Canoe Trailer Team

Pittsburg State University

Lewis Moore, Blake Hettinger, Lucas Wilson, Derek Hansen, Derek Robertson, Yunze Xie

Project Purpose

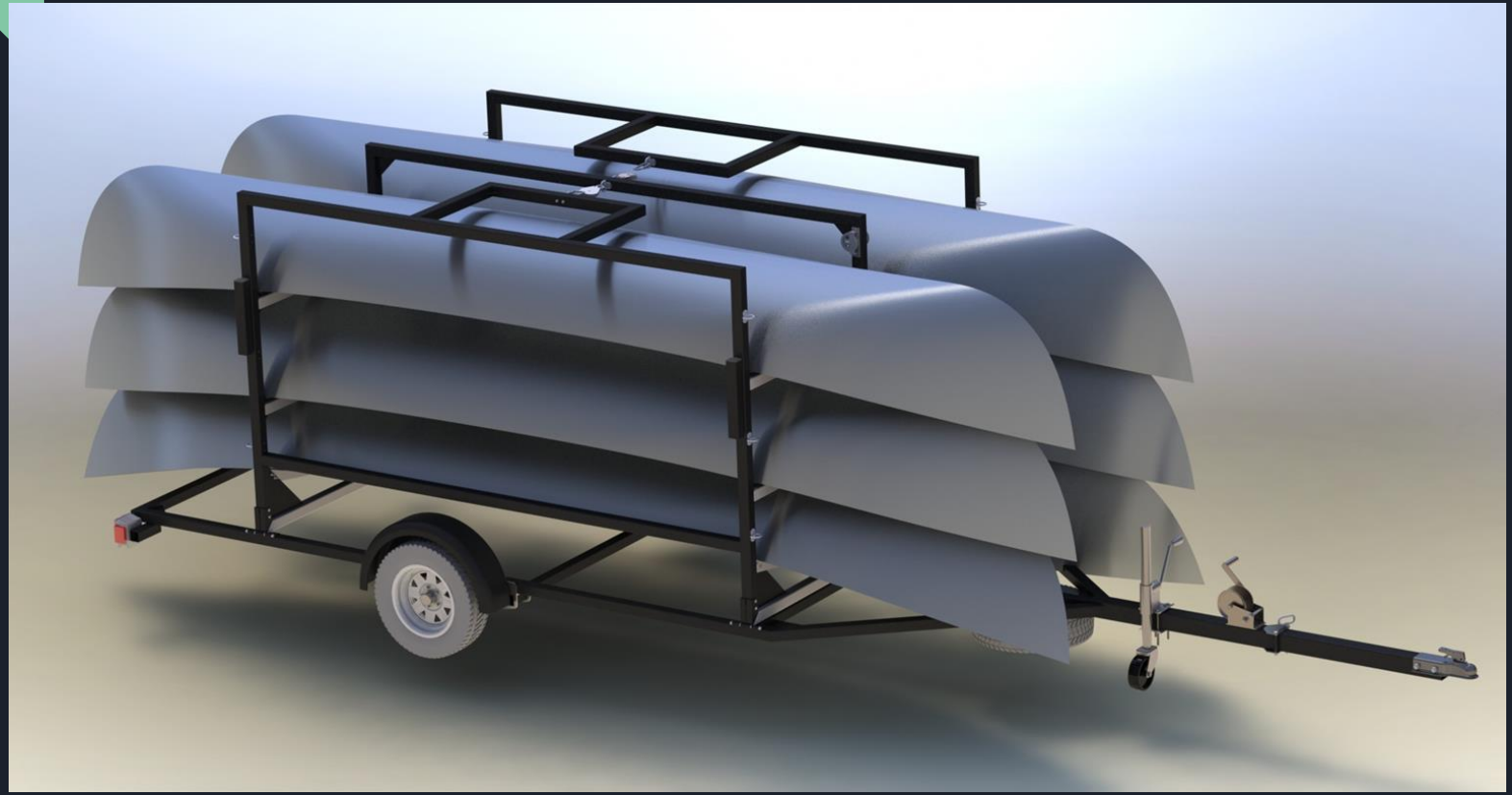
- Replace current canoe trailer for HHPR Department
- Problems with their current trailer include:
  - It is difficult to load and unload the top canoes
  - Too heavy to be moved manually
  - Too tall to fit in shed easily
  - No way to transport a single canoe at a time

Objectives

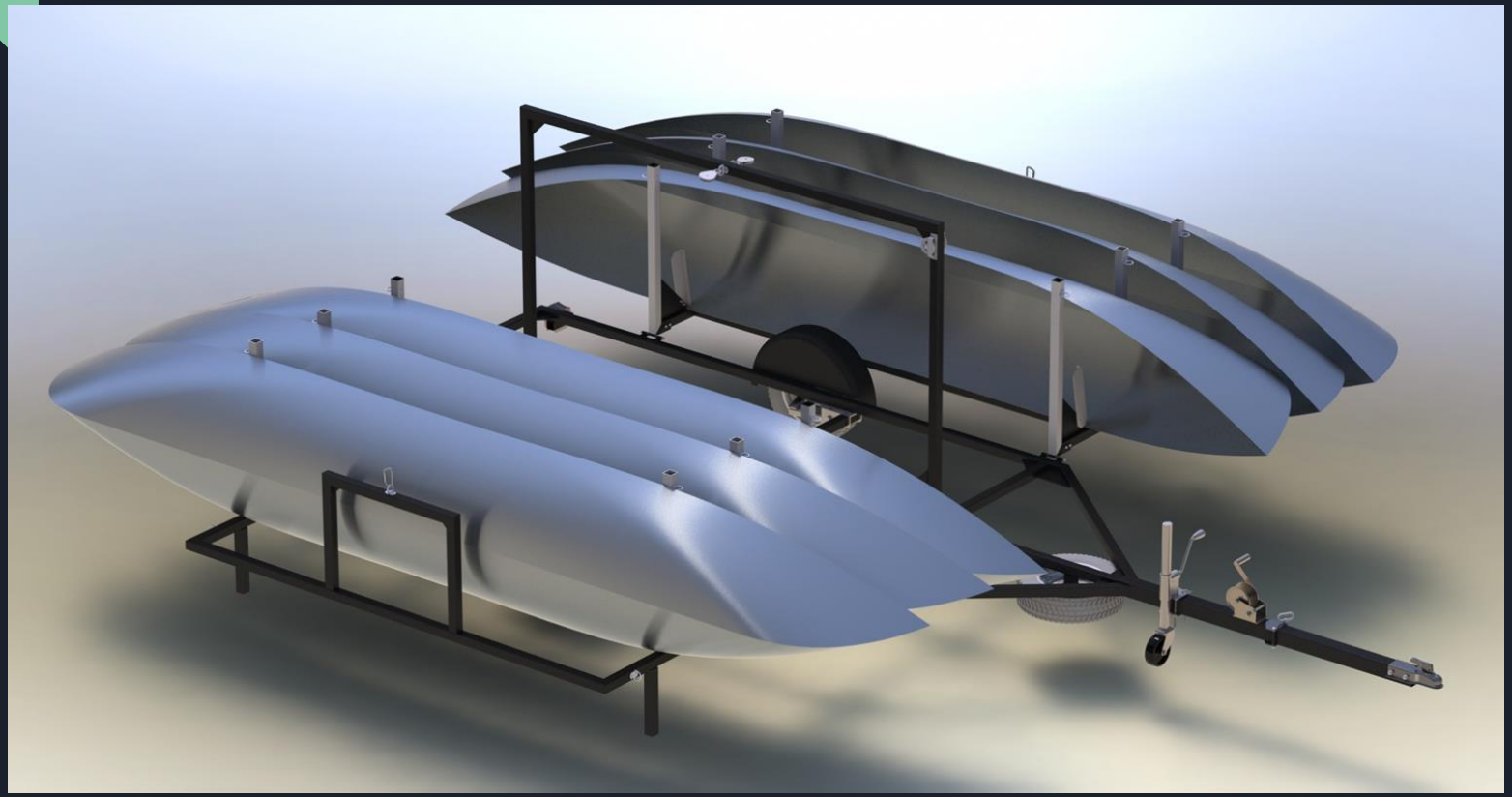
Our clients want a new trailer that can perform these functions:

- Transport six 17’ canoes
- Provide an easier way to load top canoes
- Fit in storage shed that is 93” wide, 81” tall, 232” long
- Be safe for road travel
- Have an efficient way to transport a single canoe

