Man-sized Mechanical Resetting Steel Silhouette Target System

A Baccalaureate Thesis submitted to the
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Bachelor of Science

in Mechanical Engineering Technology

by

Nicholas Ryan Walriven

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Thesis Advisor:
Professor Ahmed Elgafy, Ph.D.

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ABSTRACT

The beginning of this project was the need to design a better means of training shooters for tactical situations. It is best to train someone in as close as possible to real world situations as possible and make it convenient and cost efficient. The Problem is that no product exists that combines a AR 500 practical shooting silhouette in man-sized configuration (a suitable head and chest sized target placed at average man height) with a quick and efficient user controlled resetting mechanism. The approach to this problem started with consulting shooters (civilian and military personnel) to obtain information on what they expected out of the product in practical terms of money, resetting time, battery life and ammunition limits. Then a basic hand drawing was made of the mechanism that I had decided on with a decision matrix ultimately being a linkage. Then base calculations to determine basic properties (tubing wall thickness and material, pin diameter, bolt and pin diameters, bearing series). The solid works modeling was next to determine final dimensions that would operate effectively and determine motor torque and ensure that the forces input would have suitable safety factors with the design. The solid works design drawing was used to manufacture the design with the instructions described below in detail. Once the manufacturing was completed the finished product was tested for effectiveness with standard ammunition and firearms to ensure true functionality and the electrical components were tested to determine true electrical draws functionality. The results of this testing were somewhat successful with the pistol testing being entirely successful at the customers desired range. An intermediate rifle cartridge testing fell somewhat short at not meeting the customer's requirement of 100yrds with only being effective at 50yards with an AR – 15. The high-power rifle test was successful but not entirely conclusive the 30-06 rifle it passed at 100 yards but it was not possible for 300-yard testing due to range limitations. The conclusion to this endeavor is that the result is a highly functional prototype but one that needs further refinement to be an entirely suitable product. These improvements are but not limited to adding remote control capabilities and altering the armature pivot angle to allow for it to be easier to knock over when shot.

PROBLEM DEFINITION AND RESEARCH:

PROBLEM STATEMENT:

The systems that exist that are motor driven are only able to move a piece of metal that stands roughly waist high and doesn't give a very realistic shooting experience especially in law enforcement or government training situations where good training is a life and death matter. The downfall of the spring-loaded systems is they have a limited weight capacity only having the ability to right a 2/3 scale silhouette and often directly hinged at the ground making it very short once again not an accurate depiction of a person for training the fact that it rights itself immediately makes it impractical for competitive shooting where judgement calls may need to be made and the target would need to stay down if it was knocked down.

BACKGROUND:

Competitive and defensive shooting training is a major market around the world but specifically very popular in the United States. Defensive shooting training is made up of civilians, law enforcement and government agents. To train effectively all shooters often use steel targets that are sized or shaped like a man’s body. Either shooting the target multiple times with a pistol or with a rifle at close range. Some targets are made of steel (AR500 steel is extremely hard and durable and capable of being shot many times) but are small standing only 3ft tall and only mildly resembling a person but can be righted with an electrically driven cam system, a stationary target that just confirms a hit or at largest a 3/4 sized steel silhouette of a man’s upper body that is suspended on a spring-loaded arm that pushes the target back up when it is knocked down by the bullet. A resetting target is always preferred because it doesn't require extra manpower to go out after each attempt and manually reset the target this is important for the individual or match level where either the consumer would have to reset their own target or one of a limited staff would have to be dedicated to going forward of the firing line and resetting it manually.

RESEARCH, TECHNOLOGY, AND EXISTING PRODUCTS

The research was limited to only investigating other resetting steel target systems as to compare this system to a digital or electronic paper target system is not applicable. Most of the research involved looking at the websites of manufacturers of steel target systems on the internet to find specifications, prices and details that correlate their work to my own ideas. The research yielded that there is no product like what I'm building currently on the market to the size specifications of what I'm proposing as I thought. There are similar products that are very advanced though such as the current state of the art being a mechanically resetting target system by Texas based La rue tactical (1). A custom machine shop and manufacturing establishment in many areas of the firearms industry. Their system is a battery powered unit with a motor driven cam and shaft arrangement because the target is only a few feet tall and sits and pivots on the base the cam can right the target after it is knocked over. The system also uses a radio transmitter for sending the reset input from the shooter. This system while advanced is very expensive costing nearly 3000$ and it doesn't set the target at an appropriate height for training situations for inside buildings, behind cover or otherwise.

CUSTOMER NEEDS, SURVEY, WEIGHTED IMPORTANCE

To gather more information on what features my product needs to have I devised a questionnaire for sport shooters, law enforcement and military personnel which was somewhat successful in giving me accurate feedback. This showed me some of what I already knew the product needs to be able to be used with a variety of military standard calibers, needs to be able to be used at close to medium ranges (minimizing range and caliber requirements makes the system more versatile), needs to be affordable (available for even average people to afford) but still have a long service life(so it can be used many times without breaking or needing replaced), needs to be easily fixed and worked on with common tools (the questionnaire also asked for information on the user's technical skill which further corroborates the importance of this feature as most people have medium to low skills in this area), it needs to have a long battery life and fast reset time (so more time can be spent during range sessions shooting and training). What the questionnaire most importantly showed me was the level the customer cares about each feature and what value they put on its function. Giving adequate attention to the various features will ensure that the customer is satisfied with it as well as more likely to buy it against other competitor's products. From the list below these results indicate that the customers value affordability and longevity over all else with little care towards weight and reset time. All factors must be given reasonable design consideration regardless of their customer weight to ensure a functional and reliable design.

The weighted Results from survey

Unit Cost: 0.26

Unit Weight: 0.06

Versatility of calibers: 0.1

Target Reset time: 0.08

Battery life: 0.17

System life: 0.18

Serviceability: 0.15

PRODUCT/ENGINEERING FEATURES

The product will use a car battery powered DC electric gear motor to drive a mechanical linkage that will flip over a full sized (this will later be amended to a 2/3 scale during the design phase for practical shooting and mechanical reasons) AR-500 steel silhouette target 1/4in thick (3/8 thick will be used in the final design as it's required for rifle rounds at close range) when it is knocked over by a shooters bullet. A push button will act as the switch to turn the motor on and off for resetting the target. Structural steel tubing will form the supports for the target and rotating armature, horizontal base and for the vertical supports for the motor and linkage.

PRODUCT OBJECTIVES

To meet customer needs the product will aim to be able to be used with a pistol cartridge as small as 9x19mm at a range of up to 25 yards and a rifle of up to .308/7.62 NATO caliber at a range of 300 yards. The steel target will be full size and will have a reset time of no more than 15 seconds from the start to finish. The battery should be able to power the device for at least 4 hours but an entire day of 8 hours is optimal. The unit should be easily serviced with standard hand tools (metric/English wrenches and other basic hand tools by a person of low to medium mechanical inclination). The unit should expect to able to be shot 5000 times per year and at least 500 times in each range session. The unit needs to be priced with an MSRP between 1200$-1500 or competitively priced with other such products on the market.

Design

DESIGN ALTERNATIVES AND SELECTION:

Background/Assumptions:
All design options will utilize the same style of steel frame with equal target weight and height with similar sized and orientated steel armatures. ONLY the mechanical method used to reset the target will differ

Design Option 1:
Pneumatic Actuator method

Requires:
Regulators
Actuator
DC electric compressor and Battery
Storage tank
Air lines/fittings
Estimated cost:
500-600$

Design option 2:
Electric Linear Actuator
Requires:
DC electric Linear actuator and Battery
Estimated cost:
250$

Design option 3:
Motor Driven Linkage

Requires:
DC electric motor and Battery
Bearings
Steel bar and Steel rectangular tube
Hardware (nuts, bolts, washers etc.)
Motor coupler
Estimated cost:
500-600$

Decision matrix table:

Criteria	Weight (%)	Pneumatics rating	Pneumatics wt. Rating	Linear actuator rating	Linear actuator wt. Rating	Linkage rating	Linkage wt. Rating
		Alternative Concepts / Embodiments					
Cost	25	2	.50	4	1	2	.50
Serviceability	25	0	0	2	.5	3	.75
Reliability in adverse conditions	25	1	.25	2	.5	3	.75
Reset time	25	4	1.00	0	0	3	.75
	100	na	1.75	na	2	na	2.75

Table 1

Unsatisfactory	0
Just tolerable	1
Adequate	2
Good	3
Very Good	4

CONCEPT DRAWINGS/HAND CALCULATIONS:

(see appendices for all technical drawings of project)

Hand drawings:

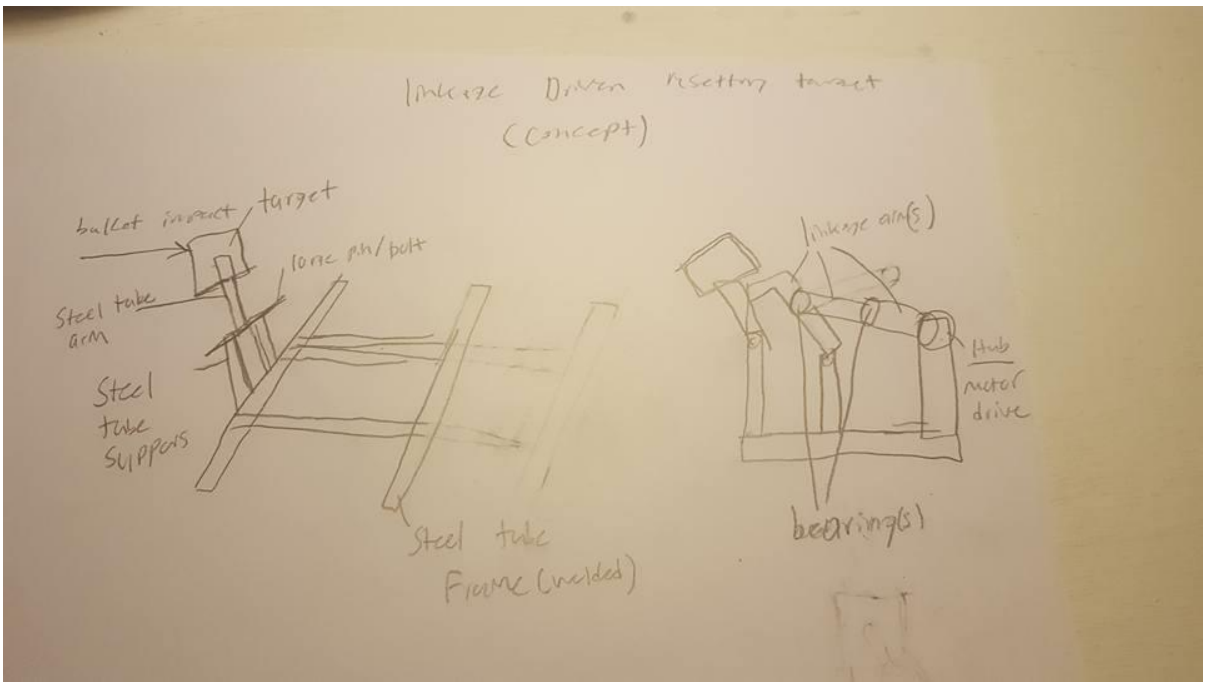

Figure 1

Hand calculations:

Design properties
A36 = 36ksi yield
1018 steel = 56ksi yield
A513 steel = 72ksi yield
Grade 5 bolt = 92ksi yield
200 series bearing rated for 500hrs at 2200lbf
55AH deep cycle battery
280in-lb motor input
9.4A dc electric motor
Stress concentration factor for pin holes 1.15x
Safety factor for overall design 12x
Service factor for battery = 1.25x
5-degree incline (recommended by manufacturer to deflect spalling away from shooter)

All bolts Grade 5
All bearings .625in bore 200 series
All support tubes .083in wall – A513 steel
Rocker stop .125in wall – A513 steel
Bearing pins .625in dia. – A36 steel
Lynch pins - .75in dia. – 4140 steel

Max bullet impact force
(115*1200)/(7000*32.2*.01)*cos(5) = 61.22
(55*2200)/(7000*32.2*.01) *cos(5) = 55lbf
(125*2200)/(7000*32.2*.01)*cos(5) = 149.4lbf = 150lbf (greatest lbf will be used for design)

Force on armature support points
((150/6)/(.625*.083))*12 = 5783 < 72ksi (acceptable)

Force on linchpin for armature
((150/6)/(.375^2*pi))*12 = 680psi < 52ksi (acceptable)

Motor input torque
(estimated to be 280in-lb from a .625in diameter shaft this was confirmed post design with solid works motion analysis showing 280in-lb gives service factor for motor of 1.4x)

Motor input force
(280/(.625/2)) = 896lbf = 900lbf

Stress on bearing pin
(900/ (.625*1)) *12 = 17,280 < 36ksi (acceptable)

Stress on bearing bolts
((900/3)/(.25*.083*2))=86,746psi < 92ksi (acceptable)

Stress on linkage linchpin
(((900/6)/(.375^2*pi)) *12) = 40,76psi < 56ksi (acceptable)

Stress on linkage arm from motor
((900/3)/(.083*.625*2))*12*1.15 = 39,903psi < 72ksi (acceptable)

Bearing life
((2200/900) ^3) *500 = 7200hrs
7200hrs/4 = 1819 range trips
1819/365 = 5 years of life being used 4hrs per day (acceptable)

Battery draw
9.4Amp motor draw at 12v
9.4*1.25 = 11.75Amps
4hrs*11.75A = 47AH < 55AH (acceptable)

Target selection
Industry standard for rifle targets AR500 steel minimum 3/8in thick
Full size silhouette is a standardize dimension as well

Wire
6GA is standard automotive wiring for car batteries (12v high amps)

Switch (35amp 110v)
110v > 12v battery and motor draw
35amp > 9.4-amp motor draw

Motor controller (20amp 12v)
12v controller = 12v battery and motor
20amp controller > 9.4-amp motor draw

LOADING CONDITIONS:

Overall conditions:
Gravity is on at (32ft/sec^2) in the down direction
Comparable Materials were set for each component:

Bullet impact force (see calculations in above section for validation)

150-lbf force was applied in the center of the target mounted on armature to simulate impact of the most power full cartridge for testing
(see below image)

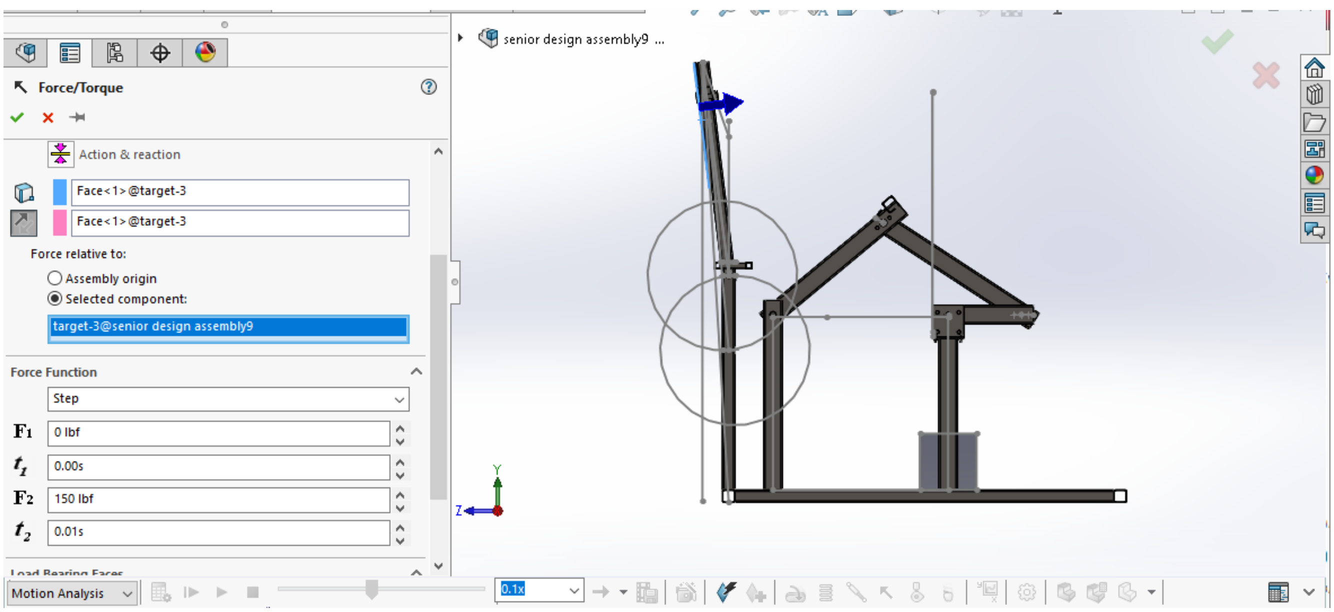

Figure 2

Linkage forces (motion analysis was used to find need inputs)

Motion analysis was used to find the needed motor input torque to move linkage and successfully reset the target (200in-lbs minimum)

280in-lb (200x1.4 service factor) torque applied about the inside of the of the shaft hub to simulate driving torque of motor
(see below image)

