

Joe Johnson

Mechanical Design Tips for FRC Success & Reliability
8/3/2024

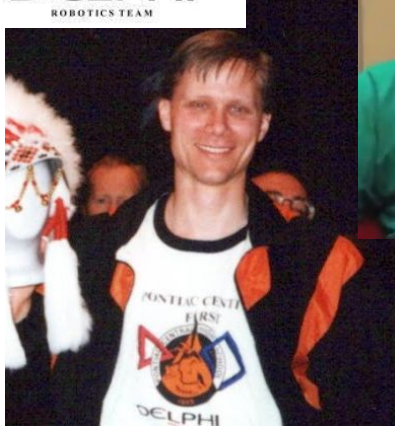


Who is this guy & why should I listen to him?





Dr. Joe Johnson, Ph.D., P.E



- #47 - cofounder/mentor 1995-2007
- #573 - parent/mentor 1997-98
- #2849 - mentor 2011
- #3958 - cofounder/mentor/parent 2012-2014
- BOOM DONE. - Ri3D 2014
- #248 - mentor 2015-2017
- #88 - mentor 2018-present



Who is this guy & why should I listen to him?

- IRVING LIIMATTA
 - Student on Chief Delphi 1st Year
- PAUL TERRASI
 - Student on Schrodinger's Cat 1st Year

Who is this guy & why should I listen to him?



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 - Student on Schrodinger's Cat 1st Year



WPI



[INSERT Standard Disclaimer Here]

- One Man's Opinion
- YMMV
- User Discretion is Advised
- Contact your doctor if you develop double vision, acid reflux, or projectile diarrhea

Standardize fasteners



Standardize fasteners - why?

- Simplifies build
- Simplifies maintenance
- Saves time during repairs
- Less stress during time outs
- Wins matches

Standardize fasteners - how?

1. **PLANNERS** gotta **PLAN**
2. **BUYERS** gotta **BUY**
3. **CADDERS** gotta **CAD**
4. **BUILDERS** gotta **BUILD**
5. **ORGANIZERS** gotta **ORG**

Standardize fasteners – how?

1. **PLANNERS** gotta **PLAN**
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3. CADDERS gotta CAD
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1. **PICK A THREAD (or maybe two)**
2. **CREATE A PECKING ORDER**
3. **LET EVERYONE KNOW ABOUT IT**

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- **#10 is a size natural choice**
 - **Lots of FIRST things use it**
 - **Goldie Locks Size (i.e. “just right”)**
- **Hex drive**
- **10-32 vs. 10-24 debate**
- **Button heads & Flat heads only**
 - **skip standard head**



Standardize fasteners – how?

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- **But #10 is too big! Now what?**
- **Pick a small standard thread as well**
- **4-40 works for me**
 - **Common Clamp collar screw**

Standardize fasteners – how?



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1. **STD > SMALL STD > OTHER**
2. **BUTTON HEAD > FLAT HEAD > OTHER**
3. **NYLOC > STAR NUT > STD NUT**
4. **STD WASHER > OTHER**

Standardize fasteners – how?

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**Document & Communicate
your pecking order!**

**If you keep it a secret, no
one will use it.**

Standardize fasteners – how?

1. PLANNERS gotta PLAN
2. **BUYERS gotta BUY**
3. CADDERS gotta CAD
4. BUILDERS gotta BUILD
5. ORGANIZERS gotta ORG

- **BUY TRAYS**
- **BUY SCREWS, NUTS, WASHERS, & SPACERS**
- **BUY TOOLS TOOLS TOOLS TOOLS TOOLS**
- **BUY SPARES (and keep them separate)**

Standardize fasteners – how?

Default behaviors

They are actions we make without thinking (habits, routines, compulsions). They control more than 40% of our daily actions.

So if we want to change our lives and be more productive, we need to first change our default behaviors.

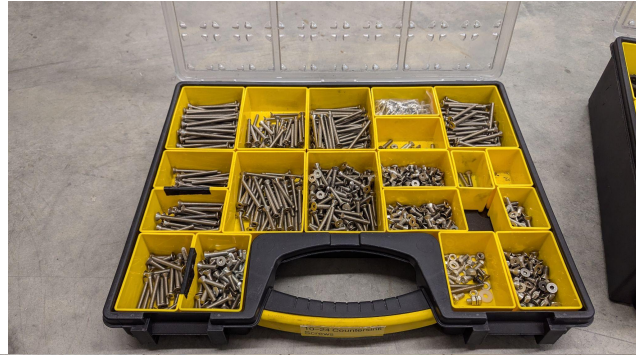
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Standardize fasteners – how?

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4. BUILDERS gotta BUILD
5. **ORGANIZERS** gotta **ORG**

- **USE THE TRAYS**
- **RESTOCK THE TRAYS (and Tools)**
- **HAVE A SECRET STASH (and KEEP IT USEFUL)**
- **PERIODICALLY REORGANIZE & SORT, SORT SORT**

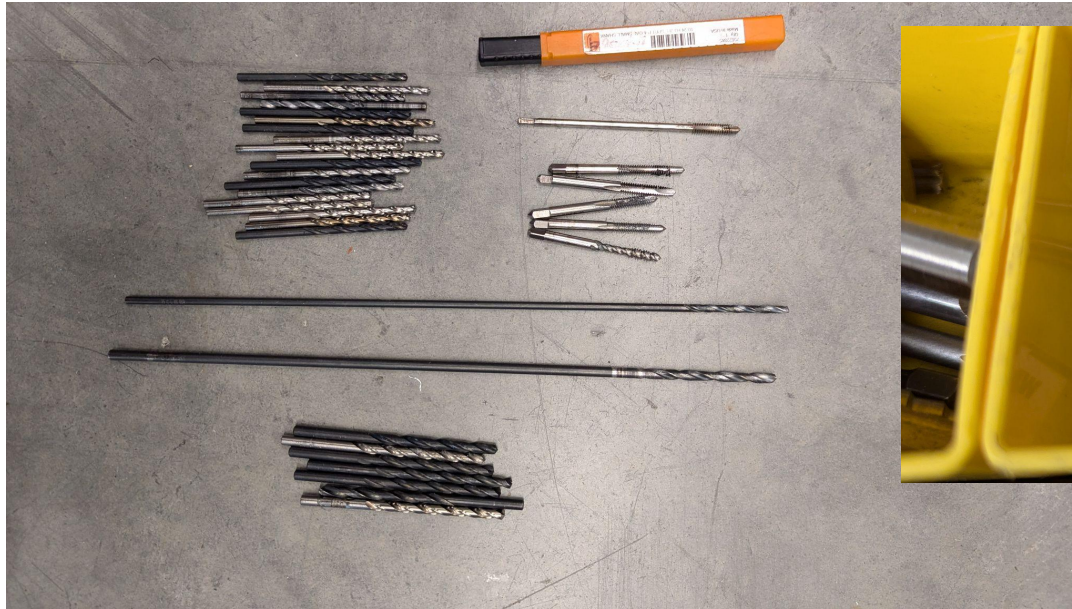
Standardize fasteners – how?



Standardize fasteners - how?



Standardize fasteners - how?



Standardize fasteners - how?



