Maintenance

The SeaCatch TR3 requires visual maintenance every six months as well because it is not operating in a highly corrosive environment. A light coat of WD-40 is recommended to ensure smooth release of the clamp. If the clamp becomes too easy to open (almost no effort to release), it needs to be sent back to MacMillan design for a base cost of $ 50 and refurbishment which includes surface cleaning, attending to any issue with function (cost of replacement parts are not included) and re-lubrication. [18]

17.3 Spring Maintenance

Maintenance of the spring is minimal. While maintenance is ongoing for the other components, the spring should be inspected for visual damage. The spring is designed to have a test life of 40,000 cycles from Sec. 12. If spring replacement needs to occur, the user needs to simply remove rubber stoppers holding the spring in place, slide off the spring, and put the replacement spring on the assembly.

18 Additional Considerations

It is important to identify the impacts of the mechanical stabber and slasher on a broader scale than engineering a solution for the specific objectives Dr. Nassersharif and Amerisewn have identified. A list of additional considerations are:

- Economic Impact
- Environmental Impact
- Societal Impact
- Political Impact
- Ethical Considerations
- Health, Ergonomics, and Safety Considerations
- Sustainability Considerations

which have allowed the group to consider the larger implications of the project and how it could potentially benefit society in a holistic manner.

18.1 Economic Impact

The larger economic impact and implications of reliable armor testing means that better body armor is developed. If the armor performs as designed and protects law enforcement and correctional officers, there is a potential for cities and prisons settling civil lawsuits that are extremely expensive for tax payers. An example is Chicago which paid $ 52 million to settle and litigate excessive force and police misconduct cases. [19] URI and companies like Desmark/Amerisewn are are researching a developing protective clothing law enforcement. If the quality of the equipment is better, than the officer will potentially feel better protected and not in as many dangerous situations. Use of force incidents would decrease and cities could potentially pay less for civil cases and outside litigation.

18.2 Environmental Impact

The environmental footprint of the design is minimal. For fabrication, the designed had several steel components that were heavy and ground shipped which affected the environment through fossil fuel consumption. Certification of armor designs consumes fossil fuels as well. As stated in Section 3, Desmark/Amerisewn will send test specimens to Quantico in Virginia to the FBI to ensure compliance with the NIJ non-ballistic armor certification which requires shipping from Rhode Island.

18.3 Societal and Political Impact

The larger societal and political impacts of effective armor are directly related to the economic impacts. Continuing with Chicago as an example, the costs of lawsuits are passed onto the tax payers in the form of municipal bonds. In August 2017, the city had already paid more than the budgeted $ 20 million for civil lawsuits. The budget was increased by $ 4 million, but those expenses did not cover the $ 13 million in litigation fees resulting in long-term bonds being issues to cover budget shortfalls which is not encouraged by financial experts. [20] When cities and towns pay this amount of money on misconduct proceedings, the tax payers ultimately bear the cost through interest payments on the bonds. Interest in turn affects the annual budget governments allocated to various departments outside of law enforcement which can affect schools for example. Nationwide, the cost of the 10 ten largest police forces for misconduct payouts have been $ 248 million in 2015 which included the number listed in the cases of Chicago. [21]

18.4 Ethical Considerations

Ethical considerations for armor testing are minimal. The armor is certified in a safe environment where testing is only performed on armor samples. There is no live testing on animals and people do not wear armor unless it has been certified by the NIJ. The mechanical stabber and slasher only mimics NIJ testing and performs a near equivalent test. What is not controlled for is the temperature requirements for certifications. URI and Desmark/Amerisewn can essentially reduce costs of testing by performing near equivalent NIJ tests while developing armor samples and have products evaluated by the NIJ.

18.5 Health, Ergonomics, and Safety Considerations

Health, ergonomics, and safety considerations were primary considerations during the design and fabrication of the capstone project. The ergonomics of the project were focused on a single person being able to use the easily. The physical components facilitating easy use are the DRO ans SeaCatch TR3. The DRO is simple to use for the tester because of the simple on/off switch, easy to change units, and quick zero button that always allows the user to know how much the spring is compressed. The other major ergonomic and safety consideration is the quick release clamp (TR3). The testing procedure always has the clamp loaded in the manner recommended by the manufacturer. [18] The clamp itself has two safety mechanism as well. The first is a pin that must be removed in order to conduct testing. Second is the effort to release of 8 lbs. The effort is at a particular point for the user that requires a conscious effort to pull while being small enough so that there is a smooth release the user does not fight against and focus on test conduct.

18.6 Sustainability Considerations

Sustainability considerations for the testing device were focused on the materials selected. In particular, high endurance components were chosen so that parts did not have to be ordered or replaced. Also, the device need minimal maintenance, particularly the track and cart lubrication which makes testing environmentally friendly. [17] Finally, the clamp needs minimal maintenance outside of visual inspection of for corrosion. [18]

19 Conclusion

The design of the variable force mechanical stabber and slasher was successful for the 2017 - 2018 URI capstone. The process from concept generation, theoretical modeling, fabrication, and testing showed a device that performed as intended. The initial design specifications from Sec. 6 were met through testing design and results. The key success of testing confirmed the assumption made in Sec. 12 that there was a linear relationship between the compression of the spring and the velocity achieved of the cart. This allowed for delivering the repeatable energy needed for mimicking the NIJ standards specified in the non-ballistic armor standards. [2]

The data acquisition systems used allowed for accurate measurements in Sec. 14 which consistently showed a an error of 5% or less for any given testing event. Throughout testing, the fabrication of the device showed the sound design principles that went into sizing the proper bolted connections and welds. The table and track were able to handle testing loads and performed especially well for tests conforming to the NIJ energy levels.

The current status of the tester shows that it can perform stab attacks consistently and record the energy at impact. There is further work for URI or Desmark/Amerisewn can do to analyze more testing results. One possibility is placing a pressure sensor on the back face of the of the target cart the determine the dissipation of impact pressure. Another area to optimize is the automation of data selection to populate the correct impact velocity into the Excel Macro so that the user does not have to switch between LoggerPro 3 and Excel. Another possibility is automating the winch displacement so that the user does not have to manually control spring compression which would lead to even more repeatable testing.

The product that was delivered can perform and record NIJ tests simply for any user. There is not a lot of training required to start performing testing of any material samples developed by URI or Desmark/Amerisewn. The device can also deliver larger energy levels based on the spring that was used in the design. Another deliverable was determining the energy level of a stab based on weight, skill, sex, and stab type that is clearly shown in Fig. 127. The product delivered has the ability to improved, but the major deliverable items were designed and achieved by the group.

Acknowledgements

Dr. Nassersharif's feedback and guidance has proved helpful for engineering aspects of the deign and how to handle logistics for the project. The group would like to thank the sponsors from Desmark/Amerisewn, particularly John Caito III and Layne Meyer for their constructive feedback and focus. Professor Jouaneh has been instrumental in the control system design and modeling. Team 20 has been working hard on their design and helpful with their potential measuring requirements to analyze their designs. Additionally, there have been students from the 2018 class that have provided guidance or ideas on how to approach complex design issues too. In particular, Dillon Fontaine has proved invaluable in the control system implementation as well as spring design. The group would like to thank them all.

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20 Appendices

The various appendices listed detail various aspects of the table design and analysis used for determining key components used during the design and implementation process. In particular, the Matlab codes, tests forms, reference drawings, and order forms are included for reference.

20.1 Relating Spring Compression to Velocity

```
function [V_R, DRO]=veloctiy2(k, m1, KE, d);

% k - the spring contant, units of lbs/in.
% m1 - the cart mass in kg.
% KE - The kinetic energy in J.
% d - the initial compression of the spring in in.
%
% V_R - the relase velocity in m/s.
%
% DRO - the digital readout indicator in in.

k = 127 * 175.127;

m1 = 19;

d = 0.5 * 0.0254;

% The basic KE corresponding to the NIJ energy level in a 1 x 6 array.

KE = [24 33 43 36 50 165];

% The range of KE values with in a 2 x 6 array where the first row is the
% low range of acceted NIJ energy levels and the second row is the high
% range.

KE_Range = [KE(1)-.5 KE(2)-.6 KE(3)-.6 KE(4)-.6 KE(5)-.7 KE(6)-.8;...
            KE(1)+.5 KE(2)+.6 KE(3)+.6 KE(4)+.6 KE(5)+.7 KE(6)+.8];

% A loop for the length of KE_Range that determines the minimum and maximum
% V_R and DRO.

for i = 1:length(KE_Range)
    V_Rmin(i) = sqrt((2*KE_Range(1,i))/m1);
    V_Rmax(i) = sqrt((2*KE_Range(2,i))/m1);
    DRO_min(i) = (sqrt(((2*KE_Range(1,i))/(k))+d^2)-d)*39.3701;
    DRO_max(i) = (sqrt(((2*KE_Range(2,i))/(k))+d^2)-d)*39.3701;
end

% An array V_R for plotting.

V_R = [V_Rmin; V_Rmax]

% An array DRO for plotting.

DRO = [DRO_min; DRO_max]

% The ploting commands for the data determined.

x=[DRO(1,:),DRO(2,:)];
y=[V_R(1,:),V_R(2,:)];
plot(x,y,'linewidth',2)
xlabel('DRO (in)','fontsize', 14)
ylabel('Velocity (m/s)','fontsize', 14)
```

Figure 146: Matlab Code for velocity2.m

20.2 Determining Cart Position over Time

```
function xdot = Team21_rhs(t,x)
% The elastic modulus of the the spring steel in Pa.
E = 5E7;

% The area of the spring (m^2).
A = .00194;

% The length of the spring (m).
L = .0254;

% The spring rate (n/m).
k_spring = 127*175.127;

% The mass of the cart (kg).
m = 19;

% The initial compression of the spring (m).
pre_disp = 0.5*.0254;

% Determines what the spring rate and dampeneing of the system is depending
% on the cart location.
if x(1) <= pre_disp
    k_eff = (E*A/L) - k_spring;
    c_eff = 25000;
else
    k_eff = -k_spring;
    c_eff = 0;
end

% The velocity of the system (m/s).
xdot = [x(2); (-c_eff/m)*x(2) + k_eff*x(1)/m];

% The initial and final times of the system from release (s).
t_i = 0;
t_f = 0.65;
t_span = t_i:0.001:t_f;

% Creating the initial condition of the system before release.
init_disp = 0.07796276;
init_vel = 0;
init_cond = [init_disp, init_vel];

% Plots poisiton vs. time.
[t,x]=ode45(@Team21_rhs, t_span, init_cond);
hold on
plot(t,x(:,1));
legend('Cart Position');
xlabel('Time (s)');
ylabel('Position (m)');
max_v=max(abs(x(:,2)));
disp(['Maximum velocity is ',num2str(max_v),' m/s'])
```

Figure 147: Matlab Code for xdot.m

20.3 Test Procedure

STEP	DESCRIPTION	COMPONENTS/CONDITIONS INVOLVED	RESULT	COMMENTS
1	Start the required software and hardware for data recording.	Excel Macro Starts on Launch	Pass/Fail	
		Graphical Analysis 4 Launches and Communicates on Bluetooth	Pass/Fail	
		LabQuestMini Connected to Photogate	Pass/Fail	
		LoggerPro Software Launches	Pass/Fail	
2	Power the winch ensuring that the spring can be drawn into position.	The winch is powered.	Pass/Fail	
		Clamp is disconnected from the leash.	Pass/Fail	
3	The DRO is powered and set to read '0' inches.	DRO is powered.	Pass/Fail	
		DRO is set to read inches.	Pass/Fail	
		DRO reads '0'	Pass/Fail	
4	The desired potential energy is determined either through Excel Macro or specified by tester.	Determined or specified potential energy value is determined.	Pass/Fail	
5	The Excel Macro determines the displacement the winch needs to draw.	Required draw distance is determined through Excel Macro.	Pass/Fail	
6	The system is ready to be drawn into position. The clamp needs to be secured to the leash with the safety engaged.	The clamp is securely conencted to the leash and winch.	Pass/Fail	
		The safety pin in the clamp engaged.	Pass/Fail	