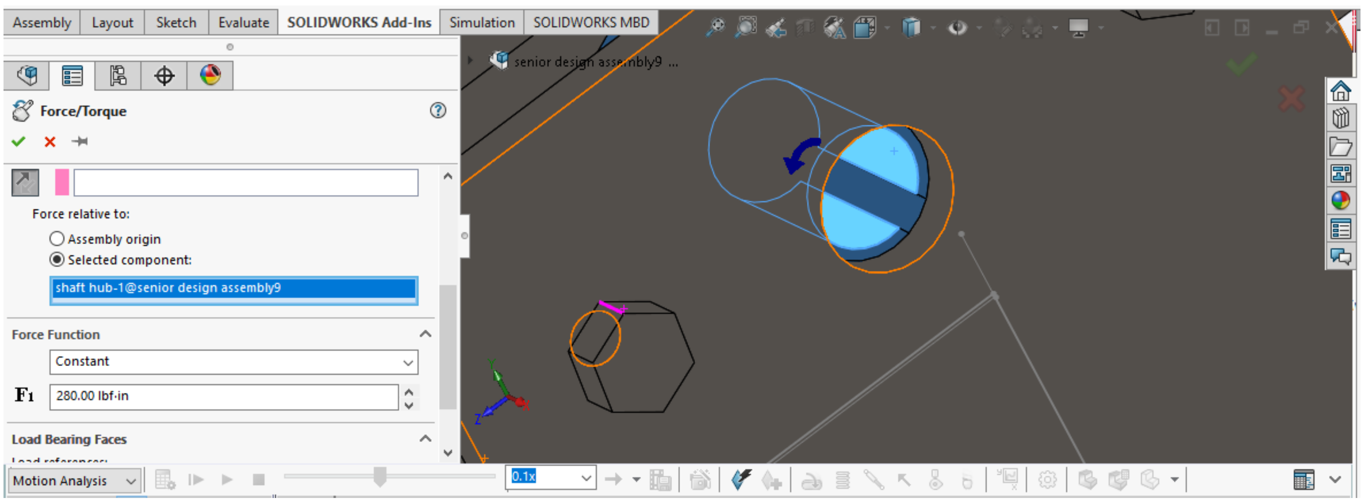

Figure 3

Design analysis:

Bullet impact analysis

Stresses

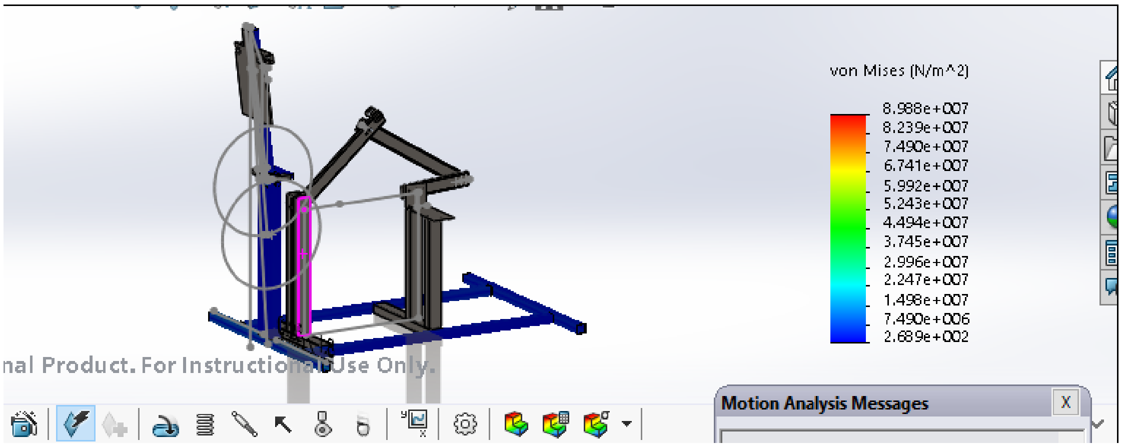

Figure 4

(The max stress is present at the pin hole of the swinging armature its structural problem is described below see factors of safety of concern for further details)

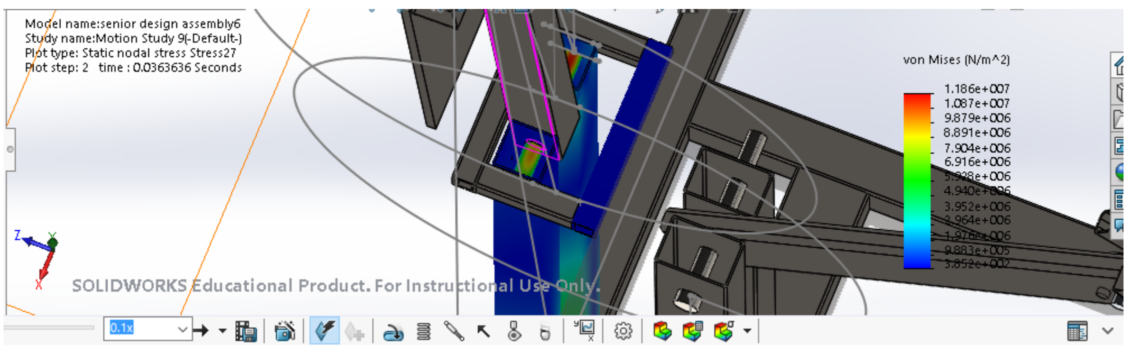

Figure 5

(The max stress is present at the armature pin the stress exerted converts to 1700 psi the pin is made of 1018 steel with a yield of 56ksi this more than accounts for dynamic safety factor of 12x)

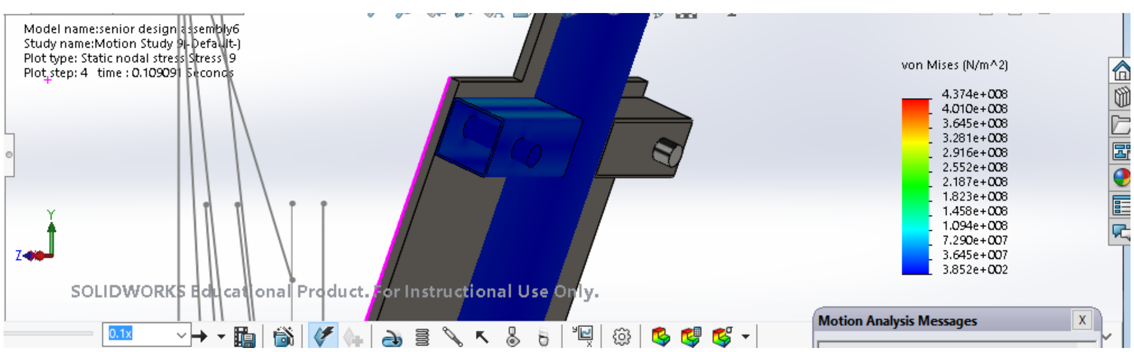

Figure 6

(The armature supports are only responsible for a static load the force exerted on them by supporting the targets weight this is roughly 21ksi they are made of A513 steel with a yield of 72ksi this accounts for a greater than 3x safety factor)

Linkage force analysis

Stresses

Linkage pins

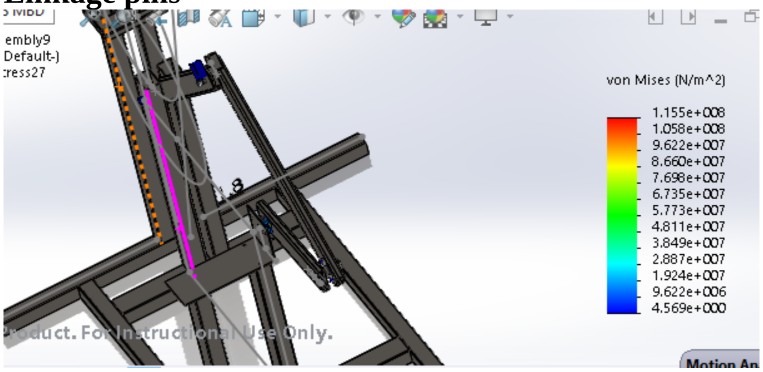

Figure 7

(Stress appear to be low on the linkage pin and connection points at around 1300 psi this gives all the various materials at least a safety factor of 12x given the pins are the weakest mad of A36 with a yield point of 36ksi)

Linkage arms

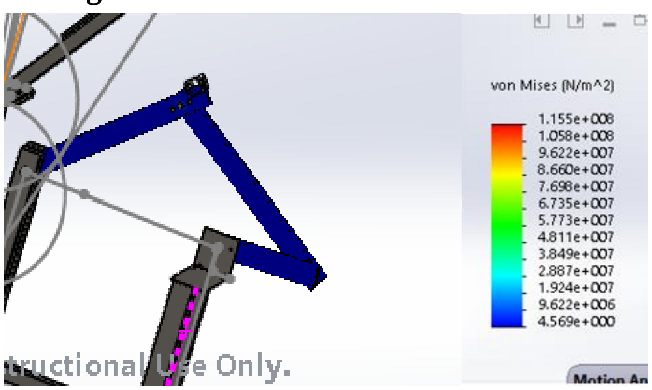

Figure 8

(Given similar scales the linkage arms are under minimal stresses and deflection is being only a few millimeters' maximum)

Factors of safety of concern:

Target armature (from bullet impact):

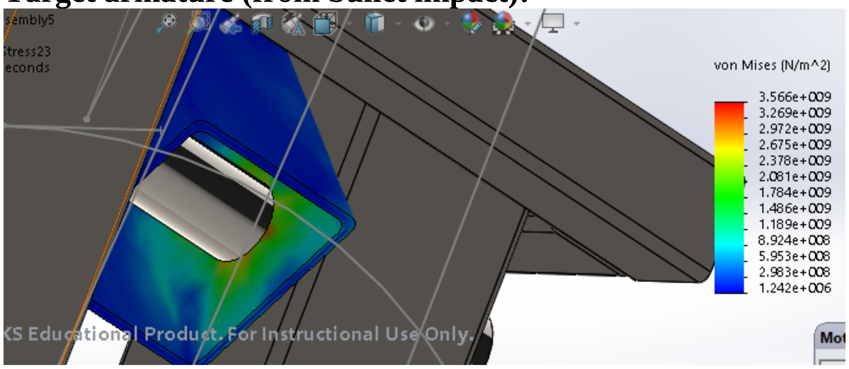

Figure 9

(There seemed to be a constant test problem with the motion analysis software that made the stress about the pin hole in the swinging target armature it is a concern but it is most likely a malfunction of the software given the stress indicates over 1 million psi from an applied 150 lbf)

Shaft hub:

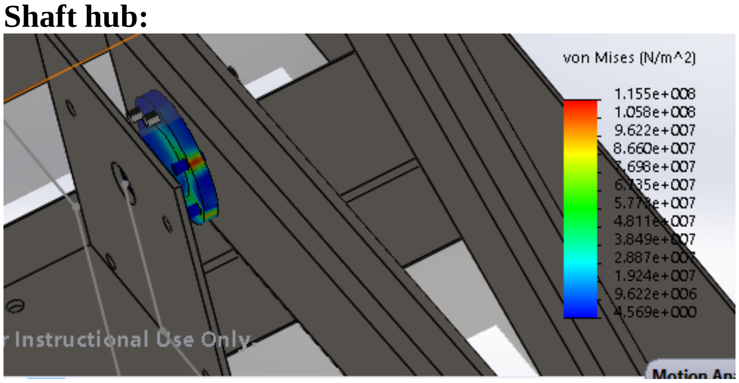

Figure 10

(This is an intentional lack of safety in the design. The drive hub is made to break at a lower force than the surround components as to help protect other critical areas of the linkage system and to give clear signs to operators and maintenance personnel that the system is/was being over stressed 6061 aluminum yields at 45ksi stresses are around 16ksi giving a safety factor of 2.8x)

Target Armature (from linkage pushing on it)

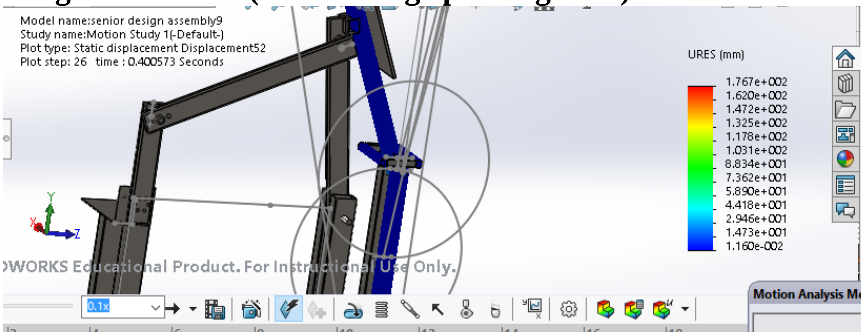

Figure 11

(The simulation with the bullet impact tried to show that there would be extreme deflection on the bottom of the armature when pressed on by the linkage arm. Deflection is in a similar area as the high stresses in the images above that seem unrealistic but are noted)

COMPONENT SELECTION:

(all components have corresponding calculations above to validate selection)

Mechanical components:

Structural Tube:

All Tube is made of A513 steel
2x2 .083 wall square tube
2x3 .083 wall rectangular tube
1x1 .125in wall square tube
1x3 .083 wall rectangular tube

Linkage pins:

All round bar is made of A36 steel
.625in diameter round bar stock

Linchpins:

7in long (6.5in of usable length) linchpins are used
Lynchpins are made of 4140 steel

Shooting target:

Steel shooting target is made of A500 steel
Steel target is 3/8 thick full size silhouette

Mounting hardware:

All hardware is Grade 5
3/16in bolts used
1/4in bolts used (various lengths)
3/4in bolts used

Motor:

12v 280in-lb DC electric gear motor

Mounting plate:
All plate is made of A36 steel
¼in thick 1ft x 2ft plate is used

Motor coupler:
Motor coupler is made of 6061 aluminum
Motor coupler for 5/8in dia keyed shaft with mounting flange (6x 3/16 in bolts required)

Bearings/Bearing housing:
200 series steel bearing used
Sheet steel bearing housing used

Shaft collar
0.625in bore steel shaft collar (with socket head set screw)

Electrical components:

Switch:
35amp 110v
Push button switch with E-Stop function

Wire:
6GA electrical wire (standard automotive battery wire)
15-20ft (for initial test purposes)

Battery:
Deep cycle sealed lead acid battery
12v 55AH

Motor controller:
20amp 12v DC
Variable voltage (to control output speed)
(SEE APPENDIX D FOR COMPONENT PICTURES)

Bill of Material:

Required tools/equipment

Hand tools
hand file
English box end wrench set for (3/16in, 1/4in, 3/4in)
English hex key set
Metal scribe
Steel ruler (5ft long preferably)
Wire cutters/strippers (able to accommodate 6GA wire)
3/16in drill bit/end mill (TiN or carbide coated preferably)
1/4in drill bit/end mill (TiN or carbide coated preferably)
5/8in drill bit/end mill (TiN or carbide coated preferably)
3/4in drill bit/end mill (TiN or carbide coated preferably)
Chip brush/chipping hammer
MIG wire (any suitable for welding carbon steel to carbon steel)

Machine tools
Vertical Mill/Drill press (variable speed with 1in chuck)
Grinder (hand held or free standing)
Metal cutting band saw
MIG welder (flux core wire)

Table 2

Raw materials/standard parts:

Component Name	QTY
8ft section of 2inx2in A513 steel tube	4
8ft section of 1inx3in A513 steel tube	1
8ft section of 2inx4in A513 steel tube	2
4ft section of 1inx1in A513 steel tube	1
1ft x 2ft x .25in A36 Steel plate	1
0.75in dia 7in long linchpin	2
0.75in .125in thick steel washer	6
0.75in 3.5in long grade 5 bolt	2
0.75in hex nut	2
0.25in 1.5in long grade 5 bolt	4
0.25in 1in long grade 5 bolt	8
0.25in hex nut	12
0.1875in grade 5 bolt	6
0.1875in hex nut	6
0.625in bore 200 series steel bearing	2
Sheet steel bearing housing	2
0.625in bore steel shaft collar	2
.375in thick full size AR500 steel target	1
6061 aluminum shaft hub	1
Retaining clip for linchpin	2
12v 280in-lbf DC gear motor	1
55ah 12v deep cycle battery	1
6GA wire (1ft lengths)	10
DC motor controller	1
Push button switch with E stop	1
Switch housing	1

Table 3

Assembly drawing bill of materials: (electrical components not included)

Part #	Part name	QTY.
1	.083in wall 60in L frame tube	2
2	.083in wall tube 48in L frame tube	2
3	.083 wall tube 24in L support tube	2
4	.083in wall 36in L support tube	1
5	.75in dia 7in L Linchpin	2
6	Long rocker stop piece	2
7	Short rocker stop piece	2
8	.083in wall tube target support	2
9	Steel target	1
10	Motor mount base	1
11	Motor mount front	1
12	Shaft hub	1
13	.065in bar stock	2
14	.083in wall 2x4in 24in L tube	6
15	.083in wall 2x4 27.37in L tube	2
16	Shaft collar	3
17	3/4in bolt	2
18	14in Rectangular linkage arm	1
19	26in rectangular linkage arm	1
20	22in rectangular linkage arm	1
21	3/16 mounting bolt	6
22	Bearing housing	2
23	200 series bearing	2
24	0.25in 1.5in long bolt	4
25	.083in wall 1x1in tube	2
26	0.25in hex nut	12
27	3/4in hex nut	2
28	3/16in hex nut	6
29	55ah battery	1
30	DC motor	1
31	0.75in bore .125in thick washer	6
32	0.25in 1in long bolt	8
33	Retaining clip	2

Table 4

Project management

PURPOSED BUDGET:

Table 5

Item	Cost ($)
Steel structural	317
Motor	420
Bearings	30
Linchpins	22
Shaft collars	23
Hardware (all)	30
Steel Target	70
Drive hub	12
Electrical components (switch, wire ect)	55
55ah deep cycle battery	120
Ideal total ($)	
1000	
Total ($)	
1100	

ACTUAL BUDGET:

Table 6

Actual budget	
Item	**Cost ($)**
Structural Steel	200
Motor	418
Bearings	37
linchpins	10
Hardware (all)	25
Steel Target	70
Drive Hub	33
Electrical Fittings	25
55AH deep cycle Battery	110
Paint	9
Shaft Collars	27
Electrical Components (switch, housing etc.)	48
Ideal total ($)	
1000	
Total ($)	
1012	

Shipping and sales tax costs are figured into individual component cost

PROJECT SCHEDULE

PURPOSED DESIGN SCHEDULE: (2nd half of fall semester 2016)

Table 7

Week #	Task
1	Make schedule
2	Begin formulating concepts
3	Design Target stand/Frame
4	Design linkage arrangement
5	Design electrical power system
6	Make final changes and make drawings and write report

ACTUAL DESIGN SCHEDULE: (2nd half of fall semester 2016)