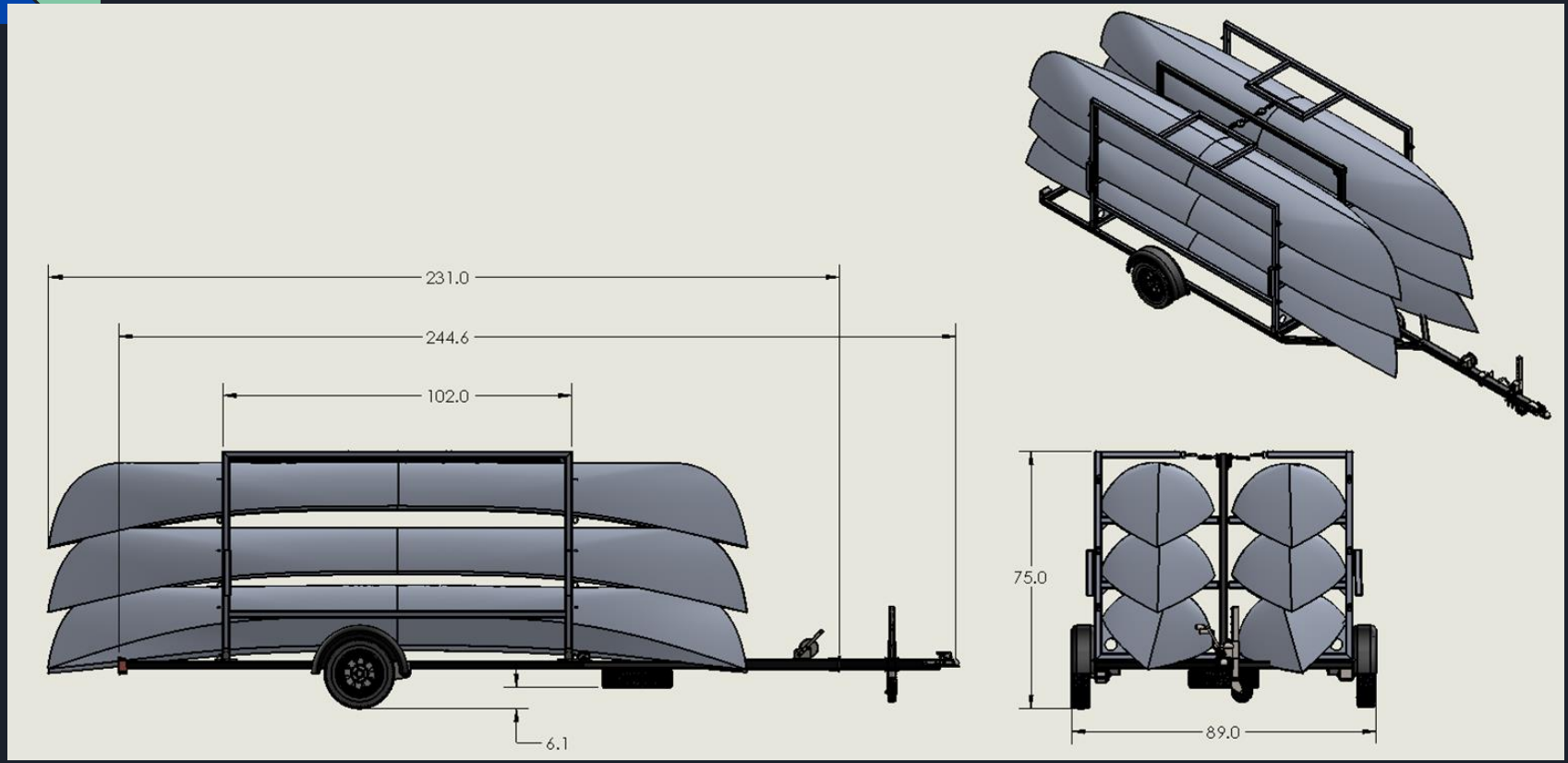
Problem Solution: Final Design



Arms Folded Down

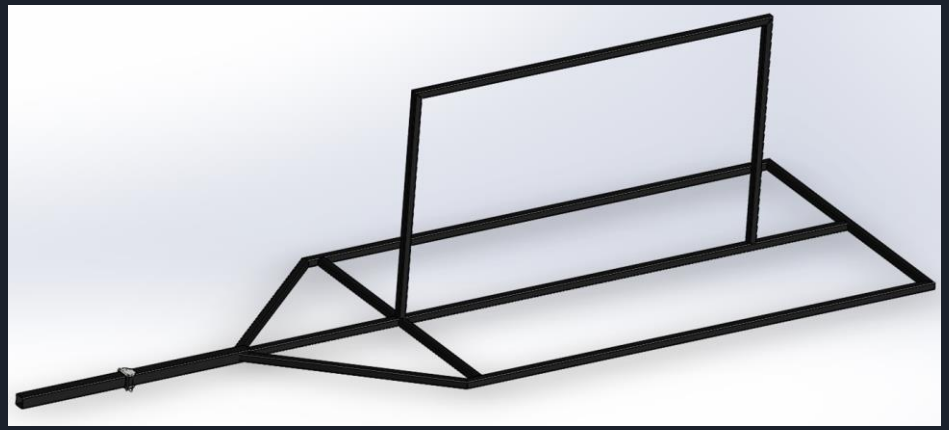


Trailer Assembly Drawing

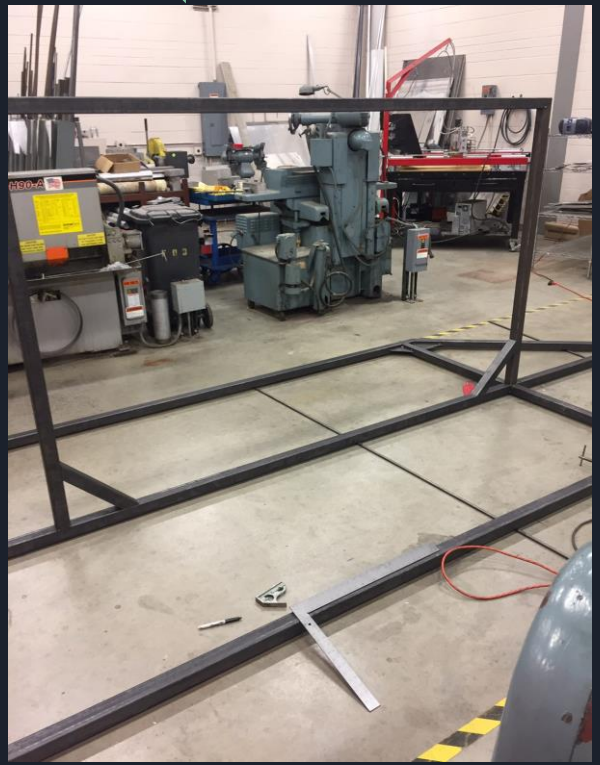


Frame

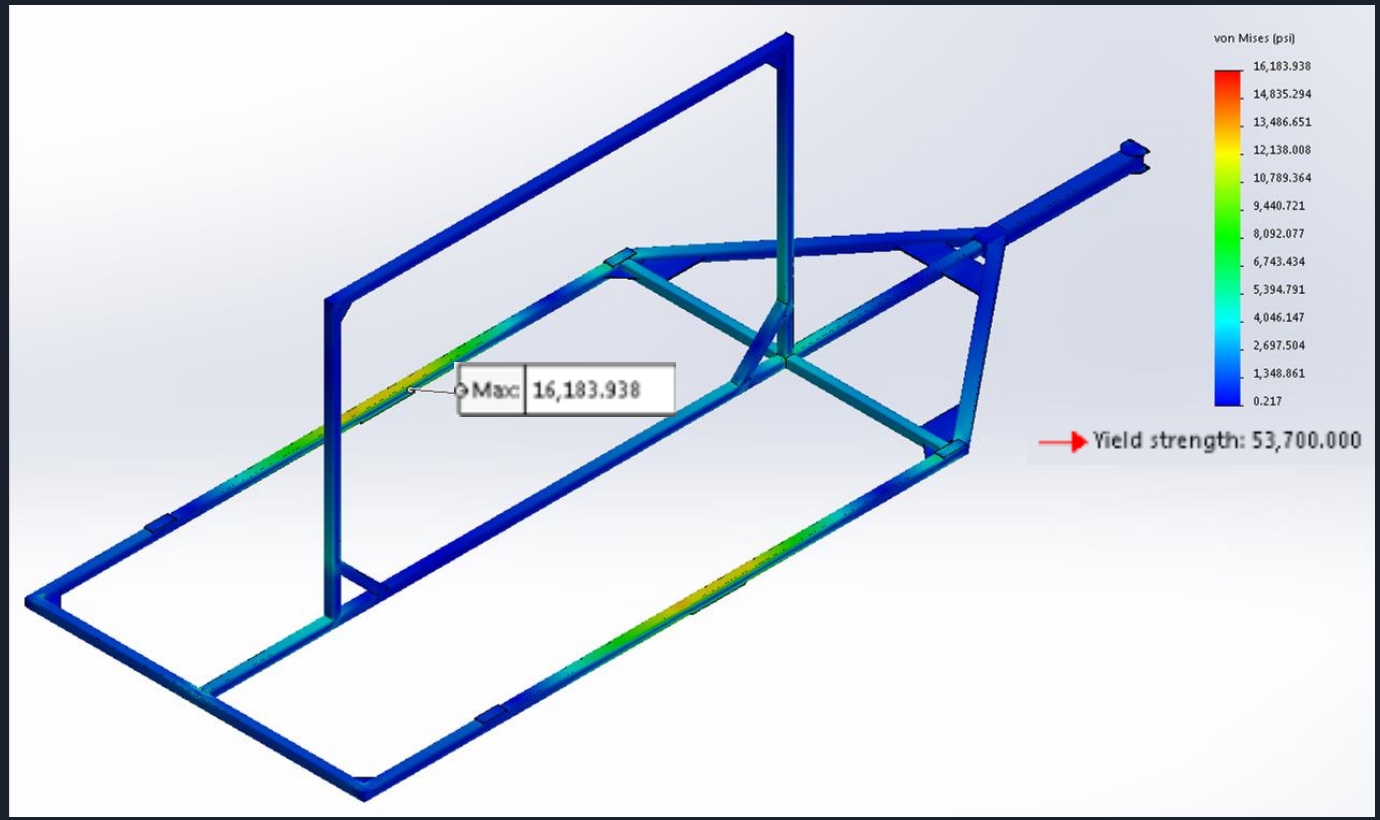
- Basic A-Shape frame
- 2” x 2” x .125” 1020 Carbon Steel
- Tongue made from 3” x 3” x .125” 1020 Carbon Steel
- All joints MIG welded



