The Capper Foundation Field Chair Design Project

Jeremy Borchert
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Kenny Lamas
Jerry Sum

Background

- The Capper Foundation
  - “Enhance the independence of people with disabilities, primarily children.”
- Track and Field
  - Shot put
  - Discus
  - Javelin
  - Club Throw

Motivation

- Compete from wheelchair or Eagle's Nest chair
  - Limited stability
  - Minimal upper body rotation
- A field chair will improve their performance
  - Stable base
  - Rotating seat

Goals

- Design and build a field chair for a team of athletes at the Capper Foundation
- Improve on current designs
  - Stable base
  - Added restraints
  - Rotating seat
  - Adjustable

Design Process

- Fundraising
- Customer requirements
- Brainstorming
- Concept evaluation and selection
- Material selection
- Safety analysis
- Prototype construction, testing, and modification
- Engineering analysis
- Modify design
- Bill of materials
- Fabrication and assembly
- Testing and refinement

Design Objectives

- Stable
- Compact
- Adjustable
- Rotating seat
- Low back
- Narrow
- Safety belt for trunk and legs
- Easy to set up and transport

Safety Analysis

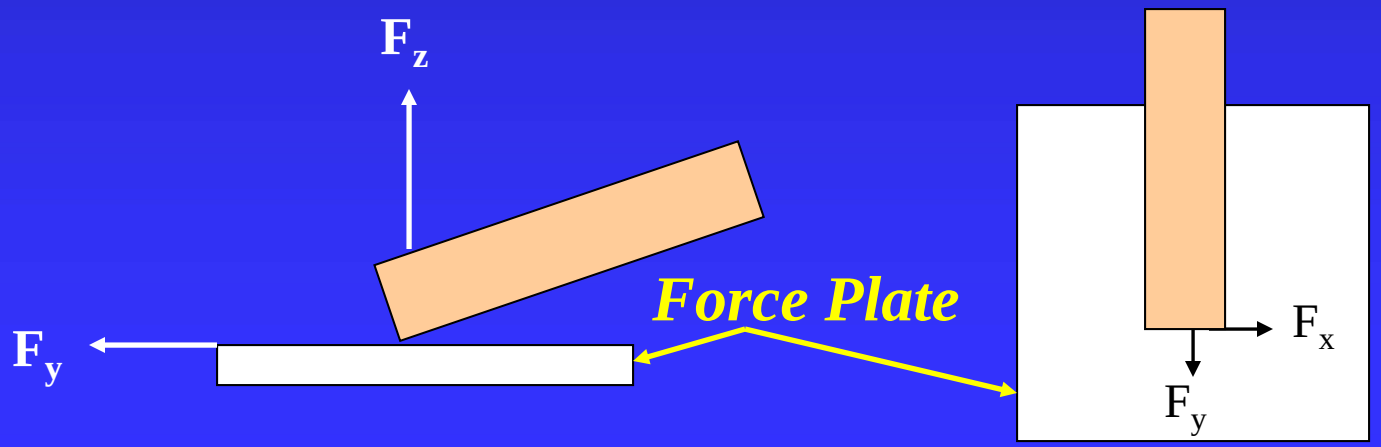
Hazard	Frequency	Consequence	Interpretation
User falls out of the chair	***Remote***	***Critical***	***Acceptable with Review***
User falls over while in chair	***Improbable***	***Marginal***	***Acceptable***
Fingers pinched while attaching legs	Occassional	Marginal	Acceptable with Review
Adjustable parts slip out of place	Remote	Marginal	Acceptable with Review
Implement thrown into the crowd	***Remote***	***Critical***	***Acceptable with Review***
Cuts from sharp edges of metal	Remote	Marginal	Acceptable with Review
Injured while putting stakes in footplates	Remote	Marginal	Acceptable with Review
Falls during transfer	***Remote***	***Marginal***	***Acceptable with Review***

Prototype Testing

- Capper athletes
- Results
  - Seat length: 10”-14”
  - Footrest: 8”-10” below seat
  - Greater than 180° rotation

Force Plate Testing

- Methodology
  - Test to find max forces
  - 5 trials of simulated throws on each leg
  - Max vertical force: 92 lb



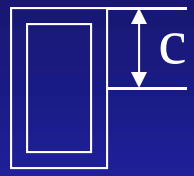
Engineering Analysis

- Force plate testing (5 leg prototype)
  - Max vertical force: 92 lb
- Estimate forces for 4 leg chair
  - (5/4)*Max force =115 lb
- Factor of Safety:
  - At least 2.5 (force data accounts for dynamic loading)

Engineering Analysis

- Determined necessary cross-section for box tubing legs

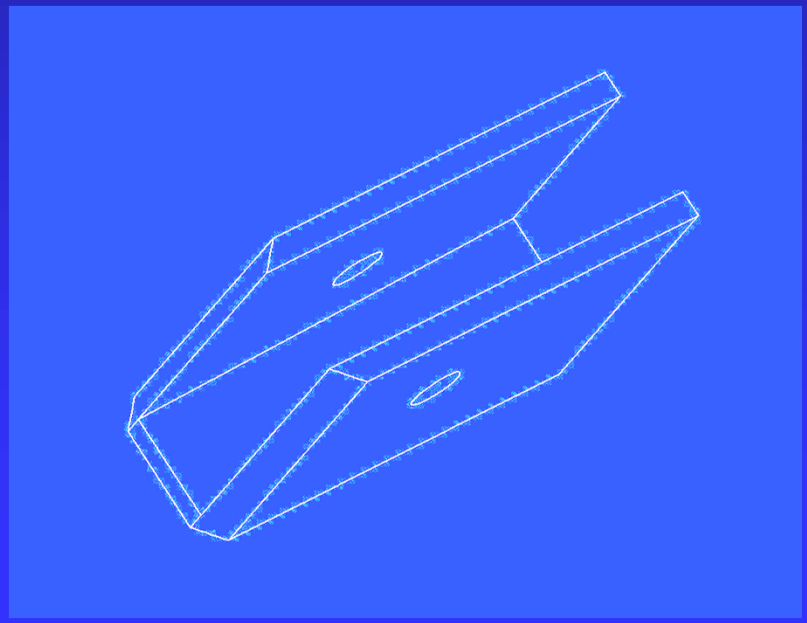
$$\sigma = F_s \frac{Mc}{I}$$

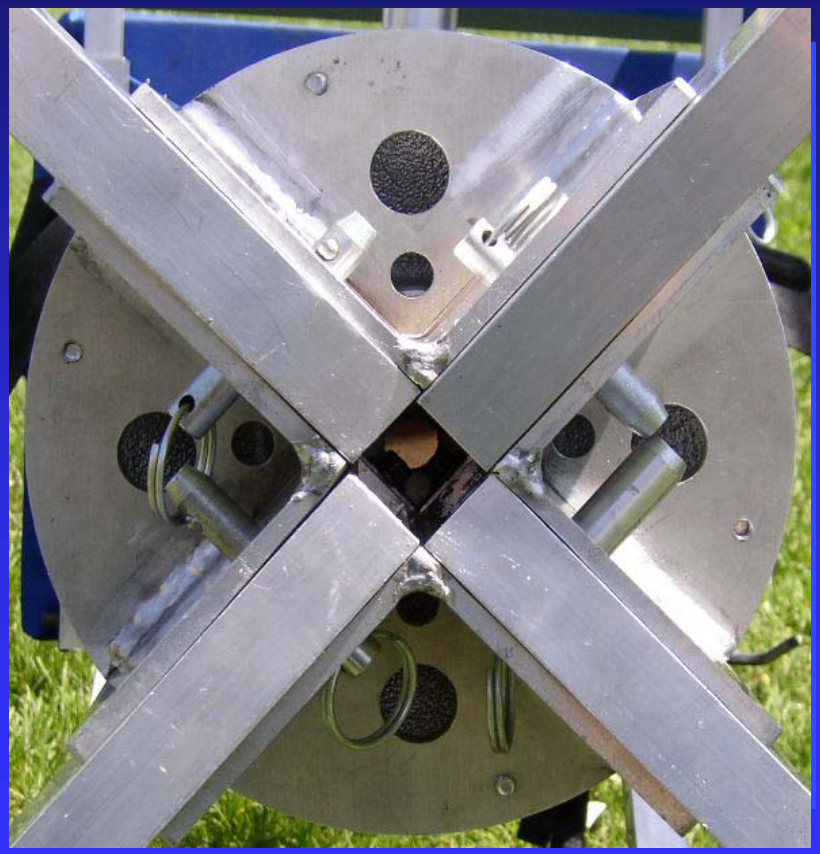


- Aluminum 6063-T52 σ_{yld} = 21,000 psi
- M= Moment from force plate data (115 lb x 36 in)
- Minimum F_s = 2.5
- Determined minimum moment of inertia, I, and c
- Decided to use 1” x 3” x 1/8” for legs:
  - σ_{max}= 6540 psi
  - Actual F_s = 3.2
- Reaction bar deflection: 70 lb to deflect 0.25”

