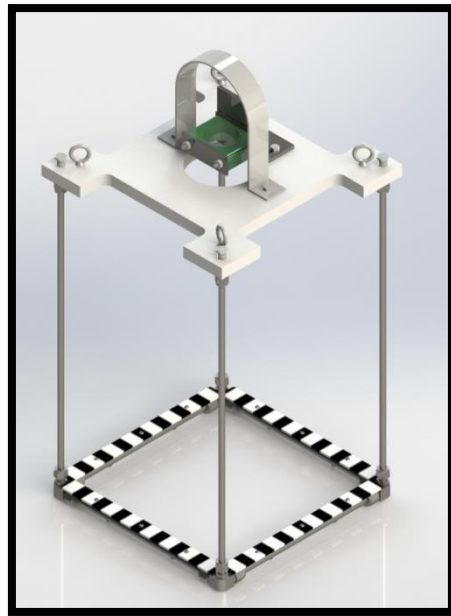


Camera Cage Construction Manual

Center of Coastal and Ocean Mapping

Designed and Constructed by: Paul Lavoie
Manual Written and Compiled by: Tim Brown and Matthew Birkebak
Reviewed by: Shachak Pe'eri and Emily Terry





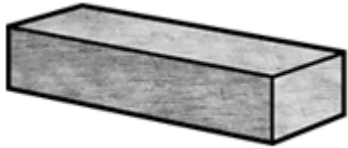
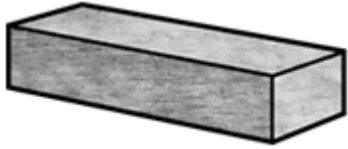


Preface

The Center for Coastal and Ocean Mapping uses a camera cage underwater video camera system with real-time feedback to ground-truth survey measurements. The underwater imaging system designed to perform in situ measurements that help calibrate and validate optical remote-sensing and swath-sonar surveys for mapping and monitoring coastal ecosystems and ocean planning. The system enables researchers to collect underwater imagery using relatively inexpensive instruments and materials that can be hand-deployed from a small vessel. This document is the first manual out of two that describes the design of the cage of the camera. The second manual describes the camera systems and procedures to capture imagery.

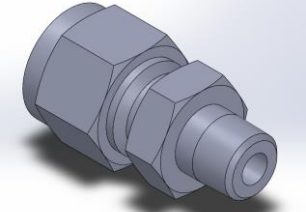
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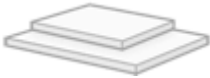


Bill of Materials

| Camera Cage Bottom Components | | | | | | |
|-------------------------------|---|---|---|------------|----------------------|-------------------------------|
| # | Part Name | Picture | Reference to Buy | Price Each | Purchase Quantity | Physical Quantity |
| 1 | Type 304 Smooth-Bore Seamless SS Tubing 1/2" OD, .43" ID, .035" Wall, 6' Length |  <p>Figure 1 - McMaster Carr</p> | McMaster Carr Reference number: 89895K744 | \$31.65 | 1 (need 4x~12" rods) | 4 rods of length 20" |
| 2 | SS Swagelok Tube Fitting, Union Elbow, 1/2 in. Tube OD |  <p>Figure 2 - Swagelok</p> | Swagelok Part Number: SS-810-9 | \$32.30 | 4 | 4 |
| 3 | Multipurpose 304 Stainless Steel Bar 1/4" X 1/2", 3' Long |  <p>Figure 3 - McMaster Carr</p> | McMaster Carr Reference number: 8992K504 | \$14.03 | 1 (need 4x 9" bars) | 4 bars of 1/4" x 1/2" X 9" |
| 4 | Multipurpose 304 Stainless Steel Bar 1/8" X 1", 2' Long |  <p>Figure 4 - McMaster Carr</p> | McMaster Carr Reference number: 8992K133 | \$7.77 | 2 (need 4x12" bars) | 4 bars of 1/8" X 1" X 11.625" |
| 5 | 18-8 SS Round Head Phillips Machine Screw 6-32 Thread, 5/16" Length, Packs of 100 |  <p>Figure 5 - McMaster Carr</p> | McMaster Carr Reference number: 91773A145 | \$3.69 | 1 (Need 12) | 12 |
| 6 | 18-8 SS Round Head Phillips Machine Screw 8-32 Thread, 5/8" Length, Packs of 100 |  <p>Figure 6 - McMaster Carr</p> | McMaster Carr Reference number: 91773A196 | \$5.66 | 1 (need 8) | 8 |

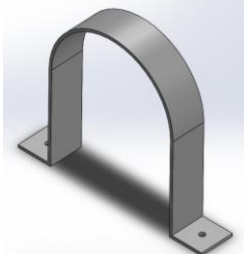
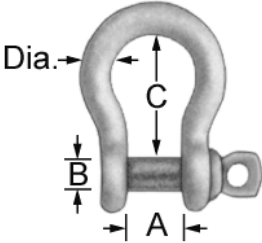
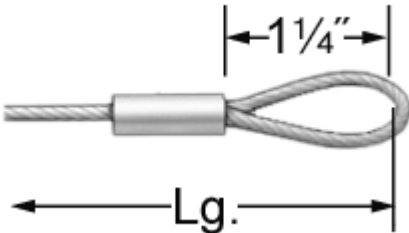
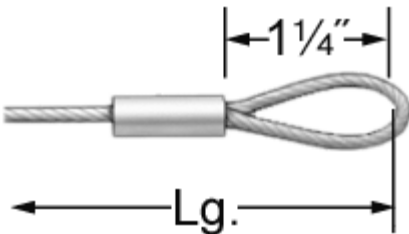

Camera Cage Middle Components

| | | | | | | |
|---|--|---|---|---------|---|------------------------|
| 7 | SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/8 in. Male NPT |  <p align="center">Figure 7 - Swagelok</p> | Swagelok Part Number: SS-600-1-2 | \$8.80 | 4 | 4 |
| 8 | Type 304 Smooth-Bore Seamless SS Tubing 3/8" OD, .277" ID, .049" Wall, 6' Length |  <p align="center">Figure 8 - McMaster Carr</p> | McMaster Carr Reference number: 89895K738 | \$31.65 | 2 | 4 rods of length 11.4" |
| 9 | SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/4 in. Male NPT |  <p align="center">Figure 9 - Swagelok</p> | Swagelok Part Number: SS-600-1-4 | \$9.90 | 4 | 4 |

Camera Cage Top Components

| | | | | | | |
|---------|--|--|--|----------|---|----------------------------|
| 10 a | White Delrin® Acetal Resin Sheet, 3/4" Thick, 12" x 12" (If using this sheet the model will be slightly smaller than the 14"x14" first model therefore all dimensions presented would need to be resized) |  <p align="center">Figure 10 - McMaster Carr</p> | McMaster Carr Reference number: 8573K21 | \$67.67 | 1 | 1 sheet 14"X 14" |
| 10 b | White Delrin® Acetal Resin Sheet, 3/4" Thick, 24" x 24" |  <p align="center">Figure 10 – McMaster Carr</p> | McMaster Carr Reference number: 8573K81 | \$217.50 | 1 | Machine to 1 sheet 14"x14" |
| 11 | Type 304 Stainless STL Threaded Pipe Fitting 1/4 Pipe Size, Hex Head Plug, 150 PSI |  <p align="center">Figure 11 - McMaster Carr</p> | McMaster Carr Reference number: 4464K252 | \$2.00 | 4 | 4 |

| | | | | | | |
|----|--|---|---|---------|---|---|
| 12 | Corrosion-Resistant Eyebolt for Lifting W/Shoulder, 316SS, 1/4"-20 Thrd Size, 1" Lg Thrd |  | McMaster Carr Reference number: 8891T72 | \$11.28 | 4 | 4 |
| | | Figure 12 - McMaster Carr | | | | |
| 13 | Type 18-8 Stainless Steel Hex Nut, 1/4"-20 Thread Size, 7/16" Wide, 7/32" High (Pack of 100) |  | McMaster Carr Reference number: 91845A029 | \$4.64 | 1 | 6 |
| | | Figure 13 - McMaster Carr | | | | |
| 14 | Multipurpose Type 304 Stainless Steel 90 Degree Angle, 1/4" Thick, 3" x 4" Leg Lengths 6" |  | McMaster Carr Reference number: 1260T56 | \$36.49 | 1 | 1, 2.5" X 3.5" X 3.5" (could be larger) |
| | | Figure 14 - McMaster Carr | | | | |
| 15 | 18-8 Stainless Steel Hex Head Cap Screw 1/4"-20 Thread, 1" Long, Fully Threaded, Packs of 50 |  | McMaster Carr Reference number: 92240A542 | \$6.93 | 1 | 2 |
| | | Figure 15 - McMaster Carr | | | | |
| 16 | 18-8 Stainless Steel Hex Head Cap Screw 1/4"-20 Thread, 3-1/2" Long, Packs of 10 |  | McMaster Carr Reference number: 92198A556 | \$4.06 | 1 | 2 |
| | | Figure 16 - McMaster Carr | | | | |
| 17 | Go Pro Quick Release Mount |  | http://shop.gopro.com/mounts/curved-plus-flat-adhesive-mounts/AACFT-001.html#/start=1 | \$19.99 | 1 | 1 |
| | | Figure 17 - Go Pro Quick Release Mount | | | | |
| 18 | Camera Mount |  | Included in Camera Package | - | 1 | 1 |

| 19 | Stainless steel bracket (Handle) |  | Custom made | - | 1 | 1 |
|-------------------------------------|--|--|---|------------|-------------------|----------------------|
| Cage Carrying Components | | | | | | |
| 20 | Type 316 SS High-Strength Anchor Shackle with Screw Pin, 7/16" Diameter, 2000# Work Load Limit |  Figure 18 - McMaster Carr | McMaster Carr Reference number: 3583T83 | \$19.21 | 5 | 5 |
| 21 | Stainless Steel Load-Rated Wire Rope Lanyard Coated, Loop/Loop, 1/8" Rope Diameter, 1' Length |  Figure 19 - McMaster Carr | McMaster Carr Reference number: 30745T436 | \$21.78 | 4 | 4 |
| 22 | Stainless Steel Load-Rated Wire Rope Lanyard Coated, Loop/Loop, 1/8" Rope Diameter, 3' Length |  Figure 20 - McMaster Carr | McMaster Carr Reference number: 30745T436 | \$29.72 | 1 | 1 |
| 23 | Double Loop Cable-Support Grip Corrosion Resistant, Midcable, 0.5"-0.61" Cable Dia |  Figure 21 - McMaster Carr | McMaster Carr Reference Number: 70095K71 | \$54.51 | 1 | 1 |
| Camera Electrical Components | | | | | | |
| # | Part Name | Picture | Reference to Buy | Price Each | Purchase Quantity | Physical Quantity |
| 24 | Ocean Systems Delta Vision Hi Definition (HD) | | http://www.sea- | ~\$2100 | 1 or 0 | Buy Either HD or STD |

| | | | | | | |
|----|--|---|---|----------|--------|----------------------|
| | |  <p>Figure 22- www.sea-viewdiving.com</p> | viewdiving.com/diving_equipment/cameras/ocean_systems/delta_visionhd.htm | | | |
| 25 | Ocean Systems Delta Vision Standard Definition (STD) |  <p>Figure 23 - www.sea-viewdiving.com</p> | http://www.sea-viewdiving.com/diving_equipment/cameras/ocean_systems/delta_visioncolor.htm | - | 1 or 0 | Buy Either HD or STD |
| 26 | GoPro Hero3+ Silver |  <p>Figure 24 - GoPro</p> | http://shop.gopro.com/cameras/hero3plus-silver/CHDH-N-302-master.html | \$299.99 | 1 | 1 |
| 27 | Elgato Game Capture HD |  <p>Figure 25 - Elgato</p> | https://www.elgato.com/en/gaming/gamecapture-hd | \$149.95 | 1 | 1 |