Additional Frame Support

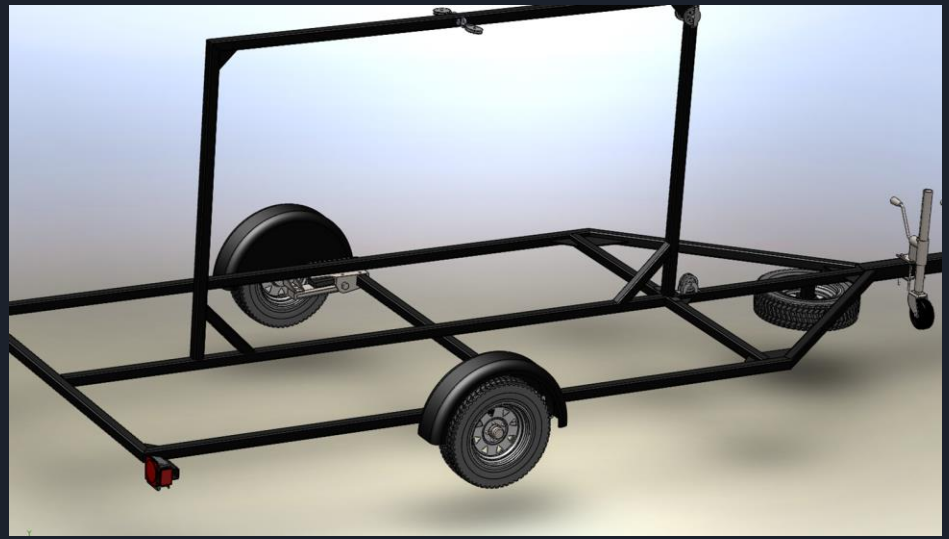


Frame FEA

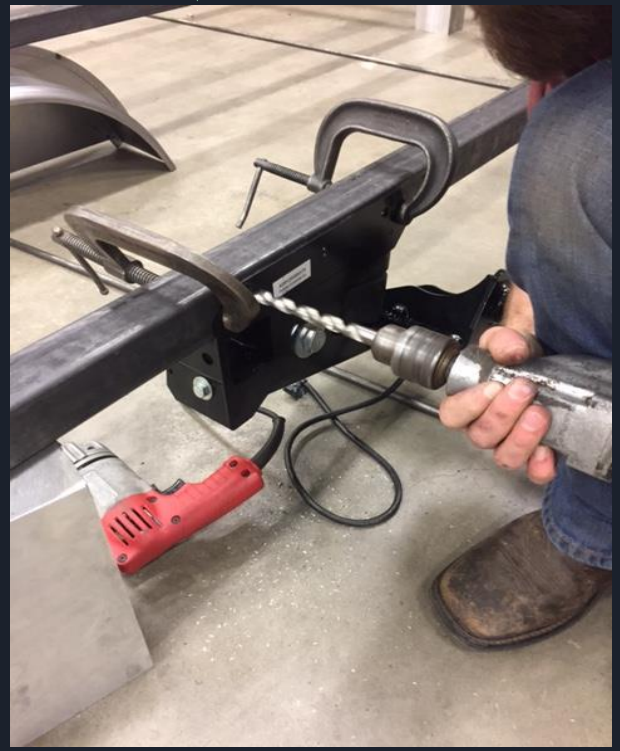

von Mises (psi)
16,183.938
14,835.294
13,486.651
12,138.008
10,789.364
9,440.721
8,092.077
6,743.434
5,394.791
4,046.147
2,697.504
1,348.861
0.217
Max: 16,183.938
Yield strength: 53,700.000

Suspension

- Timbren Axle-Less Suspension
  - 5” on 4½ hubs
  - Rated for 1200 lbs each
- Chosen for weight reduction
- Bolted on using three ½”-20 x 2.5” grade 5 bolts & nuts
  - Mounting hardware specified by retailer to achieve rating



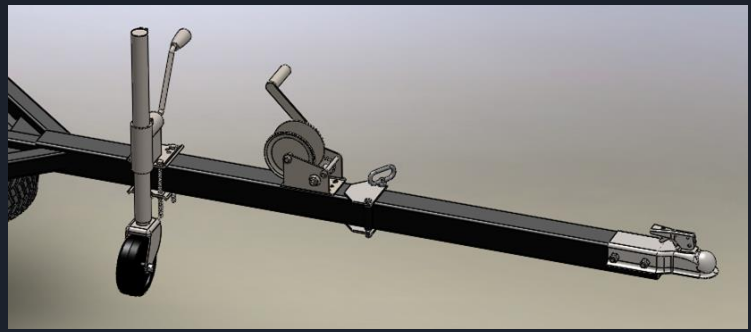
Suspension Installation



Suspension Problem/Solution

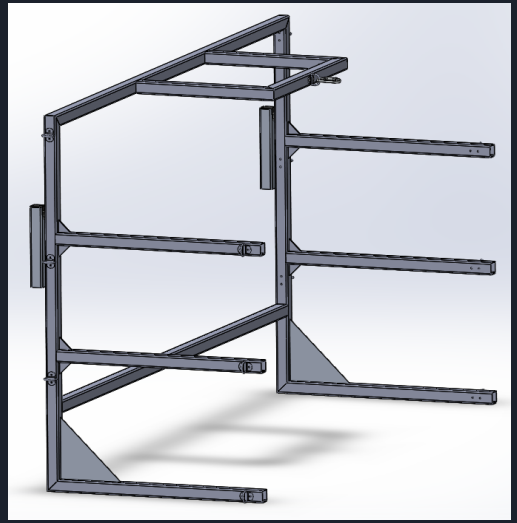
Folding Trailer Tongue

- Folding tongue saves 35” for storage in shed
- Allows for both the winch and jack be mounted
- Uses two brackets welded on
- Two 1/2” grade 5 fasteners have a safety factor of 3.6 in static shear
- Tongue assembly welded onto frame