Table 8

Week #	Task
1	Make schedule
2	Begin formulating concepts
3	Design Target stand/Frame
4	Design linkage arrangement
5	Design electrical power system
6	Make final changes and make drawings
7	Write report

PURPOSED BUILD SCHEDULE: (Spring semester 2017)

Table 9

Week #	Task
1	Machine/weld sub frame
2	Machine/weld target armature and mount it to sub frame
3	Test frame and armature
4	Make repairs or modifications
5	Machine/weld linkage arms
6	Machine/weld motor and linkage supports
7	Assemble motor and linkage assembly
8	Weld drive mechanism to sub frame
9	Test for fitment and adjust final assembly
10	Mount battery and wire electrical system
11	Test final assembly for functionality
12	Make repairs or modifications post testing
13	Prepare showcase for tech expo
13	Present at tech expo

ACTUAL BUILD SCHEDULE: (Spring semester 2017)

Table 10

Actual Schedule	
Week #	Task
1	Machine/weld sub frame
2	Machine/weld target armature and mount it to sub frame
3	Machine/weld linkage arms
4	Machine/weld linkage arms
5	Machine/weld motor and linkage supports
6	Machine/weld motor and linkage supports
7	Machine/weld motor mount
8	Assemble and mount drive mechanism
9	Test for fitment and adjust final assembly
10	Mount battery and wire electrical system
11	Test final assembly for functionality
12	Prepare showcase for tech expo
13	Present at tech expo

PLAN TO FINISH

(SEE ABOVE SCHEDULES FOR TIMING)
(SEE APPENDIX C FOR ASSEMBLY/MANUFACTURE INSTRUCTIONS AND STEPS)
(SEE APPENDIX C FOR TESTING PLANS/PERAMETERS)
(SEE APPENDIX B FOR TECHNICAL DRAWINGS)

FABRICATION AND TESTING

BUILDING MODIFICATIONS AND DEVIATIONS FROM PLANNED DESIGN:

(fabrication followed the described plan see appendix C for details the following amendments are the only deviations)

Linkage arms

1. Linkage pin hole drilled all the way through on all linkage arms in pin position
2. Linkage pin length extended 1.5in
3. Linkage pin place through linkage arm and welded on outer side of tube instead of inner side near bearings with .5in exposed on end to facilitate welding this is done to avoid interfering with bearing mating face and linkage motion from weld slag
4. 2in diameter hole drilled in inner side of linkage arms with mounted bearings to allow for flush fit of boss on bearing housing (hole needs to only be through one wall of tube but in alignment with 5/8 pin hole to allow for pin to pass through bearing straight.
5. Linkage pins should be made of cold rolled steel not hot rolled steel as cold rolled steel is naturally undersized and will not require fitting to slip inside bearing. (hot rolled steel was used and sanded down to fit for prototype)

Hardware:

1. All bolts (except motor hub mounting bolts) are increased to Grade 8 from Grade 5 for greater commercial availability in sizes required and bulk pricing
2. .125-inch-thick .75in bore grade 8 washers are used to shim pivot pins (double required amount to ensure proper fitment) due to commercial availability and bulk pricing
3. 0.75in mounting bolts for target are changed to 0.625in (of same grade and length) adjust holes in target support arms accordingly as well.

Electrical:

1. Use 10GA electrical wire for better malleability and easier electrical assembly while maintaining high safety factor.
2. Use 10GA electrical connectors and Flexible conduit capable of housing 2-3 strands of this gauge of wire.
3. Zip tie electrical conduit to motor supports to avoid snagging or entanglement
4. Use auto body double sided adhesive tape to secure motor controller and display to side of outermost motor support beam.

Frame/Armature/Target:

1. Add reinforcing member (see below) made for 1x3 .083 wall A513 steel tube MIG welded together to reinforce frame between armature supports and front linkage support areas. Placed half inch in from the edge of the support centering it and 21.5 inches up from the bottom of the post then MIG welded around the mating points to the post.

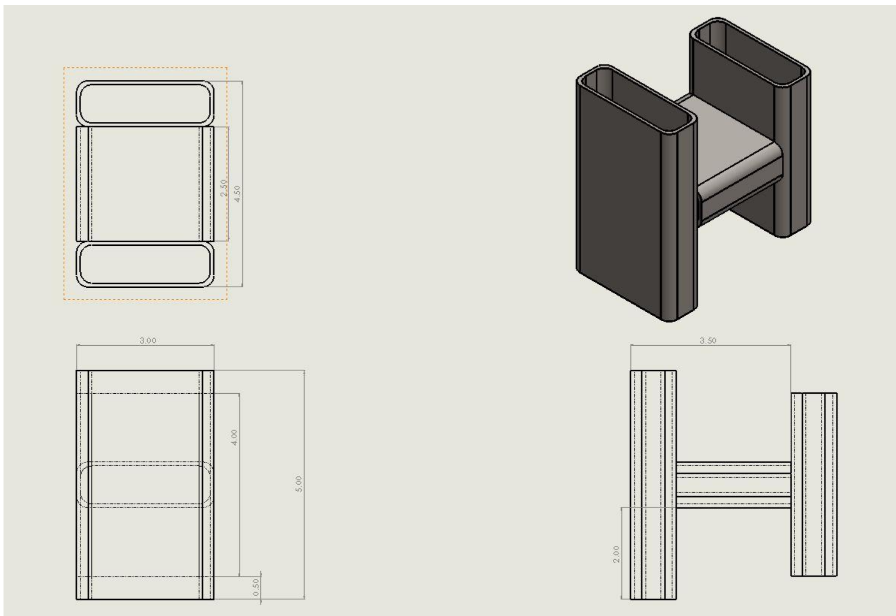

Figure 12

2. Target mounting arms bolt hole size reduced from 3/4in diameter to 5/8in diameter to allow for proper mounting with selected target.

3. A 2/3 IDPA target was used in place of a true full size target as the benchmark is professionally used and utilizes a 2/3 target. This type of target reduces motor power and increases range without impeding practical usage by the customer. The Entire design was based on this change as the overall purpose was for this product to be functional and practical. A full-scale target wouldn't have been practical or functional.

Actual Testing plan and test results:

(see appendix C for full testing process details)

Mechanical and electrical settings testing:

Tests linkage ability to move target armature from standing position quickest setting without causing armature to bounce over top dead center

Results:
50% setting on motor controller yielded a 5.5 second cycle time safely

Range testing:

(all range testing was conducted post final assembly no prior test with just armature and frame was possible or necessary)

Pistol Testing:

Test ability to knock target over reliably with a hand gun caliber
.45 ACP Beretta cx4 storm carbine was used at 25yrds
2 shots were permitted per benchmark stipulation
Results: 2 successive shots at 25yrds successfully knocked target over

Intermediate rifle testing:

Test1:
Test ability to knock target over reliably with intermediate rifle caliber
.223 Remington 20in HBAR AR-15 was used at 100yrds
1 shot was permitted
Results: 1 shot was unsuccessful to knock the target over

Test2:
Test ability to knock target over reliably with intermediate rifle caliber
.223 Remington/5.56 NATO 20in HBAR AR-15 was used at 50yrds
1 shot was permitted
Results: 1 shot was successful to knock the target over

Full power rifle testing:

Test ability to knock target over reliably with full power rifle caliber
30-06 Winchester model 70 was used at 100yrds
1 shot was permitted
Results 1 shot was successful to knock the target over
(ranges were limited to 100yrds due to land restraints testing at greater distances was not possible nor was more than 1 test trip in the given time

Additional Electrical Testing:

Motor – 9.5A max draw
Battery – 55AH

Test:
Place multimeter in Amp reading mode between battery and connecting wire to measure electrical draw of motor under actual operating conditions
(at 50% settings on motor controller)

Results:
Max 5amp draw is present during operation showing that a smaller battery and cheaper less efficient 280in-lb dc electrical motor could be used to reduce cost without any degradation of performance

Overall Results:
The unit suffered no mechanical damage, broken welds, or noticeable deformation of any kind on any part during operation or testing. Indicating that the design and subsequent modifications do not impede durability or functionality and is thus successful.

Unit pricing

- Machining man hours – 50 hours *$10/hour = $500
- Welding man hours – 10 hours * $15/hour = $150
- Electrical wiring hours – 5 hours * $12/hour = 60
- estimated Manufacturing costs - $710 (all work done myself for free)
- Life cycle/Maintenance cycle (5 years):
- Paint - $9   replacement bearings - $22   replacement battery - $110
- $880 for components and materials (using minimum build quantities)
- Total unit price $1622

Benchmark comparison

Table 11

	Man sized resetting target system	La rue tactical sniper target system
Cycle time	5 seconds	9 seconds
Cycles per charge	2800	1800
Weight	150lbs	72lbs
Target size	12in x 20in x 3/8in AR 500	11.5in x 23.5in x 3/8in AR 500
Unit Cost	1622$	2800$

Future modifications and Recommendations:

- Wireless Remote control with limit switch for cycling at longer distances
- Implement less efficient motor to reduce costs by estimated 120$
- Implement less amp hour battery to reduce costs by estimated $60
- Shielding over motor and battery areas
- Further water proof electrical system
- Increase effective range by adjusting forward incline of target

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Customer Questionnaires

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16. (http://www.azom.com/, n.d.)

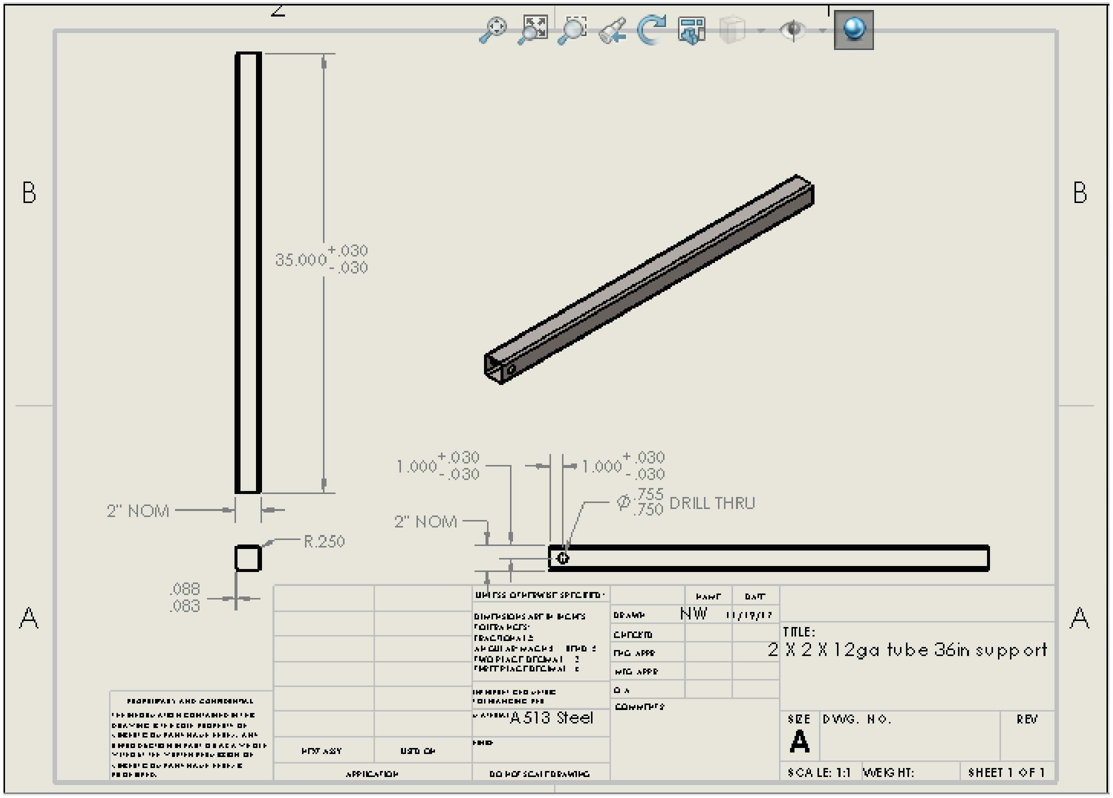
APPENDIX A

Customer Feature Weighting Results

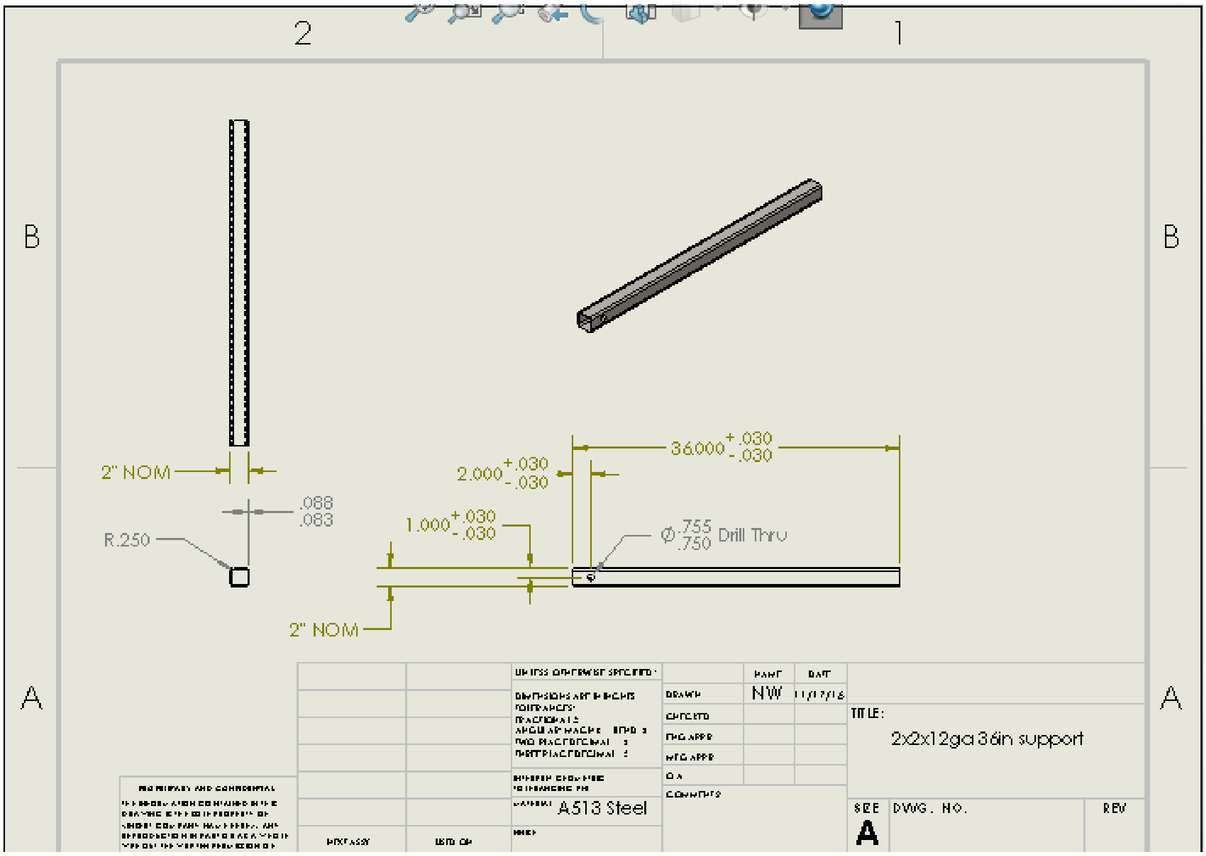
Unit cost	Unit Weight	Versatility of calibers	Target Reset time	Battery Life	System Life	Serviceabilit y	Total
0.1	0	0	0.1	0.3	0.3	0.2	
0.2	0.05	0.2	0.15	0.1	0.15	0.15	
0.2	0.15	0.2	0.05	0.15	0.15	0.1	
0.4	0.1	0.1	0.1	0.1	0.1	0.1	
0.4	0	0	0	0.2	0.2	0.2	
Average	Average	Average	Average	Average	Average	Average	
0.26	0.06	0.1	0.08	0.17	0.18	0.15	1

