NFPA Fluid Power Vehicle Challenge

NFPA
Education and Technology Foundation

Final Presentation
West Virginia University Institute of Technology
Dr. Yogen Panta
4/15/2020

WV TECH

TEAM INTRODUCTION

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AGENDA

- Summary of Midway Presentation
- Design Objectives
- Vehicle Design
- Assemblies and Subassemblies
- Cost and Time Estimates
- Finite Element Analysis
- Hydraulic Components
- Gear Ratio and Calculations
- Wrap Up
- Acknowledgements

MIDWAY SUMMARY

- **At midway the decision matrices were completed, material purchased (awaiting arrival) --- Team was at Stage 1.**

- **Future Work consisted of completing CAD modeling, FEA, perform calculations based on working model, begin frame fabrication, test and evaluate vehicle, perform time trials, ambassador to local schools to promote fluid power interest.**

DESIGN OBJECTIVES

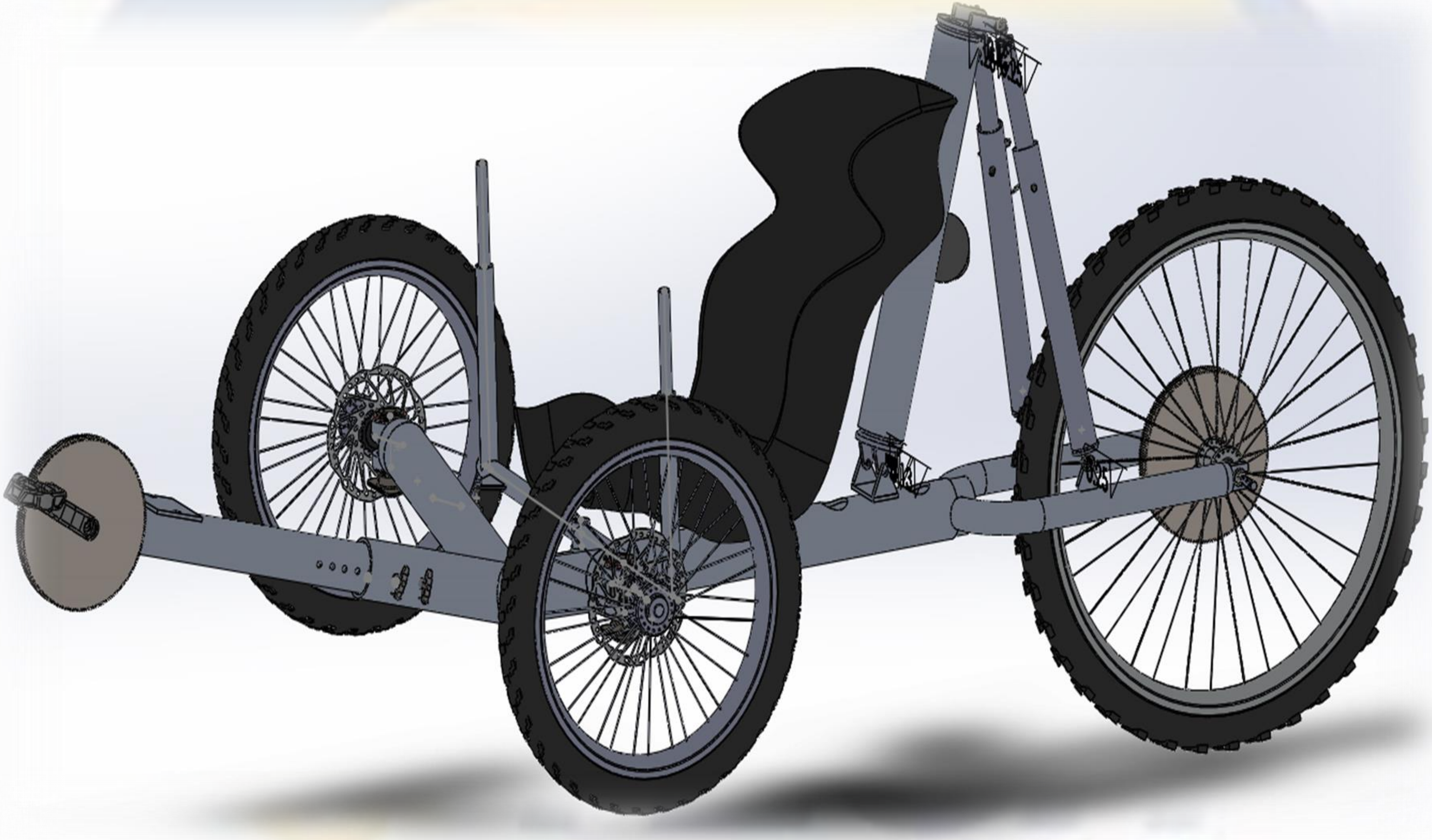
- Produce a competitive vehicle that is lightweight, under budget, and more efficient than previous designs.
- Vehicle must be roadworthy and intended for a variety of users regardless of sex, height, or weight.
- Vehicle must be ergonomic with adjustability for rider height and reach.
- Vehicle must operate within the capability of rider input (i.e. pedaling RPMs).
- Vehicle must be able to negotiate curves, obstacles, and small hills.
- Safety designed into the hydraulic circuit to protect the rider from over pressurization of hydraulic components.
- Vehicle must have an active braking system and a regenerative braking system.
- Vehicle design must fall within the manufacturing capabilities of WVUIT's engineering laboratories.

VEHICLE DESIGN

- **Decision Matrices culminated in a three-wheel design (discussed at mid-way review)**
  - **Include an integrated fluid reservoir into the frame of the vehicle**
  - **Route hydraulic hoses through the body to streamline design.**
  - **Lightweight design to maximize component efficiency.**
  - **Low center of gravity to negate skidding in turns (problematic feature of three-wheel tadpole designs).**

