



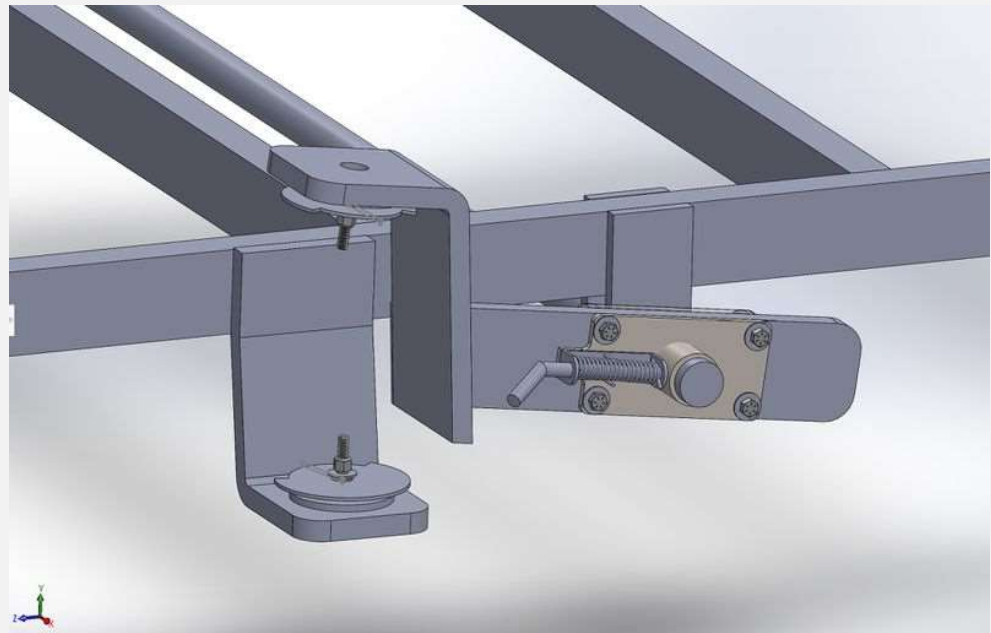
University of Idaho
College of Engineering

3S SINGLE AXLE TRAILER SUSPENSION

CAITLIN SWENSON
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ANSON LUNSTRUM
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SINGLE OBJECTIVE

- Innovation suspension
- First-Class Lever
- Dependent to Independent





VALUE PROPOSITION

There have been minor improvements to trailer suspension for the last 50 years. Our team of engineers is creating a new and innovative suspension system where both drivers and passenger side suspension is coupled together but can be quickly made independent by retracting a pin. This innovation is the use of a first-class lever system and adds value by improving carrying and leveling performance, without increasing overall cost. By creating solid works models and testing the stresses on our suspension system we will be able to carry a range of loads from 2000lbs up to 6000lbs. The goal in the future is to implement our suspension system onto as many trailers as possible.

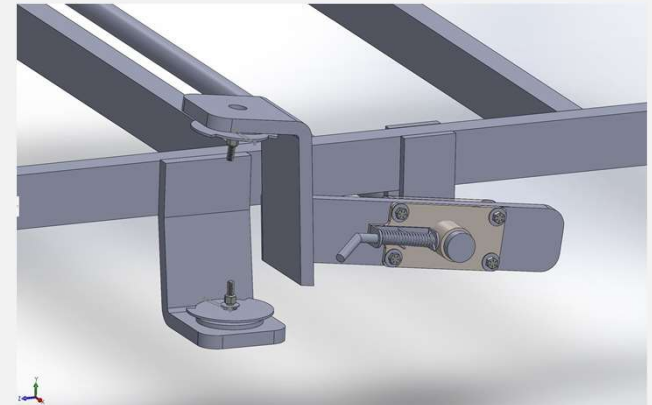
BACKGROUND

- First-Class lever
- Load Stability
- Increase Safety and Capabilities
- Rough Terrain/High Crosswinds
- Commercial suspension



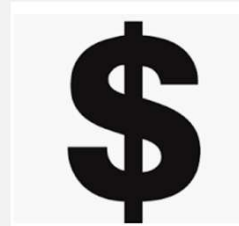
LEAF SPRING VS. 3S SUSPENSION

- Traditional Leaf Spring Suspension
- Problem We Are Trying to Solve
- Our Suspension System
- Independent Vs. Dependent Suspension



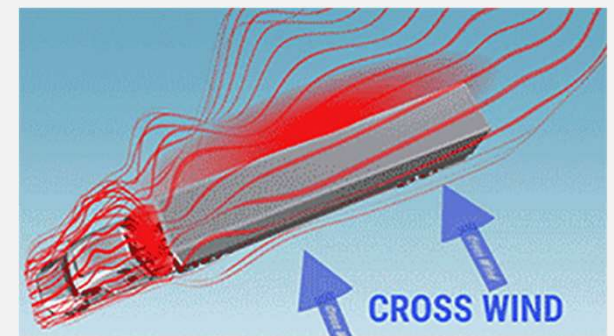
CUSTOMER/PRODUCT REQUIREMENTS

- User Installation Time
- Dependent to Independent
- Static Rated load Capacity
- Dynamic Load per tire/spring
- Durability/Reliability Requirements
- Cost Requirements



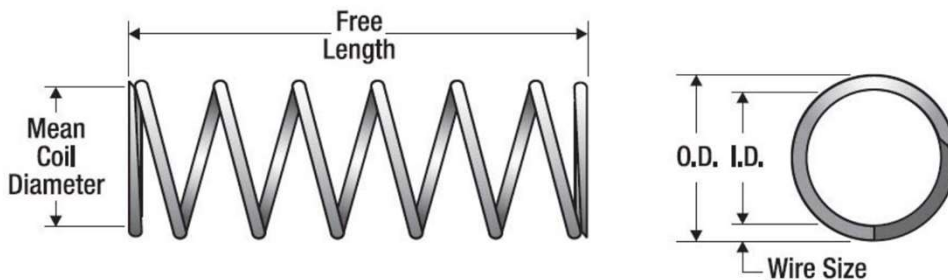
KEY ATTRIBUTES

- *Dependent* suspension linkage
 - Improves response to sudden wind loading
 - Improves cornering
- Cost reduction
 - Not necessary to purchase traditional axle
 - Weld-on kit vs. Total Product





SPRING SELECTION



Regular compression spring in oil tempered with 10.2 total coils and closed/ground ends. This spring features an O.D. of 4.687in, an I.D. of 3.687in, a spring rate of 148. This spring is unfinished.