Key Final Design Components

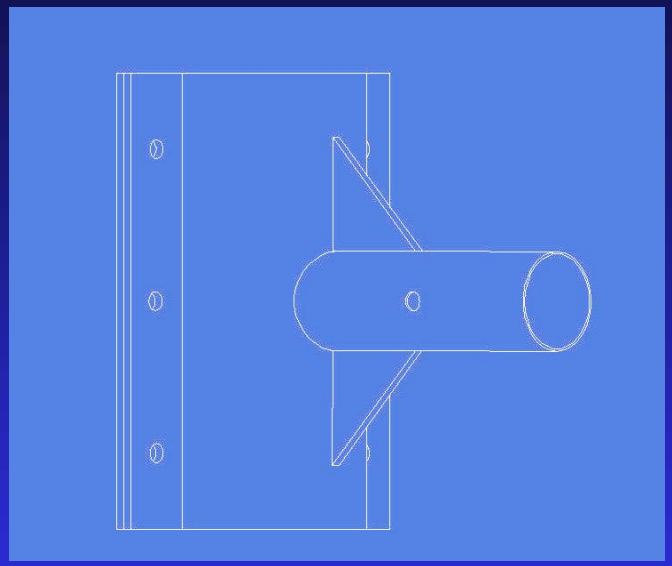
- New base design
- Machining process





Key Final Design Components

- Reaction bar attachment
- Attaching bar to shaft
- Machining Process



Key Final Design Components

- Using marine chair shaft and swivel

Completed Field Chair

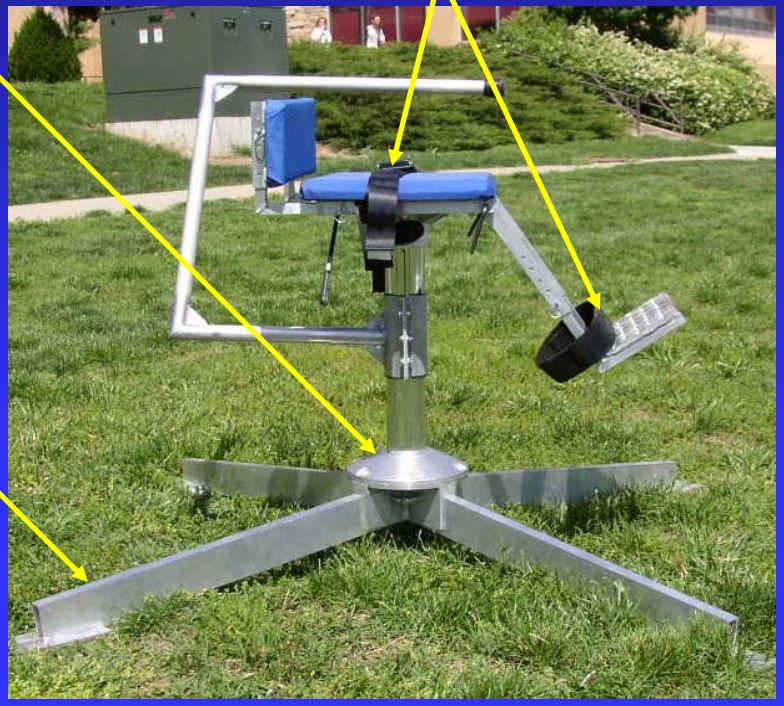
Design Features

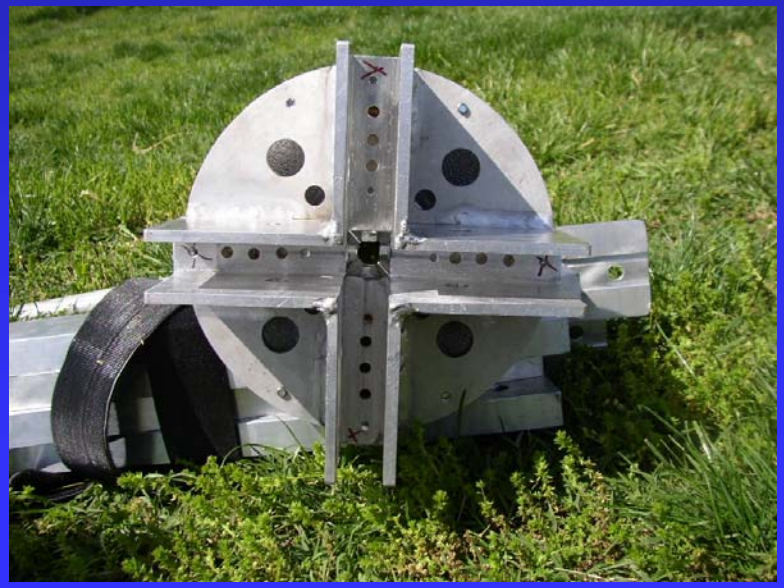
- Stability

Solid base plate

Hip and leg restraints

Wide base





Design Features

- Rotation

Locking Thrust Bearing

Removable Set Pin

Design Features

- Adjustability
  - Back height, depth
  - Leg height, angle
  - Left/right hand
  - Reaction bar height
- Full size seat

Design Features

Adjustment Screws

Adjustment Pins

Design Features

- Easy set up
- Portable
- Compact

Testing

Testing

- Feedback:
  - SPINS!
  - More comfortable
  - More stable
  - Shorter set up time
  - Good adjustability
  - Lightweight

Testing

- Throwing Results:
  - No significant improvement in throw distance
  - Should improve with practice

Bill of Materials

Bill of Materials				
No.	Quan	Description	Material	Total Cost
1		Prototype	PVC pipe	$20.00
2		Prototype	Wood, Fasteners	$26.55
3	1	Shaft	Todd 24 in. pedestal	$49.99
12	1	Arm Bar	Aluminum 6061 T6	$36.60
13	1	Leg Rest	Aluminum 5052-H32	$15.84
14	2	Leg/Back Bars	Aluminum	$27.65
15	4	Quick Release Pins	Steel	$10.80
16	8	Quick Release Pins	Steel	$29.27
17		Fasteners	misc	$6.80
18		Seat Belt	nylon	$18.99
19		Ankle belt	velcro	$10.72
20	2	belts	velcro	$2.12
21	3	90 deg. Fitings	Aluminum Alloy	$25.32
22		Hardware	misc	$11.34
			Total:	**$431.11**

Total Materials: $431.11

Estimated Labor (25 hrs @$25/hr): $625.00

Total Cost: $ 1056.11

Design Objectives

- ✓ Stable
- ✓ Compact
- ✓ Adjustable
- ✓ Rotating seat
- ✓ Low back
- ✓ Narrow base
- ✓ Safety belt for trunk and legs
- ✓ Easy to set up and transport

Acknowledgements

- Ms. Kerri A. Graunke
  - $100 donation
- Mr. and Mrs. Martin and Barbara Pape
  - $100 donation
- Postural Seating Materials: Mr. David Greenburg
  - Seat and backrest material (High Density Polyethylene)
  - Closed cell foam padding

Questions??

The Capper Foundation
Field Chair Project

Jeremy Borchert

Kenny Lamas

Molly McVey

Jerry Sum

Motivation and Goals

- Capper athletes currently compete from their wheelchair; the field chair will improve their performance by offering greater stability and range of motion
- Design and build a field chair for a team of athletes at The Capper Foundation
- Improve on current designs by adding adjustability and a rotating seat

Design Objectives

- Safe
- Stable
- Compact (fits inside minivan trunk)
- Easy to set up and transport
- Adjustable
- Rotating seat
- Low back
- Narrow base

Design Process

- Customer requirements
- Brainstorming
- Concept evaluation and selection
- Safety analysis
- Prototype construction, testing, and modification
- Engineering analysis
- Finalize design and bill of materials
- Fabrication and testing
- Fundraising

Safety Analysis

Hazard	Frequency	Consequence	Interpretation
User falls out of the chair	Remote	Critical	Acceptable with Review
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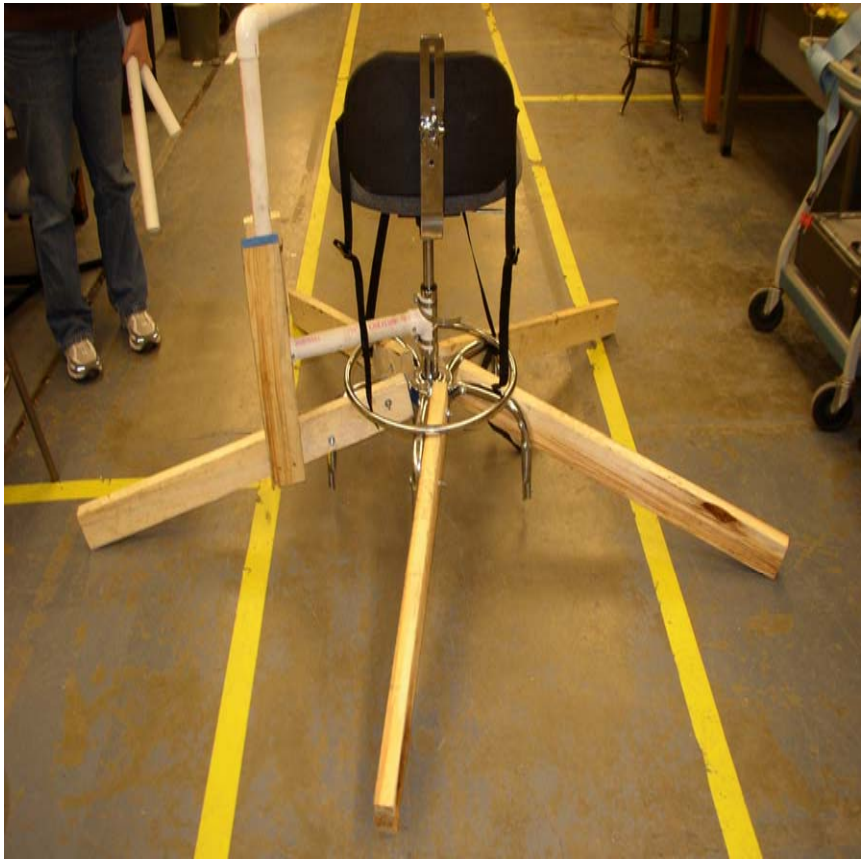
Fingers pinched while attaching legs	Occassional	Marginal	Acceptable with Review
Adjustable parts slip out of place	Remote	Marginal	Acceptable with Review
Implement thrown into the crowd	Remote	Critical	Acceptable with Review
Cuts from sharp edges of metal	Remote	Marginal	Acceptable with Review
User is choked by harness	Improbable	Catastrophic	Acceptable with Review
Injured while putting stakes in footplates	Remote	Marginal	Acceptable with Review
Falls during transfer	Remote	Marginal	Acceptable with Review

Prototype



Prototype Testing

- Capper athletes: determined ideal placements and sizes for seat, leg rest, and back rest
- Force plate testing: determined the maximum vertical force: 92 lb

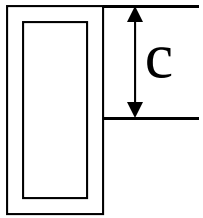
Modified Prototype

- New base to accommodate 4 legs
- Added foot rest
- Tested for stability
  - Decided to shorten legs to 30 in.