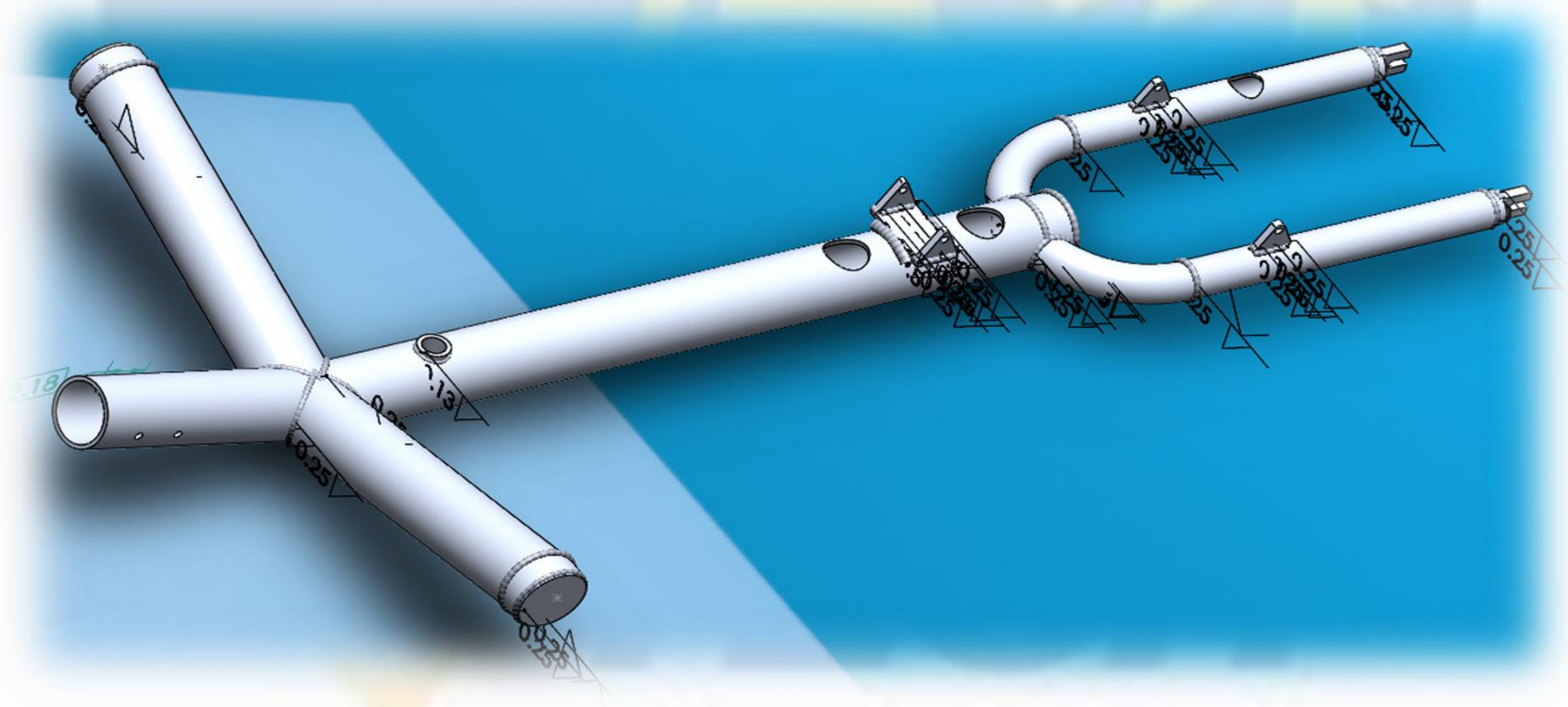
ASSEMBLIES AND SUBASSEMBLIES

ROLLING CHASIS



BASIC FRAME WELDMENTS

- **Welded segments of frame assembly**
- **Frame consists of varying sizes of schedule 40 pipe made of 6061 T-6 aluminum**
- **Holes in frame are for immergence/emergence of hydraulic hoses**



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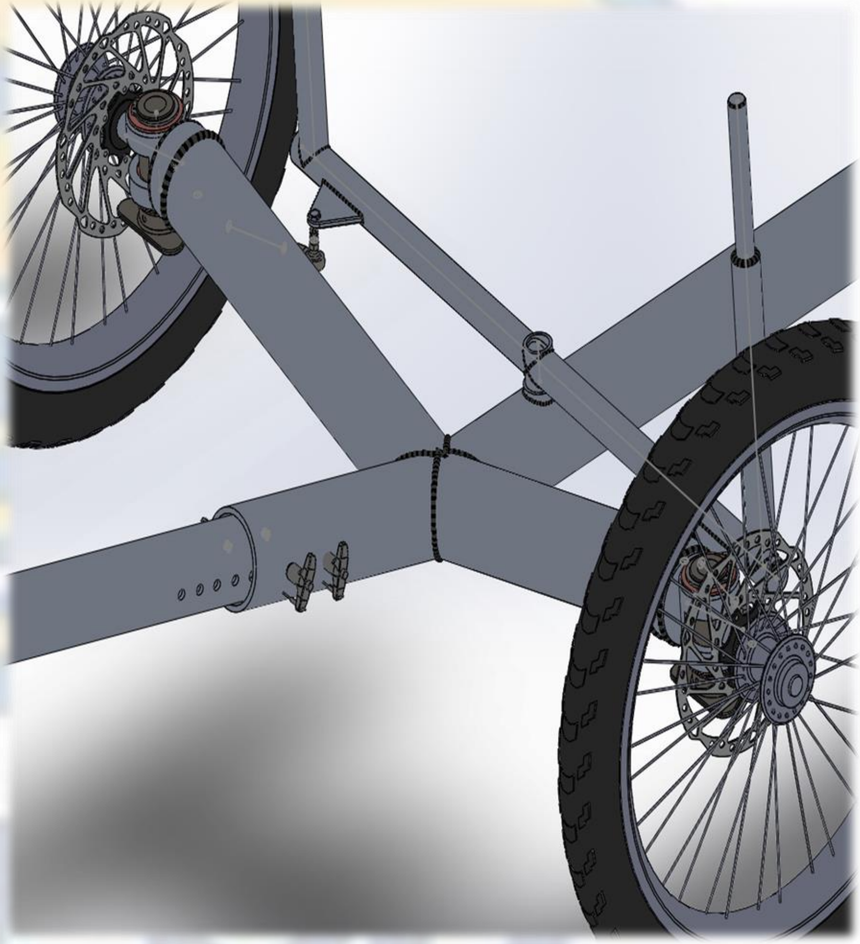
ADJUSTABLE HYDRAULIC TANK/SEAT SUPPORT

- **Adjustability was integral to the concept of fitting all types of riders.**
- **Hydraulic tank is hinged so it can be reclined from 90 degrees to 120 degrees.**
- **Quick pinned telescoping gussets allow for easy transition with adjustment by the inch.**
- **All hinges are cushioned with nylon washers to reduce vibration.**
- **Ball joint connectors on the compound angle sections of the gussets**
- **Tank volume = .96 gallon**