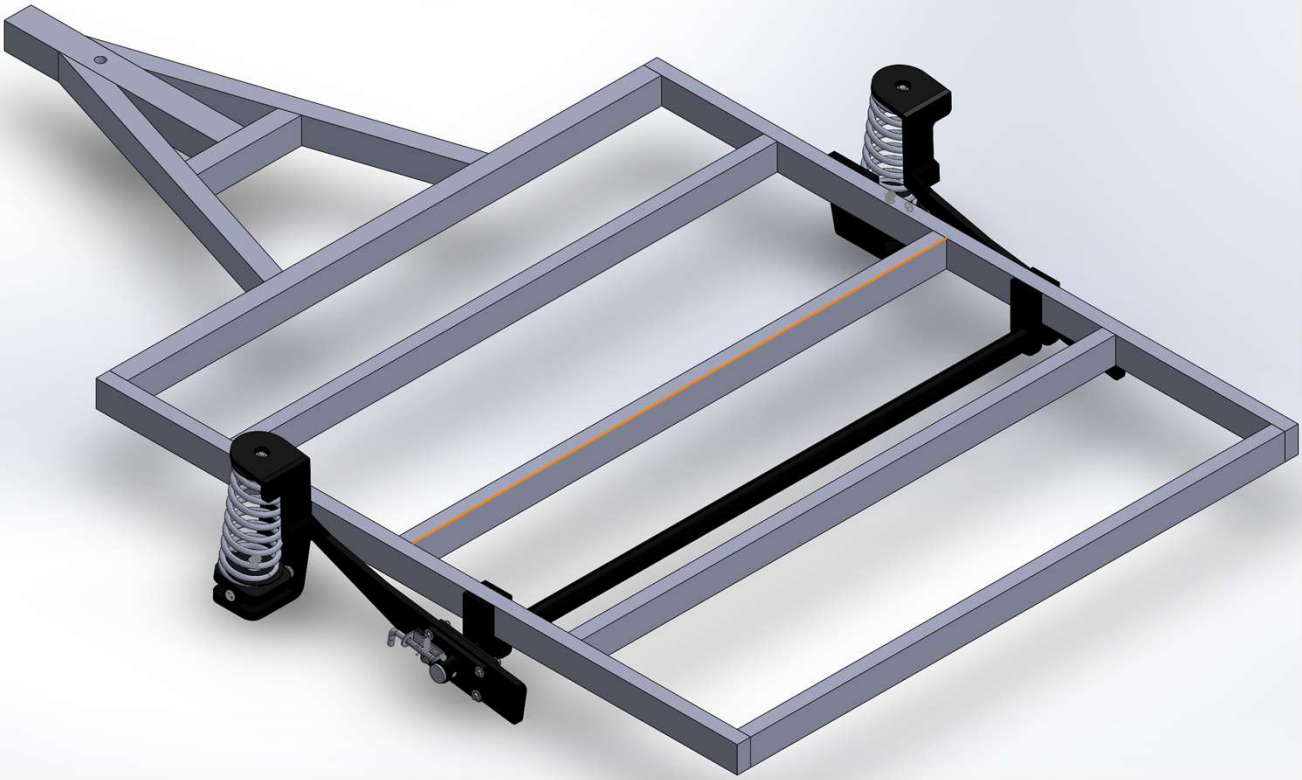
Part Number: 73606

Material	Oil Tempered - OT
Wire Dia (in)	0.500
O. D. (in)	4.687
I. D. (in)	3.687
Free Length (in)	12.00
Total Coils	10.20
Rate (lb/in)	148.00
Ends	Closed/Ground - CG
Suggested Max Load (lb)	696.000
Suggested Max Deflection (in)	4.700
Solid Length (in)	5.12
Standard Finish	None - N

- $F_{spring} = (3/2) * F_{load} / \text{Lever_Ratio}$
 - $K = \text{Spring Stiffness (lb/in)}$
 - $\text{Preload} = 0.75 * K \text{ (lb)}$
 - $F_{load} = 2000 \text{ (or)} 35000 \text{ (or)} 6000 \text{ (lb)}$
 - $\text{Lever_ratio} = (3/2) * F_{load} / F_{spring}$
 - $\text{Deflection_max} = (F_{spring} - \text{Preload}) / K \text{ (in)}$
 - $\text{Deflection_wheel} = \text{Deflection_max} / \text{Lever_ratio}$
- $\text{Spring_load_max} = K * \text{Deflection_max} \text{ (lb)}$
 - $\text{Spring_load_max} \gg F_{spring}$

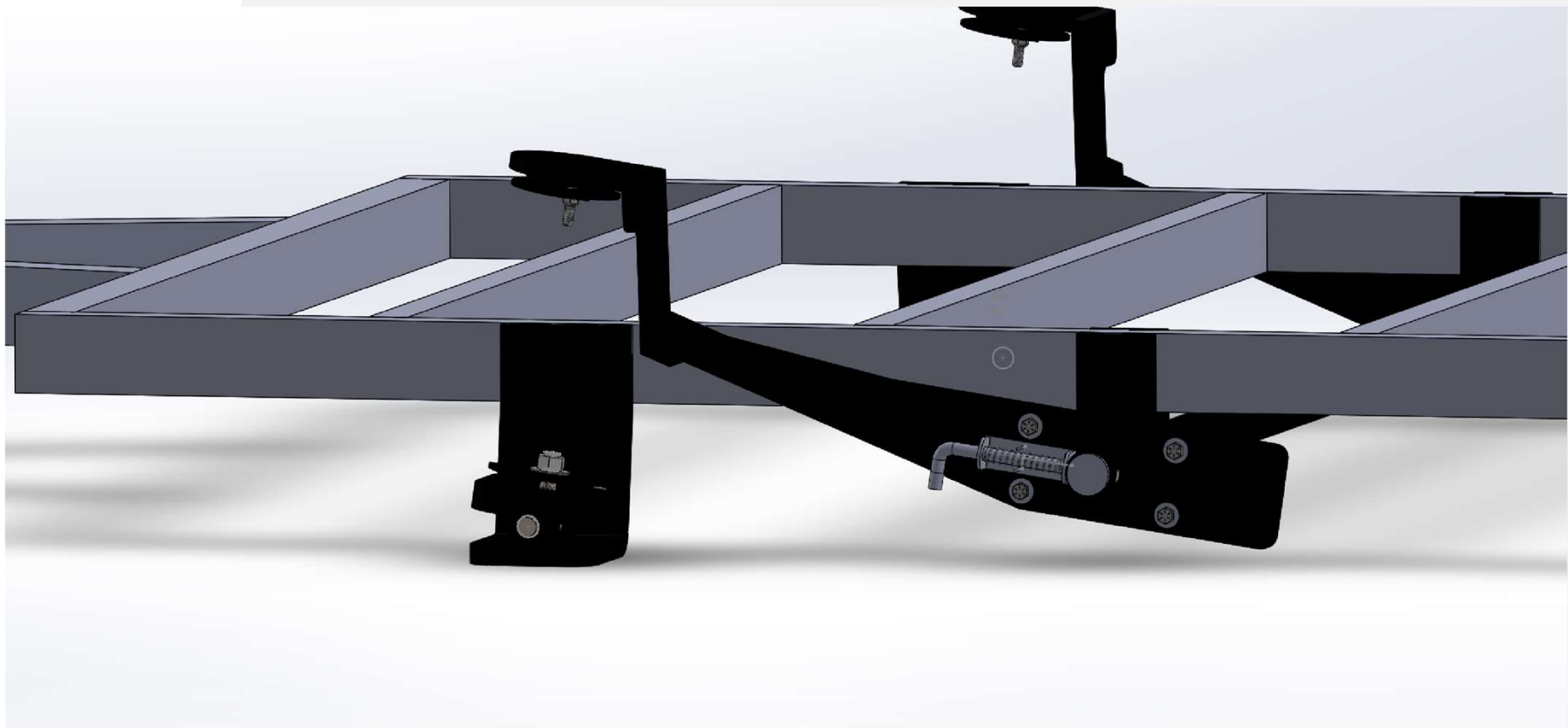


“BIG PICTURE”



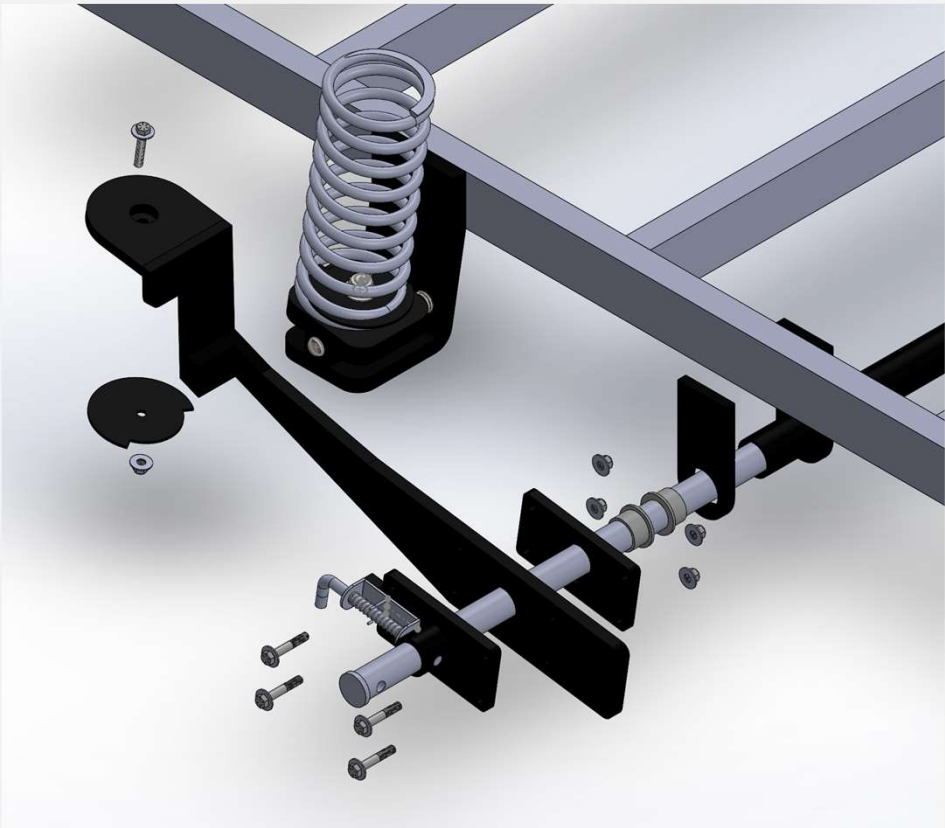
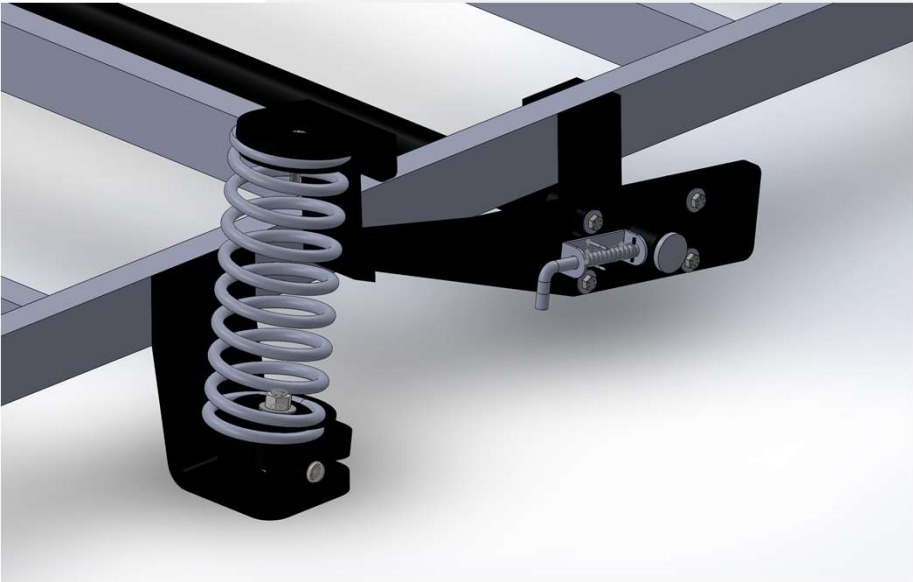