APPENDIX B

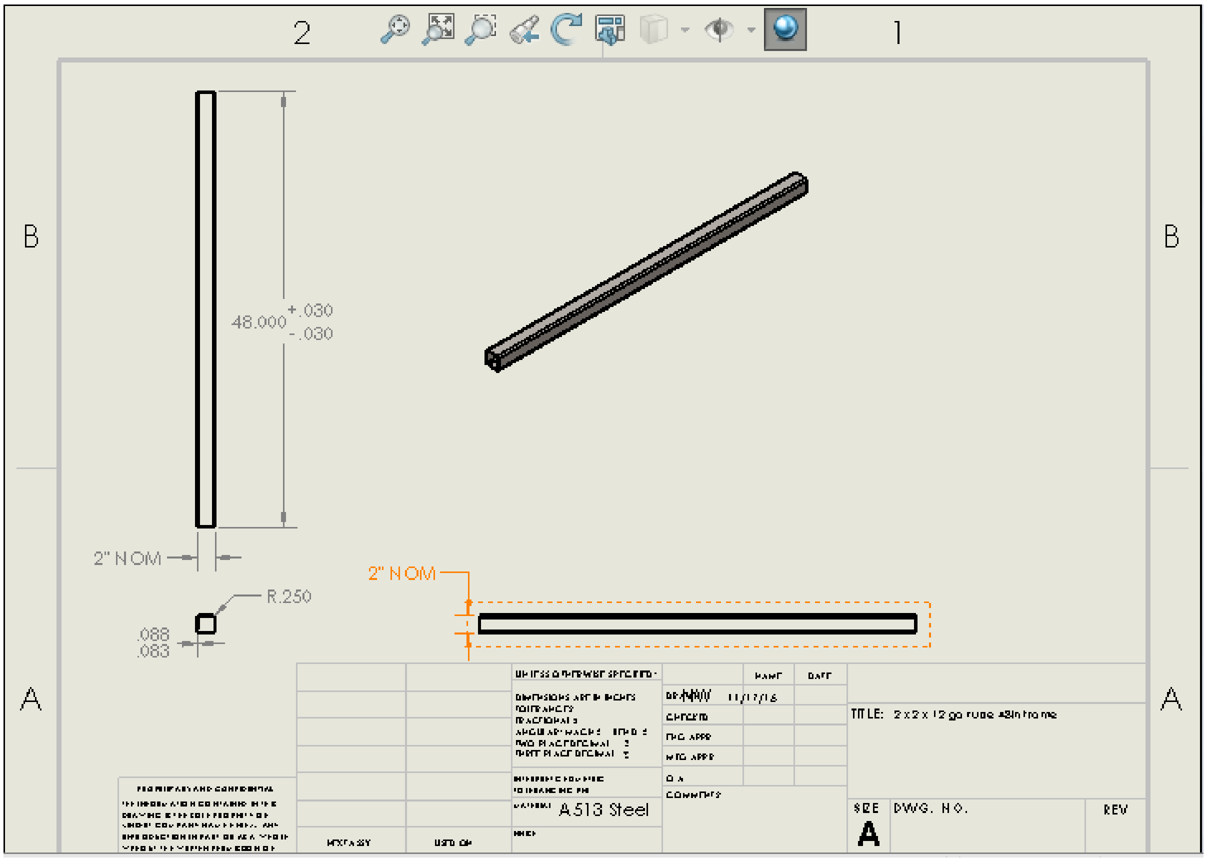
2in x 2in x 35in 12ga armature



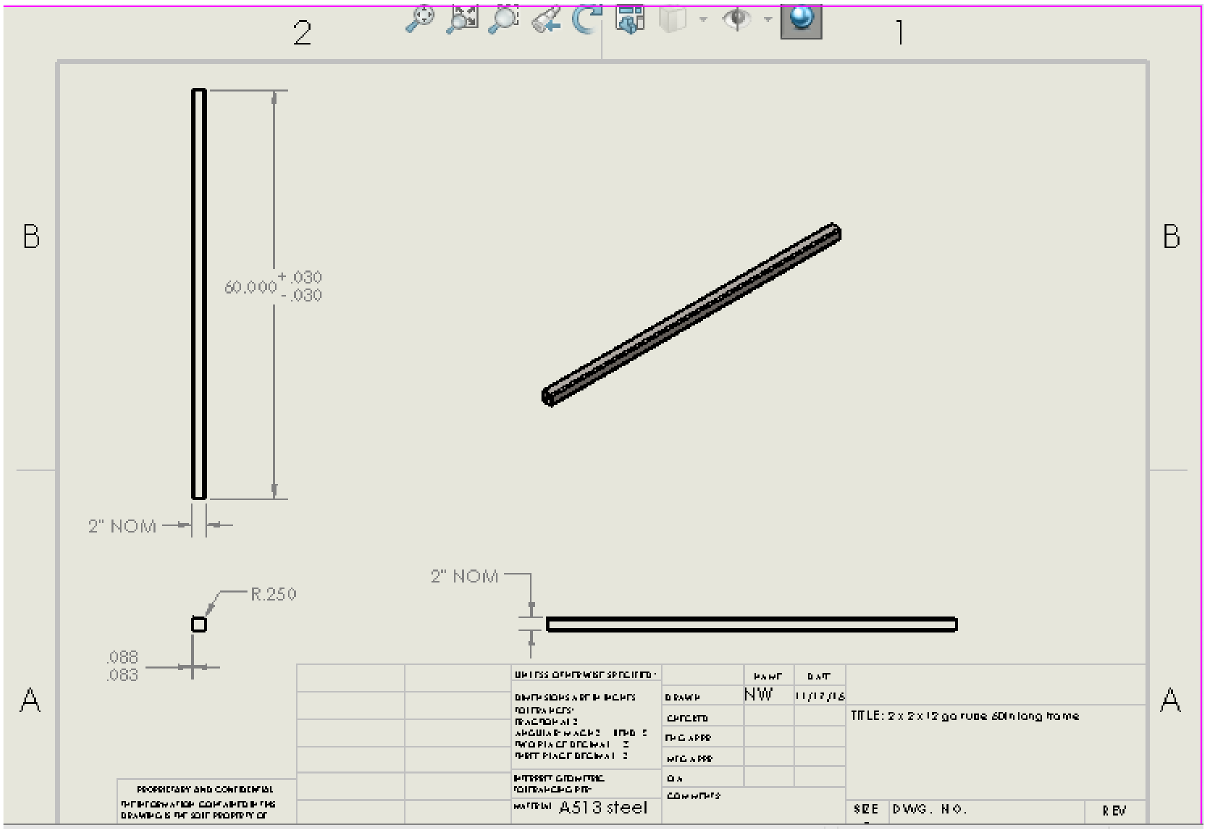
2in x 2in x 36in armature support



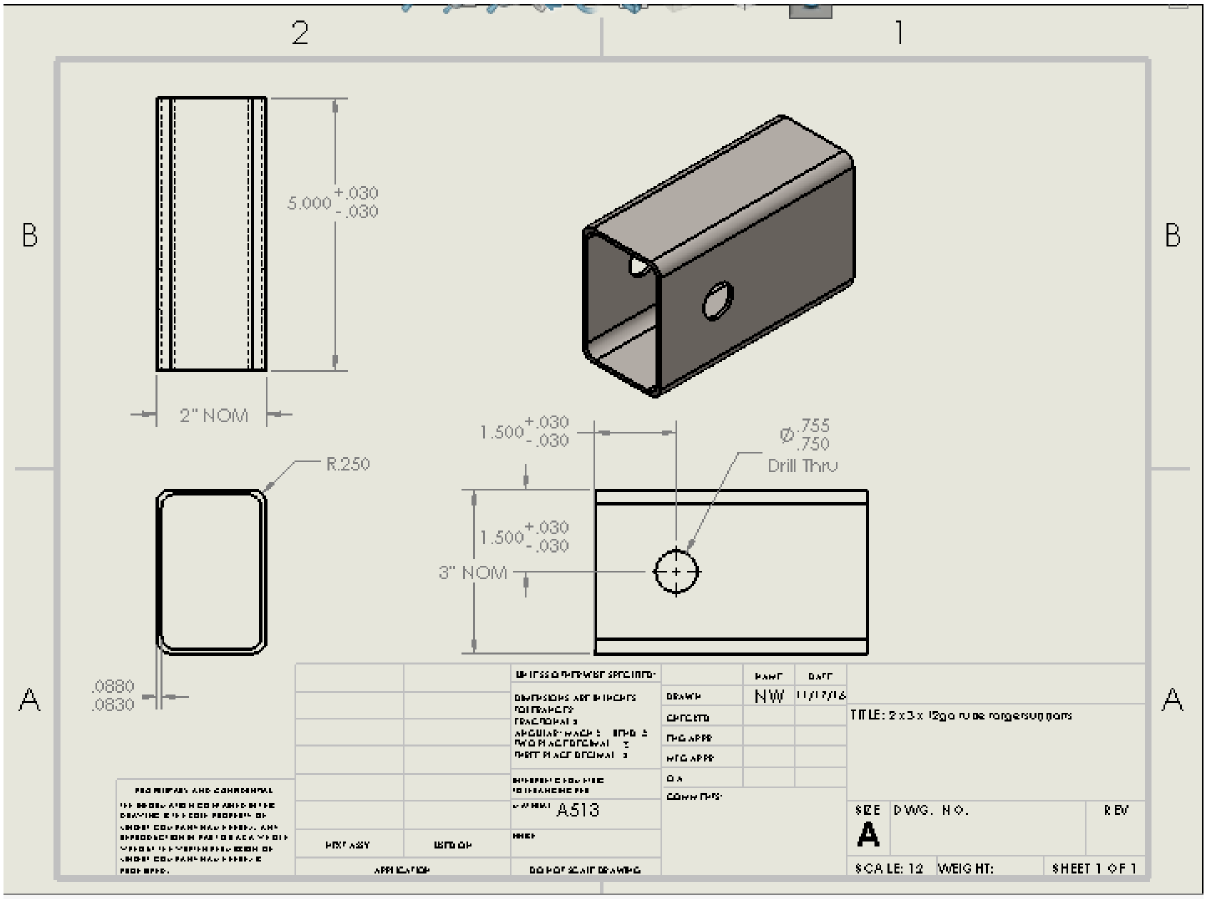
2in x 2in x 48in 12ga frame tube



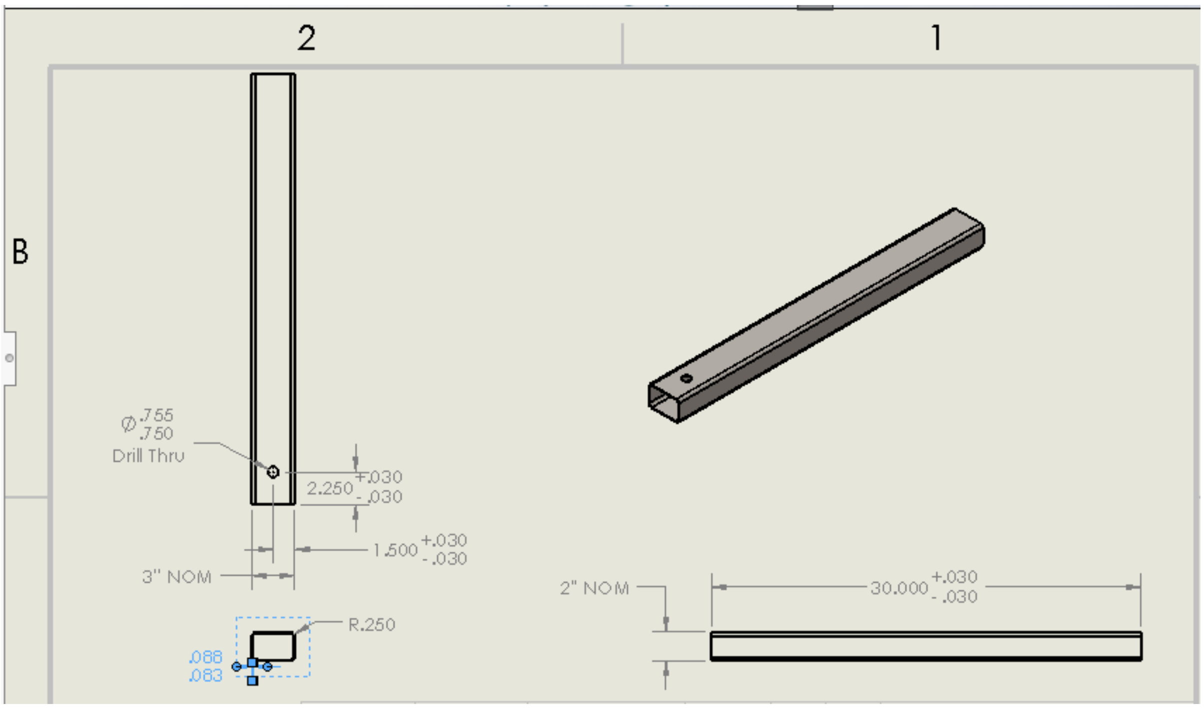
2in x 2in x 60in 12ga frame tube



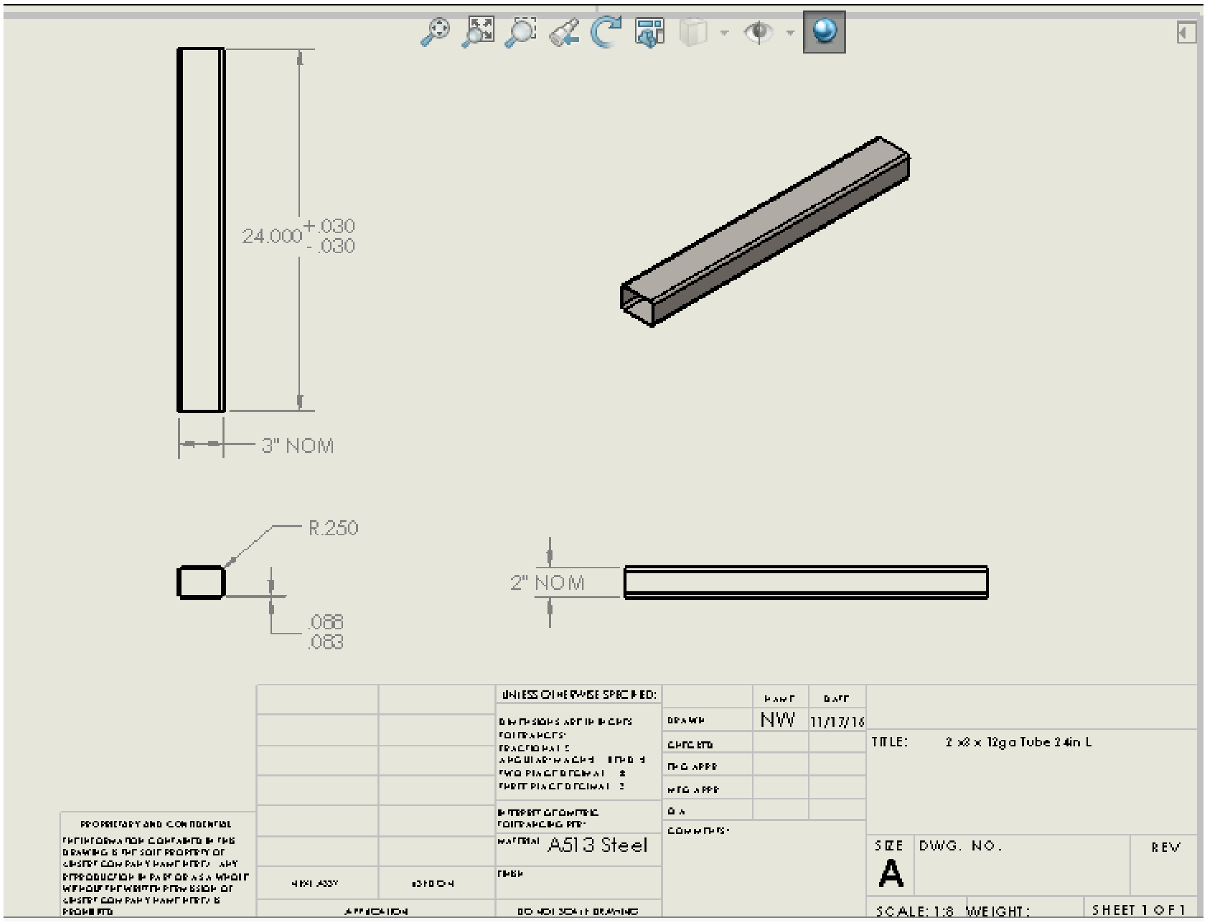
2in x 3in x 12ga target support



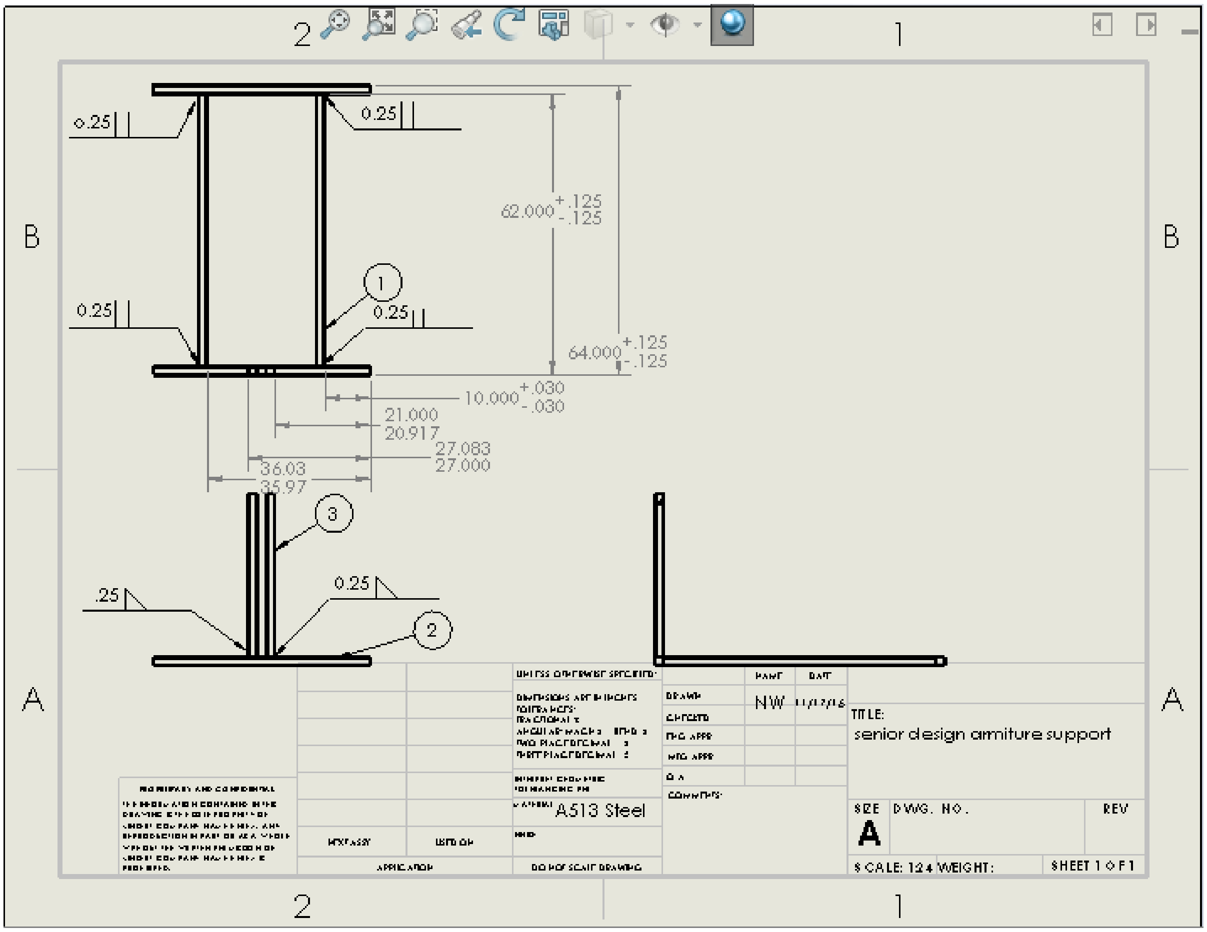
2in x 3in x 30in 12ga front linkage support