Engineering Analysis

- Determined necessary cross-section for box tubing legs

$$\sigma = F_s \frac{Mc}{I}$$



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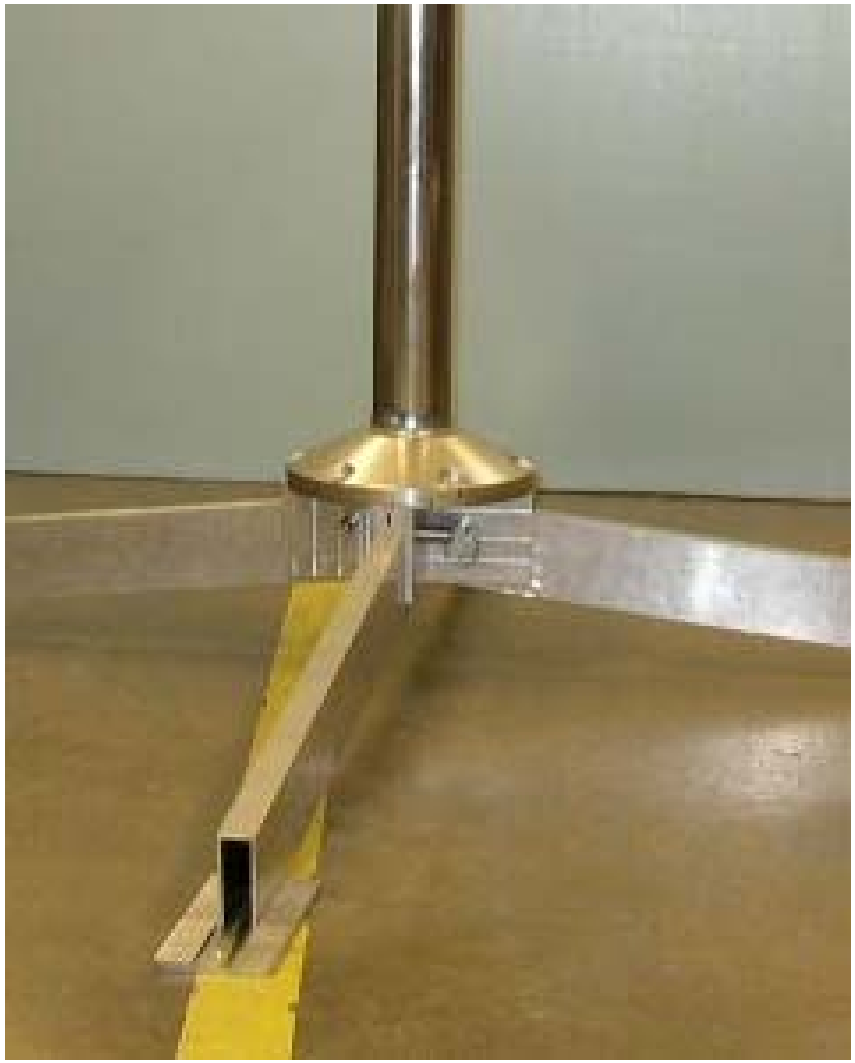
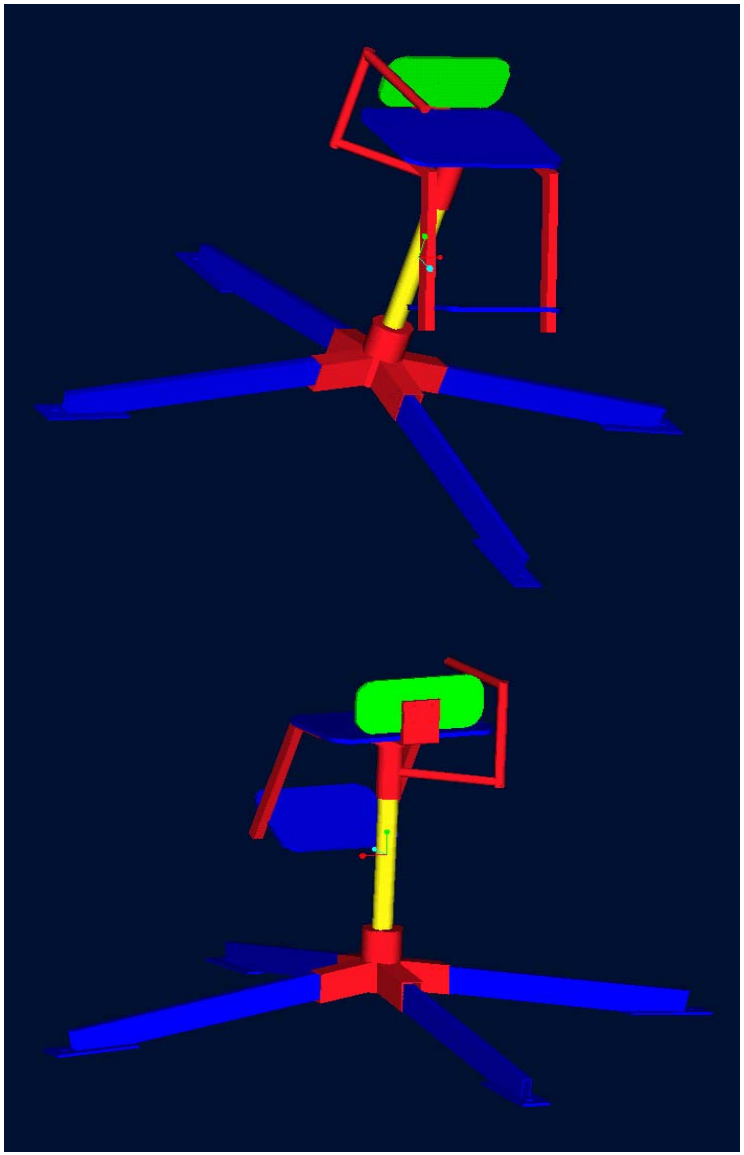
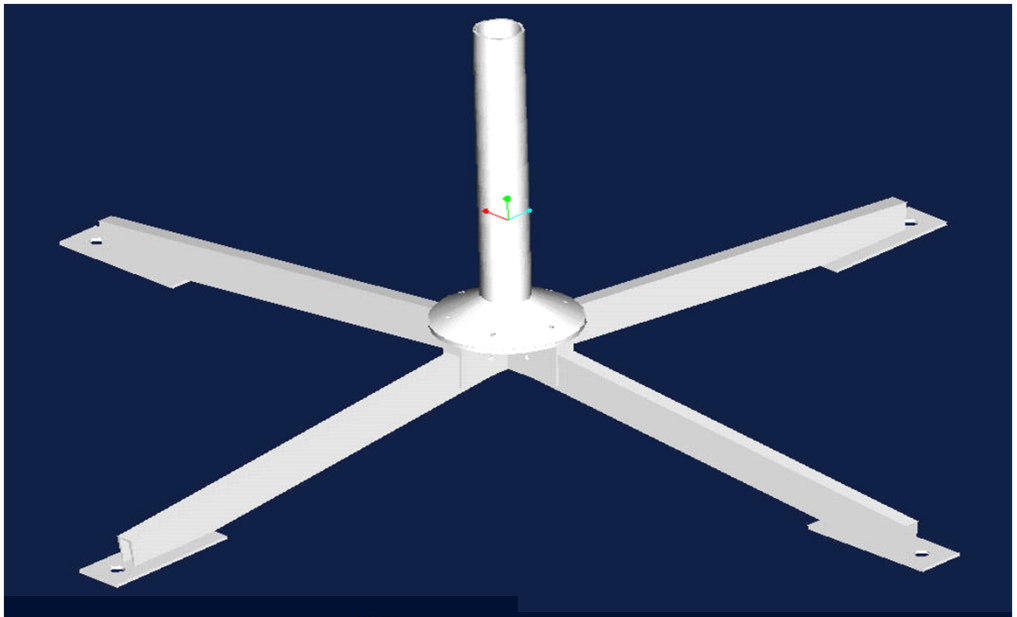
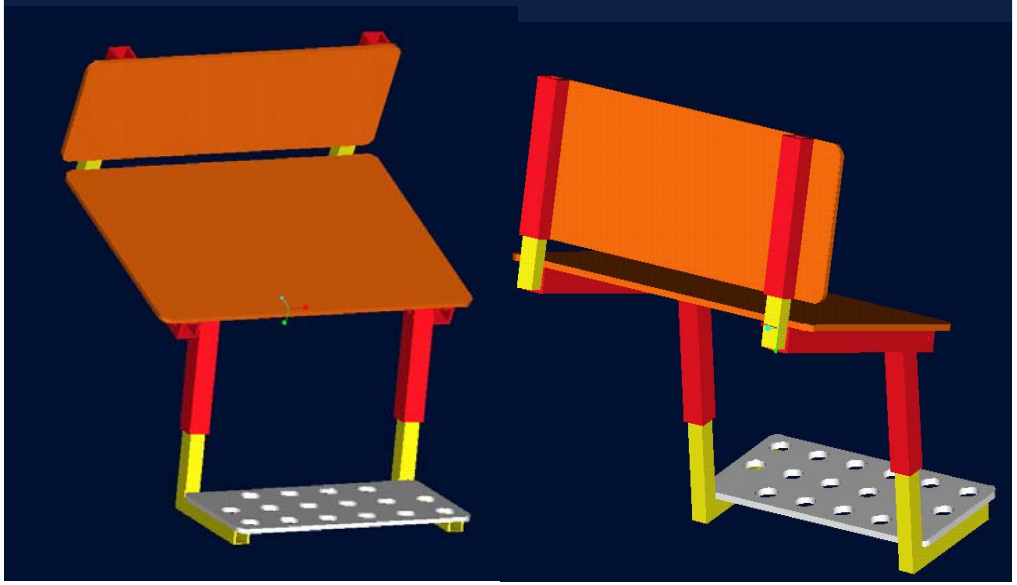
Final Design