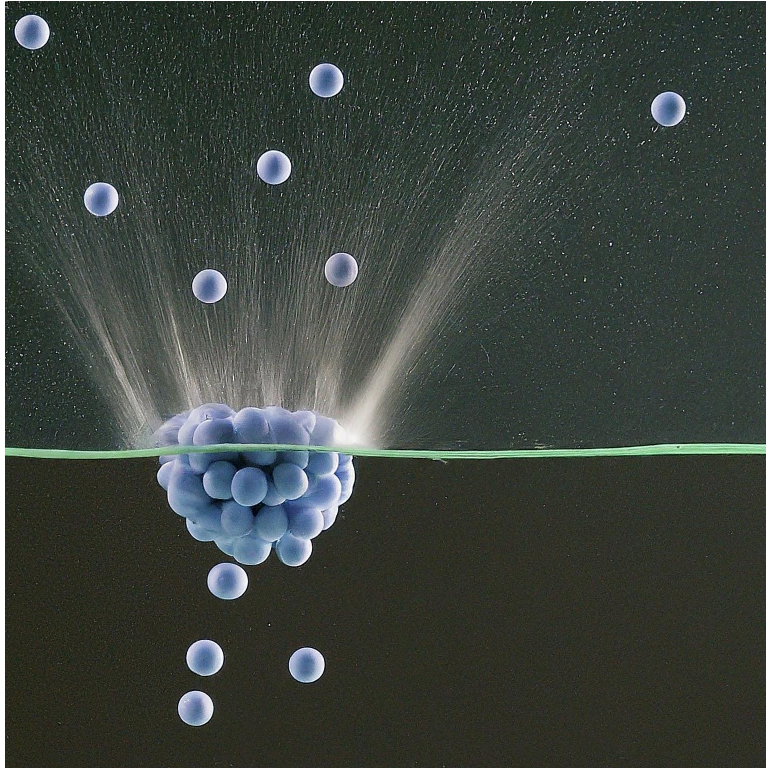
Standardize fasteners - how?



Standardize fasteners – how?



Standardize fasteners – how?



Ideal State: Reach
TOOL TORR PRESSURE
(for each critical tool
that your team needs to
support your standard
fasteners)

Standardize fasteners - how?

4-40 TORX PLUS

BROWSE CATALOG

McMASTER-CARR®

socket head cap screws

X | Q

Filter by [Clear all](#)

Drive Style [See all](#)

Torx Plus [?](#)

Tensile Strength [?](#)

150,000 psi or greater

Thread Direction

 Right Hand

Head Diameter



0.183"

DFARS Compliance [?](#)

Specialty Metals Compliant
(252.225-7009)

Hardness

Rockwell C39

REACH Compliance

REACH (EC 1907/2006)
(01/17/2023, 233 SVHC) Compliant

RoHS Compliance

5 Products

[▶ About Socket Head Screws](#)

[More](#)

Torx Alloy Steel Socket Head Screws



Fully Threaded



A Torx-Plus drive has more points of contact than a hex drive, allowing you to tighten these screws with less slippage or damage to the recess. With a tensile strength of 180,000 psi, these alloy steel screws are stronger than Grade 8 steel screws. Their black-oxide finish provides mild corrosion resistance in dry environments. They can be used with both Torx-Plus and standard Torx tools (see Torx bits and Torx keys and drivers). Screws meet ASTM A574 specifications and testing requirements for material quality. Length is measured from under the head.

Coarse threads are the industry standard; choose these screws if you don't know the threads per inch.

 For technical drawings and 3-D models, click on a part number.

Lg.	Threading	Thread Spacing	Head		Drive Size	Tensile Strength, psi	Specifications Met	Pkg. Qty.	Pkg.	
			Dia.	Ht.						
Black-Oxide Alloy Steel										
4-40										
1/4"	Fully Threaded	Coarse	0.183"	0.112"	IP10	180,000	ASTM A574	100	92610A108	\$9.93
3/8"	Fully Threaded	Coarse	0.183"	0.112"	IP10	180,000	ASTM A574	100	92610A106	11.05
1/2"	Fully Threaded	Coarse	0.183"	0.112"	IP10	180,000	ASTM A574	100	92610A110	11.21
5/8"	Fully Threaded	Coarse	0.183"	0.112"	IP10	180,000	ASTM A574	50	92610A112	11.74
3/4"	Fully Threaded	Coarse	0.183"	0.112"	IP10	180,000	ASTM A574	50	92610A114	11.13



Standardize fasteners – how?

REPLACE EVERY 4-40 $\frac{3}{8}$ "
WITH TORX PLUS



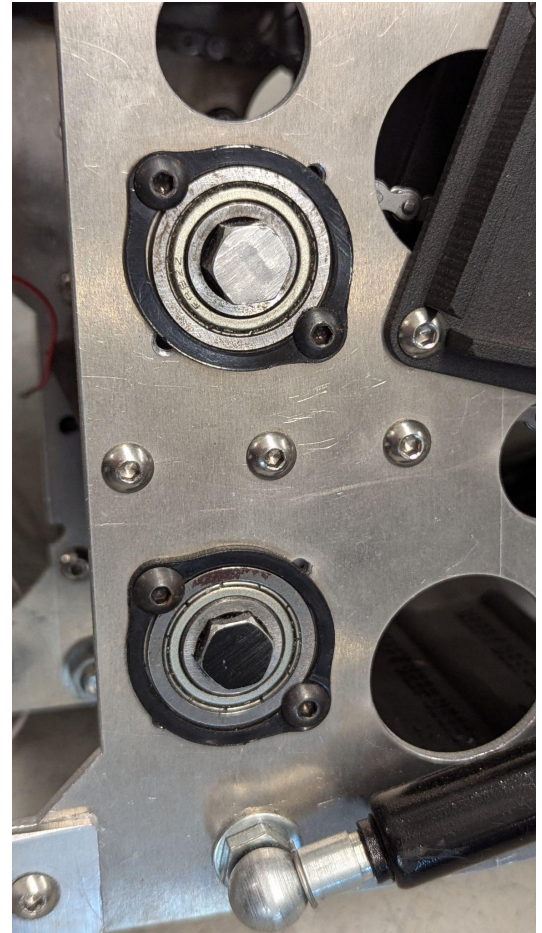
Standardize fasteners - final thoughts

- **Alloy Steel 170,000psi > Stainless 70,000psi**
- **Don't sleep on nylon spacers (so nice)**
- **10,000 washer types & styles. Pick 2 or 3 always buy those.**
- **Reuse (just sort them well and toss the baddies)**