2in x 3in x 24in 12ga support

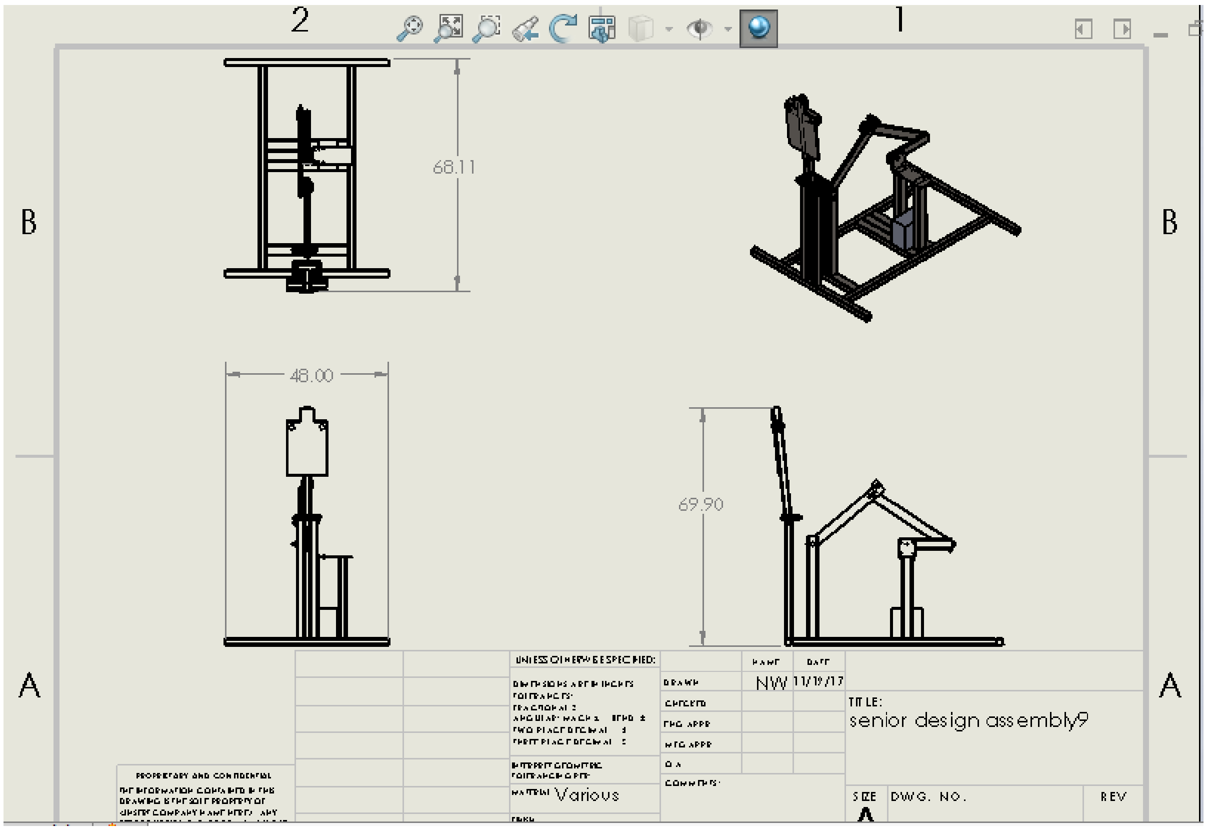


Armature support assembly

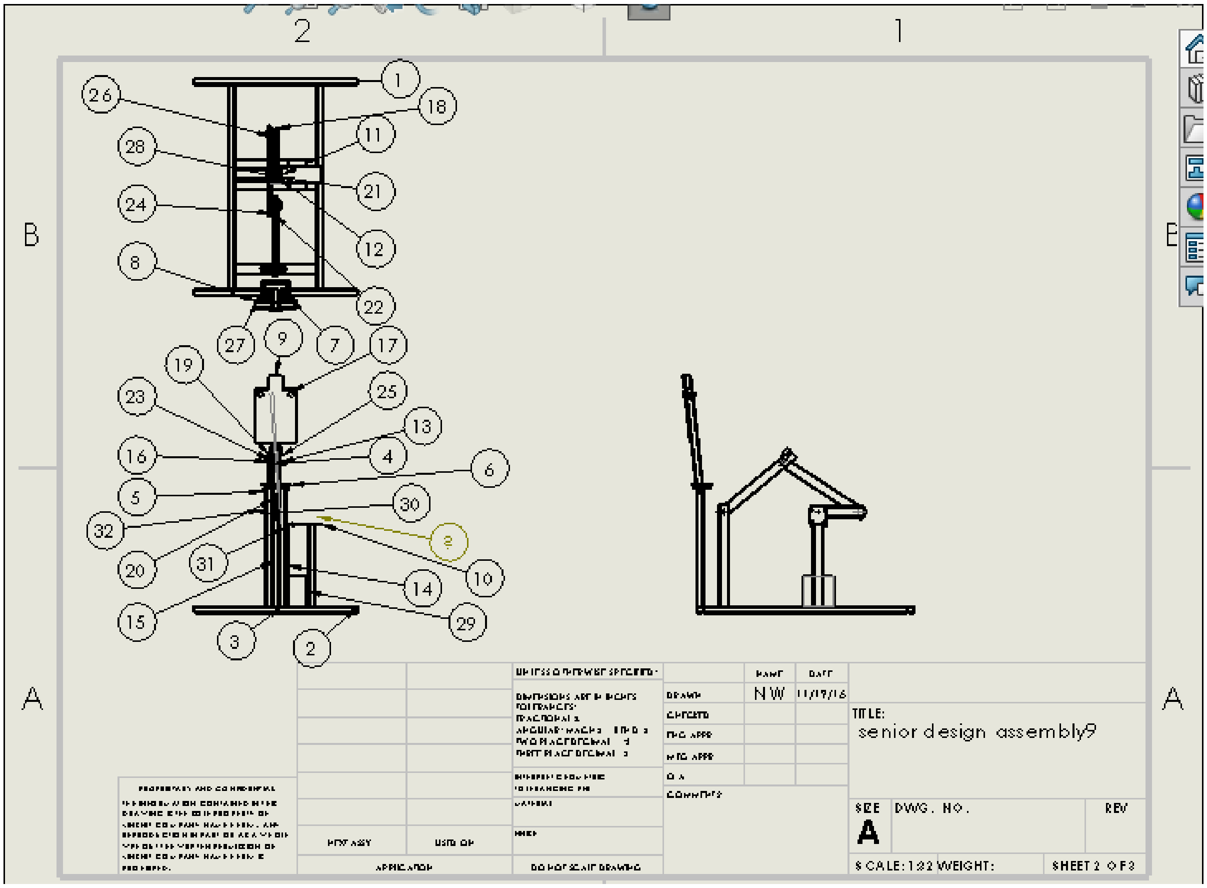


Balloon #	Component name	QTY
1	2in x 2in x 60in 12ga frame tube	2
2	2in x 2in x 48in 12ga frame tube	2
3	2in x 2in x 36in 12ga armature support	2

Final Assembly

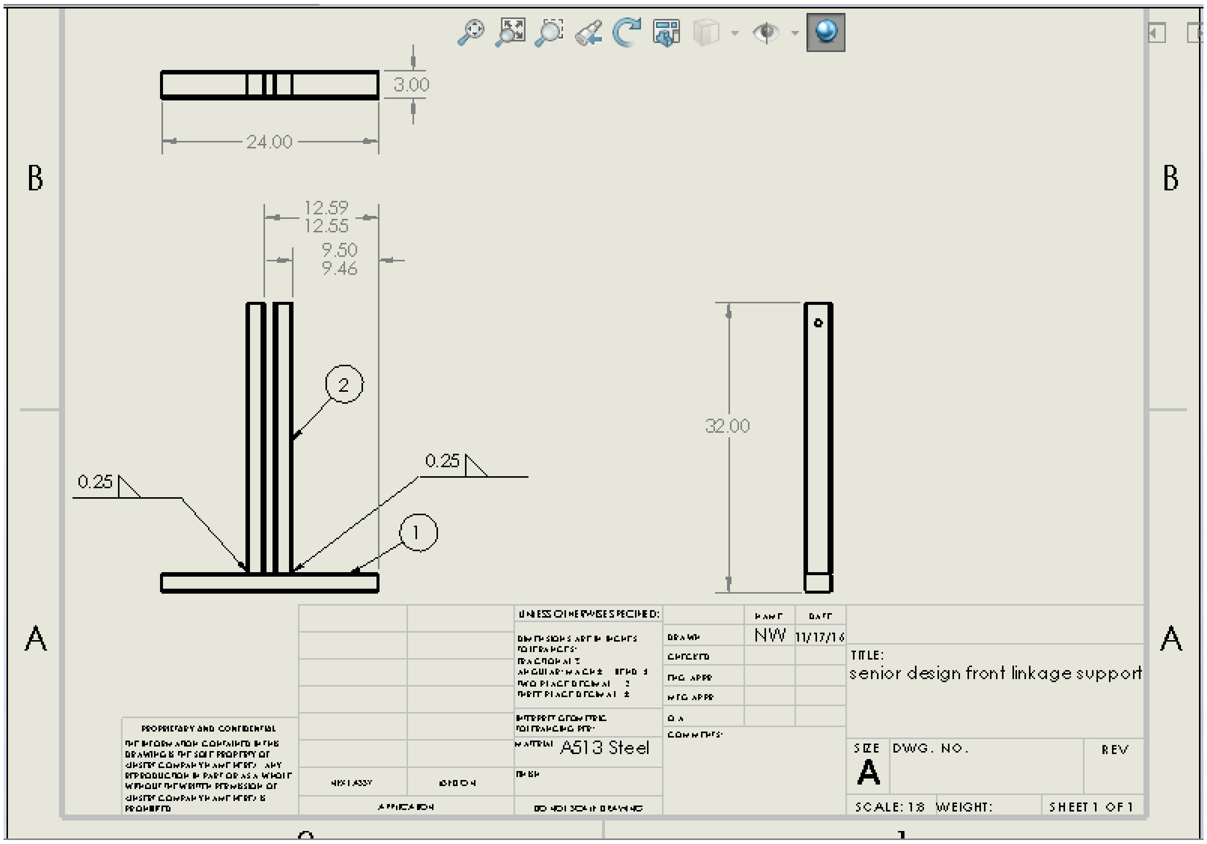


Final Assembly Balloon Drawing



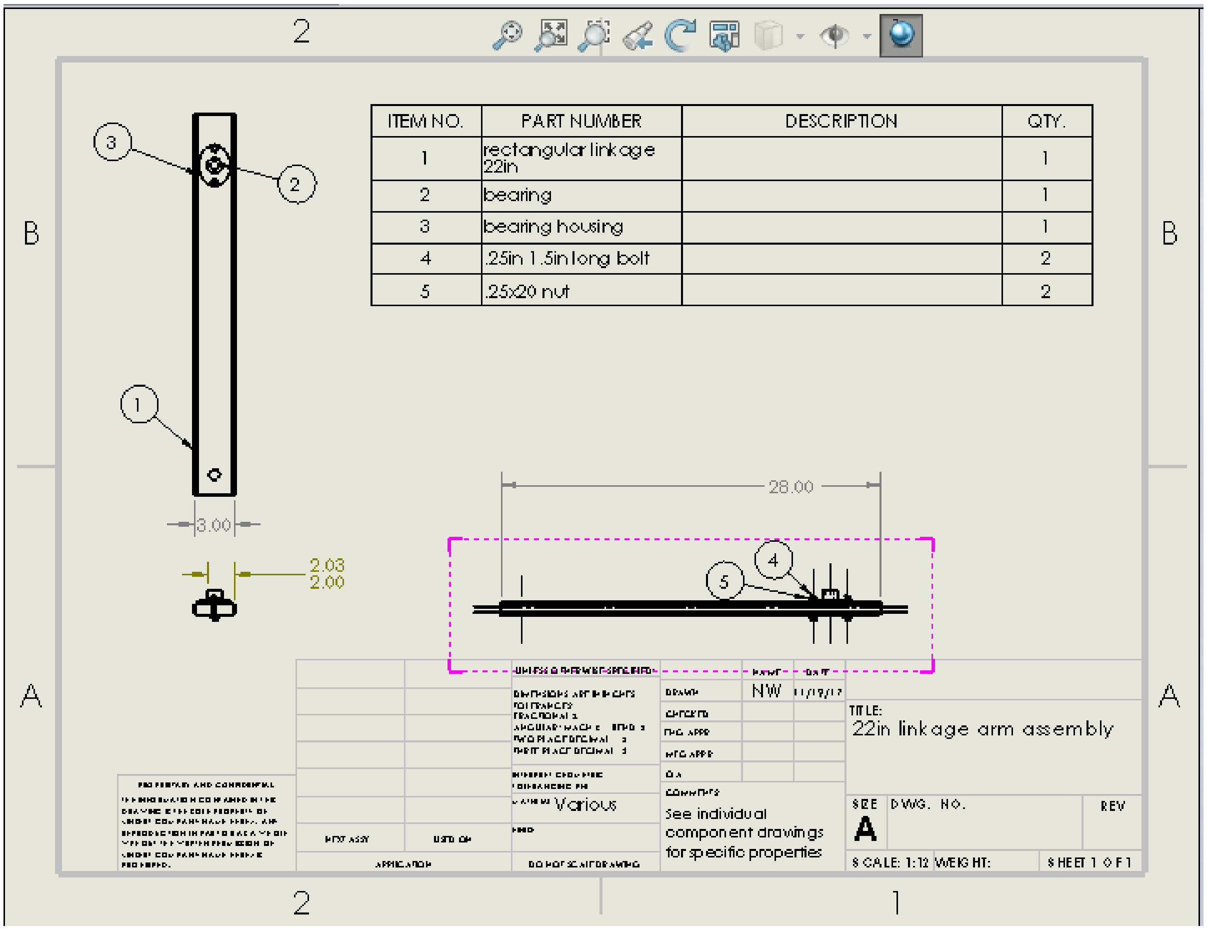
(see bill of materials section for full component listings)

Front linkage support assembly

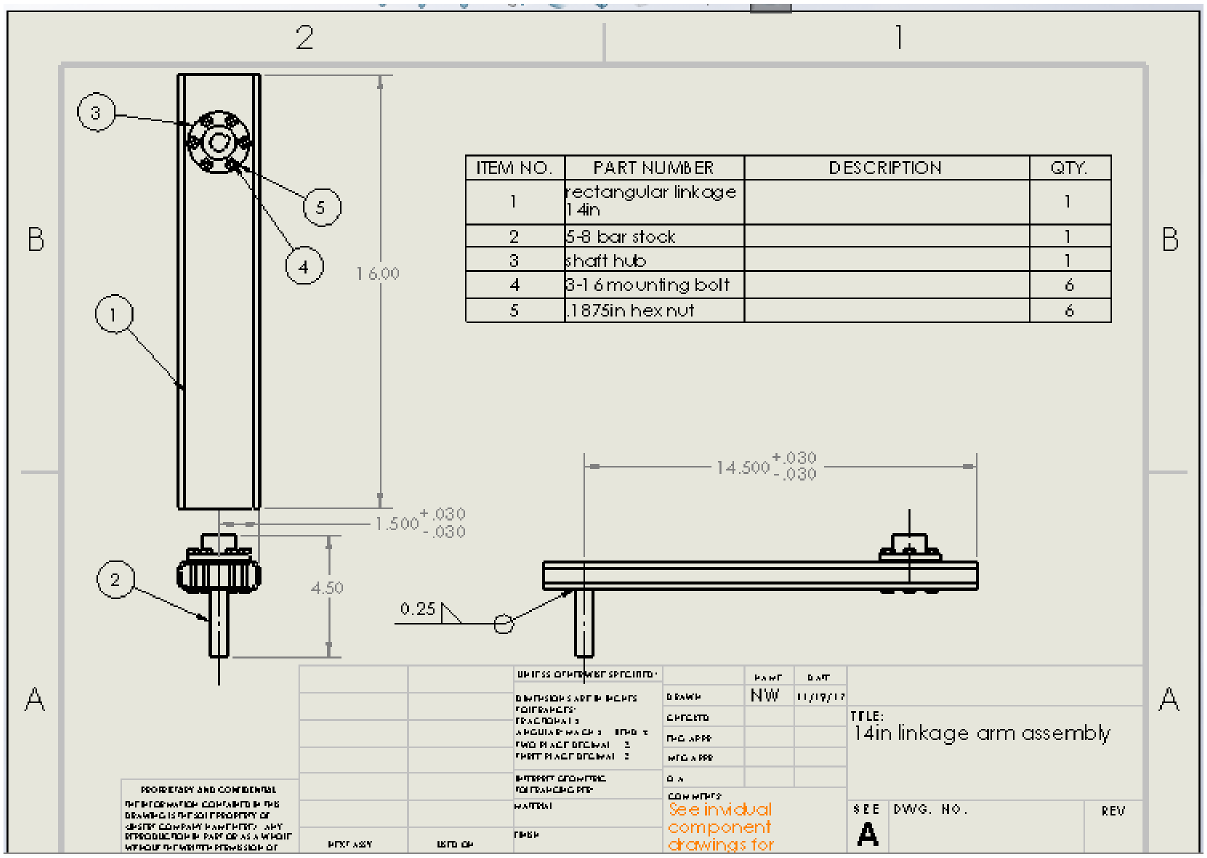


Balloon #	Component name	QTY
1	2in x 2in x 24in 12ga support	1
2	2in x 2in x 30in 12ga front linkage support	2