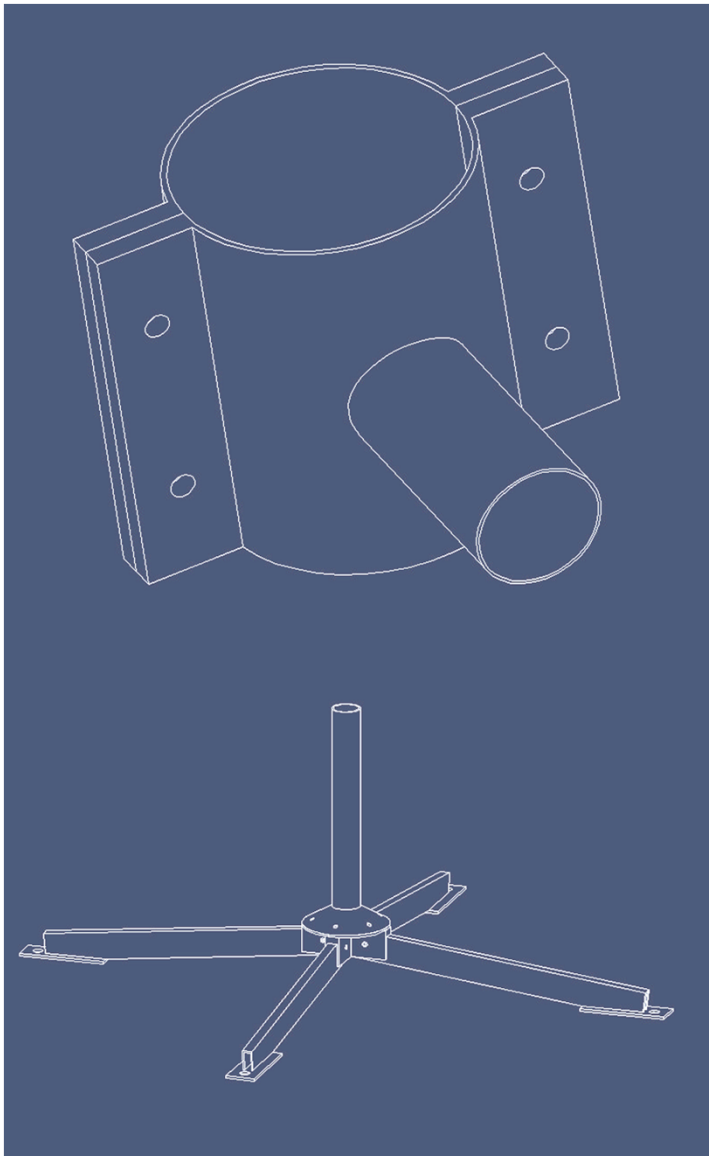
Field Chair Design

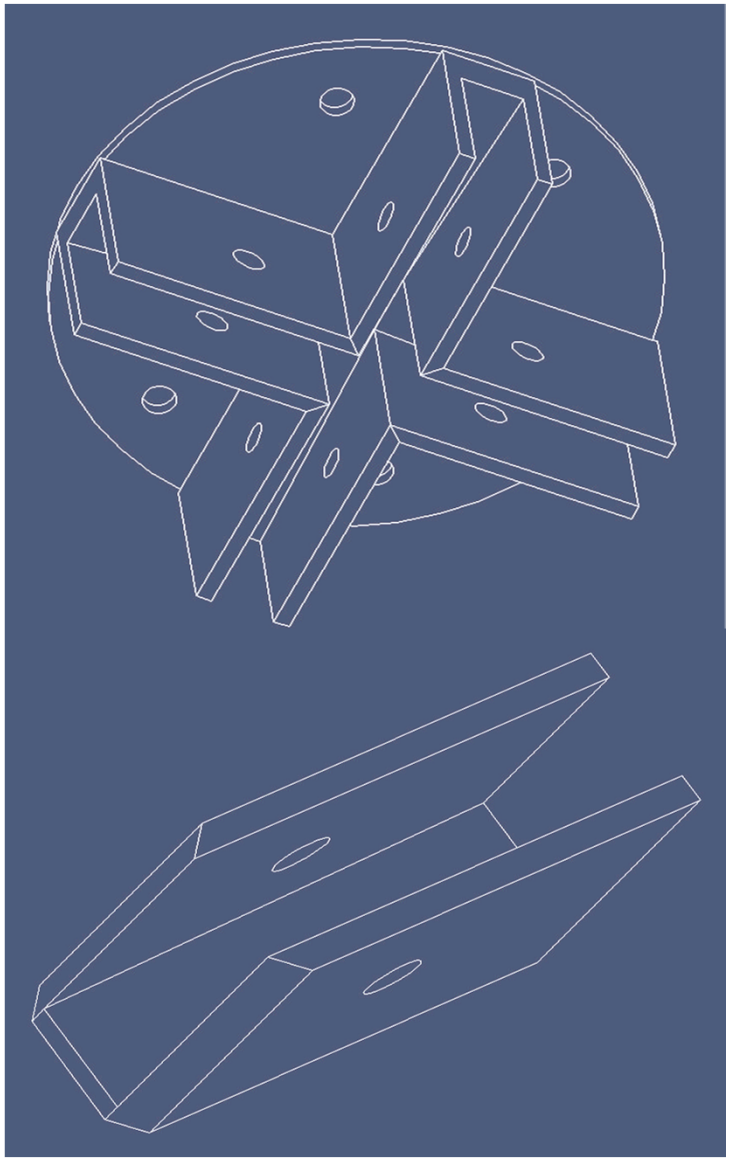






Design Components





	Bill of Materials			
No.	**Quan**	**Description**	**Material**	**Total Cost**
1	1	Base	Aluminum Block	$45.00
2	1	Shaft	Todd 24 in. Bell style pedestal	$49.99
3	1	Locking Swivel	B&M 12-way locking swivel	$19.99
4	1	Spider	Garelick Aluminum	$27.99
5	4	Legs	Aluminum 6063-T52	$56.28
6	4	Leg Plates	Aluminum 6061-T6	$26.76
7	4	Plate Covers	Rubber Shelf Liner	$5.00
8	1	Seat	High Density Polyethelene	$0.00
9	1	Back Rest	High Density Polyethelene	$0.00
10	2	Back and Seat Cover	Nylon w/PVC backing	$16.20
11	1	Arm Bar	Aluminum 6061 T6	$36.60
12	1	Leg Rest	Aluminum 5052-H32	$15.84
13	1	Legs and Back Bars	Square Tubing (outside)	$11.66
14	1	Leg and Back Bars	Square Tubing (inside)	$6.92
16	4	Quick Release Pins	Steel	$10.80
17	2	90 deg. Fitings	Aluminum Alloy	$16.88
				$345.91
				$34.59
				$380.50

Capper Foundation Design Team: Field Chair Survey Results

1. Where are the ideal placements for the extra Velcro seatbelts?
    a. Knee
    b. Ankle *1*
    c. Calf
    d. Knee and Ankle
    e. Other: ***1: Figure 8 type strap- ankles only***

2. If you would like a seatbelt on the calf or ankle, would you want one belt around each leg or one belt around both legs? (Demonstrate if needed)
One belt but goes around both legs like a figure 8

3. Is the chair comfortable to use?
There is a sharp edge on the backrest that is uncomfortable
Yes

4. Will you use the spinning feature of the chair? Do you think it will improve your throw?
"Yeah! Yes-ir-ee!"
"Yes, oh yeah!"
"Yes, after some practice."

5. Does the chair feel stable? More or less stable than your wheelchair and Eagle's Nest? Are their any other safety concerns you might have?
Would like something to hold knees in place, feels much safer in the KU chair, likes the wider seat.
Yes, more stable than the Eagle's Nest
There are some bolts sticking out at the bottom of the chair.
"Feels a lot safer!"

6. Do you think the chair will help you to throw farther?
"Whoo-hoo yeah!"
yes
yes
7. Would you choose this chair over the Eagle's Nest? Why or why not?
KU Chair
KU Chair

8. What are the 3 features that you like best about this chair?
Metal and shiny, spins, footrest
Full seat, swivel, auto-stop
Weight, stability, portability

9. What suggestions do you have to improve the field chair?
"rocket boosters"
Taller and narrower back rest
Lock for the reaction bar
Less spinning (not as fast)
Allow the backrest to recline- not always at 90 degrees

10. (Coaches) What are your thoughts on transporting the chair? Would you like to have wheels added in some way? Do you think it is feasible to carry it across the field with 2 people?
Shouldn't be a problem, it is very easy to carry, no need for wheels
Not a problem, easy for 2 people to carry, wheels are not necessary.