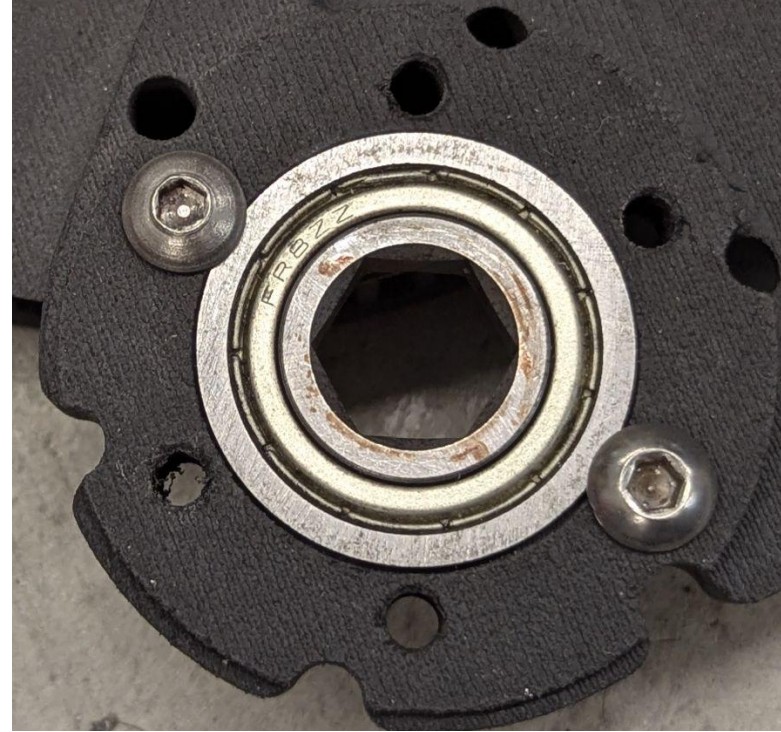
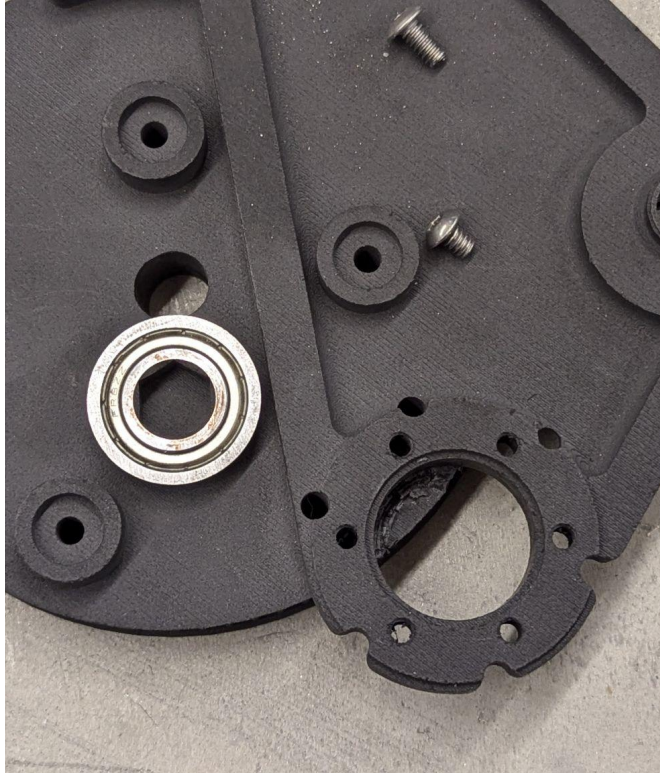
HOLD YOUR BEARINGS IN PLACE

1. PRESS FITS ARE AWESOME...
except when they're not
2. LENGTH OF THE SHAFT
STRATEGIES CAN WORK
WELL... but they can also fail in
spectacularly
3. TWO SCREWS CAN SAVE YOU

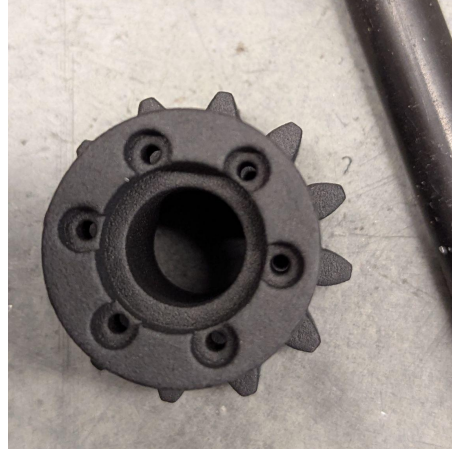
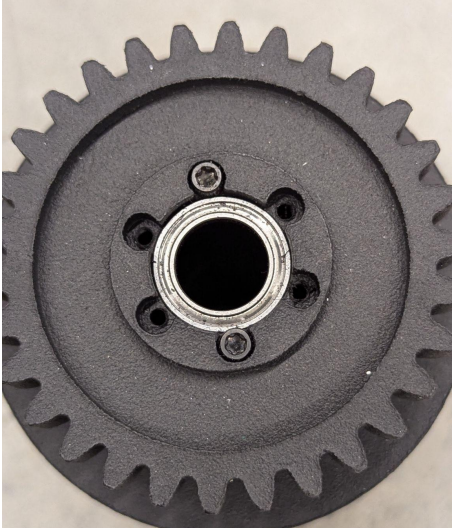
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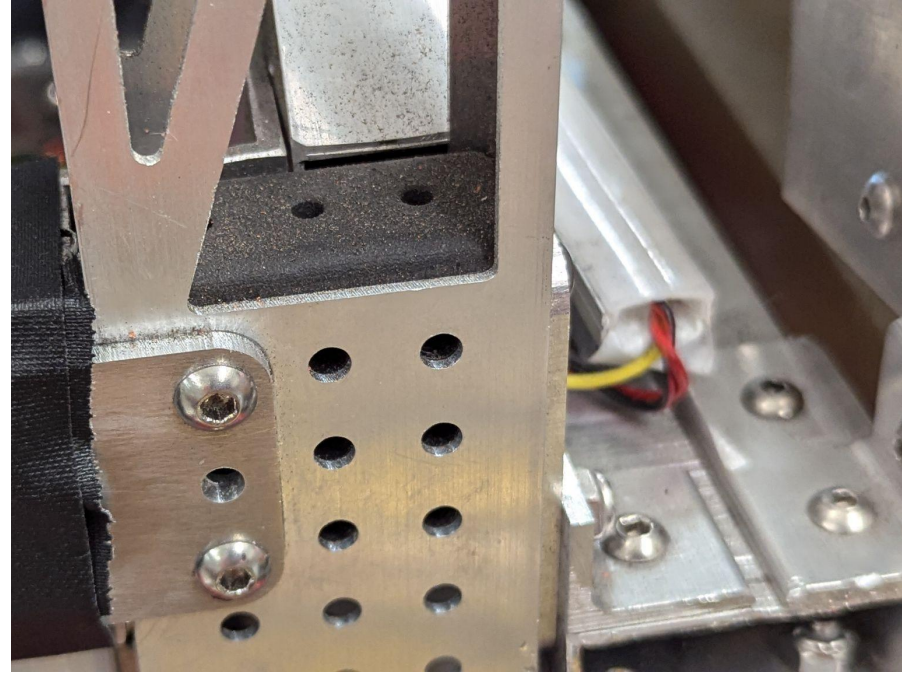


HOLD YOUR BEARINGS IN PLACE



Don't Crush your Thin walled hollow tubes

It's 2024, PEOPLE!!! 3D print plugs to fill that inner space



Fast Eddy Bearings FTW



Search by Size or R/C model...

CATEGORIES



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RC Engine Bearing Kits

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Thrust Bearings

Screws & Accessories

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INVENTORY IS IN STOCK AND WI



WEIGHT? Who doesn't wish they could save weight

1/2"X1/2"X1/16" wall Square Polycarb Tube plus VHB is Super Light, Super Easy and Super Useful