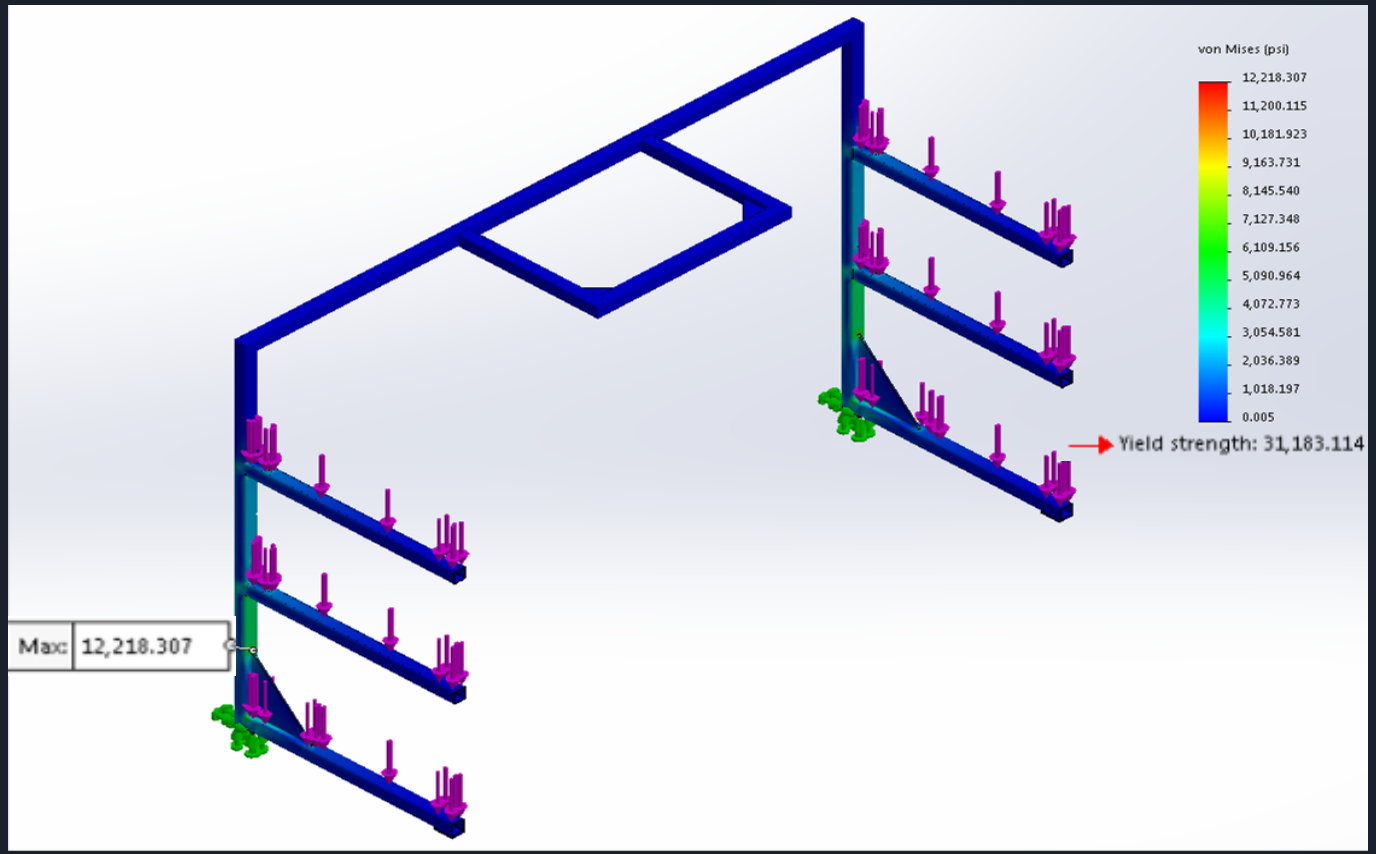


Folding Arms

- 2” x 2” x .125” 6063 T5 Aluminum
- 2”x 2”x .125” aluminum gussets in all loaded corners
- 10” x 10” x .125” aluminum gusset in bottom corner
- Tow straps connected to D-Rings to hold canoes
- All joints TIG welded



Arm FEA

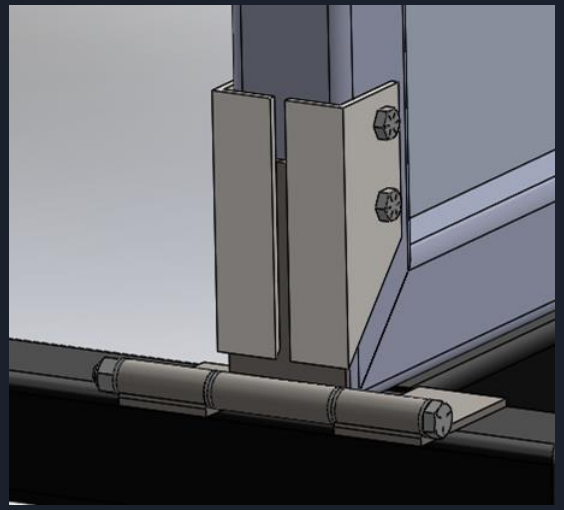

von Mises (psi)
12,218.307
11,200.115
10,181.923
9,163.731
8,145.540
7,127.348
6,109.156
5,090.964
4,072.773
3,054.581
2,036.389
1,018.197
0.005
Yield strength: 31,183.114
Max: 12,218.307

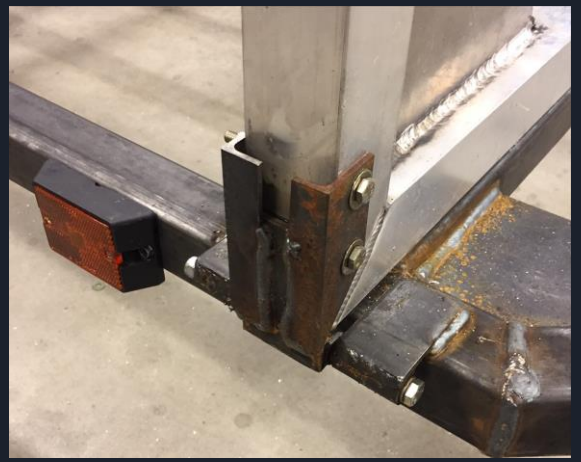
Folding Arms

Folding Arm Problem/Solution

Sub-components: Hinges

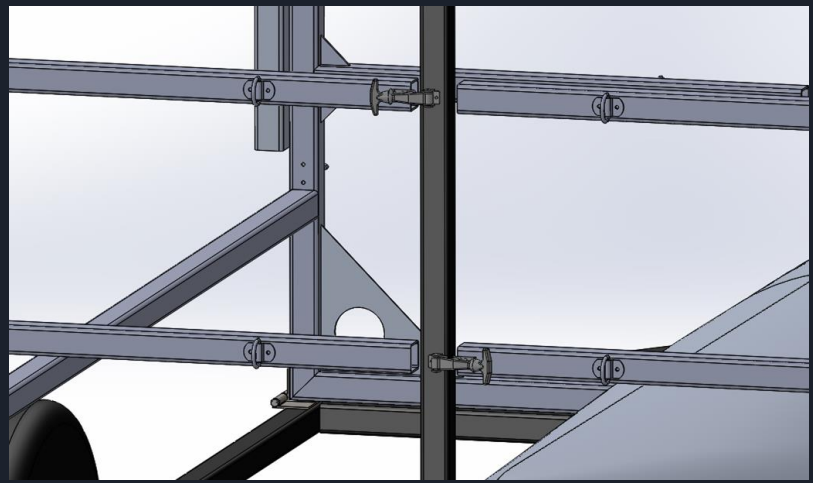
- Hinges were made instead of bought
- Welded onto frame and bolted onto arms
  - Two ¼”-20 bolts and locknuts
- Hinge knuckles turned on lathe
- Knuckle welded on 1/4” carbon steel strap
- Shoulder bushings on both knuckles
- 5/16” Grade 5 shoulder bolt for the pin



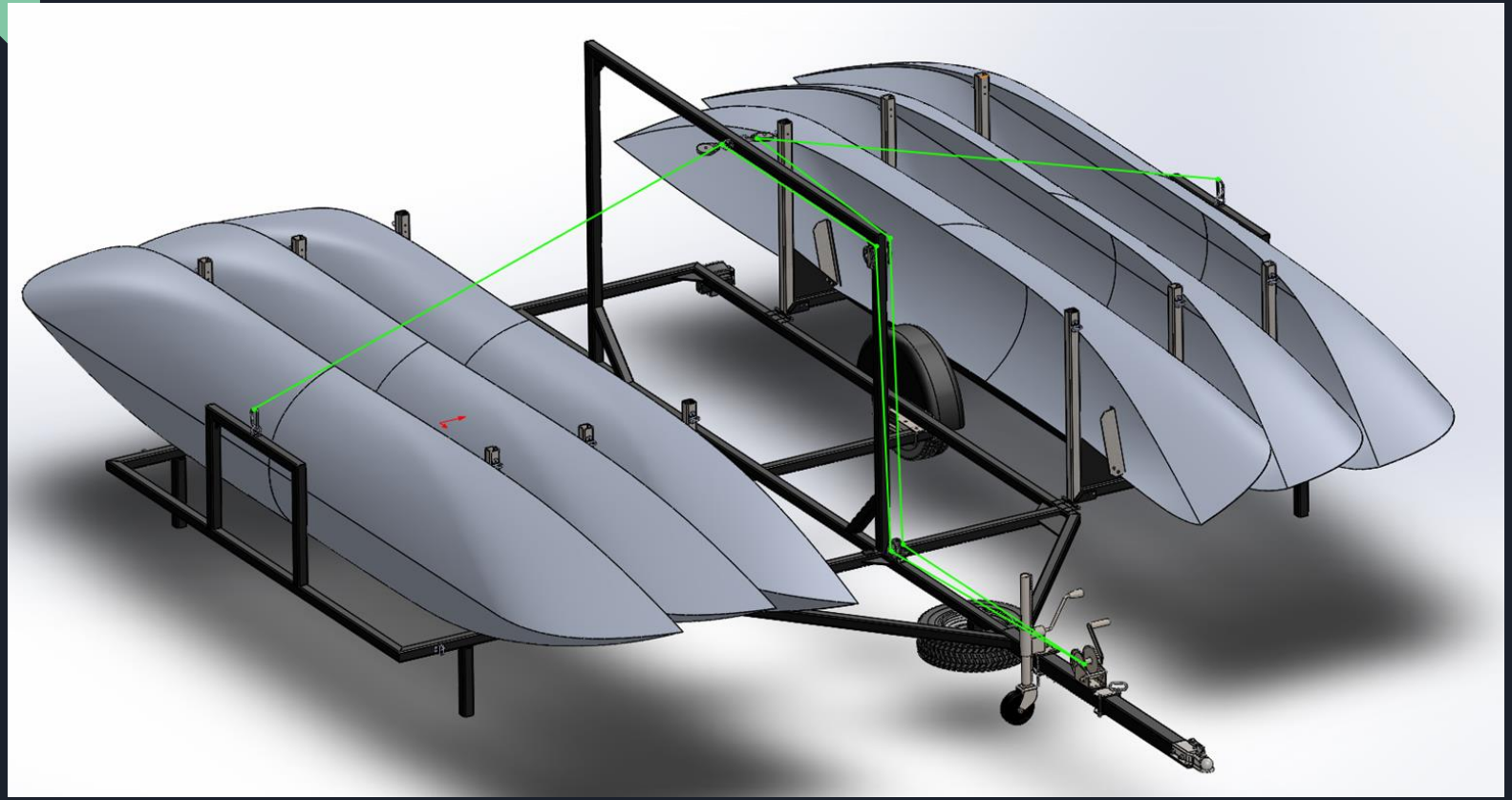


Arm Latches

- Weather Resistant draw latch
- Safety precaution for cable malfunction
- Mounted from frame to both arms
  - 1/4” grade 8 bolts and nuts