11. (Coaches) Will this chair fit the majority of your athletes? Will you use the adjustability features?
Yes
Yes

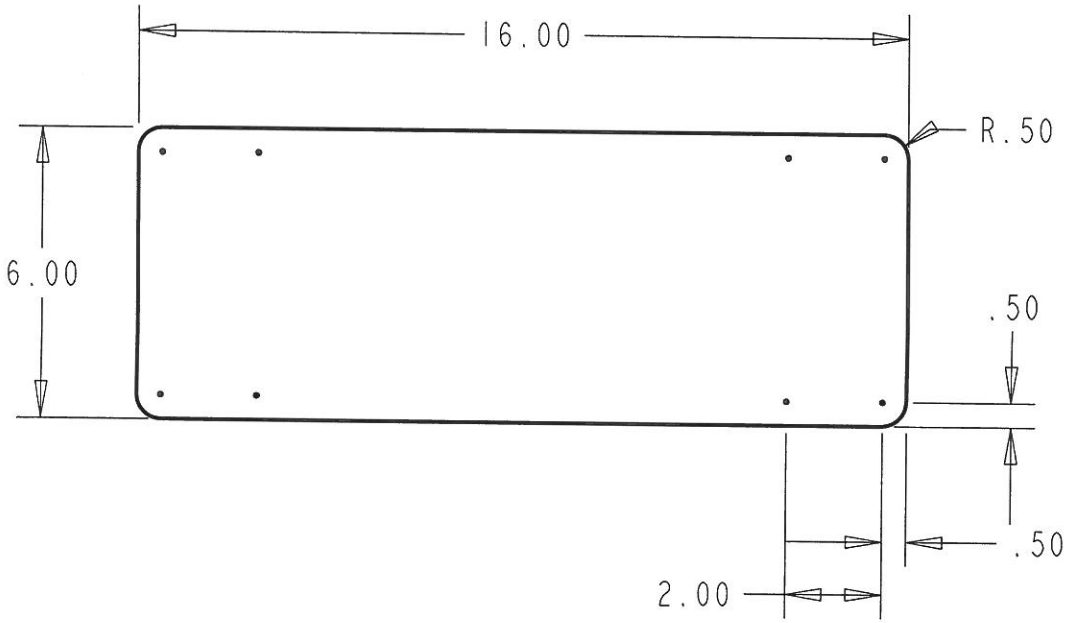
12. (Coaches) What improvements could be made to make this chair easier for *you* to use? (As opposed to the athlete's use of the chair)
none

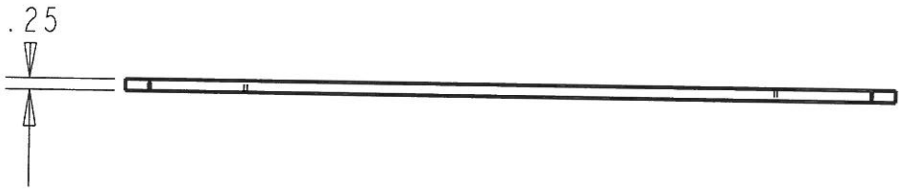
13. Do you feel that this chair has met the requirements set forth at the beginning of this design process? Are there any areas where your expectations were exceeded or where the chair fell short of your expectations? Please explain.
Hoping for rocket boosters
Yes, "Best chair I ever used"
Yes, exceeds. "Seems real stable"
"This chair is much better than the Eagle's Nest"
"You did a great job"

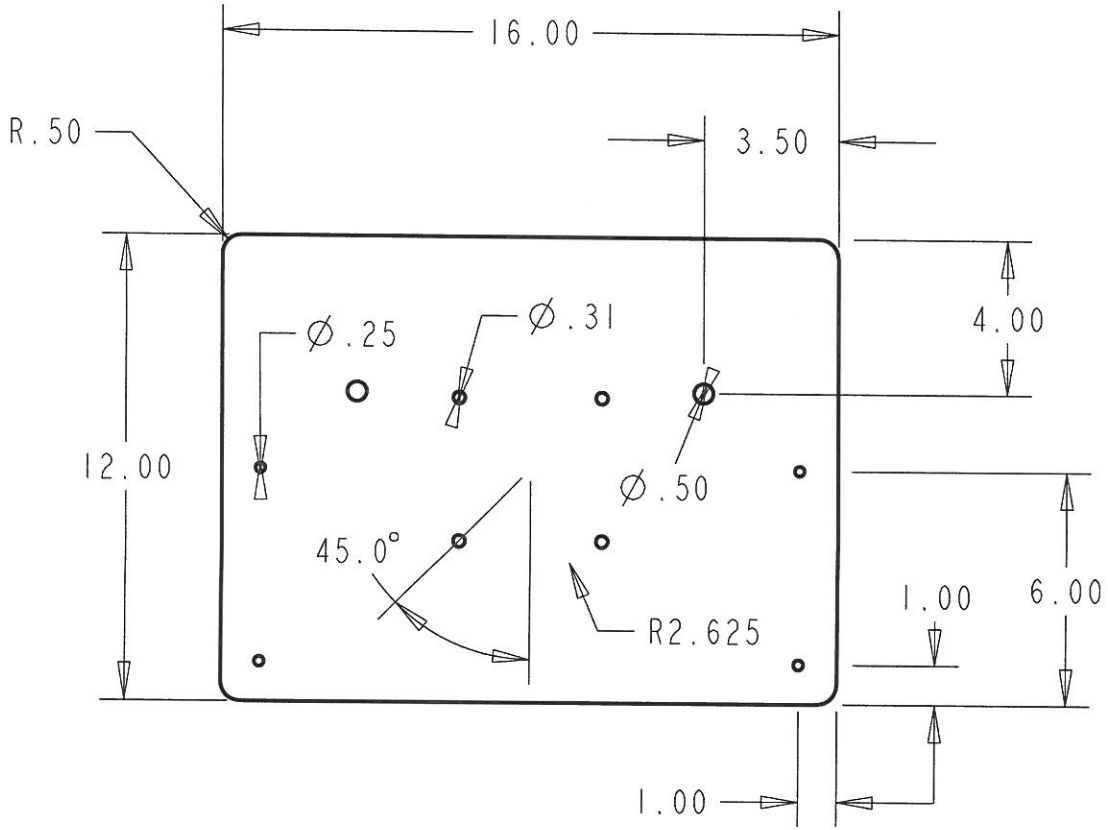
Capper Foundation Design Team: Field Chair Testing Data

		Throw Distance (m)		
User	**Age**	**Event**	**Eagle's Nest**	**KU Chair**
Jasper	9	**Hammer**		3.65
				3.3
				3.26
		Softball		4.1
				3.73
				4.69
Jacob	13	**Discus**	5.8	5.82
			5.9	6.38
			7.7	6
				6.1
		avg	6.47	6.08
		std dev	1.07	0.29
		Club		13.11
			12.95	13.26
			13.74	13.18
			14.03	12.19
		avg	13.57	12.94
		std dev	0.56	0.50
		Shotput	3.75	3.03
			3.55	3.4
		avg	3.65	3.22
		std dev	0.10	0.18