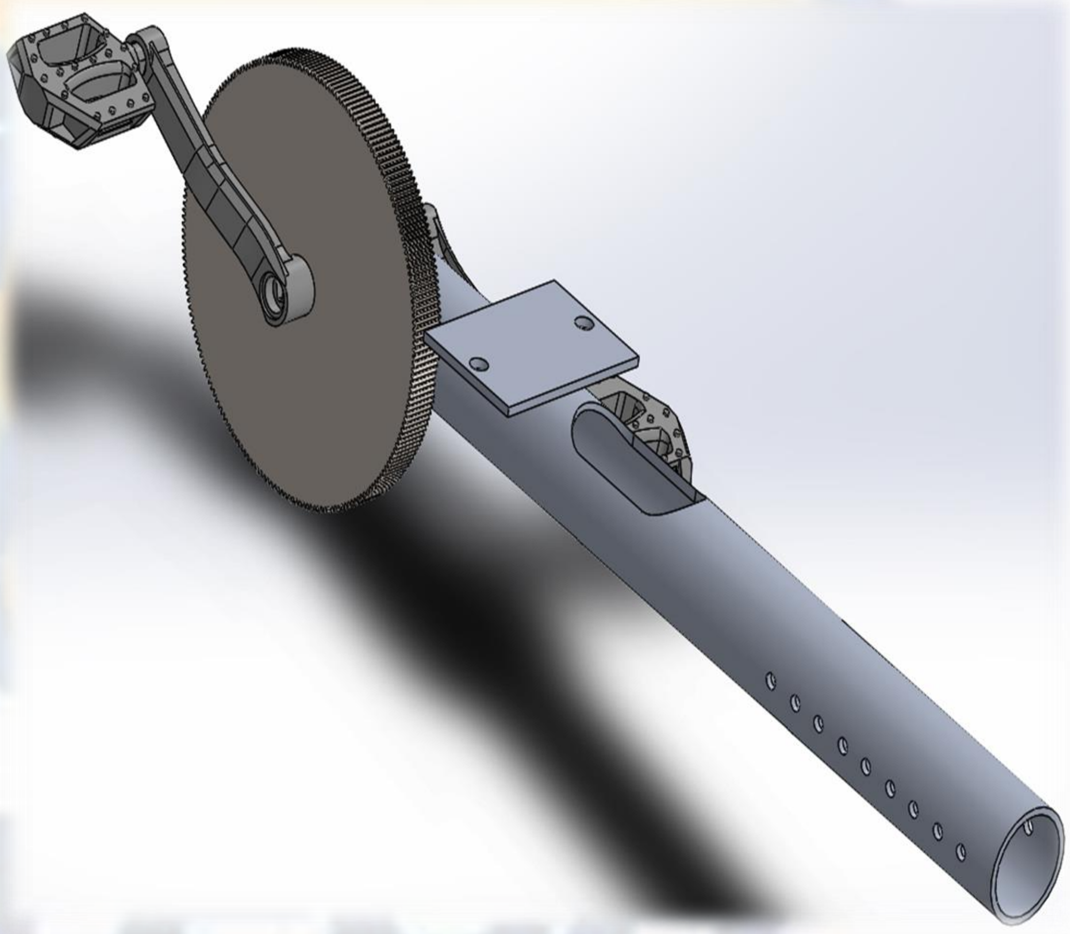
ADJUSTABLE FRONT PEDALS

- Once again adjustability being key, the front pedal assembly is fully adjustable using quick pin connections.
- 5 adjustability settings for 10” of extension or retractation.
- Dual quick pins provide leverage



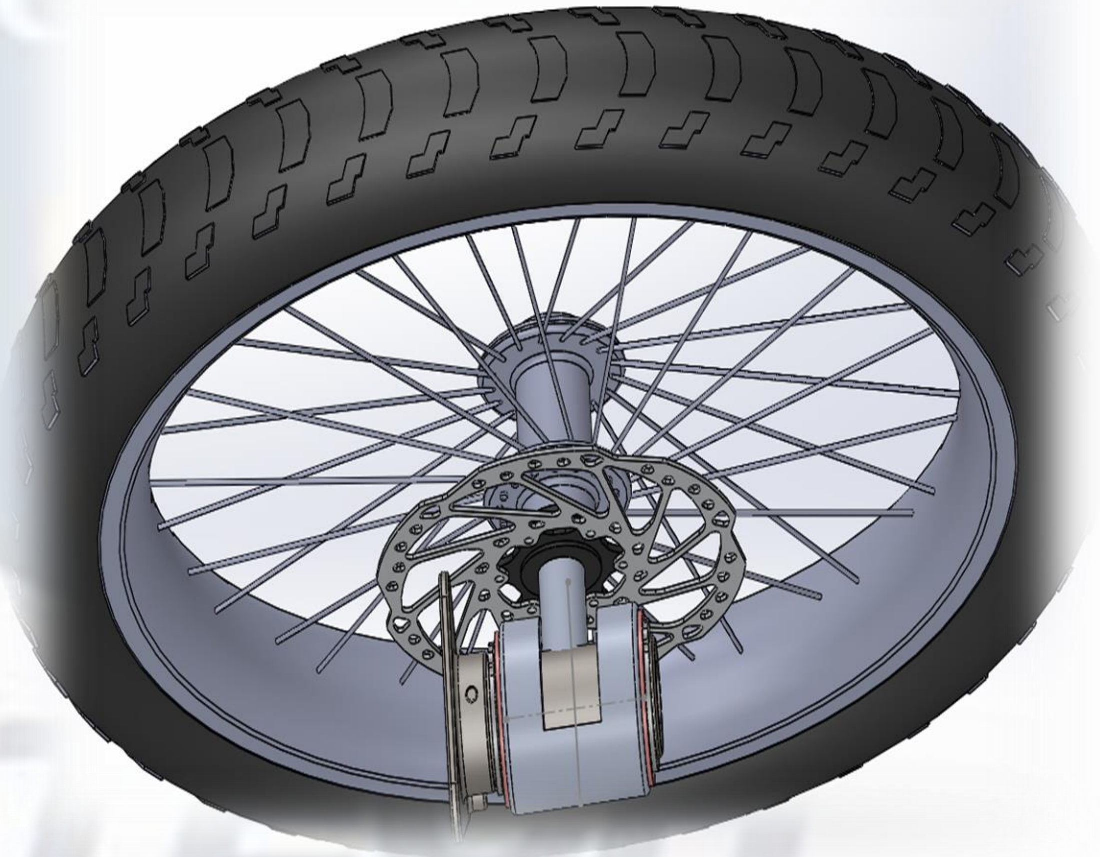
FRONT PEDAL ASSEMBLY

- 200 tooth 10" diameter pump drive gear.
- Pedal assembly
- Pump mount



FRONT WHEEL ASSEMBLY

- **Wheel assembly consists 20" tire and wheel, disk brake, disk brake caliber, axle, and hub assembly.**