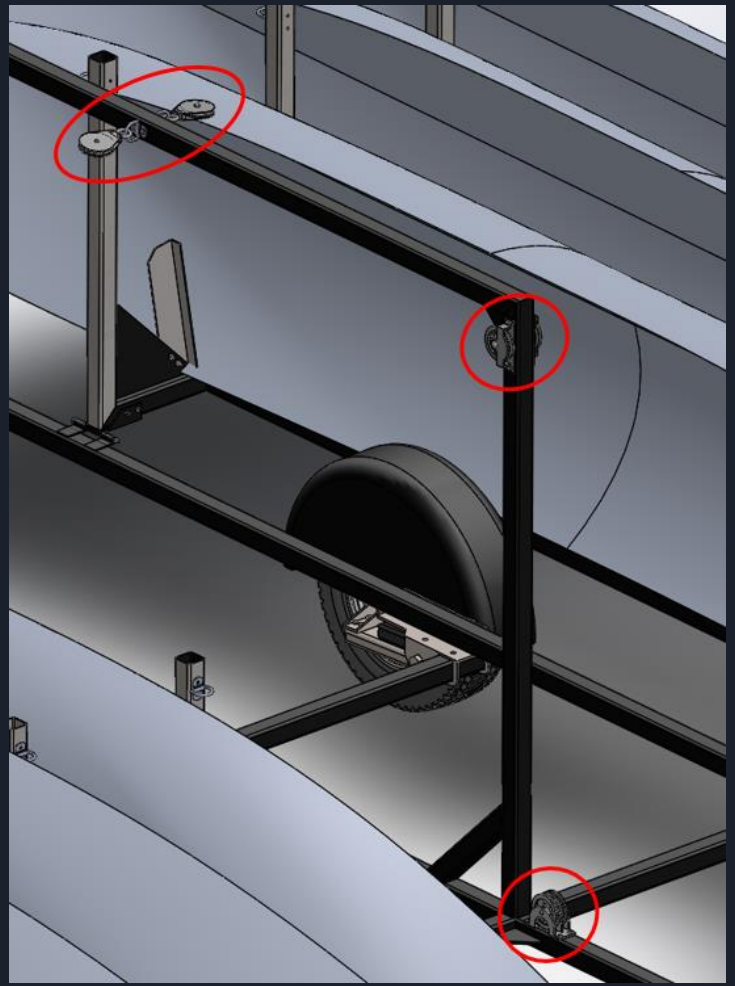


Cable System

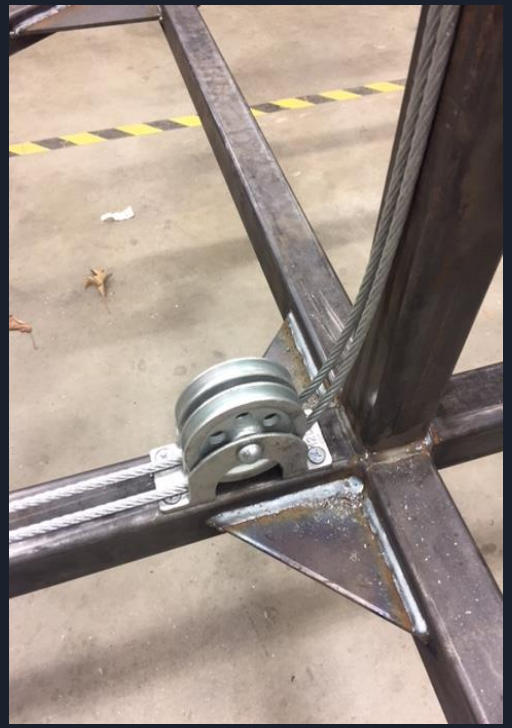


Pulley System

- Consists of 3 different types of pulleys
  - Double Pulley
  - Two side mount pulleys
  - Two swivel pulleys
- 1/4” grade 8 fasteners



Pulley Installation



Winch

- Fulton winch
  - Two gear ratios: 4:1:1 and 9:8:1
  - 2000lb rating
- ¼” wire cable
  - 1400lb tension working load
  - Galvanized
- Implemented fail-safe mechanism
  - Approximately 5 lb. pull

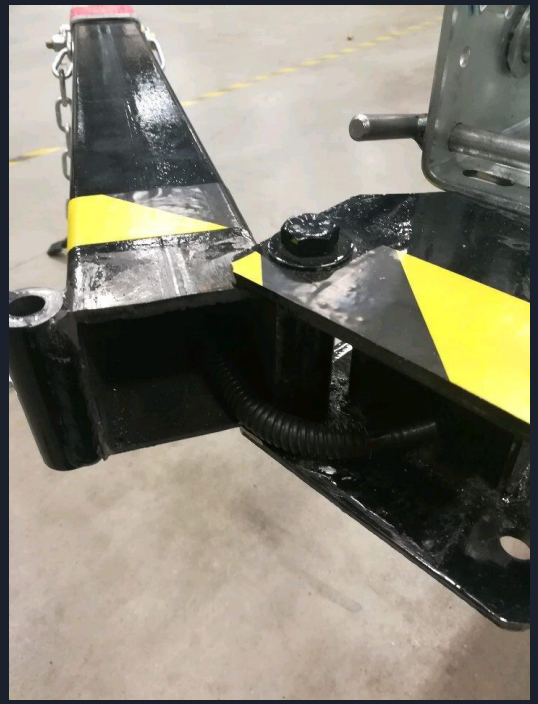
Wheels

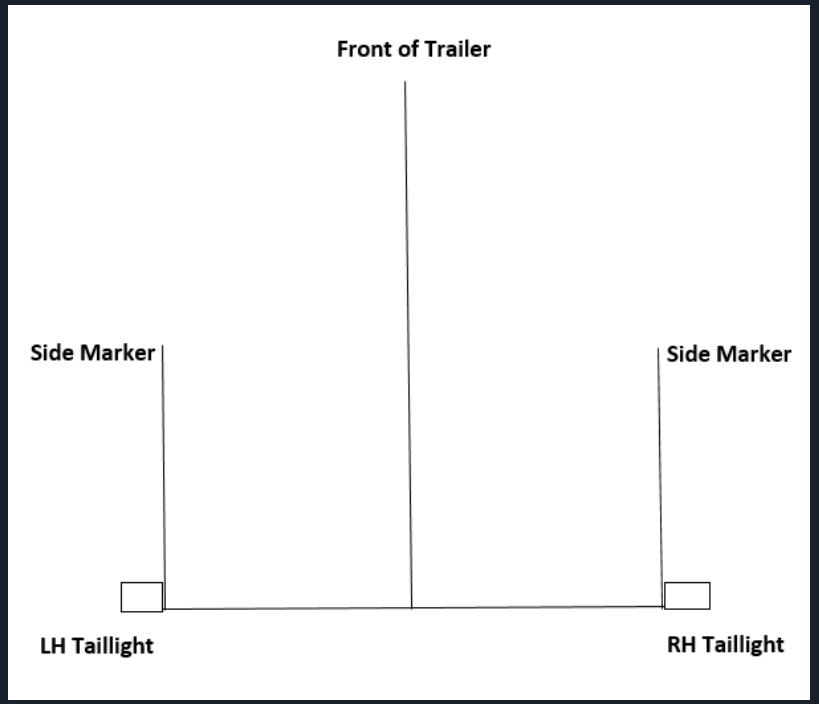
- Tires rated for 1100lb each at 35 PSI
  - 4 ply load range B
  - Kenda 13” wheels
  - 5 on 4 ½” bolt pattern

Trailer Lights

- LED lights
  - Weather resistant
  - More dependable than Incandescent bulbs
  - Complies with DOT standards
- Kit came with wiring and 4 pin harness
  - Clients 2012 Ford Ranger uses 4 pin connection
  - Runs on standard 12v truck battery
- Reflectors mounted on fenders