ANIMATION



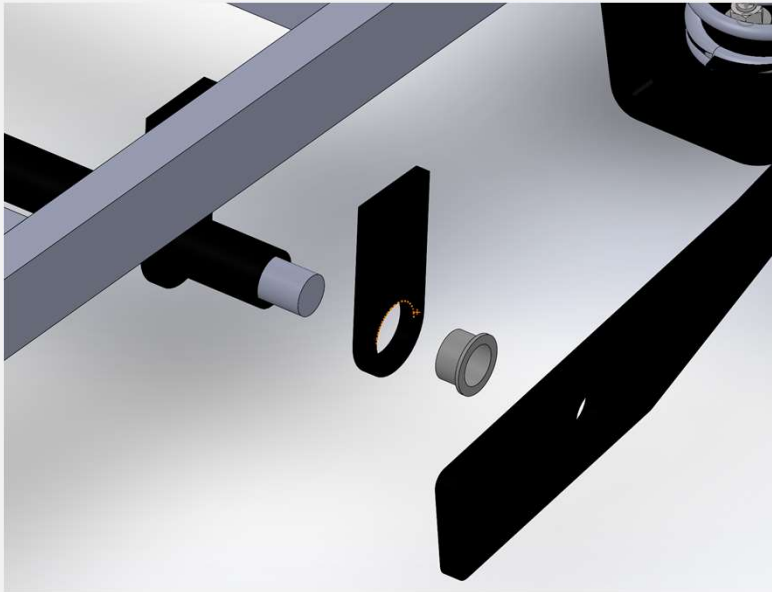
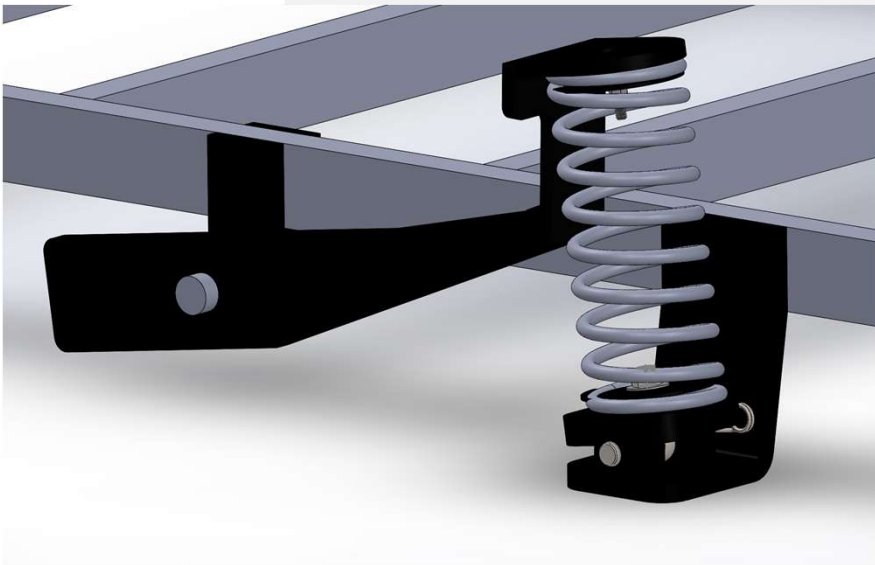


