Strider

By

Eric Johnson
Ricardo Garcia
Alex Trask

Mechanical Engineering Department
California Polytechnic State University
San Luis Obispo
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Statement of Disclaimer

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CALIFORNIA POLYTECHNIC STATE UNIVERSITY

Strider

Final Report

Sponser: Dr. Kevin Taylor

Amy Cooper

Advisor: Dr. Lou Rosenberg

Prepared By: Alex Trask

adawt9@gmail.com

Eric Johnson

erictimothyjohnson@gmail.com

Ricardo Garcia

rdgarcia@calpoly.edu

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Chapter 1: Introduction

The purpose of this project is to design and build a STRIDER (STanding RIDER) for Nathan Cooper. Nathan is a four year old boy in San Luis Obispo with Spinal Muscular Atrophy (SMA). SMA is a neuromuscular disease which results in weakness and limited motion in the limbs, particularly the legs. Because of this weakness, Nathan is forced to spend most of his time in a sitting or laying position. Therefore, the STRIDER project strives to create a device which will support Nathan in a standing position, facilitating better circulation and allow him to get some physical exercise. With increased exercise, the hope is that Nathan will develop strength and endurance, breaking some of the barriers previously associated with patients having SMA.

Chapter 2: Background

Nathan

Nathan Copper is a 3-year-old boy who suffers from Spinal Muscular Atrophy (SMA), a disability that does not allow for complete muscular development. Amy, Nathan's mother, has spent a lot of time and effort trying to find the best means to provide transportation and exercise for him. Nathan's current means of exercise include water therapy, stretching, swinging, and vibration therapy from his current standing electric wheel chair. One added therapy that will greatly befit Nathan is moderate impact in his legs that will help to build up his bone density. High bone density correlates to stiffer bone, which minimizes the chance of braking or fracturing.

Nathan's current mobility devices include a "Go-Bot" and "The KidWalk". Both devices have positive features and drawbacks. For instance, the "Go-Bot" allows Nathan to move around because it's electrically powered, but it does not provide a form of exercise. It is very heavy making it difficult to transport, is very expensive ($13,000), and locks Nathan in an upright frontal position with limited perimeter interaction. While "The KidWalk" allows more for frontal perimeter interaction, it can be very uncomfortable and does not supply all the support that Nathan needs.

Figure 1: Nathan boogying around in his Go Bot. The Go Bot allows Nathan to move around freely, but it does not allow him to interact with anyone or anything directly in front of him. The Go Bot also does not provide head or neck support for Nathan.

Figure 2: "The KidWalk" is a passive standing wheel chair that tends to be uncomfortable and isn't collapsible for portability. www.primeengineering.com

Spinal Muscular Atrophy

SMA is a neuromuscular disease affecting the motor neurons, neurons responsible for stimulating muscle contraction, of the Central Nervous System (CNS). More specifically, damage of the lower motor neurons (horn cells) and is characterized with muscle weakening and atrophy. Without the proper functioning of the motor neurons, muscle fibers are unable to receive the muscle impulses generated by the neurons to initiate an action required to contract the skeletal muscle, which ultimately inhibits voluntary movement of the muscular system. Without regular usage, the muscle tissue decreases (entropies) in size and weakens.

The skeletal muscular system is an organ system developed from the somatic nervous system (SNS), providing the body with support, temperature regulation, movement, posture, and sites of attachment (tendons) for bone, skin, and other muscles. A mutation within the Survival of Motor Neuron 1(SMN1) gene located on chromosome 5 initiates the development of a protein that has adverse effects and is manifested into the symptoms that coincide with the disease.

Symptoms for SMA vary from infancy to childhood and include: difficulty in breathing and feeding, poor muscular tone development, little spontaneous movement, a progressing weakness of the muscular system, speech impediment, and poor posture and can develop into severe infections within the respiratory system. SMA is one of the leading causes of infant mortality. One out of every twenty-five thousand people have the disease and usually both father and mother must carry the recessive defective gene in order for the patient to display characteristics of the disorder1. Although, there are no present treatments for the deteriorating disease, physical therapy and corrective surgery are available to help alleviate the effects of SMA.

Spinal Muscular Atrophy is categorized into three types, ranging from severity and the time of onset. Type 1 SMA (SMA1) display symptoms at six months and patients require assistance in sitting upright. Patients with type 1 SMA do not survive past two years. Nathan carries type 2 SMA (SMA2) which is not as severe. Nathan and other patients show symptoms between six and eighteen months and are able to sit unaided, but may develop scoliosis and become wheelchair bound. As the least severe of the three forms, type 3 SMA patients are able to walk unaided and maintain a normal lifespan. Type 3 SMA occurs in infants eighteen months or older.

Aside from the structural and functional complications that accompany SMA, patients sustain normal facial, upper and lower limb sensations and no evident deviations of intelligence.

Medical Breakthrough:

There has been no specific therapy for patients with SMA. Treatment is mainly supportive, with its primary aim towards preventing the development of complication like respiratory infections and scoliosis. Therefore, a new therapeutic strategy is of great importance.

A recent study conducted in 2005 determined that regular exercise prolongs survival in type 2 SMA on mice2. The study consisted of three different physical exercises that tested a mouse's endurance, strength, and ambulatory behavior. Although these tests were conducted on lab mice that share like symptoms and characteristics found in humans with SMA the article strongly believes that similar results can be achieved with humans3.

The results concluded that the mice experienced better sustainability of their motor functions, and lived about 57.3% longer. This research provided the first evidence of the benefits of exercise in SMA patients and might lead to important therapeutic development for human.

References:

1. fightsma.org, http://www.fightsma.org/index.php?fact_sheet, 10/10/2009
2. The Journal of Neuroscience, August 17, 2005, http://www.jneurosci.org/cgi/reprint/25/33/7615, 10/13/2009
3. Oxford Journals, http://hmg.oxfordjournals.org/cgi/content/full/9/5/849 10/13/2009

Chapter 3: Design Development

Objective

The end objective of the Strider project is to provide Nathan with a device that provides the ability to perform exercise in the vertical position. The device must be able to fully support Nathan while he is in a standing position as well as allow him to support a small amount of his weight on his own. The Strider must also work with Nathan's hip, knee, ankle and foot orthotics (HKAFO) and ideally it would be able to replace the HKAFO while he was in the device.

The project requirements and goals from the original Strider presentation are listed below. This list includes all the requirements that must be met to consider the project as a success.

- Goals and Requirements
    - Provide a working prototype of the Strider by May 10th, 2009
    - Provide exercise and health benefits for Nathan
    - Able to accommodate Nathan for ages 4 – 6 years.
    - Enjoyable way to exercise
    - Survive duration of Nathan's use
    - Include a suspension that allows Nathan to traverse multiple terrains without sustaining injury
    - Easy to assemble and disassemble for transport
    - Low weight
    - Easy for Nathan to get into and out of
    - Compatible with or in place of HKAFO
    - Adaptable for future improvements
    - Variable weight bearing for different levels of exercise
    - Easily maneuverable
    - Cleanable and maintainable

A complete list of the engineering specifications for the Strider has been developed and is outlined on the next page. This list is a summary of the table which contains the specifications, target values, risk, and compliance. The complete table can be found on the page following the summary list. The specifications were taken from a combination of the design requirements given by Dr. Taylor and existing devices that are similar in function but designed for a different need.

- Specifications
  - Geometry
    - Width: 24 in
    - Length: 36 in
    - Height: 40 in
    - Wheel Size: 10 in
    - Portable Width: 12 in
    - Portable Length: 36 in
    - Portable Height: 40 in
  - Forces
    - Droppable Height: 5 ft
    - Durability: Minor impact
    - Weight Range: 25 – 60 lbs
    - Weight Bearing: 100 – 90 % Nathan's weight
  - Operation
    - Age Range: 4 – 6 years
    - Enjoyable: yes
    - Ease of Assembly: Able to be assembled by one adult
    - Ease of Accessibility:
    - Life Expectancy: 5 years
  - Transport
    - Weight: 40 lbs
    - Steps to Transport: 6 steps
  - Maintenance
    - Wear: Dirt resistant
    - Cleaning: Able to be cleaned with household products
  - Assembly
    - Expansion: Expandable with household tools
  - Safety
    - Overall Safety: Sponsor's approval
    - Finish: No sharp edges
    - Sturdiness: 30° tilt
  - Cost
    - Total Cost: $1500

The main goal of the Strider project is to provide Nathan with a way to get exercise, but we are also making something that allows Nathan more freedom and interaction with the environment. The project is being designed with the mindset of having the Strider be as unobtrusive as possible. We want Nathan to be able to interact with other children, move the Strider off of smooth concrete, and have more freedom than he currently has with his other aides.

Table 1: Complete list of engineering specifications with level of rick and how each specification is to be tested

Design Specifications				
Spec. #	**Parameter Description**	**Target**	**Risk**	**Compliance**
1	Width	24 in	L	I
2	Length	36 in	L	I
3	Height	40 in	L	I
4	Weight	40 lbs	M	A, I
5	Wheel Size	10 in	L	I
6	Life Expectancy	5 years	H	A
7	Enjoyable	yes	M	U
8	Portable Width	12 in	H	I
9	Portable Length	36 in	L	I
10	Portable Height	40 in	L	I
11	Ease of Assembly	Able to be assembled by one adult	M	U
12	Ease of Accessibility	Nathan is able to get into and out of with the help of one adult	M	U
13	Wear	Dirt and sand resistant	M	A, T
14	Cleaning	Able to be cleaned with household products	L	I
15	Steps to Transport	6 steps	M	I
16	Expansion	Expandable with household tools	H	I
17	Droppable Height	5 ft	H	T
18	Durability	Minor impact	M	T
19	Cost	$1,500	H	I
20	Age Range	4 - 6 years	M	A
21	Weight Range	25 - 60 lbs	H	I
22	Weight Bearing	100 - 90 % Nathan's weight	M	T, I
23	Overall Safety	Sponsor's approval	M	U
24	Finish	No sharp edges	L	I
25	Sturdiness	30° tilt	H	T

Legend	
Risk	
L	Low Risk
M	Medium Risk
H	High Risk
Compliance	
A	Analysis
I	Inspection
U	User Feedback
T	Test

Method of Approach

Early research was a key component to tackling this project. There are many assistive devices on the market which address some of the issues that the Strider strives to address, however no device addresses all of them. We used these existing products in the early design process to gather an idea of proven concepts as well as for additional design ideas. We sought the advice of several local medical professionals in order to help define Nathan's needs relating to comfort and ergonomics.

The evaluation of the various design concepts was primarily done using a decision matrix. We received continual input on the design from our sponsor and kinesiology contact to determine if the design met Nathan's needs. The in-class design reviews and presentations allowed our team to get input on the designs and different perspectives on possible issues. Rough analysis was then used to determine if the design was plausible and once it was shown to be, in depth analysis was used to determine the size of the components.

The final design process was a continual evolution throughout the project. Before we started any manufacturing, we submitted our final design to Dr. Rosenberg, Dr. Taylor, our Kinesiology contacts, and Nathan's mother Amy. Once we got approval from all parties involved, we counted that as our final design and created dimensioned drawings for use during manufacturing.

The manufacturing process was a very time consuming part of our project as we were not prepared for some of the obstacles we encountered. We ended up having to find professional help for the welding and sewing that was critical to Nathan's safety. The manufacturing process also forced us to continuly evolve our final design. There were several features of our original design that were not possible to create in the machine shop.

After manufacturing we were able to start our testing phase. The prototype passed most of the tests, but several small issues became evident as the testing progressed. We have documented the changes that need to be made and plan on working out the current minor problems after the completeion of the project.

Design Development

Concepts

The following concepts are split into two categories, complete system concepts and component concepts. The decision process, which will be discussed later, was done by splitting the project into components that were taken from both the component concepts and the complete system concepts. The components the Strider was split into are support, variable weight bearing, and frame.

Complete System

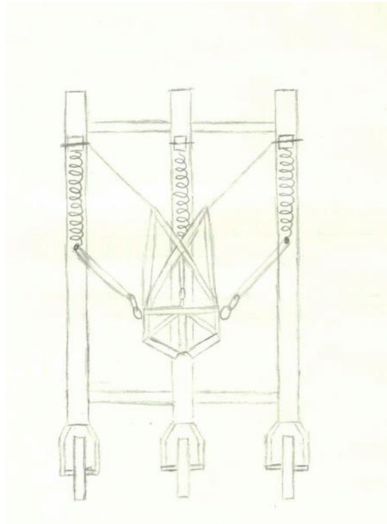


Figure 3: The concept shown is based on a current design by Cal Poly's chapter of SHPE. This design uses pulleys that are attached to springs enclosed in hollow support tubes. The three point suspension of Nathan would allow him to be fully supported by the Strider. To adjust to Nathan's growth and to allow him a varying amount of interaction with the ground, the springs would have to be moved up or down in the tubes which would result in Nathan moving up or down with relation to the ground.

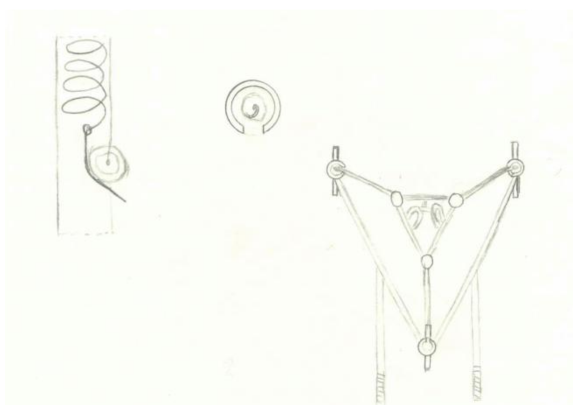


Figure 4: Top view and detail of the concept shown in Figure 3.

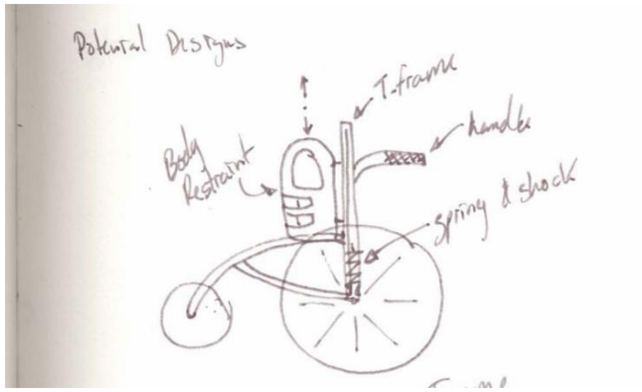


Figure 5: This complete system is a quick sketch several components that are detailed below. More information on each component will be given is the discussion of the concept of that component.

Support

We have come up with three support options for holding Nathan while he is in the Strider. The vest option is shown below in figure 6, the full body harness is shown on the previous page in figure 3, and the climbing harness is shown on a following page in figure 10 .

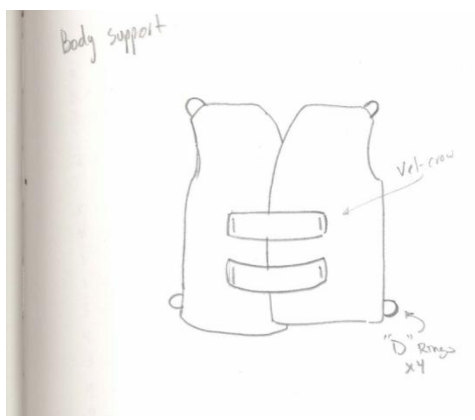


Figure 6: A vest support of Nathan. This support system would be easily incorporated into the other components of our design and would possibly allow for use of his HKAFO with the Strider.

Variable Weight Bearing

Coil Over

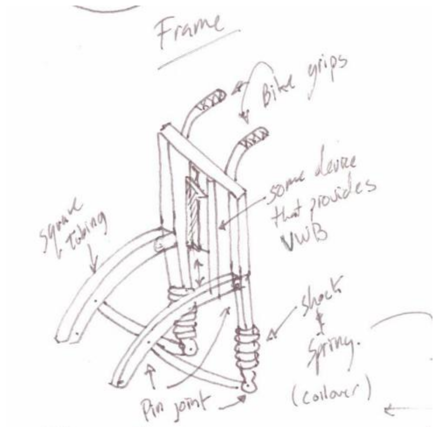


Figure 7: Coil-over suspension system. This system features two springs, one on each side, that rest on stationary perch and one moving perch. The top perch is attached to a threaded sleeve that allows it to be adjusted up or down. The moving of the top perch effectively will change Nathan's position in relation to the ground which will allow him the opportunity to be fully support by the Strider or to support some of his own weight. When the top perch is threaded down, the spring will push Nathan away from the ground which will allow the Strider to support more of his weight.

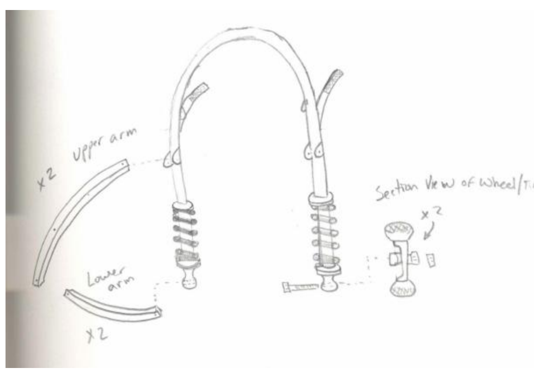


Figure 8: A detailed view of the coil-over suspension system. This figure shows and exploded view of Figure 7.

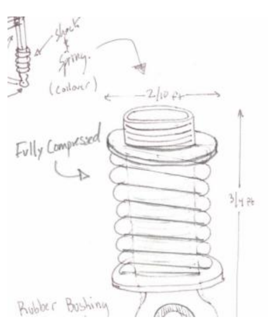


Figure 9: Detailed view of one spring in the fully compressed position.

Pogo Suspension System

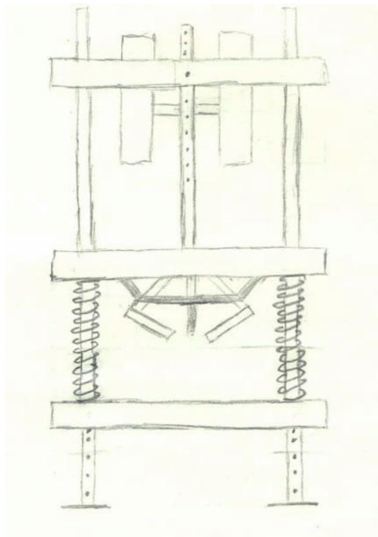


Figure 10: Back view of the Pogo Suspension system. The second variable weight bearing concept has been given the nickname of Pogo. This design utilizes a climbing harness and shoulder strands to support Nathan while in the Strider. The Pogo design works with three moveable horizontal bars that are all supported by two parallel tubes. The bottom horizontal bar is what allows Nathan to be moved in relation to the ground. By lowering the bottom bar, Nathan would be moved closer to the ground which would allow him the opportunity to support varying amounts of his weight.

The middle horizontal bar is where the climbing harness that supports Nathan would connect to the VWB. This bar is free to move in the vertical direction and rests on two springs for support. The two springs provide both a suspension for the entire device and the opportunity for Nathan to be fully or partially supported by the Strider.

The top bar provides support for Nathan's upper body. This bar moves independently from the other two allowing for adaption to Nathan's growth.

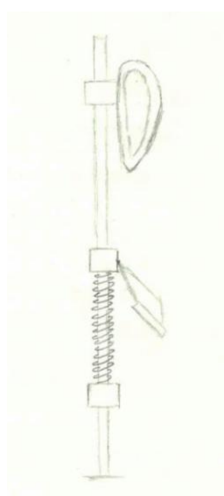


Figure 11: Side view of the Pogo suspension shown in figure 10 with added shoulder straps.

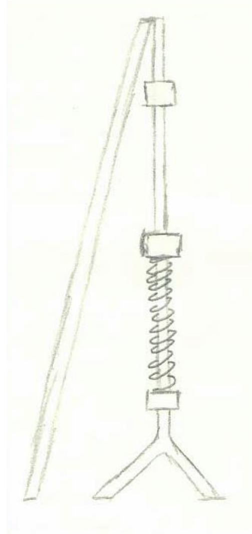


Figure 12: Another side view of figure 10 with added support to compensate for the bending moment created if Nathan were to be put into the device.

Cliffhanger Suspension

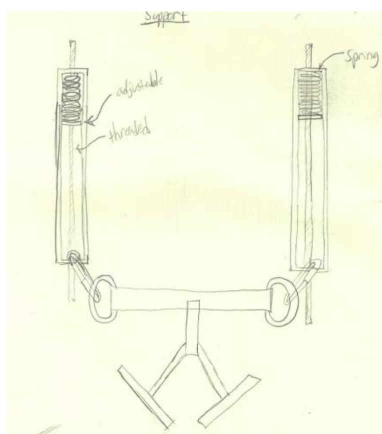


Figure 13: Cliffhanger suspension for the variable weight bearing. This design is very similar to the Pogo design except that the spring would be located above the climbing harness and adjustments would be made by moving the bottom of the spring along a threaded rod. This design would also feature a climbing harness and shoulder straps for support.

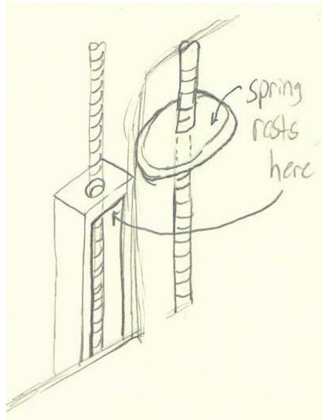


Figure 14: Detailed view of the threaded portion of the Cliffhanger suspension shown in Figure 13.

Frame

We have three concepts for the design of the Strider frame; four wheels, three wheels with one in front and three wheels with one in back. Sketches and discussion of each type are shown below.

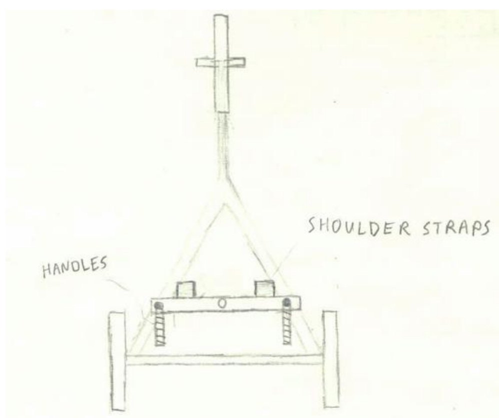


Figure 15: Three wheel frame design with one wheel in front. This concept is modeled after many of the jogging strollers that are on the commercial market today. This frame is very stable and versatile, but it does not give the feeling of openness for Nathan that we are trying to accomplish. The one wheel in front cuts off any interaction Nathan would have with someone or something directly in front of him, but does allow him interaction to the sides of the front wheel.

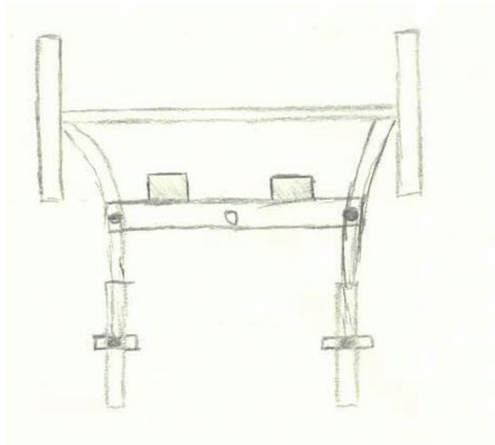


Figure 16: Four wheel design. This design is a combination of "The Kidwalk" shown in figure 2 and a standard wheelchair. The four wheel design allows Nathan to have a lot of interaction with people and things in front of him and provides a compact frame that can incorporate the variable weight bearing concept. This design is slightly less stable than the three wheel designs, but it is more compact and maneuverable. The four wheel design can also be created with or without the front axle.

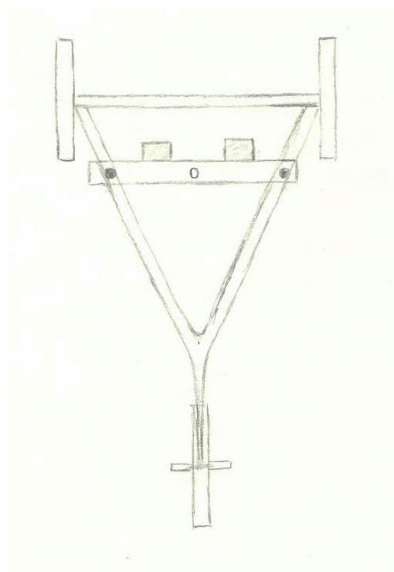


Figure 17: Three wheel design with one wheel in back. Like the four wheel concept, this frame allows Nathan an open front for interaction with things in front of him. The three wheel design is also the most stable, but it is less maneuverable than the other two, more restricted to flat surfaces, and uncomfortable for anyone walking behind it.

Decision Process

We split the project up into three components: the frame, the support system and the variable weight bearing (VWB). The decision for each component was based on a decision matrix that utilized a number of different criteria, which can be seen in the decision matrices below. Each criterion was given a weight of one to five, with five being most important to the design and one, not critical to the design. We then evaluated the designs with respect to each criterion, giving each design a value of one to five, depending on how well that design fulfilled a particular criterion. Much of this was speculation, as things such as comfort, could not be given concrete, quantitative values without actual testing, and it was not feasible or practical to manufacture or purchase each option. Instead, we made the best decision that we could, based on our experience and engineering background. The criteria varied slightly between each component because each component addressed different design requirements. Also, there were some criteria, such as durability, which we felt were answered equally by each design.

While the decision matrices were used in order to get an idea of which concepts would provide for the best device, the final decision on a concept is pending the input and approval of our sponsor.

Table 2: Decision matrices for each concept of all three components of the Strider.

Support				
Criteria	Weight Factor	Vest	Full Body Harness	Harness and Upper Body Support
Safety	5	3	4	5
Stability	5	4	5	5
Durability	4			
Openness	4	3	2	4
Ease of Ingression / Digression	4	5	1	5
Enjoyable	4			
Comfort	4	2	3	4
Aesthetics	4			
Weight	3			
Ease of Adjustability	3	3	1	5
Incorporation of HKAFO's	3			
Simplicity of design	2	5	3	4
Cleanable	2			
Maintenance / Serviceability	2			
Total		94	78	**125**

Variable Weight Bearing				
Criteria	Weight Factor	Design 1 (Coil-over)	Design 2 (Pogo)	Design 3 (Cliffhanger)
Safety	5			
Stability	5	5	5	4
Durability	4			
Comfort	4			
Aesthetics	4			
Weight	3	4	4	5
Ease of Adjustability	3	3	5	2
Simplicity of design	2	4	5	2
Incorporation of Vibration	2			
Cleanable	2	5	5	4
Maintenance / Serviceability	2	5	5	2
Total		**74**	**82**	57

Frame				
Criteria	Weight Factor	4 Wheel	3 Wheel-1 in Front	3 Wheel-1 in Back
Safety	5	4	4	3
Stability	5	4	5	5
Durability	4	5	5	5
Openness	4	5	2	4
Ease of Ingression / Digression	4	4	3	4
Enjoyable	4	3	5	3
Aesthetics	4	3	4	4
Weight	3	3	4	2
Collapsible for portability	3			
Ease of Adjustability	3			
Maneuverability	3	5	4	3
Braking System	3	5	5	5
Simplicity of design	2	5	3	3
Incorporation of Vibration	2			
Cleanable	2			
Maintenance / Serviceability	2	3	4	4
Terrain mobility	1	3	2	1
Adaptability of Power Drive	1	3	3	2
Total		**181**	**179**	167

Final Concept Development

For our final concept, we selected the top two choices for both the frame and the VWB since both areas had two choices that came out very close in the decision matrix. The two choices for the VWB were the coil-over design shown in figure 7 and the Pogo design shown in figure 10. The three wheel frame with one tire in front shown in figure 15 and the four wheel frame shown in figure 16 were the top two choices for the frame category.

After we narrowed it down to four concepts, in conjunction with our sponsor, we selected our final concepts. We are using the Coil-over suspension system and the four wheel concepts to proceed with our design.

For proof of concept, we did some preliminary stability calculations and stress analysis. Our analysis showed that a wall thickness of 0.25 inch for the H-Beam sleeve was sufficient to prevent failure. We also figured out that its takes a minimal external force of 100 lbs to tip the Strider over. All of these calculations were modeled with Nathan in the Strider and no external help for stability. For more detailed description of this analysis see Appendix C.

Chapter 4: Description of Final Design

Design Description

The Strider has various components which address different requirements in the design. Below are pictures of the final design with descriptions explaining their function. Detailed drawing of individual components and the entire Strider design are available in Appendix F.

Figure 18: Isometric view of the complete Strider design. This model features 12.5 inch rear wheels, 12.5 inch free rotating front wheels, and an overall height of 44 inches.

The design of the Strider allows for Nathan to get in and out of it easily. The primary support, the harness, can be put on Nathan separate from the Strider. This can then be attached to the harness supports through the use of carabineers Figure 18.

Figure 19: Side view of the Strider. The bottom carriage will extend Nathan 12 inches from the H-Beam behind him. The addition of wheelie bar minimizes the possibility of Nathan tipping over.

The harness supports and back plate are extended from the H-beam in order to allow Nathan the freedom to swing his legs without obstruction.

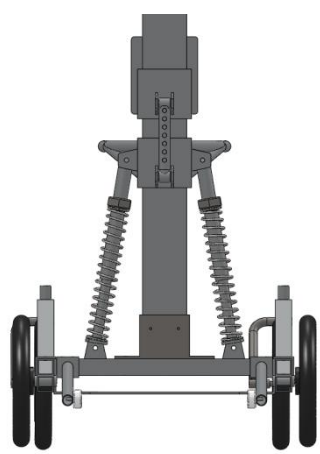


Figure 20: Rear view of the coil-over suspension system. The picture shown would be the Strider without Nathan in it and at maximum spring defection.

The primary functions of the coil-over system are to allow Nathan to support a varying amount of his own weight and to allow for growth. Twisting the perches associated with each coil-over raises or lowers the carriage. Lowering the carriage increases Nathan's interaction with the ground, allowing him to support more of his own weight and raising the carriage can allow Nathan to be completely supported by the harness. The coil-over system also serves as suspension and allows Nathan to bounce in the Strider.

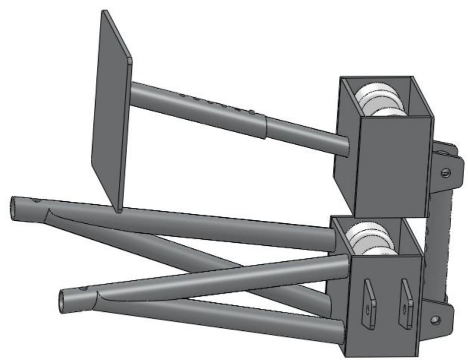


Figure 21: An isolated view of the double carriage support system. The cylinders shown on the back plates connect the top carriage to the bottom carriage and allow for adjustment to account for Nathan's growth over the next 3 years.