Wiring Installation & Diagram





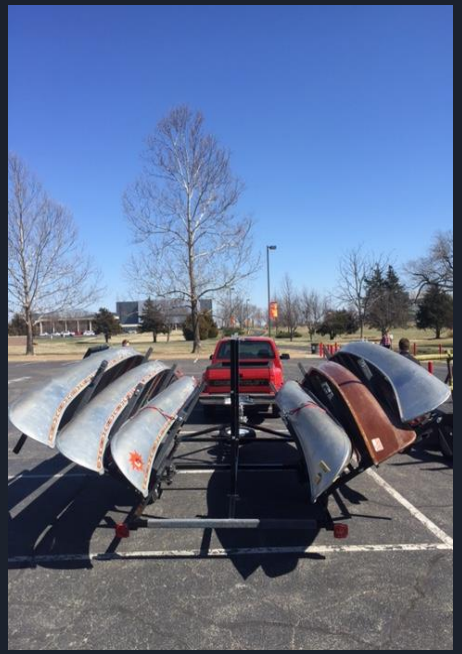
Paddle Storage

- Velcro straps
  - Quick disconnects
  - Holds up to 8 paddles

Shed Test Fitting

Weigh In at Midwest Minerals

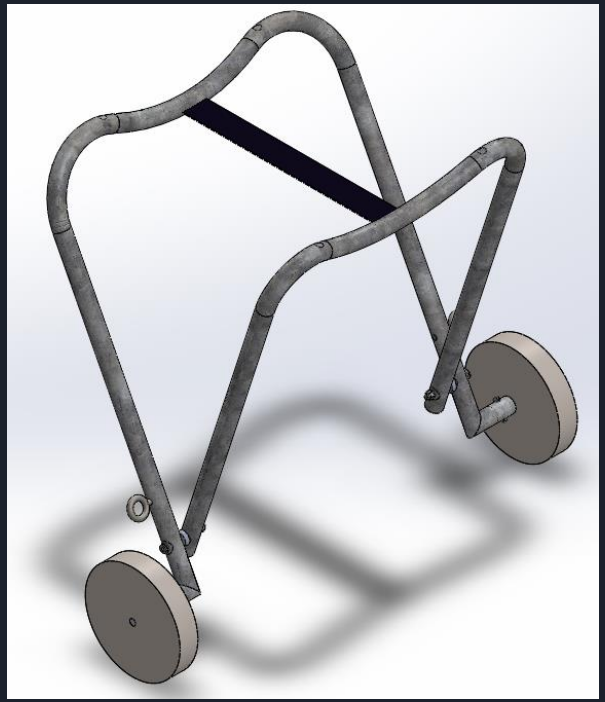
Finished Product




THUNDERBIRDS
ACCESS LANE

Canoe Cart: Original Plan

- Standard 1” EMT tubing
- Strap connection at eyebolt
- 90 degree conduit fitting
- No-flat wheels
- Calculated load to carry approx. 30 pounds
    - With FOS to carry 90 pounds



Canoe Cart Solution

Budget

Catergory	Price
Suspension/Wheels	$640.71
Trailer Materials	$641.90
Trailer Accessories	$332.32
Canoe Cart Materials	$93.86
Misc.	$201.43
Subtotal:	$1,913.46
Contingency (10%)	$191.02
Total*	$2,101.24

Reflections

- Overall Design
  - Instead of folding arms- something similar
  - “Wasted” material after arms on the frame
- Arm Functionality
  - Would have put more thought into lowering/raising
- Canoe Cart
  - Different material
  - Smaller Design

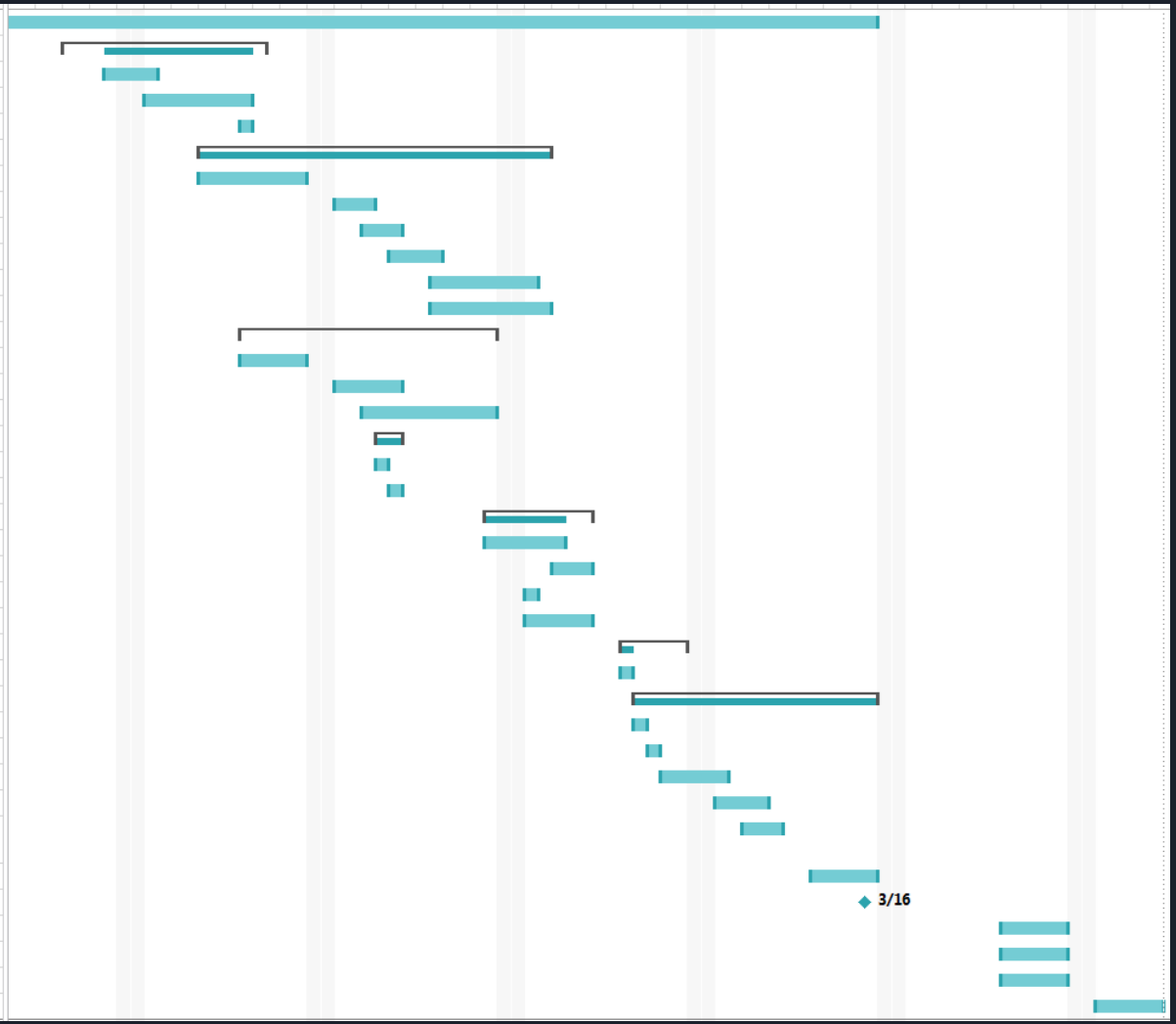
Any Questions?