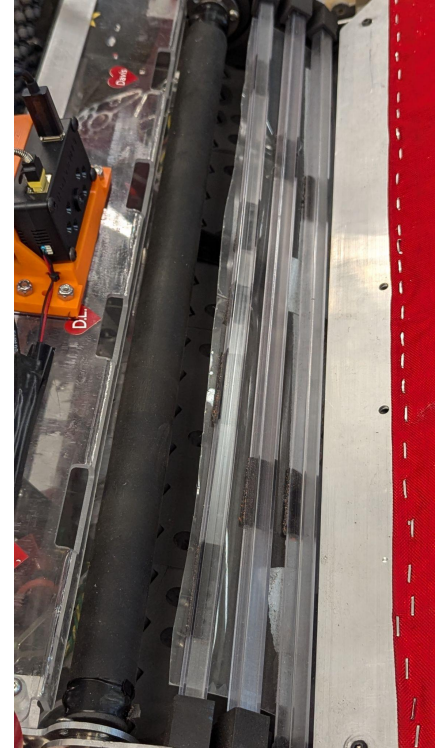
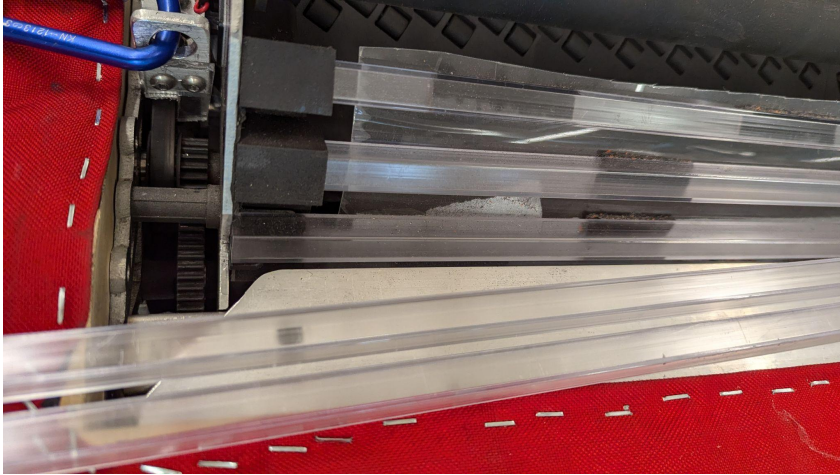
Takes a hit and bends back into place

Build structures easily using thin PC sheets and VHB

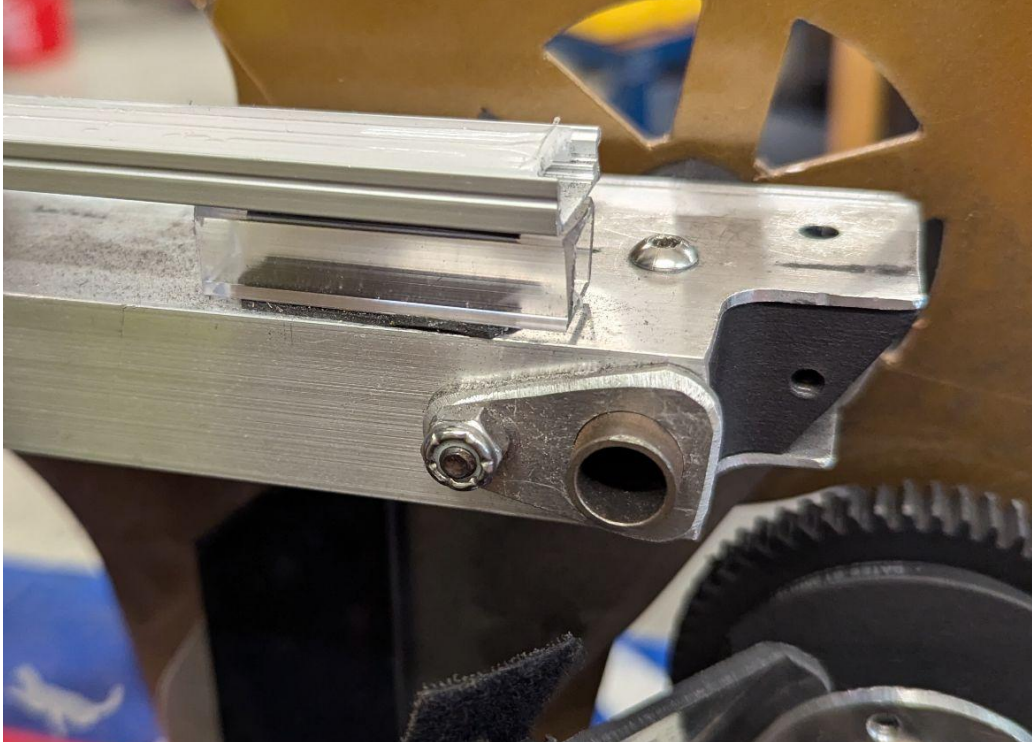
Useful for last minute hacks too



WEIGHT? Who doesn't wish they could save weight



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WEIGHT? Who doesn't wish they could save weight

1/2" Thunder Hex - The Hollowing!

11/32" Jobber Drill + a Lathe

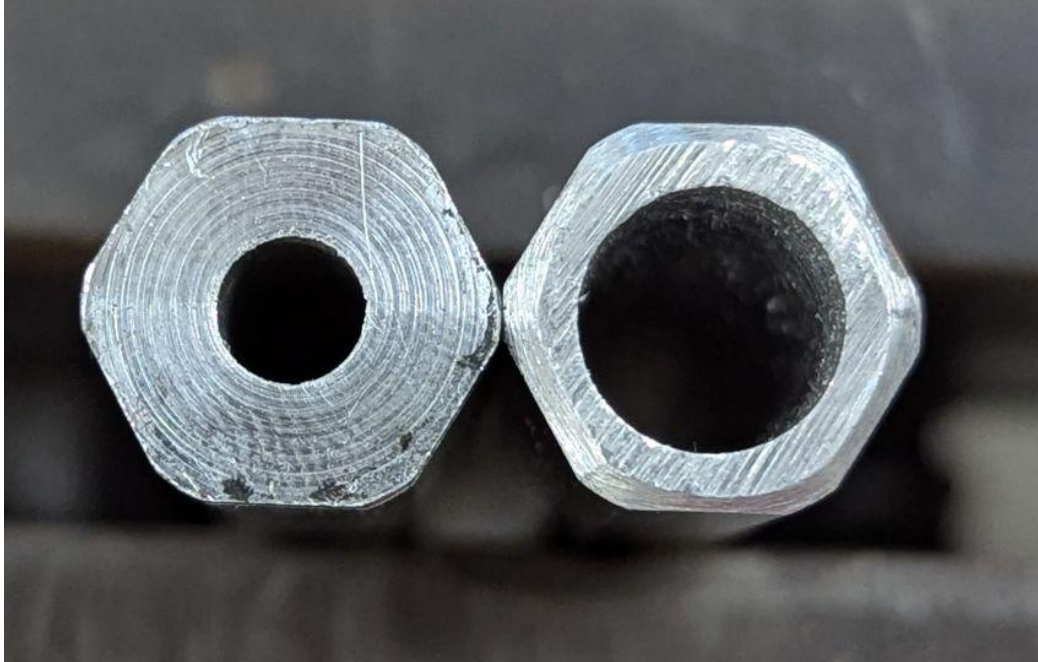
Twisting stiffness comparison As Sold: As Hollowed:

Twisting yield comparison As Sold: As Hollowed:

0.1lbs for a 26" shaft - not a LOT but not nothing either



WEIGHT? Who doesn't wish they could save weight



WEIGHT? Who doesn't wish they could save weight

1/2" 4130 Steel tube with 0.049" wall

Bending stiffness comparison Solid: Hollow: Solid AL

Bending yield comparison Solid: Hollow: Solid AL

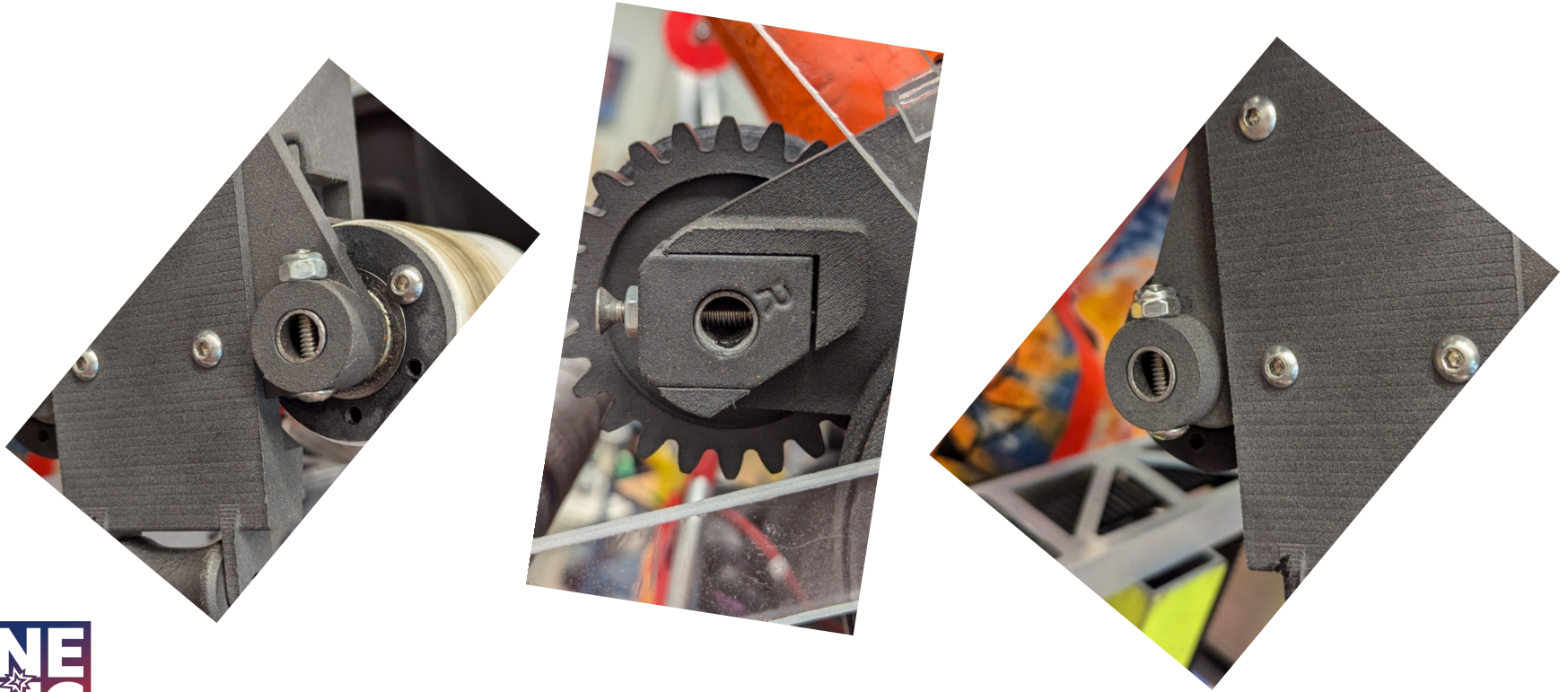
Weight comparison (1" shaft): 0.12lbs 0.04lbs 0.04lbs

Same as AL but X time stiffer!

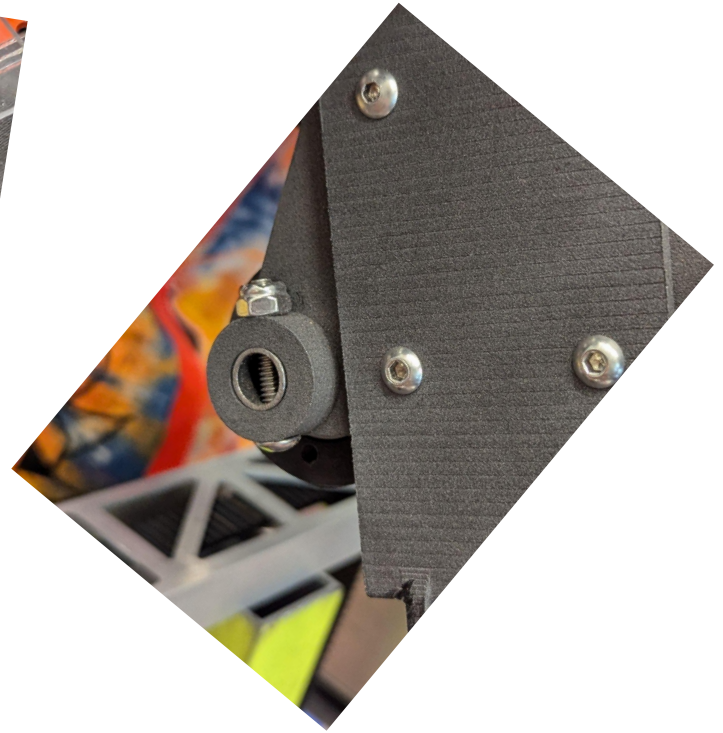
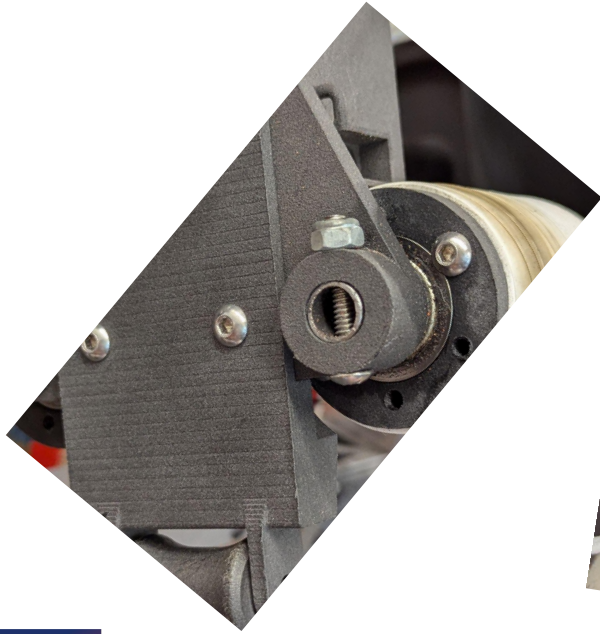
WARNING: as purchased it's always a few thousandths over (lathe or sand paper)



WEIGHT? Who doesn't wish they could save weight



Long Live Dead Axles – but make sure they stay dead



WEIGHT? Who doesn't wish they could save weight

		32	0.337	11/32	0.344	T	0.338
		14	0.350	U	0.368	25/64	0.391
7/16	0.438	20	0.376	25/64	0.391	13/32	0.406
		28	0.394	Y	0.404	Z	0.413



AL Tube is an awesome thrust limiter




AL Tube is an awesome thrust limiter

General Purpose Aluminum Tubing



- Temperature Range: -450° to 400° F
- Bending Method: Tube Bender
- Compatible Tube Fittings: Flared

This tubing is lightweight with good corrosion resistance and weldability. It has magnesium and silicon added for strength. Tubing is seamless, which provides a smooth interior for unrestricted flow. It can be flared without splitting.