The upper body support is a plate for his back, which was shaped and padded for comfort, with a chest strap similar to the one used in his HKAFO's. This upper carriage is attached to the bottom carriage which allows his entire body to move in unison when bouncing but can be adjusted in relation to the lower carriage to facilitate growth.

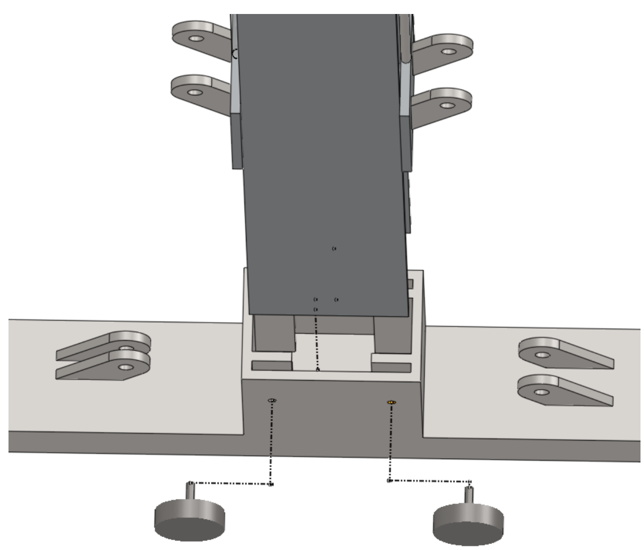


Figure 22: An exploded view of the H-beam and the sleeve that connects it to the base of the Strider. The dotted lines show the path that safety screws will travel to secure the H Beam in place.

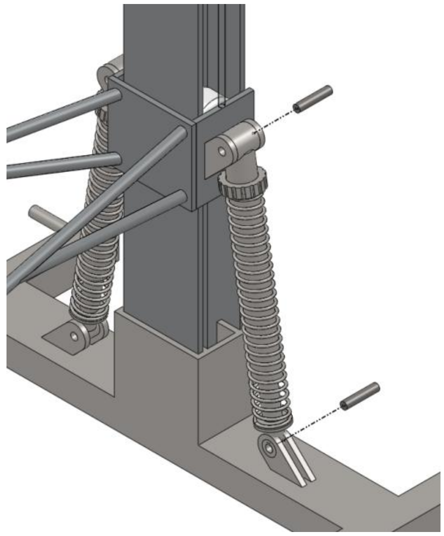


Figure 23: Exploded view of the coil-over system and the quick release pins used to connect the system to the frame and carriage. These pins are quick release which allows for easy transportation.

The Strider is designed to be portable. The H-beam can be removed from its sleeve by removing the safety screws from the back of the sleeve. The coil-overs are removed by a simple locking pin (similar to a weight machine locking pin) which attaches it to the carriage and to the frame.

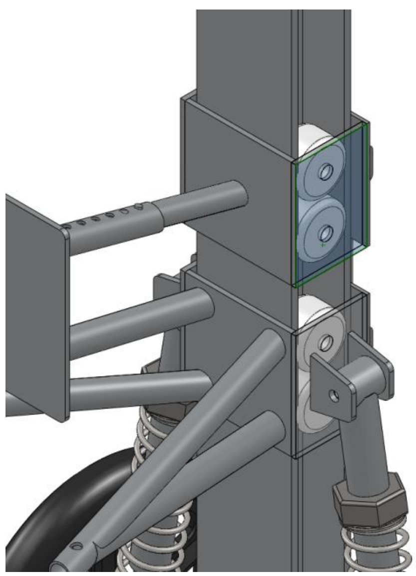


Figure 24: A detailed view of the rollers in the H-Beam. These rollers allow both Nathan to be completely supported by the springs and any moments created to be transferred to the H-Beam instead of the coil-over system.

The H-beam is used as a track for the rollers which allow the carriages to move freely in a vertical motion. By using rollers the entire vertical load of Nathan and the carriages is transferred to and supported by the springs while any bending moment – caused by the extension of the carriage from the H-beam – is transferred through the rollers into the H-beam. The H-beam was selected because its geometry allows it to have a high stiffness and relatively low weight.

The wheels are spaced to ensure stability both on flat ground and on gentle slopes. Off-road bicycle tires are used which permits the Strider to be used on various terrain, including light trails. Free rotating wheels are used in front allow for easy maneuverability.

Analysis

H-Beam

The H-beam is the primary vertical member in the design and serves as the track for the rollers to which the carriage is attached. In doing the analysis the following assumptions were made:

- The H-beam sees no vertical load (all vertical load is transferred through springs)
- The H-beam acts as a cantilever beam
- No stress concentrations
- No sleeve on base (the sleeve reduces the effective H-beam height, thus this assumptions is conservative)
- A "pushing" force of 15lbs (i.e. exerted by adult, through handles)
- Pushing force plus the weight of Nathan acts as an effective force at the top of the H-beam.

Beam theory was used to find the deflection at the end of the beam due to the effective force of Nathan's weight and the pushing force. Calculations were made for both aluminum and steel using EES and MATLAB (printouts can be seen in Appendix D). Charts were generated to show how flange thickness, flange width, web thickness and beam depth affected the beam deflection and beam weight (seen in Appendix E: H-Beam Analysis). These charts were used to determine which variables had the greatest impact on both deflection and weight. Table 3 below shows the relative impact that changing each variable has on these two criteria.

Table 3: Relative impact of each variable on the deflection and overall weight of the H-Beam.

	Deflection	Weight
Most Impact	Beam Depth (d)	Flange Thickness (t_1)
	Flange Width (w)	Web Thickness (t_2)
	Flange Thickness (t_1)	Flange Width (w)
Least Impact	Web Thickness (t_2)	Beam Depth (d)

On the next page, Table 4 shows the selected values for each of the four variables as well as the calculated values of deflection and weight for both aluminum and steel. The deflection values are well below the target of 0.05 in however a smaller beam would not be able to incorporate some of the features, such as the carriage rollers.

Table 4: Summary of selected values for the four variables in Table 3 and the calculations of deflection and weight for both aluminum and steel.

	t_1 (in)	t_2 (in)	w (in)	d (in)	Deflection	Weight

					(in)	(lbs)
Aluminum	.25	.25	4	2.5	.0216	7.05
Steel	.25	.25	4	2.5	.0075	20.3

Sleeve

The sleeve is the part on the lower frame that the H-beam rests in. The following assumptions were made during the analysis:

- The moment from the H-beam is transferred completely to sleeve.
- No vertical component of force is seen by the sleeve.
- The force is distributed evenly between all supporting surfaces.
- The force is distributed evenly across the width of the sleeve (dimension 'w')
- The force follows one of the two distribution models used (linear or quadratic).
- A "pushing" force exerted at the top of the H-beam = 10 lbs.

Calculations were done using MATLAB (printout can be seen in Appendix D). Initial calculations were made using a total of six supporting surfaces; however the middle supports were treated as one each. Figure 25 shows a top view of the sleeve with its supporting surfaces, labeled as they were during analysis (1 is the front, 4 is the back).

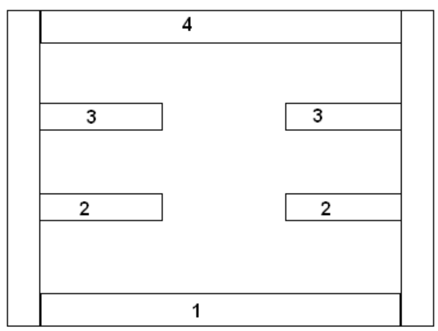


Figure 25: Diagram of the sleeve used in our initial calculations.

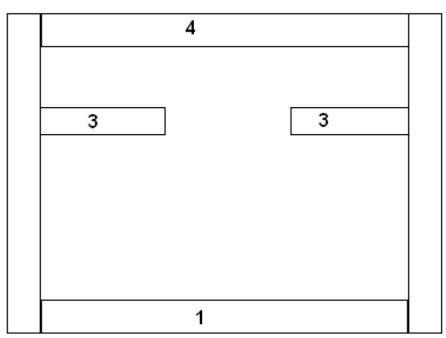


Figure 26: Diagram of the final design for the H Beam sleeve.

The analysis showed that members 1 and 3 were the main force-bearing members. Since member 2 was not a critical component, it was removed in order to make this piece significantly easier to manufacture. This resulted in the sleeve shown in 26 on the previous page.

A linear force distribution was used in the first analysis, however a quadratic force distribution is a slightly more accurate model and gives a more conservative approach and was therefore used for the primary analysis. The sleeve height, the thickness of each member as well as the length of each member (members 1 and 4 having the same length and members 2 and 3 having the same length) was varied to see what effect each would have on the factors of safety of each member (a minimum of 3.0 required on each). The selected values for both aluminum and steel are shown in Table 5 below.

Table 5: Summary of thicknesses chosen for the design of H Beam sleeve.

	t_1 (in)	t_2 (in)	t_3 (in)	t_4 (in)	w (in)	L_i (in)	h_s (in)
Aluminum	.375	N/A	.5	.25	4	.75	5
Steel	.25	N/A	.375	.25	4	.75	5

Stability

The stability analysis was done by finding the force required to lift one set of wheels (the front two, back two or side two) off the ground. The analysis showed that backwards tipping was most likely so a wheelie bar has been added in back to prevent tipping over. A side to side wheel base of 16 inches was found to require a force of 172 lbs acting at the top of the H-beam in order to tip the Strider. With this wheel base the Strider (with Nathan) will not tip over when on a slope of 30°. In order to allow Nathan sufficient room to be comfortable, as well as provide additional stability, the left-to-right wheel base is selected as 20 inches. The slope required for the Strider (with Nathan) to tip at this value is 40°.

Spring Stiffness

The spring's stiffness will be determined by knowing the desire defection of the spring as Nathan weight is fully supported and knowing the maximum weight that Nathan will weight over the desire life of the Strider (3 years). Using, growth charts from the National Center for Health Statistics[7], and knowing Nathan's current weight of about 35lbs. It was determined that Nathan will weight no more than 60lb over the intended use of the strider. The growth chart used was categorized for children between the ages of 2 to 20 years old within the 5th and 95th percentile. Nathan should fall well within the percentile because his disease doesn't affect his growth rate.

After determining Nathan expected weight and knowing the weight of the upper and lower carriage, it was determined that a total of about 70lbs would be supported by the springs. The spring configuration is that of two springs in parallel. Therefore the two springs share the same load and defection length, assuming they share the same spring rate. This would be ideal to minimize internal bending of the carriage on the H Beam. Hand Calculations of the spring system is located in the Appendix A???.

Harness Support

The harness support analysis was done to determine the size of supports needed to connect Nathan's harness to the Strider. Our calculations pointed us to use a 0.5 inch outer diameter aluminum tube with a wall thickness of .024 inches. These dimensions gave us a safety factor of 7.522 which we feel very confident in. We used these sizes because they are industry standards and readily available.

The supports were later changed to a 0.5 inch outer diameter with a wall thickness of 0.12 inch. We decided to go with the thicker tubing because it would have been impossible to weld the thinner wall thickness. When we got to the manufacturing process, we were forced to increase the size of the tubes again. The outer diameters of the tubes were increased to one inch to compensate for the carabineers, and also to increase the manufacturability of the carriage. The larger diameter tubes were significantly easier to weld when compared to the half in tubes. This changed results in a safety factor greater than 16.

Safety

Safety is the most important factor of the Strider design. The analysis process ensured that each component was designed to be safe for Nathan. Stability was one of the most obvious aspects of safety. The Strider needs to be able to maneuver over bumps and gentle slopes without the risk of tipping over. Analysis determined how wide the wheel base needed to be for sufficient stability. A wheelie bar is also included which allows the Strider to tilt backwards while not completely tipping over.

Structural integrity is another crucial safety consideration. Analysis was done on all the structural components (H-beam, sleeve, bottom frame, carriage, coil-overs, etc.) to ensure that they are sufficiently strong to support Nathan. A minimum safety factor of 4 was used during all design because the device is intended for human use.

Other safety concerns for the Strider included having no sharp edges or other areas where injury is possible from use of the Strider. There is ample room in our design to improve on these safety precautions. We did not design any sharp corners into the Strider, but there are many opportunities for pinching or other minor harm from handling of the prototype.

The final Strider design is missing wheel locks which are a major safety concern. Without these wheel locks, Nathan is free to roll out of control unless someone is handling the Strider. These wheel locks would also help for ingress and egress of the project.

Materials and Cost

One of the goals of the manufacturing process was to minimize the amount of custom parts we had to make so that parts could be easily replaced if the need arose. This was a hard goal to achieve for this prototype because so many of the parts had to be machined from bulk metal purchases. The other obstacle that made purchasing parts hard was the fact we were working with a $1500 budget.

The table on the next page shows all the vendors we purchased from, the amount of money we spent with each vendor and the total cost of the project. A complete list of vendors, materials, order numbers, and cost can be found in Appendix E.

Table 6: Summary of the vendors for all materials purchased for the Strider project along with the corresponding cost from each vendor and a total cost of the project.

Company	Purchase Amount
B&B Steel and Supply	$129.96

McMaster-Carr.com	$104.19
Lahr Industrial Welding Inc	$443.70
Ventura Metals (805-644-5511)	$252.20
www.REI.com	$54.87
www.kjmagnetics.com	$11.00
http://agressivemall.com	$17.97
http://www.dmartstores.com/	$159.96
http://www.centuryspring.com/	$49.78
TOTAL	$1,223.63

Chapter 5: Manufacturing, Testing and Results

Manufacturing

A complete set of dimensioned SolidWorks drawings were created for use during the manufacturing process. These drawings contained all the information we needed in order to fabricate all the custom parts in the Strider. The only parts that were not fabricated from the Solidworks drawings were the springs, wheels, wheel assemblies, fasteners, handlebars and the skateboard wheels. The parts that were not custom made for this project were purchased from various vendors. A complete list of vendors used is located in Appendix E.

The components that were not able to be purchased were custom made for the Strider prototype almost exclusively in the Cal Poly machine shop. The frame, H-beam, carriage assemblies, foot plate and coil-over suspension systems were created by machining sheet metal and solid Aluminum billet. Once all the parts had been machined, the majority of the welding was done by Lahr Industrial Welding Inc in Santa Maria, CA. While we were confident in our ability to machine the necessary parts for the Strider, we felt that we did not have the necessary skill or time needed to complete the welding in a safe way.

During the manufacturing process, it became apparent on several occasions that we needed to change our design in a small way to be able to complete the necessary fabrication. The most noticeable design change that was made due to manufacturing constraints was the positioning of the mechanism that connects the two carriages together. Our original design called for the connection to be on the sides of the carriage along with the connections for the coil-over suspension system. Once we started welding the carriages together, we realized that there was not enough room for everything to go on the sides. To fix this problem, we added a back plate to both carriages and attached the mechanism to the back plates, as is shown in Figure 27 on the next page.

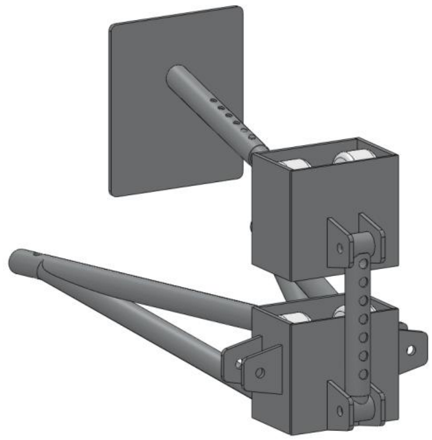


Figure 27: Rear view of the carriage assembly showing the design change for the connection of the two carriages.

The other two necessary design changes were an increase in diameter of the harness support tubes and a change in the mounting mechanisms for the wheels. The original design called for 1/2 inch tubes for the harness support which would not have supported the carabineers and also provided a challenge for welding. The increased size made welding possible and much easier and allowed for full size carabineers to be used. The change in the mounting of the wheels was necessary because the original design was effectively not possible to manufacture out of the materials were had available.

Assembly

In order to provide an easy way to transport the Strider, it was designed to be able to be fully broken down by a single person without any tools. Figure 28 shows the Strider completely disassembled and ready to be packed and transported.

Figure 28: Picture of the Strider completely broken down into all of its components.

The first step of assembly is adding the wheel to the frame. The front two wheels just slide into the open cylinders at the front of the fame and are held in place by strong magnets that were press fitted into the tubes. The rear wheels are attached with quick release pins that fit into the cylindrical holes below the back of the frame. Figure 29 shows the Strider after the first step of assembly.

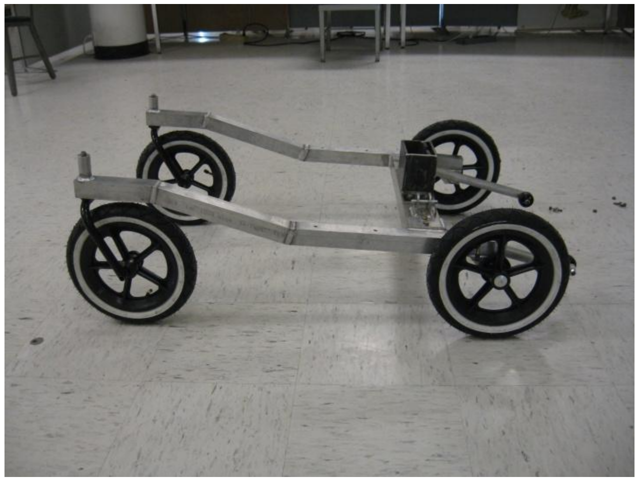


Figure 29: Step 1 of assembly, adding the wheels to the frame.

The second step of assembly is securing the H-beam to the frame. The frame has a sleeve that holds the H-beam into place. There are holes drilled though the sleeve and H-beam that allow for the use of quick release pins to lock the H-beam into place after inserting it into the sleeve. Figure 30 shows the Strider after the second step of assembly.

Figure 30: Step 2 of assembly, insert the H-beam into sleeve and secure with quick release pins.

The third step of assembly is to attach the coil-over suspension system to the frame. The coil-over system itself is three pieces that need to be assembled before attaching them to the frame. The coil-over systems are attached to each side of the frame by quick release pins. The smaller sides of the coil-overs are the sides that attach to the frame; the larger side attaches to the carriage. Figure 31 shows the Strider after step 3 of assembly.

Figure 31: Step 3 of assembly, attach the coil-over suspension system to the frame with quick release pins.

The fourth step of assembly is to attach the lower carriage to coil-over suspension. The carriage is inserted into the H-beam with the harness supports facing forward. The top of the soil-overs are then attached to the carriage by quick release pins. Figure 32 is a picture of the Strider after step 4 of the assembly.

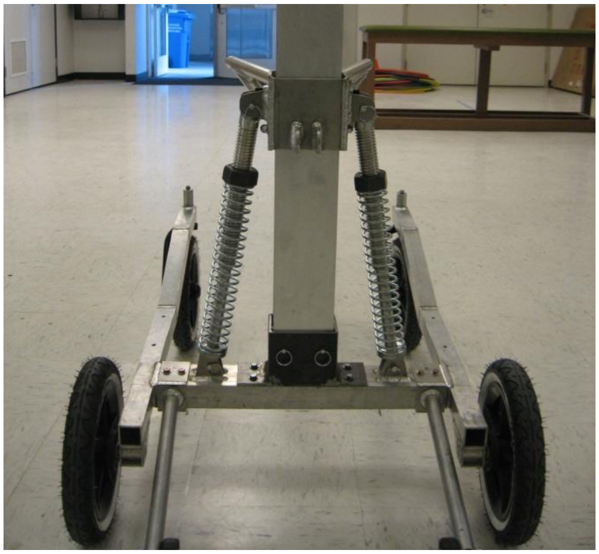


Figure 32: Step 4 of assembly, attach the coil-over system to the bottom carriage with pins after inserting the carriage into the H-beam track.

The fifth step of assembly is to attach the upper carriage to the lower carriage. This is done by first inserting the top carriage into the H-beam and then using the concentric cylinders to line up the two carriages. The two carriages are attached with quick release pins at the appropriate spacing interval. Figure 33 is a picture of the Strider after the fifth step of assembly.

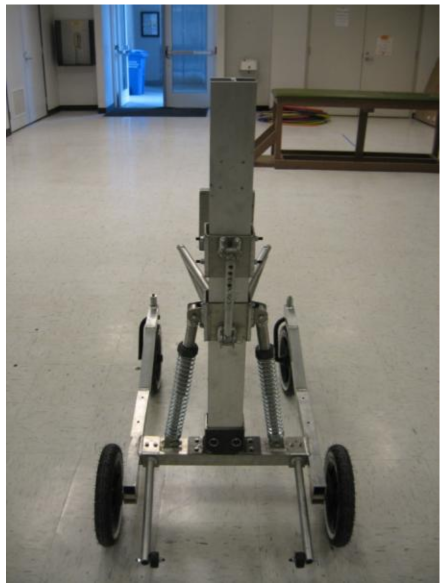


Figure 33: Step 5 of assembly, attach the top carriage to the bottom carriage with the concentric cylinders and quick release pins.

The final step of assembly is to attach the handlebars to the H-beam. This is done with four bolts and wings nuts to get rid of the need for any tools. Figure 34 is a picture of the Strider after the final step of assembly.

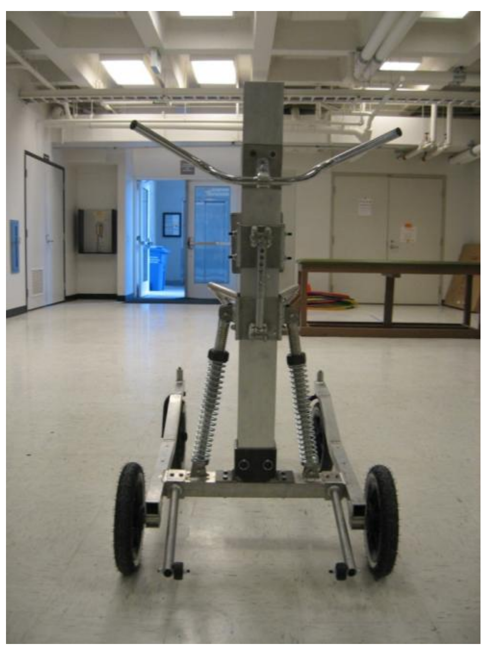


Figure 34: Step 6 of the assembly, attach the handle bars to the H-beam with four bolts and wing nuts.

Design Verification and Testing

Full scale testing of the Strider was conducted over a period of three days. The first day was a test of general stability and how the Strider would handle different types of terrain. A dummy simulating the height and weight of Nathan was used for these tests. The different types of terrain tested were cement (sidewalk), synthetic (running track), grass and packed dirt. Figures 35 and 36 show the grass and packed dirt terrains that were used for this testing.

Figure 35: Testing of the Strider's ability to traverse multiple terrain. The strider is making a transition from packed dirt to grass while being loaded with a dummy child that represents Nathan's height and weight.

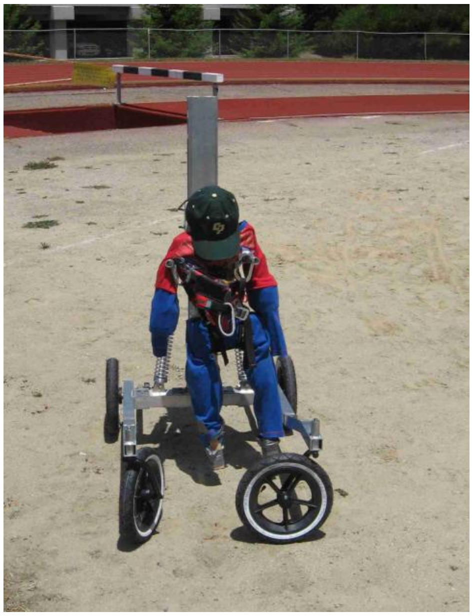


Figure 36: Maneuverability test on packed dirt conditions.

The parameters we were most concerned with for the initial testing were stability and handling on each surface. These are difficult to quantify so we made value judgments and qualified the results. The Strider was then placed on an angled surface to test for its general stability. Three angles were tested: 12, 20 and 30 degrees.

The second day of testing was done with two different children, one approximating Nathan's height and weight now, and one approximating him after he has grown. Figure 37 shows a 4 year old girl that is approximately Nathan's height and weight trying to propel the Strider under her own power. Figure 38 shows the Strider being put through a figure-eight test with a boy that represents Nathan's projected size in 3 years.

Figure 37: Self propulsion test being conducted with a little girl with no physical disabilities.

Figure 38: Figure eight test being done with a child that represents Nathan's projected size and weight when he is 7 - 8 years old.

By using actual people in the testing we were able to get feedback on things such as comfort, pressure points and ease of use. The main thing tested was handling with the child in the Strider. This was done by pushing the Strider through a figure-eight and tight turns.

The third day of testing was completed with Nathan in the Strider. To ensure his safety, he was also wearing one of his orthotic devices that helped him maintain torso rigidity. The goal of these tests was to determine Nathan's comfort while using the Strider and his satisfaction with the Strider. Figure 39 shows Nathan being supported by the Strider.

Figure 39: Nathan testing out the comfort using the Strider in addition to his torso support orthotics.

Results

The Strider satisfactorily handled on each surface tested. The handling was more sluggish on grass and dirt than on the cement or synthetic surface. The Strider also passed each of the stability requirements, not tipping when placed on a 30 degree slope. Figure 40 shows this test. The front wheel had to be held in place, as it had a tendency to turn and roll down the slope. However this did not affect the test and stability.

Figure 40: The stability test on a slope of 30°. The front wheel had to be held so that it could not turn, but no additional help was given to increase stability.

The wheelie bars also provided the necessary stabilizing support when the Strider was tipped back. This is seen in Figure 41

Figure 41: Wheelie bar functionality test with no load which represents a worse case scenario for tipping over backwards.

The primary issue encountered during testing was the harness – or more specifically, the child in the harness – sitting too far below the carriage support bars. Approximations in the calculations caused this value to be off by about six inches. This led a number of problems. The harness support bars sat near the child's arm pits which caused some rubbing and pressure points at that location as can be seen in Figure 42.

Figure 42: Position test to determine child's actual position in relation to the harness support tubing.

With the child sitting so low, the coil-overs had to be raised close to their maximum height to lift the child's feet off the ground. This removed any functionality of the footplate, as the child could not be raised high enough to put it in use. The back plate also was in much too high of a position to offer back support, and acted almost as more of a head rest.

The Strider was able to turn admirably from a straight position, particularly on cement, synthetic and grass surfaces. Some problems arose during the second day of testing on a tile floor. The front tires could not easily maintain the traction necessary to become reoriented in the proper direction and often slid across the floor if one got stuck in a sideways (perpendicular) orientation. This problem can be seen in Figure 43. One reason for this could be "sticking" at the point of contact between the J-bar assembly and the frame. In order to fix this problem, we added a thin layer of Teflon to avoid metal on metal contact.

Figure 43: Demonstration of the problem of the front left tire not being able to straighten itself out after it has been turned sideways on a low friction surface.

Another remedy could be to add more weight to the front wheels. This solution would have a greater effect than adding the Teflon to decrease friction. The weight of the structure and child is transferred to the rear wheels, so the normal force on the front wheels is very little. This can be seen in Figure 44, which shows the Strider, in an unloaded (no child) status, with its front, left tire resting slightly above the ground.

Figure 44: Wheel contact test with no load on the Strider.

When the testing was done with Nathan, he wore his torso support orthopedic device to compensate for the lack of a useable back plate. This orthopedic device can be seen in Figure 45. With the extra support from his device, the tests with Nathan in the Strider were successful. He was able to swing his legs while suspended, be taken over both sidewalks and grassy surfaces, simulate a walking motion while being pushed around, and he was able to slightly propel the Strider without any help. This last result was a goal of the project, but not one that we expected to be able to be met until he had gained some strength in his legs. Also because Nathan is slightly shorter than the other children used for testing, he would currently be able to utilize the footplate if needed.

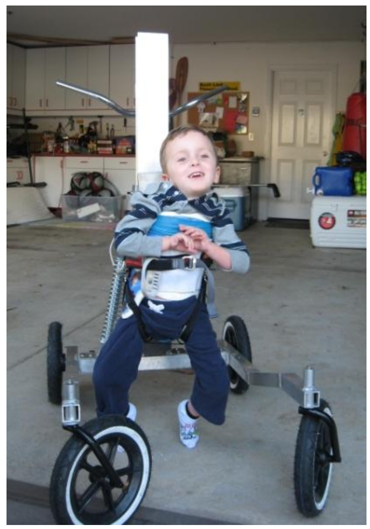


Figure 45: Nathan using the Strider in conjunction with his torso support orthotic device.

Chapter 6: Project Management Plan

In order to efficiently and effectively complete Strider project, we developed a plan that distributed responsibilities for each group member. The roles and responsibilities for each member are listed below. We have also developed a Gantt chart for the first quarter of the Strider project which can be found in Appendix F.

- Eric Johnson - Interface with sponsor, Solidworks models and drawings, and multimedia documentation
- Ricardo Garcia - Background research, contact with local vendors, purchasing, fabrication and welding
- Alex Trask - Design overseer, manufacturing and documentation assembly

Although each member was designated certain tasks, we are all had influence on each other's areas. The assignments are meant to give each task someone who is responsible for that particular task to be completed and can answer any questions about a particular task.

Chapter 7: Conclusions and Future Recommendations

Recommendations for Future Improvements

The primary improvement on this design is to come up with a method of raising the child's location, relative to the carriage. A temporary solution used during testing was to eliminate the use of the carabineers and hang the harness loops directly onto the support bars, as seen in Figure 46. This, however, is not a recommended permanent solution as it makes ingress/egress much more difficult and puts extra stress on the harness loops.

Figure 46: Temporary fix of the child's position in relation to the harness support.

The horizontal distance between the harness support bars should also be increased. This will help avoid rubbing on the torso and prevent the child from being supported under his arm pits.

The front tires should be loaded more heavily. As described in the Results section, this will help solve the tire ground clearance issue and allow for the tires to turn and straighten more easily.

A braking or tire-locking system also should be developed to prevent unwanted rolling. This system is also essential to approving the overall safety of the Strider. Without any sort of wheel locks, there is a chance Nathan could roll down a hill without the ability to stop himself.

In order to make assembly and transportation easier, a re-design of the collapsing mechanisms would be necessary. If the H-beam were able to fold down onto the frame rather than having to be taken apart it would decrease the effort that goes into making the Strider transportable.