Locations of Camera Cage Parts

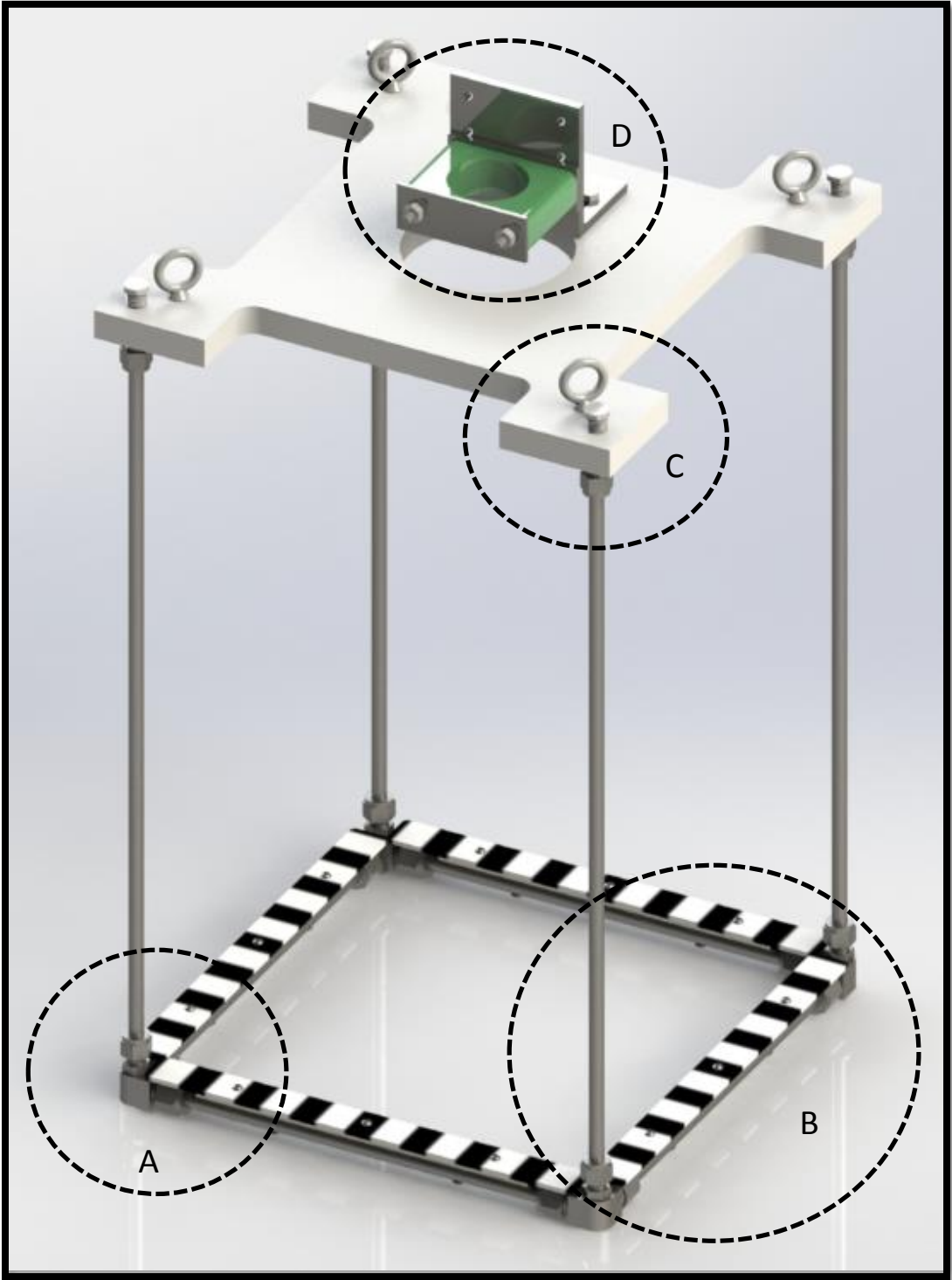


Figure 26 -Overall Camera Cage with locations of detailed views

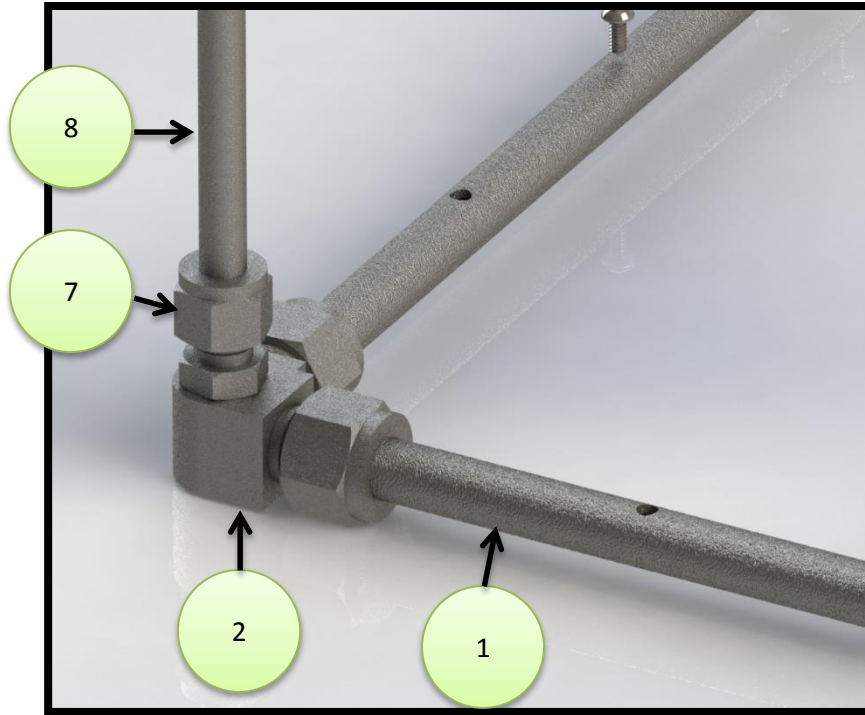


Figure 27 - Detail View A, The number in each balloon corresponds to the part number in the bill of materials

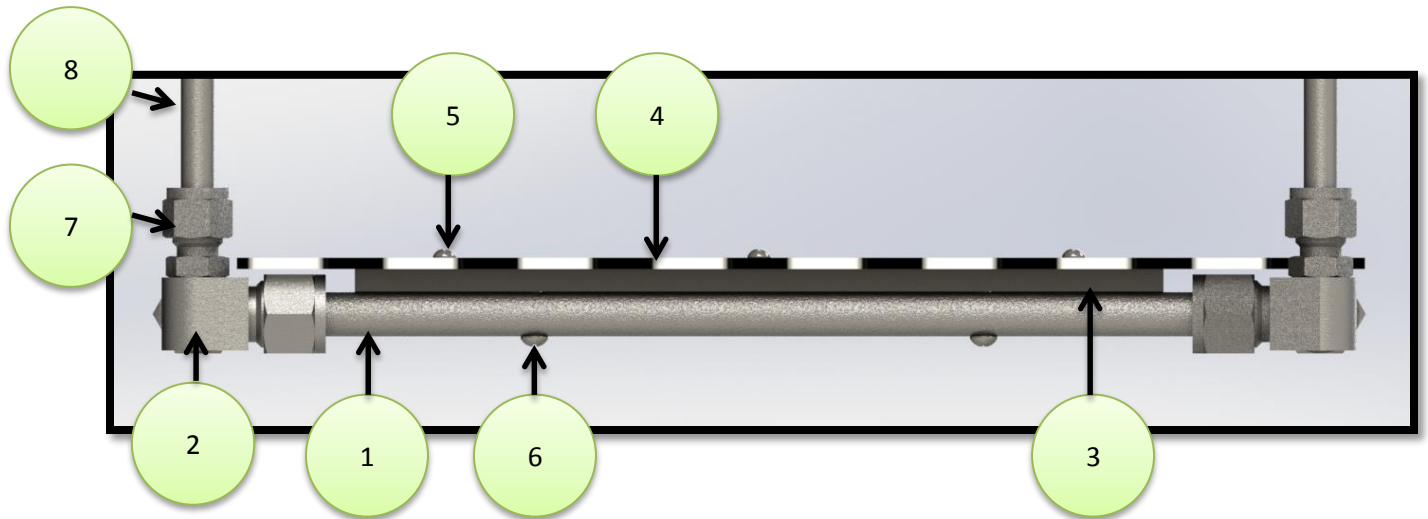


Figure 28 - Detail View B, The number in each balloon corresponds to the part number in the bill of materials

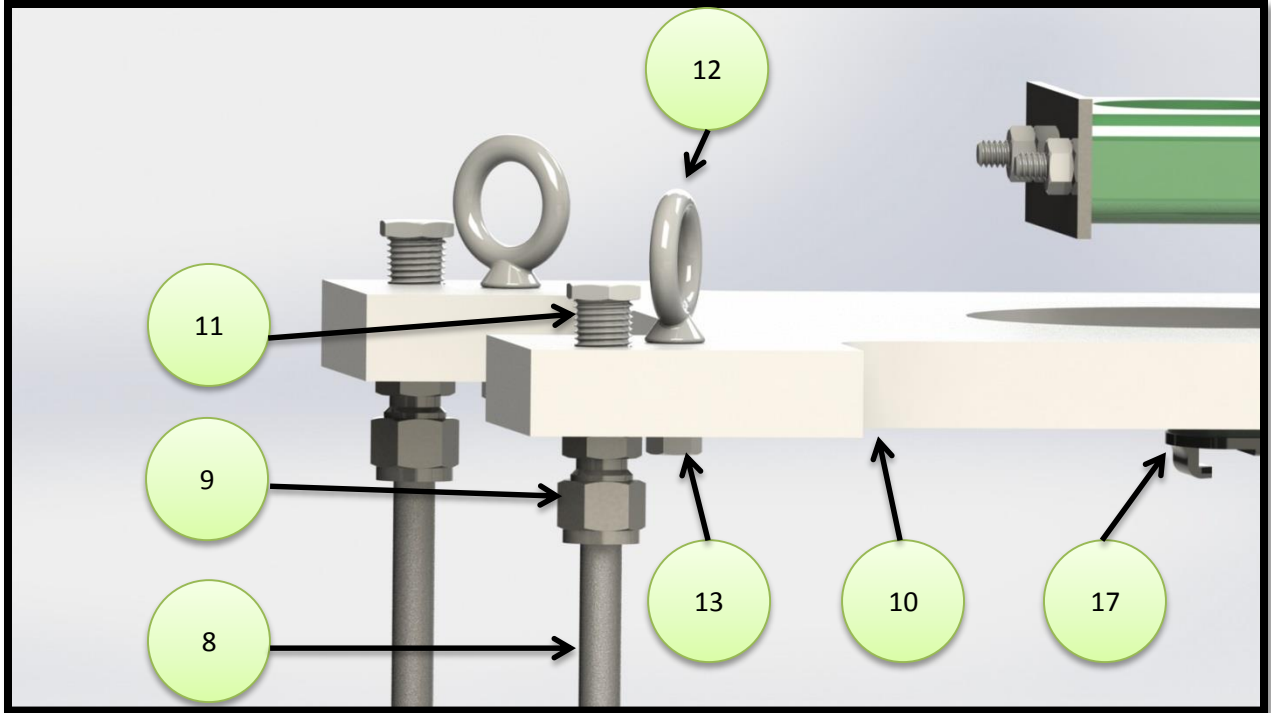


Figure 29 - Detail View C, The number in each balloon corresponds to the part number in the bill of materials