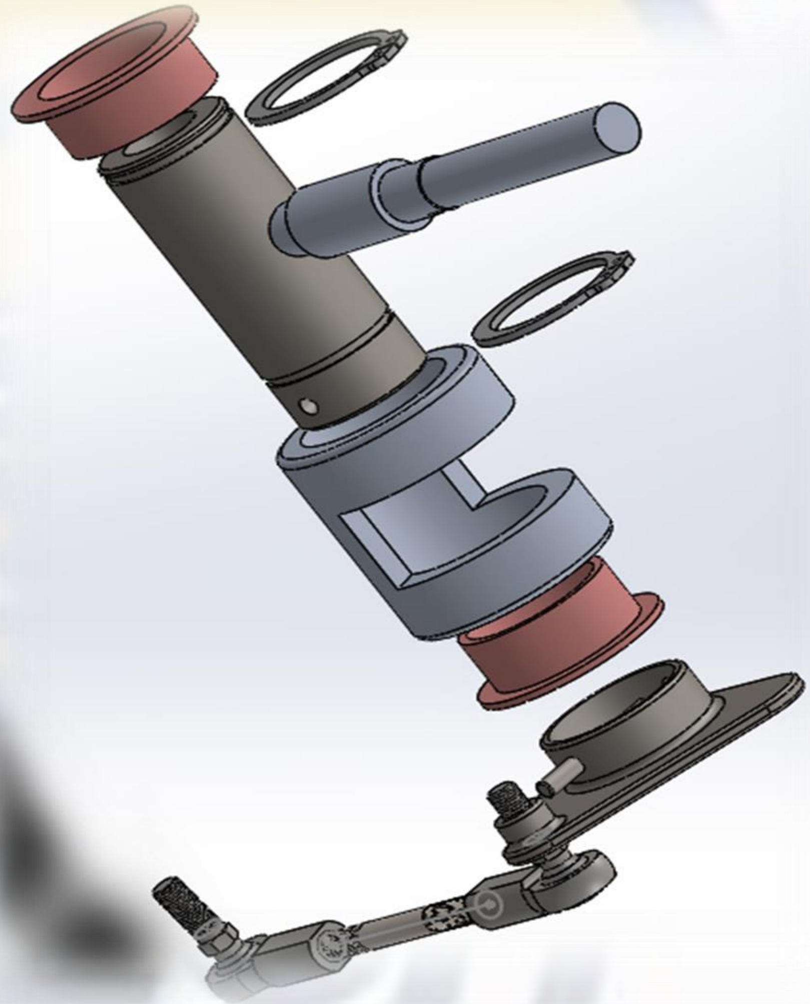


REAR TIRE ASSEMBLY

- 26” rear tire
- Large 200 tooth 10” diameter rear drive gear pressed to axle
- Free spinning rear assembly on integrated axle bearings

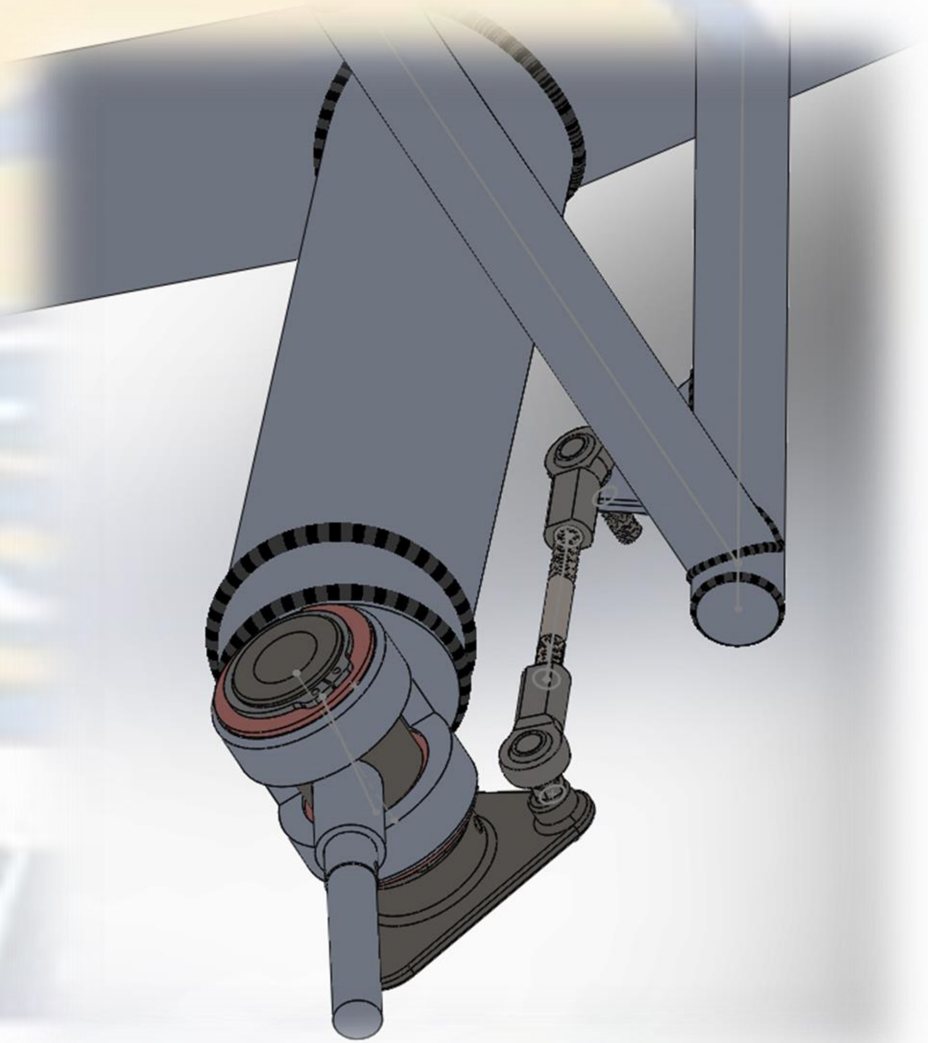
HUB ASSEMBLY BREAKDOWN

- **Oilite bushings provide lubricity to the main pin.**
- **Pivot pin is retained by upper and lower snap rings.**
- **Steering tab is retained by a press pin**