Conclusion

Every engineering project can be expected to encounter unexpected issues during testing of a prototype, and this one was no different. While our delivered prototype may not be a perfect product, it is a successful product and project. The final product meets the initial requirements of being able to suspend a child in a standing position; it provides a varying amount of contact with the ground; it has a suspension system; and it can travel over a variety of terrain. It can also be readily disassembled and assembled, making transportation of the Strider easy.

Acknowledgements

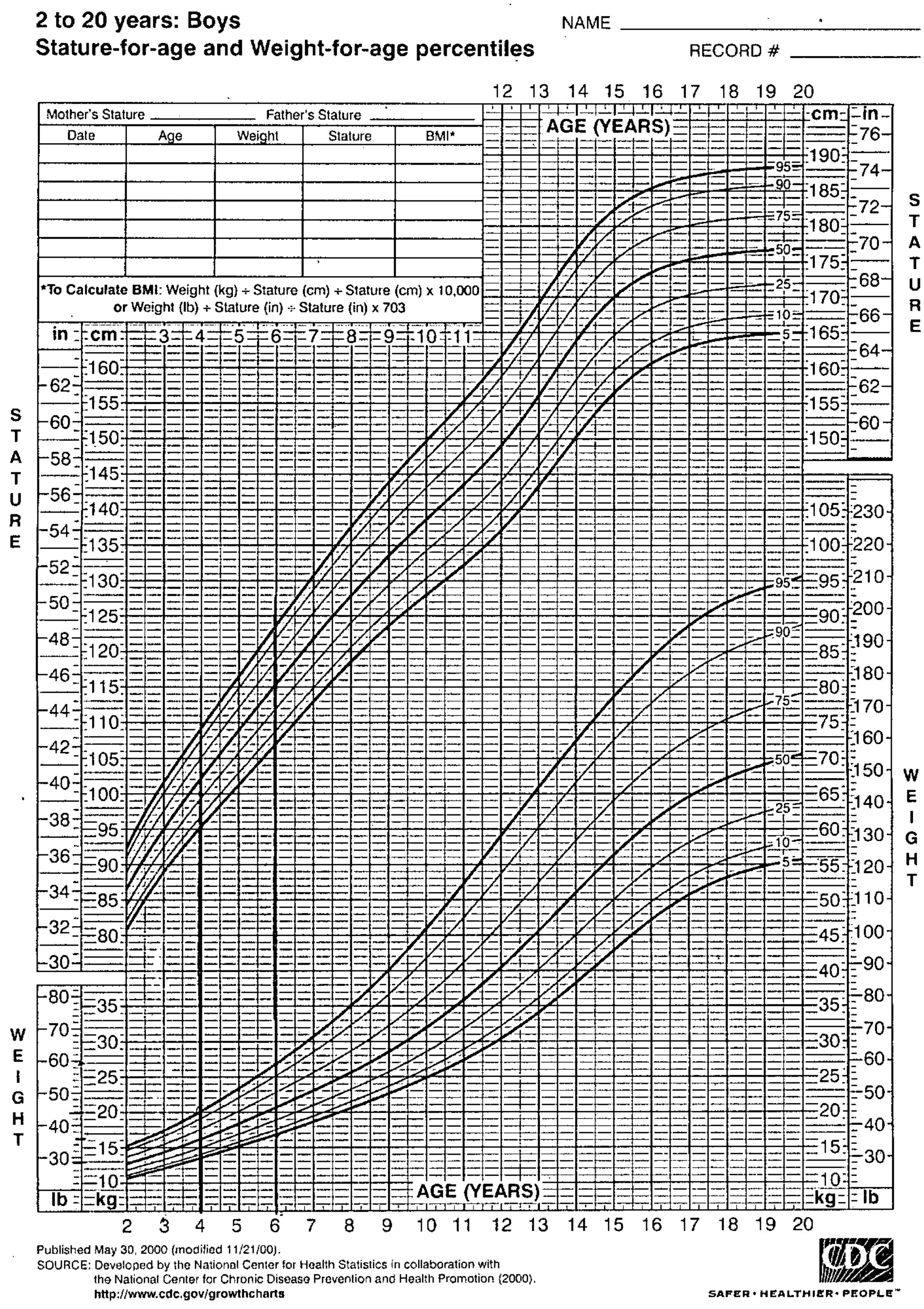
We would like to thank the following people for all their help throughout the entire Strider project.

- Dr. Kevin Taylor
- Kim McClung, Noemy Zavaleta
- Mitch's Stitches,
- Lahr Industrial Welding Inc
- Dr. Suzanne Phelan & kids Sienna, John and Joseph

Without the help that we received we very likely would not have been able to provide a working prototype of the quality that we achieved.

Table of Appendices

Appendix A: Growth Chart for 2-20 yr Old Boys

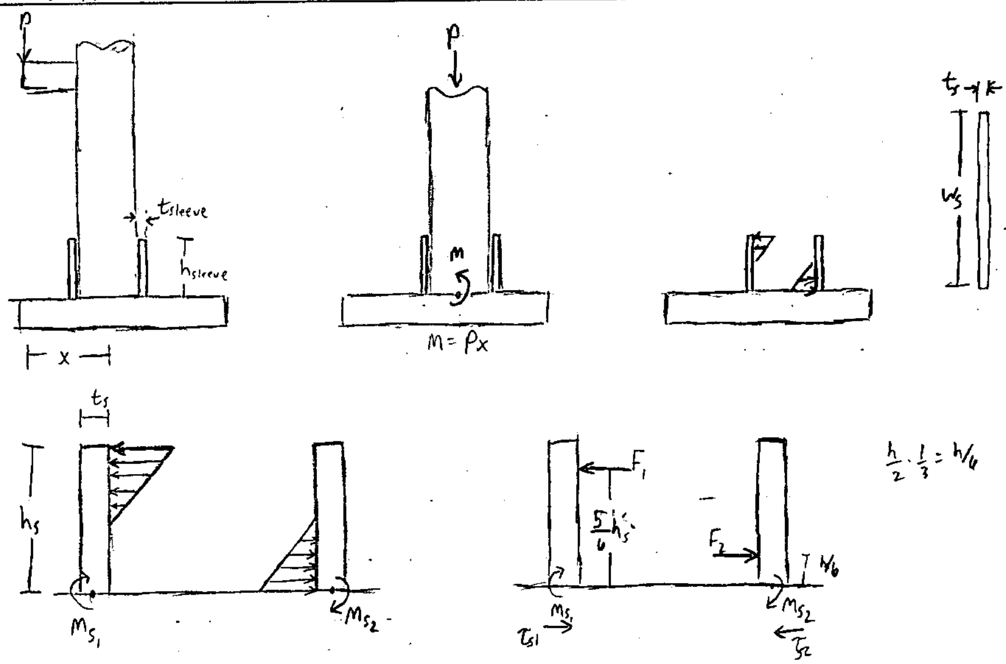


Appendix B: Analysis

Initial Analysis

H-Beam Sleeve

H-BEAM SLEEVE (rough)



$F_1(\frac{5}{6}h_s) + F_2(\frac{h_s}{6}) = M = Px$ $\quad F_1 = F_2$

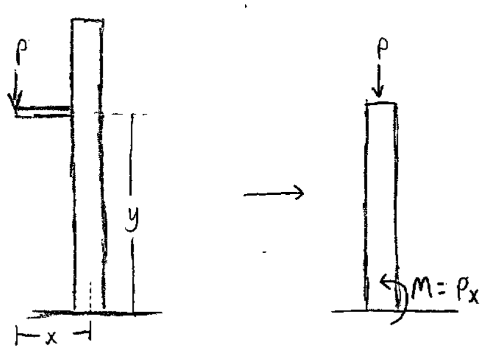
$M_{s_1} = F_1 \cdot \frac{5}{6}h_s$ $\quad M_{s_2} = F_2 \cdot \frac{h_s}{6}$

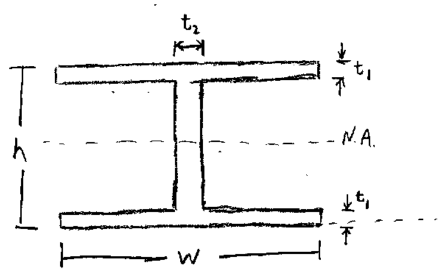
$\tau_{s1} = \frac{3}{2}\frac{F_1}{A_s}$ $\quad \tau_{s_2} = \frac{3}{2}\frac{F_2}{A_s}$ $\quad$ where: $A_s = t_s w_s$

$\sigma_{x_1} = \frac{M_{s_1}c_1}{I_s}$ $\quad \sigma_{x_2} = \frac{M_{s_2}c_2}{I_s}$ $\quad c_1 = c_2 = \frac{t_s}{2}$, $\quad I_s = \frac{1}{12}w_s t_s^3$

$\sigma'_{s_1} = \sqrt{\sigma_{x_1}^2 + 3\tau_{s_1}^2}$ $\quad \sigma'_{s_2} = \sqrt{\sigma_{x_2}^2 + 3\tau_{s_2}^2}$

H-BEAM ANALYSIS (rough)





$$I = \Sigma \frac{1}{12} b h^3 + A d^2$$

$$I = 2\left(\frac{1}{12} w t_1^3 + t_1 w \left(\frac{h}{2} - t_1\right)^2\right) + \frac{1}{12} t_2 (h-2t_1)^3$$

STRESS:

FRONT EDGE

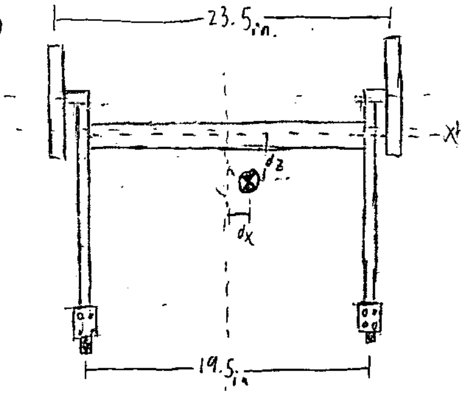
$$\sigma = \frac{P}{A} + \frac{Mc}{I}, \quad A = 2wt_1 + (h-2t_1)t_2, \quad c = \frac{h}{2}, \quad M = Px$$

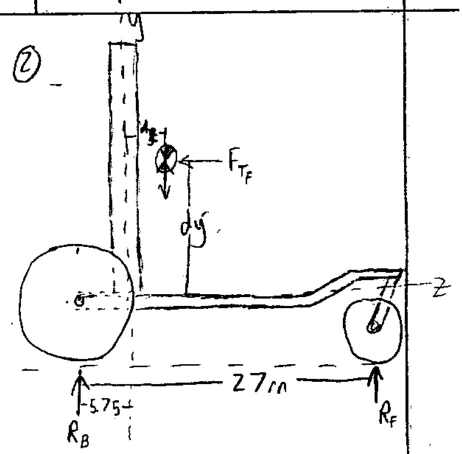
BACK EDGE

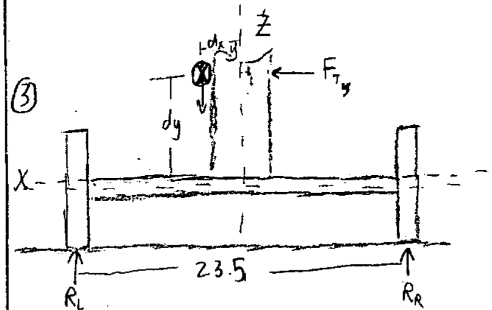
$$\sigma = \frac{P}{A} - \frac{Mc}{I}$$

Stability

STABILITY (rough)

①


②


③


Ⓧ = Center of mass, W_T

F_T = Tipping Force

VIEW 2 (FRONT TO BACK)

$R_B + R_F = W_T$, $R_B(5.75 + dz) = R_F(21.25 - dz) + F_{T_F} dy$

VIEW 3 (SIDE TO SIDE)

$R_L + R_R = W_T$ $R_L(11.75 - dx) = R_R(11.75 + dx) + F_{T_S} dy$

ASSUME NATHAN'S COM: (AT BELLY BUTTON)

$\bar{Y}_N = 21$

$\bar{X}_N = 0$

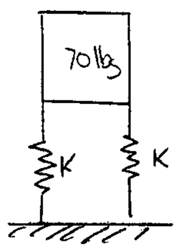
$\bar{Z}_N = 5.75$

Springs

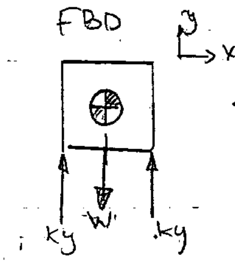
Stiffness

Determining Spring Stiffness

- Weight : 70 lbs
- Desired spring deflection at full weight support : 3"



FBD



$$\Sigma F_y = 0$$

$$W = ky + ky$$

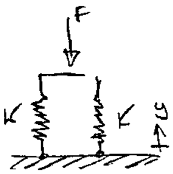
$$W = 2ky \Rightarrow k = \frac{W}{2y}$$

$$K = \frac{70\,\text{lb}_f}{2(3\,\text{in})} = 11.66\ \frac{\text{lb}_f}{\text{in}} = K$$

Stress

Spring stress

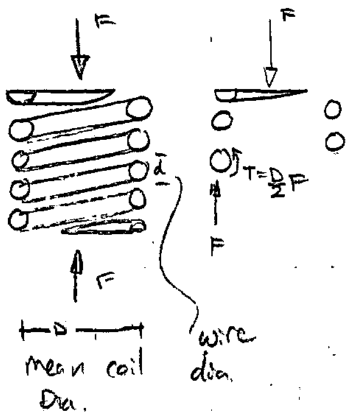
Note: the use of square or rectangular wire is not recommended for springs unless space limitations make it necessary.



$$F = Ky + Ky$$

$$F = 2Ky$$

$$K = \frac{F}{2y}$$



$J = \frac{\pi d^4}{32}$: Only for circular sections.

$$\tau_{max} = \underbrace{\frac{Tr}{J}}_{\text{Torsional shear}} + \underbrace{\frac{F}{A}}_{\text{direct shear}} = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$$

$$A = \frac{\pi d^2}{4}$$

Spring Index: Measure of coil curvature

$$C = D/d$$

Shear-stress correction factor w/ Direct Shear.

$$K_B = \frac{4C+2}{4C-3} \quad (\text{"Bergsträsser factor"})$$

$$\tau = K_B \frac{8FD}{\pi d^3}$$

Stability

Spring stability

$$y_{cr} = L_0 C_1' \left[1 - \left(1 - \frac{C_2'}{\lambda_{eff}^2}\right)^{1/2}\right]$$

$$\lambda_{eff} = \frac{\alpha L_0}{D}, \quad C_1' = \frac{E}{2(E-G)}, \quad C_2' = \frac{2\pi^2(E-G)}{2G+E}$$

Table 10-2
Pg 554

Absolute stability occurs

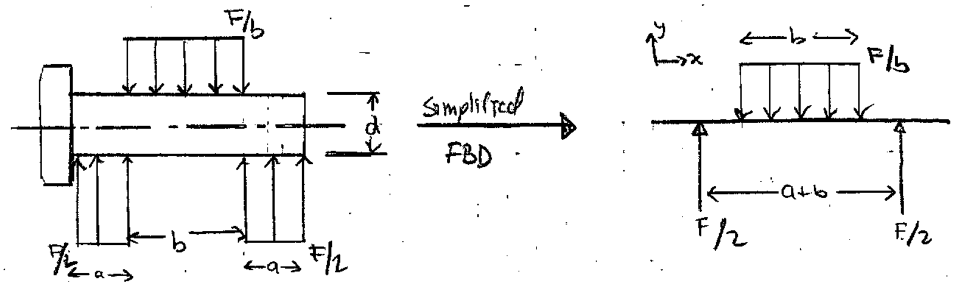
$$L_0 < \frac{\pi D}{\alpha}\left[\frac{2(E-G)}{2G+E}\right]^{1/2}$$

$\underline{L_0 < 5.26D}$ w/ square & grounded ends

Pin Analysis

Pin Analysis

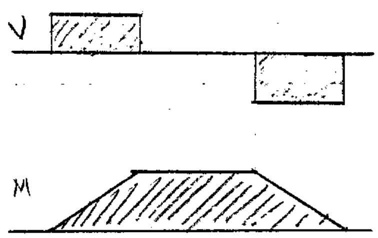
∴ Determine if the pin used to lock the coilover has an acceptable safety of factor



d: Diameter of Pin
a: width of Brackets
b: width of coilover.
F: weight of Nathia, Carrage, Coilovers, Wheels

Shear & Moment Diagrams.

$$M_{max} = \frac{F}{2}\left(\frac{a+b}{2}\right) - \frac{F}{2}\left(\frac{1}{2}\right)\left(\frac{b}{2}\right)^2 = F\left(\frac{a}{2}+\frac{b}{4}\right)$$



$$\sigma_y = \frac{-F}{A} = \frac{-F}{bd}$$

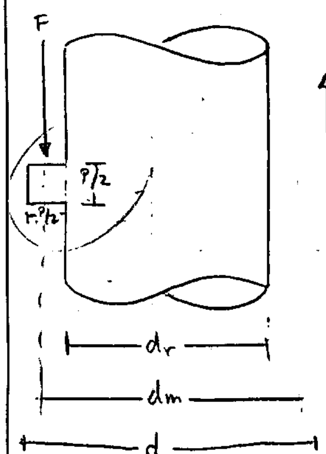
$$\sigma_x = \frac{Mc}{I} = \frac{32M}{\pi d^3}$$

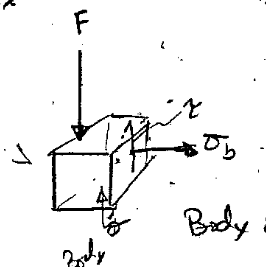
From Mohrs circle, $\tau_{max} = \sigma_x/2$

$$n = \frac{S_{sy}}{\tau_{max}}.$$

Thread Stress

Pg 401 | Thread Stresses.





Raising Torque:

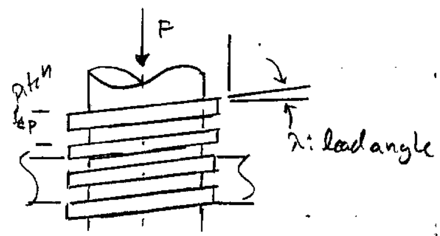
$$T = \frac{F d_m}{2}\left(\frac{l + \pi f d_m}{\pi d_m - f l}\right) + T_{applied}$$

10.24 N (arduino)

Body stress:

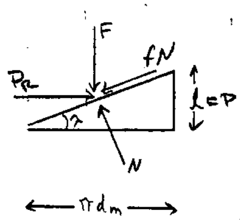
Body Stress $\tau = \frac{16T}{\pi d_r^3}$

axial $\sigma = \frac{4F}{\pi d_r^2}$ Compressive



Thread Root Bending stress

$$\sigma_b = \frac{6(0.38F)}{\pi d_r (n_t) p} \quad (1)$$



Von-Mises.

$$\sigma' = \frac{1}{\sqrt{2}}\left[(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2+6(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2)\right]^{1/2}$$

Note: First engaged thread carries 38% of load, 2nd carries 25%, 3rd carries 18%

$$\tau_1,\tau_2 = \pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}$$

$\sigma_x = \sigma_b$ $\quad \tau_{xy} = 0$

$\sigma_y = 0$ $\quad \tau_{yz} = \tau$

$\sigma_z = \sigma$ $\quad \tau_{zx} = 0$

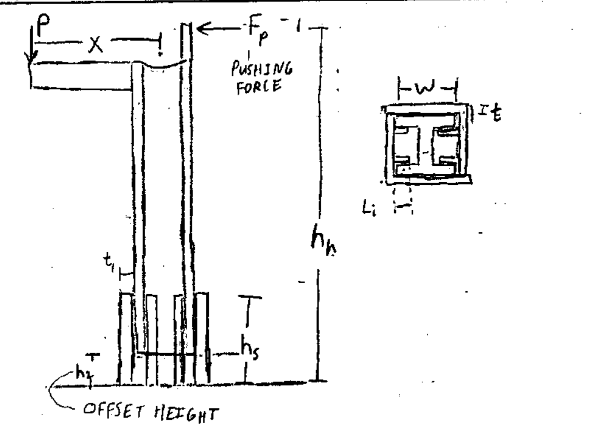
Principle stress max, min x

$$\sigma_1,\sigma_2 = \frac{\sigma_z+\sigma_y}{2} + \sqrt{\left(\frac{\sigma_z-\sigma_y}{2}\right)^2+\tau_{yz}^2}$$

$$\tau_{max} = \frac{\sigma_1-\sigma_3}{2}$$

Sleeve

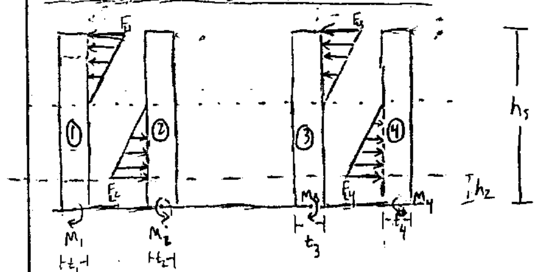
SLEEVE



ASSUMPTIONS.

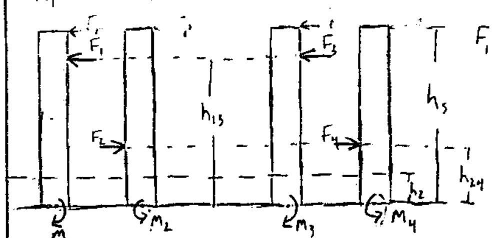
- MOMENT TRANSFERRED COMPLETELY TO SLEEVE
- NO VERTICAL COMPONENT
- FORCE DISTRIBUTED EVENLY BETWEEN SLEEVE SUPPORTS
- FORCE DISTRIBUTED EVENLY ACROSS LENGTH (DIMENSION 'w')

LINEAR FORCE DISTRIBUTION



$$F_1 = F_2 = F_3 = F_4$$

$$M_1 + M_2 + M_3 + M_4 = P_x + F_p h_h$$



$$F_1 = F_2 = F_3 = F_4$$

$$h_{13} = h_s - \frac{1}{3}\left(\frac{h_s - h_2}{2}\right)$$

$$h_{24} = h_2 + \frac{1}{3}\left(\frac{h_s - h_2}{2}\right)$$

$$M_1 = M_3 = F_1 h_{13}$$

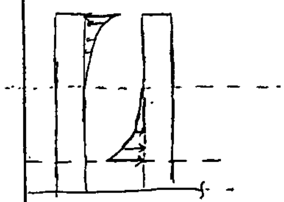
$$M_2 = M_4 = F h_{24}$$

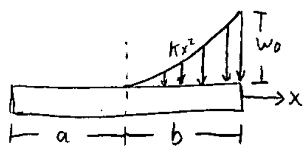
$$2F h_{13} + 2F h_{24} = P_x + F_p h_h$$

$$F = \frac{P_x + F_p h_h}{2h_{13} + 2h_{24}}$$

SLEEVE (2)

QUADRATIC FORCE DISTRIBUTION



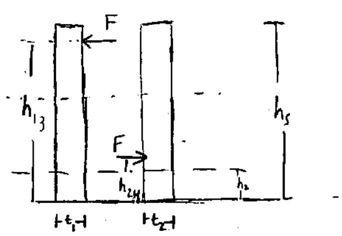


$kb^2 = w_0$

$\int_0^b kx^2 = \frac{1}{3}kb^3 = F$ $\qquad k = \frac{3F}{b^3}$

$M = \int_0^b kx^2 \cdot x \, dx$

$M = \frac{1}{4}kb^4$ $\qquad \frac{1}{4}kb^4 = \frac{1}{3}kb^3 x_{eq}$ $\qquad x_{eq} = \frac{3}{4}b$



$h_{13} = h_s - \frac{1}{4}\left(\frac{h_s - h_2}{2}\right)$

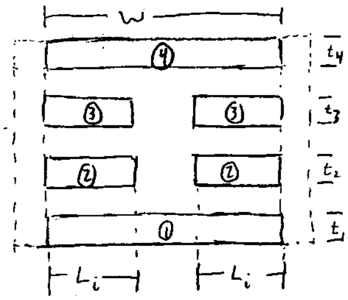
$h_{24} = h_2 + \frac{1}{4}\left(\frac{h_s - h_2}{2}\right)$

$M_1 = M_3 = F h_{13}$

$M_2 = M_4 = F h_{24}$

SLEEVE (3)

TREAT (2) AND (3) EACH, AS ONE BEAM



$I_1 = I_1 = \frac{1}{12} w t_1^3$

$I_2 = 2 \cdot \frac{1}{12} L_i t_2^3$

$I_3 = 2 \cdot \frac{1}{12} \cdot L_i t_3^3$

$I_4 = \frac{1}{12} w t_4^3$

STRESS

$\sigma = \frac{Mc}{I}$ $\qquad \sigma_1 = \frac{M_1 t_1/2}{I_1}$; $\sigma_2 = \frac{M_2 t_2/2}{I_2}$; $\sigma_3 = \frac{M_3 t_3/2}{I_3}$; $\sigma_4 = \frac{M_4 t_4/2}{I_4}$

FOR RECTANGLE:

$\tau = \frac{3}{2} \frac{F}{A}$ $\qquad \tau_1 = \frac{3}{2} \frac{(F+F_p)}{w t_1}$; $\tau_2 = \frac{3}{2} \frac{(F-F_p)}{2 \cdot L_i \cdot t_2}$; $\tau_3 = \frac{3}{2} \frac{(F+F_p)}{2 \cdot L_i \cdot t_3}$; $\tau_4 = \frac{3}{2} \frac{(F-F_p)}{w t_4}$

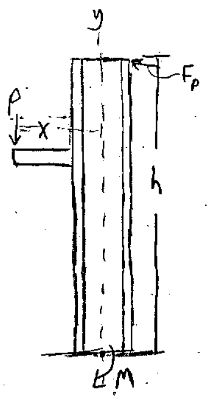
MISES

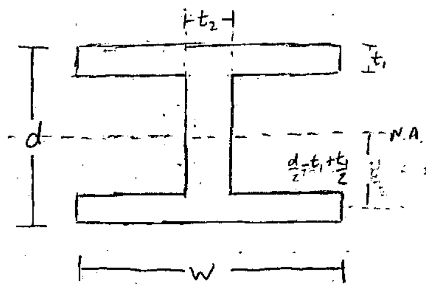
$\sigma' = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau^2}$ $\qquad \sigma_y = 0$

$\sigma' = \sqrt{\sigma_x^2 + 3\tau^2}$

H Beam

H-BEAM

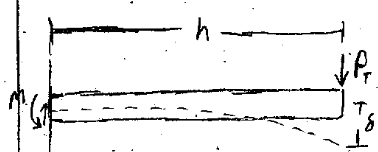




ASSUMPTIONS:
- NO VERTICAL LOAD SEEN BY H-BEAM
- ACTS AS CANTILEVER BEAM
- NO SLEEVE

$$I = \Sigma \frac{1}{12} b h^3 + A d^2$$

$$I = 2\left[\frac{1}{12} w t_1^3 + t_1 w \left(\frac{d-t_1}{2}\right)^2\right] + \frac{1}{12} t_2 (d-2t_1)^3$$



$$M = Px + F_p h$$

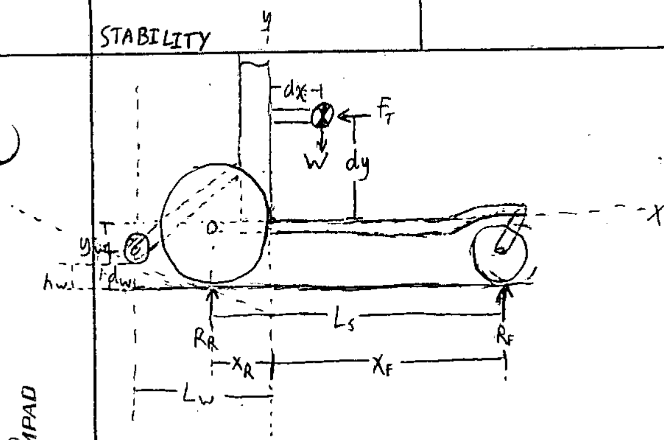
$$P_T = \frac{M}{h} ; \quad P_T = \frac{Px + F_p h}{h} ; \quad P_T = P\frac{x}{h} + F_p$$

$$\delta = \frac{P_T h^3}{3EI}$$

TARGET: $\delta < .1 in$

Stability

STABILITY



ASSUMPTIONS:

-NATHAN'S C.O.M:
$\bar{x}_n = 0;\ \bar{y}_n = 6;\ \bar{z}_n = 12$

OLD: $\bar{x} = 0,\ \bar{y} = 5.26,\ \bar{z} = 2.22$

ASSUME NEW: $\bar{x} = 0;\ \bar{y} = 5.26;\ \bar{z} = 3.25$

NO TIP FORCE

$W = W_N + W_D$

$R_R + R_F = W$ $\qquad$ $R_F = W - R_R$

$R_R x_R = R_F x_F$ $\qquad$ $x_F + x_R = L_s$ $\qquad$ $R_F = R_R \frac{x_R}{x_F}$ $\qquad$ $W = R_R + R_R\left(\frac{x_R}{x_F}\right)$; $\quad W = R_R\left(1 + \frac{x_R}{x_F}\right)$

WITH TIP FORCE (THROUGH C.O.M)