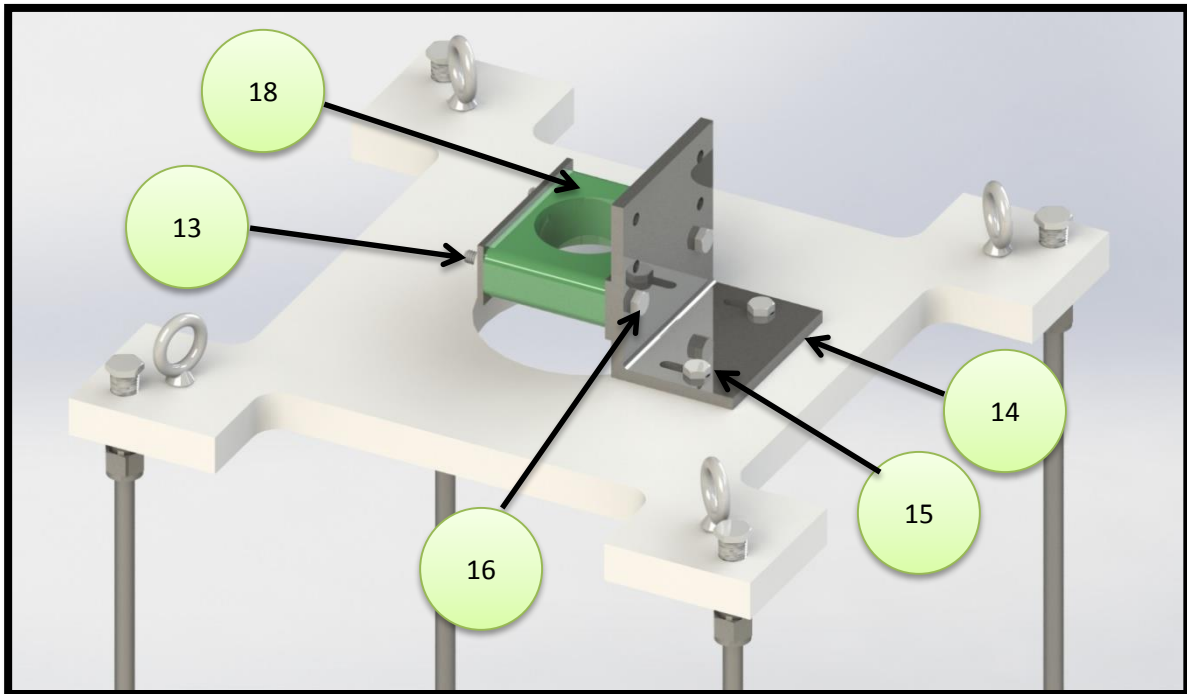


Figure 30 - Detail View D, The number in each balloon corresponds to the part number in the bill of materials

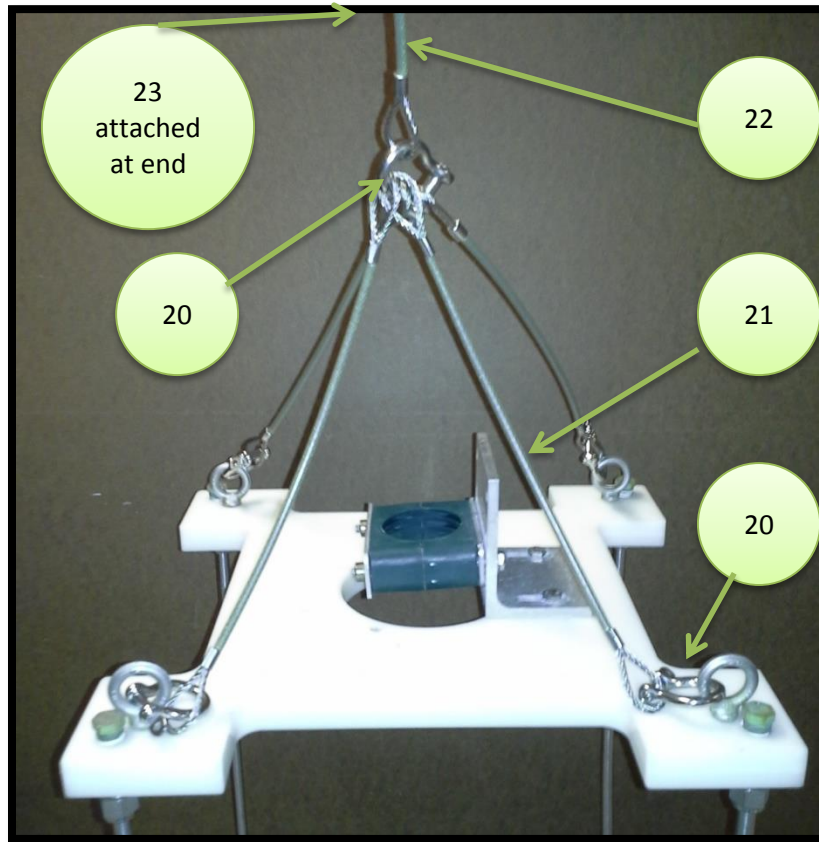


Figure 32 - Detail View showing cage carrying components. The number in each balloon corresponds to the part number in the bill of materials

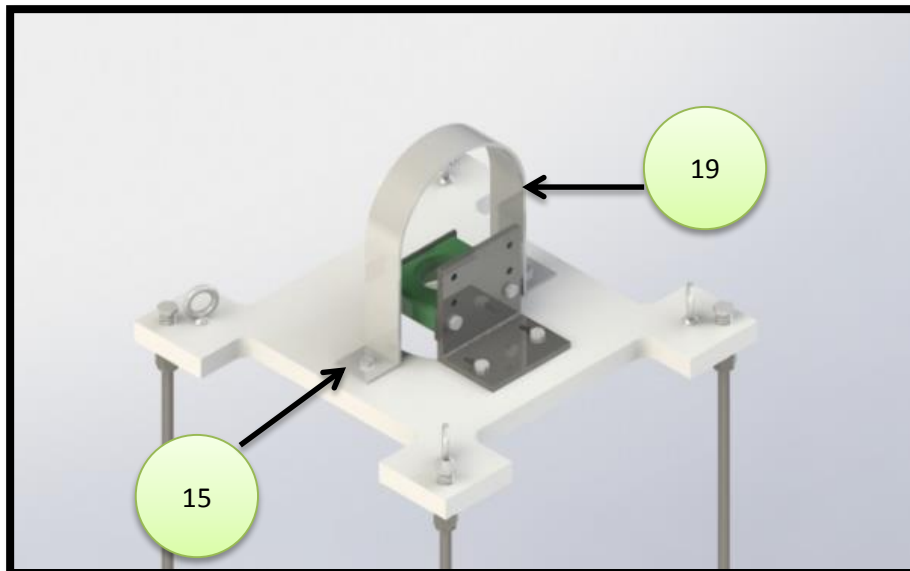


Figure 31 - Top of Camera Cage with Metal Handle

Tools Required

1. Table or Band saw
2. A method of sanding Delrin
3. At least 2 wrench's for Swagelok components (Adjustable is the best)
4. Drill that can penetrate stainless Steel 304 with a .5" diameter and much smaller hole (Can be a drill press.
5. Funnel (to insert lead shot into 3/8" tubing)
6. 1/4" NPT tap and a 1/8" NPT tap
7. hacksaw

Construction

Bottom of Camera Cage

The bottom assembly is put together first.

Gather Materials

1. Gather materials from the bill of materials listed under bottom components or alternate components of same size and material from a different vendor.

| # | Part Name | Reference to Buy | Price Each | Quantity |
|-------------------------------|---|---|------------|-----------------------------------|
| 1 | Type 304 Smooth-Bore Seamless SS Tubing 1/2" OD, .43" ID, .035" Wall, 6' Length | McMaster Carr Reference number: 89895K744 | \$31.65 | 1 (need 4 rod of length 12") |
| 2 | SS Swagelok Tube Fitting, Union Elbow, 1/2 in. Tube OD | Swagelok Part Number: SS-810-9 | \$32.30 | 4 |
| 3 | Multipurpose 304 Stainless Steel Bar 1/4" X 1/2", 3' Long | McMaster Carr Reference number: 8992K504 | \$14.03 | 1 (need 4 bars of length 9") |
| 4 | Multipurpose 304 Stainless Steel Bar 1/8" X 1", 2' Long | McMaster Carr Reference number: 8992K133 | \$7.77 | 2 (need 4 bars of length 11.625") |
| 5 | 18-8 SS Round Head Phillips Machine Screw 6-32 Thread, 5/16" Length, Packs of 100 | McMaster Carr Reference number: 91773A145 | \$3.69 | 1 (Need 12) |
| 6 | 18-8 SS Round Head Phillips Machine Screw 8-32 Thread, 5/8" Length, Packs of 100 | McMaster: 91773A196 | \$5.66 | 1 (need 8) |
| Middle Camera Cage Components | | | | |
| 7 | SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/8 in. Male NPT | Swagelok Part Number: SS-600-1-2 | \$8.80 | 4 |

Machine Parts to Specifications

2. Once all Components are gathered they must be cut and custom machined to the specifications provided in the following steps (All dimensions in inches):
 - a. **1/2" ss tubing:**
 - i. Use machine to cut 6' of 1/2" stainless steel tubing into 4 rods of length 11.4".
NOTE: For rod to sit in fully to both union elbows the length would need to be 11.4475".

- ii. Set stainless steel tubing in a rig and drill two holes with a #29 drill bit (.1360") in the 1/2" tubing spaced 5" apart, centered both length and width wise in all 4 rods.
- iii. Use an 8-32 tap to create threads in all the holes on each 1/2" ss tubing. Keep tapping until the tap extends .125" past other side of tubing unless tap is not long enough. (May need carbide or stronger tap and die set for use with 304 stainless steel). NOTE: Tubing should be tapped from Bottom to Top.

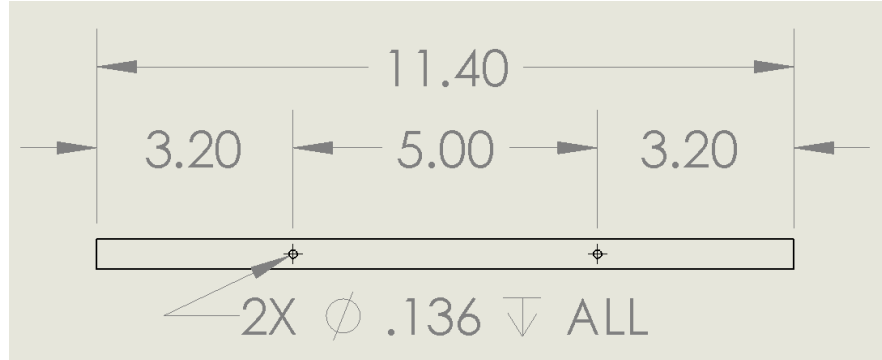


Figure 33 - working drawing 1/2" ss tubing

b. 304 Bar 1/4" X 1/2" X 9":

- i. Use a machine to cut 3' 304 stainless steel bar into 4 bars of length 9".
- ii. Secure piece and drill two holes with a #29 drill bit (.1360") in the bar 2" from the left side and 7" from the left side.
- iii. Use an 8-32 tap to create threads in the holes with a diameter of .1360". They should be tapped to a depth of .125". NOTE: Should be tapped Bottom to Top.
- iv. Secure piece and drill three holes with a # 35 drill bit (.11") in the bar 1" from left side, 4.5" from left side, and 8" from left side.
- v. Use a 6-32 tap to create threads in the holes with a diameter of .11". NOTE: These should be tapped starting on the opposite side as the 8-32 tap. Or should be tapped Top to Bottom
- vi. Repeat steps b. 2-5 with all four 9" bars.

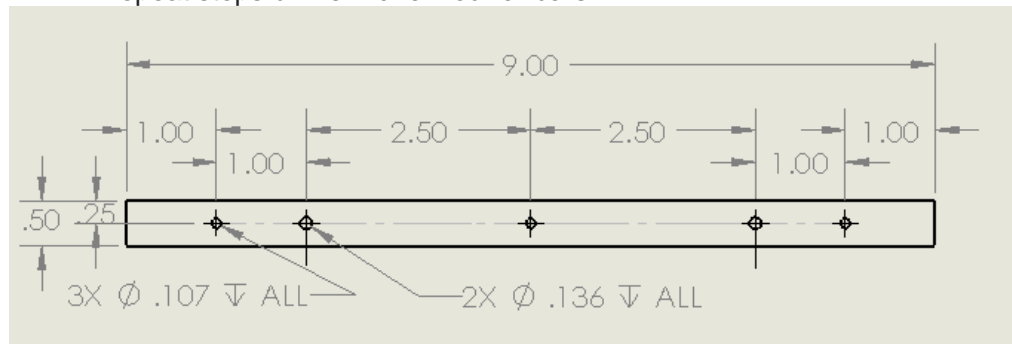


Figure 34 - working drawing 304 ss bar

c. 304 Bar 1/8" X 1" X 11.625":

- i. Use a machine to cut 6' 304 stainless steel bar into 4 bars of length 11.625".
- ii. Secure piece and drill three holes with a # 35 drill bit (.11") in the bar 2.31" from left side, 7.81" from left side, and 9.315" from left side.
- iii. Use a 6-32 tap to create threads in the holes with a diameter of .11". NOTE: Tap Top to Bottom
- iv. Sand corners with to a .15" fillet

- v. Repeat steps 2-4 with all four 11.625" bars.