Figure 148: Team 21 Test Matrix Page 1

STEP	DESCRIPTION	COMPONENTS/CONDITIONS INVOLVED	RESULT	COMMENTS
7	The spring is drawn to the required displacement calculated in the Excel Macro.	DRO readout matches Excel Macro calculation to ± 0.1 in.	Pass/Fail	
		Leash is visbly stable.	Pass/Fail	
8	The launching cart is flush with the stabbing cart and the attack angle is set.	Launch cart and stabber cart are placed next to eachother.	Pass/Fail	
		Blade is oriented to ± 0.5 degrees of desired attack angle.	Pass/Fail	
9	A second visual inspection of the launch mechanism is performed to verify the stability of the system. The safety pin is removed from the clamp.	Second visual inspection of sytem stability.	Pass/Fail	
		Safety pin removed from clamp.	Pass/Fail	
10	Plexiglass safety cover is closed for safe testing.	Plexiglass cover latches in closed position.	Pass/Fail	
11	The data recording software is initiated to capture test results.	Start Capture' is pressed on Graphical Analysis 4.	Pass/Fail	
		Start Capture' is pressed on LoggerPro 3.	Pass/Fail	
12	The clamp is released with secure pull of the lanyard.	Clamp is disengaged.	Pass/Fail	

Figure 149: Team 21 Test Matrix Page 2

STEP	DESCRIPTION	COMPONENTS/CONDITIONS INVOLVED	RESULT	COMMENTS
13	The data recording software is stopped with data being exported to proper format for the Excel Macro to read.	Stop Capture' is pressed on Graphical Analysis 4.	Pass/Fail	
		Stop Capture' is pressed on LoggerPro 3.	Pass/Fail	
		Graphical Analysis 4 data is exported to proper format.	Pass/Fail	
		LoggerPro 3 data is exported to proper format.	Pass/Fail	
14	The Excel Macro performs analysis for impact velocity, kinetic energy and force on the target.	Excel Macro determines impact velocity to 0.01 m/s.	Pass/Fail	
		Excel Macro determines impact kinetic energy with 3% error of potential energy.	Pass/Fail	
		Excel Macro determines impact force to 0.01 lbf.	Pass/Fail	
15	The system is powered down after testing is complete.	The winch is powered down.	Pass/Fail	
		The DRO is turned off.	Pass/Fail	

Figure 150: Team 21 Test Matrix Page 3

20.4 Test Results

This section details the test results collected.

Compression	Test	X	Theoretical V	Actual V	Error
0.5"					
1.0"	1	0.957	1.281	0.757	40.92%
	2	1.042	1.362	0.803	41.03%
	3	1.117	1.433	0.856	40.26%
	4	0.971	1.295	0.66	49.02%
	5	1.158	1.472	0.874	40.61%
	AVG	1.049		0.79	42.37%
1.5"	1	1.641	1.929	1.577	18.26%
	2	1.528	1.822	1.512	17.03%
	3	1.384	1.686	1.431	15.12%
	4	1.665	1.952	1.636	16.19%
	5	1.324	1.629	1.384	15.04%
	AVG	1.508		1.508	16.33%
2.0"	1	2.094	2.358	2.047	13.21%
	2	1.982	2.252	1.916	14.93%
	3	2.112	2.376	2.034	14.38%
	4	2.114	2.377	2.025	14.82%
	5	1.908	2.182	1.896	13.12%
	AVG	2.042		1.9836	14.09%

Compression	Test	X	Theoretical V	Actual V	Error
2.5"	1	2.460	2.705	2.401	11.25%
	2	2.633	2.869	2.43	15.30%
	3	2.584	2.823	2.491	11.75%
	4	2.653	2.888	2.571	10.98%
	5	2.281	2.536	2.209	12.88%
	AVG	2.522		2.4204	12.43%
3.0"	1	2.969	3.187	2.845	10.74%
	2	3.157	3.366	3.03	9.97%
	3	3.008	3.224	2.77	14.09%
	4	3.131	3.341	2.96	11.40%
	5	3.020	3.236	2.897	10.47%
	AVG	3.057		2.9004	11.33%
3.5"	1	3.488	3.679	3.378	8.18%
	2	3.396	3.592	3.465	3.53%
	3	3.426	3.620	3.196	11.72%
	4	3.628	3.812	3.046	20.09%
	5	3.705	3.885	3.129	19.45%
	AVG	3.529		3.2428	12.60%
4.0"	1	3.940	4.107	4.299	4.67%
	2	4.084	4.244	3.727	12.18%
	3	4.029	4.192	4.192	0.01%
	4	3.903	4.072	4.484	10.11%
	5	4.038	4.200	3.8	9.53%
	AVG	3.999		4.1004	7.30%

Figure 151: Preliminary Calibration Testing Initial Velocity

Compression	Test	X	Theoretical V	Actual V	Error
0.5"					
1.0"	1	0.957	0.819	0.757	7.53%
	2	1.042	0.905	0.803	11.30%
	3	1.117	0.982	0.856	12.81%
	4	0.971	0.833	0.660	20.76%
	5	1.158	1.023	0.874	14.61%
	AVG	1.049		0.790	13.40%
1.5"	1	1.641	1.516	1.577	4.05%
	2	1.528	1.400	1.512	7.96%
	3	1.384	1.254	1.431	14.14%
	4	1.665	1.540	1.636	6.23%
	5	1.324	1.193	1.384	16.05%
	AVG	1.508		1.508	9.69%
2.0"	1	2.094	1.977	2.047	3.53%
	2	1.982	1.863	1.916	2.84%
	3	2.112	1.996	2.034	1.93%
	4	2.114	1.998	2.025	1.37%
	5	1.908	1.788	1.896	6.06%
	AVG	2.042		1.984	3.15%

Compression	Test	X	Theoretical V	Actual V	Error
2.5"	1	2.460	2.350	2.401	2.17%
	2	2.633	2.526	2.430	3.81%
	3	2.584	2.476	2.491	0.59%
	4	2.653	2.547	2.571	0.95%
	5	2.281	2.168	2.209	1.90%
	AVG	2.522		2.420	1.89%
3.0"	1	2.969	2.869	2.845	0.83%
	2	3.157	3.060	3.030	0.99%
	3	3.008	2.908	2.770	4.76%
	4	3.131	3.034	2.960	2.43%
	5	3.020	2.921	2.897	0.81%
	AVG	3.057		2.900	1.96%
3.5"	1	3.488	3.398	3.378	0.57%
	2	3.396	3.304	3.465	4.88%
	3	3.426	3.334	3.196	4.15%
	4	3.628	3.540	3.046	13.96%
	5	3.705	3.619	3.129	13.53%
	AVG	3.529		3.243	7.42%
4.0"	1	3.940	3.858	4.299	11.43%
	2	4.084	4.005	3.727	6.94%
	3	4.029	3.949	4.192	6.16%
	4	3.903	3.820	4.484	17.37%
	5	4.038	3.958	3.800	3.99%
	AVG	3.999		4.100	9.18%

Figure 152: Preliminary Calibration Testing Corrected Velocity

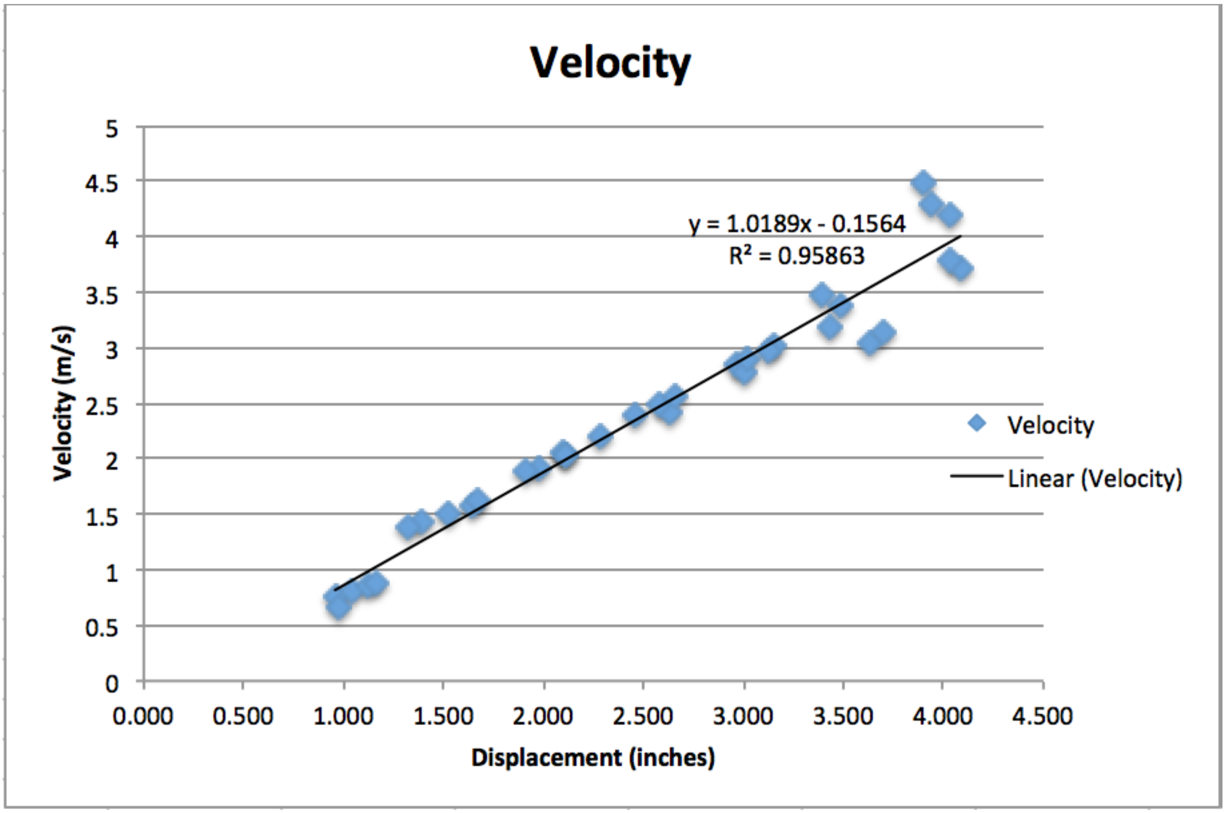

Figure 153: Initial Calibration Testing Velocity Trendline

Compression	Test	X	Theoretical KE	Actual KE	Error	KE Difference	STDEV
0.5"							
1.0"	1	0.957	5.563	4.756	14.50%	0.81	
	2	1.042	6.802	5.352	21.32%	1.45	
	3	1.117	7.999	6.082	23.97%	1.92	
	4	0.971	5.759	3.615	37.22%	2.14	
	5	1.158	8.694	6.340	27.08%	2.35	
	AVG	1.049		5.180	24.82%	1.73	0.62
1.5"	1	1.641	19.066	20.642	8.26%	1.58	
	2	1.528	16.279	18.975	16.56%	2.70	
	3	1.384	13.047	16.996	30.27%	3.95	
	4	1.665	19.686	22.215	12.85%	2.53	
	5	1.324	11.806	15.898	34.67%	4.09	
	AVG	1.508		18.875	20.52%	2.97	1.05
2.0"	1	2.094	32.447	34.779	7.19%	2.33	
	2	1.982	28.809	30.470	5.76%	1.66	
	3	2.112	33.051	34.338	3.89%	1.29	
	4	2.114	33.119	34.035	2.77%	0.92	
	5	1.908	26.525	29.837	12.49%	3.31	
	AVG	2.042		32.658	6.42%	1.90	0.95

Compression	Test	X	Theoretical KE	Actual KE	Error	KE Difference	STDEV
2.5"	1	2.460	45.840	47.848	4.38%	2.01	
	2	2.633	52.975	49.011	7.48%	3.96	
	3	2.584	50.902	51.502	1.18%	0.60	
	4	2.653	53.833	54.863	1.91%	1.03	
	5	2.281	39.001	40.501	3.85%	1.50	
	AVG	2.522		48.624	3.76%	1.82	1.31
3.0"	1	2.969	68.305	67.180	1.65%	1.12	
	2	3.157	77.731	76.201	1.97%	1.53	
	3	3.008	70.210	63.685	9.29%	6.53	
	4	3.131	76.392	72.721	4.80%	3.67	
	5	3.020	70.802	69.659	1.61%	1.14	
	AVG	3.057		69.822	3.87%	2.80	2.33
3.5"	1	3.488	95.808	94.710	1.15%	1.10	
	2	3.396	90.594	99.652	10.00%	9.06	
	3	3.426	92.279	84.780	8.13%	7.50	
	4	3.628	104.022	77.008	25.97%	27.01	
	5	3.705	108.684	81.262	25.23%	27.42	
	AVG	3.529		87.281	14.09%	14.42	12.06
4.0"	1	3.940	123.543	153.396	24.16%	29.85	
	2	4.084	133.118	115.291	13.39%	17.83	
	3	4.029	129.419	145.855	12.70%	16.44	
	4	3.903	121.140	166.882	37.76%	45.74	
	5	4.038	130.020	119.852	7.82%	10.17	
	AVG	3.999		139.550	19.17%	24.01	14.09