22in linkage arm assembly

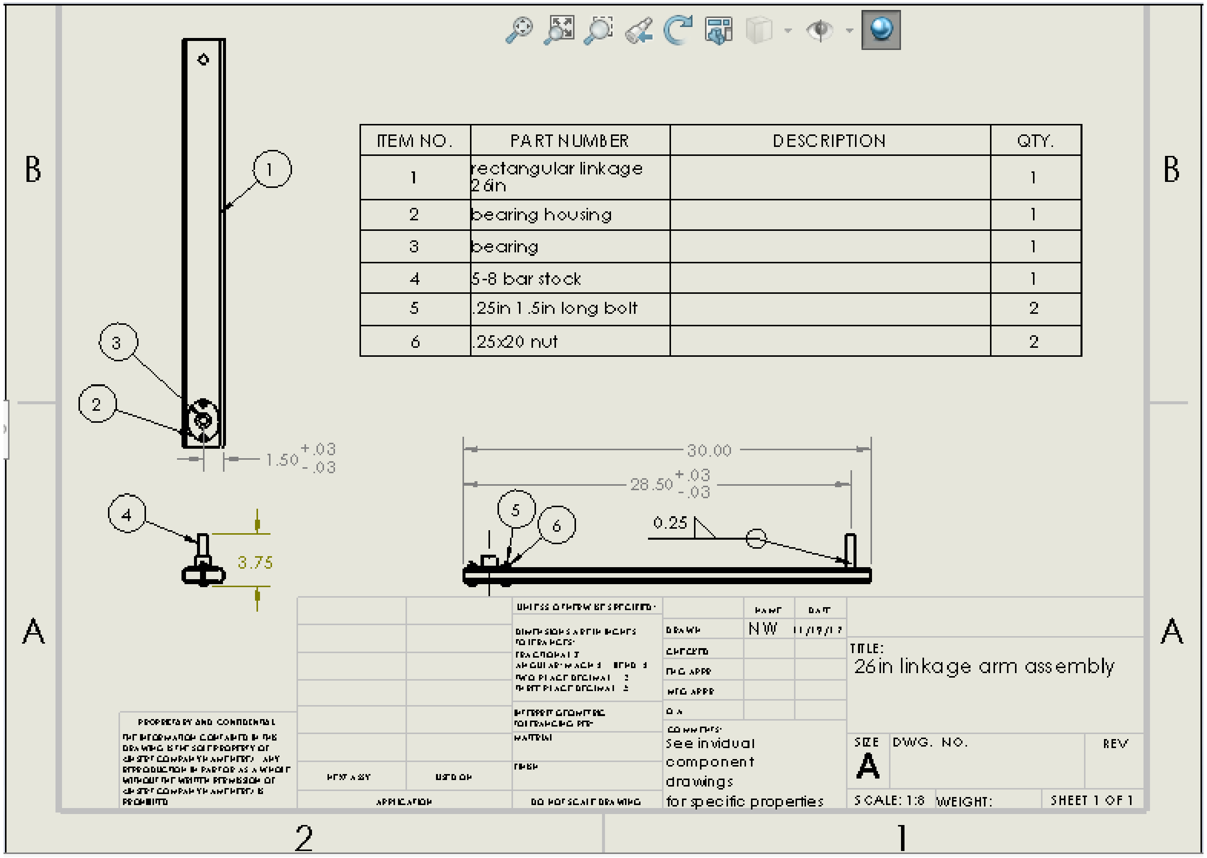


14in linkage assembly

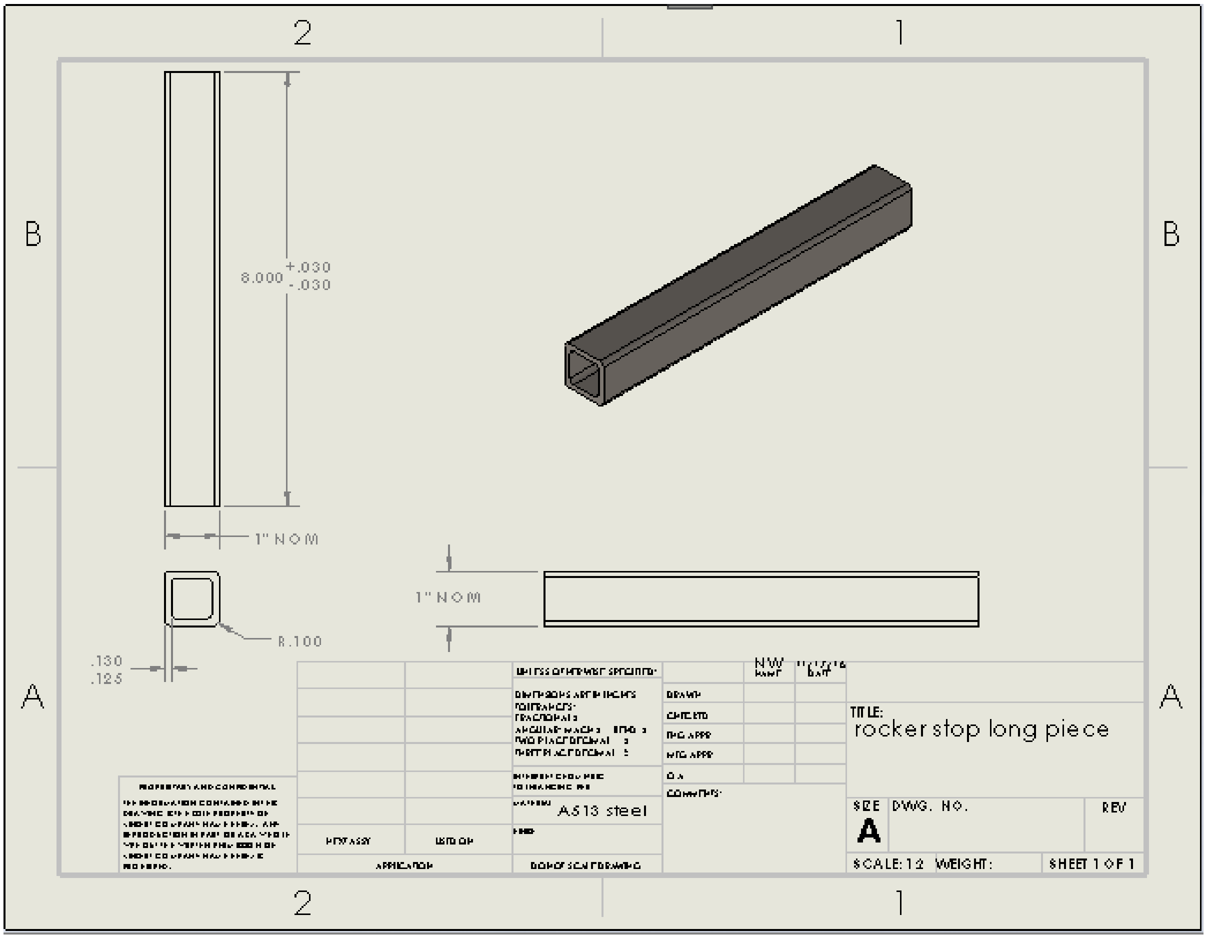


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	rectangular linkage 14in		1
2	5-8 bar stock		1
3	shaft hub		1
4	8-16 mounting bolt		6
5	.1875in hex nut		6