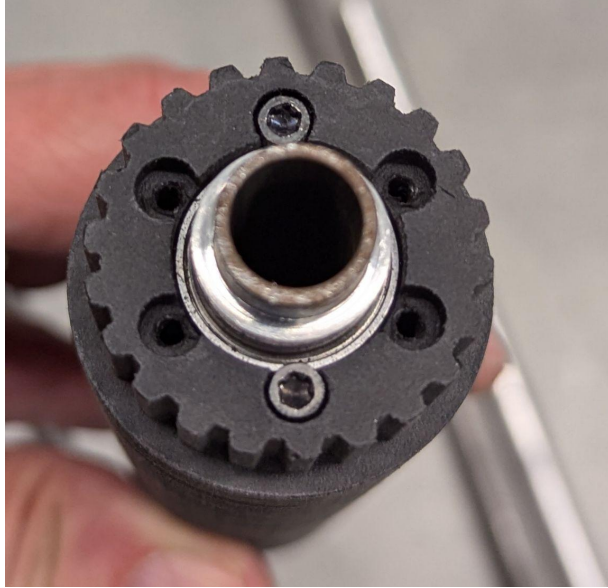
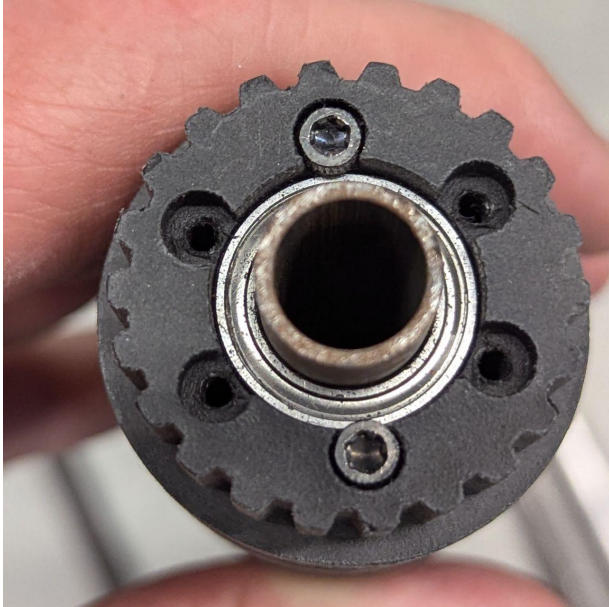
 For technical drawings and 3-D models, click on a part number.

Inch

OD	Wall Thick.	ID	Max. Pressure	Temper	Temper Rating		1 ft.	3 ft.	6 ft.
For Use With Air, Diesel Fuel, Fuel Oil, Gasoline, Hydraulic Fluid, Water									
5/8"	0.028"	0.569"	780 psi @ 72° F	T6	Hard	9390N14	\$7.97	\$21.69	\$34.98
5/8"	0.035"	0.555"	1,000 psi @ 72° F	T6	Hard	89965K27	10.95	15.07	24.31
5/8"	0.049"	0.527"	1,400 psi @ 72° F	T6	Hard	89965K14	11.89	18.29	29.50
5/8"	0.058"	0.509"	1,600 psi @ 72° F	T6	Hard	9390N15	9.74	26.51	42.76
5/8"	0.065"	0.495"	1,900 psi @ 72° F	T6	Hard	89965K571	13.05	20.57	33.17
5/8"	1/8"	3/8"	3,500 psi @ 72° F	T6	Hard	9390N16	14.64	39.84	64.25



AL Tube is an awesome thrust limiter



Vernier Eccentric Adjuster

Tight belts (and chain) are happy belts (and chains). Often that something people accomplish with cams and tightening things. I hate things that can slip and cause issues.

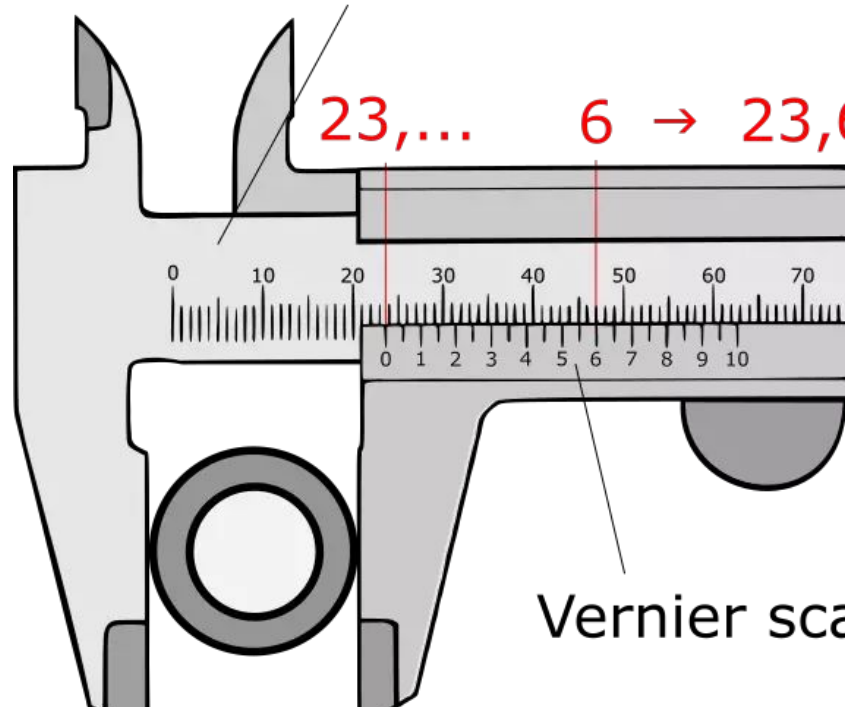
You might think 10 increments per 360 deg (36 deg per increment)

But we have 12 holes on the eccentric and 10 on the PC plate a different set up holes line up assuming 2 screws required we can have 36 degrees on the PC plate and 30 deg on the eccentric so different holes line up every 6 deg or 60 increments per 360 degrees!