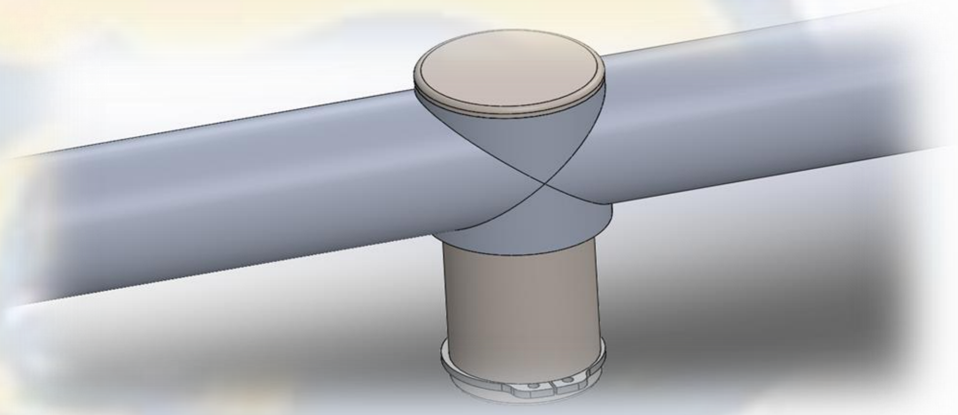
STEERING LINKAGE

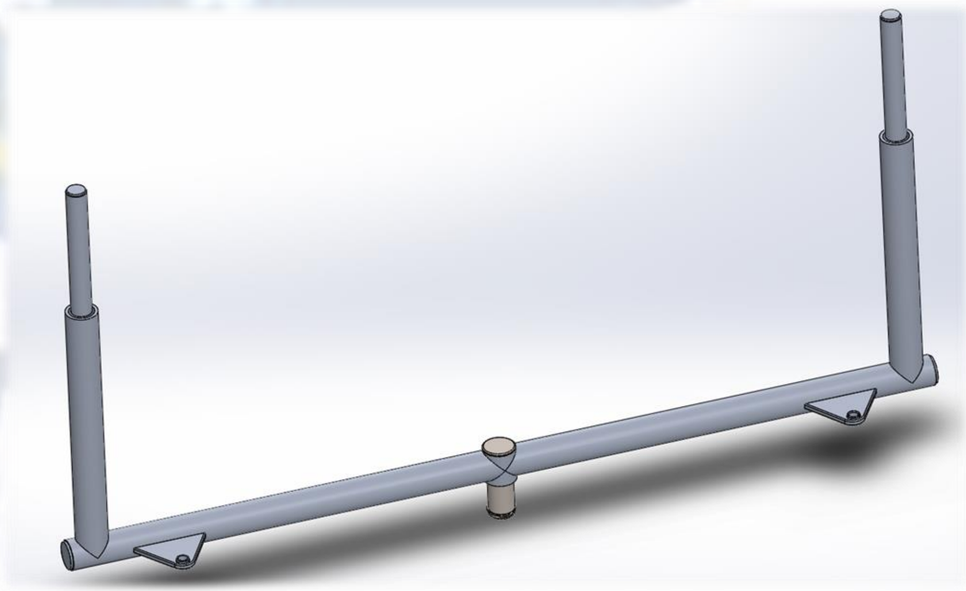
- **Handlebar is on a central pivot to the frame centerline.**
- **Tie rod linkage connects handlebar to hub assembly**



STEERING ASSEMBLY

- Steering assembly works on a central pivot pin
- Pin is retained inside frame by a snap ring
- Pin is steel
- Handle bar is schedule 40 1 and 1.5 pipe





COST AND TIME ESTIMATES

FABRICATION TIME ESTIMATE

MACHINE	Material Amount	Rate	Setup Time (L)	Time	Machine Time (M)	Rate	Cleanup Time (L)	Rate	Total Amount
Paint Frame	(purchased sep)		120 min	.16 min			10 min	.2	21.2
Component Welding	(purchased sep)		120 min	.20 min	3600 min	.60/min	15 min	.2	243.0
WaterJet (drive gears) CAD	(purchased sep)		15 min	.40 min					6.00
WaterJet (drive gears) Work	(purchased sep)				60 min	.4/min			24.00
Fabricate Pump Mount	(purchased sep)				120 min	.52/min	15 min	.2	65.40
Fabricate Motor Mount	(purchased sep)				120 min	.52/min	15 min	.2	65.40
Fabricate Accumulator Mount	(purchased sep)				60 min	.52/min	15 min	.2	34.20
Waterjet (mount tabs) CAD	(purchased sep)		15 min	.40 min					6.00
Waterjet (mount tabs) Work	(purchased sep)				30 min	.4/min			12.0
Metal cutting (Saw Work)	(purchased sep)				30 min	.16/min	5 min	.2	5.8
Machine Hub Housing	(purchased sep)				120 min	.52/min	5 min	.2	63.4
Machine Hub Axles	(purchased sep)				120 min	.52/min	5 min	.2	63.4
Machine Hub Bushings	(purchased sep)				60 min	.52/min	5 min	.2	32.2
Machine Wheel Axles	(purchased sep)				60 min	.52/min	5 min	.2	32.2
Assembly of Parts	(purchased sep)		120 min	.16 min					19.2
Fabrication of Seat	(purchased sep)				180 min	.52/min	5 min	.2	94.6
Total									**788.00**

COST TO MANUFACTURE

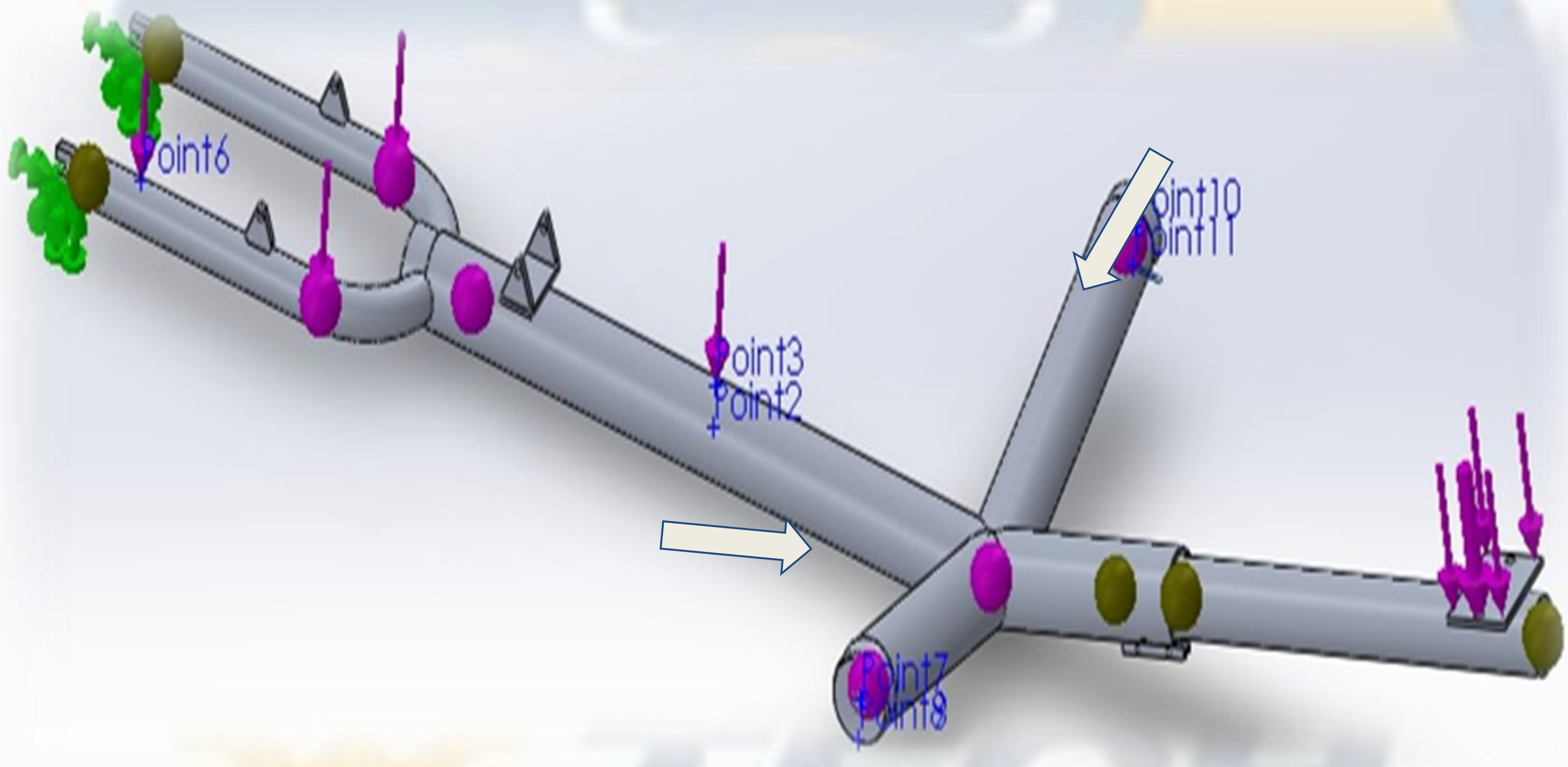
SunSource Components	$1974.00
Seat (scavenged from BAJA buggy)	$0.00
Cannibalization Bicycle	$248.00
Frame Materials	$386.65
Fabrication Cost	$788.00
Total to Date	**$3396.65**