Canoe Trailer Team Budget

Category	Part	Price	Qty.	Total Cost	Source	Shipping
Suspension	13" Wheels/Tires	$71.70	3	$215.10	https://www.etrailer.com/Tires-and-Wheels/Kenda/AM3S050.html	Free
	Torsion Axles	$425.61	1	$425.61	https://www.etrailer.com/Trailer-Axles/Timbren/A12WS545.html	Free
Accessories	Fenders	$32.58	2	$65.16	https://www.etrailer.com/Trailer-Fenders/Redline/F775X28-1RWB.html	Free
	Jack	$30.56	1	$30.56	https://www.etrailer.com/Trailer-Jack/etrailer/MJ-1206B.html	Free
	LED Trailer Lights/Wiring	$24.99	1	$24.99	https://www.amazon.com/MaxxHaul-70205-12V-Trailer-Light/dp/B008CE0W5Y/	Free
	2" Trailer Coupler	$14.98	1	$14.98	https://www.etrailer.com/Straight-Tongue-Trailer-Coupler/etrailer/CT-3003-Z.html	Free
	Hand Winch	$66.43	1	$66.43	https://www.etrailer.com/Trailer-Winch/Fulton/FT20250301.html	Free
	Side Mounted Pulley	$25.44	2	$50.88	https://www.mcmaster.com/#rope-pulleys/=19yzxey	$14
	Double Pulley	$32.90	1	$32.90	https://www.mcmaster.com/#rope-pulleys/=19yzx82	Free
	Swivel Pulley	$17.44	2	$34.88	https://www.mcmaster.com/#rope-pulleys/=1a3ikoy	Free
	27" Safety Chain	$5.77	2	$11.54	https://www.etrailer.com/Safety-Chains-and-Cables/Laclede-Chain/2118-605-04.html	Free
	Adhesive Reflectors	$1.62	2	$3.24	https://www.etrailer.com/Trailer-Lights/Optronics/RE10RB.html	Free
Materials	Steel 2"x2"x1/8" HSS	$2.36/ft	80	$188.80	Boyd Metals in Joplin MO	
	Steel 3"x3"x1/8" HSS	$3.68/ft	5	$18.40	Boyd Metals in Joplin MO	
	Aluminum 2"x2"x1/8" HSS	$3.35/ft	126	$434.70	Boyd Metals in Joplin MO	
Canoe Cart	10'x1" EMT Tubing	$7.40	2	$14.80	https://www.homedepot.com/p/1-in-EMT-Conduit-101568/100400409	None
	4"x3/8" Eye Bolt	$1.70	2	$3.40	Local Home Depot	None
	Tires/Wheels	$8.00	2	$16.00	https://www.tractorsupply.com/tsc/product/martin-wheel-8x175-light-duty-plastic-wheel-1-2-in-bore-	None
	3/8" 2.5" Shoulder Bolt	$2.56	2	$5.12	Local Home Depot	None
	3/8" Nylon Nut	$0.47	6	$2.82	https://www.lowes.com/pd/Hillman-3-8-in-Stainless-Steel-Standard-Sae-Nylon-Insert-Lock-Nut/4756059	None
	3/8"x1.75" Hex Bolt	$0.86	2	$1.72	Local Home Depot	None
	Strap for Canoe	$10.00	1	$10.00	https://www.homedepot.com/p/Husky-1-in-x-6-ft-Locking-Tie-Down-4-pack-FH0898/206802389	None
	Purchased Canoe Cart	$40.00	1	$40	Local Academy Sports	None
Misc.	Tie-down Straps	$2.98	12	$35.76	https://www.homedepot.com/p/Husky-36-in-Adjustable-EPDM-Rubber-Strap-56268/206967360	None
	D-Ring anchor points	$1.25	26	$32.50	https://www.homedepot.com/p/Keeper-1-in-D-Ring-with-Bracket-89311/205510053	None
	Carpet for arms	1/linear ft	4	$9.64	Local Home Depot	None
	Hinge Bushings	$1.01	16	$16.16	https://www.mcmaster.com/#6338k453/=1acchyb	None
	Locking Pin w/ Retainer	$4.99	1	$4.99	https://www.mcmaster.com/#97143a640/=1acd1os	None
	Draw Latch	$9.20	2	$18.40	https://www.mcmaster.com/#1685a24/=1actgw5	None
	Steel Cable	$20.77	1	$20.77	https://www.homedepot.com/p/Crown-Bolt-1-4-in-x-50-ft-Uncoated-Wire-Rope-64712/202972287	Free
	Paint	$28.21	1	$28.21	https://www.amazon.com/RustOleum-7779402-Protective-Enamel-Gallon/dp/B000VWAOVW/ref=sr_1_1?ie=UTF8&qid	
	Nuts/Bolts	$35.00	1	$35.00		
			Subtotal:	$1,913.46		
			Contingency (10%)	$ 191.35		
			Total*	$2,104.81		

**Current total does not account for sales tax*

Fundraise	101 days	Fri 10/27/17	Fri 3/16/18
Frame	**11 days**	**Tue 1/16/18**	**Tue 1/30/18**
Order Stock	2 days	Fri 1/19/18	Mon 1/22/18
Layout	6 days	Mon 1/22/18	Mon 1/29/18
Welding	1 day	Mon 1/29/18	Mon 1/29/18
Suspension	**18 days**	**Fri 1/26/18**	**Tue 2/20/18**
Order Online	6 days	Fri 1/26/18	Fri 2/2/18
Position	3 days	Mon 2/5/18	Wed 2/7/18
Attach to Frame	3 days	Wed 2/7/18	Fri 2/9/18
Attach Wheels	2 days	Fri 2/9/18	Mon 2/12/18
Attach Fenders	6 days	Mon 2/12/18	Mon 2/19/18
Leveling Jack	7 days	Mon 2/12/18	Tue 2/20/18
Arms	**15 days**	**Mon 1/29/18**	**Fri 2/16/18**
Order Aluminum	5 days	Mon 1/29/18	Fri 2/2/18
Layout	5 days	Mon 2/5/18	Fri 2/9/18
Welding	8 days	Wed 2/7/18	Fri 2/16/18
Folding Tongue	**2 days**	**Thu 2/8/18**	**Fri 2/9/18**
Make components	1 day	Thu 2/8/18	Thu 2/8/18
Install	1 day	Fri 2/9/18	Fri 2/9/18
Hinges	**6 days**	**Fri 2/16/18**	**Fri 2/23/18**
Manufacture	4 days	Fri 2/16/18	Wed 2/21/18
Attach hinges	3 days	Wed 2/21/18	Fri 2/23/18
Attach Hand Crank	1 day	Mon 2/19/18	Mon 2/19/18
Implement Cable System	5 days	Mon 2/19/18	Fri 2/23/18
Attach Hitch Coupler	**5 days**	**Mon 2/26/18**	**Fri 3/2/18**
Attach Safety Chains	1 day	Mon 2/26/18	Mon 2/26/18
Paint and Accessories	**14 days**	**Tue 2/27/18**	**Fri 3/16/18**
Attach Trailer Lights	1 day	Tue 2/27/18	Tue 2/27/18
Shed Fit Testing	1 day	Wed 2/28/18	Wed 2/28/18
Paint Trailer Black	3 days	Thu 3/1/18	Mon 3/5/18
Manufacture cart	4 days	Mon 3/5/18	Thu 3/8/18
Implement Tie down components	3 days	Wed 3/7/18	Fri 3/9/18
Optimize functionality	5 days	Mon 3/12/18	Fri 3/16/18
Turn in Final Project	0 days	Fri 3/16/18	Fri 3/16/18
Modify Canoe Cart	5 days	Mon 3/26/18	Fri 3/30/18
Enhance Safety	5 days	Mon 3/26/18	Fri 3/30/18
Relocate Legs for Arms	5 days	Mon 3/26/18	Fri 3/30/18
Update FEA's	5 days	Mon 4/2/18	Fri 4/6/18



Design Inputs

Design Inputs	Nominal Value	Tolerance	Rationale	Importance
Safety				
Strength requirement	Load on frame will be multiplied by 1.8x to compensate for road bumps. Safety factor of 3 on top of this value for all loaded members.	3 Min	1.8 is a widely used multiplier to compensate stresses of road bumps according to truckinginfo.com. Design safety factor of 3 was chosen after speaking with American Trailer Company (ATC) in regards to	10
Stability	Stable on a 9 degree incline	9 degree Min	Max gradient of land behind gate at the president's lake and max gradient of standard boat ramp are both 9 degrees	10
Injury prevention	No pinch points or sharp edges that could cause injury	N/A	OSHA Gotcha stick	10
Trailer can be Handled by Two People				
Empty trailer weight	Empty trailer weighs under 550lbs	550lbs Max	Per clients request	8
Loaded trailer weight	Loaded trailer weighs under 2000lbs	2000bs Max	Trailer does not need a liscense if under 2000lbs, accoriding to Kansas Highway Patrol	10
Tongue weight	Trailer must be able to be picked up by the tonge and pulled out of shed by two people	N/A	OSHA does not have a standard which sets limits on how much a person may lift or carry	10
Stored in Shed by President's Lake				10
Width	93"	Max	Measurements of Shed	10
Length	230"	Max	Measurements of Shed	10
Heigth	81"	Max	Measurements of Shed	10
Capable of Road Travel/DOT Certified				
Electrical system	Trailer must connect via standard flat 4 pin truck connector. Must run on the 12V truck battery.	N/A	Client's 2012 Ford Ranger uses a standard flat 4 pin connector	10
Tail light assembly	2 tail light assemblies on rear of trailer, one on the right and one on the left. The tail light assemblies serve as runnnig lights, brake lights, and turn signals. Assemblies will be mounted on the back frame of trailer, 2" from each edge horrizontally and 13" from the ground.	+/- 1" for all mounting locations	Resource: kansaslegislation.org	10
Safety chains	2 safety chains with S hooks that attach from trailer to truck, SAE certified 2,000lb tow capacity. Permanently connected to trailer tongue.	N/A	Resource: kansaslegislation.org	10
Hooks up to 2" receiver hitch	Must have a standard 2" straight tongue coupler mounted on tongue of trailer via weld on or bolt on connection. Passes SAE-684 performance testing and has a tow capacity of	N/A	Client's truck uses 2" hitch	10
Ground clearance	At least 5" from bottom of trailer frame	5" Min	ksdot.org	10
Turning Radius				
Inside turing radius	17.5'	17.5' Min	Requirement provided by AASHTO	10
Outside turning radius	34.5'	34.5' Min	Requirement provided by AASHTO	10
Equipment Storage Capacity				
Canoe capacity	6- 17' canoes to be carried	Up to 6	Per clients request	8
Equipment storage	Carry oars for all passengers, one oar per passenger	12 oars Min	Per clients request	6
Miscellaneous				
Curb appeal	Fenders, PSU logos	N/A	Per clients request	5
Paint	Black	N/A	Per clients request	10