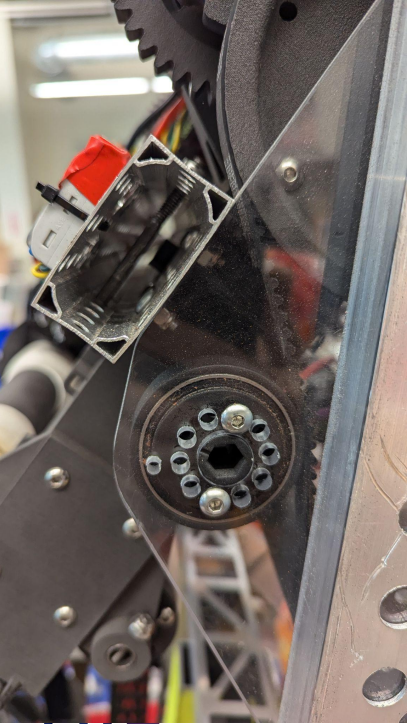


Vernier Eccentric Adjuster

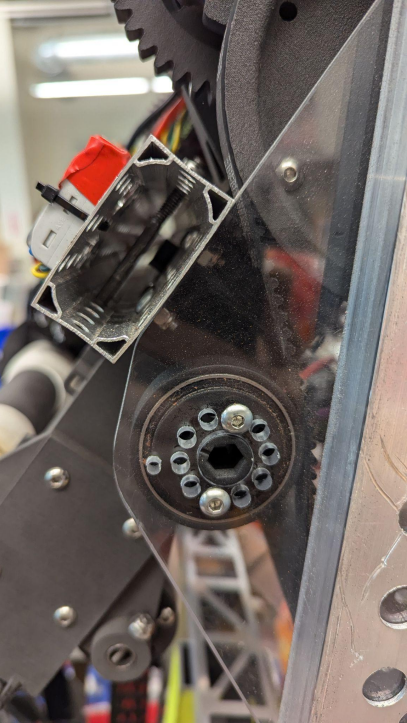
Main scale



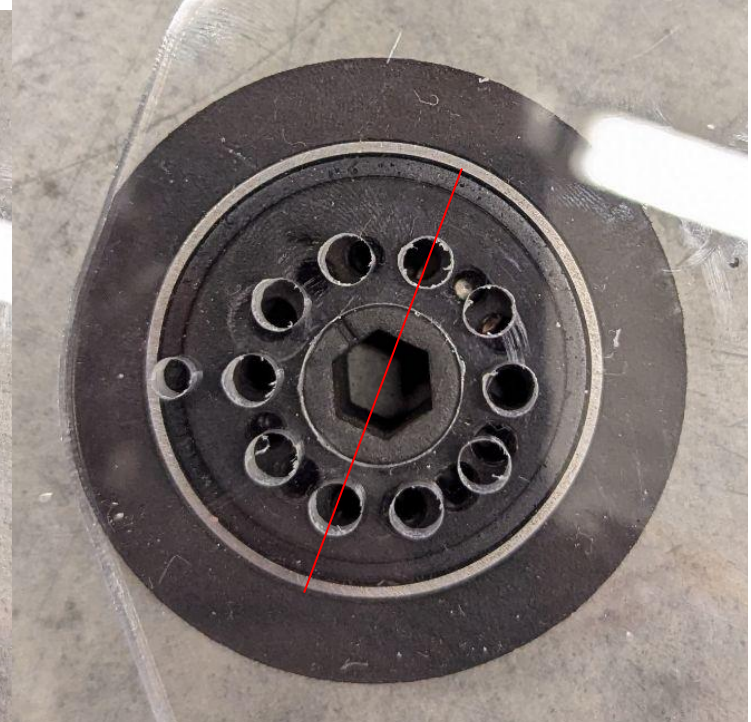
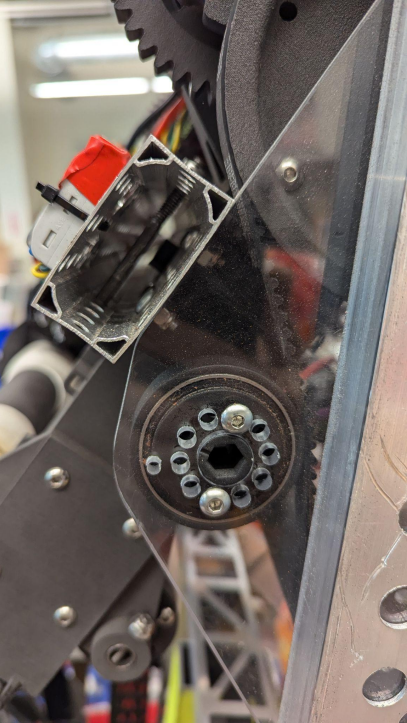
Vernier Eccentric Adjuster



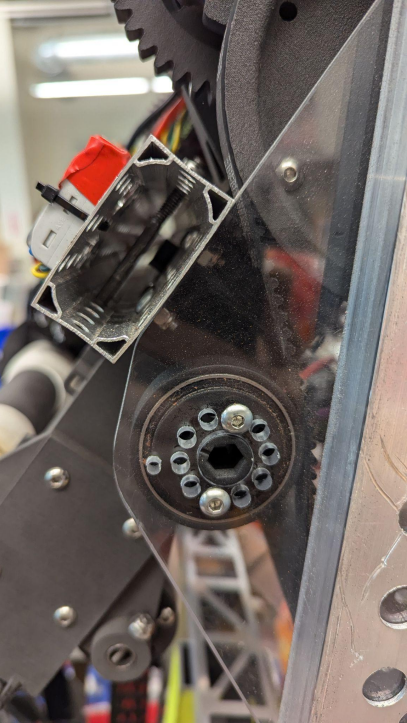
Vernier Eccentric Adjuster



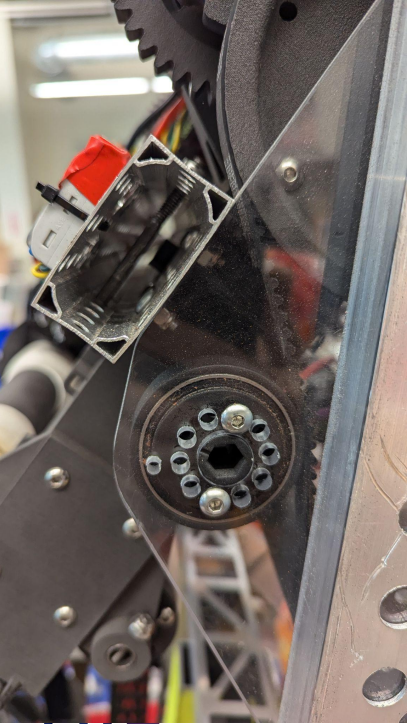
Vernier Eccentric Adjuster



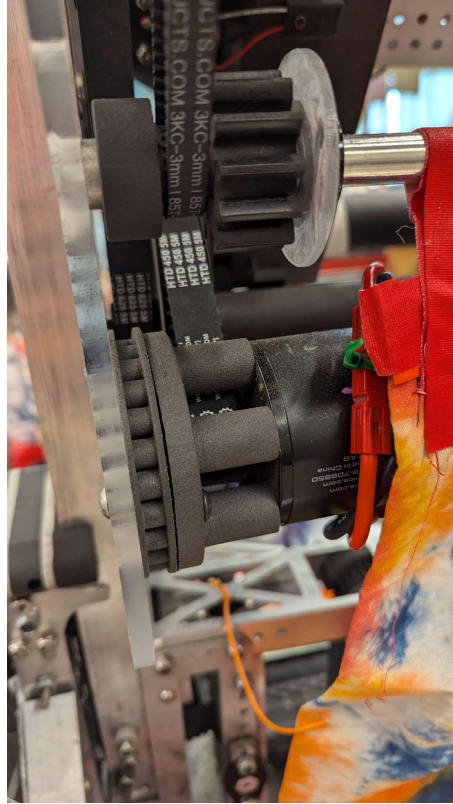
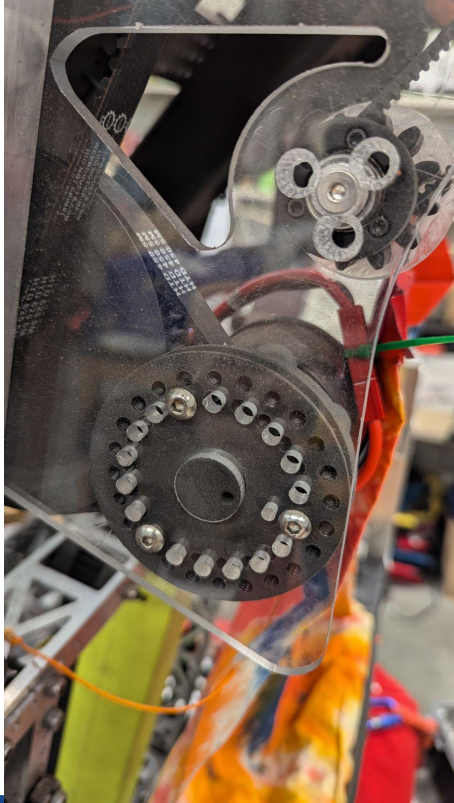
Vernier Eccentric Adjuster



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Vernier Eccentric Adjuster



General Fighting Last War...



General Fighting Last War...

1. **BE LESS STUPID**
2. **BUMPER RULES ARE COMPLICATED
BUT PROVIDE OPTIONS**
3. **NOT ALL STEELS ARE THE SAME**
4. **ALUMINUMS? ALSO DIFFERENT**
5. **WOOD? ALSO DIFFERENT**

General Fighting Last War...

BE LESS STUPID

Don't put a lot of holes and cuts in your main beam (like we did)

If you must have holes, make them small and get them as close to the neutral axis as possible



General Fighting Last War...

**BUMPER RULES ARE COMPLICATED
BUT PROVIDE OPTIONS**



General Fighting Last War...