Figure 154: Preliminary Calibration Testing Energy

Compression	Test	X	Theoretical V	Actual V	Error	V Difference	STDEV
1"	1	0.982	0.438	0.846	93.22%	0.408	
	2	1.046	0.443	0.888	100.23%	0.445	
	3	1.045	0.443	0.879	98.24%	0.436	
	4	0.988	0.438	0.828	88.88%	0.390	
	5	1.096	0.448	0.924	106.30%	0.476	
	6	1.210	0.458	1.015	121.64%	0.557	
	7	1.054	0.444	0.874	96.76%	0.430	
	8	1.209	0.458	1.005	119.50%	0.547	
	AVG	1.079		0.907	103.10%		
1.5"	1	1.652	0.497	1.400	181.73%	0.903	
	2	1.492	0.483	1.141	136.32%	0.658	
	3	1.422	0.477	1.082	127.00%	0.605	
	4	1.520	0.485	1.167	140.48%	0.682	
	5	1.458	0.480	1.104	130.09%	0.624	
	6	1.508	0.484	1.149	137.28%	0.665	
	7	1.418	0.476	1.066	123.81%	0.590	
	8	1.610	0.493	1.189	141.07%	0.696	
	AVG	1.510		1.162	139.72%		
2.0"	1	2.009	0.528	1.645	211.31%	1.117	
	2	1.924	0.521	1.552	197.94%	1.031	
	3	2.023	0.530	1.658	213.04%	1.128	
	4	2.128	0.539	1.754	225.47%	1.215	
	5	1.981	0.526	1.578	200.03%	1.052	
	6	1.955	0.524	1.578	201.35%	1.054	
	7	1.957	0.524	1.579	201.43%	1.055	
	8	1.968	0.525	1.564	198.02%	1.039	
	AVG	1.993		1.614	206.07%		

Compression	Test	X	Theoretical V	Actual V	Error	V Difference	STDEV
2.5"	1	2.520	0.573	2.211	285.54%	1.638	
	2	2.601	0.581	2.223	282.87%	1.642	
	3	2.610	0.581	2.231	283.72%	1.650	
	4	2.535	0.575	2.170	277.52%	1.595	
	5	2.423	0.565	2.133	277.57%	1.568	
	6	2.501	0.572	2.184	281.95%	1.612	
	7	2.460	0.568	2.147	277.87%	1.579	
	8	2.446	0.567	2.164	281.69%	1.597	
	AVG	2.512		2.183	281.09%		
3.0""	1	3.002	0.616	2.661	331.99%	2.045	
	2	3.074	0.622	2.735	339.47%	2.113	
	3	2.944	0.611	2.562	319.40%	1.951	
	4	2.979	0.614	2.568	318.27%	1.954	
	5	2.979	0.614	2.555	316.15%	1.941	
	6	3.028	0.618	2.599	320.36%	1.981	
	7	3.013	0.617	2.497	304.73%	1.880	
	8	2.943	0.611	2.586	323.39%	1.975	
	AVG	2.995		2.595	321.72%		
3.5""	1	3.428	0.654	2.995	358.26%	2.341	
	2	3.563	0.665	3.133	370.80%	2.468	
	3		0.351		100.00%	0.351	
	4		0.351		100.00%	0.351	
	5		0.351		100.00%	0.351	
	6		0.351		100.00%	0.351	
	7		0.351		100.00%	0.351	
	8		0.351		100.00%	0.351	
	AVG	3.496		3.064	166.13%		
4.0"	1		0.351		100.00%	0.351	
	2		0.351		100.00%	0.351	
	3		0.351		100.00%	0.351	
	4		0.351		100.00%	0.351	
	5		0.351		100.00%	0.351	
	6		0.351		100.00%	0.351	
	7		0.351		100.00%	0.351	
	8		0.351		100.00%	0.351	
	AVG	#DIV/0!		#DIV/0!	100.00%		

Figure 155: Final Calibration Testing Initial Velocity

Compression	Test	X	Theoretical V	Actual V	Error	V Difference	STDEV
1"	1	0.982	0.746	0.846	13.40%	0.100	
	2	1.046	0.805	0.888	10.37%	0.083	
	3	1.045	0.804	0.879	9.38%	0.075	
	4	0.988	0.752	0.828	10.18%	0.076	
	5	1.096	0.850	0.924	8.67%	0.074	
	6	1.210	0.955	1.015	6.33%	0.060	
	7	1.054	0.812	0.874	7.65%	0.062	
	8	1.209	0.954	1.005	5.39%	0.051	
	AVG	1.079		0.907	8.92%	0.073	
1.5"	1	1.652	1.359	1.400	3.04%	0.041	
	2	1.492	1.212	1.141	5.89%	0.071	
	3	1.422	1.148	1.082	5.78%	0.066	
	4	1.520	1.238	1.167	5.74%	0.071	
	5	1.458	1.181	1.104	6.55%	0.077	
	6	1.508	1.227	1.149	6.36%	0.078	
	7	1.418	1.145	1.066	6.88%	0.079	
	8	1.610	1.320	1.189	9.95%	0.131	
	AVG	1.510		1.162	6.27%	0.077	
2.0"	1	2.009	1.685	1.645	2.39%	0.040	
	2	1.924	1.607	1.552	3.45%	0.055	
	3	2.023	1.698	1.658	2.36%	0.040	
	4	2.128	1.794	1.754	2.23%	0.040	
	5	1.981	1.660	1.578	4.92%	0.082	
	6	1.955	1.636	1.578	3.54%	0.058	
	7	1.957	1.638	1.579	3.58%	0.059	
	8	1.968	1.648	1.564	5.08%	0.084	
	AVG	1.993		1.614	3.44%	0.057	

Compression	Test	X	Theoretical V	Actual V	Error	V Difference	STDEV
2.5"	1	2.520	2.153	2.211	2.72%	0.058	
	2	2.601	2.227	2.223	0.16%	0.004	
	3	2.610	2.235	2.231	0.17%	0.004	
	4	2.535	2.166	2.170	0.17%	0.004	
	5	2.423	2.064	2.133	3.35%	0.069	
	6	2.501	2.135	2.184	2.29%	0.049	
	7	2.460	2.098	2.147	2.35%	0.049	
	8	2.446	2.085	2.164	3.80%	0.079	
	AVG	2.512		2.183	1.88%	0.040	
3.0""	1	3.002	2.593	2.661	2.61%	0.068	
	2	3.074	2.659	2.735	2.85%	0.076	
	3	2.944	2.540	2.562	0.85%	0.022	
	4	2.979	2.572	2.568	0.17%	0.004	
	5	2.979	2.572	2.555	0.67%	0.017	
	6	3.028	2.617	2.599	0.69%	0.018	
	7	3.013	2.603	2.497	4.09%	0.106	
	8	2.943	2.539	2.586	1.84%	0.047	
	AVG	2.995		2.595	1.72%	0.045	
3.5""	1	3.428	2.983	2.995	0.41%	0.012	
	2	3.563	3.106	3.133	0.86%	0.027	
	3		-0.152		100.00%	0.152	
	4		-0.152		100.00%	0.152	
	5		-0.152		100.00%	0.152	
	6		-0.152		100.00%	0.152	
	7		-0.152		100.00%	0.152	
	8		-0.152		100.00%	0.152	
	AVG	3.496		3.064	75.16%	0.119	
4.0"	1		-0.152		100.00%	0.152	
	2		-0.152		100.00%	0.152	
	3		-0.152		100.00%	0.152	
	4		-0.152		100.00%	0.152	
	5		-0.152		100.00%	0.152	
	6		-0.152		100.00%	0.152	
	7		-0.152		100.00%	0.152	
	8		-0.152		100.00%	0.152	
	AVG	#DIV/0!		#DIV/0!	100.00%	0.152	

Figure 156: Final Calibration Testing Corrected Velocity

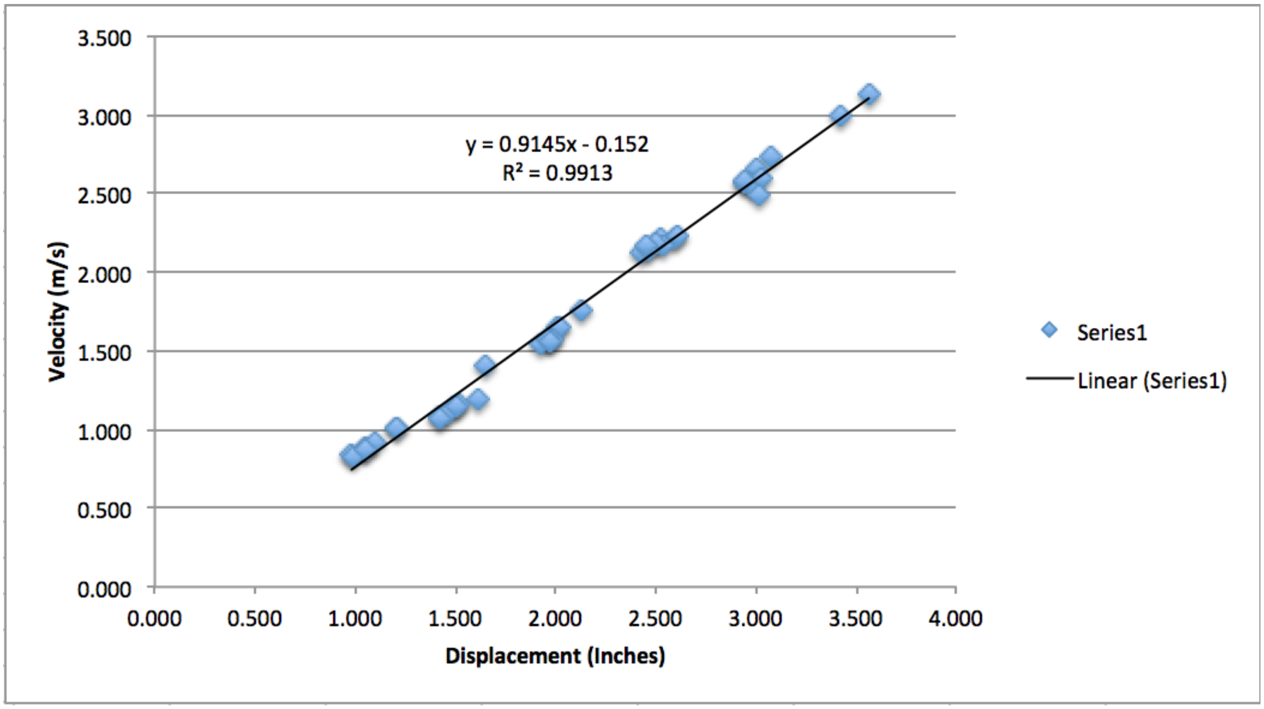

Figure 157: Final Calibration Testing Velocity Trendline

Compression	Test	X	Theoretical KE	Actual KE	Error	KE Difference	STDEV
1"	1	0.982	5.287	6.799	28.59%	1.512	
	2	1.046	6.150	7.491	21.82%	1.342	
	3	1.045	6.136	7.340	19.63%	1.204	
	4	0.988	5.366	6.513	21.39%	1.148	
	5	1.096	6.868	8.111	18.09%	1.242	
	6	1.210	8.656	9.787	13.07%	1.131	
	7	1.054	6.262	7.257	15.89%	0.995	
	8	1.209	8.639	9.595	11.06%	0.956	
	AVG	1.079		7.822	18.69%	1.191	
1.5"	1	1.652	17.539	18.620	6.16%	1.081	
	2	1.492	13.965	12.368	11.44%	1.597	
	3	1.422	12.529	11.122	11.23%	1.407	
	4	1.520	14.561	12.938	11.15%	1.623	
	5	1.458	13.258	11.579	12.67%	1.679	
	6	1.508	14.304	12.542	12.32%	1.762	
	7	1.418	12.450	10.795	13.29%	1.654	
	8	1.610	16.561	13.430	18.91%	3.131	
	AVG	1.510		12.833	12.14%	1.742	
2.0"	1	2.009	26.980	25.707	4.72%	1.273	
	2	1.924	24.548	22.883	6.79%	1.666	
	3	2.023	27.392	26.115	4.66%	1.276	
	4	2.128	30.577	29.227	4.42%	1.350	
	5	1.981	26.166	23.656	9.59%	2.511	
	6	1.955	25.422	23.656	6.95%	1.766	
	7	1.957	25.479	23.686	7.04%	1.793	
	8	1.968	25.793	23.238	9.91%	2.555	
	AVG	1.993		24.732	6.76%	1.774	