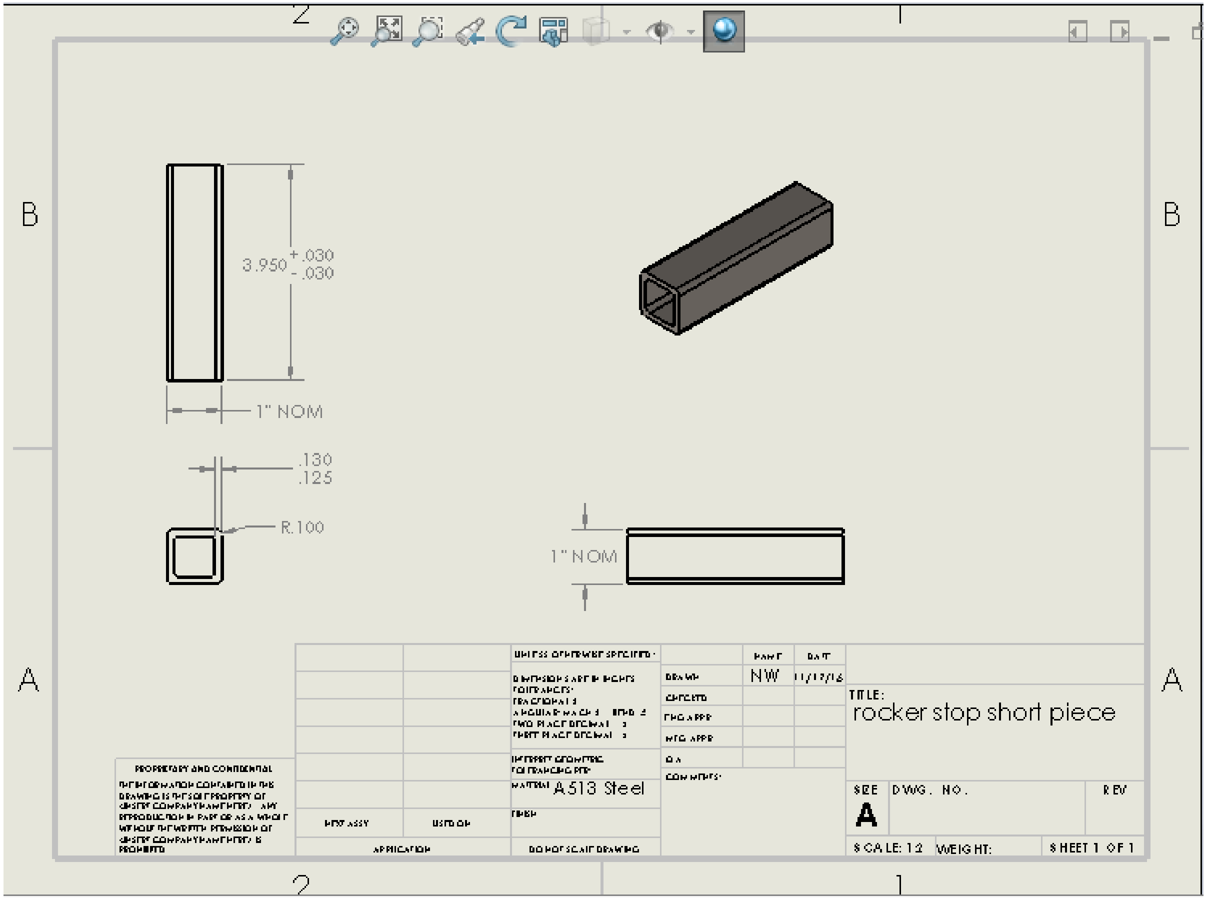
26in linkage arm assembly



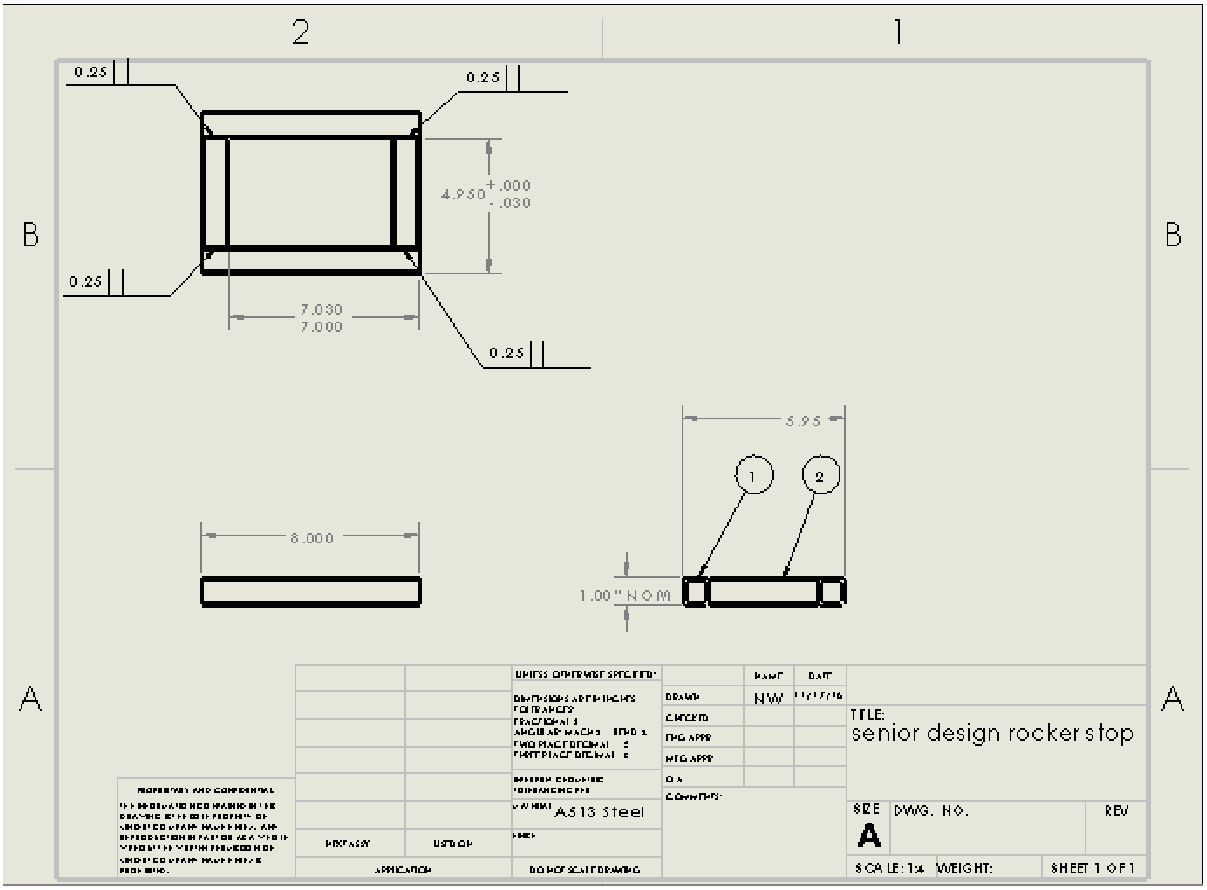
Rocker Stop Long Piece



Rocker stop short piece

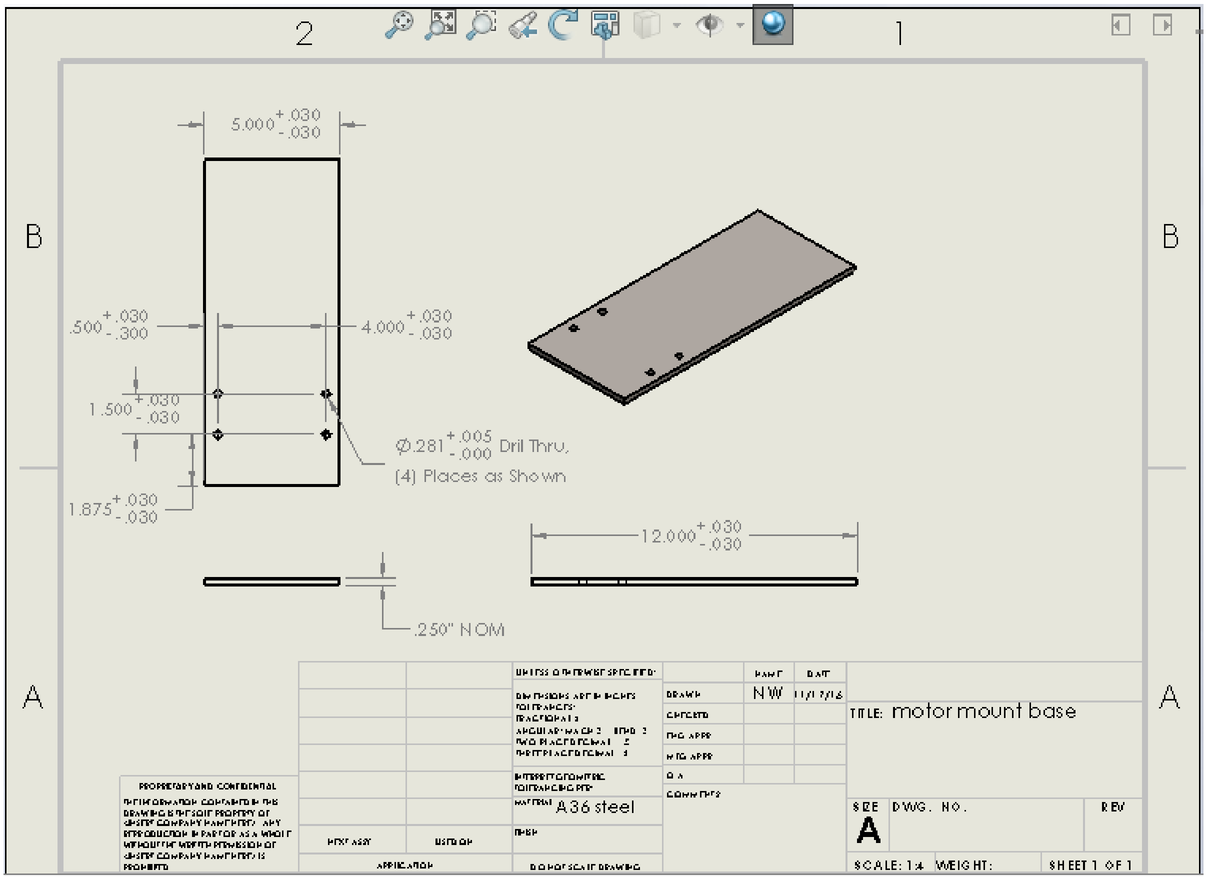


Rocker stop assembly

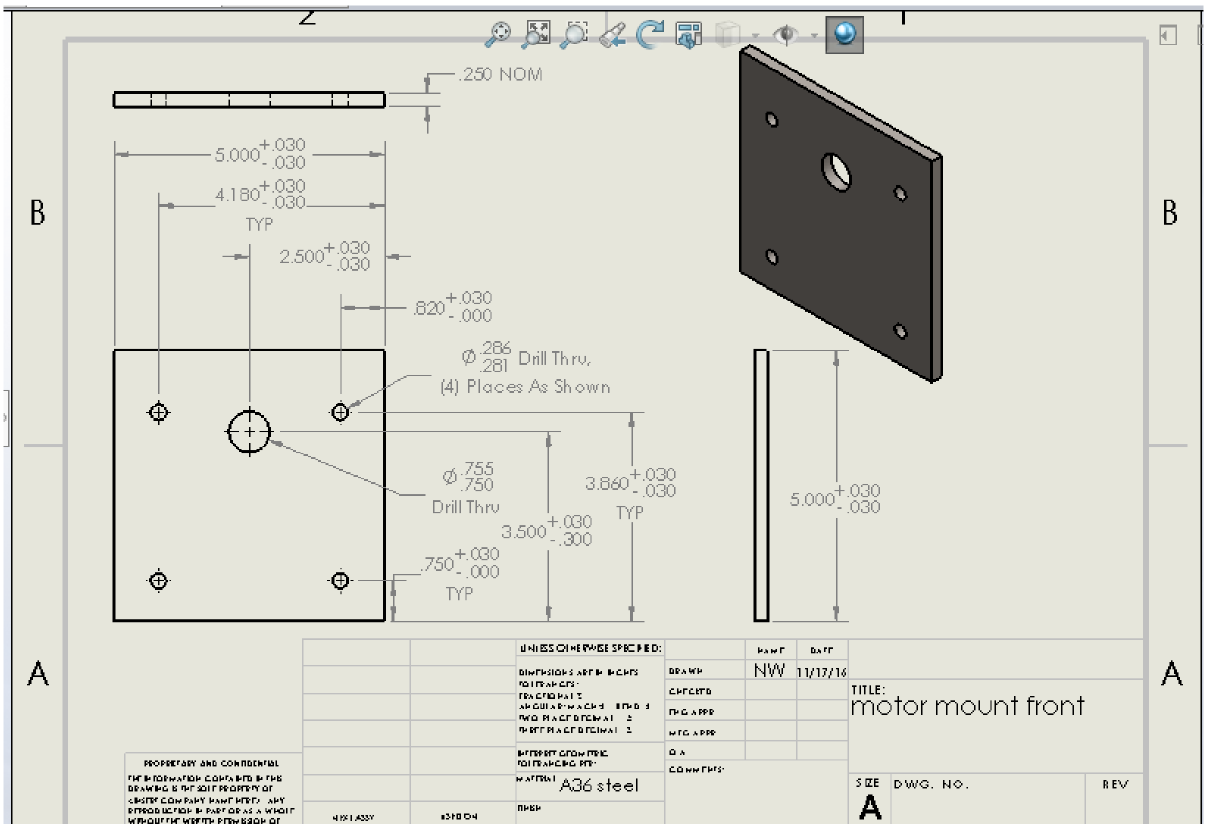


Balloon #	Component name	QTY
1	Rocker stop long piece	2
2	Rocker stop short piece	2

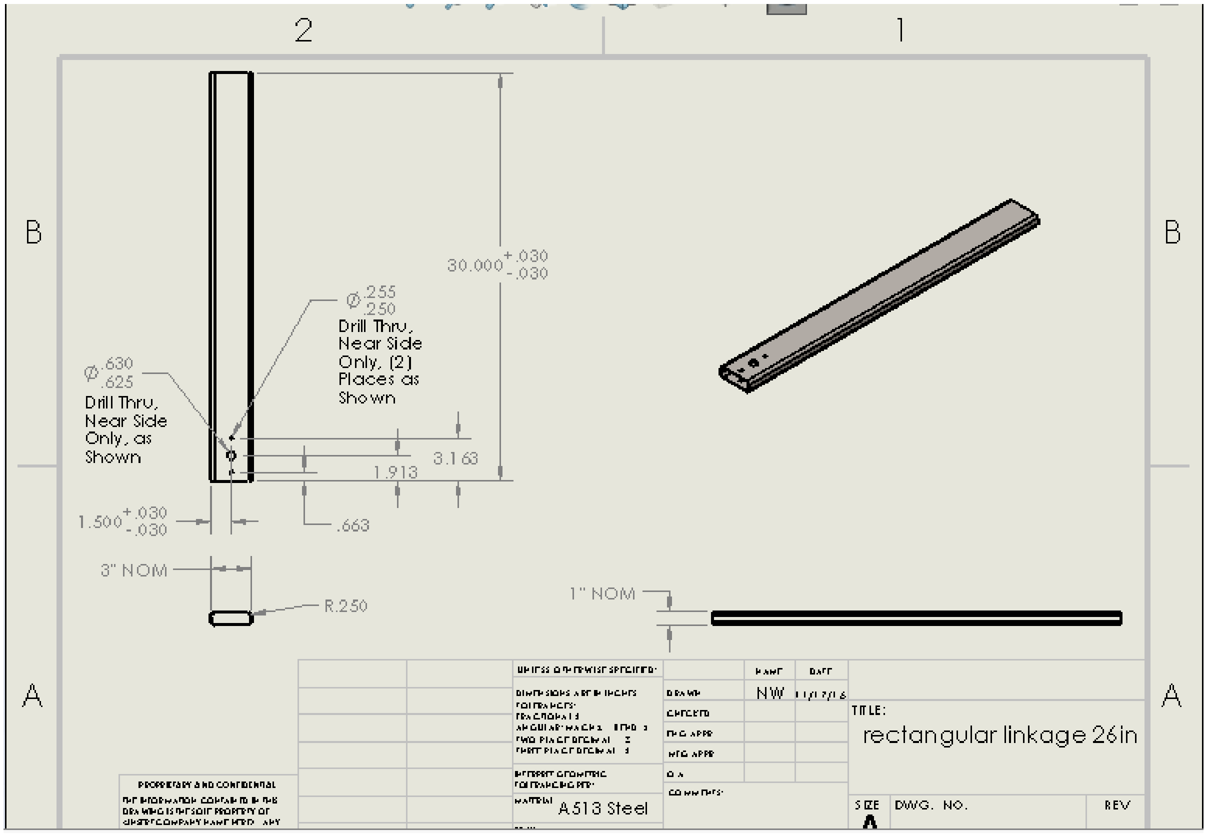
Motor mount base



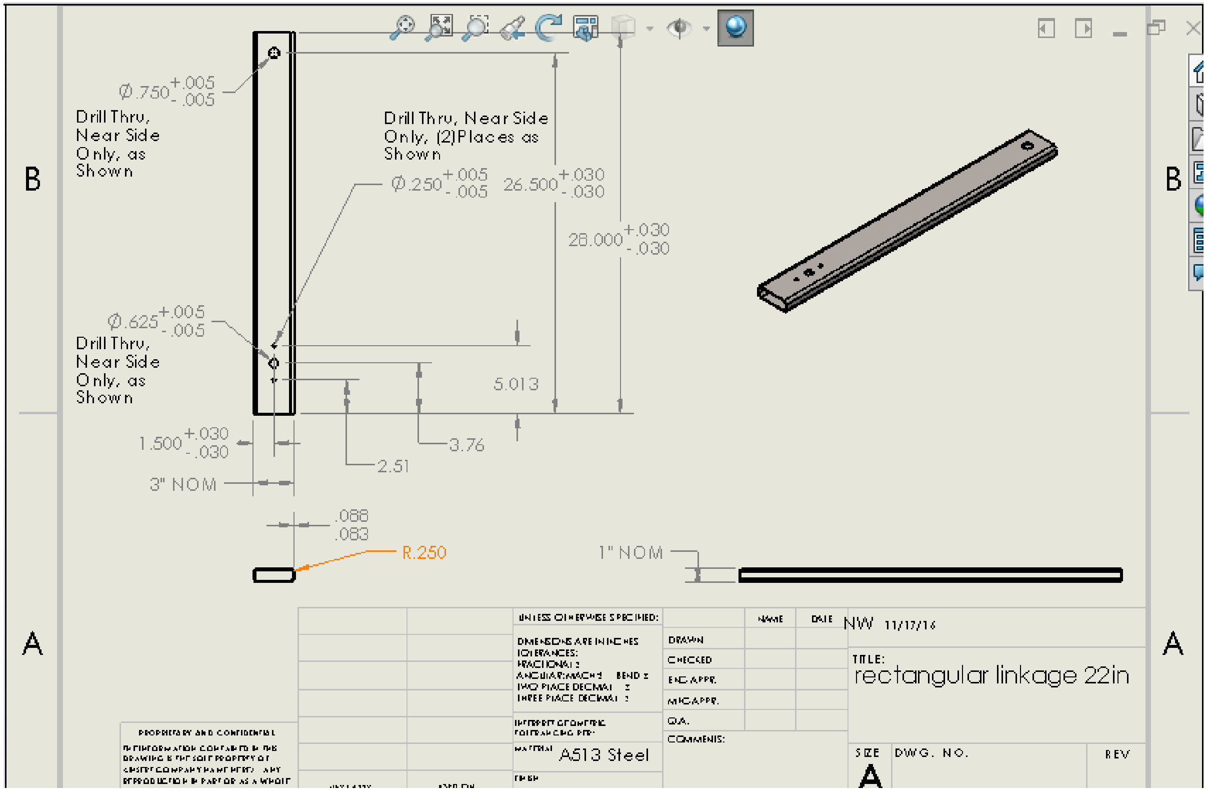
Motor mount front



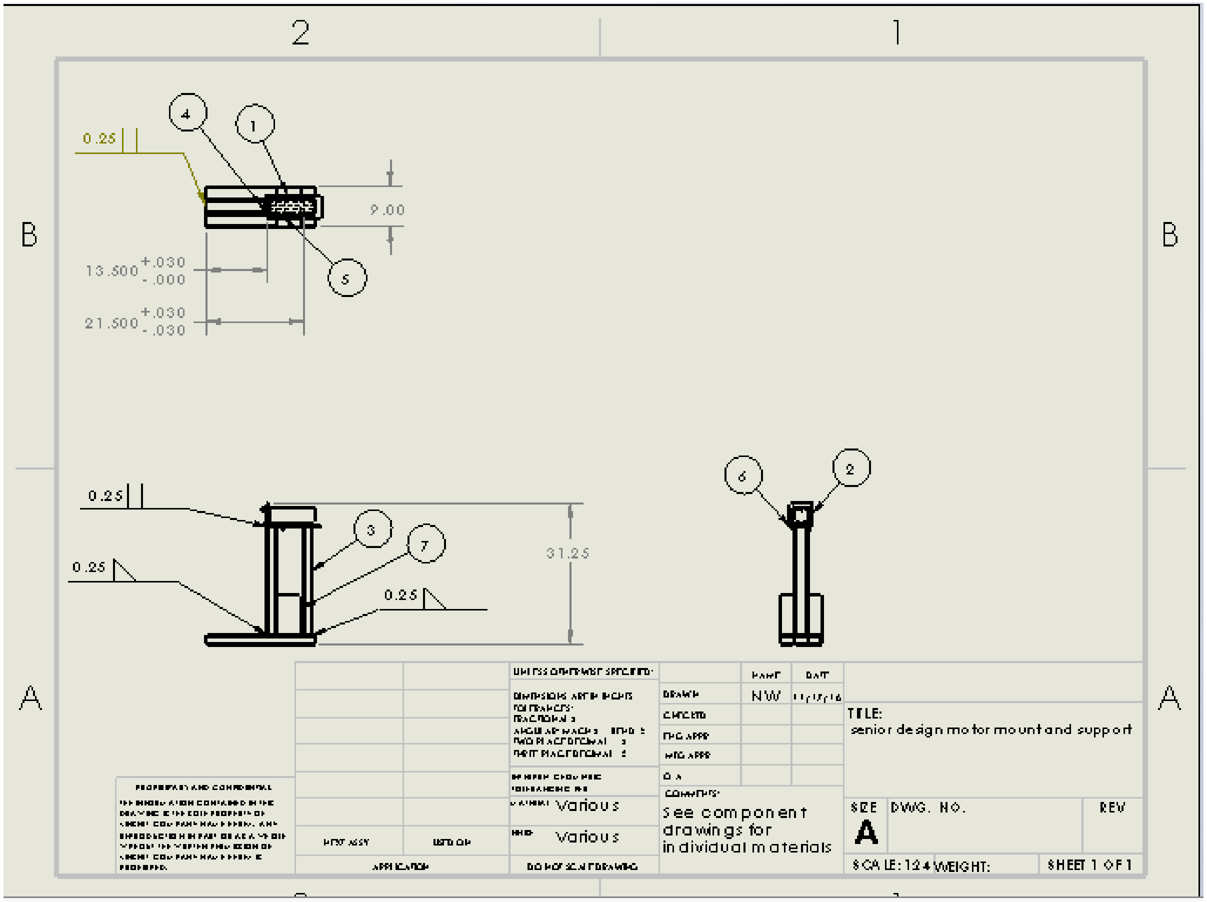
26in linkage arm



22in linkage arm

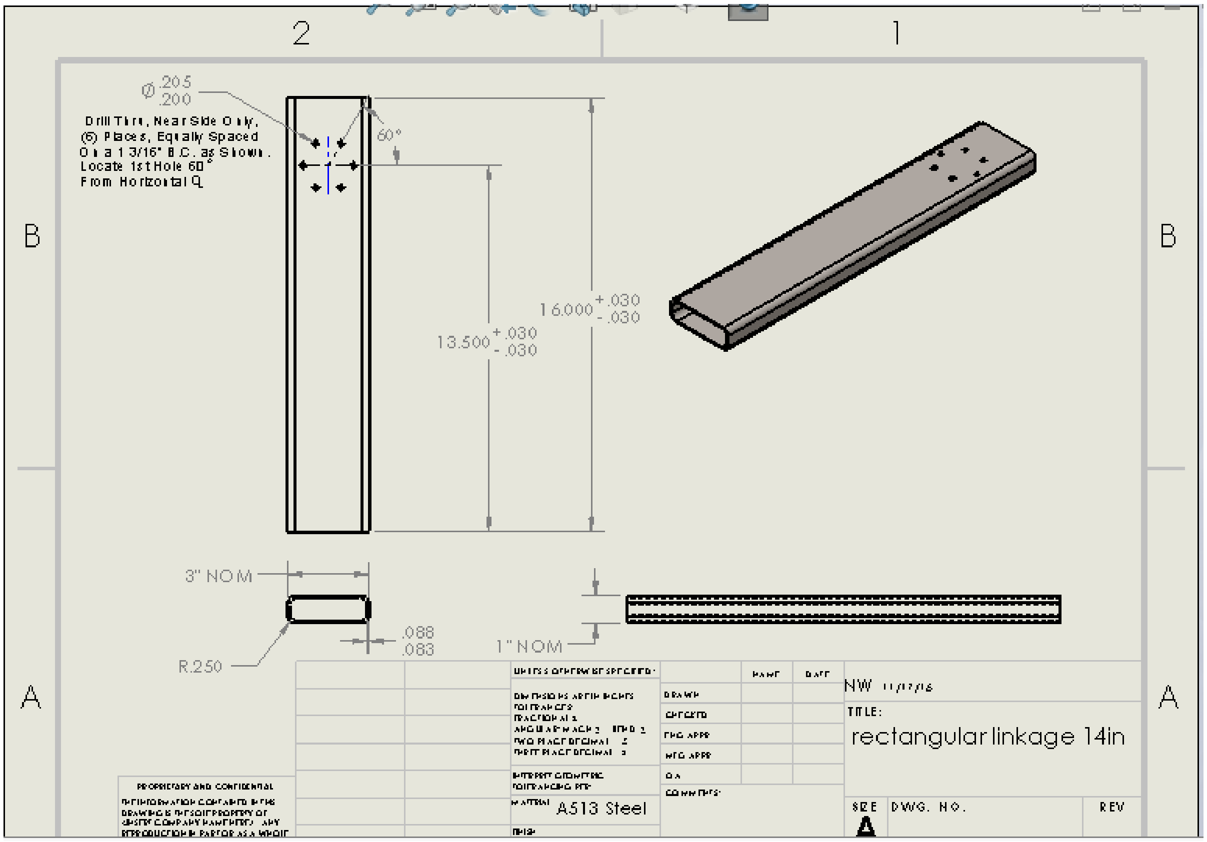


Motor mount assembly

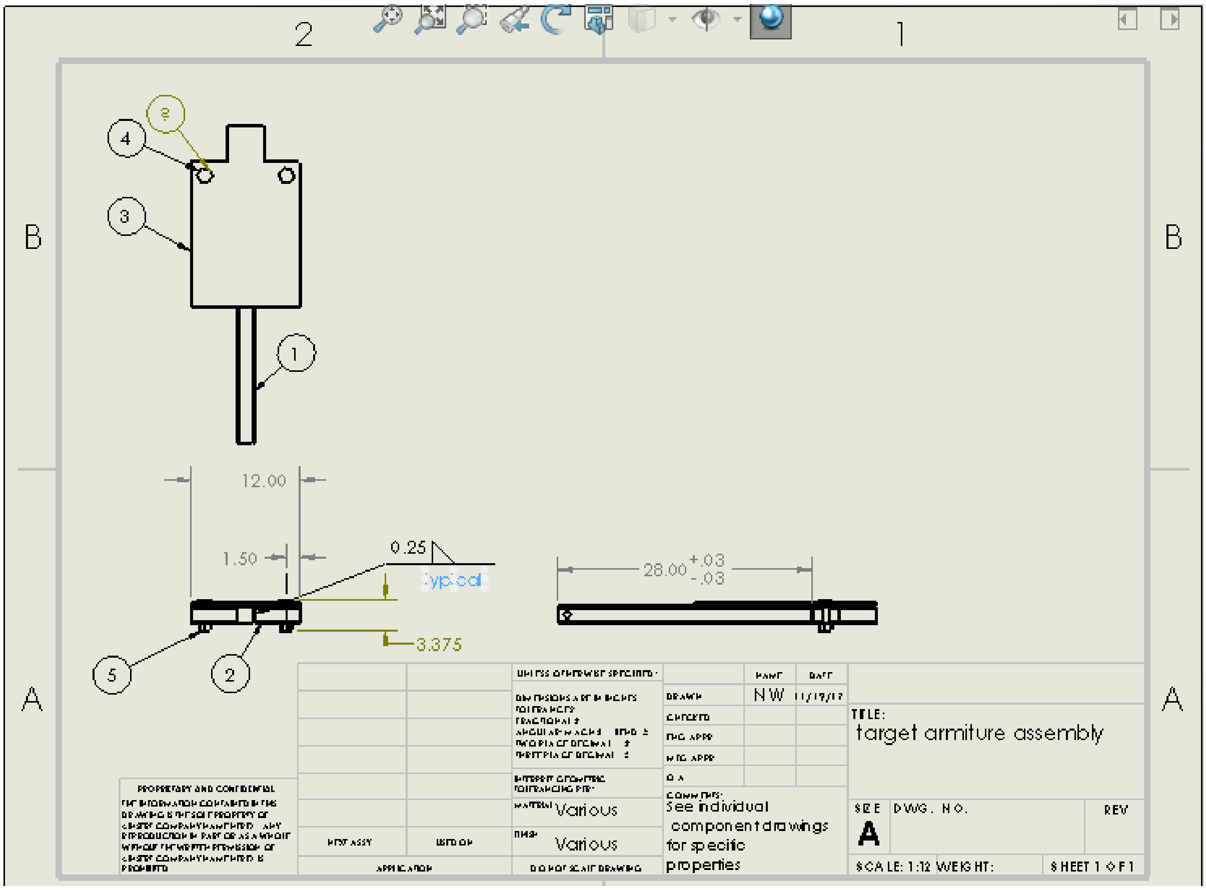


Balloon #	Component name	QTY
1	Motor mount front	1
2	Motor model	1
3	2in x 2in x 24in 12ga motor mount support	5
4	0.25in 1in long grade 5 bolt	8
5	0.25in hex nut	8
6	Motor mount base	1
7	Battery	1