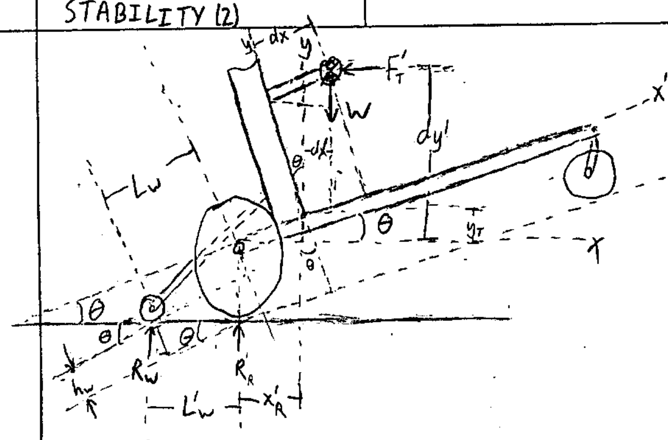
$R_F = 0;\quad R_R = W;$

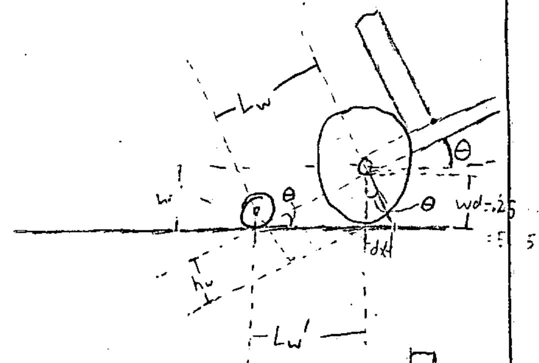
$R_R x_R = F_T dy - W dx$

TIP FORCE AT TOP OF H-BEAM

$R_R x_R = F_{T_2} \cdot h_b - W dx$ $\qquad$ $h_b = 36''$

STABILITY (2)





$$F_T' dy' = R_R' x_R' + R_w(L_w' + x_R') + W dx'$$

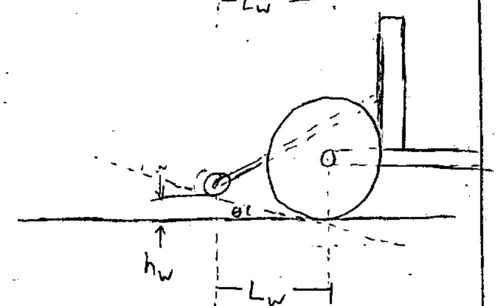
$$L_w' = L_w \cos\theta$$

$$dy' = \frac{dy}{\sin\theta} + \frac{y_T}{L_w}$$

$$y_T = dx \sin\theta$$

$$dx' = dx\cos\theta - dy\sin\theta$$

$$x_R' = x_R - (wd + .25)\tan\theta$$



$$\theta = \tan^{-1}\left(\frac{h_w}{L_w}\right)$$

$$R_w + R_R' = W$$

$$R_R' = W - R_w' \qquad F_T' dy' = (W - R_w)x_R' + R_w(L_w' + x_R') + W dx'$$

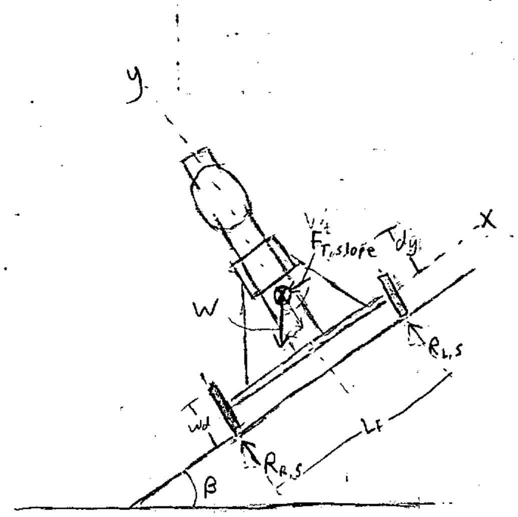
$$F_T' dy' = W x_R' - R_w x_R' + R_w(L_w' + x_R') + W dx'$$

$$R_w(L_w' + \cancel{x_R} - \cancel{x_R}) = F_T' dy' - W x_R' - W dx'$$

"TIP" CONDITION

$$R_R' = 0$$

STABILITY (3)



$R_{R,S} + R_{L,S} = W\cos\beta_f =$

AT "TIP" $R_{L,S} = 0$

$$R_{L,S} \cdot \frac{L_f}{2} + W \cdot \left(dy + \frac{wd}{2}\right)\sin\beta + F_{T,slope}\left(dy + \frac{wd}{2}\right) = R_{R,S} \cdot \frac{L_f}{2}$$

Appendix C: Analysis code

Stability Analysis

Summary of variables for EES stability analysis:

β	=Slope angle
dx	=x-distance from origin to combined center of mass (C.O.M.)
dy	=y-distance from origin to combined C.O.M.
dy_{prime}	=y-distance from origin to combined C.O.M. at tilted position
dz	=z-distance from origin to combined C.O.M.
dz_{prime}	=z-distance from origin to combined C.O.M. at tilted position
$F_{T,center}$	=Tip force (front to back) acting at C.O.M.
$F_{T,center,prime}$	=Tip force (front to back) acting at C.O.M. at tilted position
$F_{T,side,top}$	=Tip force (side to side) acting at top of H-beam
$F_{T,Slope}$	=Tip force acting at C.O.M. on slope
$F_{T,top}$	=Tip force (front to back) acting at top of H-beam
$F_{T,top,prime}$	=Tip force (front to back) acting at top of H-beam, at tilted position
h_b	=Height of H-beam
h_w	=Height wheelie bar is off the ground
L_f	=Wheel base as seen from the front (distance between right and left)
L_s	=Wheel base as seen from the side (distance between front and back)
L_w	=Distance from wheelie bar to center of rear wheel
$L_{w,prime}$	=Distance from wheelie bar to center of rear wheel, at tilted position
R_F	=Front wheel reaction force (both wheels combined)
R_{left}	=Left wheel reaction force (both wheels combined)
$R_{Left,Slope}$	=Left wheel reaction force (both wheels combined) on slope
R_R	=Rear wheel reaction force (both wheels combined)
$R_{R,prime}$	=Rear wheel reaction force (both wheels combined), at tilted position
$R_{Right,Slope}$	=Right wheel reaction force(both wheels combined) on slope
R_{right}	=Right wheel reaction force (both wheels combined)
R_w	=Wheelie bar reaction force
Θ	=Tilt angle
W	=Total weight
wd	=Rear wheel diameter
w_n	=Weight of Nathan
w_s	=Weight of Strider
$\overline{x}$	=dx
$\overline{x}_n$	=x-C.O.M. of Nathan
$\overline{x}_s$	=x-C.O.M. of Strider
x_F	=x-distance from origin to center of front wheels
x_R	=x-distance from origin to center of rear wheels
$x_{R,prime}$	=x-distance from origin to center of rear wheels, at tilted position
$\overline{y}$	=dy
$\overline{y}_n$	=y-C.O.M. of Nathan
$\overline{y}_s$	=y-C.O.M. of Strider
y_t	=Change of position, y-direction, of origin between resting and tilted position
$\overline{z}$	=dz
$\overline{z}_n$	=z-C.O.M. of Nathan
$\overline{z}_s$	=z-C.O.M. of Strider

EES

Stability Analysis for Strider Project

Origin taken as top of frame and front of H-Beam

Design Parameters

$L_s = 26$ Side view wheel base (front to back) (in)

$L_f = 20$ Front view wheel base (distance from left to right) (in)

$h_b = 36$ Height of H-Beam (in)

$wd = 12$ Rear wheel diameter (in)

$x_R = 5$ Distance (in z-direction) from origin to center of rear wheel

Weights

$w_n = 60$ Weight of Nathan (35-60lbs)

$w_s = 61$ Weight of Strider

$W = w_n + w_s$ Total weight

Nathan's Center of Mass Assumption

Dimensions

$\bar{x}_n = 0$

$\bar{y}_n = 6$

$\bar{z}_n = 12$

Strider C.O.M. (Assumed new values)

$\bar{x}_s = 0$

$\bar{y}_s = 5.26$

$\bar{z}_s = 3.25$

Combined C.O.M

$$\bar{x} = \frac{\bar{x}_n \cdot w_n + \bar{x}_s \cdot w_s}{w_n + w_s}$$

$$\bar{y} = \frac{\bar{y}_n \cdot w_n + \bar{y}_s \cdot w_s}{w_n + w_s}$$

$$\bar{z} = \frac{\bar{z}_n \cdot w_n + \bar{z}_s \cdot w_s}{w_n + w_s}$$

$dx = \bar{x}$

$dy = \bar{y}$

$dz = \bar{z}$

Front to Back Stability

$R_R + R_F = W$ Front, Rear reaction forces

$R_R \cdot x_R + W \cdot dx = F_{T,center} \cdot dy + R_F \cdot x_F$ Sum of moments: tip force acting through C.O.M.

$R_R \cdot x_R + W \cdot dx = R_F \cdot x_F + F_{T,top} \cdot h_b$ Sum of moments: tip force acting at top of H-Beam

$x_R + x_F = L_s$

Analysis for condition of resting on wheelie bar

Design parameters

$h_w = 3$ Height of wheelie bar off the ground (in)

$L_w = 12$ Distance from wheelie bar to center of rear tire (in)

Calculated parameters

$\theta = \textbf{arctan}\left[\frac{h_w}{L_w}\right]$ Title angle when on wheelie bar

$dy_{prime} = \frac{dy}{\cos[\theta]} + y_t$ New C.O.M. location

$y_t = dz \cdot \sin[\theta]$

$dz_{prime} = dz \cdot \cos[\theta] - dy \cdot \sin[\theta]$

$x_{R,prime} = x_R - [wd + 0.25 \; [in]] \cdot \tan[\theta]$ New moment arm to rear wheel

$L_{w,prime} = L_w \cdot \cos[\theta]$ New distance from wheelie bar to center of rear wheel

$R_w + R_{R,prime} = W$ Reaction forces

Sum of moments: tip force acting through C.O.M.

$F_{T,center,prime} \cdot dy_{prime} = R_{R,prime} \cdot x_{R,prime} + R_w \cdot [L_{w,prime} + x_{R,prime}] + W \cdot dz_{prime}$

Sum of moments: tip force acting at top of H-Beam

$F_{T,top,prime} \cdot h_b = R_{R,prime} \cdot x_{R,prime} + R_w \cdot [L_{w,prime} + x_{R,prime}] + W \cdot dz_{prime}$

Reaction Forces

$R_R=0$

Tip forward

$R_W=0$

$R_F = 0$ Tip backward

$R_{R,prime} = 0$

$F_{T,center}=0$

No tip force

$F_{T,top}=0$
$F_{T,center,prime}=0$
$F_{T,top,prime}=0$

Side to side stability

$R_{right} + R_{left} = W$

$R_{right} \cdot \frac{L_f}{2} = R_{left} \cdot \frac{L_f}{2} + F_{T,side,top} \cdot dy$

$R_{left} = 0$ Tip sideways

$R_{right}=R_{left}$

No tip

Stability on a slope

beta=30

Slope angle

$R_{Right,Slope} + R_{Left,Slope} = W \cdot \cos[\beta]$ Reaction forces, right and left, on slope

Sum of moments on slope

$$R_{Left,Slope} \cdot \frac{L_f}{2} + W \cdot \left[dy + \frac{wd}{2}\right] \cdot \sin[\beta] + F_{T,Slope} \cdot \left[dy + \frac{wd}{2}\right] = R_{Right,Slope} \cdot \frac{L_f}{2}$$

$R_{Left,Slope} = 0$ At 'tip' condition, the left (upper) side loses contact with the ground

Parametric Table: Table 1

Determining critical direction of tipping

	R_W [lbf]	R_R [lbf]	$R_{R,prime}$ [lbf]	R_F [lbf]	$F_{T,top}$ [lbf]	$F_{T,center}$ [lbf]	$F_{T,top,prime}$ [lbf]	$F_{T,center,prime}$ [lbf]
Run 1	0	0	121	121	-104.2	-666.6	26.67	125.7
Run 2	121	121	0	0	16.81	107.5	65.8	310

Parametric Table: Table 2

Varying front-to-back wheel base with tipping force acting towards the back

	L_s [in]	$F_{T,center}$ [lbf]	$F_{T,center,prime}$ [lbf]	$F_{T,top}$ [lbf]	$F_{T,top,prime}$ [lbf]
Run 1	12	107.5	310	16.81	65.8
Run 2	16	107.5	310	16.81	65.8
Run 3	20	107.5	310	16.81	65.8
Run 4	24	107.5	310	16.81	65.8
Run 5	28	107.5	310	16.81	65.8
Run 6	32	107.5	310	16.81	65.8
Run 7	36	107.5	310	16.81	65.8
Run 8	40	107.5	310	16.81	65.8
Run 9	44	107.5	310	16.81	65.8
Run 10	48	107.5	310	16.81	65.8

Parametric Table: Table 3

Varying back wheel location

	x_R [in]	$F_{T,center}$ [lbf]	$F_{T,top}$ [lbf]	$F_{T,center,prime}$ [lbf]	$F_{T,top,prime}$ [lbf]
Run 1	1	21.5	3.361	246.7	52.36
Run 2	2	43.01	6.722	262.5	55.72
Run 3	3	64.51	10.08	278.4	59.08
Run 4	4	86.01	13.44	294.2	62.44
Run 5	5	107.5	16.81	310	65.8
Run 6	6	129	20.17	325.9	69.16
Run 7	7	150.5	23.53	341.7	72.52
Run 8	8	172	26.89	357.5	75.88
Run 9	9	193.5	30.25	373.4	79.24
Run 10	10	215	33.61	389.2	82.61

Parametric Table: Table 4

Varying side-to-side wheel base

	L_f [in]	$F_{T,side,top}$ [lbf]
Run 1	16	172
Run 2	17	182.8
Run 3	18	193.5
Run 4	19	204.3
Run 5	20	215
Run 6	21	225.8
Run 7	22	236.5
Run 8	23	247.3
Run 9	24	258
Run 10	25	268.8

Parametric Table: Table 5

Varying front-to-back wheel base with tipping force acting towards the front

	L_s	$F_{T,center}$	$F_{T,top}$	$F_{T,top,prime}$	$F_{T,center,prime}$	$F_{T,side,top}$
	[in]	[lbf]	[lbf]	[lbf]	[lbf]	[lbf]
Run 1	12	-150.5	-23.53	65.8	310	215
Run 2	16	-236.5	-36.97	65.8	310	215
Run 3	20	-322.6	-50.42	65.8	310	215
Run 4	24	-408.6	-63.86	65.8	310	215
Run 5	28	-494.6	-77.31	65.8	310	215
Run 6	32	-580.6	-90.75	65.8	310	215
Run 7	36	-666.6	-104.2	65.8	310	215
Run 8	40	-752.6	-117.6	65.8	310	215
Run 9	44	-838.6	-131.1	65.8	310	215
Run 10	48	-924.7	-144.5	65.8	310	215

Parametric Table: Table 6

Varying side-to-side wheel base on 30 deg slope

	L_f	$F_{T,Slope}$
	[in]	
Run 1	14	2.588
Run 2	15.11	7.595
Run 3	16.22	12.6
Run 4	17.33	17.61
Run 5	18.44	22.62
Run 6	19.56	27.62
Run 7	20.67	32.63
Run 8	21.78	37.64
Run 9	22.89	42.64
Run 10	24	47.65

Parametric Table: Table 7

Varying slope angle at 20 inch side-to-side wheel base

	β	$F_{T,Slope}$
Run 1	0	104.1
Run 2	4	95.37
Run 3	8	86.22
Run 4	12	76.64
Run 5	16	66.69
Run 6	20	56.41
Run 7	24	45.86
Run 8	28	35.08
Run 9	32	24.13
Run 10	36	13.07
Run 11	40	1.944
Run 12	44	-9.193
Run 13	48	-20.29
Run 14	52	-31.28
Run 15	56	-42.12
Run 16	60	-52.75

H-Beam Analysis

Summary of variables for EES: H-beam

d = Depth of H-beam

δ_{Al} =Deflection using aluminum

δ_{st} =Deflection using steel

E_{Al} =Modulus of elasticity of aluminum

E_{st} =Modulus of elasticity of steel

F_p =Pushing force

h =Height of H-beam

I =Moment of inertia

M =Moment

P =Weight of Nathan (acting as point load)

P_t =Total effective load acting at top of H-beam

t_1 =Flange thickness

t_2 =Web thickness

V =Volume

w =Flange width

Wt_{Al} =Weight of H-beam using aluminum

Wt_{st} =Weight of H-beam using steel

w_{Al} =Density of aluminum

w_{st} =Density of steel

x =Distance Nathan is offset from H-beam

H-Beam Analysis for Strider

Assumptions: No vertical load seen by H-Beam; Acts as canilever beam; No sleeve in initial calculations

Design parameters

$P = 60$ Nathan's weight (lbs)

$x = 12$ Distance Nathan is offset from H-Beam (lbs)

$F_p = 15$ Force due to pushing (from handles) (lbs)

$h = 36$ Height of H-Beam (assuming handles are at top) (in)

Geometric parameters

$t_1 = 0.25$ Flange thickness (in)

$t_2 = 0.25$ Web thickness (in)

$w = 4$ Flange width (in)

$d = 2.5$ Depth of H-Beam (in)

Geometric properties

$$I = 2 \cdot \left[\frac{1}{12} \cdot w \cdot t_1^{3} + t_1 \cdot w \cdot \left(\frac{d - t_1}{2} \right)^2 \right] + \frac{1}{12} \cdot t_2 \cdot \left[d - 2 \cdot t_1 \right]^2$$

Material Properties

$E_{Al} = 1.04 \times 10^7$ E of aluminum (psi)

$E_{st} = 3 \times 10^7$ E of steel (psi)

$w_{Al} = 0.098$ Density of aluminum (lbs/in^{3})

$w_{st} = 0.282$ Density of steel (lbs/in^{3})

Deflection

$M = P \cdot x + F_p \cdot h$ Total moment at bottom of H-Beam (lb-in)

$P_t = \frac{M}{h}$ Equivalent force acting at end of H-Beam (lbs)

$\delta_{Al} = P_t \cdot \frac{h^3}{3 \cdot E_{Al} \cdot I}$ Max deflection of H-Beam (in), aluminum

$\delta_{st} = P_t \cdot \frac{h^3}{3 \cdot E_{st} \cdot I}$ Max deflection of H-Beam (in), steel

Weight of H-Beam

$V = \left[2 \cdot t_1 \cdot w + t_2 \cdot \left(d - 2 \cdot t_1 \right) \right] \cdot h$ Volume of H-Beam (in^{3})

$Wt_{Al} = V \cdot w_{Al}$

$Wt_{st} = V \cdot w_{st}$

SOLUTION

Unit Settings: [F]/[psia]/[lbm]/[degrees]

$d = 2.5$	$\delta_{Al} = 0.01994$	$\delta_{st} = 0.006912$	$E_{Al} = 1.040E+07$
$E_{st} = 3.000E+07$	$F_p = 15$	$h = 36$	$I = 2.625$
$M = 1,260$	$P = 60$	$P_t = 35$	$t_1 = 0.25$
$t_2 = 0.25$	$V = 90$	$w = 4$	$Wt_{Al} = 8.82$
$Wt_{st} = 25.38$	$w_{Al} = 0.098$	$w_{st} = 0.282$	$x = 12$

Parametric Table: Table 2

Web thickness impact on deflection and weight

	t_1	t_2	w	d	δ_{Al}	Wt_{Al}	δ_{st}	Wt_{st}
Run 1	0.25	0.1	4	3	0.01362	7.938	0.00472	22.84
Run 2	0.25	0.1722	4	3	0.01348	8.575	0.004675	24.67
Run 3	0.25	0.2444	4	3	0.01336	9.212	0.00463	26.51
Run 4	0.25	0.3167	4	3	0.01323	9.849	0.004586	28.34
Run 5	0.25	0.3889	4	3	0.0131	10.49	0.004543	30.17
Run 6	0.25	0.4611	4	3	0.01298	11.12	0.0045	32.01
Run 7	0.25	0.5333	4	3	0.01286	11.76	0.004459	33.84
Run 8	0.25	0.6056	4	3	0.01274	12.4	0.004418	35.67
Run 9	0.25	0.6778	4	3	0.01263	13.03	0.004378	37.51
Run 10	0.25	0.75	4	3	0.01251	13.67	0.004338	39.34

Parametric Table: Table 1

Flange thickness impact on deflection and weight

	t_1	t_2	w	d	δ_{Al}	Wt_{Al}	δ_{st}	Wt_{st}
Run 1	0.1	0.25	4	3	0.02835	5.292	0.009829	15.23
Run 2	0.1444	0.25	4	3	0.02085	6.468	0.007226	18.61
Run 3	0.1889	0.25	4	3	0.01671	7.644	0.005791	22
Run 4	0.2333	0.25	4	3	0.01409	8.82	0.004885	25.38
Run 5	0.2778	0.25	4	3	0.0123	9.996	0.004263	28.76
Run 6	0.3222	0.25	4	3	0.011	11.17	0.003813	32.15
Run 7	0.3667	0.25	4	3	0.01002	12.35	0.003472	35.53
Run 8	0.4111	0.25	4	3	0.009254	13.52	0.003208	38.92
Run 9	0.4556	0.25	4	3	0.008647	14.7	0.002998	42.3
Run 10	0.5	0.25	4	3	0.008157	15.88	0.002828	45.68

Parametric Table: Table 3

Flange width impact on deflection and weight

	t_1	t_2	w	d	δ_{Al}	Wt_{Al}	δ_{st}	Wt_{st}
Run 1	0.25	0.25	1	3	0.04855	3.969	0.01683	11.42
Run 2	0.25	0.25	1.556	3	0.03261	4.949	0.01131	14.24
Run 3	0.25	0.25	2.111	3	0.02456	5.929	0.008513	17.06
Run 4	0.25	0.25	2.667	3	0.01969	6.909	0.006826	19.88
Run 5	0.25	0.25	3.222	3	0.01643	7.889	0.005697	22.7
Run 6	0.25	0.25	3.778	3	0.0141	8.869	0.004889	25.52
Run 7	0.25	0.25	4.333	3	0.01235	9.849	0.004281	28.34
Run 8	0.25	0.25	4.889	3	0.01099	10.83	0.003808	31.16
Run 9	0.25	0.25	5.444	3	0.009892	11.81	0.003429	33.98
Run 10	0.25	0.25	6	3	0.008996	12.79	0.003119	36.8

Parametric Table: Table 4

Beam depth impact on deflection and weight

	t_1	t_2	w	d	δ_{Al}	Wt_{Al}	δ_{st}	Wt_{st}
Run 1	0.25	0.25	4	0.5	1.256	7.056	0.4355	20.3
Run 2	0.25	0.25	4	1	0.1763	7.497	0.06112	21.57
Run 3	0.25	0.25	4	1.5	0.06442	7.938	0.02233	22.84
Run 4	0.25	0.25	4	2	0.03295	8.379	0.01142	24.11
Run 5	0.25	0.25	4	2.5	0.01994	8.82	0.006912	25.38
Run 6	0.25	0.25	4	3	0.01335	9.261	0.004626	26.65
Run 7	0.25	0.25	4	3.5	0.009552	9.702	0.003311	27.92
Run 8	0.25	0.25	4	4	0.007173	10.14	0.002487	29.19
Run 9	0.25	0.25	4	4.5	0.005583	10.58	0.001935	30.46
Run 10	0.25	0.25	4	5	0.004468	11.03	0.001549	31.73

MATLAB

```
%Analysis for H-Beam
%Analysis is done in data arrays to allow a range of variables to be tested
%Target for maximum deflection <.1 in
clc;
clear all;

%Design parameters (length dimensions in inches)

h=36;       %Total height of H-Beam
x=12;       %Distance Nathan is offset from center of H-Beam
P=60;       %Nathan's weight (lbs)
F_p=10;     %Pushing force, assumed at top of H-Beam (lbs)

n=25;       %Number of intervals/iterations


%Geometric parameters
t_1=.25*ones(1,n);          %Flange thickness
t_2=.25*ones(1,n);          %Web thickness
w=3*ones(1,n);              %Flange width
d=2.5*ones(1,n);            %H-Beam depth

%Values to vary
%t_1=[.1:(1-.1)/(n-1):1];   %Flange thickness
%t_2=[.1:(1-.1)/(n-1):1];   %Web thickness
%w=[1:(6-1)/(n-1):6];       %Flange width
%d=[1:(5-1)/(n-1):5];       %H-Beam depth


%Material properties
    %Aluminum
    E_Al=10400000; %psi
    wt_Al=.098;    %lbf/in^3

    %Steel
    E_st=30000000; %psi
    wt_st=.282;    %lbf/in^3

%Equivalent force acting on end of cantiliver beam
P_t=P*x/h+F_p;

%Treat H-Beam as cantilever beam, secured on base (no sleeve)
for i=1:n  %Mass moment of inertia
I(i)=2*((1/12)*w(i)*t_1(i)^3+t_1(i)*w(i)*((d(i)-t_1(i))/2)^2)+...
(1/12)*t_2(i)*(d(i)-2*t_1(i))^3;

%Deflection at end of beam
%Aluminum
delta_Al(i)=P_t*h^3/(3*E_Al*I(i));
%Steel
delta_st(i)=P_t*h^3/(3*E_st*I(i));

%Weight of beam
```

```
    %Volume
v(i)=(2*t_1(i)*w(i)+t_2(i)*(d(i)-2*t_1(i)))*h;

W_Al=v*wt_Al;
W_st=v*wt_st;

%Deflection multiplied by weight
q_Al(i)=delta_Al(i)*W_Al(i);
q_st(i)=delta_st(i)*W_st(i);

end

%figure
%plot([t_1],[delta_Al],'g','LineWidth',2)
%hold on;
%plot([t_1],[delta_st],'b','LineWidth',2)
%title('Beam Deflection')
%xlabel('Flange Thickness (in)')
%ylabel('Max Beam Deflection (in)')
%legend('Aluminum','Steel')
%print -djpeg Deflection_as_f(flange thickness)

%figure
%plot([t_1],[W_Al],'--g','LineWidth',2)
%hold on;
%plot([t_1],[W_st],'--b','LineWidth',2)
%title('Beam Weight')
%xlabel('Flange Thickness (in)')
%ylabel('Weight of H-Beam (lbs)')
%legend('Aluminum','Steel')
%print -djpeg Weight_as_f(flange thickness)

%figure
%plot([t_1],[q_Al],'r','LineWidth',2)
%hold on;
%plot([t_1],[q_st],'--c','LineWidth',2)
%title('Weight*Deflection')
%xlabel('Flange Thickness (in)')
%ylabel('Weight*Deflection')
%legend('Aluminum','Steel')
%print -djpeg Weight-Deflection_as_f(flange thickness)
```

Sleeve Analysis

Summary of variables: H-beam sleeve

F_P	= Pushing force
h_{13}	= Height at which equivalent force acts on support members 1 and 3
h_{24}	= Height at which equivalent force acts on members 2 and 4 (where applicable)
h_2	= Offset height of H-beam from lower frame (due to welding…, ideally zero)
h_h	= Handle height (placed at top of H-beam)
h_s	= Height of sleeve
$I_{1,2,3,4}$	= Moment of inertia of respective support member
L_i	= Length of inserts (members 2, 3)
$n_{1,2,3,4}$	= Safety factor of respective support member
P	= Weight of Nathan
t_1	= Thickness of support member 1
t_2	= Thickness of support member 2 (if applicable)
t_3	= Thickness of support member 3
t_4	= Thickness of support member 4
w	= Width of sleeve (members 1, 4)
$\sigma_{1,2,3,4}$	= Normal stress at base of respective support members
$\sigma'_{1,2,3,4}$	= von Mises stress at base of respective support members
$\tau_{1,2,3,4}$	= Shear stress at bottom of respective support members

MATLAB

```
%Sleeve calculations
%Analysis is done in data arrays to allow a range of variables to be tested
clc;
clear all;
%Parameters to define (length dimensions in inches)
n=10;        %Number of intervals/iterations

P=60;        %Weight of Nathan (lbs)
x=12;        %Distance Nathan is offset from center of H-Beam

%h_s=4*ones(1,n);      %Height of sleeve
h_2=.05*ones(1,n);     %Offset height of H-Beam from frame
w=4*ones(1,n);         %Width (long dimension) of outside supports
L_i=.5*ones(1,n);      %Length (long dimension) of inner supports
t_1=.25*ones(1,n);     %Thickness of long sleeve support (Front end)
t_2=.25*ones(1,n);     %Thickness of short sleeve support (Front center
                          %support)
t_3=.5*ones(1,n);      %Thinkness of short sleeve support (Back center
                          %support)
t_4=.25*ones(1,n);     %Thickness of long sleeve support (Back end)

%Varied parameters
h_s=[1:(8-1)/(n-1):8];        %Height of sleeve
%h_2=[.01:(.5-.01)/(n-1):.5]; %Offset height of H-Beam from frame
%w=[1:(6-1)/(n-1):6];         %Width (long dimension) of outside supports
%L_i=[.1:(.75-.1)/(n-1):.75]; %Length (long dimension) of inner supports
%t_1=[.1:(.5-.1)/(n-1):.5];   %Thickness of long sleeve support (Front end)
%t_2=[.1:(.5-.1)/(n-1):.5];   %Thickness of short sleeve support (Front
                                 %center support)
%t_3=[.1:(.75-.1)/(n-1):.75]; %Thinkness of short sleeve support (Back
                                 %center support)
%t_4=[.1:(.5-.1)/(n-1):.5];   %Thickness of long sleeve support (Back end)


F_p=15;     %Pushing force (lbs)
h_h=36;     %Handle height

%Material properties
    %Aluminum
    S_u=45000; %Ultimate stress allowable, psi
    S_y=40000; %Yield stress, psi

    %Steel
    %S_u=147000; %Ultimate stress allowable, psi
    %S_y=72000;  %Yield stress, psi



%Geometric properties
for i=1:n
I_1(i)=(1/12)*w(i)*t_1(i)^3;        %Mass moment of inertia for member 1
```

```
I_2(i)=2*(1/12)*L_i(i)*t_2(i)^3;     %Mass moment of inertia for member 2
I_3(i)=2*(1/12)*L_i(i)*t_3(i)^3;     %Mass moment of inertia for member 3
I_4(i)=(1/12)*w(i)*t_4(i)^3;         %Mass moment of inertia for member 4

%Equivalent force line of action
%h_13,h_4 are the heights where the force is acting

    %Linear force distribution
%h_13=[h_s-(1/3)*(h_s-h_2)/2];
%h_24=[h_2+(1/3)*(h_s-h_2)/2];

    %Quadratic force distribution
h_13(i)=h_s(i)-(1/4)*(h_s(i)-h_2(i))/2;
h_24(i)=h_2(i)+(1/4)*(h_s(i)-h_2(i))/2;

%Force relations
%Load distibuted evenly between all members (F_1=F_2=F_3=F_4)
    %Determining "F"
    %Equation comes from: M_1+M_2+M_3+M_4=P*x+F_p*h_h
    %where M_1=M_3; M_2=M_4
    F(i)=[(P*x+F_p*h_h)/(2*h_13(i)+2*h_24(i))];
    %Moments
M_1(i)=F(i)*h_13(i);
M_2(i)=F(i)*h_24(i);
end
M_3=M_1;
M_4=M_2;


%Stresses

    %Normal stress for each member
for i=1:n
sigma_1(i)=M_1(i)*(t_1(i)/2)/I_1(i);
sigma_2(i)=M_2(i)*(t_2(i)/2)/I_2(i);
sigma_3(i)=M_3(i)*(t_3(i)/2)/I_3(i);
sigma_4(i)=M_4(i)*(t_4(i)/2)/I_4(i);

    %Shear stress for each member
tau_1(i)=(3/2)*F(i)/(w(i)*t_1(i));
tau_2(i)=(3/2)*F(i)/(2*L_i(i)*t_2(i));
tau_3(i)=(3/2)*F(i)/(2*L_i(i)*t_3(i));
tau_4(i)=(3/2)*F(i)/(w(i)*t_4(i));

    %Mises stress
sigma_prime_1(i)=(sigma_1(i)^2+3*tau_1(i)^2)^(1/2);
sigma_prime_2(i)=(sigma_2(i)^2+3*tau_2(i)^2)^(1/2);
sigma_prime_3(i)=(sigma_3(i)^2+3*tau_3(i)^2)^(1/2);
sigma_prime_4(i)=(sigma_4(i)^2+3*tau_4(i)^2)^(1/2);


%Factor of safety, tabulated with yield stress
n_1(i)=S_y/sigma_prime_1(i);
n_2(i)=S_y/sigma_prime_2(i);
n_3(i)=S_y/sigma_prime_3(i);
```

```
n_4(i)=S_y/sigma_prime_4(i);
end

figure
plot([h_s],[FS_min],'k','LineWidth',2);
title('Minimum Safety Factor as Function of h_s');
xlabel('Height of sleeve (h_s)');
ylabel('Safety Factor');
print -djpeg SF_f(h_s);

%Tabulated values
%Aluminum, for SF>3 on all parts:
    %With L_i=.5, F_p=10
    %t_1=.25; t_2=.25; t_3=.5; t_4=.25(only .10 needed for SF>3)
    %Wtih L_1=.75 (maximum value)
    %t_1=.25; t_2=.1875; t_3=.3875; t_4=.1
%Steel, for SF>3 on all parts:
    %With L_i=.5, F_p=10
    %t_1=.1875 (3/16); t_2=.1875; t_3=.375; t_4=.125 (SF=10)
    %Wtih L_i=.75 (maximum value)
    %t_1=.175; t_2=.125; t_3=.3125; t_4<.1

%changing h_s (height of sleeve) does not improve FS at base
%recommend 3" or 4" (any shorter would not "appear" as safe)
```