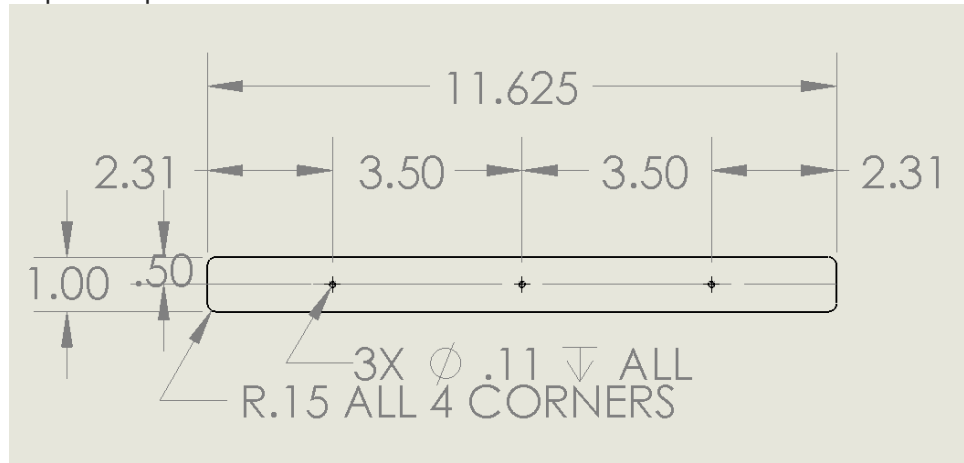


Figure 35 - working drawing 304 ss powder coated bar

- vi. Send machined stainless steel bars to be powder coated with a specific black and white pattern that alternates lengthwise on increments of .75".

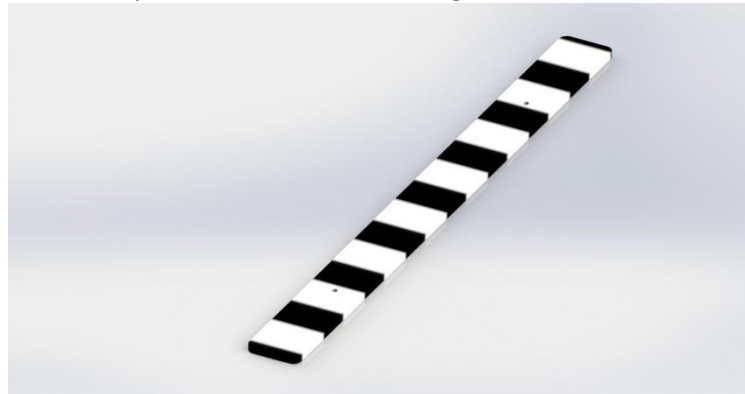


Figure 36 - Powder coated 304 ss bar

d. Union Elbow:

- i. A 1/8" NPT female hole must be drilled with a drill bit of size "Q" (0.332") to depth of .58" and tapped with a 1/8"-27 pipe tap into the SS Swagelok tube fitting, Union Elbow.

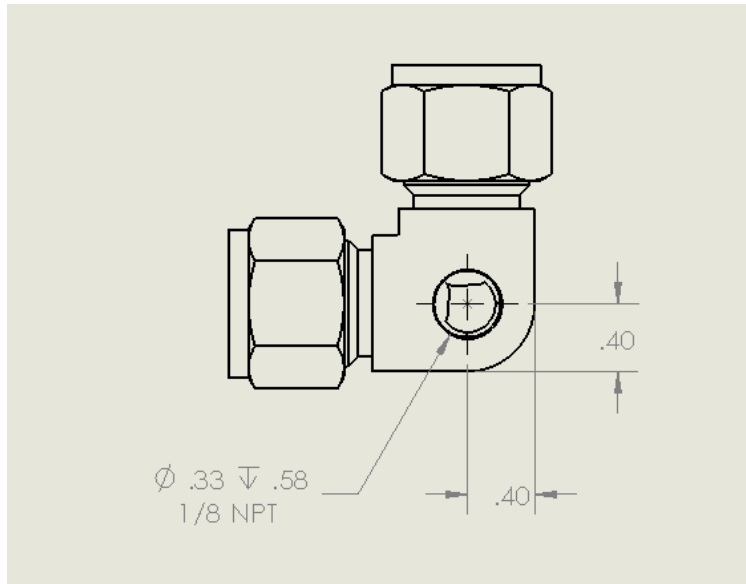


Figure 37 - Union Elbow

Assemble Bottom Components

3. Fully insert $\frac{1}{2}$ " tubing into a union elbow connector and hand tighten union elbow nut. Check that holes in $\frac{1}{2}$ " tubing are aligned vertically and are tapped from bottom to top and union elbow is aligned horizontally with tapped hole facing vertical.

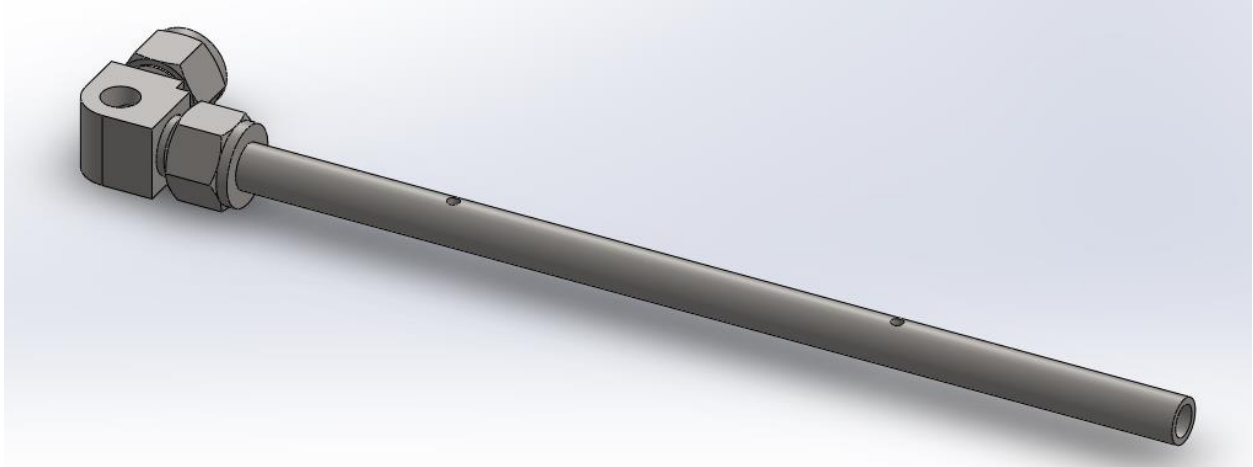


Figure 38 - Bottom Assembly Union Elbow and 1/2" ss rod

4. Fully insert the open end of the $\frac{1}{2}$ " tubing into another union elbow facing the same direction as the first. Hand tighten the nut of the Union elbow onto the $\frac{1}{2}$ " tube.

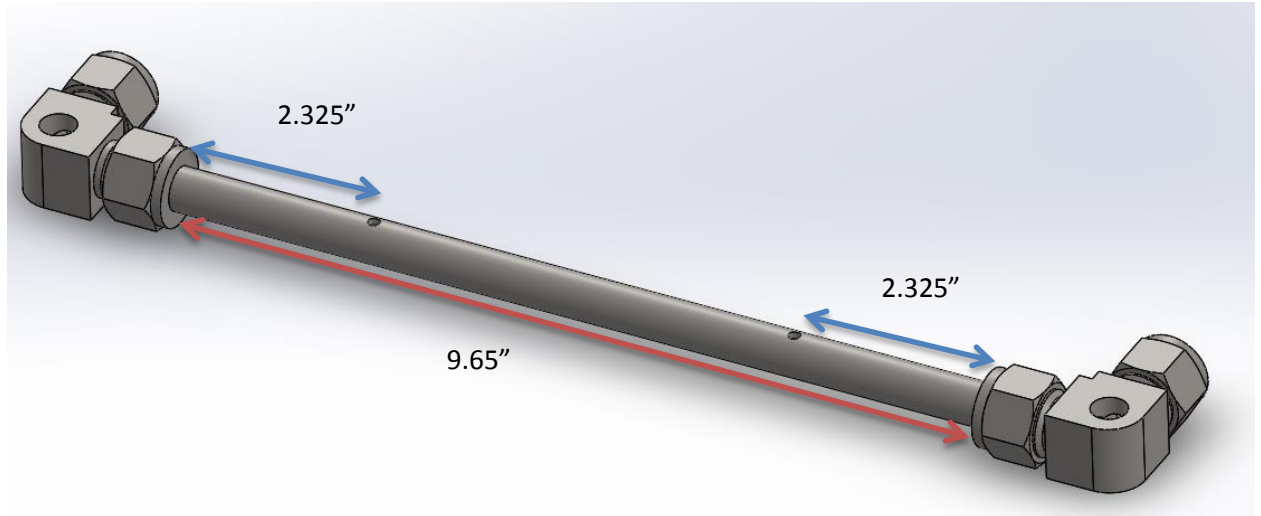


Figure 39 - Bottom Assembly

5. Check that the exposed distance of the $\frac{1}{2}$ " tubing between elbows is about 9.65" and that the holes are centered. If these values have been checked than hand tighten union elbow nuts and then tighten 1 and a quarter turns with wrenches. (Directions for tightening Swagelok pieces can be found in Appendix)
6. Continue fully inserting $\frac{1}{2}$ " tubing into Union Elbows, checking distances, and tightening to make a square. NOTE: hand tighten nut on the union elbows then tighten a turn and a quarter with a

wrench. (See Swagelok guide in Appendix.)

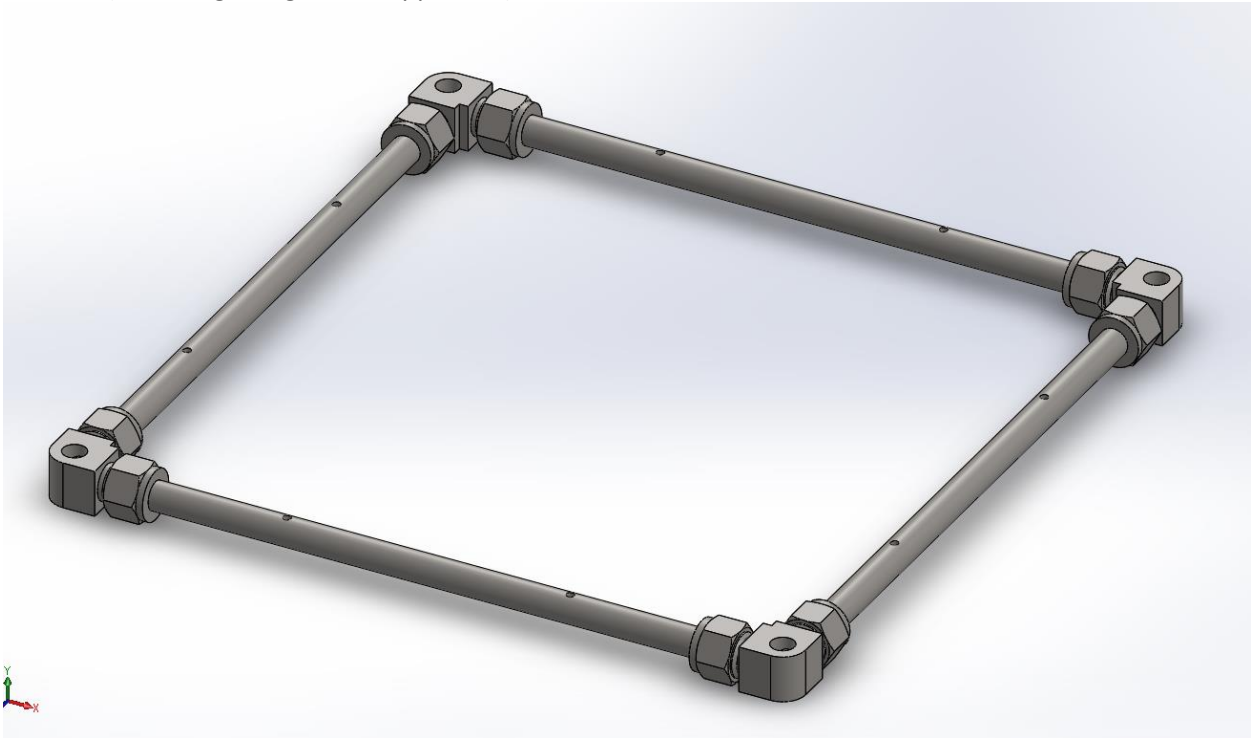


Figure 40 - Bottom Assembly

7. Place 304 Bar $\frac{1}{4}$ " X $\frac{1}{2}$ " X 9" on top of $\frac{1}{2}$ " tubing and screw in 8-32 machine screws from bottom of tubing to attach. Do this for all four pieces of $\frac{1}{2}$ " tubing.