14in linkage arm

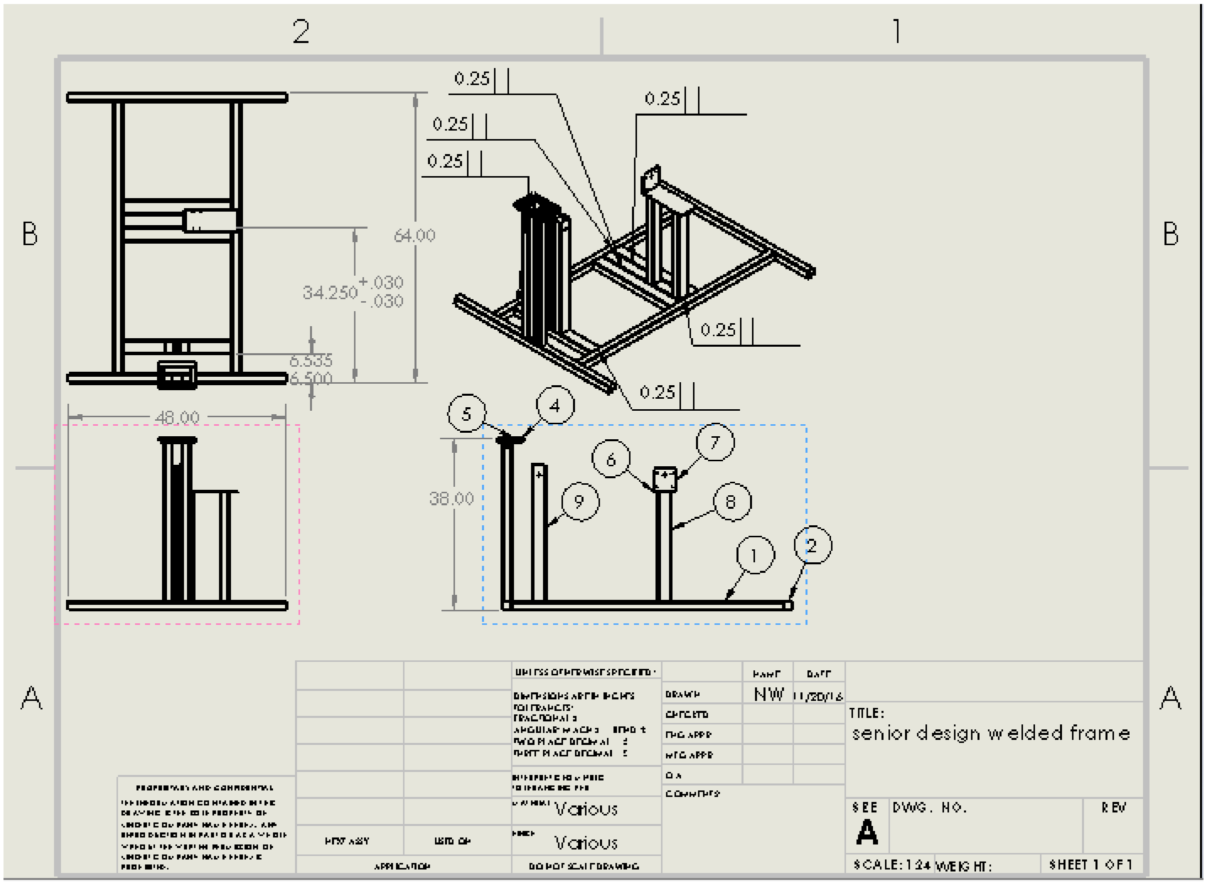


ARMATURE ASSEMBLY



Balloon #	Component name	QTY
1	2in x 2in x 35in 12ga armature	1
2	2in x 3in 12ga target support	2
3	target	1
4	0.75in 3.5in long grade 5 bolt	2
5	0.75in hex nut	2

Welded frame assembly



Balloon #	Component name	QTY
1	2in x 2in x60in 12ga frame tube	2
2	2in x 2in x 48in 12ga frame tube	2
3	2in x 2in x 36in 12ga armature support	2
4	Rocker stop long piece	2
5	Rocker stop short piece	2
6	Motor mount base	1
7	Motor mount front	1
8	2in x 3in x 24in 12ga motor mount support	6
9	2in x 3in x 30in 12ga front linkage support	2

(all other components are standard components and do not require drawings but did warrant a model for the final assembly such as bolts, nuts, washers ect)

APPENDIX C

PLANS FOR DESIGN, MANUFACTURE AND TESTING

PURPOSED DESIGN SCHEDULE: (2nd half of fall semester 2016)

Week #	Task
1	Make schedule
2	Begin formulating concepts
3	Design Target stand/Frame
4	Design linkage arrangement
5	Design electrical power system
6	Make final changes and make drawings and write report

ACTUAL DESIGN SCHEDULE: (2nd half of fall semester 2016)

Week #	Task
1	Make schedule
2	Begin formulating concepts
3	Design Target stand/Frame
4	Design linkage arrangement
5	Design electrical power system
6	Make final changes and make drawings
7	Write report

PURPOSED BUILD SCHEDULE: (Spring semester 2017)

Week #	Task
1	Machine/weld sub frame
2	Machine/weld target armature and mount it to sub frame
3	Test frame and armature
4	Make repairs or modifications
5	Machine/weld linkage arms
6	Machine/weld motor and linkage supports
7	Assemble motor and linkage assembly
8	Weld drive mechanism to sub frame
9	Test for fitment and adjust final assembly
10	Mount battery and wire electrical system
11	Test final assembly for functionality
12	Make repairs or modifications post testing
13	Prepare showcase for tech expo
13	Present at tech expo

ACTUAL BUILD SCHEDULE: (Spring semester 2017)

Actual Schedule	
Week #	Task
1	Machine/weld sub frame
2	Machine/weld target armature and mount it to sub frame
3	Machine/weld linkage arms
4	Machine/weld linkage arms
5	Machine/weld motor and linkage supports
6	Machine/weld motor and linkage supports
7	Machine/weld motor mount
8	Assemble and mount drive mechanism
9	Test for fitment and adjust final assembly
10	Mount battery and wire electrical system
11	Test final assembly for functionality
12	Prepare showcase for tech expo
13	Present at tech expo

***PURPOSED* BUDGET:**

Item	**Cost ($)**
Steel structural	317
Motor	420
Bearings	30
Linchpins	22
Shaft collars	23
Hardware (all)	30
Steel Target	70
Drive hub	12
Electrical components (switch, wire ect)	55
55ah deep cycle battery	120
Ideal total ($)	
1000	
Total ($)	
1100	

***ACTUAL* BUDGET:**

Actual budget	
Item	**Cost ($)**
Structural Steel	200
Motor	418
Bearings	37
linchpins	10
Hardware (all)	25
Steel Target	70
Drive Hub	33
Electrical Fittings	25
55AH deep cycle Battery	110
Paint	9
Shaft Collars	27
Electrical Components (switch, housing etc.)	48
Ideal total ($)	
1000	
Total ($)	
1012	

Shipping and sales tax costs are figured into individual component cost

Tools:
Metal cutting band saw
Drill press
Drill bits (English standard)
Crescent Wrenches (English standard)
Allen wrenches (English standard)
Grinder/Metal files
MIG welder (flux core wire)
Component and assembly drawings for project

Sub frame:
Cut 2inx2in A513 steel tube to 48in (cut 2x) (per component technical drawing)
Cut 2inx2in A513 steel tube to 60in (cut 2x) (per component technical drawing)
Cut 2inx2in A513 steel tube to 36in (cut 3x) (per component technical drawing)
Bore .75in diameter hole in 36in long tubes (per component technical drawing)
Arrange 48in and 60in tubes (per frame assembly welding drawing)
MIG weld tubes together (per frame assembly welding drawing)
Arrange 36in tubes on frame (per frame assembly welding drawing)
MIG weld tubes together (per frame assembly welding drawing)

Armature assembly:
Cut 2inx3in A513 steel tube to 6in (cut 2x) (per component technical drawing)
Bore .75in diameter hole in 6in long tube (per component technical drawing)
Arrange 2inx3in tubes and remaining 2inx2in A513 36in tube (per armature assembly drawing)
MIG weld tubes together (per armature assembly drawing)
Position ⅜ in thick steel silhouette target on welded armature (per armature assembly drawing)
Insert 1 grade 5 .75in bolt through each of the 2 aligned holes through the target and support
Thread on .75in hex nut onto each of the support bolts
Tighten bolts with wrench

Armature and sub frame subassembly:
Position armature and sub frame (per final assembly drawing)
Insert .75in diameter lynch pin through both vertical supports and armature mating holes
Stack .25in washers between support 2 and the retaining pin hole on lynch pin
Insert retaining pin into hole on lynch pin

Rocker stop:
Cut 2inx2in .125 tube long tubes (per component drawing)
Cut 2inx2in .125 tube short tubes (per component drawing)
Position 4 tube pieces (per rocker stop assembly drawing)
MIG weld tubes together (per rocker stop assembly drawing)

Drive Mechanism:

Motor support:

Cut 12inx5in .25in A36 steel plate (per component technical drawing)
Bore hole pattern into plate (per component technical drawing)
Cut 5inx5in .25in A36 plate (per component technical drawing)
Bore hole pattern into plate (per component technical drawing)
Cut 2inx3in 24in long A513 steel rectangular tube (cut 6x) (per component drawing)
Position 2x 2inx3in cut tubes and 12inx5in steel plate (per motor support assembly drawing)
MIG weld positioned components along full lengths (per motor support assembly drawing)
Position 1x 2inx3in cut tubes and motor support (per motor support assembly drawing)
MIG weld positioned components along full lengths (per motor support assembly drawing)
Position 2inx3in cut tubes on either side of motor support (per motor support assembly drawing)
MIG weld positioned components along full lengths (per motor support assembly drawing)
Position 5inx5in steel plate and motor support (per motor support assembly drawing)
MIG weld positioned components along full lengths (per motor support assembly drawing)

Linkage arms:

14in linkage arm:
Cut 1inx3in rectangular tube (per component drawing)
Bore .1875 holes for shaft hub (per component drawing)
Cut .625in diameter A36 round bar (per component drawing)
Position round bar on linkage arm (per linkage assembly drawing)
MIG weld round bar to linkage arm (per linkage assembly drawing)
Position shaft hub on bolt hole pattern (per linkage assembly drawing)
Insert 1 3/16in bolt into each hole (per linkage assembly drawing)
Thread 3/16in nut onto each bolt (per linkage assembly drawing)
Tighten nuts with wrench

24in linkage arm:
Cut 1inx3in rectangular tube (per component drawing)
Cut 2x 2inx2inx1in .083 square tubes (per component drawing)
Bore .25in holes for bearing (per component drawing)
Bore .625in hole for linkage pin (per component drawing)
Bore .75in diameter hole for pivot pin
Position each 2inx2inx1in square tube on rectangular tube (per linkage assembly drawing)
MIG weld both tubes in place (per linkage assembly drawing)
Position bearing on bolt hole pattern (per linkage assembly drawing)
Insert 1 .25in bolt into each hole (per linkage assembly drawing)
Thread .25in nut onto each bolt (per linkage assembly drawing)
Tighten nuts with wrench

30in linkage arm:
Cut 1inx3in rectangular tube (per component drawing)
Bore .25in holes for bearing (per component drawing)
Bore .625in hole for linkage pin (per component drawing)
Cut .625in diameter A36 round bar (per component drawing)
Position round bar on linkage arm (per linkage assembly drawing)
MIG weld round bar to linkage arm (per linkage assembly drawing)
Position bearing and housing on bolt hole pattern (per linkage assembly drawing)
Insert 1 .25in bolt into each hole (per linkage assembly drawing)
Thread 1 .25in nut onto each bolt (per linkage assembly drawing)
Tighten nuts with wrench

Linkage front support assembly:
Cut 1x 2inx3in rectangular tube 24in
Cut 2x 2inx3in rectangular tubes 27.75in
Bore .75in hole in each 27.75in rectangular tubes
Position 27.75 tubes on 24in tube base
MIG weld 27.75in tubes to 24in tube base

Final assembly of frame:
Position linkage front support assembly in sub frame
MIG weld linkage front support assembly to sub frame

Linkage assembly:
Insert linkage pin from 30in linkage arm into bearing on 24in linkage arm
Position shaft collar onto exposed shaft end
Tighten shaft collar with Allen key
Insert linkage pin from 14in linkage arm into bearing on 30in linkage arm
Position shaft collar onto exposed shaft end
Tighten shaft collar with Allen key

Final assembly:
Position 280in-lb motor on motor support assembly (per final assembly drawing)
Engage shaft key with shaft hub on first linkage arm
Insert 1 .25in bolt through each motor mount hole and the mounting plates
Thread on .25in hex nut onto each motor mount bolt
Tighten hex nuts with wrench
Position .75in hole in 22in linkage arm with .75in hole in front linkage supports
Insert .75in linchpin through all 3 tubes
Stack 5 .25in thick .75in bore washers between end of pin and second support
Insert retaining pin into hole in lynch pin

Wiring:
Position 55ah battery beneath motor support
Wire motor to 30amp dc motor controller
Insert 110v 35 amp switch into switch box
Wire 30-amp dc motor controller to 110v 35-amp switch
Wire 110v 35amp switch to 55ah battery
Begin testing phase

PLANS TO TEST STEEL SILHOUETTE RESETTING TARGET SYSTEM

Test Standards:
9mm ammo - 115gr FMJ
5.56 ammo - 55gr FMJ
308 ammo - 125gr FMJ

9mm Pistol barrel length - >4in
5.56 rifle barrel length = 16in
308 rifle barrel length - >20in

Pictures and videos will be taken during all test phases

Test 1: Test armature and frame for defects (drive mechanism is not installed yet)

Shoot target from 15-25yrds with 9mm full size pistol
Clear firearm
Inspect target and frame for stress related issues (if fails stop testing)

Shoot target from 100yrds with 5.56 caliber rifle
Clear firearm
Inspect target and frame for stress related issues (if fails stop testing)

Shoot target from 300yrds with .308 caliber rifle
Clear firearm
Inspect target and frame for stress related issues (if fails stop testing)

Post Test 1:

Make repairs or modifications to frame/retest if necessary

Test 2: Test final assembly (drive mechanism and electrical system are installed)

Shoot target from 15-25yrds with 9mm full size pistol
Clear firearm
Press reset button until target resets (if fails stop testing)
Inspect assembly for defects
Press reset button hold then flip E - stop switch (if fails to stop movement stop testing)

Shoot target from 100yrds with 5.56 caliber rifle
Clear firearm
Press reset button until target resets (if fails stop testing)
Inspect assembly for defects
Press reset button hold then flip E - stop switch (if fails to stop movement stop testing)

Shoot target from 300yrds with .308 caliber rifle
Clear firearm
Press reset button until target resets (if fails stop testing)
Inspect assembly for defects
Press reset button hold then flip E - stop switch (if fails to stop movement stop testing)

Post test 2:

Make repairs or modifications/retest if necessary
Testing complete

APPENDIX D

DC electric motor

Manufacturer:
Dayton motors

Specs:
DC
12v
280in-lb
9.4A max draw
reversible

Bearing/Bearing housing

Manufacturer:
Industrial surplus

Specs:
200 series bearing
5/8in bore
1/4in mounting holes
Stamped sheet steel housing

Push button switch

Manufacturer:
Woodstock

Specs:
110v
35Amp
Momentary switch

DC electric motor controller

Manufacturer:
Unique goods

Specs:
DC
30Amp
12-80v
LED display

55AH Battery

Manufacturer:
Universal Power

Specs:
12v
55AH
Rechargeable
Maintenance free

Steel silhouette target

Manufacturer:
AR 500 target solutions
Specs:
12in L x 20in H
5/8 mounting holes
AR 500 steel
3/8in thick

Switch housing

Manufacturer:
Taymac

Specs:
Weather proof
1/2in outlets
Single outlet box