- **NOT ALL STEELS ARE THE SAME**
- **ALUMINUMS? ALSO DIFFERENT**
- **WOOD? ALSO DIFFERENT**

316 SS 1X1X0.065” wall (90kpsi yield)

7075 AL (70kpsi yield)

SOLID BOARD (e.g. MAPLE)

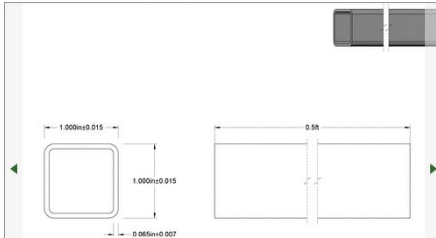
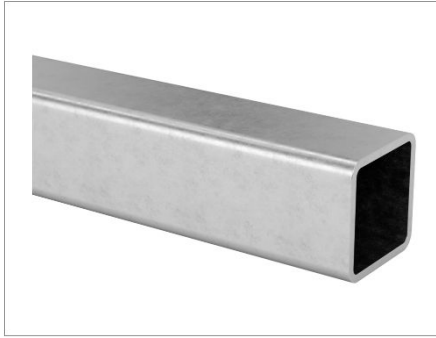
General Fighting Last War...

BROWSE CATALOG

McMASTER-CARR.

7075 angle

Corrosion-Resistant 316/316L Stainless Steel Rectangular Tube 0.065" Wall Thickness, 1" x 1" Outside



Length, ft. Each
1/2
1
3
6

ADD TO ORDER

2937K11

CAD Select a CAD file type Download

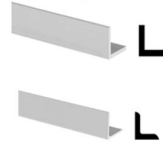
Learn more about our Solidworks Add-In

Material	316/316L Stainless Steel
Shape	Rectangular Tube
Shape Type	Rectangular Tubes
Wall Thickness	0.065"
Wall Thickness Tolerance	-0.007" to 0.007"
Tolerance Rating	Standard
Outside	
Height	1"
Height Tolerance	-0.015" to 0.015"
Width	1"
Width Tolerance	-0.015" to 0.015"
Inside	
Height	0.87"
Width	0.87"
Yield Strength	Not Rated
Fabrication	Welded
Heat Treatment	Annealed (Softened)
Hardness	Rockwell B90
Hardness Rating	Medium
Heat Treatable	No
Certificate	Material Certificate with Traceable Lot Number



General Fighting Last War...

High-Strength 7075 Aluminum 90° Angles



- Yield Strength: 70,000 psi
- Hardness: Brinell 150 (Medium)
- Temper: T6511
- Fabrication: Extruded
- Specifications Met: ASTM B221, SAE AMS-QQ-A-200/11

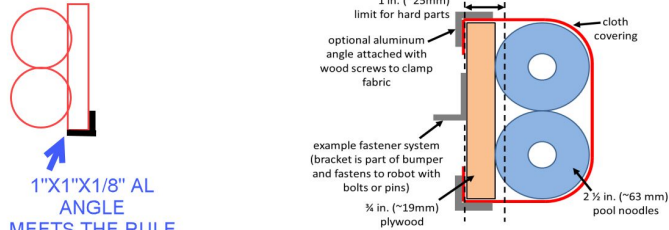
Originally developed for aircraft frames, uses for 7075 aluminum now include a wide range of high-stress parts. It is often used as a replacement for 2024 aluminum because it's stronger and provides similar performance in all other aspects.

• **CAD** For technical drawings and 3-D models, click on a part number.

• Certificates with a traceable lot number are available for these products. Download certificates from **ORDER HISTORY** after your order ships.

Outside				Inside		Heat Treatment	Temperature Range, °F	Straightness Tolerance	1 ft. Lg.	3 ft. Lg.	6 ft. Lg.	
Ht.	Ht. Tolerance	Wd.	Wd. Tolerance	Ht.	Wd.							
1 1/8" Wall Thick (-0.005" to 0.005" Tolerance)												
1/2"	-0.010" to 0.010"	1/2"	-0.010" to 0.010"	7/16"	7/16"	Hardened	-320° to 210°	0.050" per ft.	9178T11	\$14.70	\$36.76	\$81.27
3/4"	-0.010" to 0.010"	3/4"	-0.010" to 0.010"	11/16"	11/16"	Hardened	-320° to 210°	0.050" per ft.	9178T12	15.10	37.76	62.93
7/8"	-0.010" to 0.010"	7/8"	-0.010" to 0.010"	13/16"	13/16"	Hardened	-320° to 210°	0.050" per ft.	9178T13	20.50	51.25	85.41
1"	-0.024" to 0.024"	1"	-0.024" to 0.024"	15/16"	15/16"	Hardened	-320° to 210°	0.050" per ft.	9178T14	20.50	51.25	85.42
1 1/2"	-0.024" to 0.024"	1 1/2"	-0.024" to 0.024"	1 7/16"	1 7/16"	Hardened	-320° to 210°	0.050" per ft.	9178T15	35.39	88.47	147.45
1 1/8" Wall Thick (-0.007" to 0.007" Tolerance)												
7/8"	-0.010" to 0.010"	7/8"	-0.010" to 0.010"	3/4"	3/4"	Hardened	-320° to 210°	0.050" per ft.	9178T16	21.38	53.30	88.99
1"	-0.024" to 0.024"	1"	-0.024" to 0.024"	7/8"	7/8"	Hardened	-320° to 210°	0.050" per ft.	9178T17	21.96	54.89	91.49
1 1/4"	-0.024" to 0.024"	1 1/4"	-0.024" to 0.024"	1 1/8"	1 1/8"	Hardened	-320° to 210°	0.050" per ft.	9178T18	28.30	70.74	117.90
1 1/2"	-0.024" to 0.024"	1 1/2"	-0.024" to 0.024"	1 3/8"	1 3/8"	Hardened	-320° to 210°	0.050" per ft.	9178T19	32.90	82.25	137.09
2"	-0.024" to 0.024"	2"	-0.024" to 0.024"	1 7/8"	1 7/8"	Hardened	-320° to 210°	0.050" per ft.	9178T21	39.91	99.77	166.29
2 1/2"	-0.024" to 0.024"	2 1/2"	-0.024" to 0.024"	2 3/8"	2 3/8"	Hardened	-320° to 210°	0.050" per ft.	9178T23	49.11	122.78	204.64

Figure 8-6 BUMPER vertical cross section



General Fighting Last War...

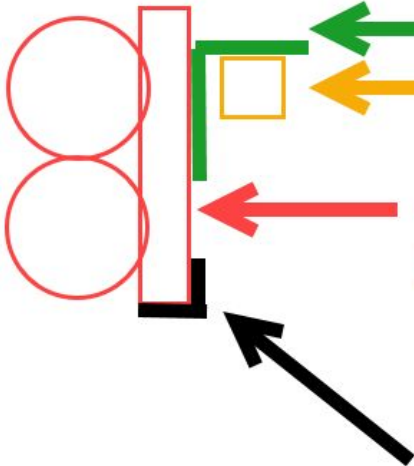
2X2X1/8 AL 1750lbs yield for 1.2lbs BUMPER WEIGHT

Put screws up high near horz leg so that we can shorten vert leg if we are over weight

1X1X0.065 STEEL 1000lbs yield for 2.0lbs ROBOT WEIGHT

4.5X3.5 MAPLE 270lbs yield for +0.7lbs BUMPER WEIGHT (FRONT ONLY)

1X1X1/8 AL 340lbs yield for 0.7lbs BUMPER WEIGHT



That's all Folks!