DRIVERS SIDE



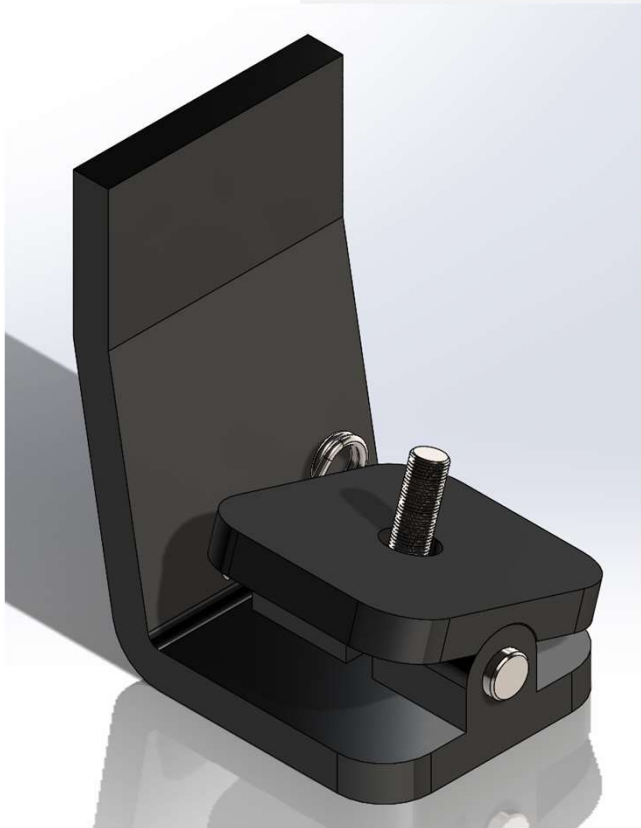


PASSENGER SIDE



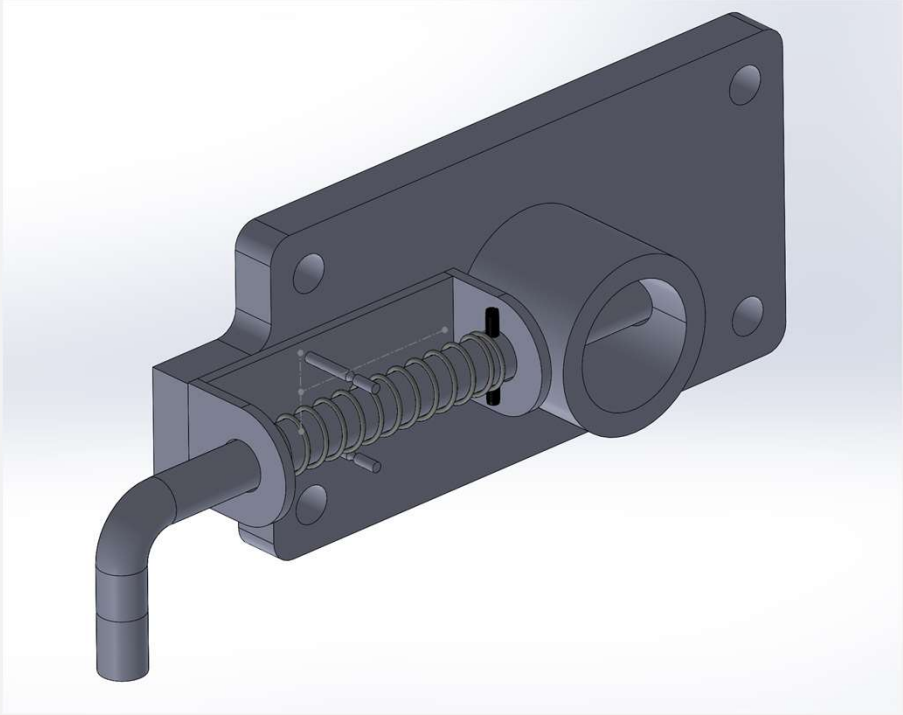
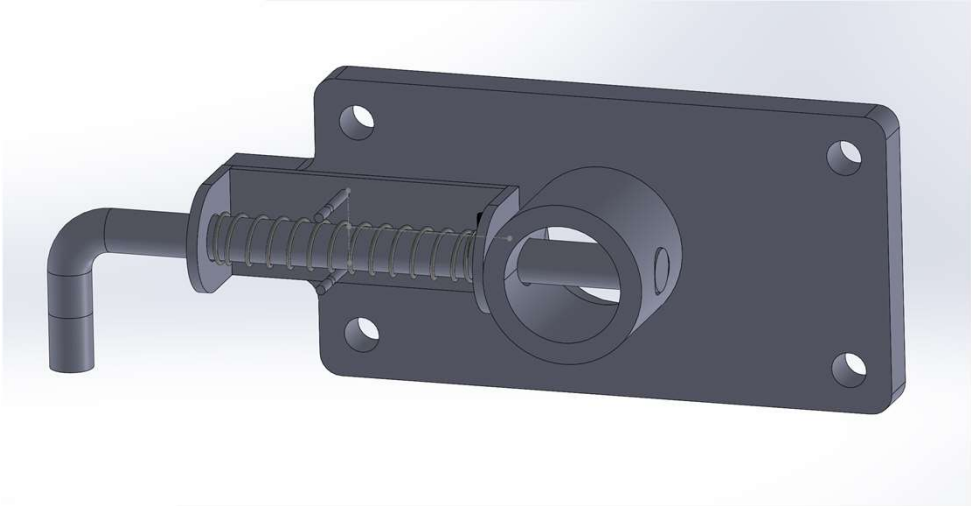