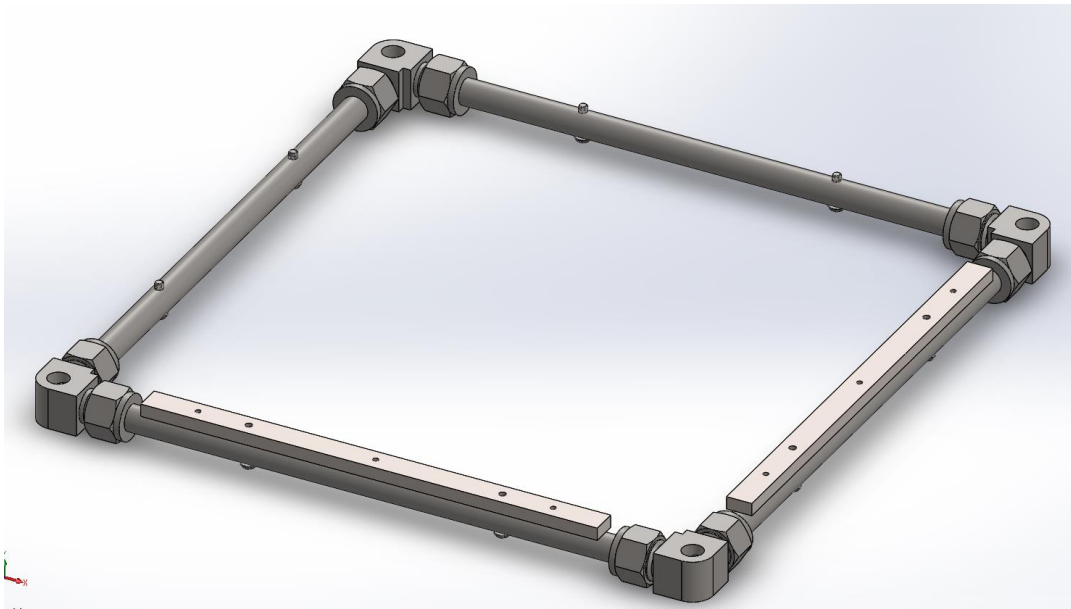


Figure 41 - Halfway through attaching 304 bars to tubing

8. Screw in SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/8 in. Male NPT to each Union Elbow. Tighten connector fully.

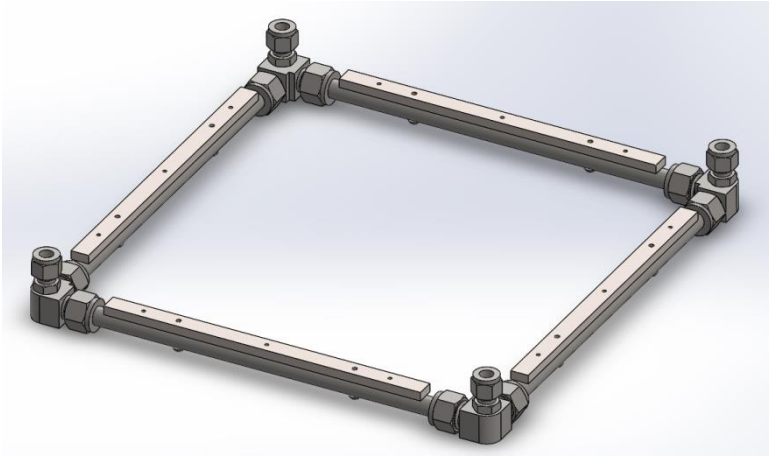


Figure 43 - Bottom Assembly Solidworks

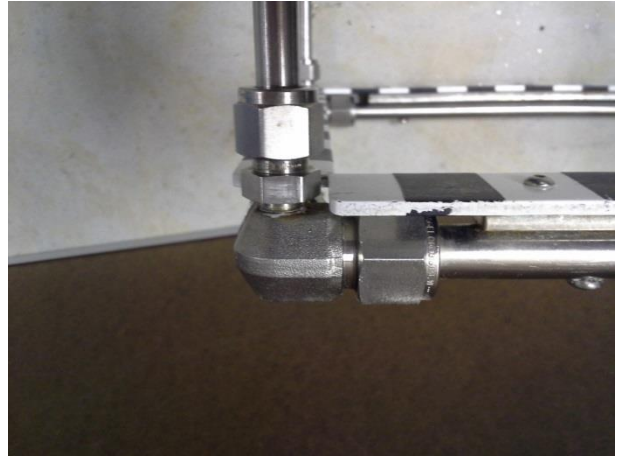


Figure 42 - Bottom assembly of Swagelok 1/8" NPT connector on model

10. Attach powder coated stainless steel bars by screwing in 6-32 machine screws from top.

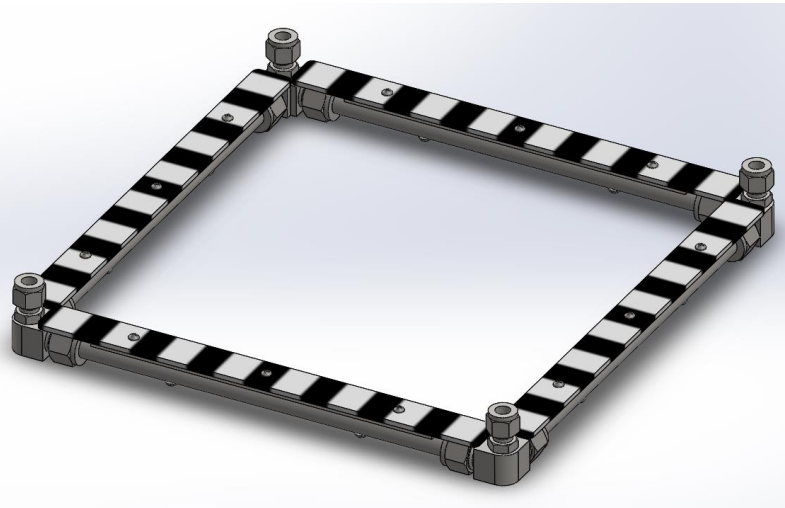


Figure 44 - Bottom Assembly Solidworks










Figure 45 - Bottom Assembly model

Top of Camera Cage

Gather Materials

1. Gather materials from the bill of materials listed under Top components or alternate components of same size and material from a different vendor.

| Camera Cage Top Components | | | | | |
|--|--|---|----------|--------|---|
| White Delrin ® Acetal Resin Sheet, 3/4" Thick, 12" x 12" (If using this sheet the model will be slightly smaller than the 14"x14" first model therefore all dimensions presented would need to be resized – See material below) |  Figure 46 - McMaster Carr | McMaster Carr Reference number: 8573K21 | \$67.67 | 1 or 0 | 1 sheet 12"X 12" |
| White Delrin ® Acetal Resin Sheet, 3/4" Thick, 24" x 24"(See above material) |  Figure 10 – McMaster Carr | McMaster Carr Reference number: 8573K81 | \$217.50 | 1 or 0 | Machine to 1 sheet 14"x14" |
| Type 304 Stainless STL Threaded Pipe Fitting 1/4 Pipe Size, Hex Head Plug, 150 PSI |  Figure 47 - McMaster Carr | McMaster Carr Reference number: 4464K252 | \$2.00 | 4 | 4 |
| Corrosion-Resistant Eyebolt for Lifting W/Shoulder, 316SS, 1/4"-20 Thrd Size, 1" Lg Thrd |  Figure 48 - McMaster Carr | McMaster Carr Reference number: 8891T72 | \$11.28 | 4 | 4 |
| Type 18-8 Stainless Steel Hex Nut, 1/4"-20 Thread Size, 7/16" Wide, 7/32" High (Pack of 100) |  Figure 49 - McMaster Carr | McMaster Carr Reference number: 91845A029 | \$4.64 | 1 | 6 |
| Multipurpose Type 304 Stainless Steel 90 Degree Angle, 1/4" Thick, 3" x 4" Leg Lengths 6" |  Figure 50 - McMaster Carr | McMaster Carr Reference number: 1260T56 | \$36.49 | 1 | 1, 2.5" X 3.5" X 3.5" (could be larger) |

| | | | | | |
|---|--|--|----------------|----------|----------|
| <p>18-8 Stainless Steel Hex Head Cap Screw 1/4"-20 Thread, 1" Long, Fully Threaded, Packs of 50</p> |  <p>Figure 51 - McMaster Carr</p> | <p>McMaster Carr Reference number: 92240A542</p> | <p>\$6.93</p> | <p>1</p> | <p>2</p> |
| <p>18-8 Stainless Steel Hex Head Cap Screw 1/4"-20 Thread, 3-1/2" Long, Packs of 10</p> |  <p>Figure 52 - McMaster Carr</p> | <p>McMaster Carr Reference number: 92198A556</p> | <p>\$4.06</p> | <p>1</p> | <p>2</p> |
| <p>Go Pro Mount Quick Release Mount</p> |  <p>Figure 53 - Go Pro Quick Release Mount</p> | <p>http://shop.gopro.com/mounts/curved-plus-flat-adhesive-mounts/AACFT-001.html#/start=1</p> | <p>\$19.99</p> | <p>1</p> | <p>1</p> |
| <p>Camera Mount</p> |  | <p>Included in Camera Package</p> | <p>-</p> | <p>1</p> | <p>1</p> |
| <p>Stainless Steel Bracket (handle)</p> |  | <p>Custom made</p> | <p>-</p> | <p>1</p> | <p>1</p> |

Machine Parts to Specifications

- Once all Components are gathered they must be cut and custom machined to the specifications provided in the following steps (All dimensions in inches):

- Delrin Plate:**

- Secure Delrin plate to table and use drill press to drill a 4.25" hole in the center.
- Use a machine to cut 8"x2" blocks on each side of the plate.

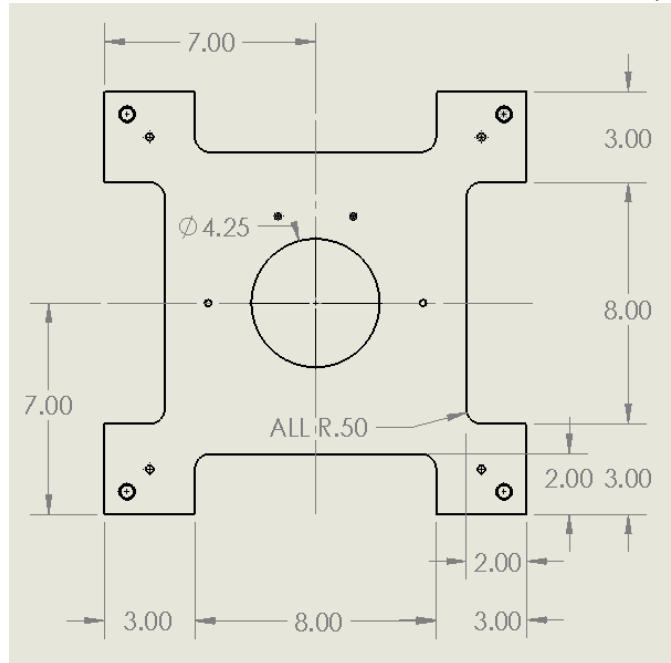


Figure 54 - Working Drawing of Delrin plate

- Secure plate with top side facing up and drill the two small holes in near center with a #7 bit and tap with a 1/4"-20 from top to bottom.