Holes are .0625 pilot holes
for self tapping screws



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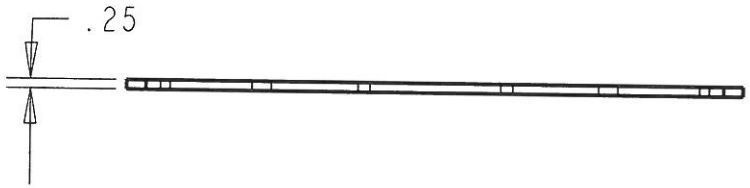
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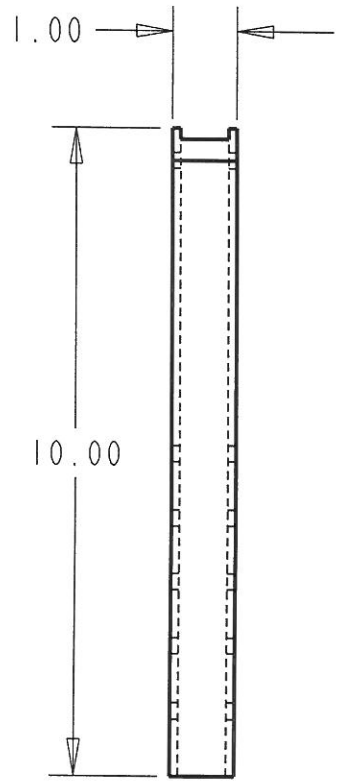
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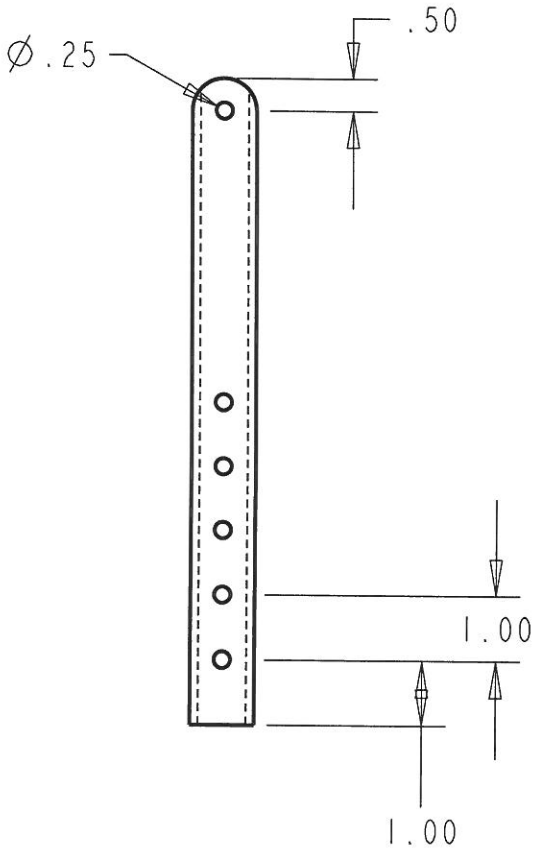
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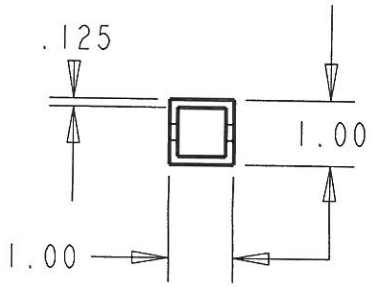
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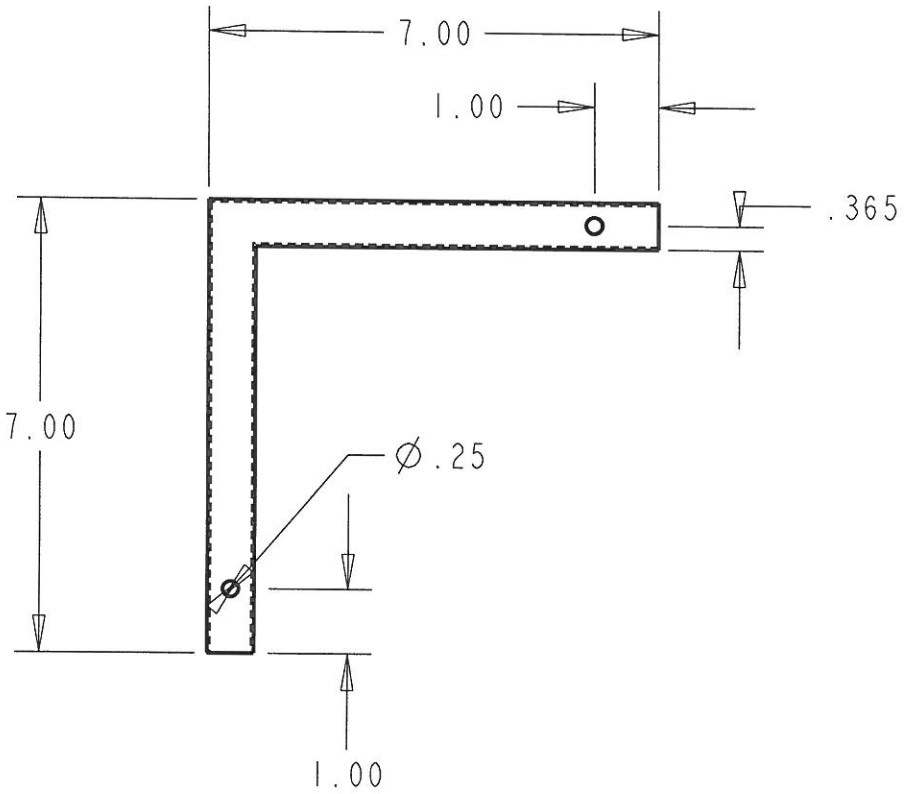
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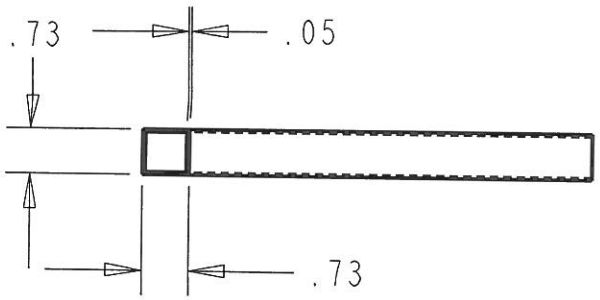
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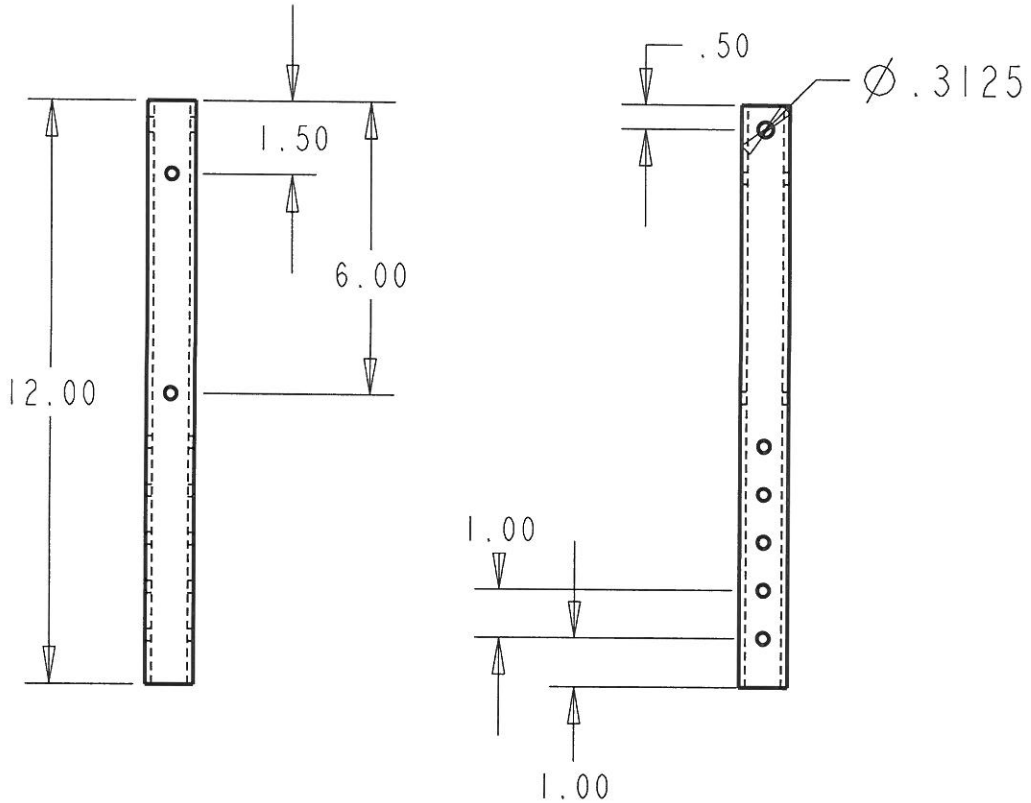
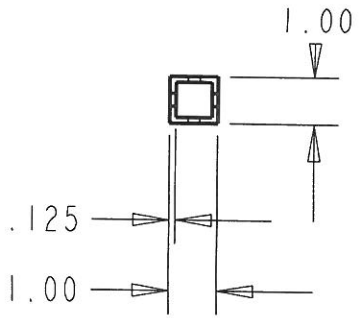
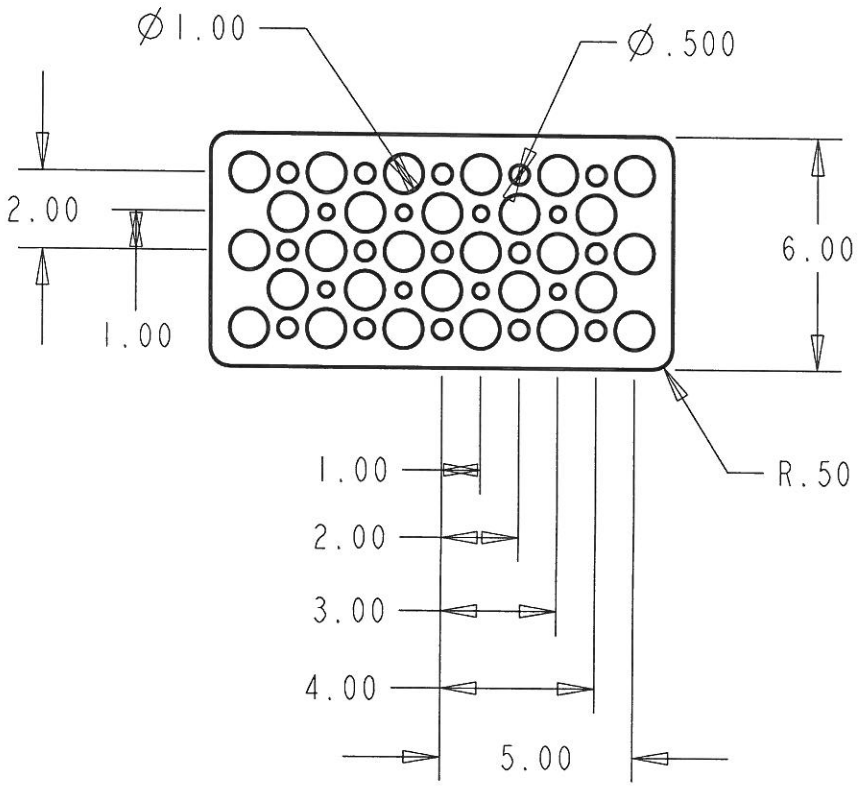
All holes .25 dia. uness specified