Harness Support

Equations

$E = 10.4 \cdot 10^{6}$

$d_o = 0.5$

$p = 35$

$d_x = 11.25$

$d_s = 12$

$S_y = 40000$

$wall_{thickness} = 0.12$

$$wall_{thickness} = \frac{d_o - d_i}{2}$$

$$A = \frac{\pi}{4} \cdot (d_o^{2} - d_i^{2})$$

$$\theta = \mathbf{arccos}\left[\frac{d_x}{d_s}\right]$$

$$I = \pi \cdot \left[\frac{d_o^{4} - d_i^{4}}{64}\right]$$

$r_s + r_a - p = 0$

$r_s - r_b = 0$

$M_A = r_s \cdot d_x - p \cdot d_x$

$r_{sy} = r_s \cdot \mathbf{cos}(\theta)$

$r_{sx} = r_s \cdot \mathbf{sin}(\theta)$

$$\delta_{sy} = \frac{r_{sy} \cdot d_s^{3}}{3 \cdot E \cdot I}$$

$$\delta_{sx} = \frac{r_{sx} \cdot d_s}{A \cdot E}$$

$$\delta_t = \frac{p \cdot d_x^{3}}{3 \cdot E \cdot I}$$

$\delta_t = \mathbf{cos}(\theta) \cdot (\delta_{sy} + \delta_{sx})$

$$\sigma_m = M_A \cdot \frac{d_o}{2 \cdot I}$$

$$tao_m = 2 \cdot \frac{r_a}{A}$$

$$\sigma_{prime} = (\sigma_m^{2} + 3 \cdot tao_m^{2})^{0.5}$$

$$P_{cr} = 1.2 \cdot \pi^{2} \cdot E \cdot \frac{I}{d_s^{2}}$$

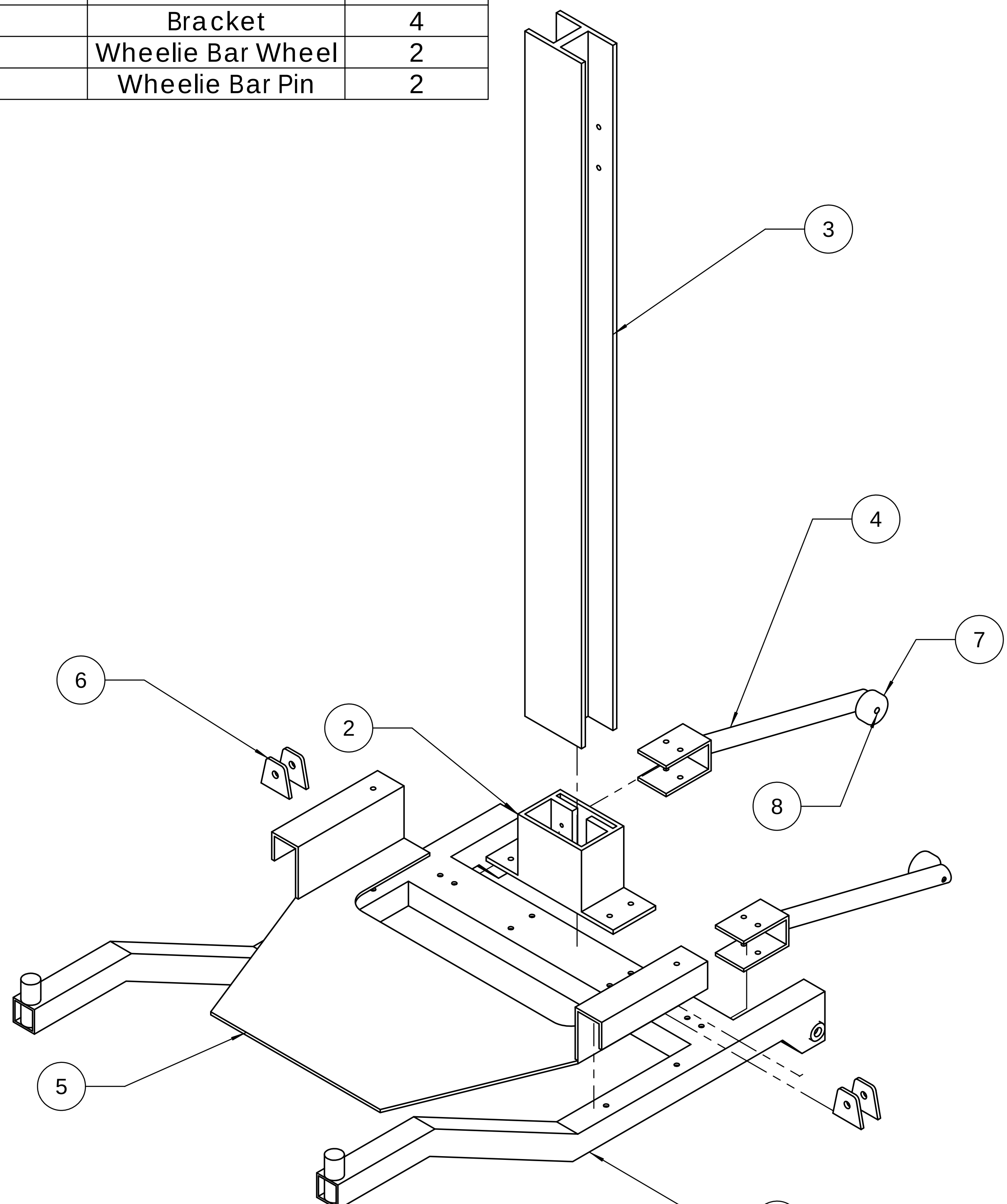
$$n = \frac{S_y}{\sigma_{prime}}$$

Results

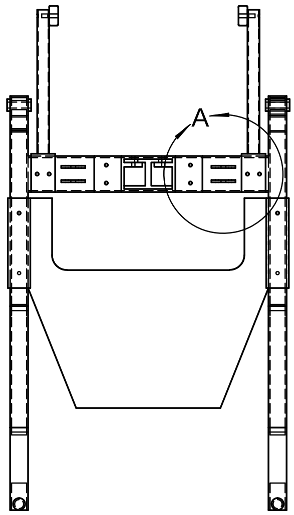
A=0.1433
delta_sx=0.00009195
delta_sy=0.599
delta_t=0.5617
d_i=0.26
d_o=0.5
d_s=12
d_x=11.25
E=1.040E+07
I=0.002844
M_A=-24.67
n=18.44
p=35
P_cr=2432
r_a=2.193
r_b=32.81
r_s=32.81
r_sx=11.42
r_sy=30.76
sigma_m=-2169
sigma_prime=2169
S_y=40000
tao_m=30.61
theta=20.36
wall_thickness=0.12

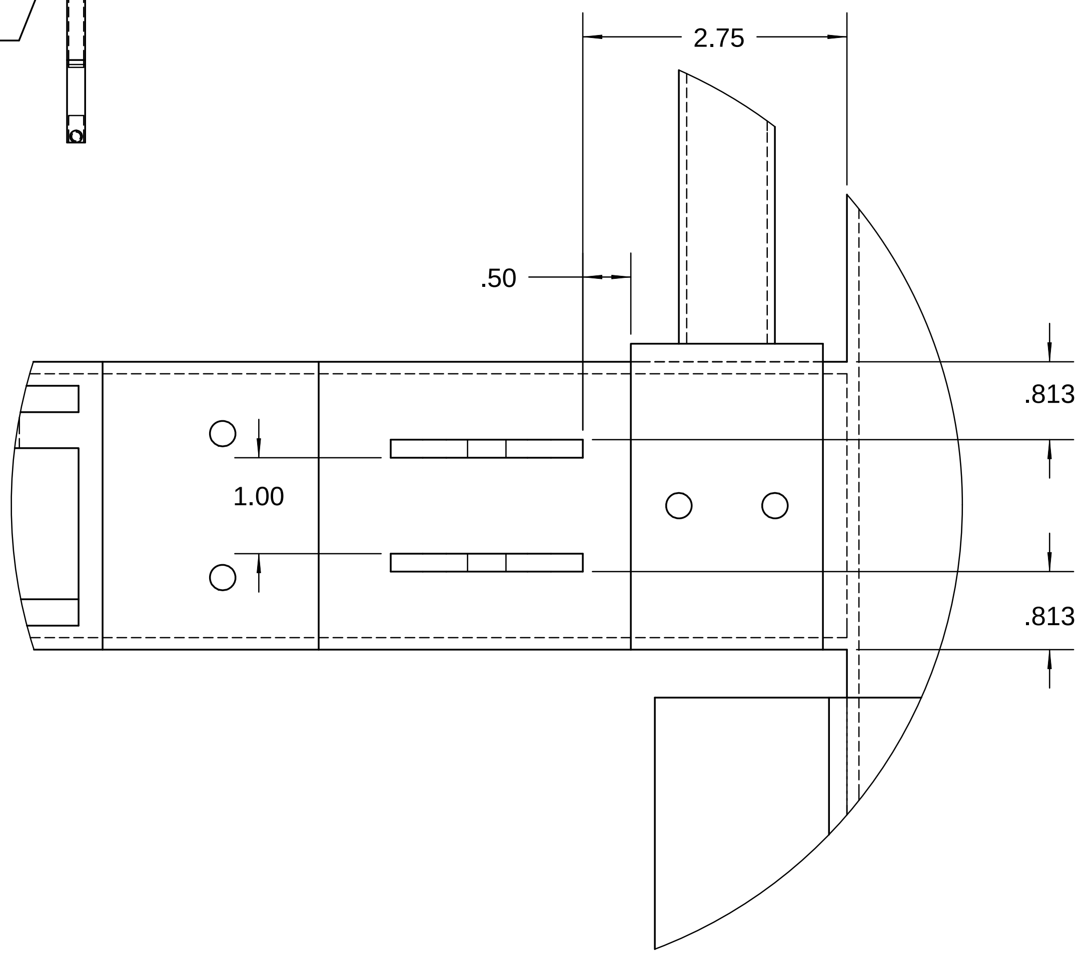
Appendix D: Drawing Packet

ITEM NO.	PART NUMBER	Description	Default/QTY.
1	010D	Bottom Frame	1
2	030C	H-Beam Sleeve	1
3	020D	H-Beam	1
4	040B	Wheelie Bar	2
5	050B	Foot Plate	1
6	212A	Bracket	4
7		Wheelie Bar Wheel	2
8		Wheelie Bar Pin	2



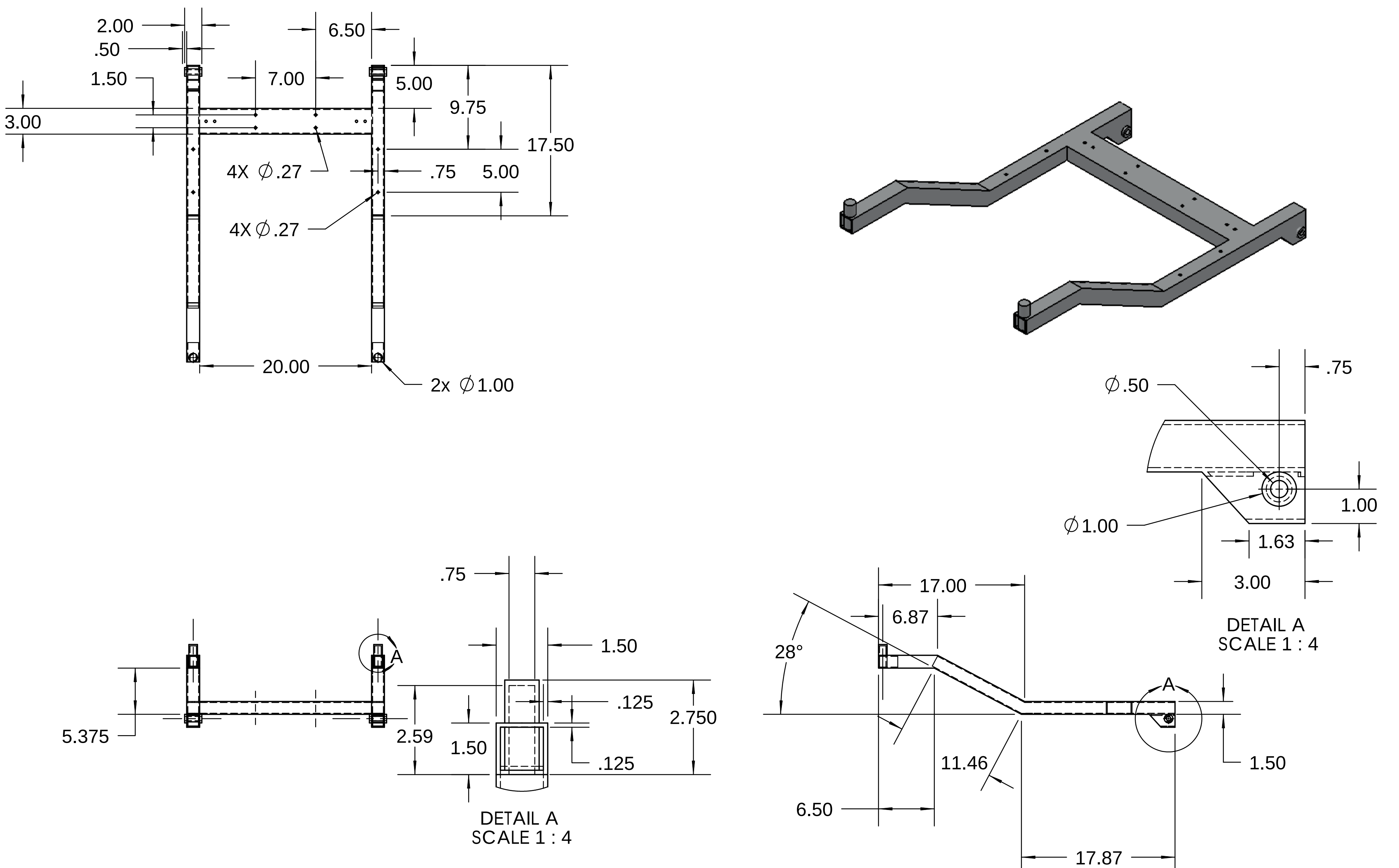
STRIDER PROJECT	MATERIAL:	NEXT ASSY: 500A	SIGNATURE:
Mechanical Engineering CAL POLY		DRAWING # 000A	ADVISOR: LOU ROSENBERG
	TOL:	UNITS:	TITLE: BOTTOM FRAME ASSEMBLY
	SCALE: 1:8	DATE: 05/31/2010	NAME: ERIC JOHNSON





DETAIL A
SCALE 1 : 2

STRIDER PROJECT	MATERIAL:	NEXT ASSY: 500A	SIGNATURE:
		DRAWING # 000A	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL:	UNITS:	TITLE: FRAME BRACKET LOCATIONS
	SCALE: 1:16	DATE:	NAME:

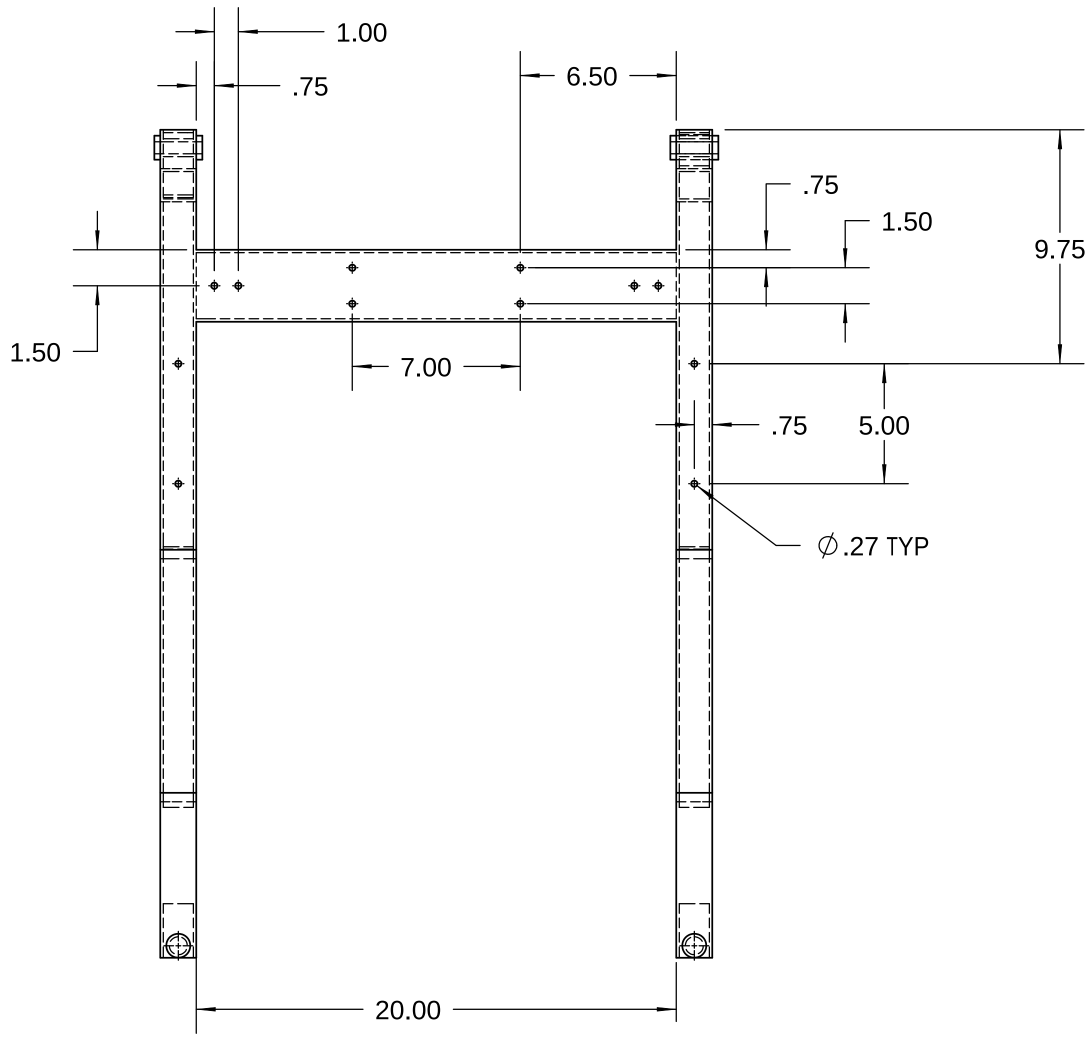


STRIDER PROJECT

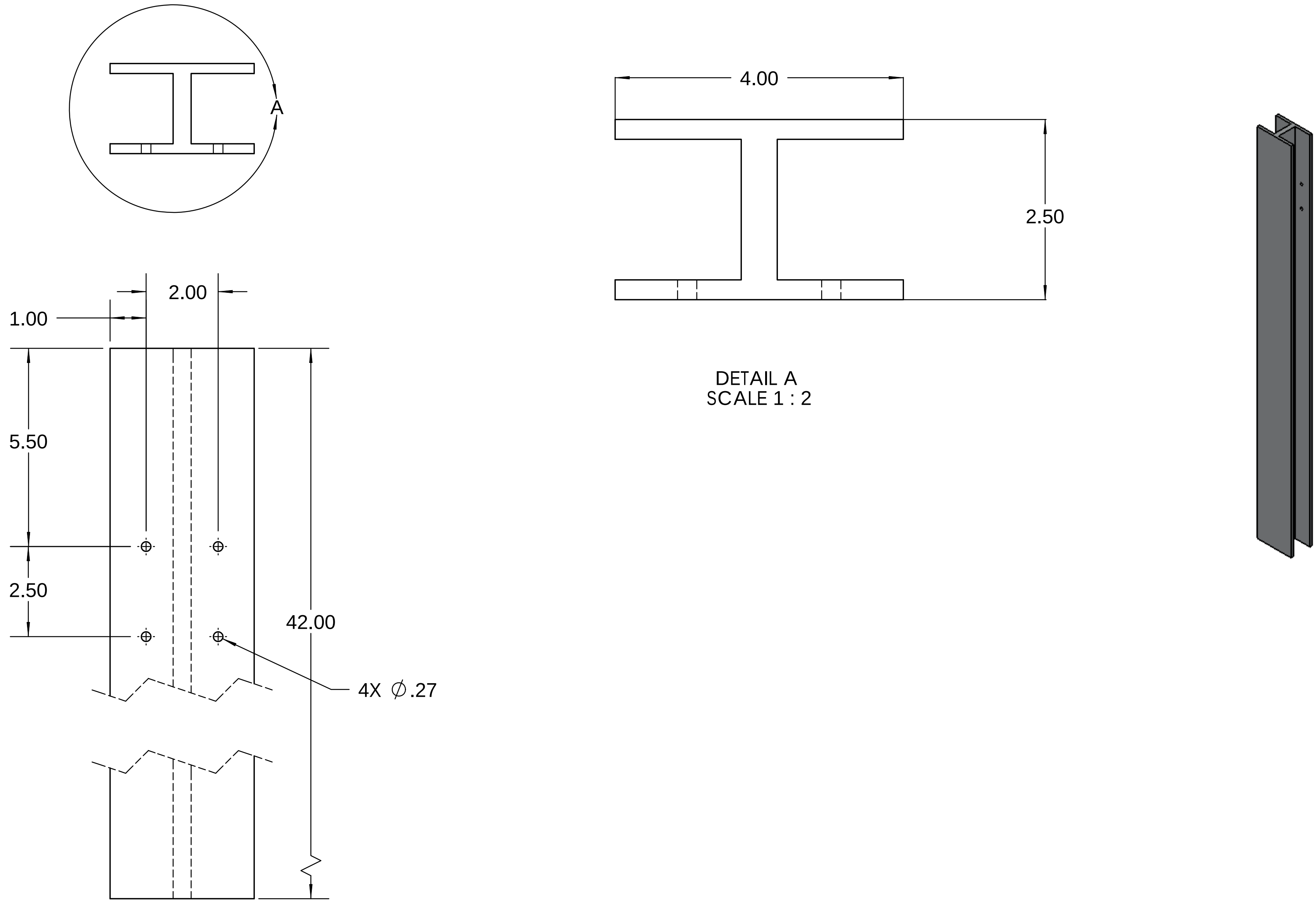
Mechanical Engineering
CAL POLY

	NEXT ASSY: 000A	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 010D	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS: IN	TITLE: BOTTOM FRAME
SCALE: 1:16	DATE: 5/27/2010	NAME: ERIC JOHNSON

5 4 3 2 1



STRIDER PROJECT	MATERIAL: Al 6061	NEXT ASSY: 000A	SIGNATURE:
		DRAWING # 010C	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL: ±.01	UNITS: IN	TITLE: BOTTOM FRAME HOLE LOCATIONS
	SCALE: 1:8	DATE:	NAME:

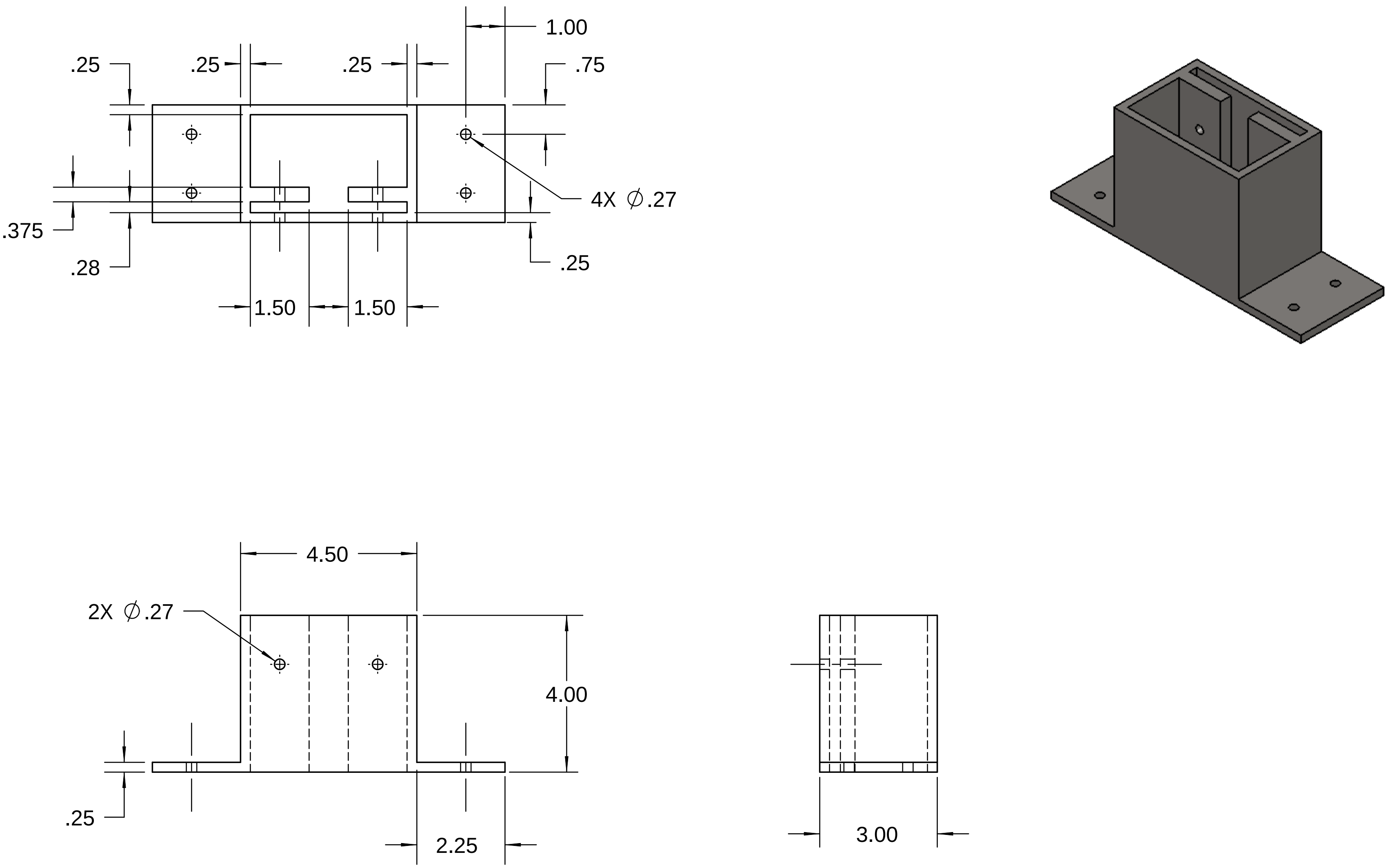


STRIDER PROJECT

Mechanical Engineering
CAL POLY

	NEXT ASSY: 000A	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 020D	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: H-BEAM
SCALE: 1:8	DATE: 05/31/2010	NAME: ERIC JOHNSON