Compression	Test	X	Theoretical KE	Actual KE	Error	KE Differenc	STDEV
2.5"	1	2.520	44.018	46.441	5.51%	2.423	
	2	2.601	47.099	46.946	0.32%	0.153	
	3	2.610	47.448	47.285	0.34%	0.163	
	4	2.535	44.580	44.735	0.35%	0.154	
	5	2.423	40.464	43.222	6.82%	2.758	
	6	2.501	43.310	45.314	4.63%	2.004	
	7	2.460	41.802	43.791	4.76%	1.989	
	8	2.446	41.293	44.488	7.74%	3.194	
	AVG	2.512		45.267	3.81%	1.605	
3.0""	1	3.002	63.891	67.269	5.29%	3.378	
	2	3.074	67.176	71.062	5.78%	3.886	
	3	2.944	61.304	62.357	1.72%	1.052	
	4	2.979	62.859	62.649	0.33%	0.210	
	5	2.979	62.859	62.016	1.34%	0.842	
	6	3.028	65.068	64.171	1.38%	0.897	
	7	3.013	64.388	59.233	8.01%	5.155	
	8	2.943	61.260	63.530	3.71%	2.270	
	AVG	2.995		63.992	3.44%	2.211	
3.5""	1	3.428	84.528	85.215	0.81%	0.687	
	2	3.563	91.670	93.249	1.72%	1.579	
	3		0.219	0.000	100.00%	0.219	
	4		0.219	0.000	100.00%	0.219	
	5		0.219	0.000	100.00%	0.219	
	6		0.219	0.000	100.00%	0.219	
	7		0.219	0.000	100.00%	0.219	
	8		0.219	0.000	100.00%	0.219	
	AVG	3.496		89.187	75.32%	0.448	
4.0"	1		0.219	0.000	100.00%	0.219	
	2		0.219	0.000	100.00%	0.219	
	3		0.219	0.000	100.00%	0.219	
	4		0.219	0.000	100.00%	0.219	
	5		0.219	0.000	100.00%	0.219	
	6		0.219	0.000	100.00%	0.219	
	7		0.219	0.000	100.00%	0.219	
	8		0.219	0.000	100.00%	0.219	
	AVG	#DIV/0!		#DIV/0!	100.00%	0.219	

Figure 158: Final Calibration Testing Energy

20.5 Machine Drawings

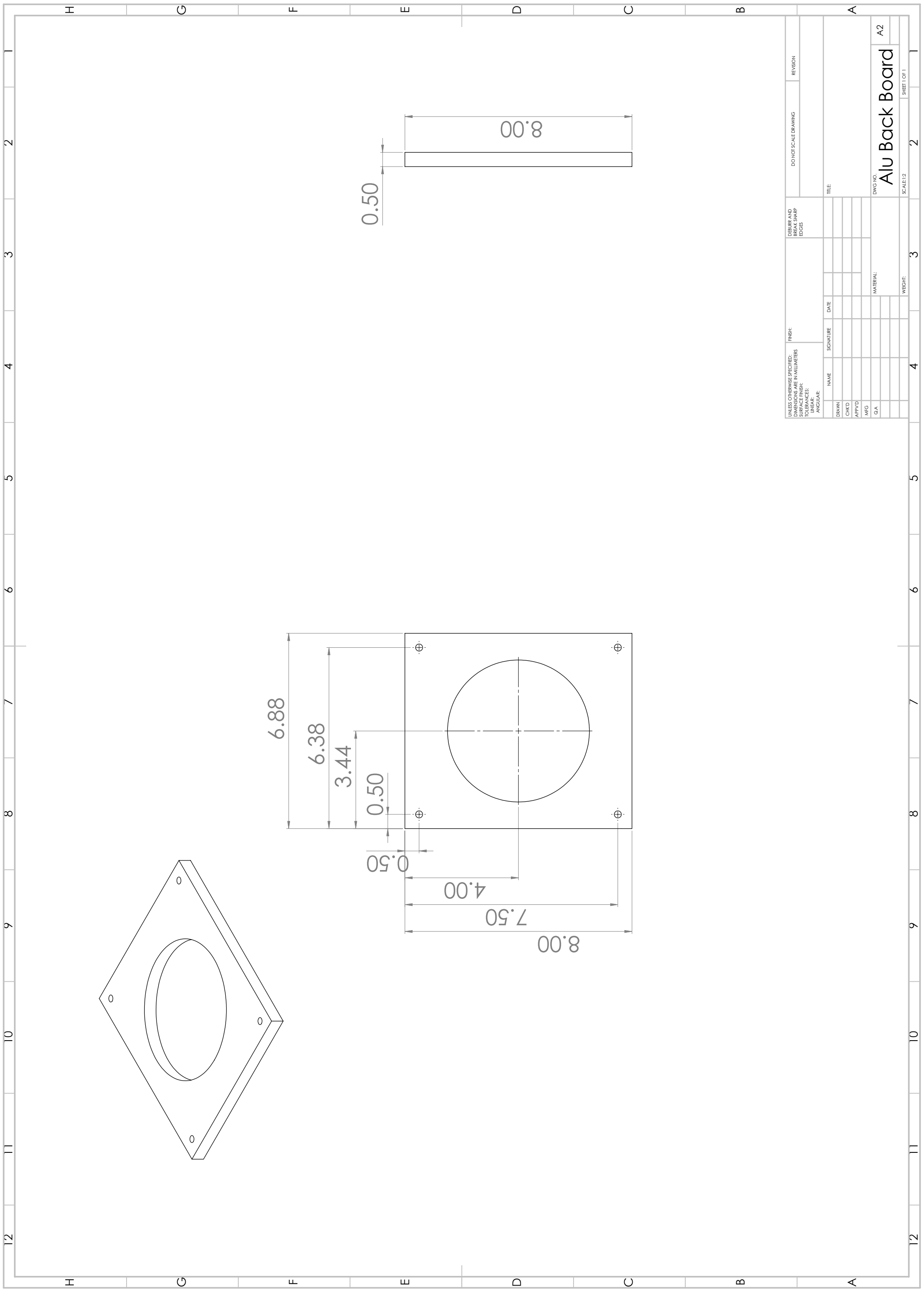

Figure 159: Aluminum Spring Housing Machine Drawing

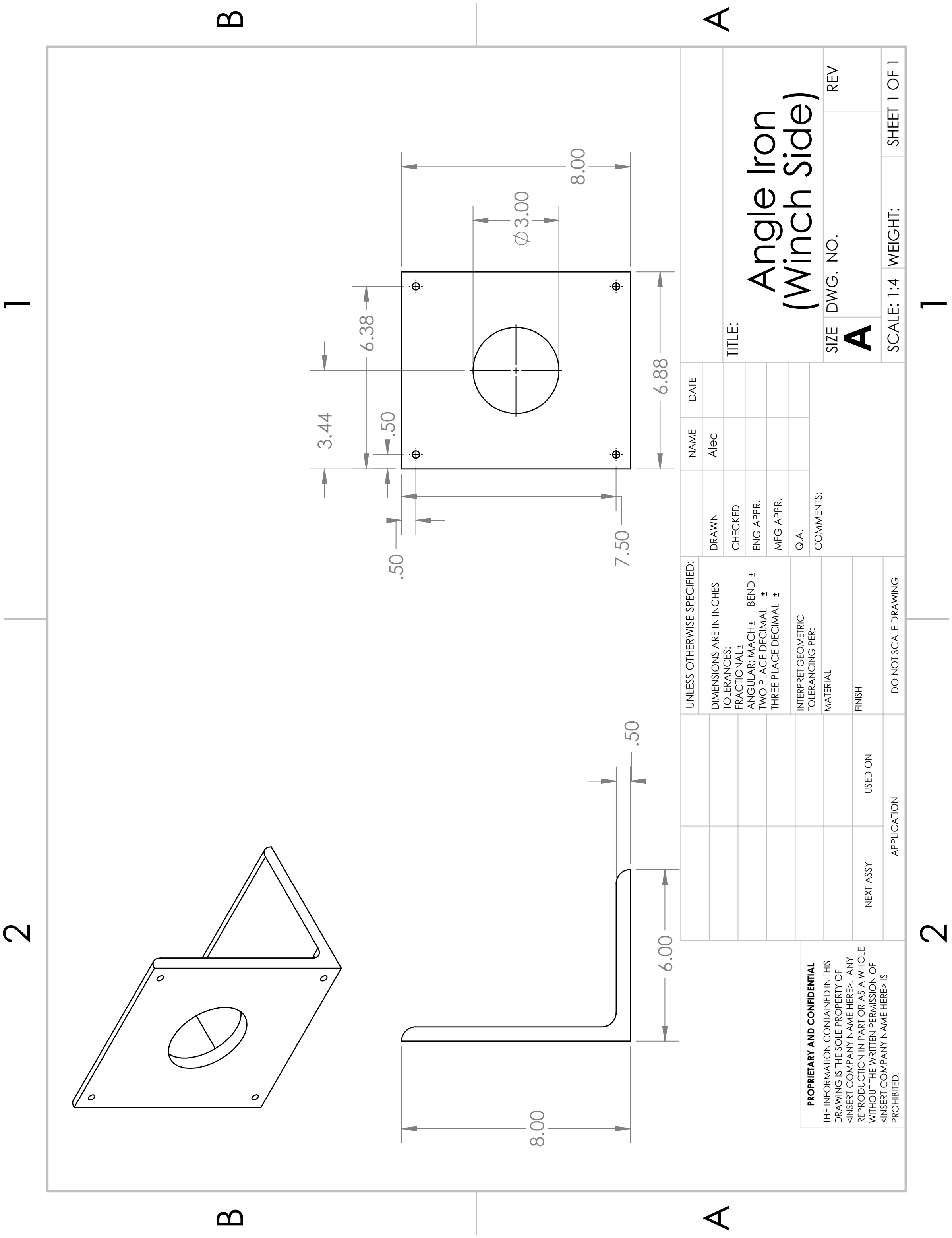

Figure 160: Steel Angle Iron Back Board (Winch Side)