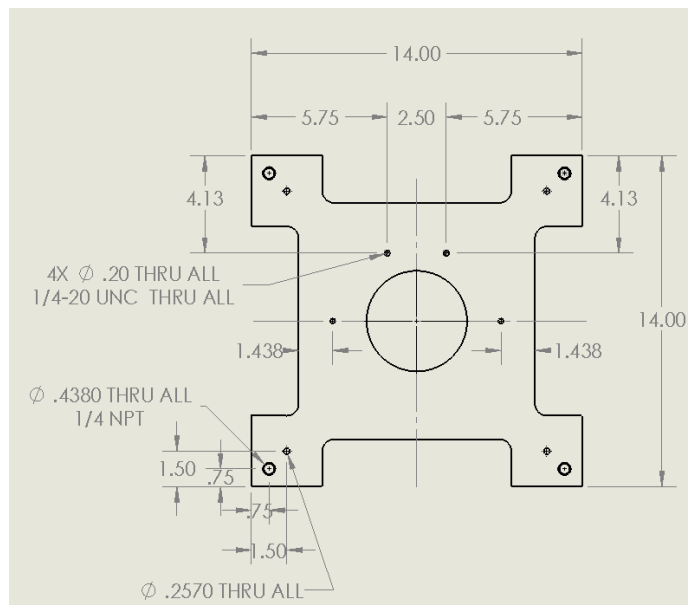


Figure 55 - Working Drawing of Delrin plate

- iv. Secure plate top side up and drill the holes on any corner. The larger hole is for a 1/4" NPT and should be drilled and the smaller hole is a clearance hole for a 1/4" close fit eyebolt and should be drilled with an F drill bit (.2570"). The 1/4" NPT should be tapped using a 1/4" NPT tap from the top to a depth of .17" (For 1/4" NPT plug) and from the bottom to a depth of .59" (For 1/4" NPT Swagelok piece).

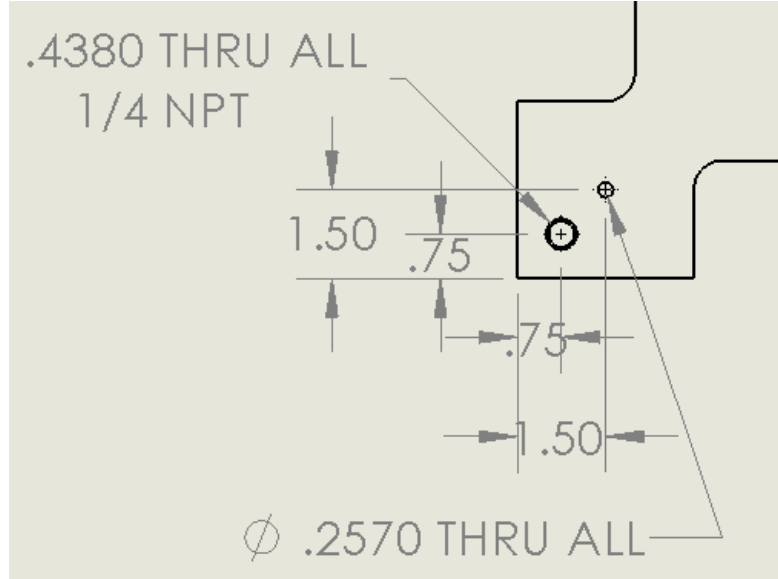


Figure 56 - One corner of Delrin plate

- v. Repeat step 4 for all four corners of the delrin plate.
- vi. Add two holes in Delrin plate for the stainless steel bracket (Handle, part 19). These holes will be dimensioned based on the metal bracket used. Make sure that the metal bracket is large enough to clear over the underwater camera itself.

b. 304 Stainless Steel 90 degree angle plate:

- i. Use a machine cut holes in 304 stainless steel plate according to the following diagram.