5 4 3 2 1

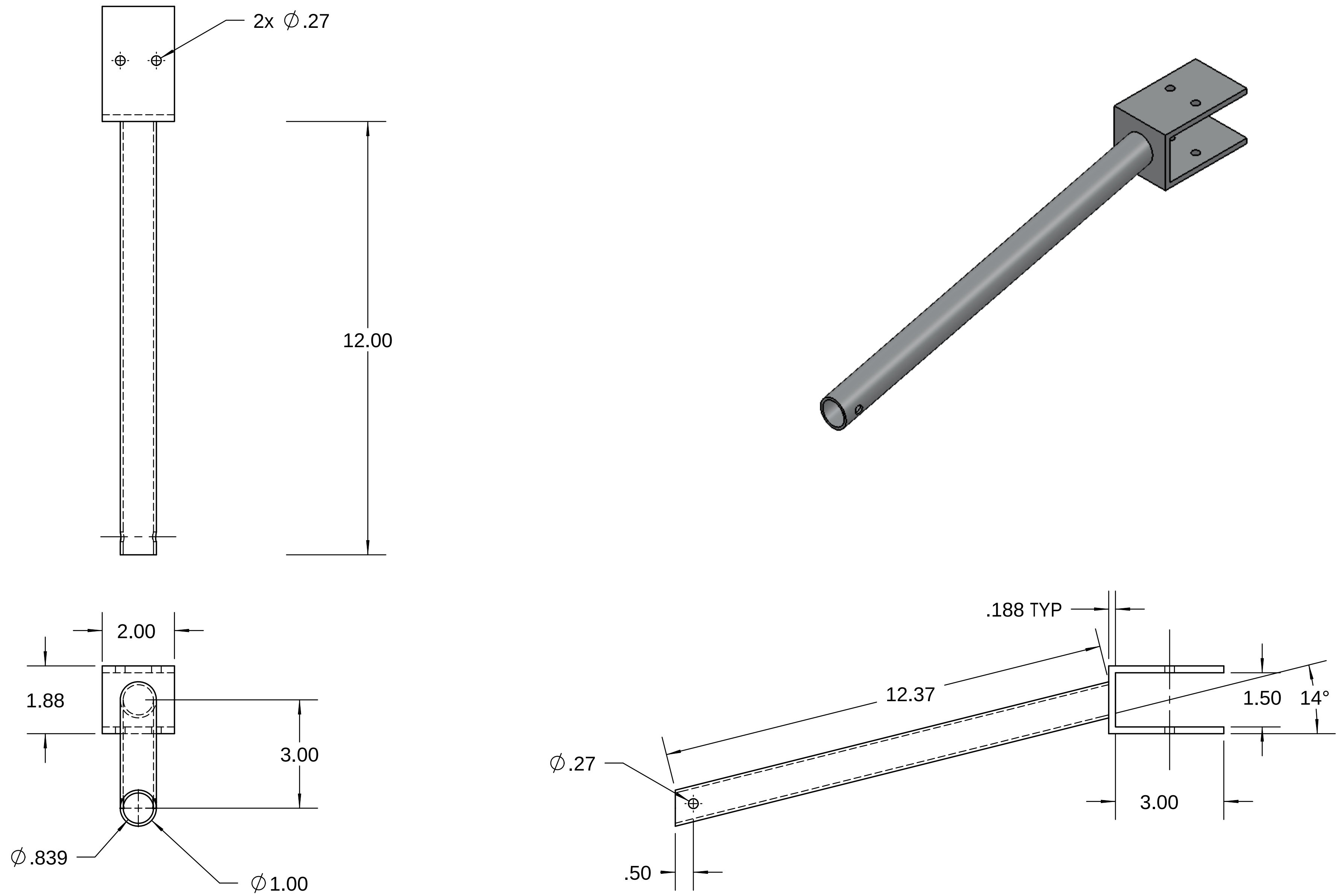


STRIDER PROJECT

Mechanical Engineering
CAL POLY

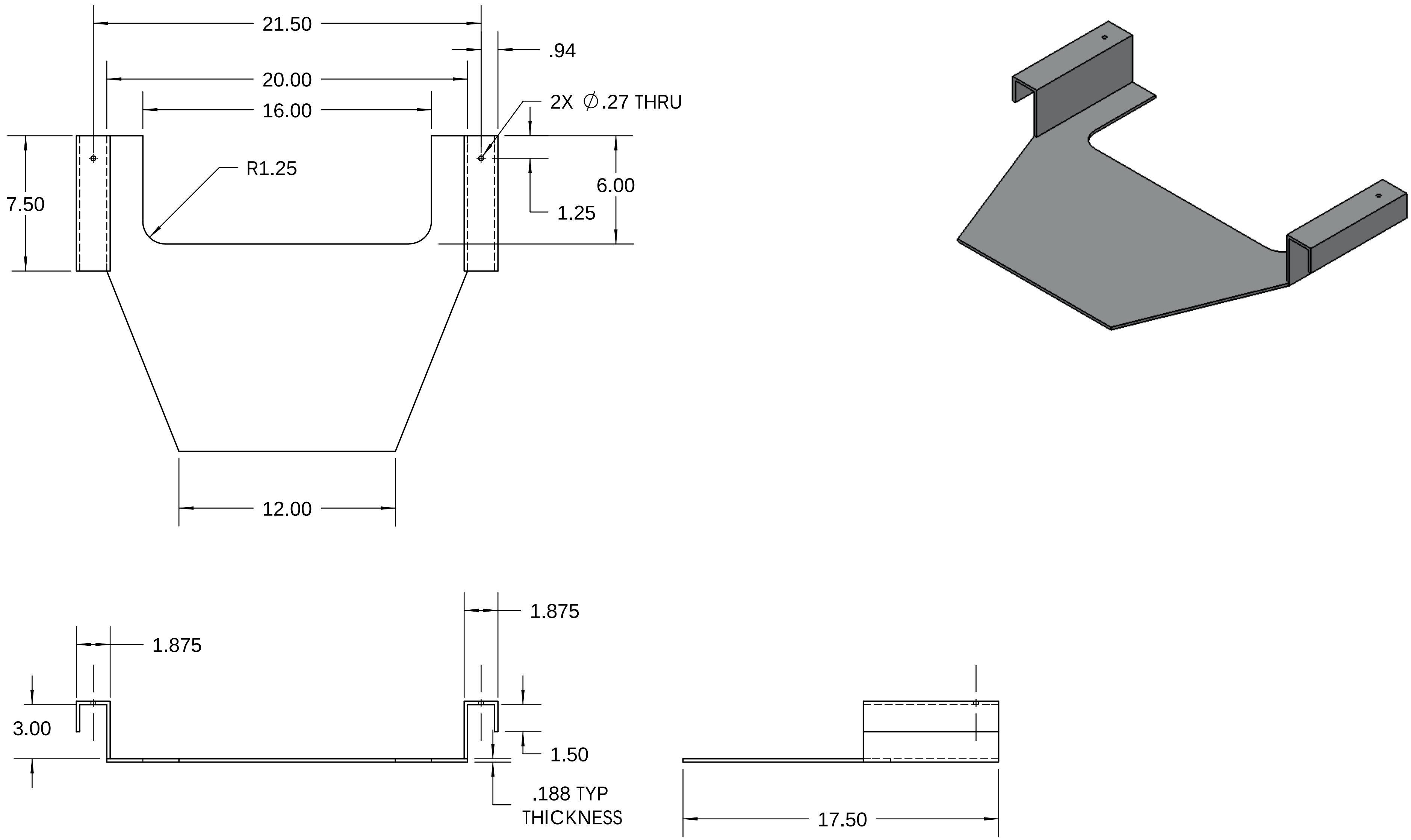
	NEXT ASSY: 000A	SIGNATURE:
MATERIAL: STEEL	DRAWING #: 030C	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS: IN	TITLE: H-BEAM SLEEVE
SCALE: 1:4	DATE: 4/24/2010	NAME: ERIC JOHNSON

5 4 3 2 1



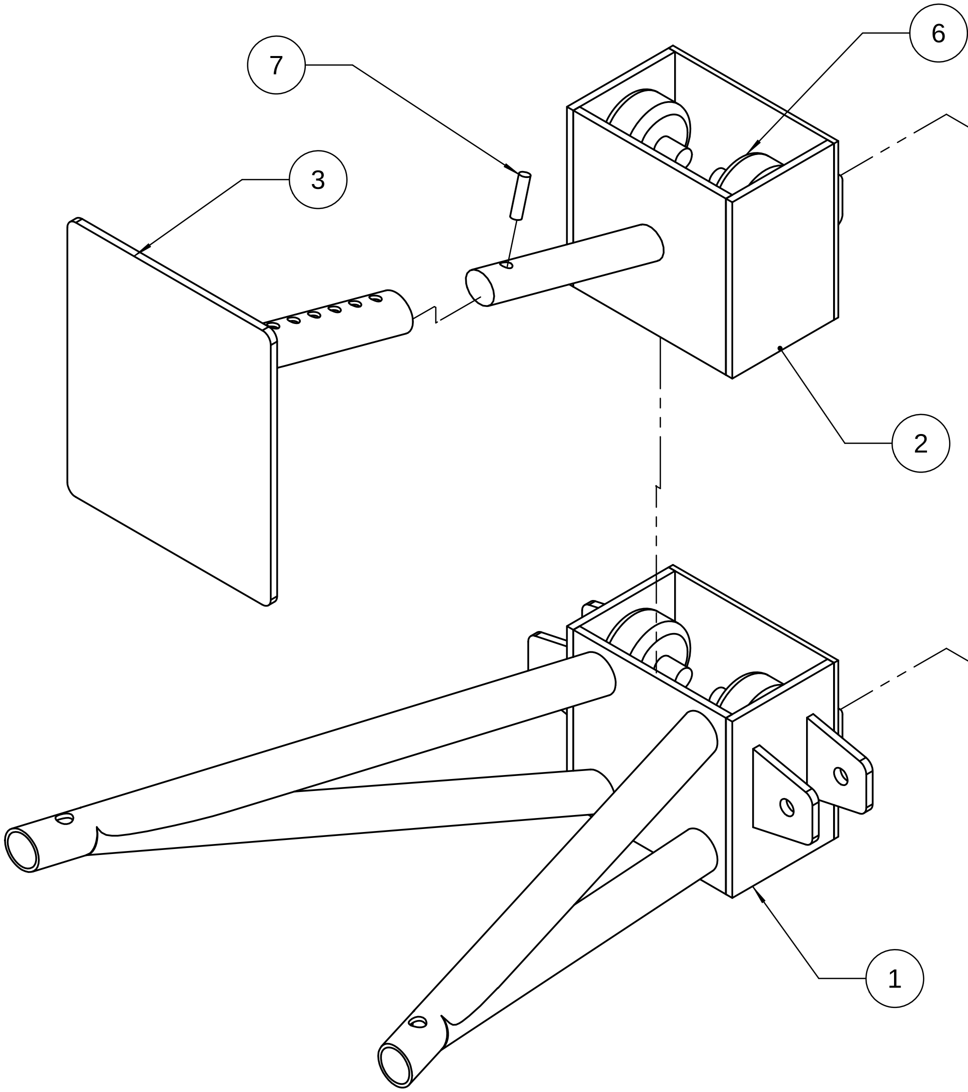
STRIDER PROJECT		NEXT ASSY: 000A	SIGNATURE:
Mechanical Engineering CAL POLY	MATERIAL: Al 6061	DRAWING #: 040B	ADVISOR: LOU ROSENBERG
	TOLERANCE:	UNITS: IN	TITLE: WHEELIE BAR
	SCALE: 1:4	DATE: 4/24/2010	NAME: ALEX TRASK & ERIC JOHNSON

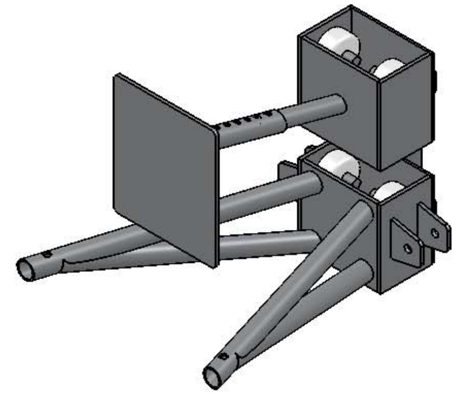
5 4 3 2 1



STRIDER PROJECT		NEXT ASSY: 000A	SIGNATURE:
Mechanical Engineering CAL POLY	MATERIAL: Al 6061	DRAWING #: 050B	ADVISOR: LOU ROSENBERG
	TOLERANCE: ±.01	UNITS: IN	TITLE: FOOT PLATE
	SCALE: 1:8	DATE: 2/10/2010	NAME: ERIC JOHNSON

5 4 3 2 1





ITEM NO.	PART NUMBER	Description	QTY.
1	101B	Carriage Sub-Assembly (Bottom)	1
2	102B	Carriage Sub-Assembly (Top)	1
3	145D	Back Plate	1
4	128A	Carriage Adjustment Post - Outside	1
5	127A	Carriage Adjustment Post - Inside	1
6		Skate Wheel	8
7		Pin	1

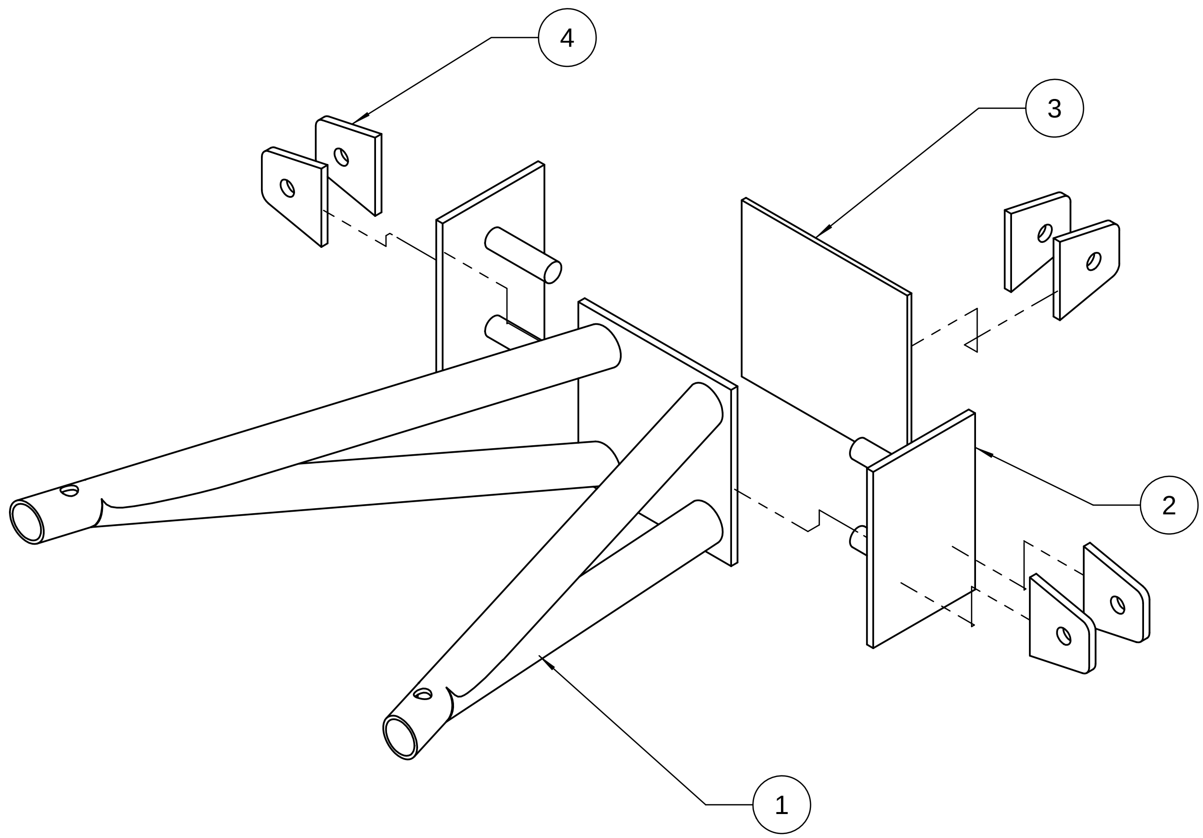
STRIDER PROJECT

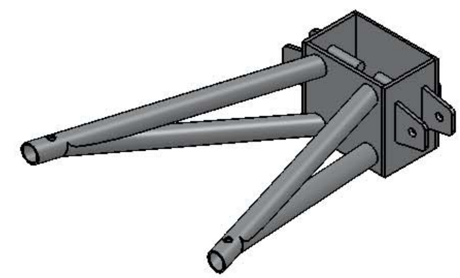
Mechanical Engineering CAL POLY

	NEXT ASSY: 500A	SIGNATURE:
MATERIAL:	DRAWING #: 100B	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS:	TITLE: CARRIAGE ASSEMBLY
SCALE: 1:4	DATE:05/31/2010	NAME:

5 4 3 2 1

ITEM NO.	PART NUMBER	Description	QTY.
1	110A	Carriage Bottom	1
2	120A	Carriage Sides	2
3	130A	Rear Carriage Plate	1
4	212A	Bracket	6



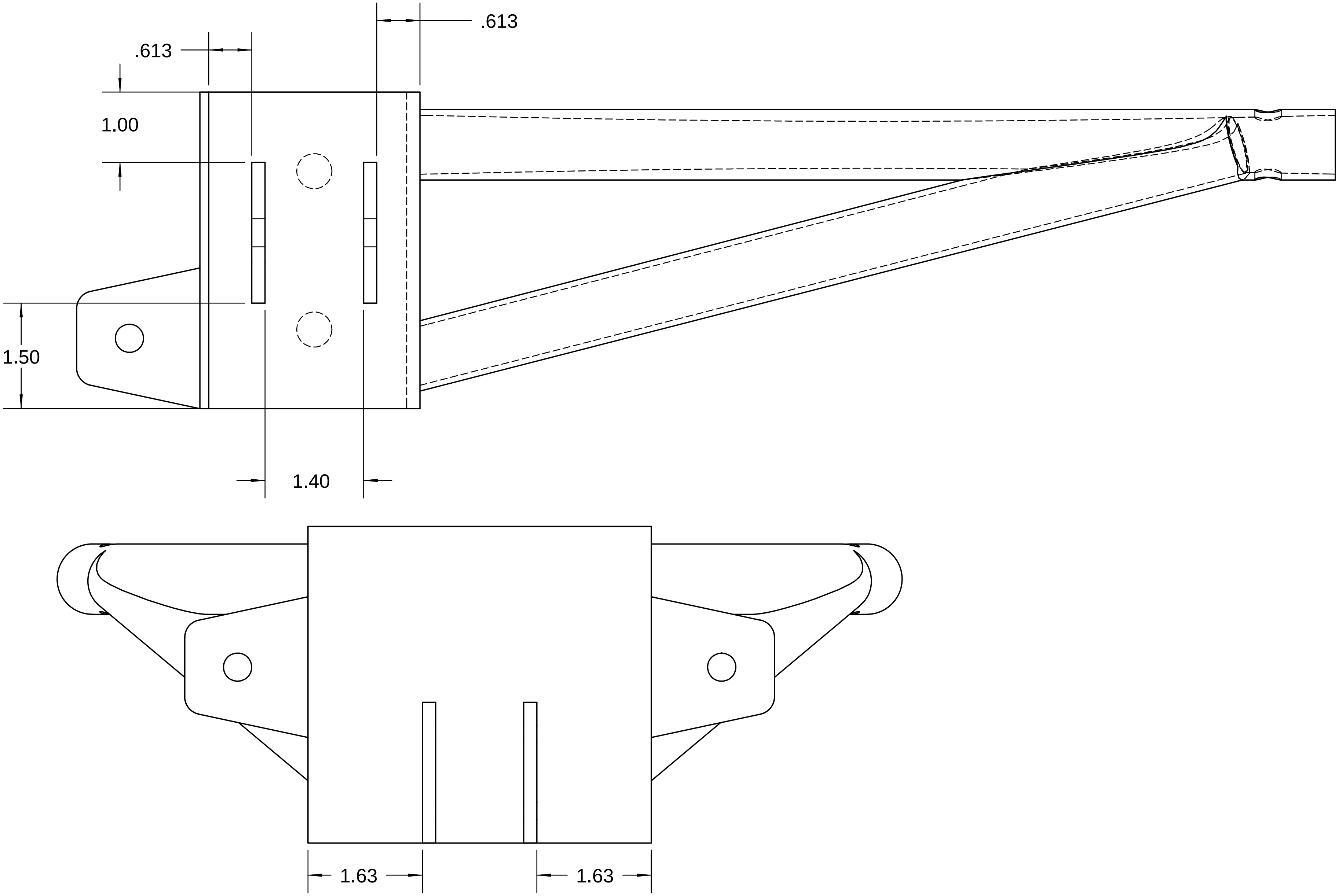


STRIDER PROJECT

Mechanical Engineering
CAL POLY

	NEXT ASSY: 100B	SIGNATURE:
MATERIAL:	DRAWING #: 101B	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS:	TITLE: CARRIAGE SUB-ASSEMBLY (BOTTOM)
SCALE: 1:4	DATE: 05/31/2010	NAME: ERIC JOHNSON & ALEX TRASK

5 4 3 2 1



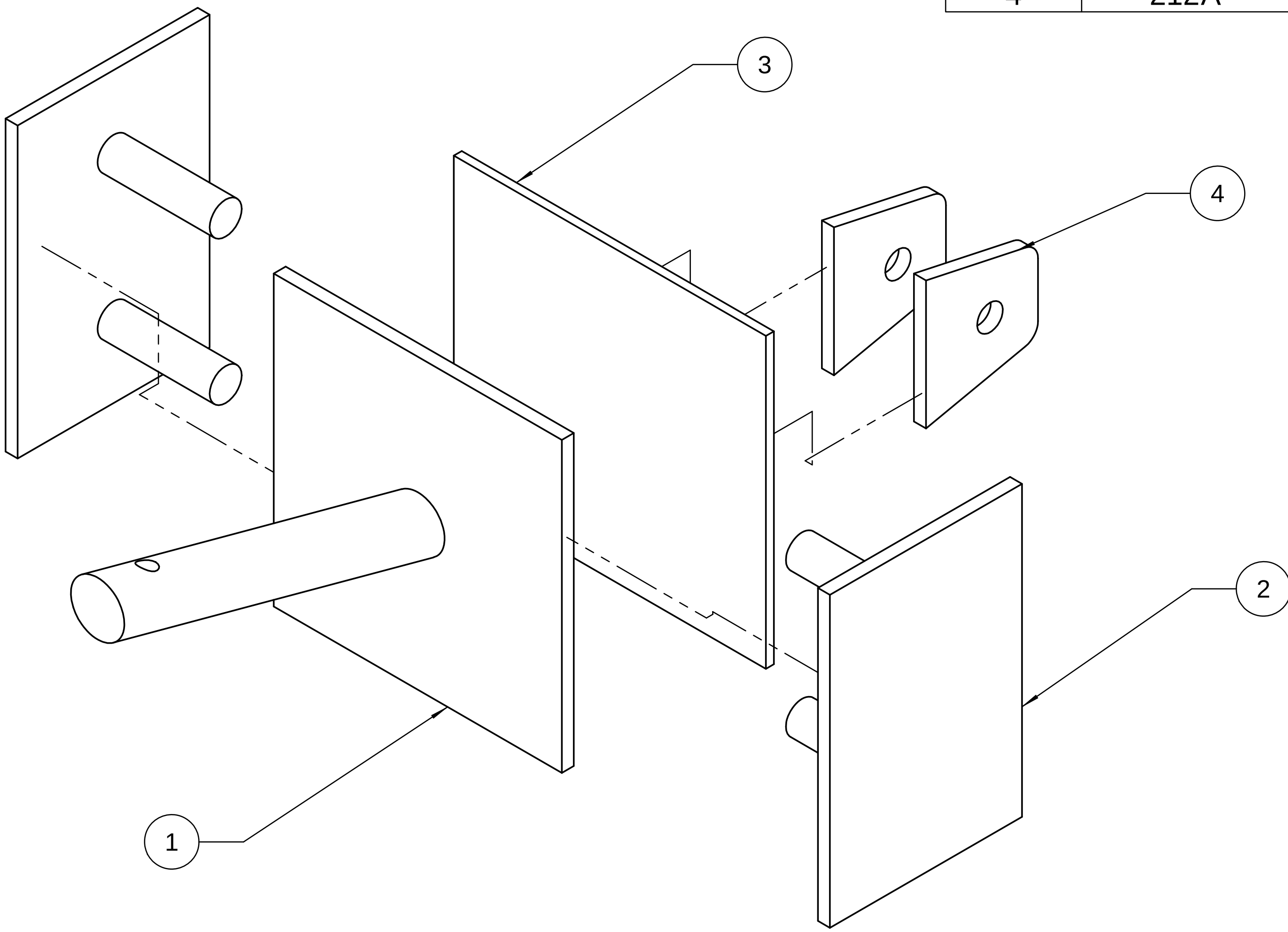
STRIDER PROJECT

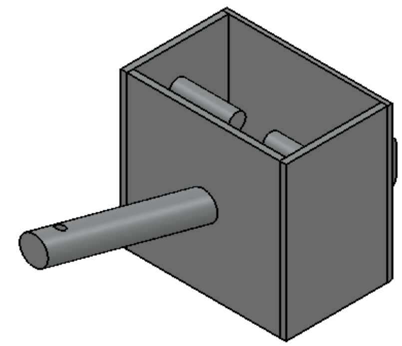
Mechanical Engineering
CAL POLY

	NEXT ASSY: 100B	SIGNATURE:
MATERIAL:	DRAWING #: 101B	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS: IN	TITLE: CARRIAGE BRACKET LOCATIONS
SCALE: 1:2	DATE:	NAME:

5 4 3 2 1

ITEM NO.	PART NUMBER	Description	QTY.
1	140D	Back Carriage - Inside	1
2	120A	Carriage Sides	2
3	130A	Rear Carriage Plate	1
4	212A	Bracket	2



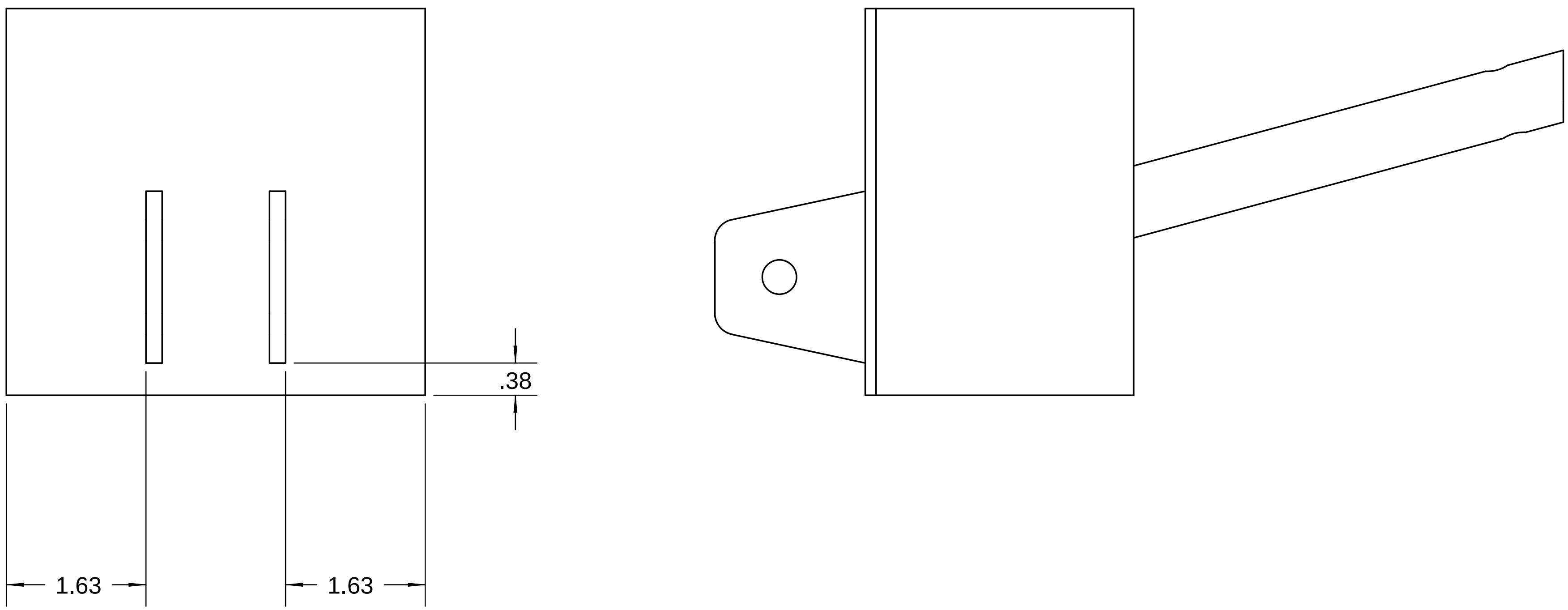


STRIDER PROJECT

Mechanical Engineering CAL POLY

	NEXT ASSY: 100B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 102B	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS:	TITLE: CARRIAGE ASSEMBLY (TOP)
SCALE: 1:2	DATE: 05/31/2010	NAME: ERIC JOHNSON

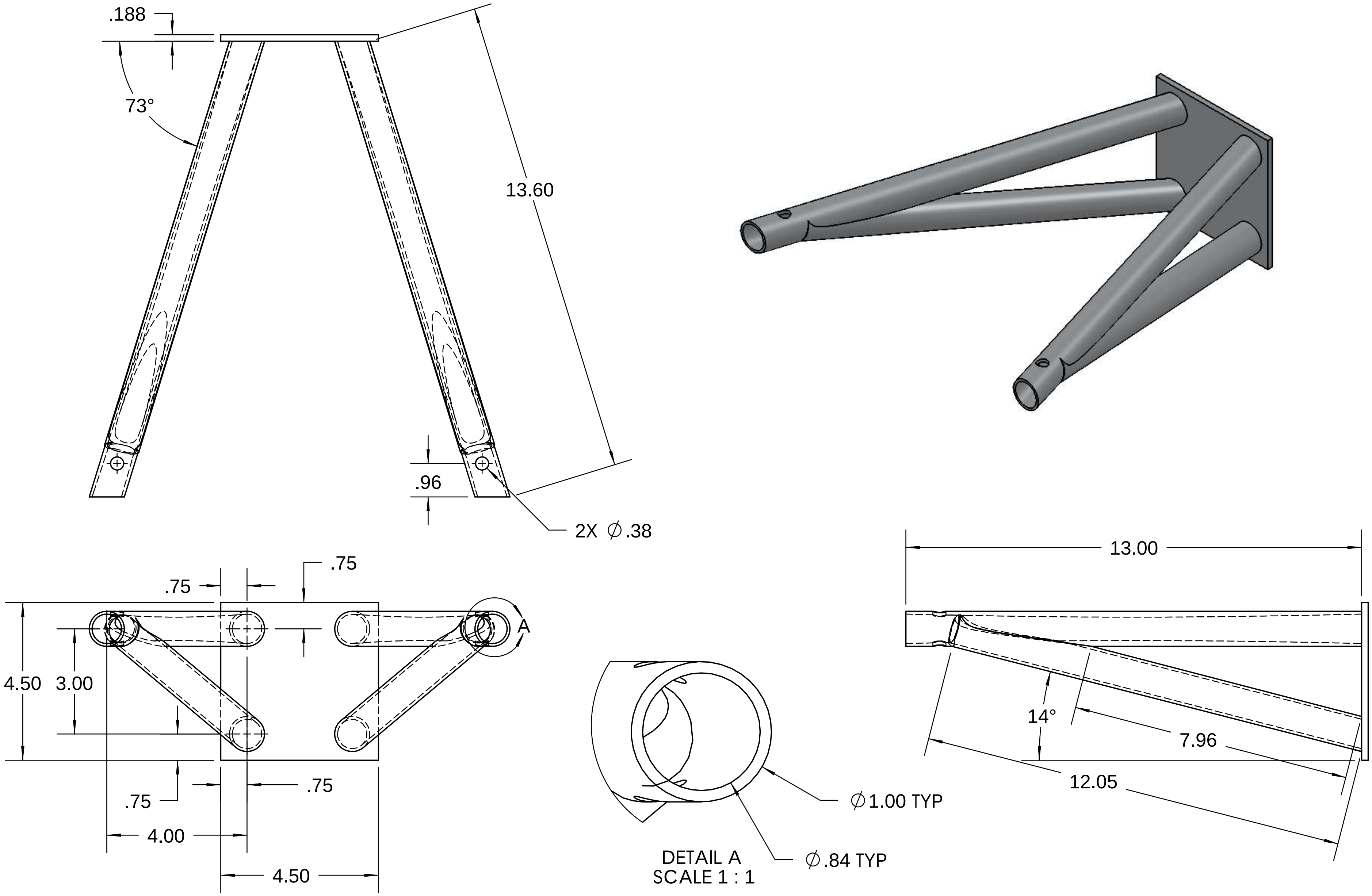
5 4 3 2 1



STRIDER PROJECT	NEXT ASSY: 101B	SIGNATURE:
MATERIAL:	DRAWING #: 102B	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS:	TITLE: TOP CARRAIGE BRACKET LOCATIONS
SCALE: 1:2	DATE: 05/31/2010	NAME:

Mechanical Engineering CAL POLY

5 4 3 2 1

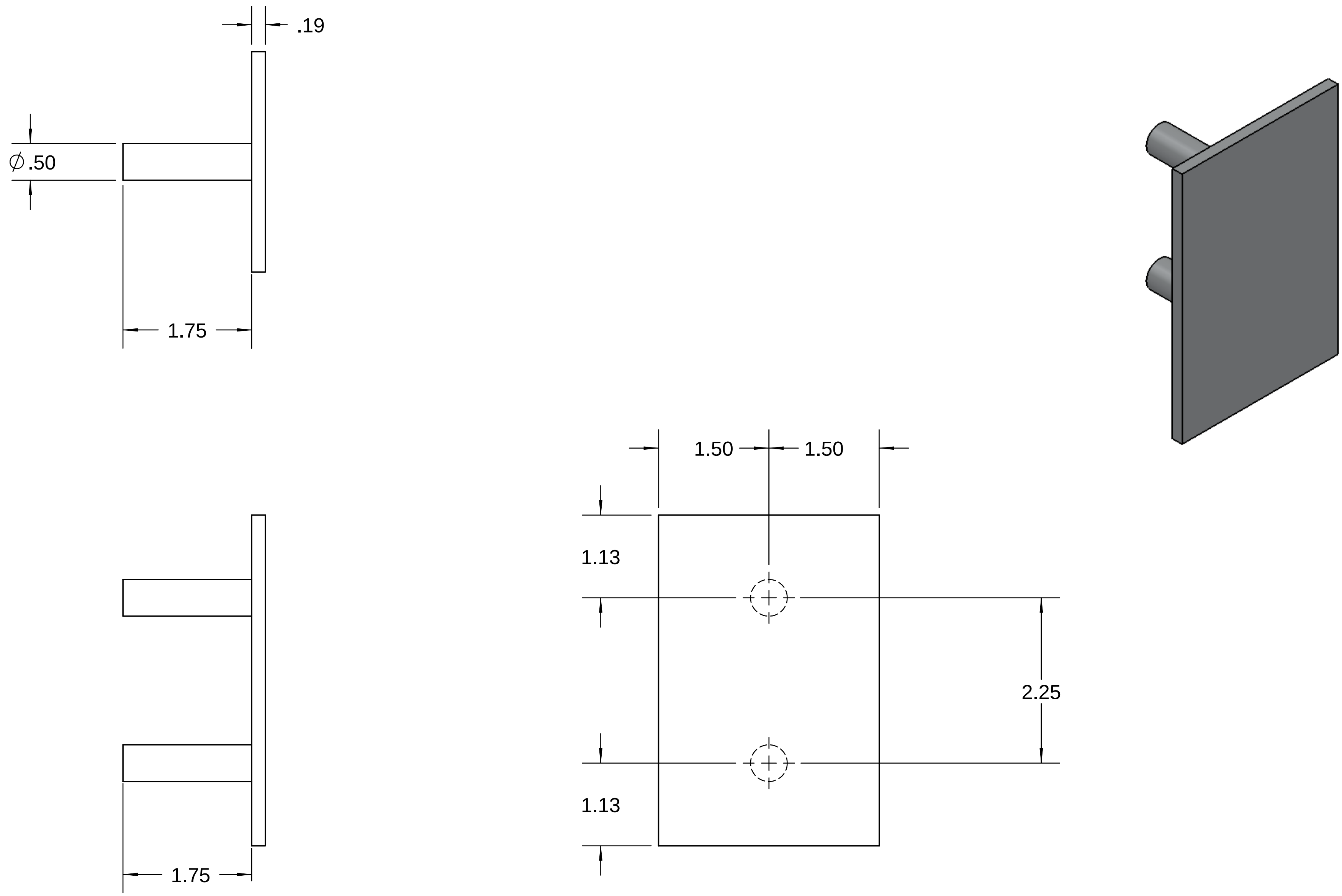


STRIDER PROJECT

Mechanical Engineering
CAL POLY

	NEXT ASSY: 101B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 110B	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: CARRIAGE - BOTTOM HARNESS
SCALE: 1:4	DATE: 4/24/2010	NAME: ALEX TRASK & ERIC JOHNSON

5 4 3 2 1

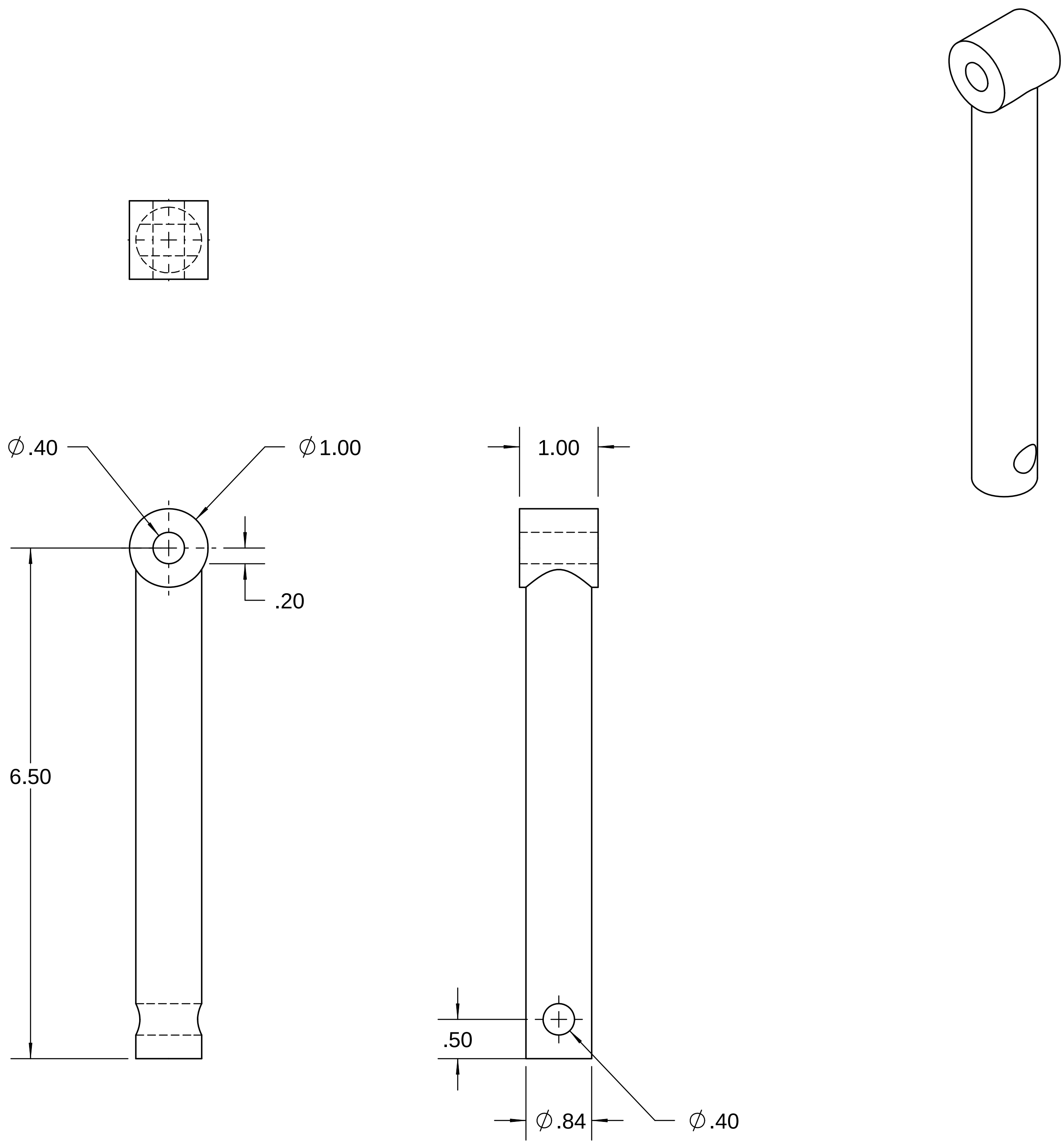


STRIDER PROJECT

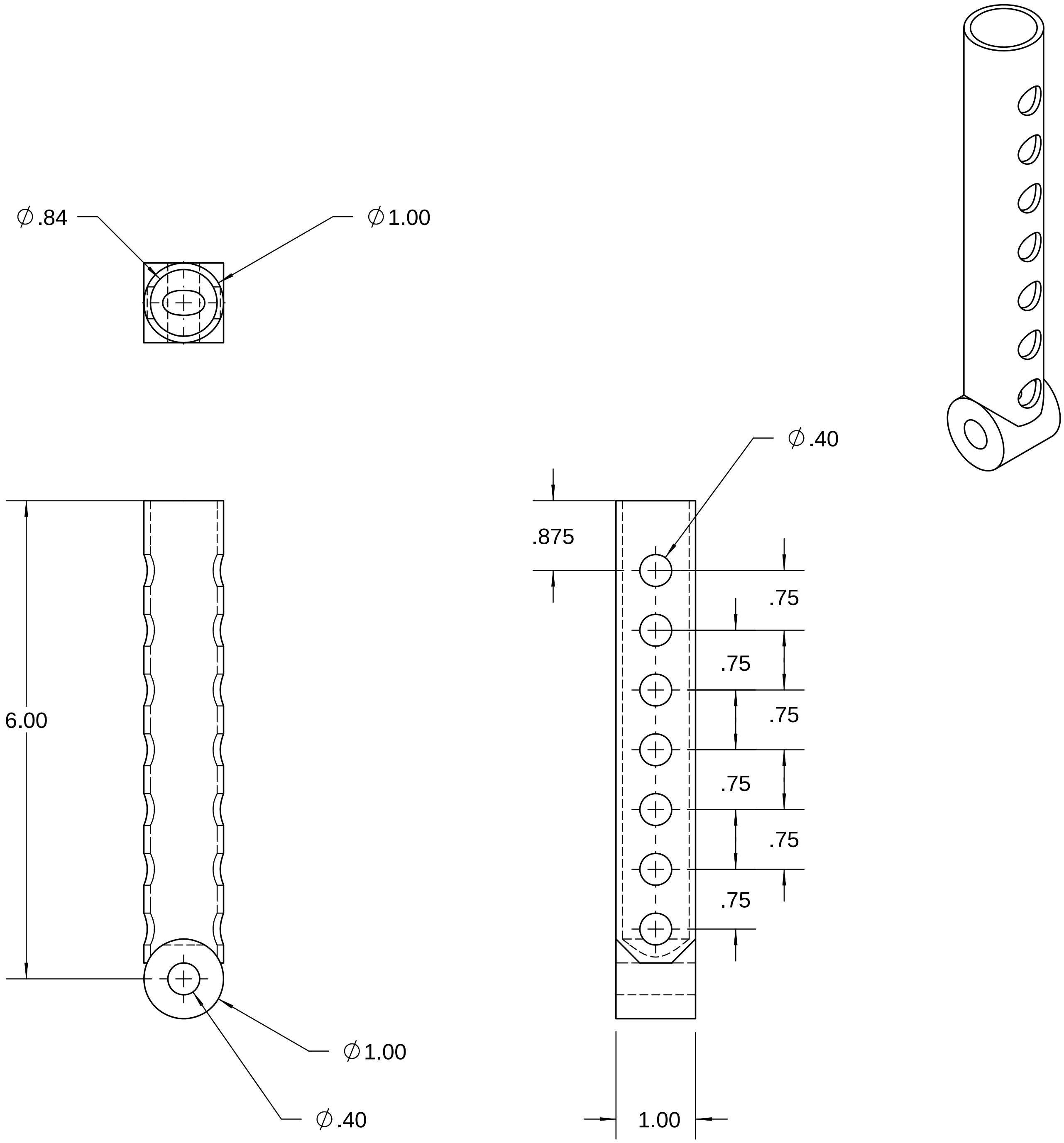
Mechanical Engineering CAL POLY

	NEXT ASSY: 101B & 102B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 120A	ADVISOR: LOU ROSENBERG
TOLERANCE:	UNITS: IN	TITLE: CARRIAGE SIDES
SCALE: 1:2	DATE: 1/18/2010	NAME: ALEX TRASK

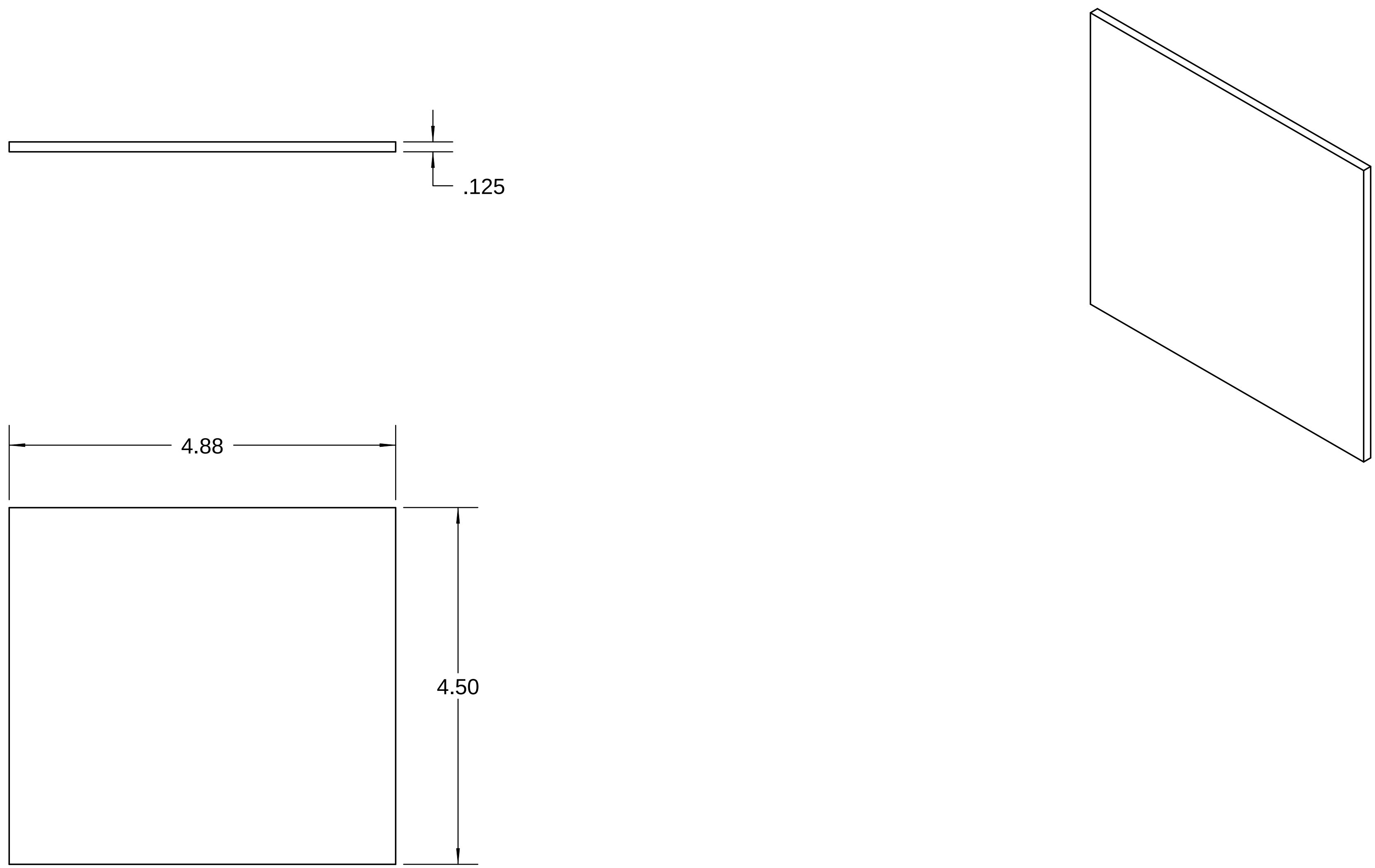
5 4 3 2 1



STRIDER PROJECT	MATERIAL: Al 6061	NEXT ASSY: 101B	SIGNATURE:
		DRAWING # 127A	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL: ±.01	UNITS: IN	TITLE: CARRIAGE ADJUSTMENT POST-INSIDE
	SCALE: 1:2	DATE: 05/31/2010	NAME: ERIC JOHNSON



STRIDER PROJECT	MATERIAL: Al 6061	NEXT ASSY: 102B	SIGNATURE:
		DRAWING #: 128A	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL: ±.01	UNITS: IN	TITLE: CARRIAGE ADJUSTMENT POST - OUTSIDE
	SCALE: 1:2	DATE: 05/31/2010	NAME: ERIC JOHNSON

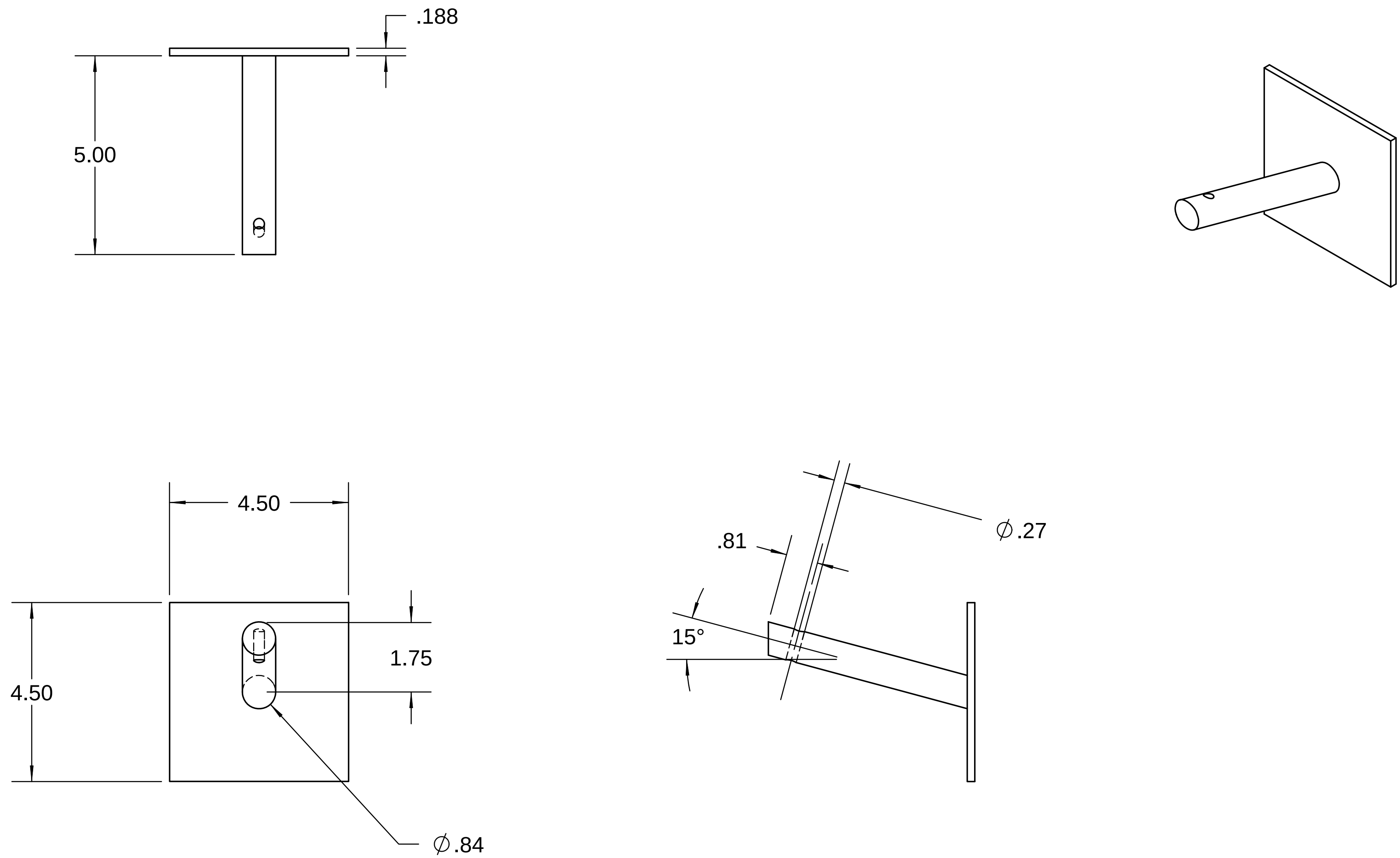


STRIDER PROJECT

Mechanical Engineering
CAL POLY

	NEXT ASSY: 101B, 102B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 130A	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: REAR CARRIAGE PLATE
SCALE: 1:1	DATE: 05/31/2010	NAME: ERIC JOHNSON

5 4 3 2 1

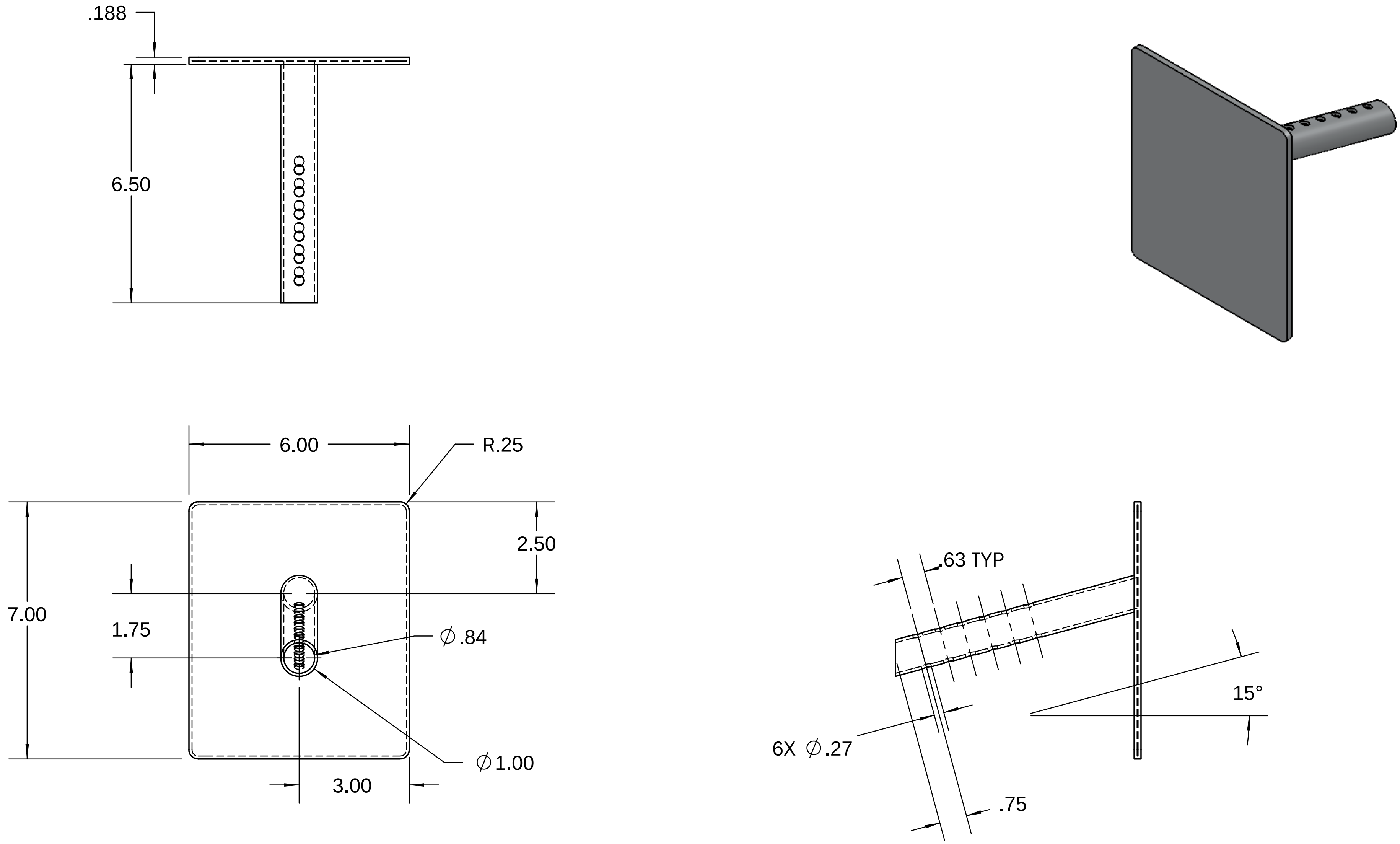


STRIDER PROJECT

Mechanical Engineering
CAL POLY

	NEXT ASSY: 102B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 140D	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: BACK CARRIAGE - INSIDE
SCALE: 1:4	DATE: 5/31/2010	NAME: ALEX TRASK

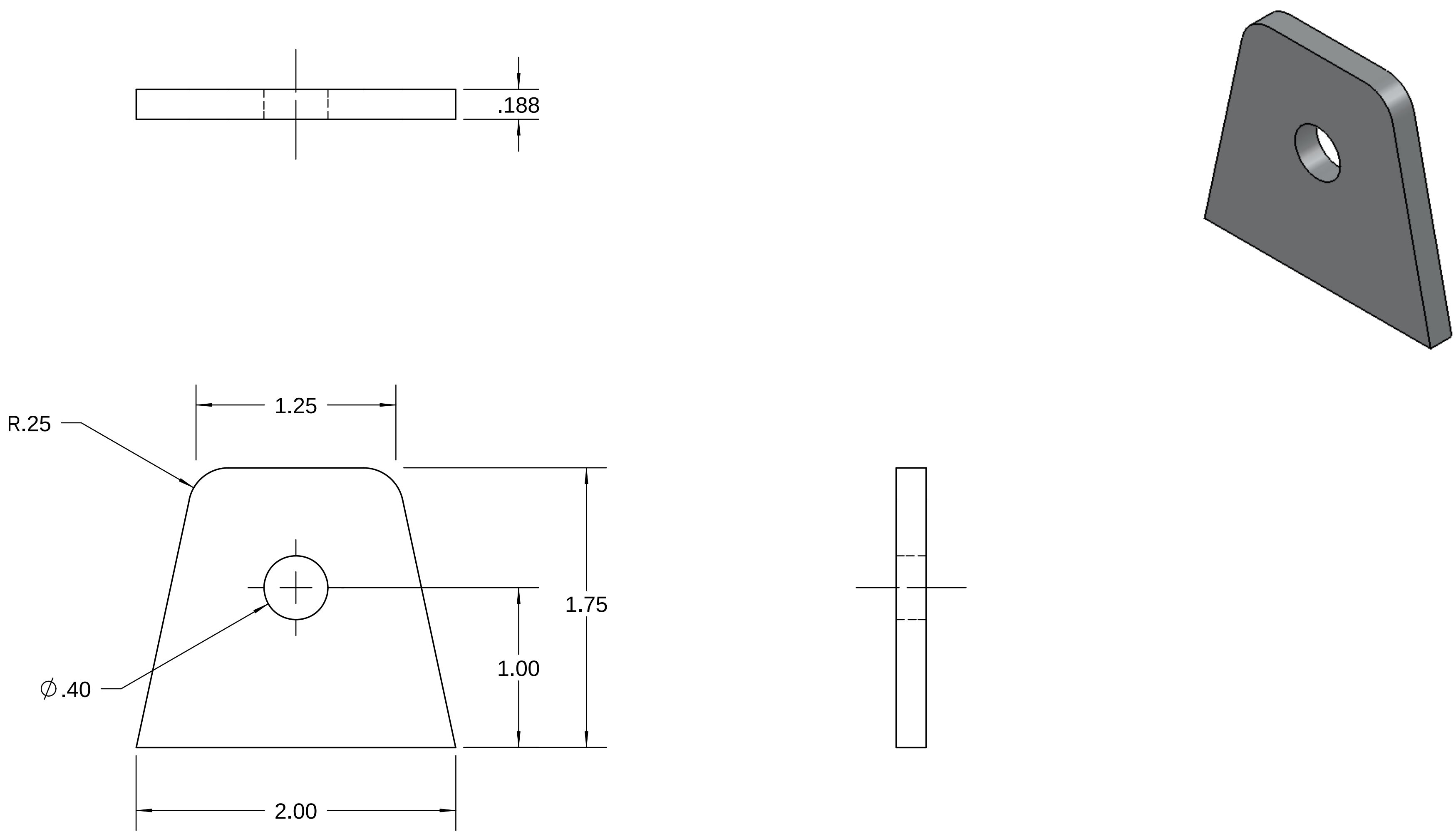
5 4 3 2 1



STRIDER PROJECT	NEXT ASSY: 100B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 145D	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: BACK PLATE
SCALE: 1:4	DATE: 5/31/2010	NAME: ALEX TRASK

Mechanical Engineering CAL POLY

5 4 3 2 1



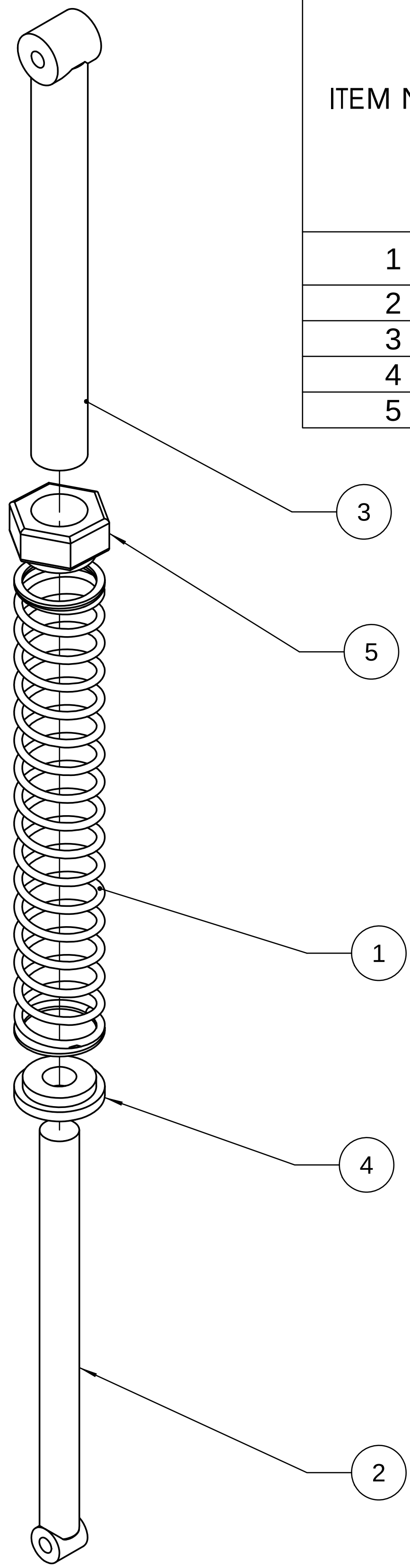
STRIDER PROJECT

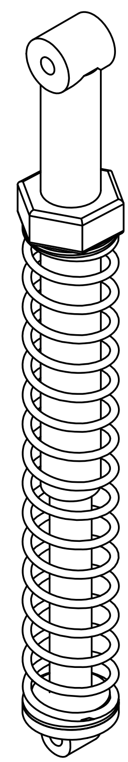
Mechanical Engineering
CAL POLY

	NEXT ASSY: 000A, 101B, 102B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 212A	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: BRACKET
SCALE: 1:1	DATE: 05/14/2010	NAME: ERIC JOHNSON