FINITE ELEMENT ANALYSIS

FINITE ELEMENT ANALYSIS
FIXED GEOMETRY & LOADS

WRONG !

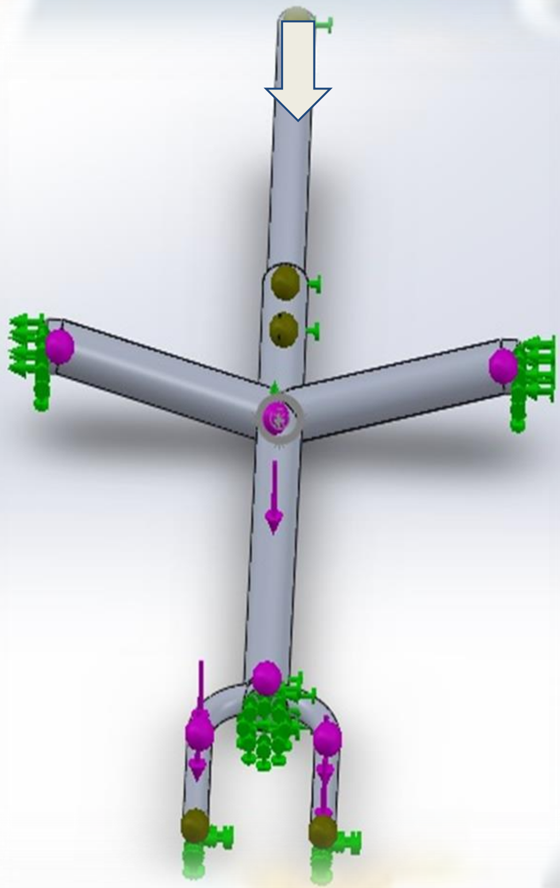
MISSING HUB ASSEMBLY FIXTURES

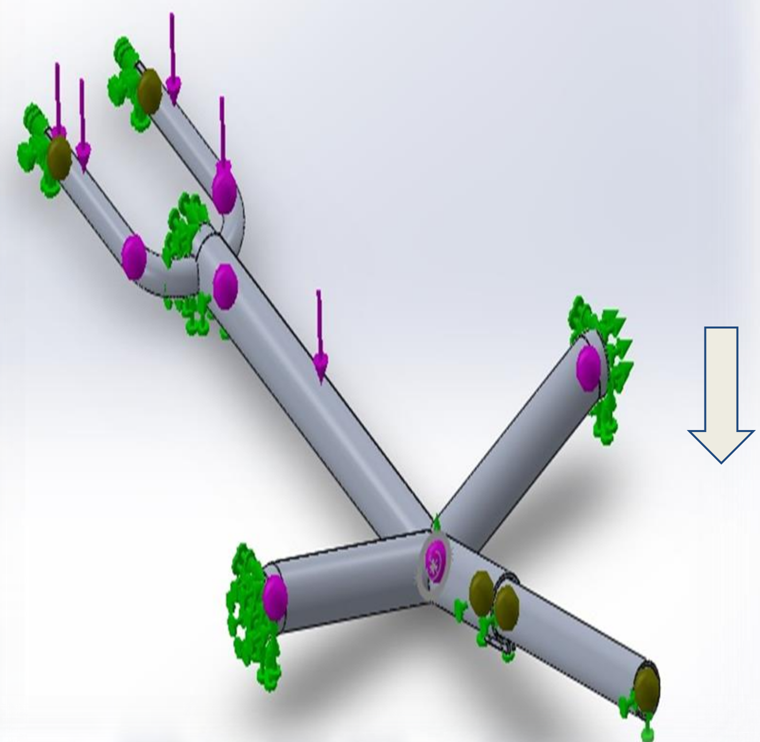


FINITE ELEMENT ANALYSIS FIXED GEOMETRY & LOADS

WRONG !