Tongue Bolt Shear Calculation

$F = 1000\,lb$ (trailer weight when loaded)

$A = \pi \cdot .1875^2 = .11$

$$\tau = \frac{F}{A} = \frac{1000\,lb}{(.11)(4)} = 2272\,lbs \text{ of max Shear}$$

Shear capability of standard 3/8" Grade 5 bolt is 8,280 lb
(according to tinelok.com/Grade-5-vs-Grade-8 fasteners)

$$FOS = \frac{8,280\,lb}{2,272\,lb} = \boxed{3.64 \text{ FOS}}$$

Swivel Pulley Bolt/D-Ring Calculations

D-ring break strength = 12001b

Loaded arm w/ canoes = 2501b

$\frac{12001b}{2501b} = 4.8$ FOS

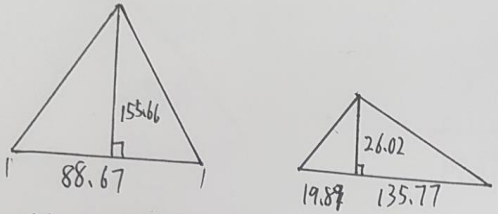
1/4" Grade 5 bolts (x2) will be used to secure both D-rings

Ultimate Tensile Stress = $\frac{2501b(2)}{\pi \cdot .125^2} = \frac{10,204\ psi}{\text{Two bolts}} = \boxed{5,102\ psi}$

Yield strength of bolt is 92,000 psi, Tensile strength 150,000 psi

$\frac{150,000\ psi}{5102\ psi} = \boxed{\text{FOS of } 29.4}$

Hill Gradient Calculation



$V_{max} = 60\,mph = 88\,ft/s$

$W = 996.38\,lb$

$\theta_1 = \tan^{-1}\left(\frac{d_1}{z_{cg}}\right) = 37°$ (Downhill, negative)

$\theta_2 = \tan^{-1}\left(\frac{d_2}{z_{cg}}\right) = 79°$ (Uphill, Pasitive)

} Critical static pitch Angles

$\theta_3 = \tan^{-1}\left(\frac{d_3}{z_{cg}}\right) = 56°$ Critical Static Roll Angles

$\theta_4 = \tan^{-1}\left(\frac{d_4}{z_{cg}}\right) = 55.02°$ Tricycle worst Scenario

$F_a = W \tan\theta_1 = 996.38 \cdot \tan 37°$

$= 751\,lb$

$m = \frac{W}{g} = \frac{996.38}{32.2}$

$= 30.94\,slugs$

$a = \frac{F_a}{m} = \frac{751}{30.94}$

$= 24.27\,ft/s^2$

$F_{an} = W \cdot \tan\theta_3 = 996.38 \cdot \tan 56°$

$= 797.39$

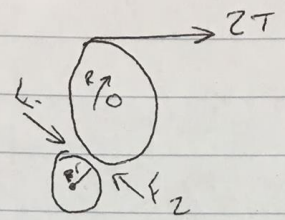
$F_{an} = m\frac{v^2}{r}$

$r = m\frac{v^2}{F_{an}}$

$= 300.47\,ft$

Winch Calculations

$$F = \frac{T}{r_1}$$



$$F_1 = F_2$$

$$\frac{T_{in}}{r} = \frac{2TR}{R}$$

$$T_{in} = \frac{2T}{r} = \frac{2(245)}{(10in)} = 49lb \text{ input force needed on } 10in \text{ handle}$$

Online Resources

Department of Motor Vehicles. "DMV: Inspection of Trailers." *CT.GOV-Connecticut's Official State Website*, www.ct.gov/dmv/cwp/view.asp?a=804&q=244914.

"Electrical Metallic Tubing (EMT)." *Steel Conduit*, steeltubeinstitute.org/steel-conduit/types-of-steel-conduit/electrical-metallic-tubing-emt/.

KDOT: Home, www.ksdot.org/Assets/wwwksdotorg/bureaus/burTransPlan/pubtrans/pdf/RMV-16%20Spec%20Final.pdf.

"Proper Dimensions for a Boat Launch Ramp." *M.B. Marsh Marine Design*, 8 Nov. 2012, marine.marsh-design.com/content/proper-dimensions-boat-launch-ramp.

Systèmes, Dassault. "3D ContentCentral." *3D ContentCentral*, www.3dcontentcentral.com/Download-Model.aspx?catalogid=171&id=654657.

"Trailers | Kansas Highway Patrol, KS." *Kansas Highway Patrol, KS | Official Website*, www.kansashighwaypatrol.org/223/Trailers.

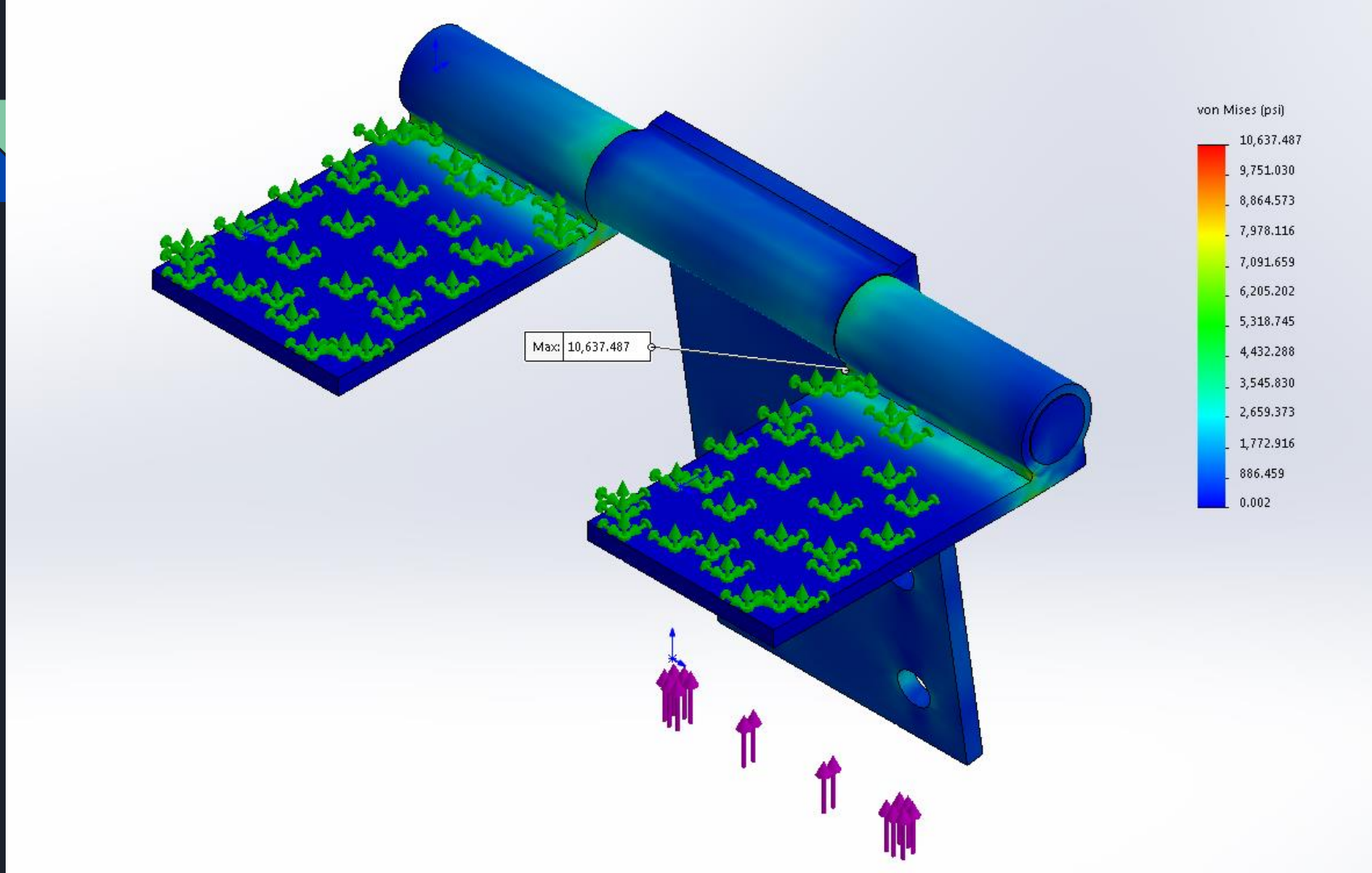
"Grade 5 Vs Grade 8 Fasteners." *TineLok*, tinelok.com/grade-5-vs-grade-8-fasteners/.

Marathon Boat Group, www.marathonboat.com/Grumman_Canoes.pdf.

Trailer Hitches & Vehicle Accessories (800)298-8924, www.etrailer.com/.

McMaster-Carr, www.mcmaster.com/.

Boyd Metals, boydmetals.com/.


Max: 10,637.487
von Mises (psi)
10,637.487
9,751.030
8,864.573
7,978.116
7,091.659
6,205.202
5,318.745
4,432.288
3,545.830
2,659.373
1,772.916
886.459
0.002