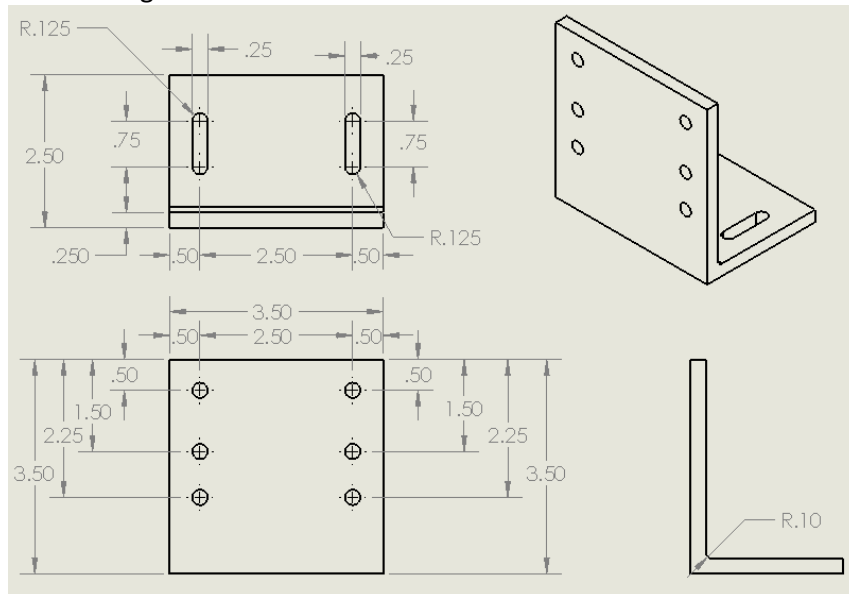


Figure 57 - 90 degree plate working drawing

Assemble Top Components

Finished top plate

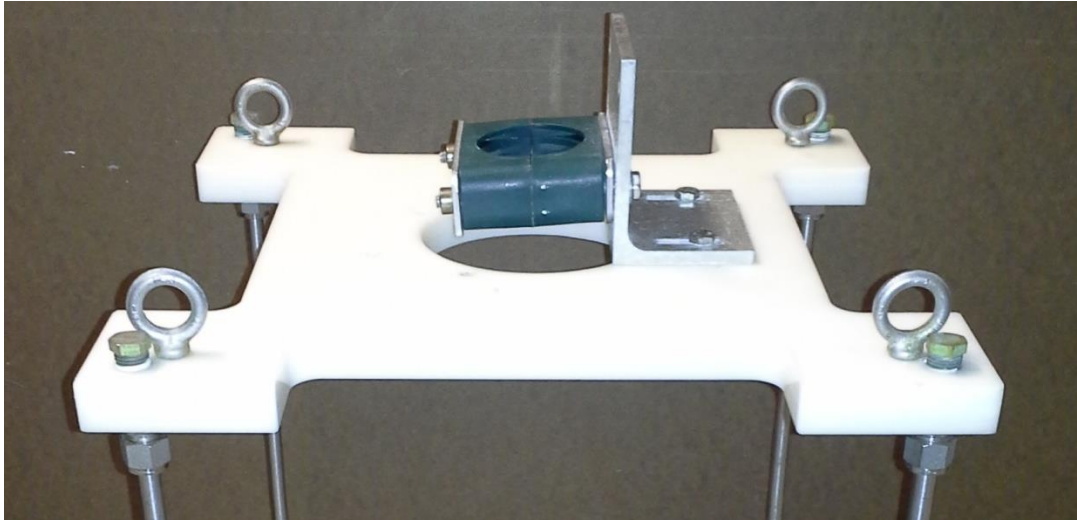


Figure 58 - Top of Camera Cage

3. Screw in NPT 1/4" plug.

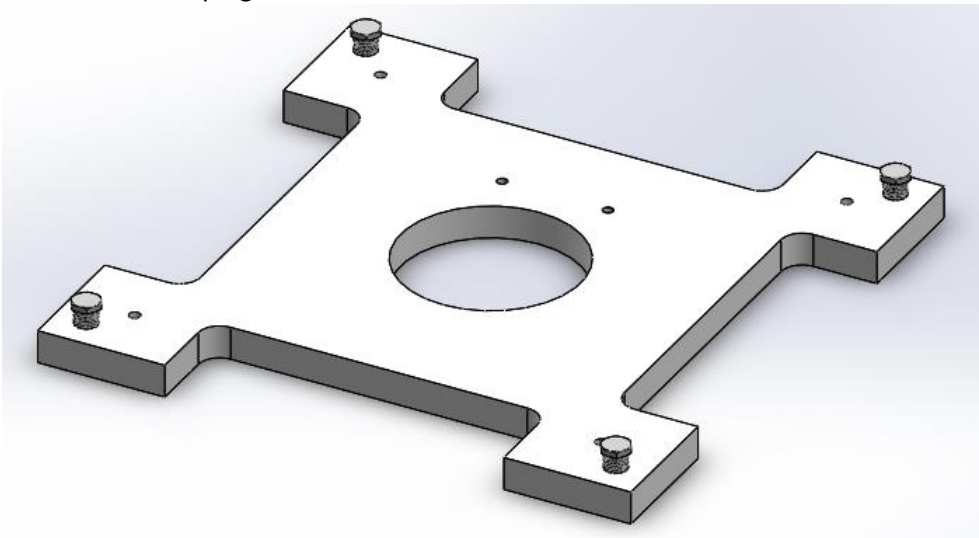


Figure 59 - Top Assembly

4. Put Eyebolts in and screw 1/4" and screw in 1/4"-20 nuts to secure them in place.

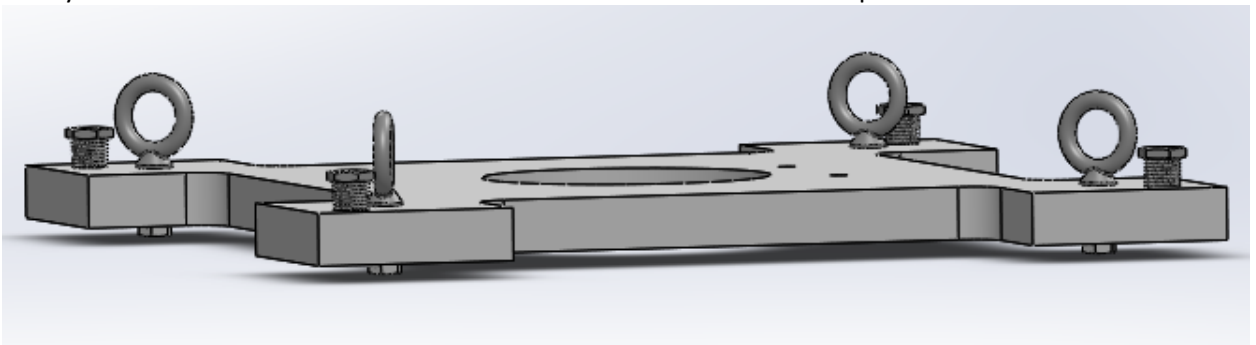


Figure 60 - Top Assembly

5. Align 90 degree angle plate and screw $\frac{1}{4}$ "-20 bolts to secure it.

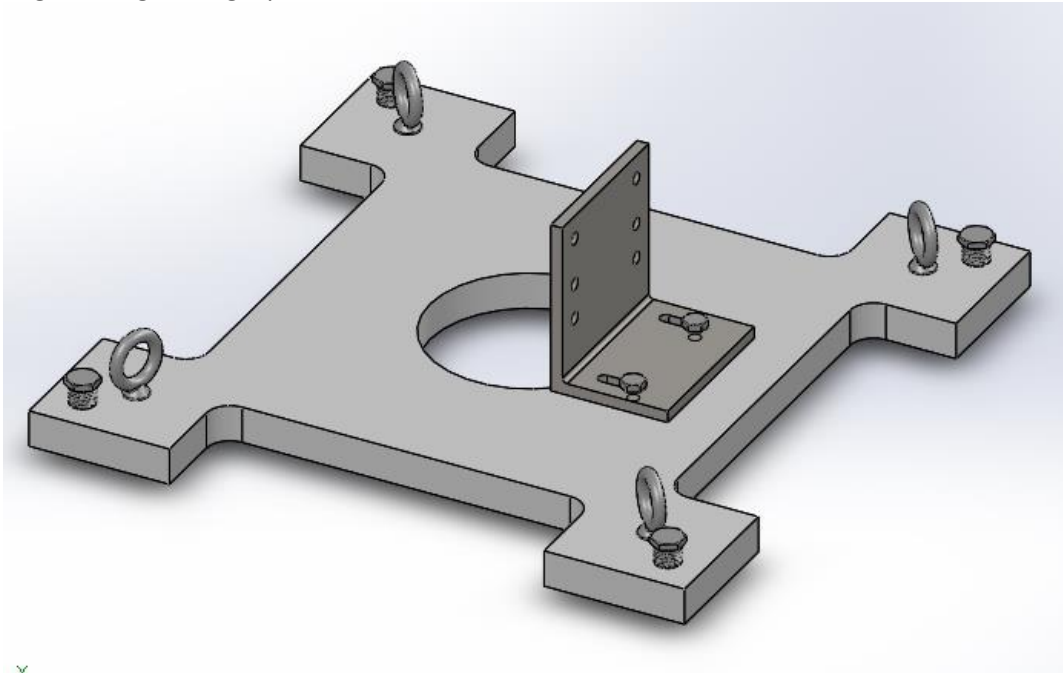


Figure 61 - Top Assembly

6. Attach camera mount with $\frac{1}{4}$ "-20 screws and nuts to 90 degree angle plate.

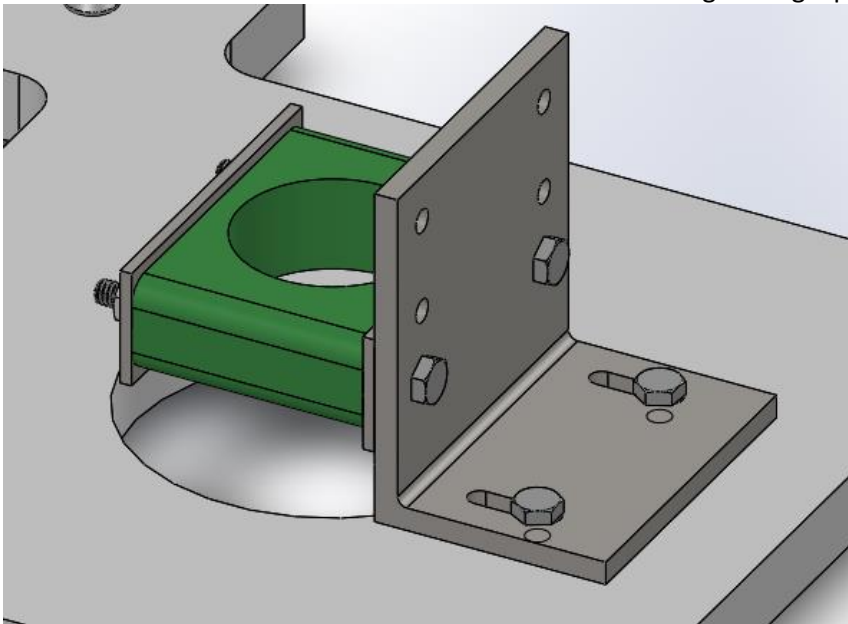


Figure 62 - Top Assembly

7. Screw in SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/4 in. Male NPT from camera cage middle components to the underside of the delrin plate.

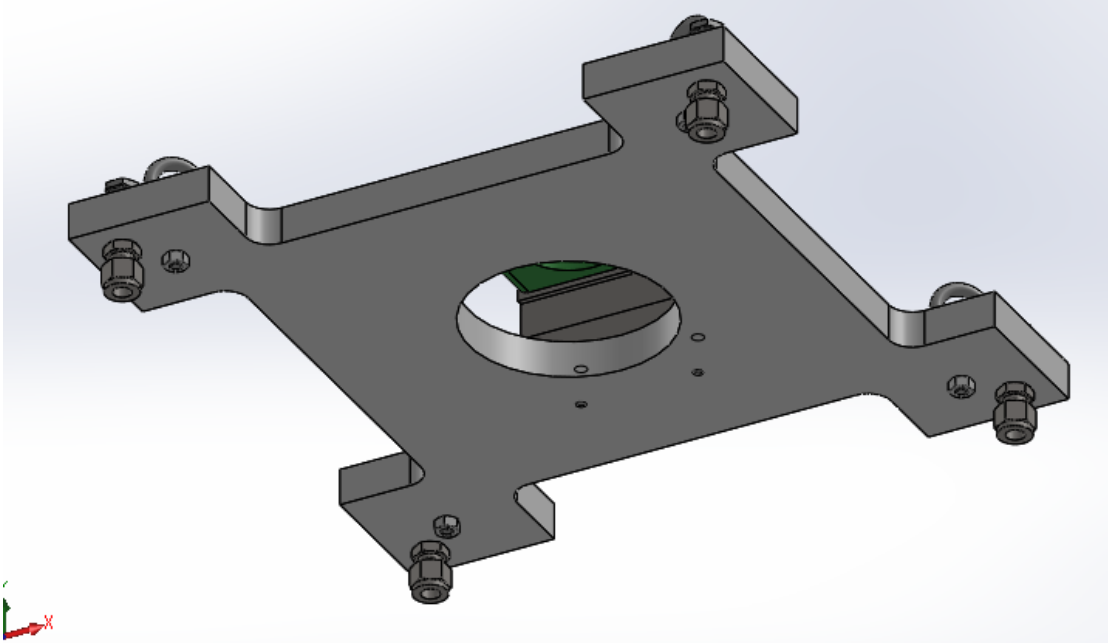


Figure 63 - Top Assembly

8. Attach Metal Handle (Part 19, stainless steel bracket) to the Delrin plate using two screws (part 15, 1/4"-20).

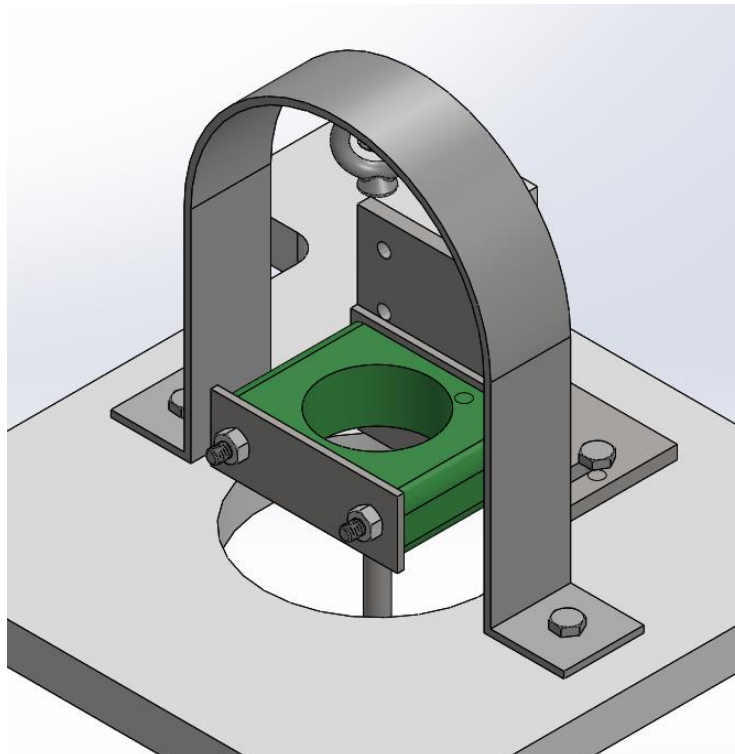


Figure 64 - Top of Delrin plate with metal handle attached

Combine middle and top

Gather Components

Camera Cage Middle Components

| | | | | | |
|---|---|--|----------------|----------|-------------------------------|
| <p>SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/8 in. Male NPT</p> |  <p>Figure 65 - Swagelok</p> | <p>Swagelok Part Number: SS-600-1-2</p> | <p>\$8.80</p> | <p>4</p> | <p>4</p> |
| <p>Type 304 Smooth-Bore Seamless SS Tubing 3/8" OD, .277" ID, .049" Wall, 6' Length</p> |  <p>Figure 66 - McMaster Carr</p> | <p>McMaster Carr Reference number: 89895K738</p> | <p>\$31.65</p> | <p>2</p> | <p>4 rods of length 11.4"</p> |
| <p>SS Swagelok Tube Fitting, Male Connector, 3/8 in. Tube OD x 1/4 in. Male NPT</p> |  <p>Figure 67 - Swagelok</p> | <p>Swagelok Part Number: SS-600-1-4</p> | <p>\$9.90</p> | <p>4</p> | <p>4</p> |

Assembling Top and Bottom

1. Fully insert type 304 3/8" tubing into bottom sub assembly male connector 3/8" tube to 1/8" Male NPT and hand tighten connection. Do this for all 4 male connectors.

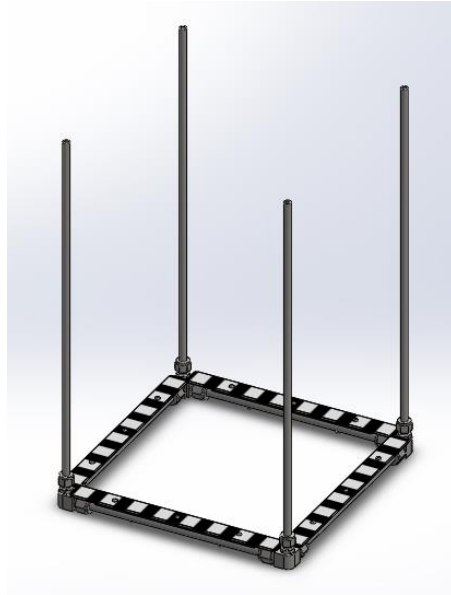


Figure 68 - Bottom Assembly

2. Fully insert top connections to tops of 3/8" stainless steel tubing.

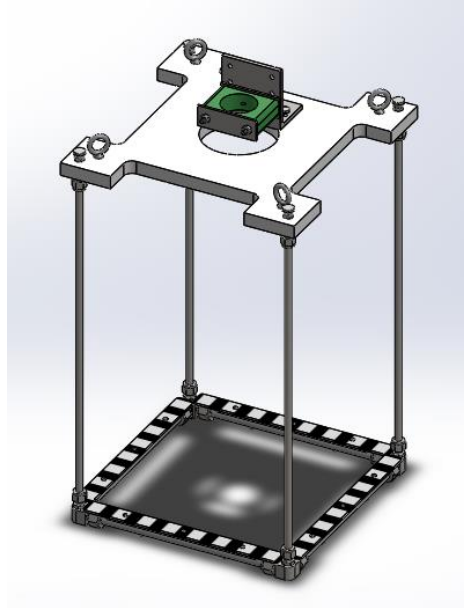


Figure 70 - Cage Fully Assembled in Solidworks



Figure 69- Cage Fully Assembled

3. Make sure all 8 3/8" male connectors are hand tightened and then tighten with a wrench for 1 and a quarter turns.

Cage Carrying Assembly

Gather Materials

| Cage Carrying Components | | | | | | |
|--------------------------|--|----------------------------------|---|---------|---|---|
| 19 | Type 316 SS High-Strength Anchor Shackle with Screw Pin, 7/16" Diameter, 2000# Work Load Limit | <p>Figure 71 - McMaster Carr</p> | McMaster Carr Reference number: 3583T83 | \$19.21 | 5 | 5 |
| 20 | Stainless Steel Load-Rated Wire Rope Lanyard Coated, Loop/Loop, 1/8" Rope Diameter, 1' Length | <p>Figure 72 - McMaster Carr</p> | McMaster Carr Reference number: 30745T436 | \$21.78 | 4 | 4 |
| 21 | Stainless Steel Load-Rated Wire Rope Lanyard Coated, Loop/Loop, 1/8" Rope Diameter, 3' Length | <p>Figure 73 - McMaster Carr</p> | McMaster Carr Reference number: 30745T436 | \$29.72 | 1 | 1 |
| 22 | Double Loop Cable-Support Grip Corrosion Resistant, Midcable, 0.5"-0.61" Cable Dia | <p>Figure 74 - McMaster Carr</p> | McMaster Carr Reference Number: 70095K71 | \$54.51 | 1 | 1 |

Assembly

1. Attach a shackle and a metal lanyard to each eyebolt. And make sure the shackle is moused with a mousing wire or nylon ziptie. In this case there will be a lot of movement so it is beneficial to use a metal wire. (Mousing is tying a wire around the shackle and through the eye of the threaded pin, so that the pin will not come unscrewed during motion.)