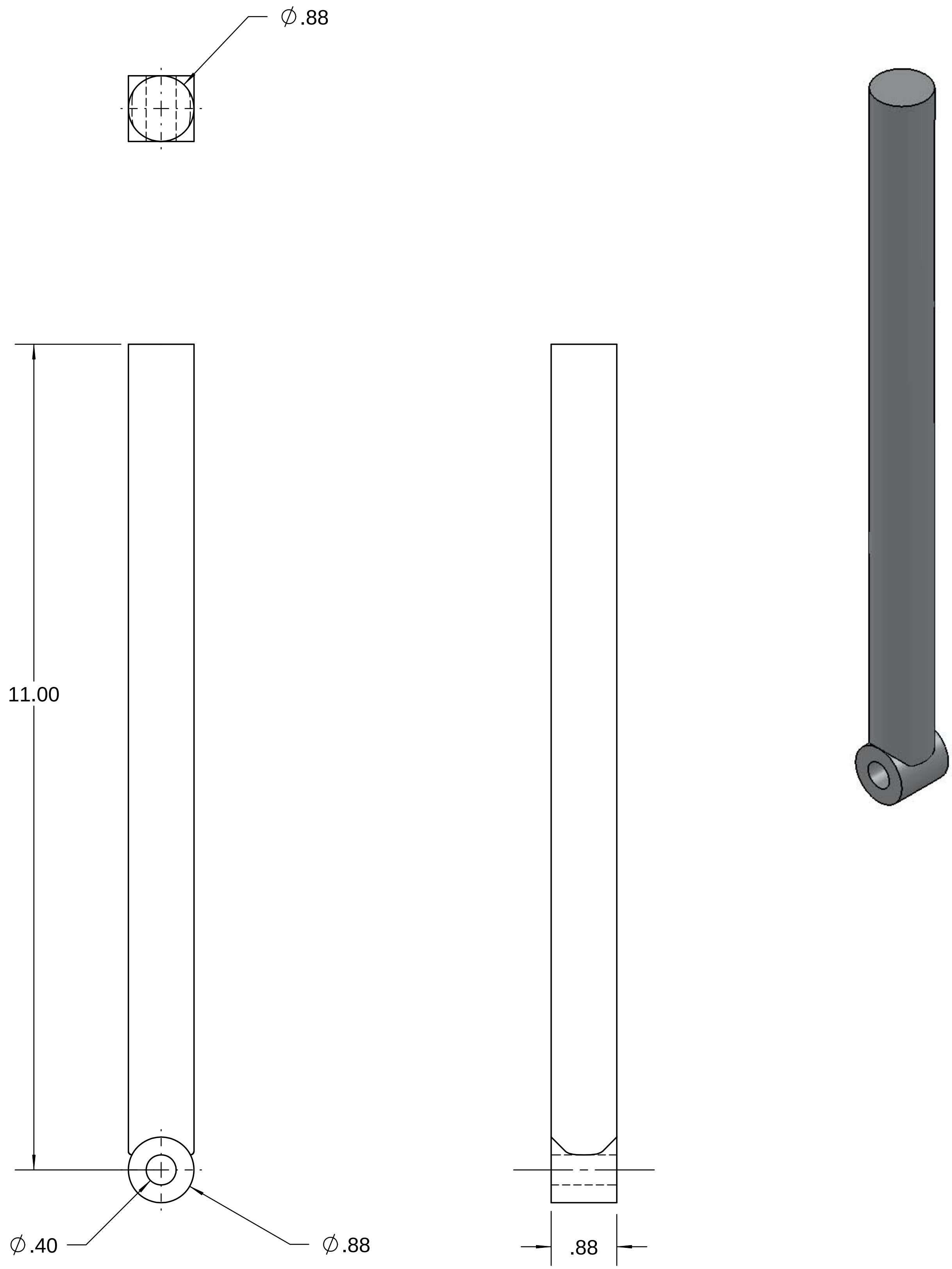
5 4 3 2 1

ITEM NO.	PART NUMBER	Description	QTY.
1	813	12 lbs/in COMPRESSION SPRING	1
2	320A	LOWER SHAFT	1
3	330A	UPPER SHAFT	1
4	340A	SPRING BASE SUPPORT	1
5	355A	HEX PERCH	1

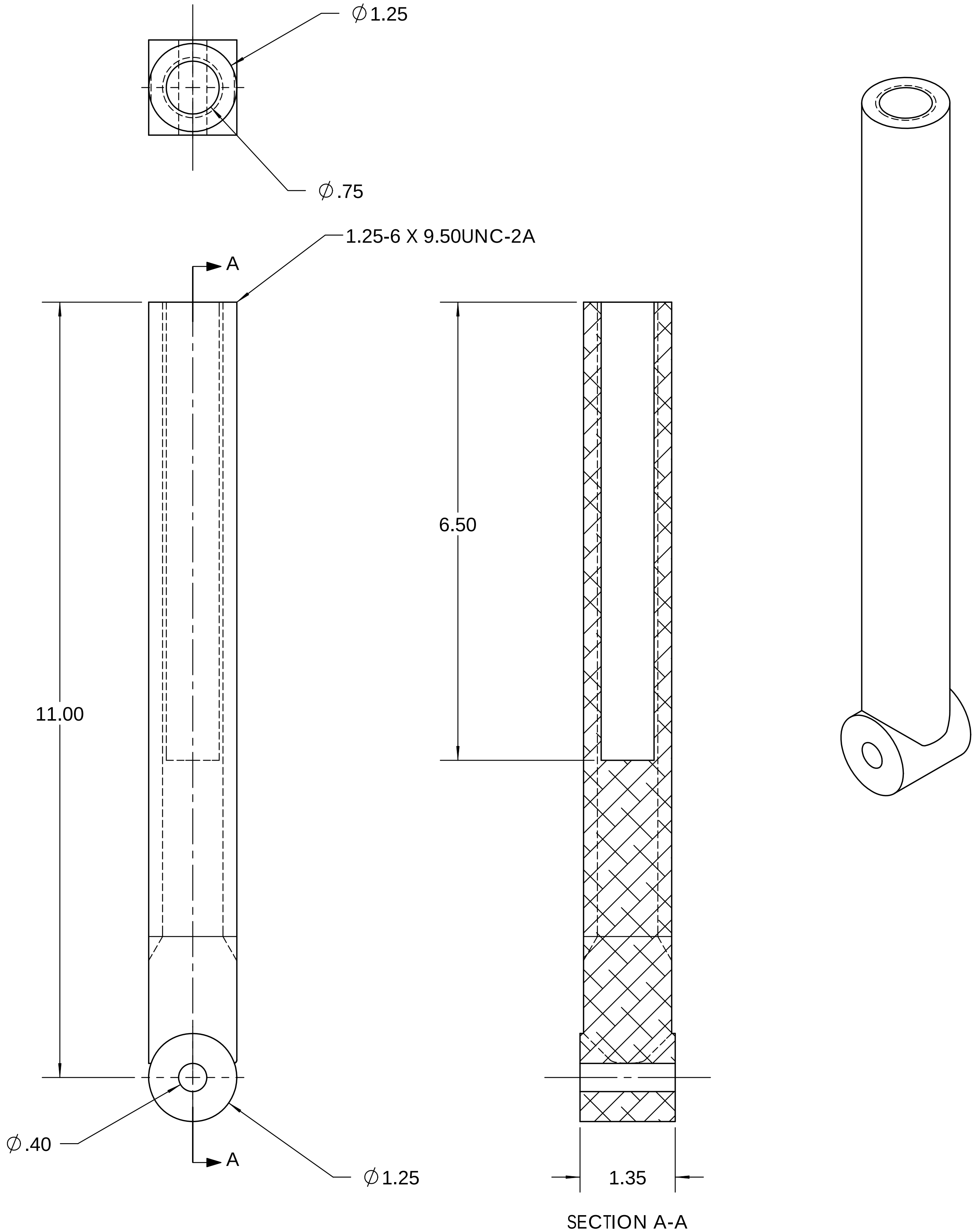




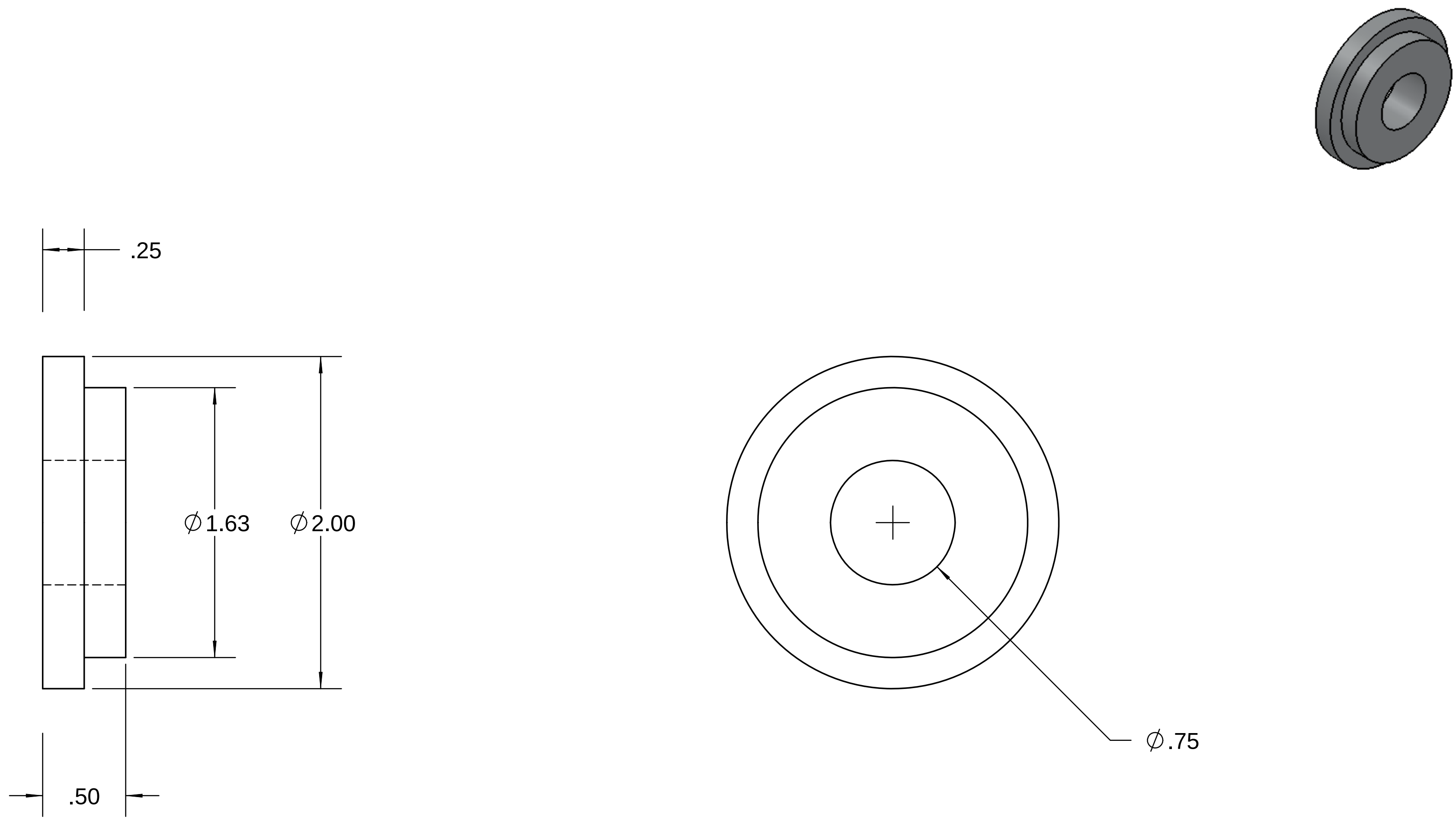
STRIDER PROJECT	MATERIAL:	NEXT ASSY: 500A	SIGNATURE:
		DRAWING #:300B	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL:	UNITS:	TITLE: COIL OVER
	SCALE: 1:4	DATE: 05/31/2010	NAME: RICARDO GARCIA



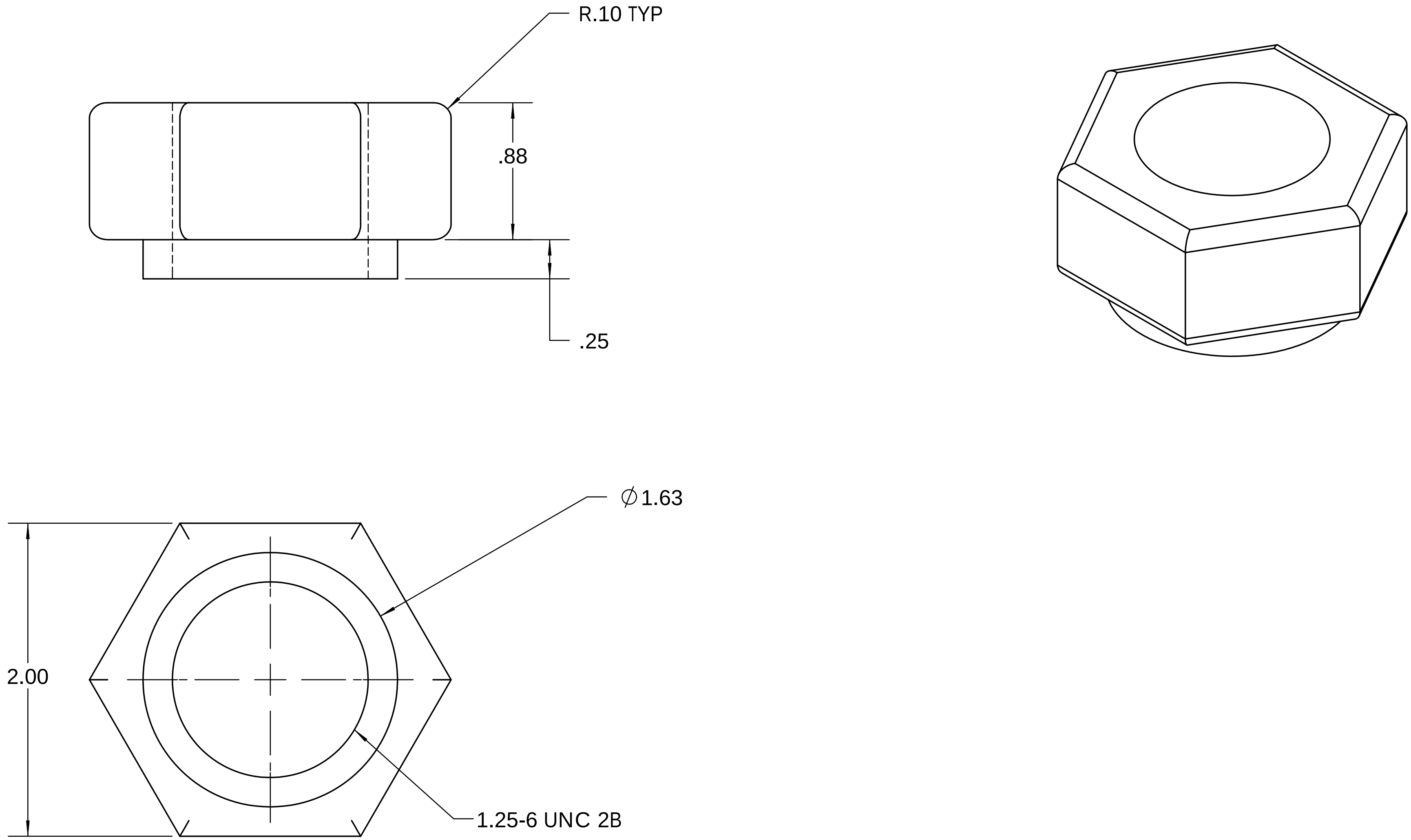
STRIDER PROJECT	MATERIAL: Al 6061	NEXT ASSY: 300B	SIGNATURE:
		DRAWING #: 320B	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL: ±.01	UNITS: INCH	TITLE: LOWER SHAFT
	SCALE: 1:2	DATE: 05/21/2010	NAME: RICARDO GARCIA



STRIDER PROJECT	MATERIAL: Al 6061	NEXT ASSY: 300B	SIGNATURE:
Mechanical Engineering CAL POLY		DRAWING # 330B	ADVISOR: LOU ROSENBERG
	TOL: ±.01	UNITS: IN	TITLE: COIL OVER - UPPER SHAFT
	SCALE: 1:2	DATE: 05/31/2010	NAME: RICARDO GARCIA

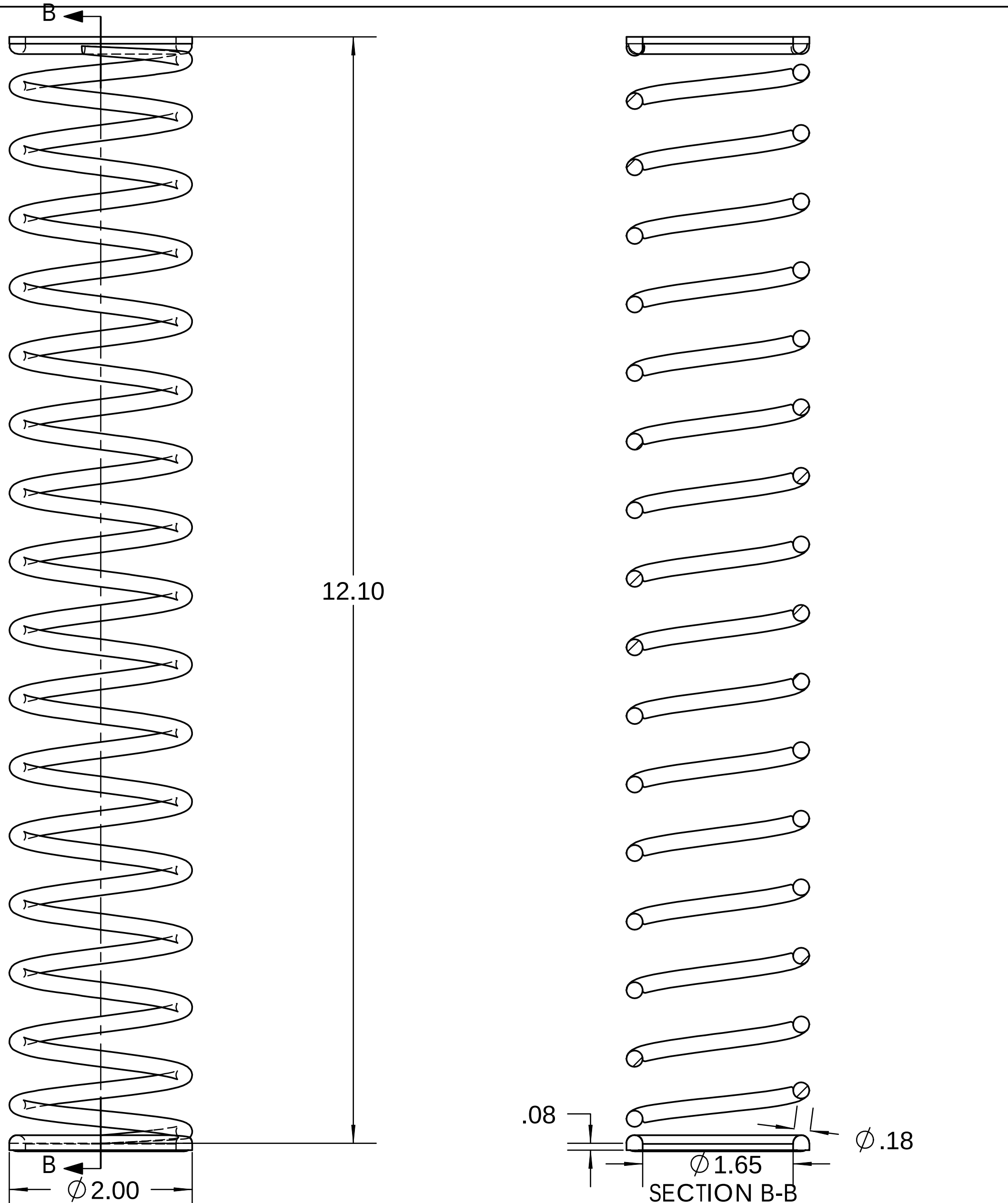


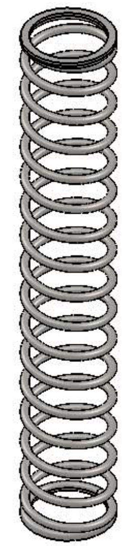
STRIDER PROJECT		NEXT ASSY: 300B	SIGNATURE:
Mechanical Engineering CAL POLY	MATERIAL : 6061 ALUMINUM	DRAWING #: 340B	ADVISOR: DR. ROSENBERG
	TOLERANCE: ±.01	UNITS: INCH	TITLE: BASE SPRING SUPPORT
	SCALE: 1:1	DATE: 05/31/2010	NAME: RICARDO GARCIA



STRIDER PROJECT

	NEXT ASSY: 300B	SIGNATURE:
MATERIAL: Al 6061	DRAWING #: 355A	ADVISOR: LOU ROSENBERG
TOLERANCE: ±.01	UNITS: IN	TITLE: HEX PERCH
SCALE: 1:1	DATE: 05/31/2010	NAME: RICARDO GARCIA



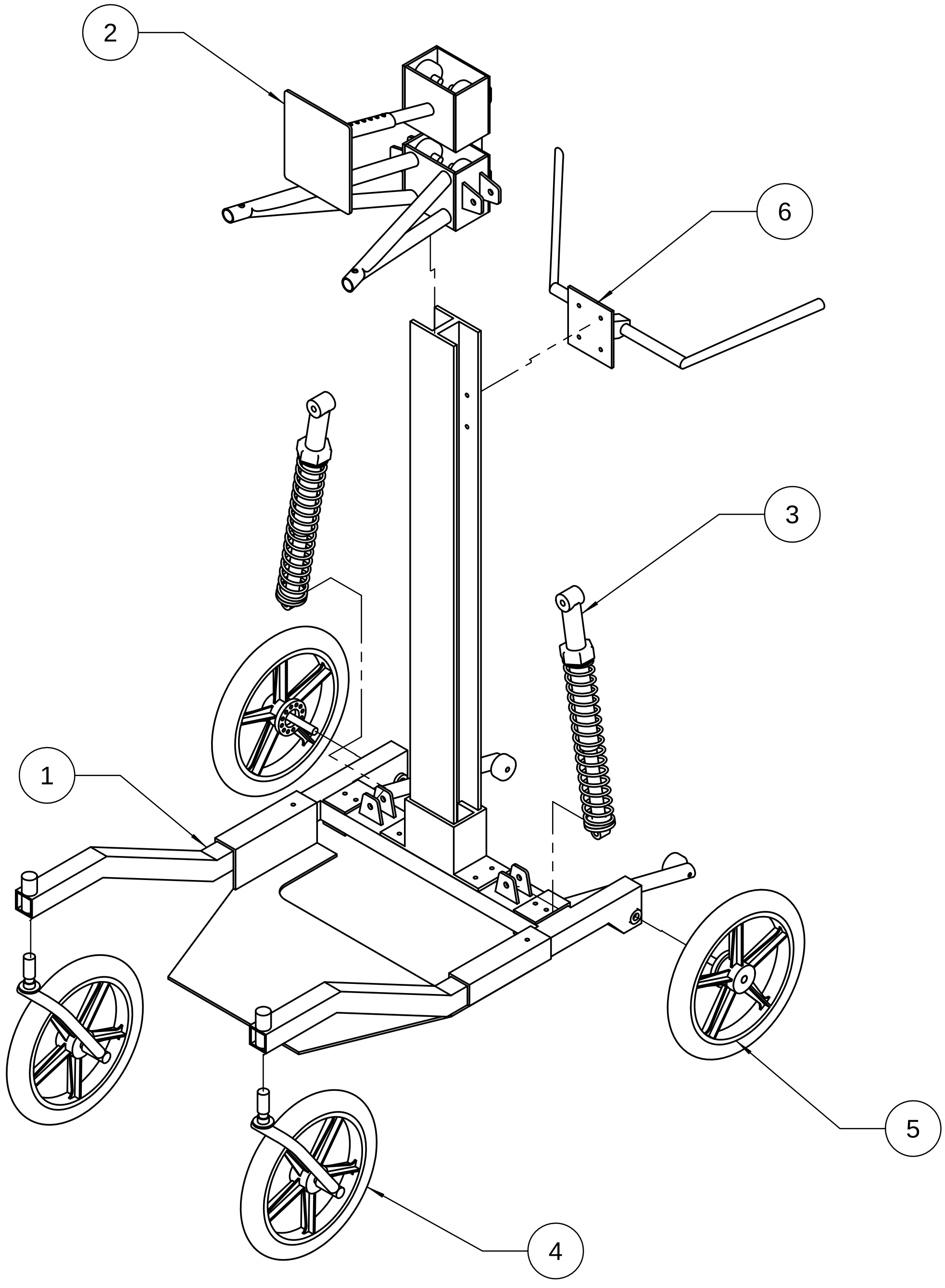


NOTE:
RATE: 12 lbs/ in
MAX DEFECTION: 6.8"
MAX LOAD: 84 lbs
SOLID HEIGHT: 3.72"
NUMBER OF COILS: 21

STRIDER PROJECT	MATERIAL: HARD DRAWN WIRE	NEXT ASSY: 300B	SIGNATURE:
Mechanical Engineering CAL POLY	FINISH: ZINK PLATED	DRAWING #: 813	ADVISOR: DR. ROSENBERG
	TOLERANCE: ± .01	UNITS: INCH	TITLE: 12 LBS/IN CENTURY SPRING
	SCALE: 1: 2	DATE: 1/18/2010	NAME: RICARDO GARCIA

5 4 3 2 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	000A	Bottom Frame Assembly	1
2	100B	Carriage Assembly	1
3	300B	Coilover	2
4	N/A	Phil & Teds, Complete Front Wheel inc. J-bar	2
5	N/A	Phil & Teds, Complete Rear Wheel inc. Axel	2
6	N/A	Handle Bars	1



STRIDER PROJECT	MATERIAL:	NEXT ASSY:	SIGNATURE:
		DRAWING #: 500A	ADVISOR: LOU ROSENBERG
Mechanical Engineering CAL POLY	TOL:	UNITS:	TITLE: STRIDER
	SCALE: 1:12	DATE: 05/31/2010	NAME: RICARDO GARCIA, ERIC JOHNSON, ALEX TRASK

Appendix E: List of Vendors

STRIDER COST SHEET

	ITEM DESCRIPTION	VENDOR DESCRIPTION	PART NUMBER	DATE OF PURCHASE	ORDER NUMBER	ITEM RECEIVED	QTY.	SALE UNIT PRICE	COST + TAX
1	12 lbf/in COMPRESSION SPRING	http://www.centuryspring.com/	813	1/11/2010	S630892	Y	2	$24.89	$49.78
2	PHIL & TEDS J BAR & 12.5 " WHEEL	http://www.dmartstores.com/	N/A	1/18/2010	DMART-193124	Y	2	$39.99	$79.98
3	PHIL & TEDS 12.5" WHEEL AND AXLE	http://www.dmartstores.com/	N/A	1/18/2010	DMART-193124	Y	2	$39.99	$79.98
4	Aluminum Tubing (lower frame)	B&B Steel and Supply (805-349-9991)	N/A	1/23/2010	342576	Y	N/A	N/A	$40.24
5	Aluminum Bar (2.5x4x42)	Ventura Metals (805-644-5511)	N/A	1/25/2010	113130	Y	N/A	$156.24	$169.13
6	CCS BLANK WHEELS WHITE - Size	http://shop.ccs.com/	30813 & 30963	1/27/2010	4872180	Y	4	$17.99	$56.51
7	Steel for H beam Sleeve	B&B Steel and Supply (805-349-9991)	N/A	2/13/2010	343956	Y	N/A	N/A	$21.21
8	Ground Control 42mm wheels-Black	http://agressivemall.com	N/A	2/24/2010	76371	Y	N/A	N/A	$17.97
9	Aluminum Round Bar for Coilovers	B&B Steel and Supply (805-349-9991)	N/A	2/23/2010	344545	Y	N/A	N/A	$17.94
10	Magnets	www.kjmagnetics.com	DC4-N52	3/3/2010	216739	Y	2	$3.00	$11.00
11	Wiz Kid Climbing Harness	www.REI.com	782-959-0022	3/3/2010	17861865	Y	1	$44.95	$54.87
12	Electrod Tungsten Rods	Aeria (805-349-8869	ANC 332X7PG	3/12/2010	00917624-00	Y	10	$24.55	$26.70
13	Aluminum 3/16 " Plate	B&B Steel and Supply (805-349-9991)	N/A	4/22/2010	348763	Y	N/A	$63.00	$68.51
14	ACME Bolts, Tefon	McMaster-Carr.com	8891034-01	4/12/2010	0412RGARCIA	Y	N/A	$46.67	$55.50
15	5/8 " Neodymium Magnet	McMaster-Carr.com	5867k32	4/30/2010	0419RGARCIA	Y	2	$20.13	$48.69
16	Welding	Lahr Industrial Welding Inc	N/A	5/3/2010	B015972	Y	N/A	$408.00	$443.70
17	Teflon Strip and Fasteners	Ventura Metals (805-644-5511)	7998k25 & 9435	5/12/2010	0512RGARCIA	Y	1&10	$78.38	$83.07
18									$32.00
								TOTAL	$1,356.78
								PERCENTAGE USED	90.45%

Appendix F: Gantt Chart