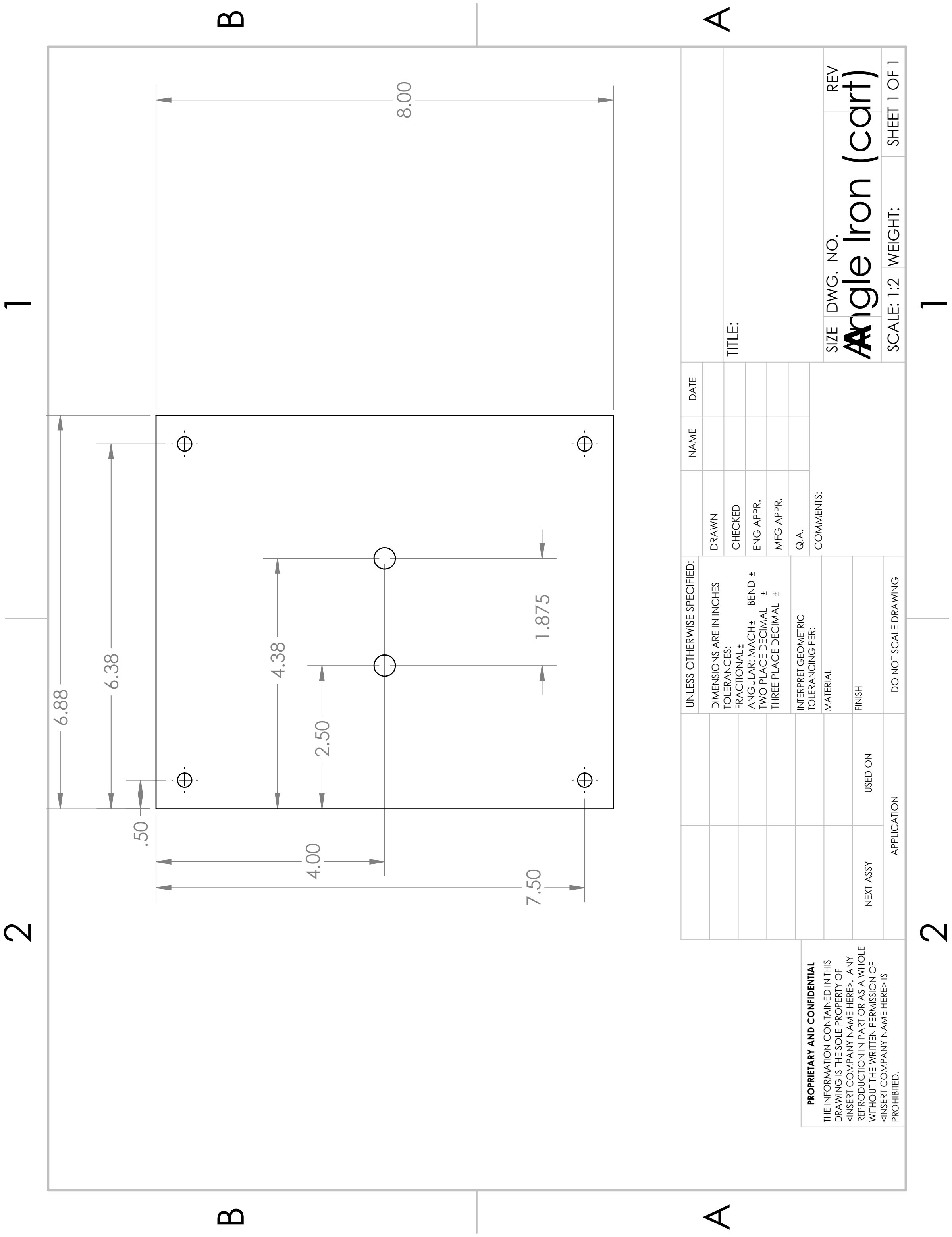

Figure 161: Steel Angle Iron Back Board (Cart Side)