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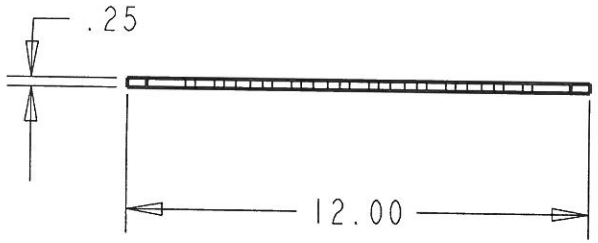
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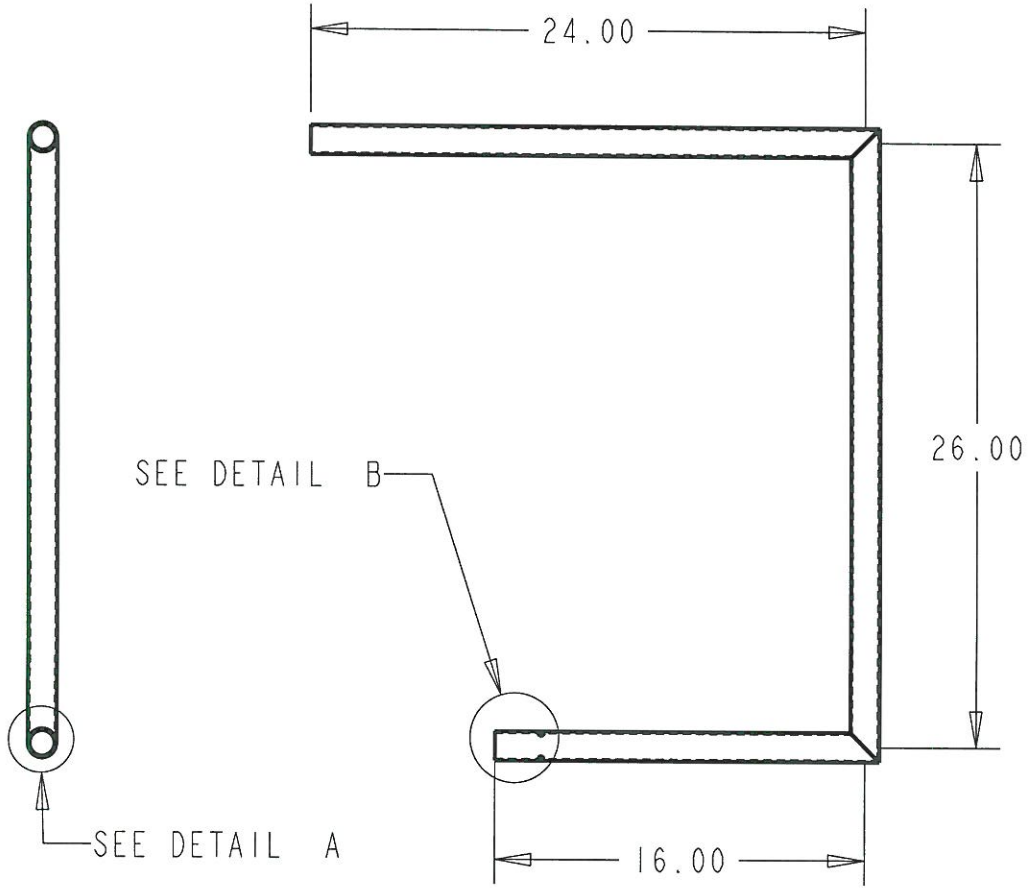

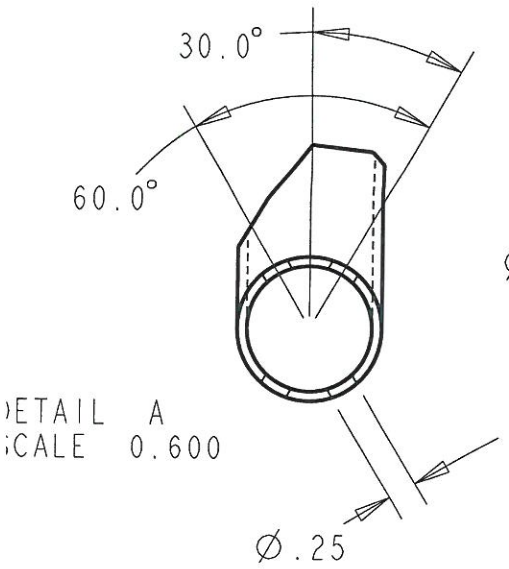

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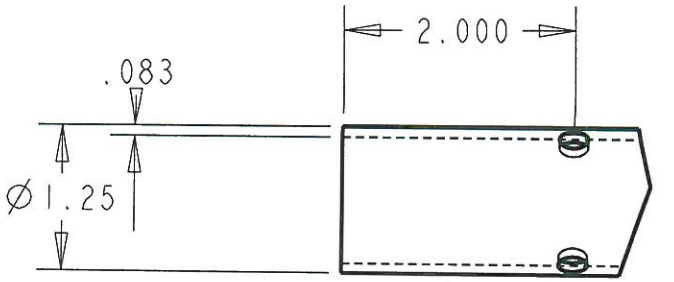
;CALE 0.600



DETAIL B
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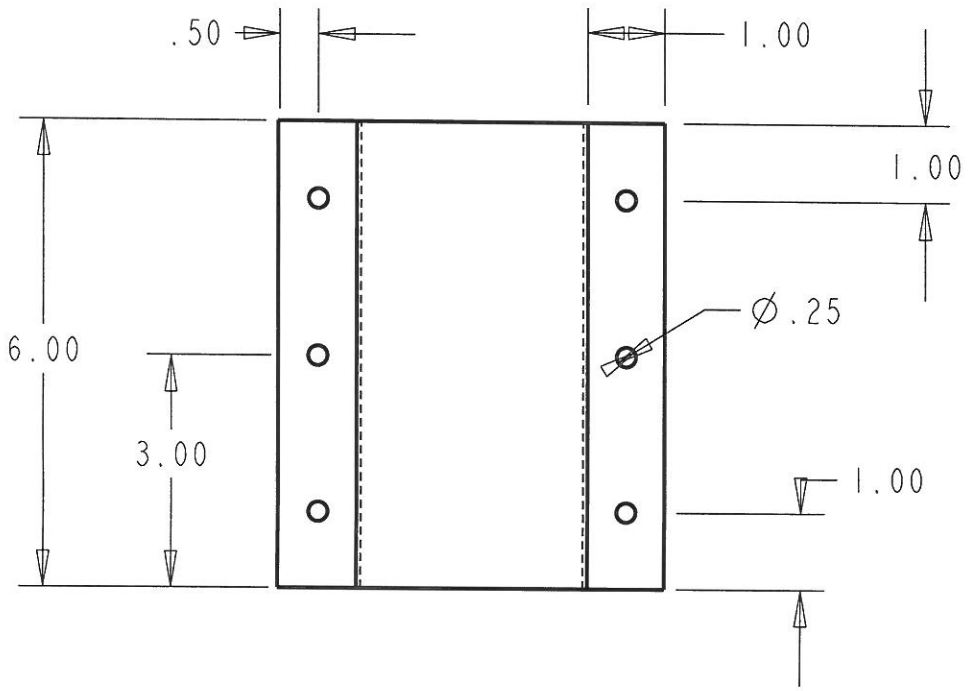
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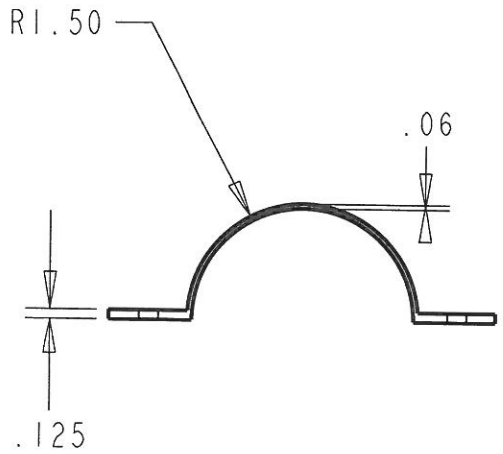
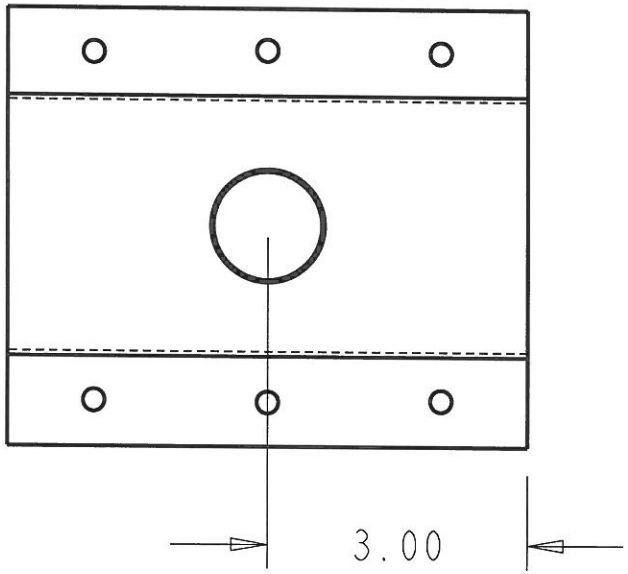

R1.50
.06
.125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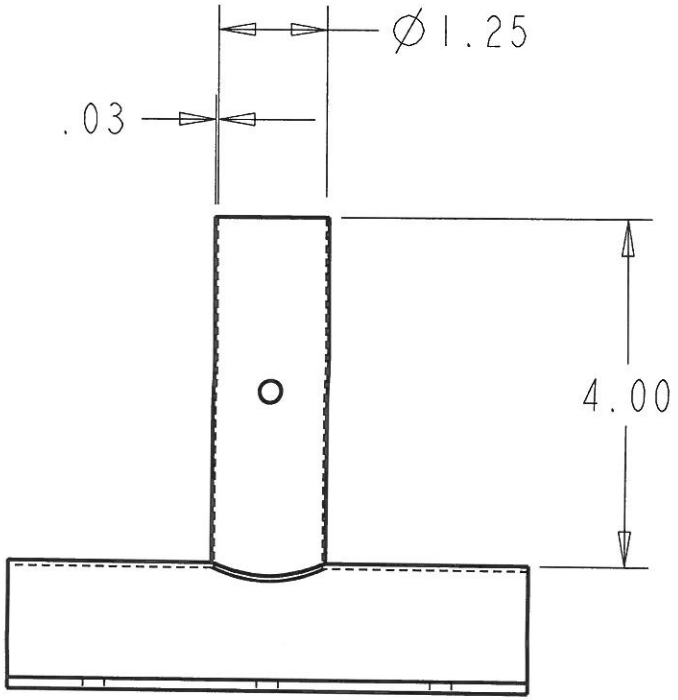
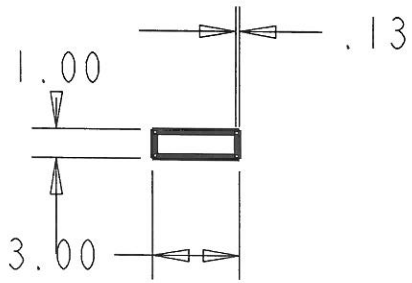