SPRING MOUNTING BRACKET

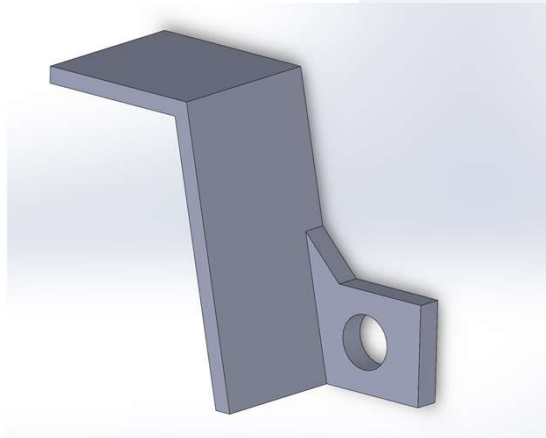




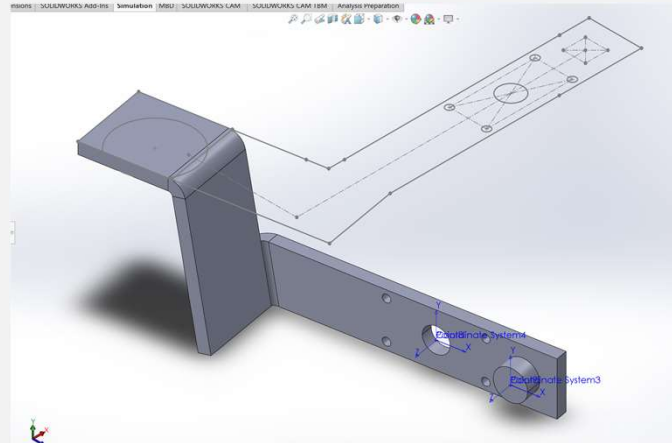
PIN LOCK BRACKET



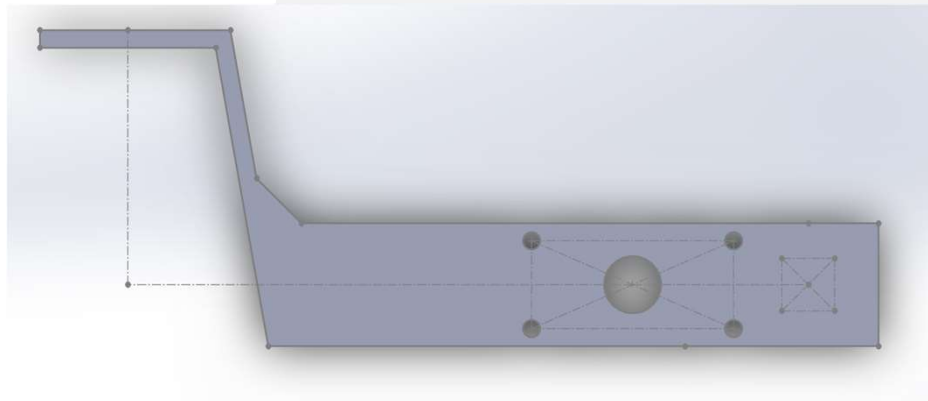
RAPID PROTOTYPING



I Too Short

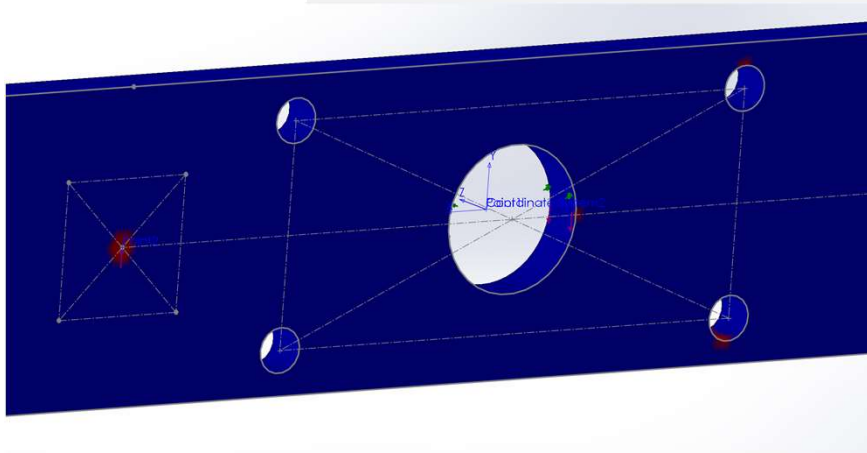


I Bent Sheet Metal

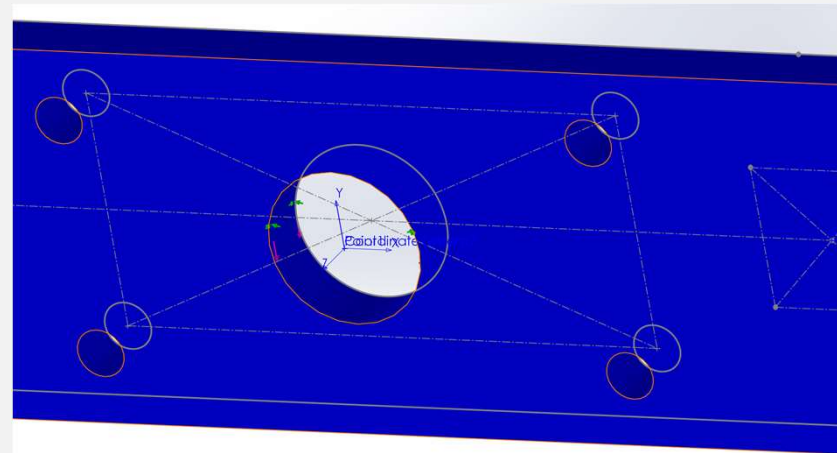


I Found Smallest Design

ROCKER ARM



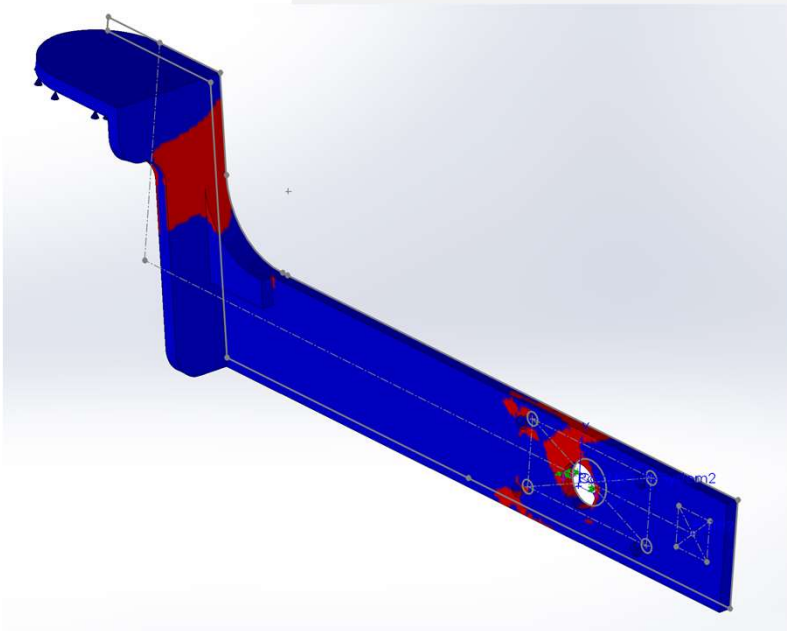
I .5" thick plate failed FS of 3
(Red Areas)



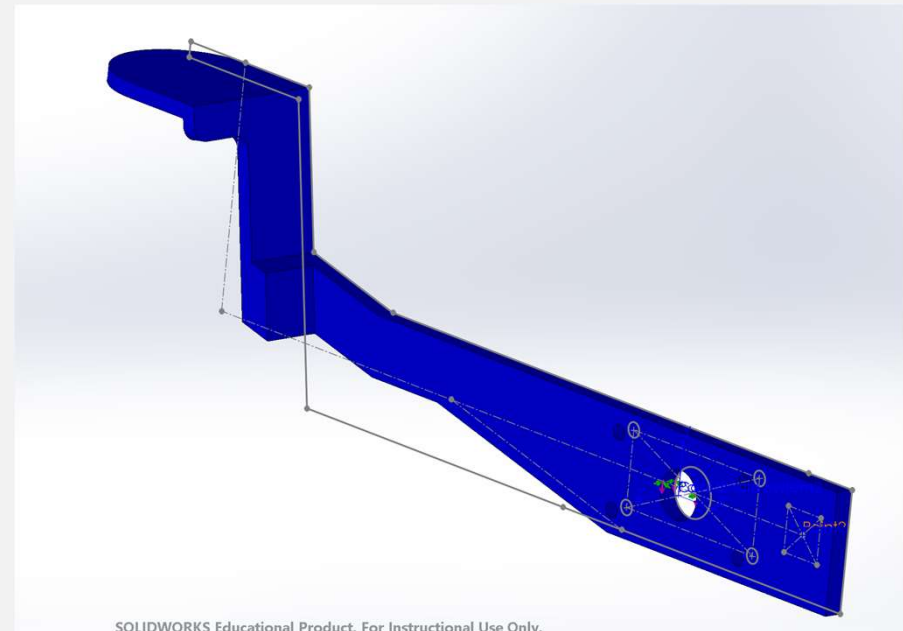
I 5/8" Plate resolves FS problems

**Blue signifies passing stress requirements with Factor of Safety of 3.0, Red signifies failing

MATERIAL SAVING



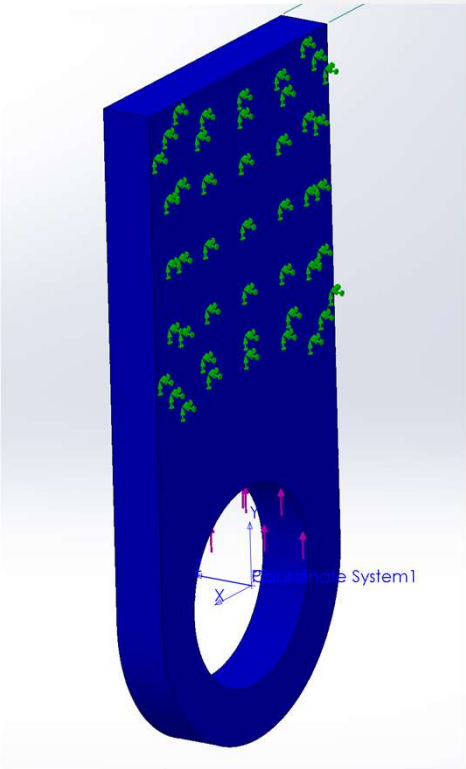
I A36 Steel fails FS of 3



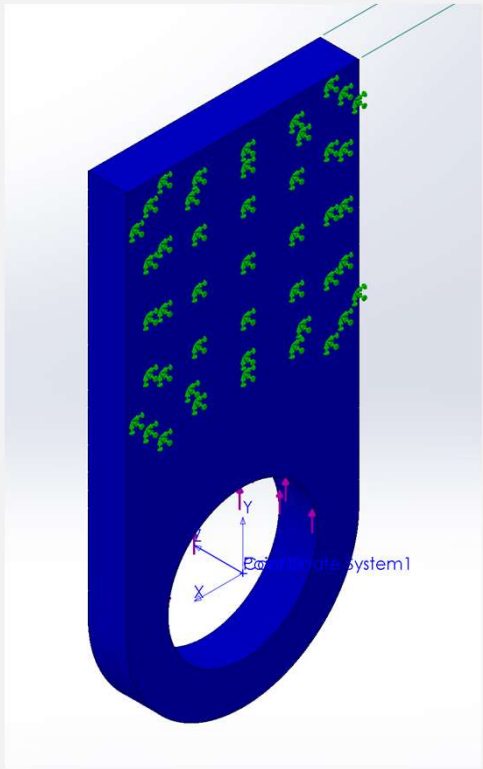
I Alloy Steel passes FS of 3 with less material