Figure 75 - Example of shackle and metal lanyard attached to eyebolt

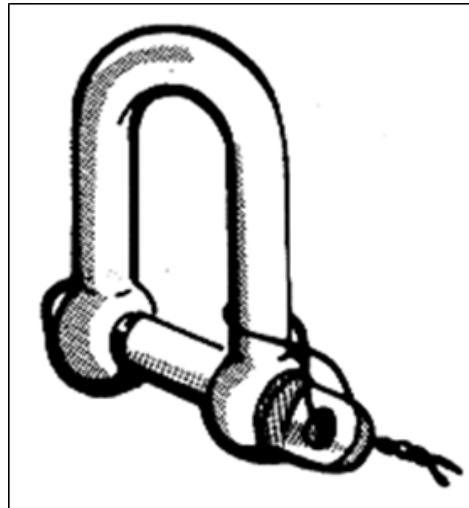


Figure 76 -Example of a moused shackle
(www.wikipedia.com)

2. Attach all metal lanyards together with another shackle and also attach a 3" metal lanyard to this connection as well.



Figure 77 - All metal lanyards and shackles are attached

3. Check that all shackles are “moused” (see step 1)
4. Attach the cable sock to the end of the central metal lanyard (longest metal lanyard).

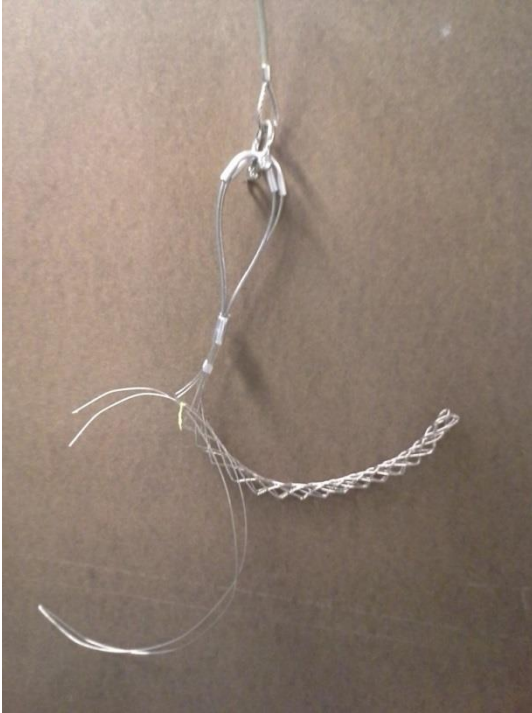


Figure 78 -mid cable grip attached to central metal lanyard to reduce tension of electrical cables

- a. In order to attach cable grip to the middle of the cable wire the cable is placed inside the cable grip where it will be attached.

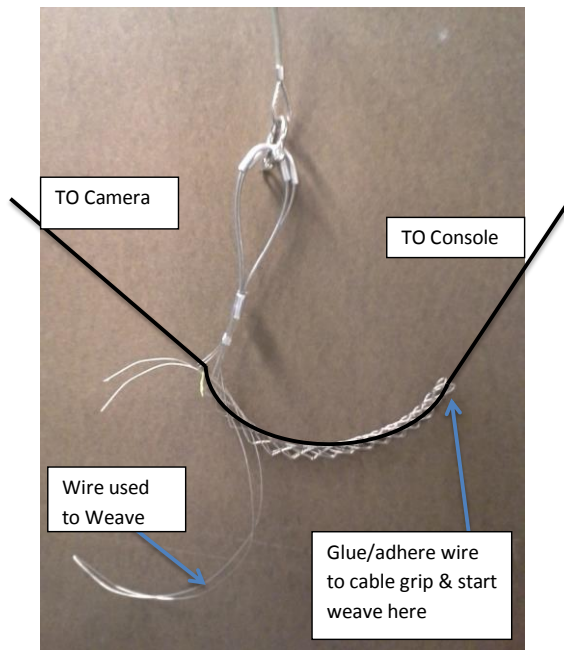


Figure 79 - mid-cable grip

- b. The cable is aligned so that the cable closest to the shackle goes to the camera. The cable leaving the other end of the cable grip goes to the computer connection (console). It is required to adhere the cable to the end of the cable grip. This can be done with marine glue, marine tape, or both.
- c. Once the cable is glued to the end of the cable grip then use the extra wire attached to weave starting at the spot glued through the entire grip like a shoe lace. At the end secure the ends of the wire weave.

Appendix

Swagelok Tube Fittings

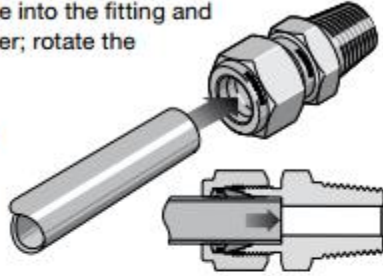
Up to 1 in./25 mm

These instructions apply both to traditional fittings and to fittings with the advanced back-ferrule geometry.

Fully insert the tube into the fitting and against the shoulder; rotate the nut finger-tight.

High-pressure applications and high safety-factor systems:

Further tighten the nut until the tube will not turn by hand or move axially in the fitting.



Mark the nut at the 6 o'clock position.

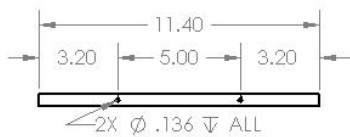
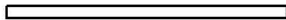


While holding the fitting body steady, tighten the nut one and one-quarter turns to the 9 o'clock position.

For 1/16, 1/8, and 3/16 in.; 2, 3, and 4 mm tube fittings, tighten the nut three-quarters turn to the 3 o'clock position.



Figure 80 - From www.swagelok.com. Swagelok Manual



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| | | ANGULAR: MAX CH ± BEND ± | MFG APPR. | | | |
| | | TWO PLACE DECIMAL ± | Q.A. | | | SIZE DWG. NO. REV |
| | | THREE PLACE DECIMAL ± | COMMENTS: | | | A 1_2 ss tube (# 1) |
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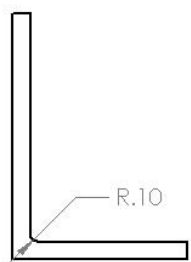
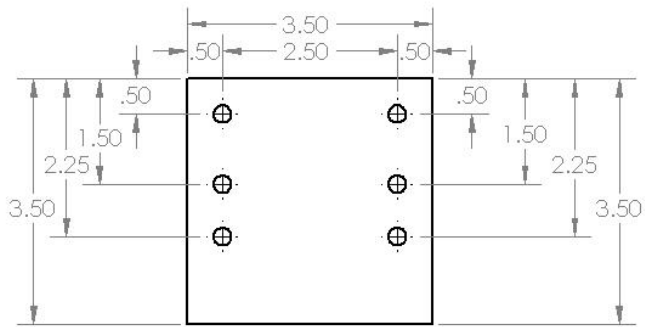
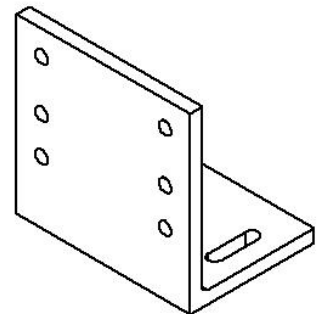
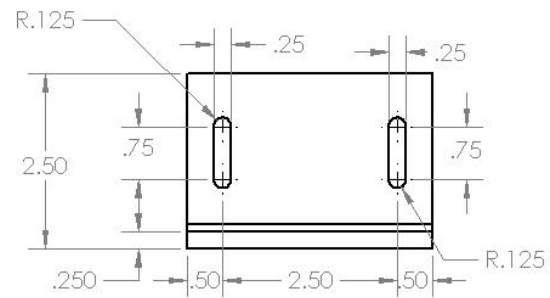
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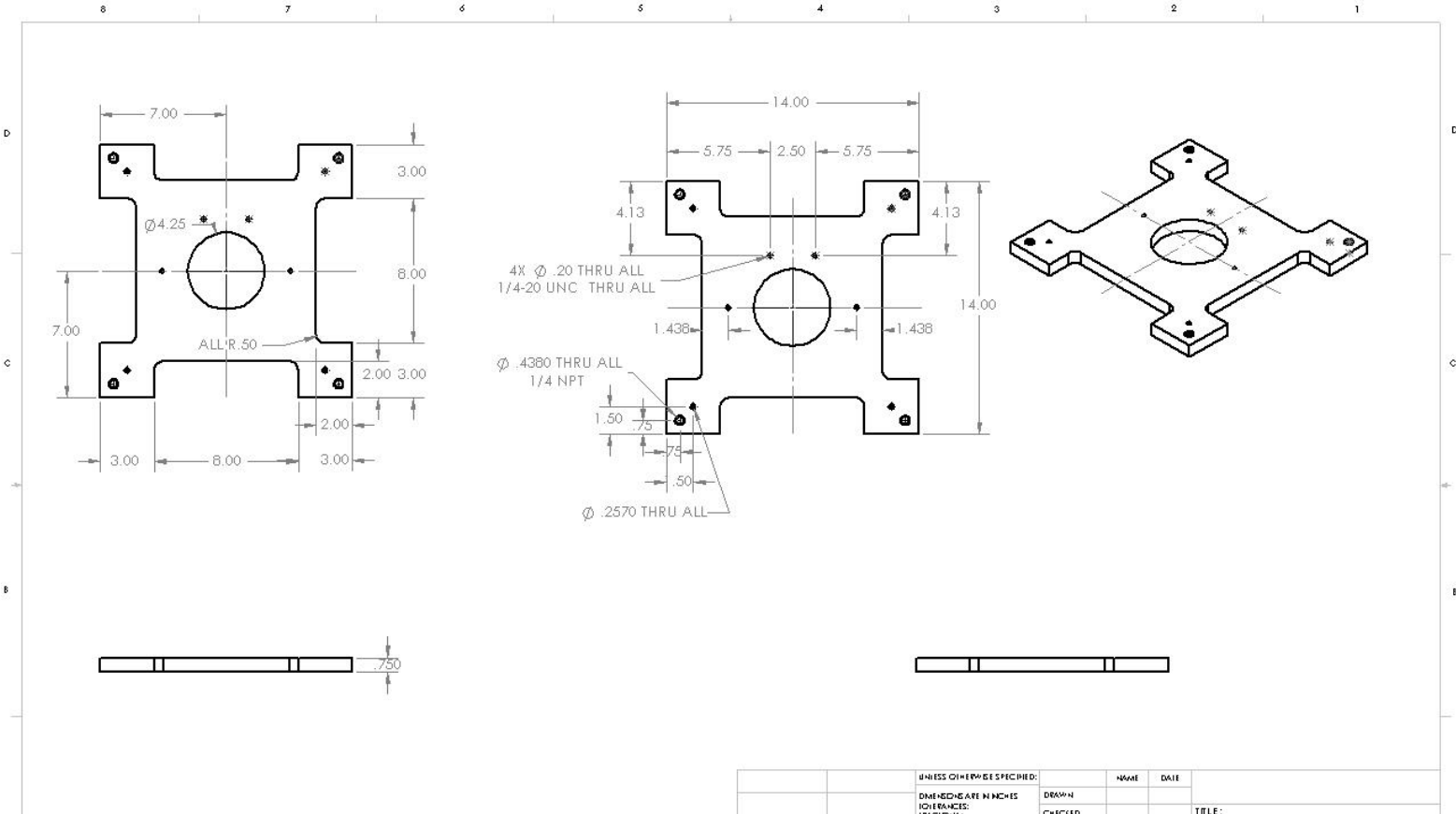
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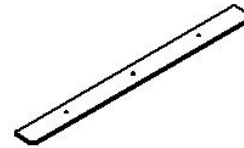
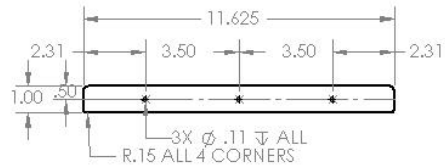
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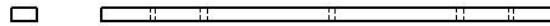
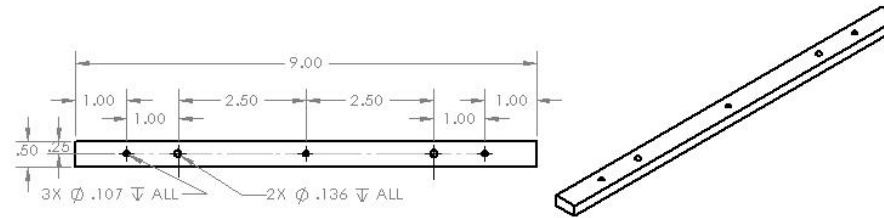
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