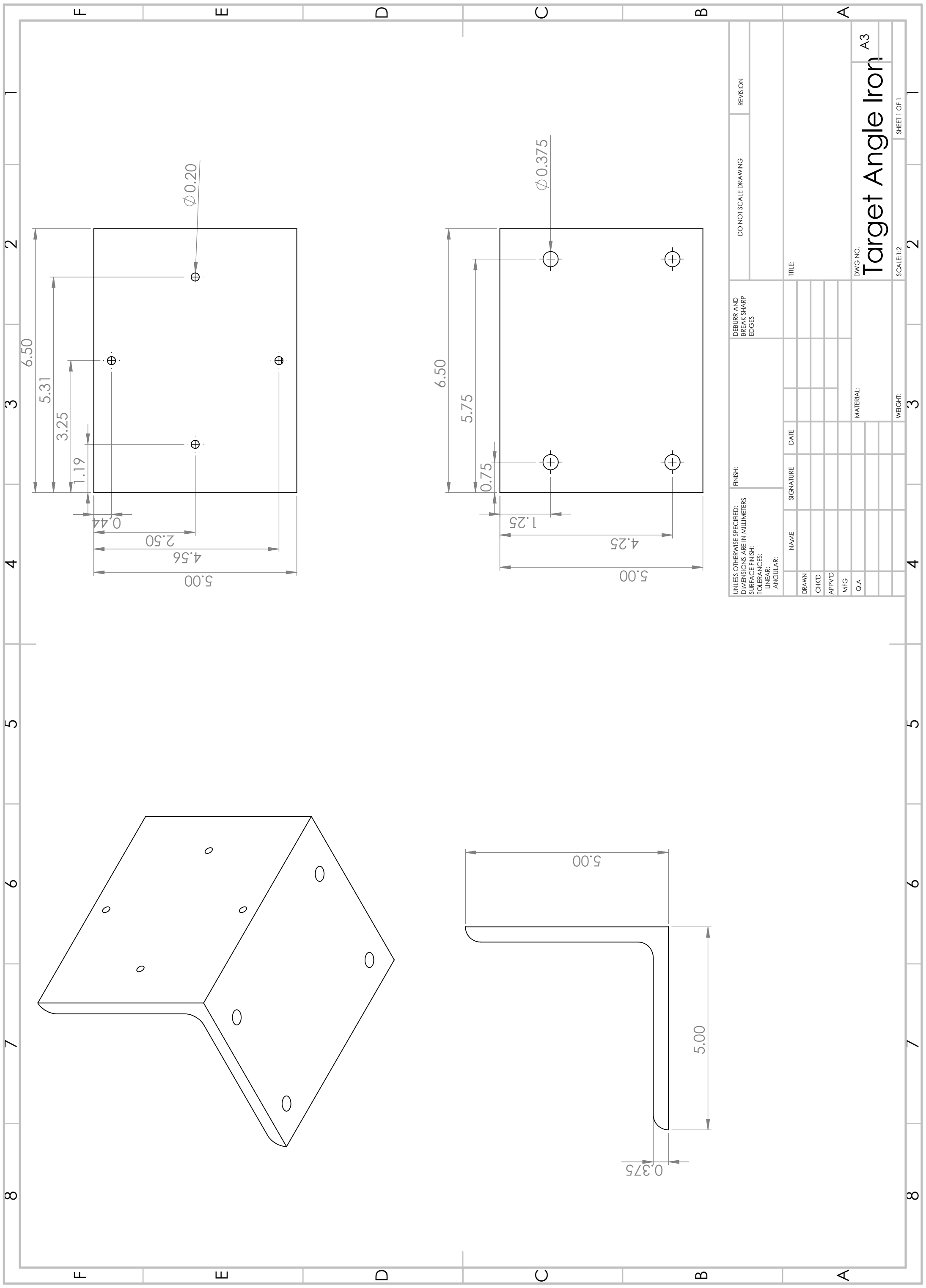

Figure 162: Steel Angle Iron for Target Mount

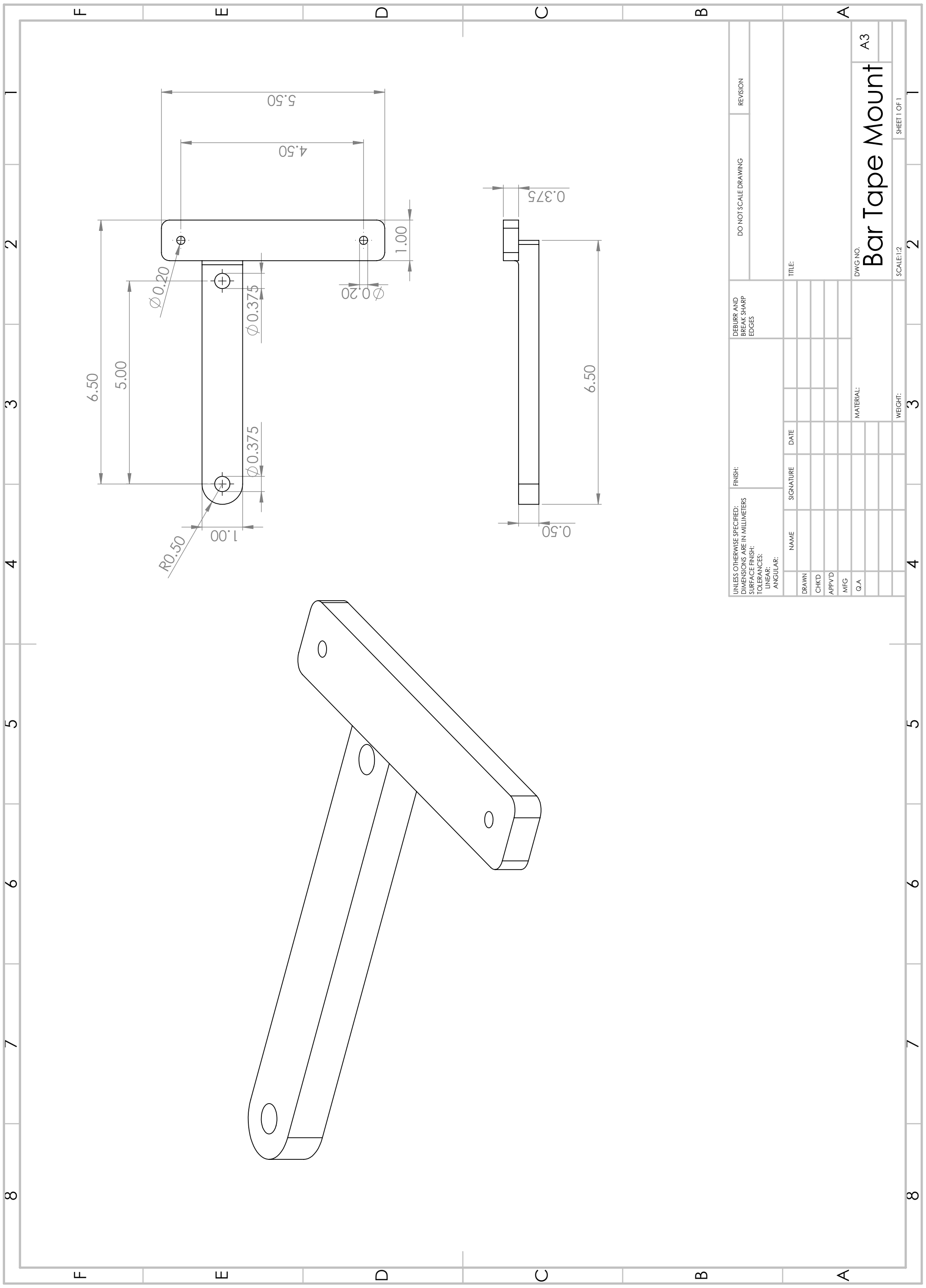

Figure 163: 3D Printed Mount for Bar Tape

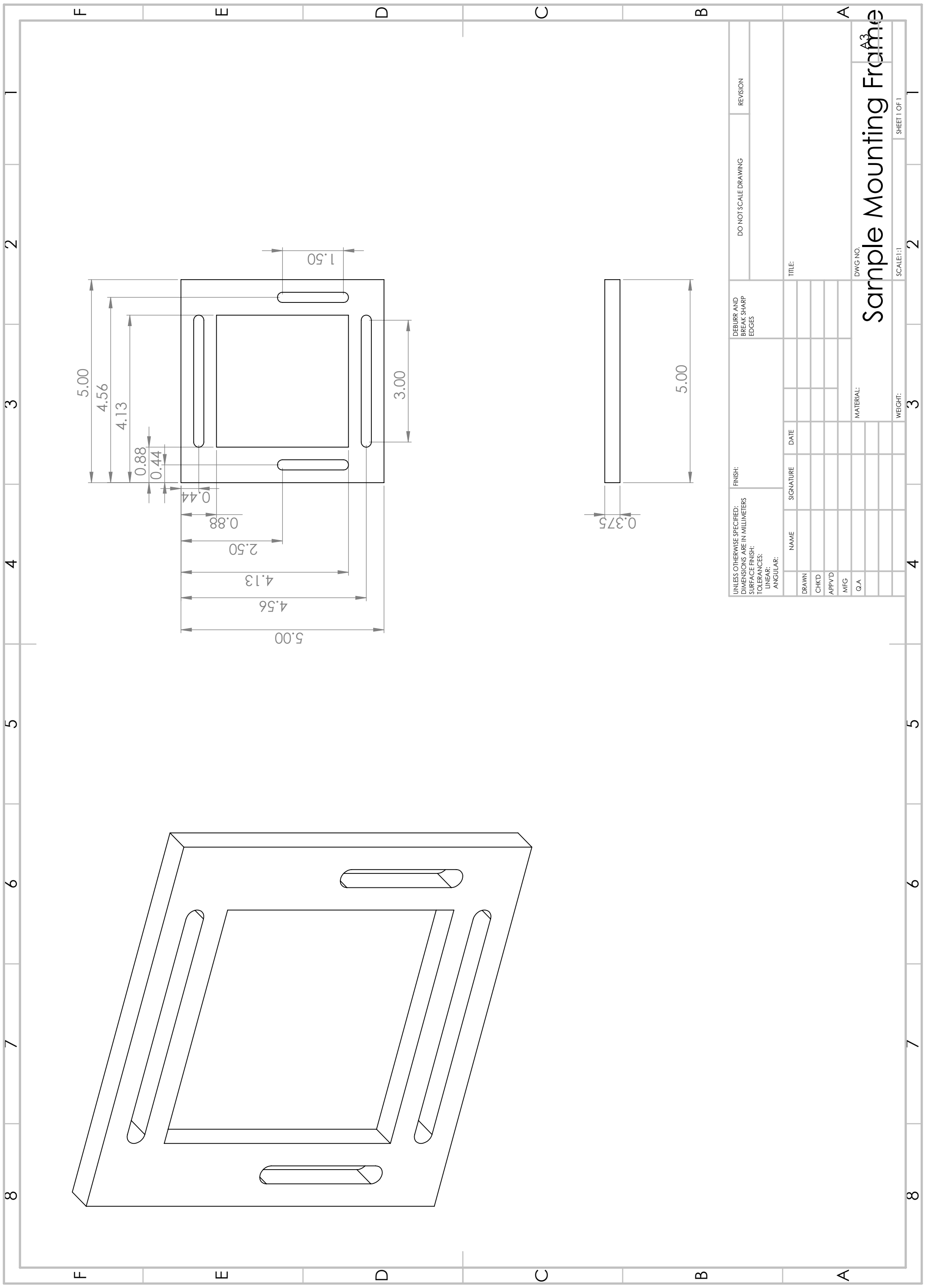

Figure 164: Polyurethane Sample Mount

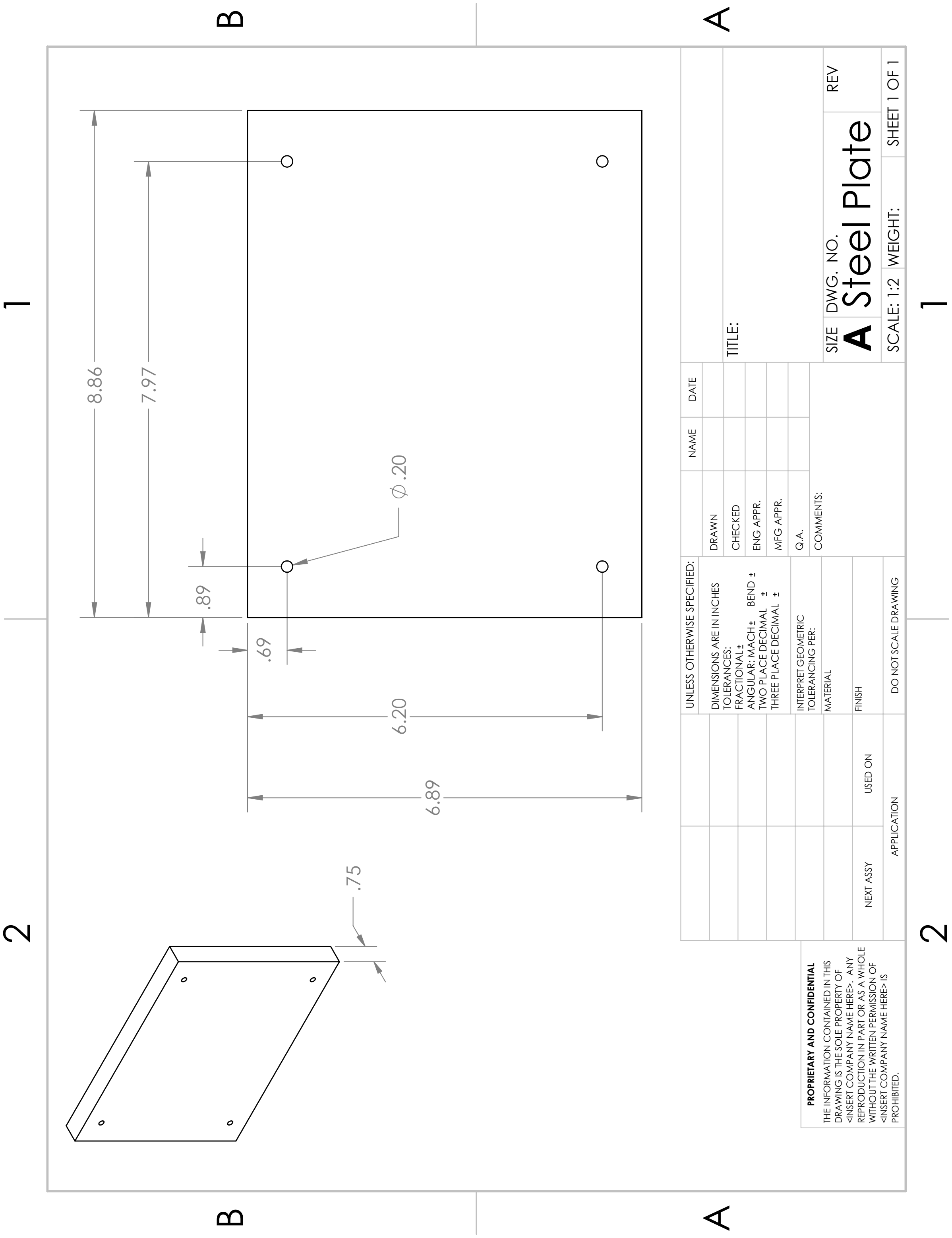

Figure 165: Steel Base Plate for Carts and Angle Iron

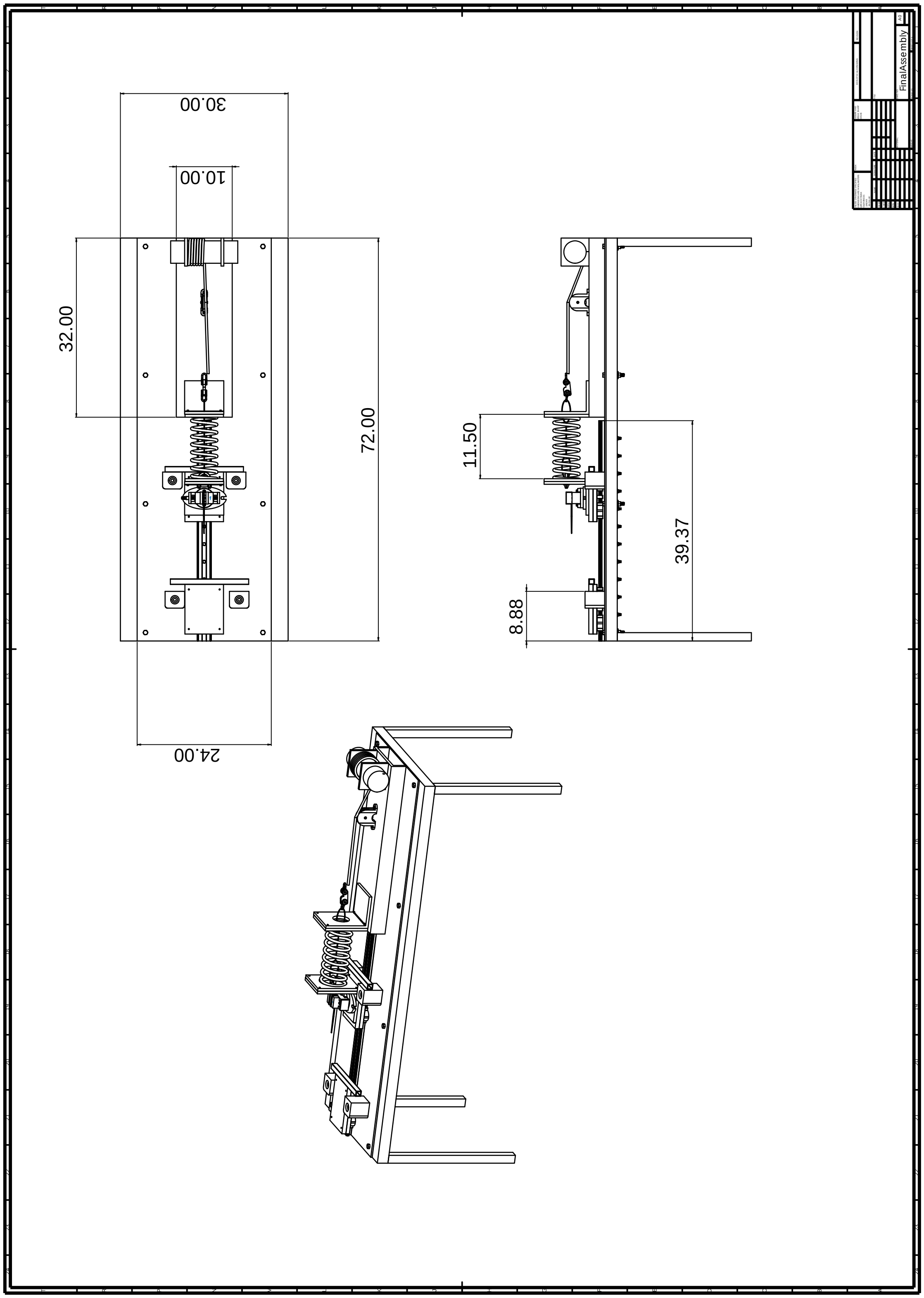

Figure 166: Final Assembly 1

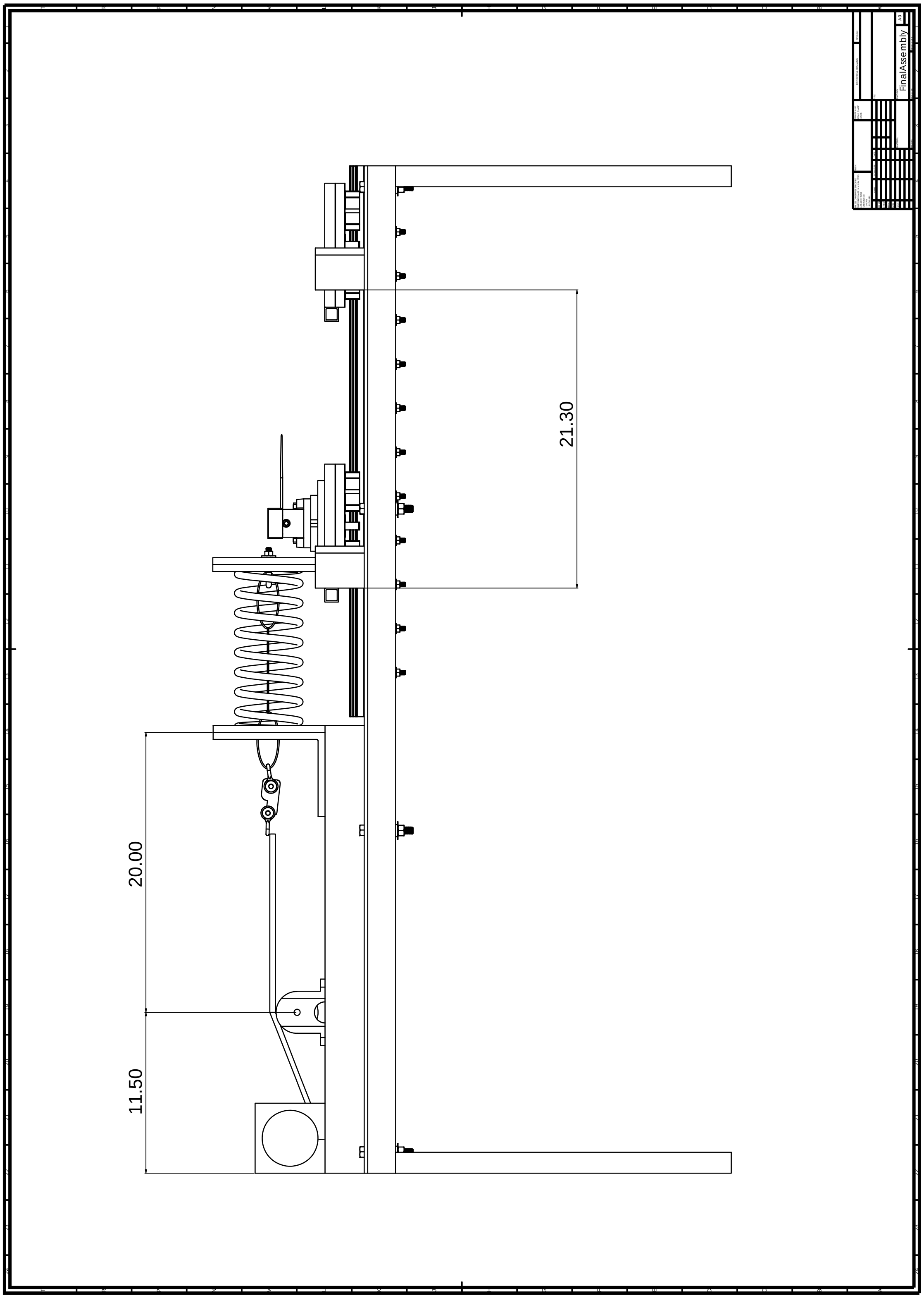

Figure 167: Final Assembly 2

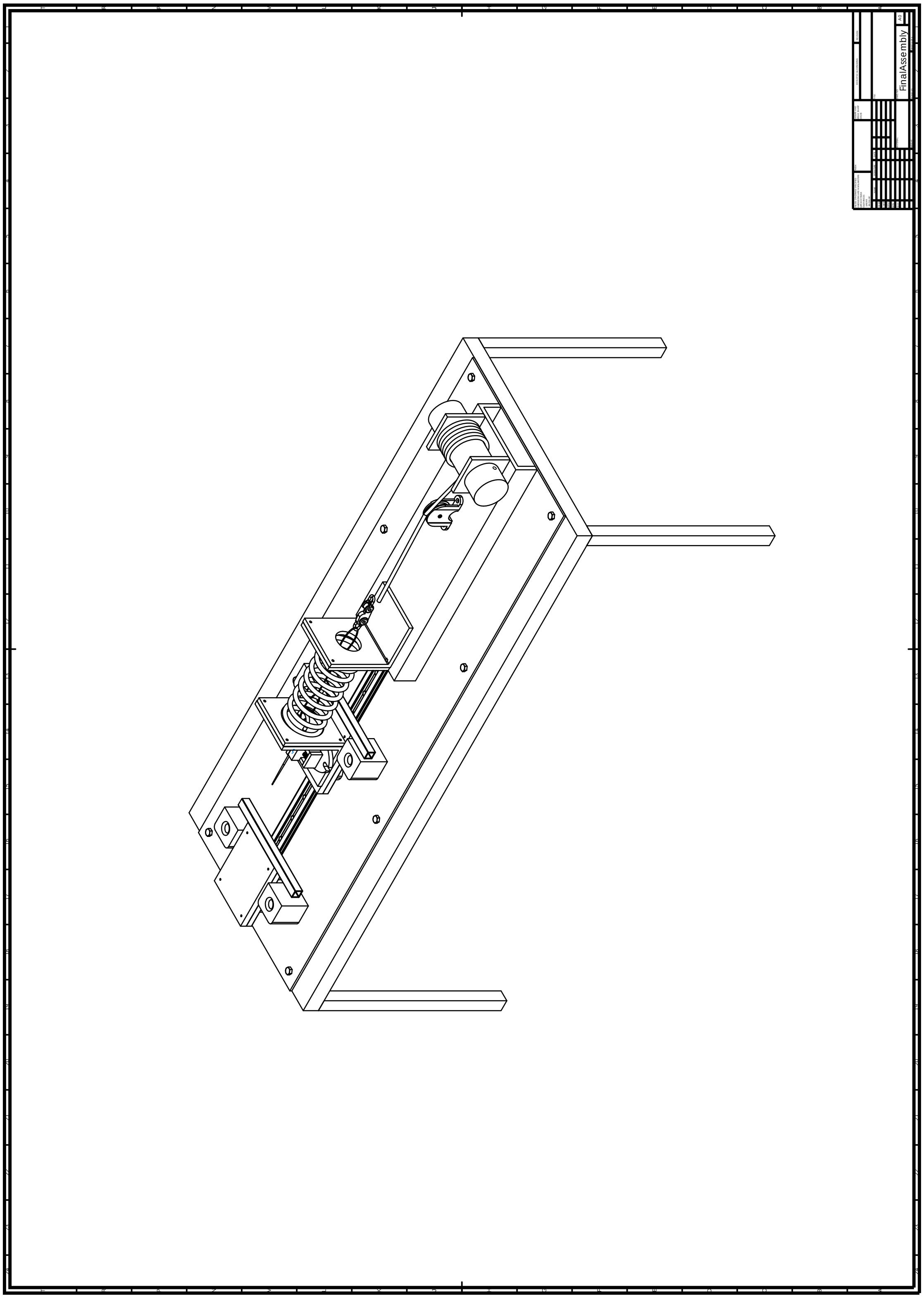

Figure 168: Final Assembly 3

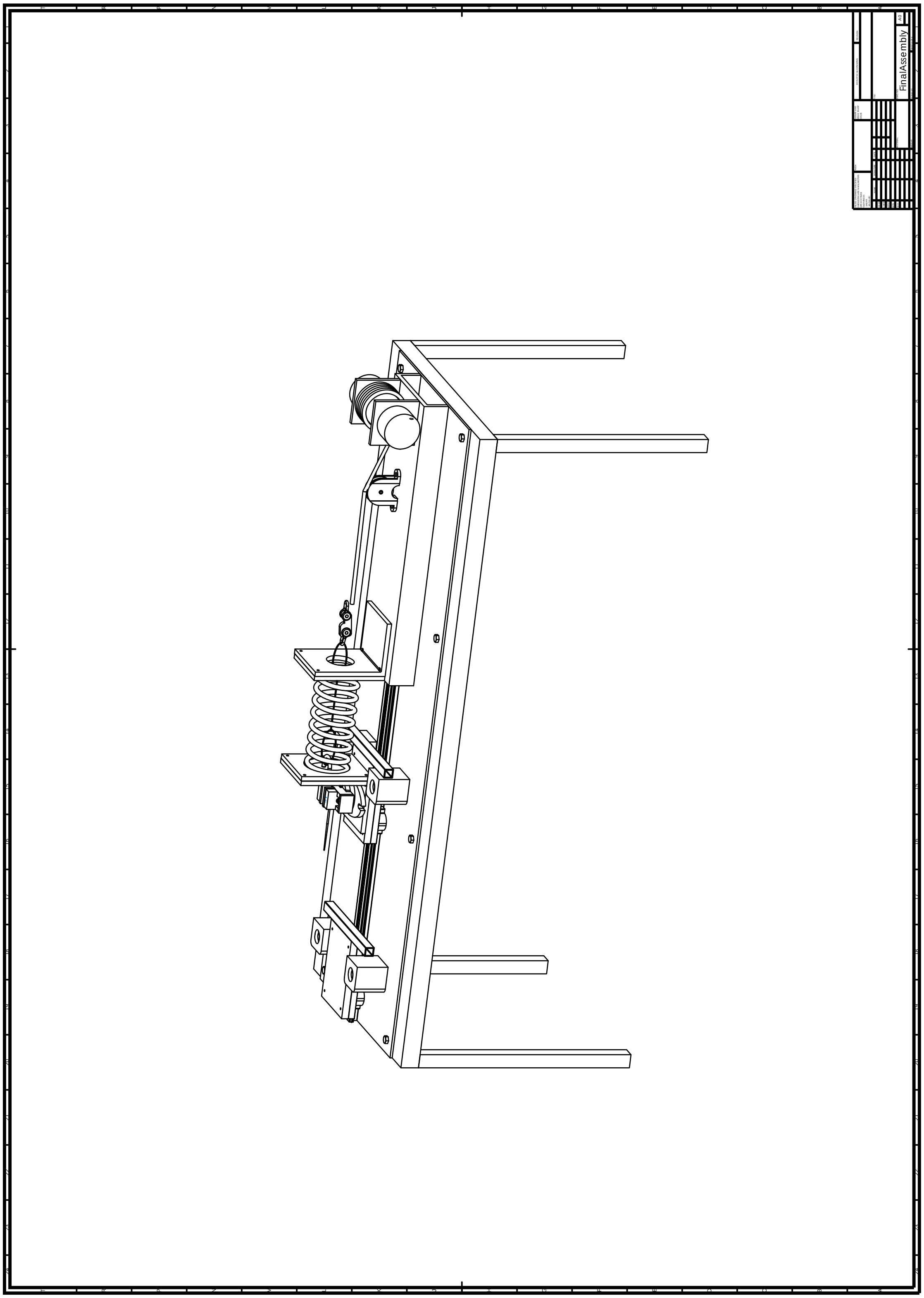

Figure 169: Final Assembly 4

20.6 Order Forms

MCISE Capstone Order Request Form

5

4103
Amazon

11/16/16

Phone Number:
1 (888) 280-4331

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	110080	Boa 110080 Precision Self Centering Vise with Swivel Base, 2 x 2	$137.81	$137.81
1	PGEON-BCSQ80010	WARN 80010 1000AC Utility Winch	$262.63	$262.63
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$400.44

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Amazon order form.xlsx

Figure 170: Amazon Order Form 1

MCISE Capstone Order Request Form

8

4103 01/31/18
Amazon

Phone Number:
1 (888) 280-4331

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	AV-16DRO001-R-6	6" Lathe Milling Machine DRO Digital Readout Scale with Remote	$33.19	$33.19
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$33.19

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Amazon 2 order form.xlsx

Figure 171: Amazon Order Form 2

MCISE Capstone Order Request Form

8

4103 02/07/18
Amazon

Phone Number:
1 (888) 280-4331

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	7779830-6PK	Rust-Oleum 7779830-6PK Stops Rust Spray Paint, 12-Ounce, Gloss Black, 6-Pack	$23.88	$23.88
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$23.88

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Amazon 3 order form.xlsx

Figure 172: Amazon Order Form 3

MCISE Capstone Order Request Form

4103
Global Industrial
11 Harbor Park Drive
Port Washington, NY 11050

11/07/16

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof Nassersharif

Project Name: Stabber/Slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	T9F183168BK	Maple Butcher Block Square Edge Workbench - Adjustable Height - Black	$299.95	$299.95
1	WGB183967	Vestil Truck & Semi-Trailer Bumper TB-20 - 3.5"W x 6"L x 3.5"H	$29.95	$29.95
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$329.90

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Global Industries Order form.xlsx