MOUNTING BRACKET



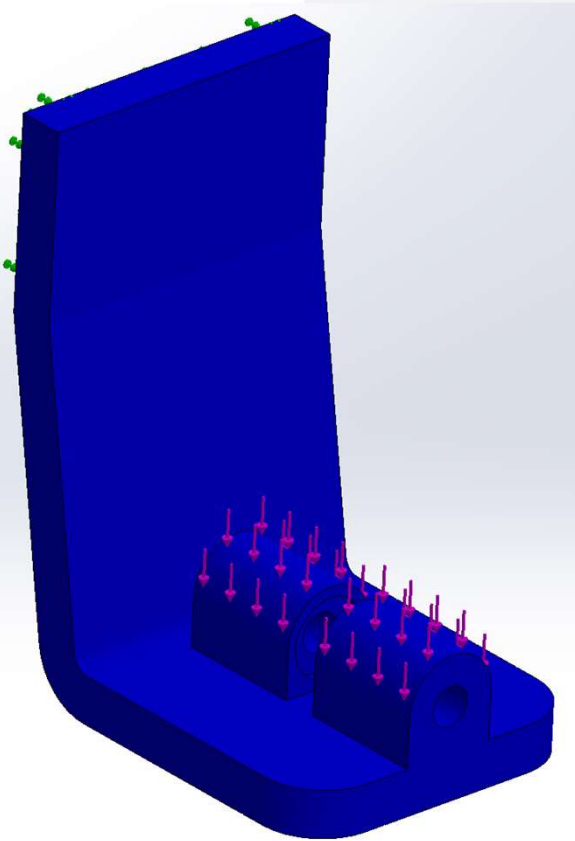
I Alloy Steel




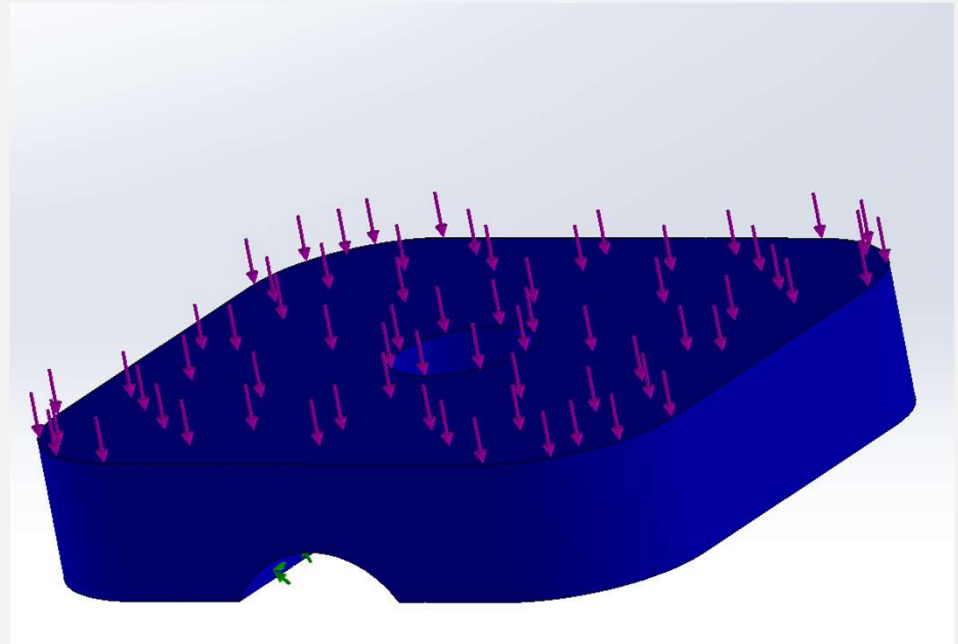
I A36 Steel



SPRING MOUNT AND HINGE PLATE



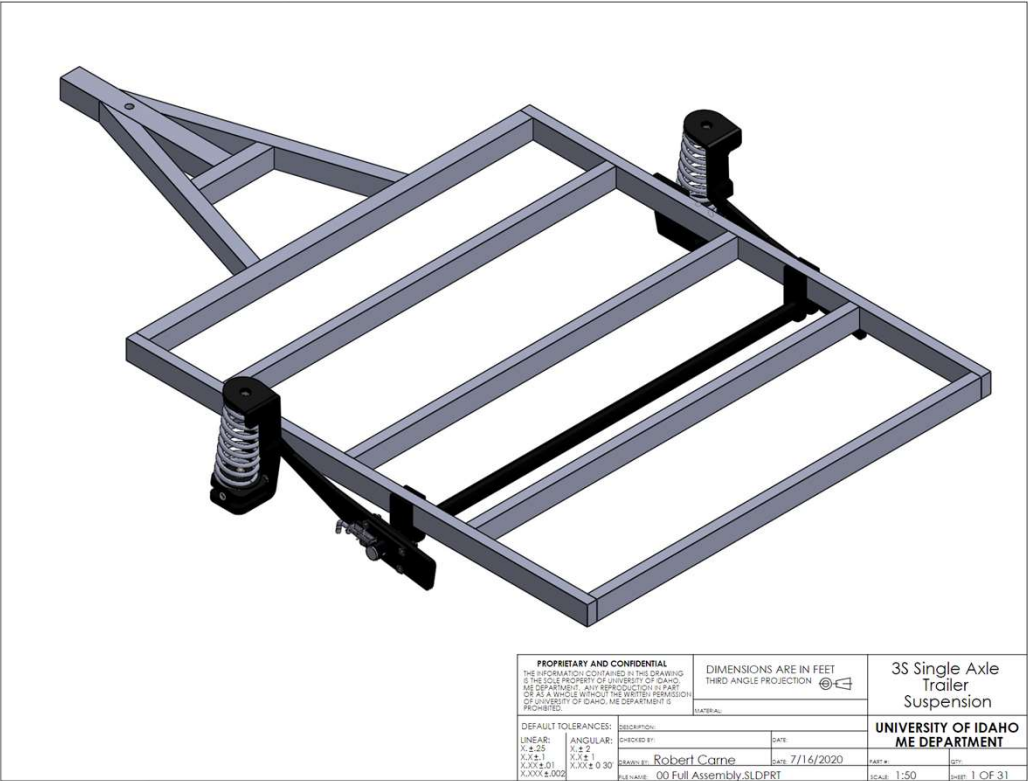
 Alloy Steel



**First test failed at 0.75" thickness, but passed at 1"



DRAWINGS



Drawing Package



BILL OF MATERIALS

Capstone Design

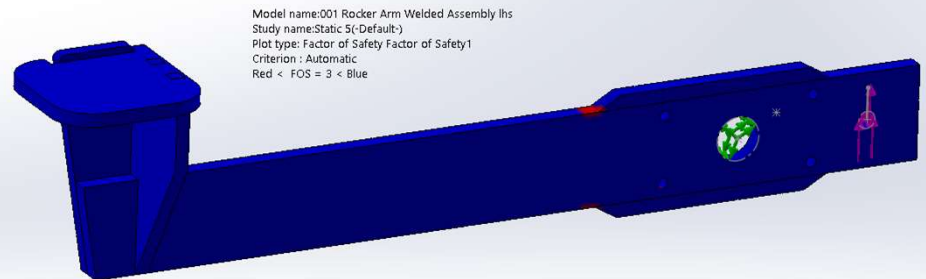
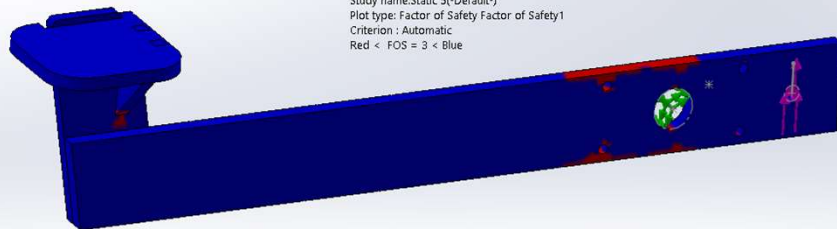
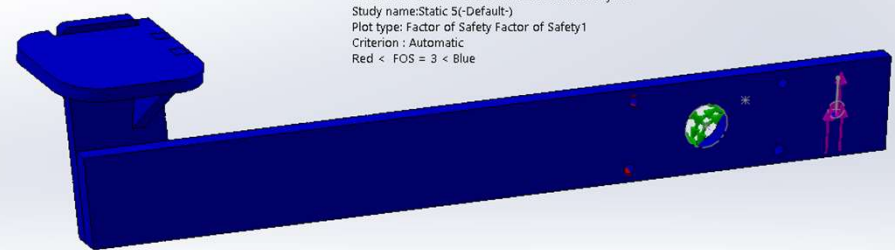
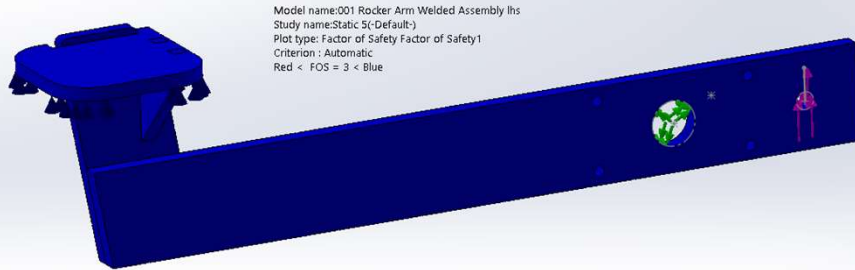
Combined BOM and Manufacturing Plan - Template