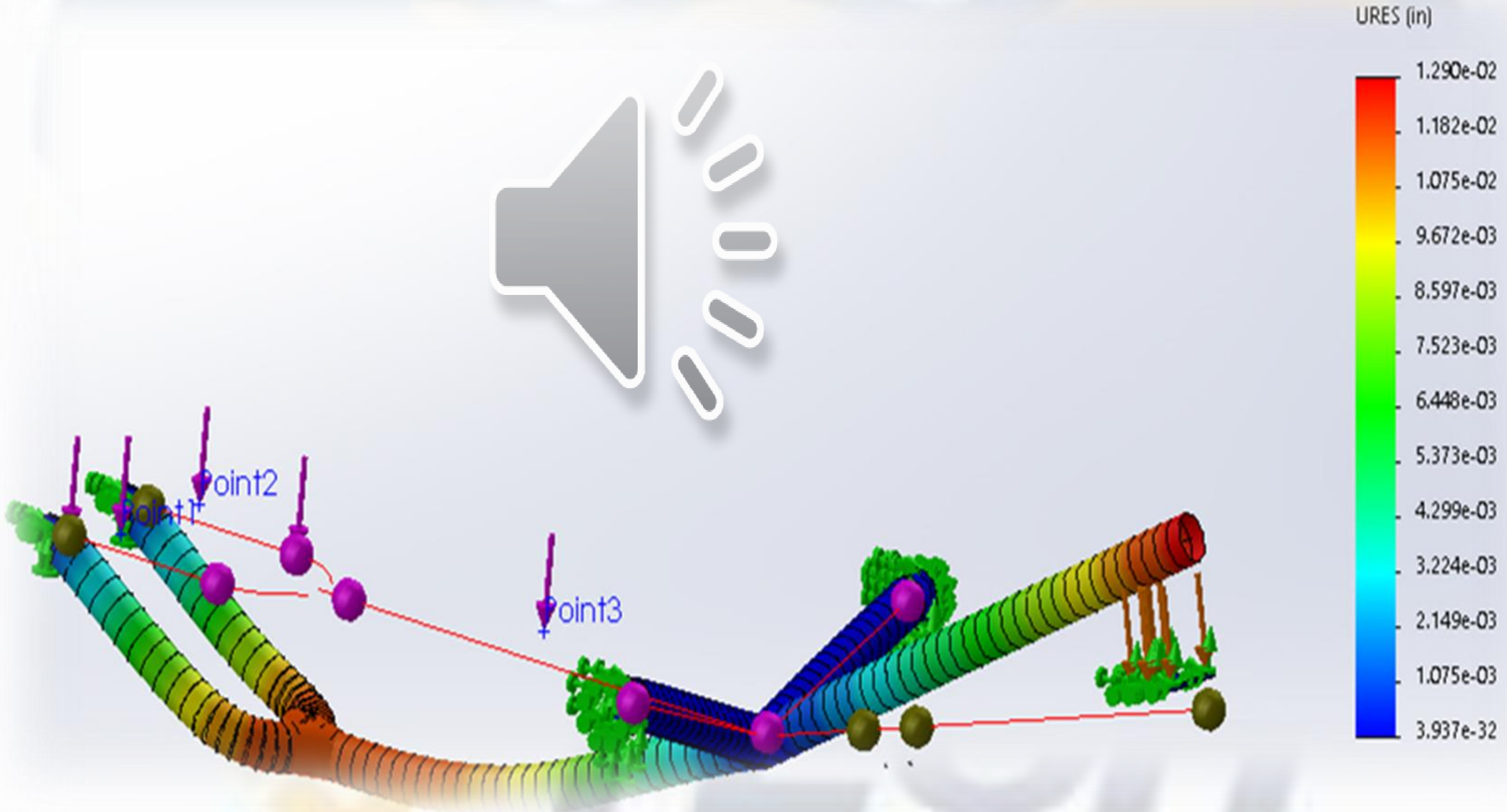
MISSING THE 5 lb. LOAD
FOR PEDALS and PUMP





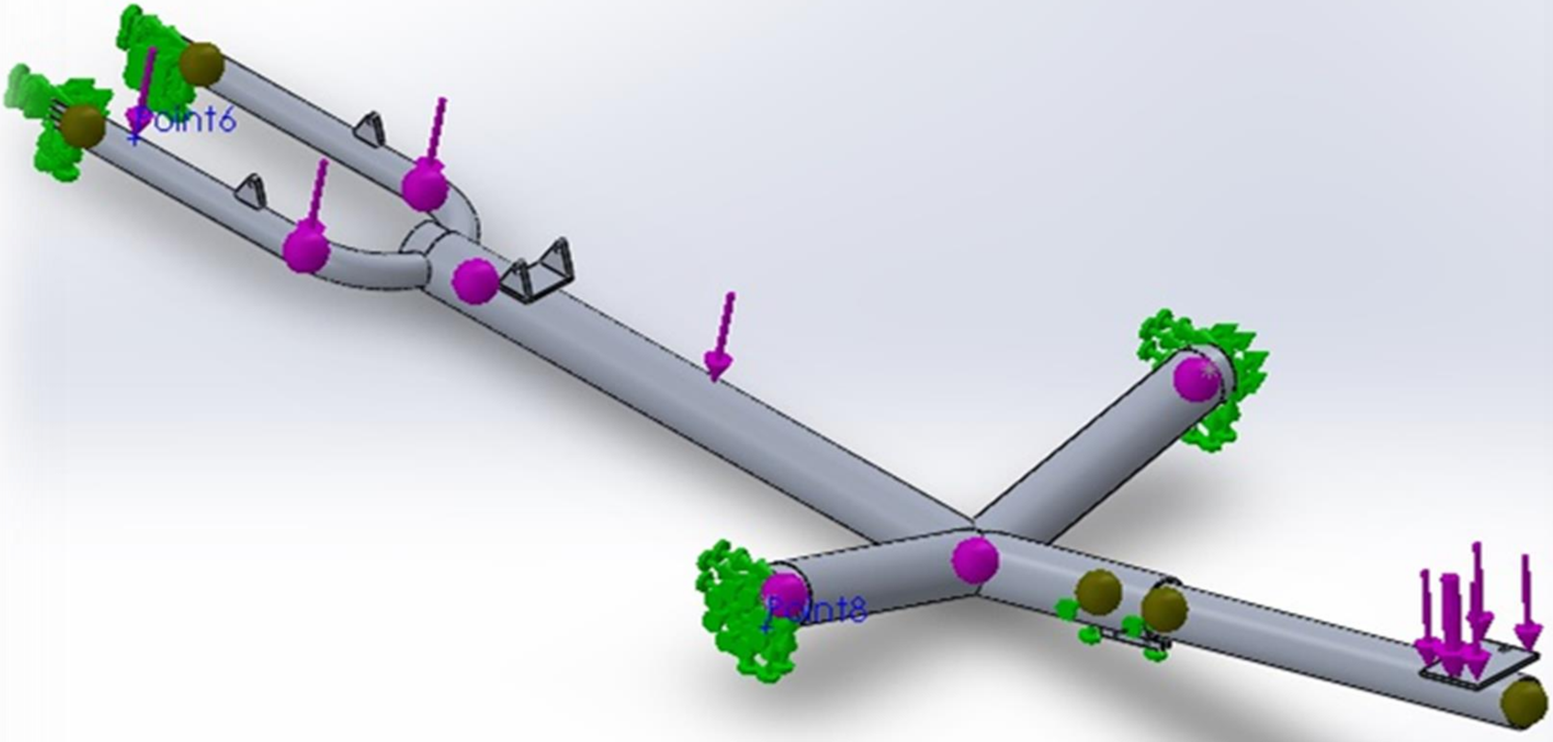
FINITE ELEMENT ANALYSIS RESULTS
LOAD = 150 [LB]