Ø1.25
.03
4.00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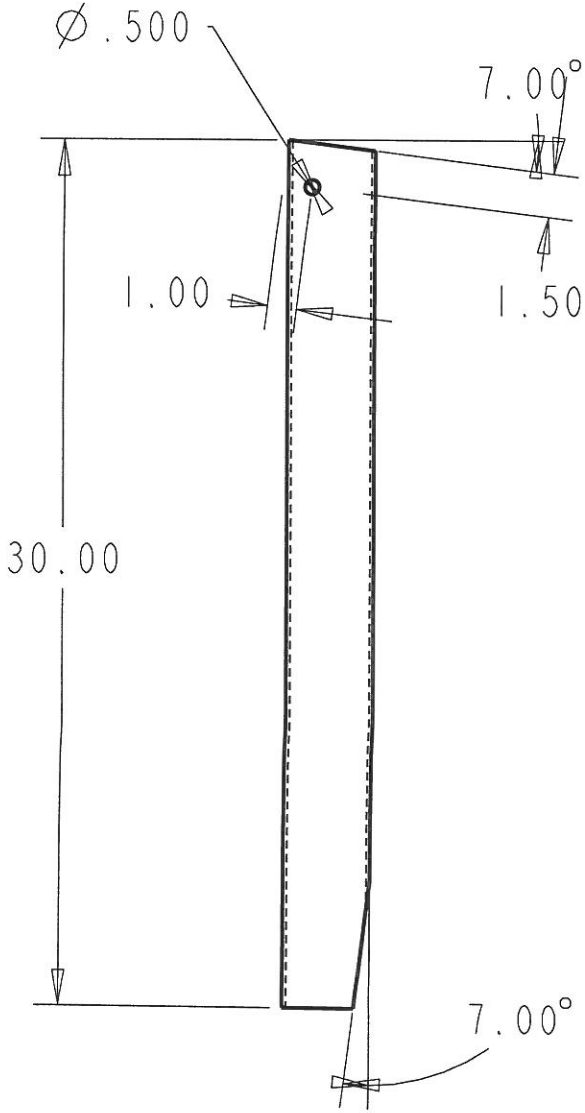
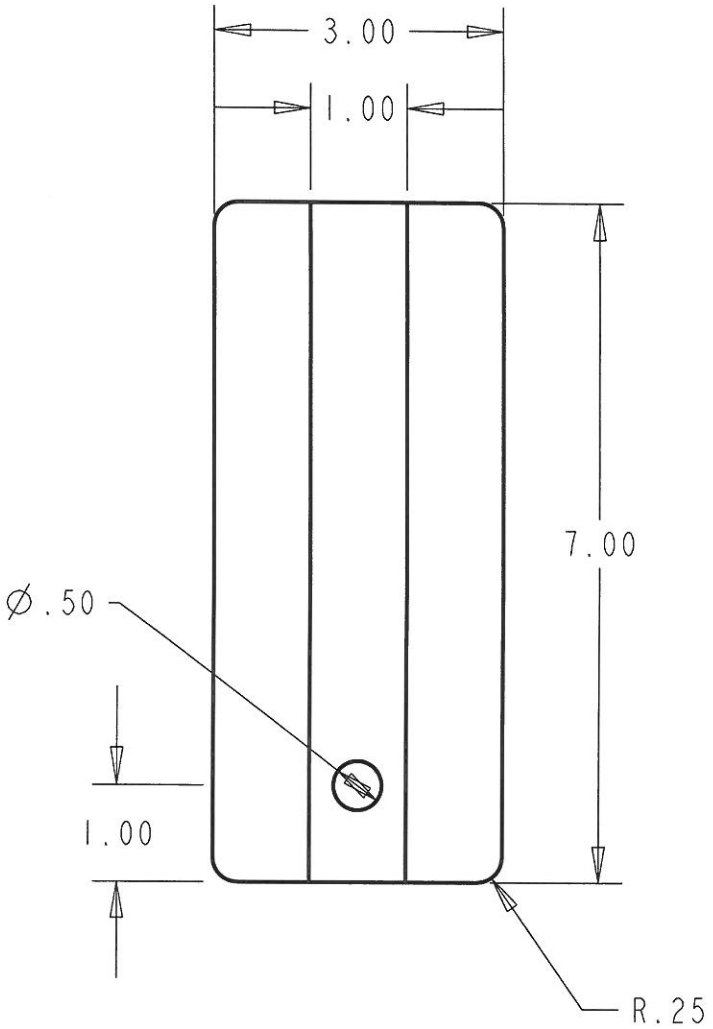
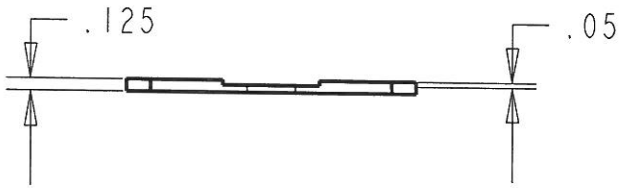
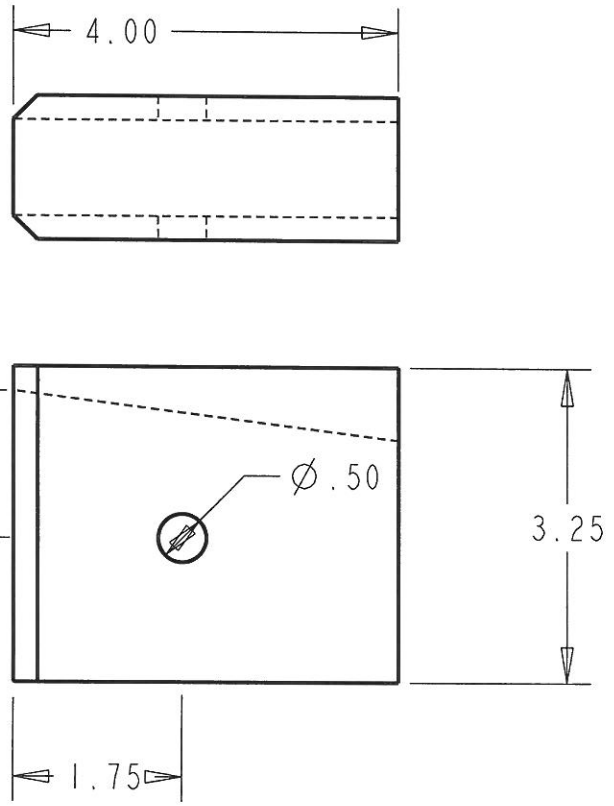
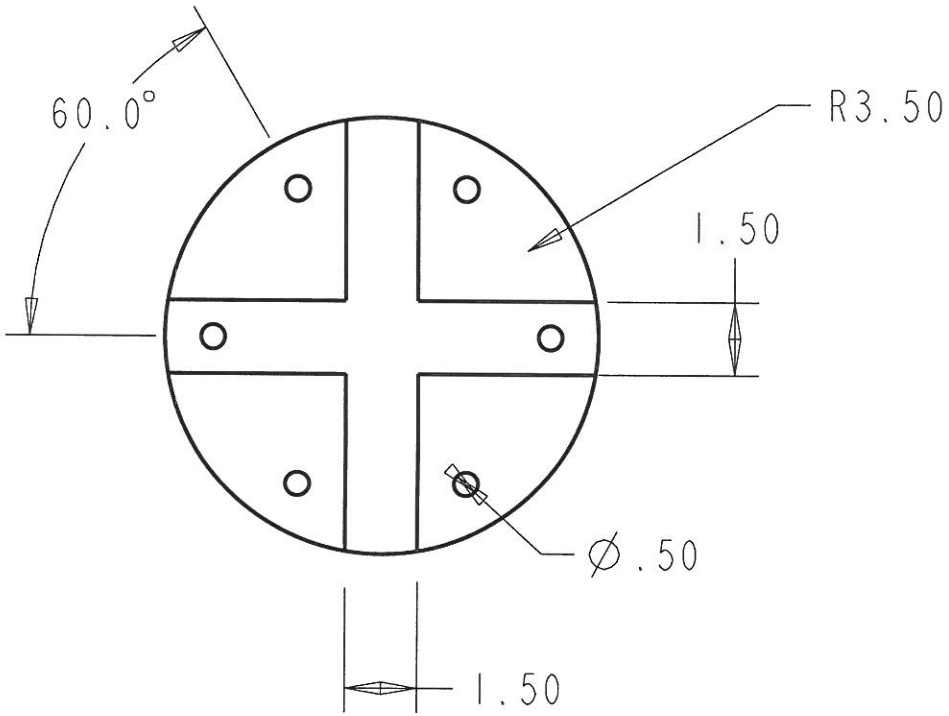
1.00
3.00

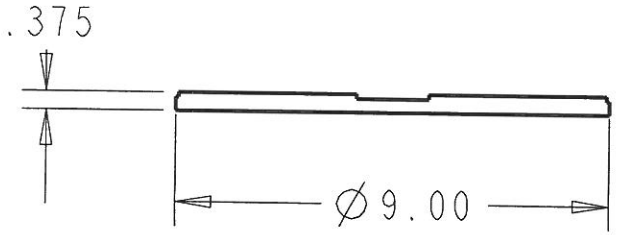

Ø.500
7.00°
1.00
1.50
30.00
7.00°


3.00
1.00
7.00
Ø.50
1.00
R.25


.125
.05


4.00
1.50
Ø.50
3.25
1.75
3.00
7.00°
SECTION A-A
.25
1.50
1.00
A
A


60.0°
R3.50
1.50
Ø.50
1.50


.375
Ø9.00