Indented Bill of Materials (BOM)				Manufacturing Plan						Cost	
Part No. or Assy No.	Description	Quantity	Make or Buy?	Source (or Fabrication Location)	Fabrication Technique (if appl.)	Is the Drawing Avail.?	Is the Material Avail.?	Who will lead (Name)?	Target Completion Date	Unit Cost (\$)	Extended Cost (\$)
Full Assy 1	Full suspension trailer W/trailer bed							Prototype			\$ 216.58
	Steel Washers - 3/8"	16	Buy	Granger Choice	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.54	\$ 8.64
	Zinc hex head screw - 3/8" - 2 1/4" long	8	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 10.02	\$ 80.16
	Nuts	8	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.21	\$ 1.68
	Bearing Spacer - Back	2	Make	UI Shop	N/A	Yes	Yes	TEAM	7/16/2020	\$ 4.50	\$ 9.00
	Century Compression Spring (73606)	2	Buy	Centruy Spring	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 51.50	\$ 103.00
	Pin Bracket - Front	2	Make	UI Shop	N/A	Yes	Yes	TEAM	7/16/2020	\$ 7.05	\$ 14.10
Subassembly 2	Spring Mount Assembly	2									\$ 136.70
	Spring mounting bracket	2	Make	UI Shop	N/A	Yes	Yes	TEAM	7/16/2020	\$ 6.40	\$ 12.80
	Spring hinge plate	2	Make	UI Shop	N/A	Yes	Yes	TEAM	7/16/2020	\$ 16.12	\$ 32.24
	Threaded Ball Joint-5/8" (60745K27)	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 40.53	\$ 81.06
	Clevis Pin-5/8" (98306A512)	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 3.70	\$ 7.40
	Cotter Pin-5/32" (96974A103)	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.67	\$ 1.34
	Steel Nut- 5/8" (90499A832)	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.30	\$ 0.60
	Steel Washer-5/8" (90107A035)	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.63	\$ 1.26
Subassembly 3	Rocker Arm Assembly	2									\$ 16.24
	Weldment (made of 3 pieces)	2	Make	UI Shop	Weld	Yes	Yes	TEAM	7/16/2020	\$ 8.12	\$ 16.24
Subassembly 4	Axle	1									\$ 235.29
	Suspension Pin	1	Make	UI Shop	N/A	Yes	Yes	TEAM	7/16/2020	\$ 2.60	\$ 2.60
	Axle - 1 3/8"	1	Buy	Trailer parts outlet	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 209.99	\$ 209.99
	Axle Cover - Sch 40 1 1/2" nom Steel pipe	1	Buy	Metals4U	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 10.70	\$ 10.70
	HL OE Flanged Sleeve Bearings - 1 5/8"	2	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 6.00	\$ 12.00
SubAssembly 5	Spring Lock	1									\$ 3.36
	Spring Steel Slotted Spring Pin- 1/8"	1	Buy	McMaster Carr	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 0.04	\$ 0.04
	Spring	1	Buy	Century Spring	Manufacturer	Yes	Yes	TEAM	7/16/2020	\$ 3.32	\$ 3.32
Total BOM Cost										\$	608

VIRTUAL TESTING: MMC @ 5/8" X3.5" ALLOY



CW from top left: 2000 # lever ratio, 3500 # lever ratio, 6000 # lever ratio, 6000# lever ratio with welded 5/8" supports



****Red areas display failure to meet 3x factor of safety in allowable stress**

MANUFACTURING PLAN

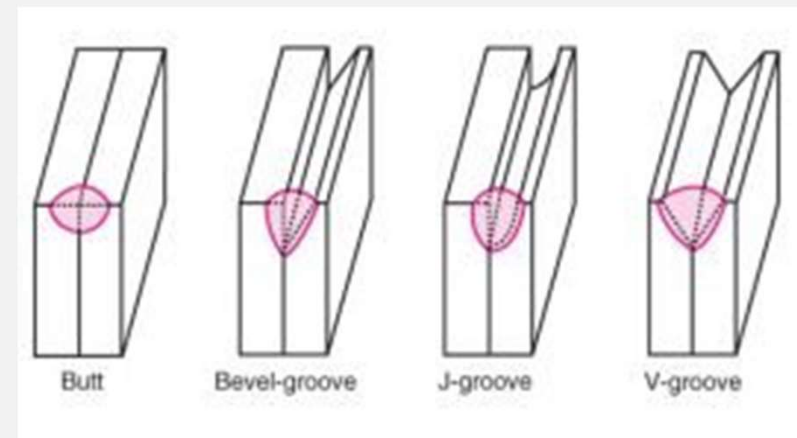
At Full Scale:

- Laser cut steel stock, bevel welds (V-groove)
- Weld mounts, subsystems to rocker arm
- Press bearings
- Mount wheel/brake hub



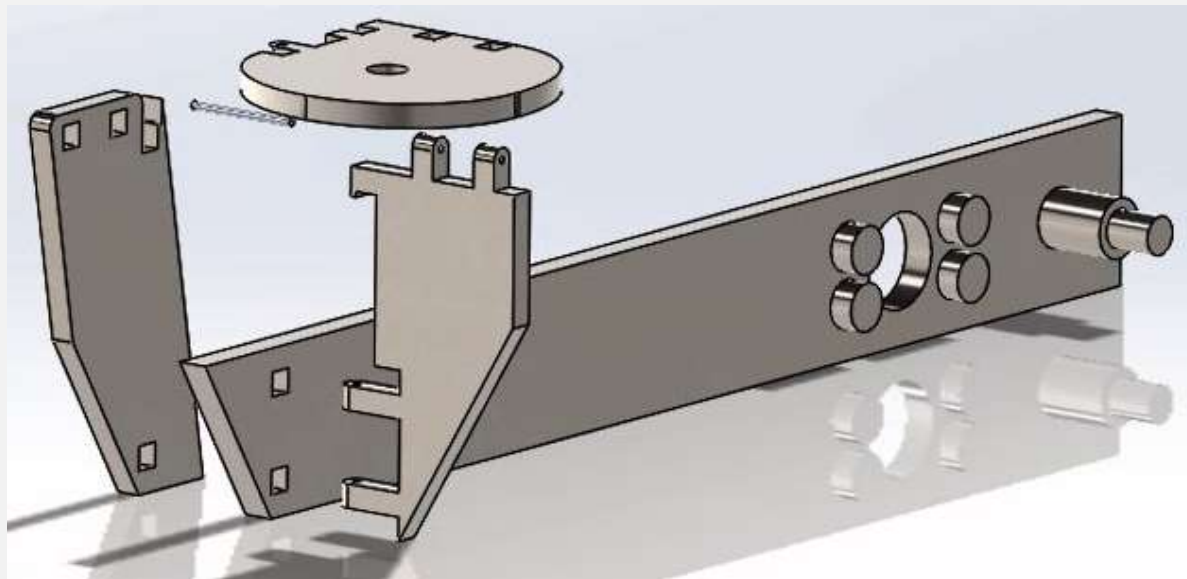
At Prototype scale:

- Purchase tires, springs and 3D filament
- 3D print 1:8 scale trailer



MAKE VS. BUY

- No similar product exists on the market, even at remote control scale.
- Selected a 2.2-inch RC tire
- Selected 1.5-inch coil spring
- Everything else to be 3D printed at 1:8 scale



COMPONENTS OF THE PROTOTYPE

- Amazon:
 - Black PLA, 1Rolls (\$29)
 - Traxxas 2479A Tires (\$23)
- Century Spring: 2x #70920S (\$14)
- UI Machine Shop Scraps: dowels, nuts
- Moscow Building Supply: misc. hardware.



LOCATION FOR MANUFACTURING

Full-Scale:

- UI Machine Shop
- Take plans to local manufacturer

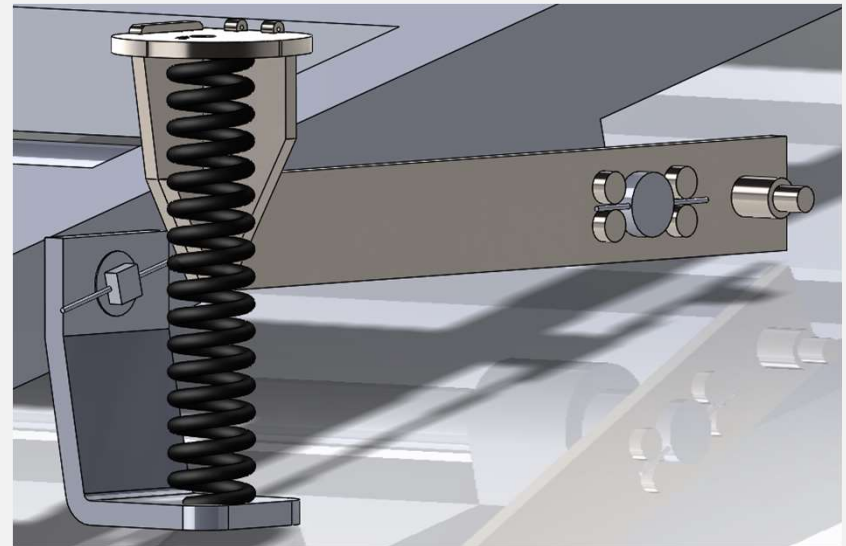
Prototype:

- UI Metrology lab
 - Sindoh 3D printers
 - Laser-cutting
 - Sanding and testing fit



FABRICATION OF PROTOTYPE COMPONENT

- 3D Print ~11 hours
 - Lever Arm
 - Trailer Frame
 - Pivoting bottom spring mount
 - Spring connections
 - Hitch
- Laser Cutter ~2 hours
 - Trailer bed
- Post-processing
 - UI Machine Shop