Figure 173: Global Industries Order Form 1

MCISE Capstone Order Request Form

4103 | **11/07/16**

Global Industrial
11 Harbor Park Drive
Port Washington, NY 11050

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof Nassersharif

Project Name: Stabber/Slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	WGB183967	Vestil Truck & Semi-Trailer Bumper TB-20 - 3.5"W x 6"L x 3.5"H	$29.95	$29.95
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$29.95

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Global Industries Order form 2.xlsx

Figure 174: Global Industries Order Form 2

MCISE Capstone Order Request Form

4103
McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

11/07/16

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	96485K436	Spring-Tempered Steel Compression Spring	$33.11	$33.11
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$33.11

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order form.xlsx

Figure 175: McMaster-Carr Order Form 1

MCISE Capstone Order Request Form

4103 **02/16/18**
McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	3201T65	Black-Oxide Steel U-Bolt with Mounting Plate, 3/8"-16 Thread Size, 1-1/2" ID	$1.94	$1.94
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$1.94

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order form 3.xlsx

Figure 176: McMaster-Carr Order Form 2

MCISE Capstone Order Request Form

4103
McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

02/22/18

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	**Part Number**	**Description**	**Unit $**	**Subtotal**
1	92865A109	Medium-Strength Grade 5 Steel Hex Head Screw Zinc-Plated, 5/16"-24 Thread Size, 1-1/4" Long	$9.39	$9.39
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$9.39

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order form 4.xlsx

Figure 177: McMaster-Carr Order Form 3

MCISE Capstone Order Request Form

4103 | 02/15/18

McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description		Unit $	Subtotal
1	3556T26	Galvanized Steel Shackle with Alloy Steel Safety Pin - for Lifting, 1/4" Thick	2	$10.53	$21.06
	3201T72	Black-Oxide Steel U-Bolt with Mounting Plate, 1/2"-13 Thread Size, 3" ID	1	$4.51	$4.51
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189			$0.00
		Shipping Cost			$0.00
				Total	$25.57

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order form 2.xlsx

Figure 178: McMaster-Carr Order Form 4

MCISE Capstone Order Request Form

4103 | 02/23/18

McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 | MPA #:

Project Sponsor: Amerisewn | Name of Sponsor: Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher | Title of Project: Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	92865A624	Medium-Strength Grade 5 Steel Hex Head Screw Zinc-Plated, 3/8"-16 Thread Size, 1" Long	$9.37	$9.37
1	92865A542	Medium-Strength Grade 5 Steel Hex Head Screw Zinc-Plated, 1/4"-20 Thread Size, 1" Long	$9.09	$9.09
1	3087T42	Mounted Pulley for Wire Rope-for Horizontal Pull 1-5/32" Wide, for 3/8" Diameter	$33.26	$33.26
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$51.72

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature | **Date**

McMaster-Carr order form 6.xlsx

Figure 179: McMaster-Carr Order Form 5

MCISE Capstone Order Request Form

4103
McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

03/02/18

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn — Name of Sponsor: Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher — Title of Project: Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	6527K364	3 feet Low-Carbon Steel Square Tube 0.120" Wall Thickness, 1" x 1" Outside Size	$14.48	$14.48
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$14.48

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order form 7.xlsx

Figure 180: McMaster-Carr Order Form 6

MCISE Capstone Order Request Form

4103 | 04/11/18

McMaster Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21

MPA #:

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description		Unit $	Subtotal
1	8975K52	6061 Aluminum 1" Thick x 1-1/2" Wide 1/2' length	1	$8.21	$8.21
	92865A645	Medium-Strength Grade 5 Steel Hex Head Screw Zinc-Plated, 3/8"-16 Thread Size, 5" Long, Fully Threaded	1	$8.60	$8.60
	91363A150	Big-Grip Knob with Screw Head Mount for 3/8" Hex Head Cap Screws	1	$15.87	$15.87
	90201A446	Extreme-Strength Grade 9 Steel Hex Head Screw 1/2"-13 Thread Size, 5" Long	2	$5.69	$11.38
	92865A628	Medium-Strength Grade 5 Steel Hex Head Screw Zinc-Plated, 3/8"-16 Thread Size, 1-1/2" Long, Fully Threaded	1	$6.66	$6.66
	9017K9	Low-Carbon Steel 90 Degree Angle 3/8" Wall Thickness, 5" x 5" Outside Size 1 foot length	1	29.29	$29.29
	91404A550	Zinc-Plated Iron Wing-Head Thumb Screw 1/4"-20 Thread Size, 2" Long	4	$4.48	$17.92
					$0.00
					$0.00
					$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189			$0.00
		Shipping Cost			$0.00
				Total	$97.93

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

McMaster-Carr order formm9.xlsx

Figure 181: McMaster-Carr Order Form 7

MCISE Capstone Order Request Form

9

4103 | 11/16/16
Metalsdepot.com

Phone Number:
1-859-745-2650

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 | **MPA #:**

Project Sponsor: Amerisewn | Name of Sponsor | Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher | Title of Project | Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	**Part Number**	**Description**	**Unit $**	**Subtotal**
1	A28612	14" length cut to size (8 x 6 x 1/2) A-36 Steel Angle: Under size, select cut to size and enter the dimentions 1' and 2"	$100.50	$100.50
2	P134	3/4 inch THICK A36 Steel Plate sut to size(6" 7/8 x 8" 3/4): under size, select cut to size and enter 6" 7/8 x 8" 3/4 and select a quantity of 2	$26.92	$53.84
2	P312T6	1/2" 6061-T651 Aluminum Plate custom cut to 8" x 6" 7/8: Under size, select cut to size and enter the dimentions 8: and 6" 7/8 and select a quantity of 2	$40.06	$80.12
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$234.46

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Metals Depot order form.xlsx

Figure 182: Metals Depot Order Form 1

MCISE Capstone Order Request Form

9

4103 | 02/23/18

Metalsdepot.com

Phone Number:
1-859-745-2650

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 | MPA #:

Project Sponsor: Amerisewn | Name of Sponsor: Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher | Title of Project: Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	C21025	10 x 25 lb (10 x 2.886 x .526) A36 Steel Channel" cut to size of 2'8"	$106.65	$106.65
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$106.65

Account #

Professor:
(your name or person your preparing the order for)

Date

Metals Depot order form 2.xlsx

Figure 183: Metals Depot Order Form 2

MCISE Capstone Order Request Form

4103 | **11/07/16**

PBC Linear
6402 ROCKTON ROAD
ROSCOE, IL 61073

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof Nassersharif

Project Name: Stabber/Slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	**Part Number**	**Description**	**Unit $**	**Subtotal**
1	IVTAABR-000	1 meter IVTAABR RAIL STD NO SLOT	$128.17	$128.17
2	IVTAABC-A23A0	IVTAAB CAR-TAP-SEAL ROL/ADJ WHL COV LUB	$271.63	$543.26
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$671.43

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

PBC Linear Order Form.xlsx

Figure 184: PBC Linear Order Form

MCISE Capstone Order Request Form

4

4103 **11/14/16**
The Lightship Group, LLC
606 Ten Rod Road
Wickford, RI 02852

Phone Number:
(401) 294-3341

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	TR3	sea catch quick release	$312.01	$312.01
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$312.01

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Sea Catch order form.xlsx

Figure 185: Sea Catch Order Form

SOUTH COUNTY STEEL, INC.

192 WAITES CORNER ROAD
WEST KINGSTON, RI 02892

Estimate

Date	Estimate #
1/31/2018	440

Name / Address
URI / Dept. of Engineering

Project

Description	Total
Supply for customer pick up: 1/4" x 24" x 72" A36	116.00
Tax exempt RI Sales Tax	0.00
Total	$116.00

Phone #	Fax #	E-mail
(401) 789-5570	(401) 789-1400	david@southcountysteel.com

Figure 186: South County Steel Order Form

MCISE Capstone Order Request Form

4103
US Cargo Control
202 Blue Creek Drive
Urbana, IA 52345

02/15/18

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof. Nassersharif

Project Name: Stabber/slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	**Part Number**	**Description**		**Unit $**	**Subtotal**
1	SW1-516-2	Wire Rope Sling - Single Leg - 5/16" x 2'	1	$17.61	$17.61
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
					$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189			$0.00
		Shipping Cost			$0.00
				Total	$17.61

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

US Cargo Control Order Form.xlsx

Figure 187: US Cargo Control Order Form

MCISE Capstone Order Request Form

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4103 **02/02/18**

Vernier
13979 SW Millikan Way
Beaverton, OR 97005

Fax Number:
XXX-XXX-XXXX

Capstone Design
URI Department of Mechanical, Industrial & Systems Engineering
51 Lower College Road, 231 Pastore, Kingston RI 02881

Team # 21 **MPA #:**

Project Sponsor: Amerisewn Name of Sponsor Desmark/Amerisewn and Prof Nassersharif

Project Name: Stabber/Slasher Title of Project Take A Stab At It

Forward this form electronically to: Professor Nassersharif
Email: bn@uri.edu

Quantity	Part Number	Description	Unit $	Subtotal
1	VPG-BTD	Photogate	$45.00	$45.00
1	GDX-ACC	Go Direct® Acceleration Sensor	$99.00	$99.00
1	TAPE	Bar Tape	$5.00	$5.00
1	LQ-MINI	LabQuest® Mini	$149.00	$149.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
				$0.00
		No Tax -- URI is Tax Exempt -- RI Tax Exempt 189		$0.00
		Shipping Cost		$0.00
			Total	$298.00

Account #

Professor:
(your name or person your preparing the order for)

PI Approval Signature **Date**

Vernier Order Form.xlsx

Figure 188: Vernier Order Form

Notes	Description	Dimensions	Source	Part Number	SolidWorks Model	Quantity	Price Per Unit	Total Cost	Submitted	Recieved
	Table	72"x30"	Global Industrial	T9F183168BK	Yes	1	$299.95	$299.95	11/16/2017	11/29/2017
	WARN 80010 1000AC Utility Winch	11 x 18.8 x 8 inches	Amazon	PGEON-BCSQ80010	Yes (Approximate)	1	$262.63	$262.63	11/30/2017	1/23/2018
	Spring-Tempered Steel Compression Spring	3.906" x 4.906" x 12'	McMaster Carr	96485K436	Yes	1	$33.11	$33.11	11/7/2017	11/14/2017
Called 11/9/2017	Integral V Linear Guide, Bolt-On Series - Single Width	0.5 - 1 m	PBC Linear	IVTAABR-000	Yes	1	$128.17	$128.17	11/9/2017	1/23/2018
called again 11/29/2017	Rubber stopper	3.5" x 3.5" x 6"	Global Industrial	WGB183967	Yes	2	$29.95	$59.90	11/16/2017	12/5/2017
	Right angle plates	8" x 6" x 1/2" cut to 14"	Metals dept	A28612		1	$100.50	$100.50	1/31/2018	2/7/18
	Cart Top Plates	6" 7/8 x 8" 3/4 x 3/4"	Metals dept	P134		2	$26.92	$53.84	1/31/18	2/7/2018
	Spring mount plates	8" x 6" 7/8 x 1/2"	Metals dept	P312T6		2	$40.06	$80.12	1/31/18	2/7/2018
7.5 lb	Boa 110080 Precision Self Centering Vise	2"	Amazon	B110080		1	$137.81	$137.81	11/16/17	11/29/2017
Rated 1302 lbs	Quick Release Shackle	.47" x 2.85'	Sea Catch	TR3	Yes	1	$312.01	$312.01	11/16/17	1/23/2018
	Cart	8.86"x6.89"	PBC Linear	IVTAABC-A23A0	Yes	2	$271.63	$543.26	11/9/2017	1/23/2018
	6" DRO Digital Readout for Lathes & Milling Machines		amazon	AV-16DRO001-R-6		1	$33.19	$33.19	1/31/2018	2/7/18
	Rust Preventing Paint		Amazon	7779830-6PK		1	$23.88	$23.88	2/7/18	2/9/18
	Table Steel Top		South County Steel	N/A	Yes	1	$116.00	$116.00	1/31/18	2/7/18
	Steel Square Channel	1" x 1" x 3'	McMaster Carr	6527K364		1	$14.48	$14.48	3/2/18	3/4/2018
	Pulley		McMaster Carr	3087T42		1	$33.26	$33.26	2/23/18	2/28/18
	C-Channel	10 x 2.886 x .526	Metals Depot	C21025	Yes	1	$106.65	$106.65	2/23/18	2/25/18
	U-Bolt		McMaster Carr	3201T65		1	$1.94	$1.94	2/16/18	2/21/18
	6061 Aluminum for cart stop	1.5"x1"x6"	McMaster Carr	8975K52		1	$8.21	$8.21	4/11/18	4/13/18
	Target Right Angle Plate	5x5	McMaster Carr	9017K9		1	$29.29	$29.29	4/11/18	4/13/18
	Cart Stop Knob		McMaster Carr	91363A150		1	$15.87	$15.87	4/11/18	4/13/18
	Shackles		McMaster Carr	3556T26		2	$10.53	$21.06	2/15/18	2/21/18
	Wrong U-Bolt		McMaster Carr	3201T72		1	$4.51	$4.51	2/15/18	2/21/18
	Lanyard		US Cargo	SW1-516-2		1	$17.61	$17.61	2/15/18	2/21/18
	Total							**$2,437.25**		
	Hardware:									
	3/8"-16 Thread Size, 1" Long		McMaster Carr	92865A624		1	$9.37	$9.37	2/23/18	2/28/18
	1/4"-20 Thread Size, 1" Long		McMaster Carr	92865A542		1	$9.09	$9.09	2/23/18	2/28/18
	5/16"-24 Thread Size, 1-1/4" Long		McMaster Carr	92865A109		1	$9.39	$9.39	2/22/18	2/28/18
	3/8"-16 Thread Size, 5" Long, Fully Threaded		McMaster Carr	92865A645		1	$8.21	$8.21	4/11/18	4/13/18
	Extreme-Strength 1/2"-13 Thread Size, 5" Long		McMaster Carr	90201A446		2	$5.69	$11.38	4/11/18	4/13/18
	Wing-Head Thumb Screw 1/4"-20 Thread Size, 2" Long		McMaster Carr	91404A550		4	$4.48	$17.92	4/11/18	4/13/18
	3/8"-16 Thread Size, 1-1/2" Long, Fully Threaded		McMaster Carr	92865A628		1	$6.66	$6.66	4/11/18	4/13/18
	Eye hook nuts							$0.00		
	Stopper nuts							$0.00		
	Total							**$72.02**		

Figure 189: Bill Of Materials