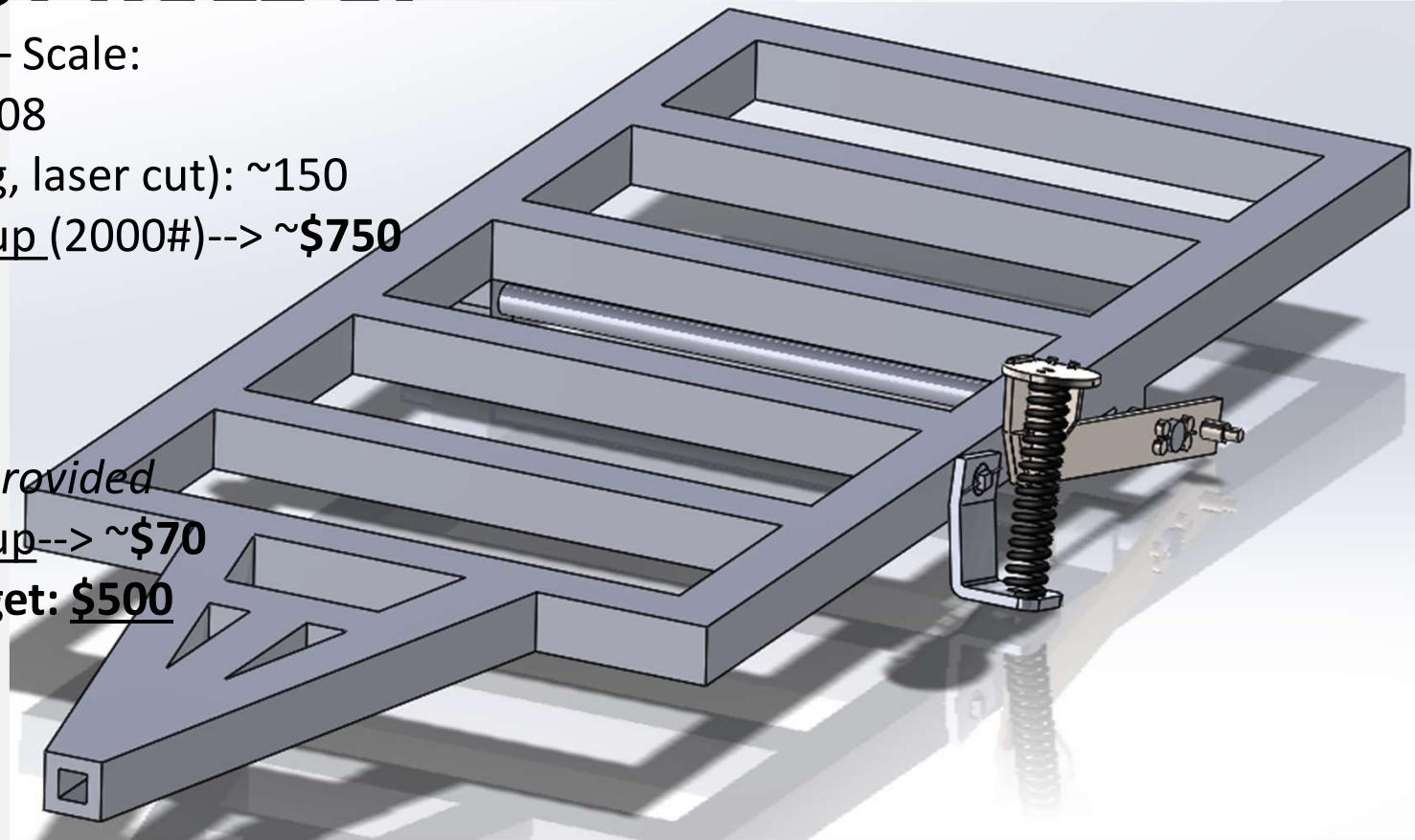
TOTAL COST ROLL-UP

2000-pound capacity Full – Scale:

- Material cost(BOM): \$608
- Manufacturing (welding, laser cut): ~150
 - Estimate cost roll-up (2000#)--> **~\$750**

Prototype:

- Material cost: \$66
- Manufacturing: \$0 --> *provided*
 - Estimate cost roll-up--> **~\$70**
 - **Allotted budget: \$500**





VALIDATION APPROACH (DVP)

Design Validation Plan & Results (DVP&R)					
Requirement	Test	Test Subject	Target Date	Result	Recommendation
Testing for best 3D filament	Online Searching	Prototype	7/6/20	Tested 7/6/202 - Approved by our mentor we decided on this black Filament.	Meets requirements for the 3D printer - no further action required.
Testing Spring Capacity and Maximum load limit for Springs 2000lb	Matlab Script	Springs	7/9/20	Tested 7/8/2020 - Spring capacity - 148 lb/in Max load Limit - 696 lbs	Meets requirements - no further action required.
Testing for Stress Concentrations 2000lb	Finite Element Analysis	Lever arm	7/9/20	Tested 7/7/2020 - There was only 1 spot that was under the FOS of 3 but it was within 2-3 FOS.	Meets requirements - no further action required.
Axle Mounting brackets must support the load of the trailer	Finite Element Analysis	Axle Mounting Brackets	7/9/20	Test 7/8/2020 - The FEA was all within the FOS of 3	Meets requirements - no further action required.
Testing Lever ratio - 2000lb	Matlab Script	Lever arm	7/9/20	Tested 7/8/2020 Lever Ratio = 4.31	This Lever ratios were the best fit to meet the requirements of our project
We want the bearings to last at the least 10K hours - 2000lb	Life Cycle Analysis	Bearings	7/9/2020	High Load Oil Embedded flange sleeve bearings - Manufacturers provided this information	Meets requirements - no further action required.

VALIDATION APPROACH (DVP)



We want the bearings to last at the least 10K hours - 3500lb	Life Cycle Analysis	Bearings	7/9/20	Oil Embedded flange sleeve bearings - Manufacturers provided this information	Meets requirements - no further action required.
We want the bearings to last at the least 10K hours - 6000lb	Life Cycle Analysis	Bearings	7/9/20	Oil Embedded flange sleeve bearings - Manufacturers provided this information	Meets requirements - no further action required.
Coil Spring Mounting Brackets need to be able to withstand the force put on the suspension system - 2000lb	Finite Element Method	Coil Spring Mounting Brackets	7/10/20	Tested 7/14/2020 - The FEA was all within the FOS of 3	Meets requirements - no further action required.
Testing Lever ratio - 3500lb	Matlab Script	Lever arm	7/15/20	Tested 7/14/2020 Lever Ratio = 1.7	Meets requirements - no further action required.
Testing Lever ratio - 6000lb	Matlab Script	Lever arm	7/15/20	Tested 7/14/2020 Lever Ratio = 2.75	Meets requirements - no further action required.
Testing Spring Capacity and Maximum load limit for Springs 3500lb	Matlab Script	Springs	7/15/20	Tested 7/15/2020 - Spring capacity - 329 lb/in Max load Limit - 1764 lbs	Meets requirements - no further action required.
Testing Spring Capacity and Maximum load limit for Springs 6000lb	Matlab Script	Springs	7/15/20	Tested 7/15/2020 - Spring capacity - 281.6 lb/in Max load Limit - 1090.16 lbs	Meets requirements - no further action required.
Testing for Stress Concentrations 3500lb	Finite Element Analysis	Lever arm	7/20/20	In-progress	In-progress
Testing for Stress Concentrations 6000lb	Finite Element Analysis	Lever arm	7/20/20	In-progress	In-progress
Coil Spring Mounting Brackets need to be able to withstand the force put on the suspension system - 3500lb	Finite Element Method	Coil Spring Mounting Brackets	7/20/20	In-progress	In-progress
Coil Spring Mounting Brackets need to be able to withstand the force put on the suspension system - 6000lb	Finite Element Method	Coil Spring Mounting Brackets	7/20/20	In-progress	In-progress
Full assembly analysis	Finite Element Analysis/Production ready drawings	Prototype	7/30/20	In-progress	In-progress

POTENTIAL RISKS

- Small Parts in Prototype Hard to Print
- Bearings – May not be bought or printed
- How to Mount the Wheels and Tires
- Drawing getting rejected by machinist





**THANK YOU,
QUESTIONS?**