Displacement - WRONG



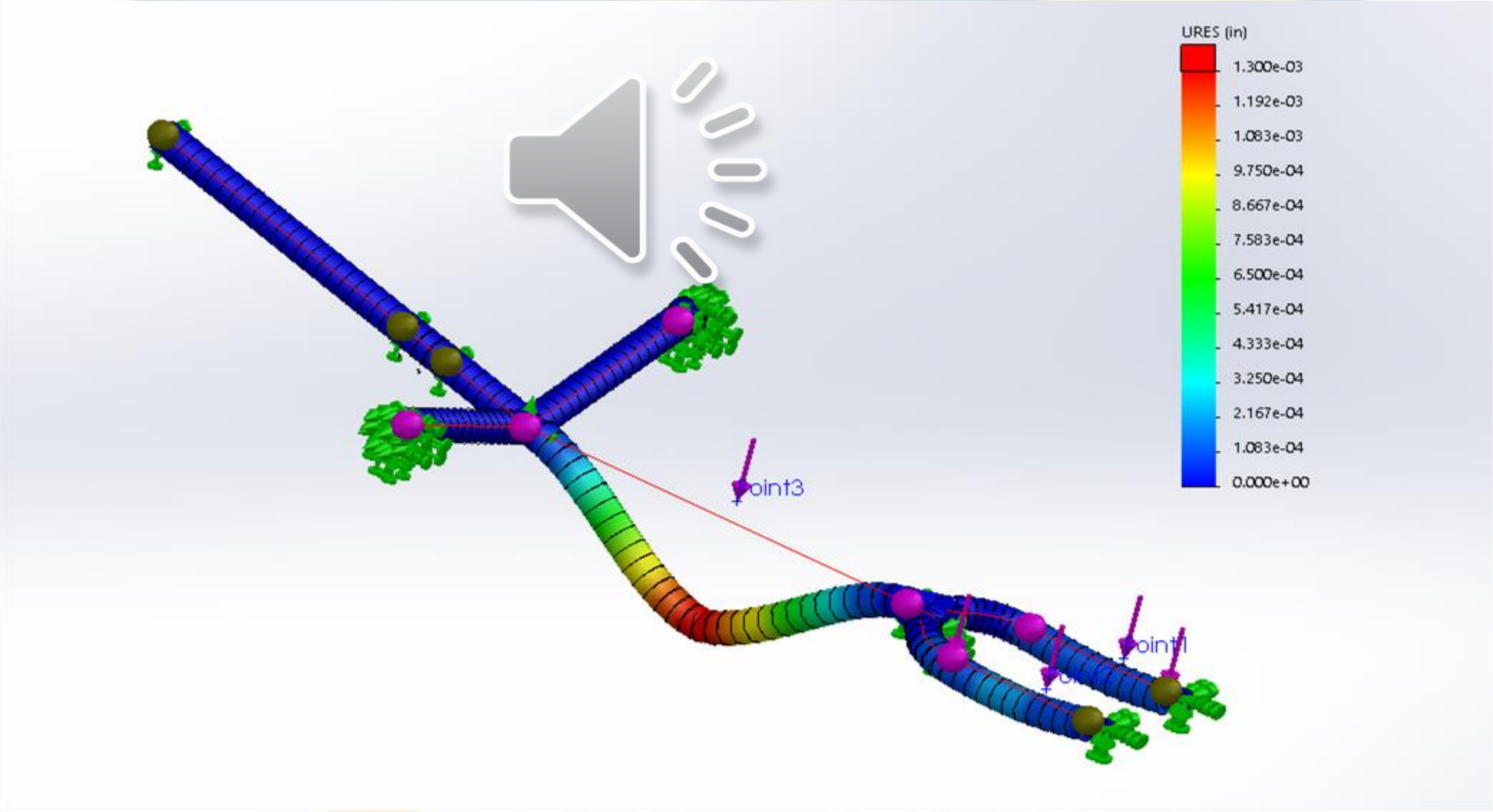
FINITE ELEMENT ANALYSIS FIXED GEOMETRY & LOADS

RIGHT !



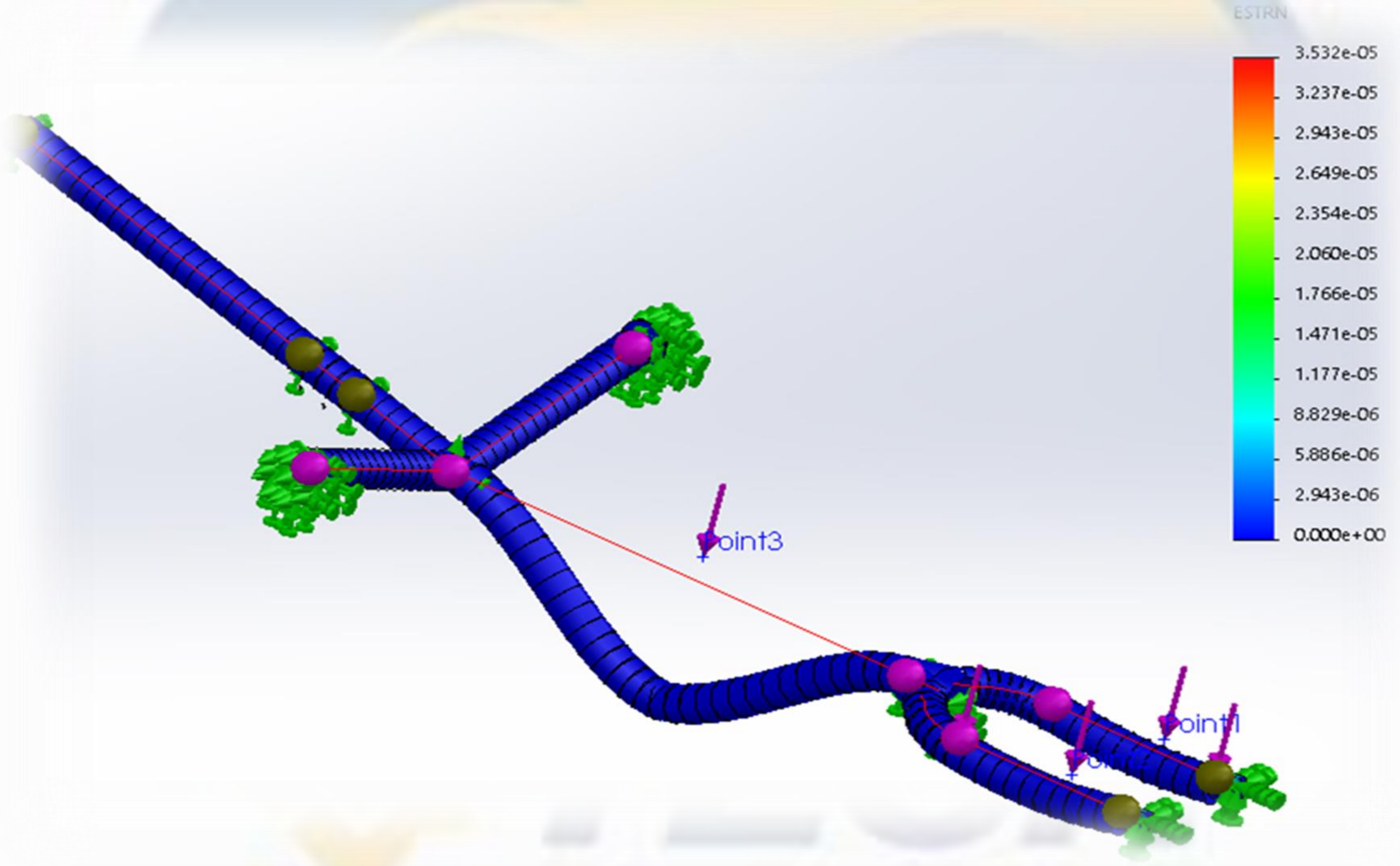
FINITE ELEMENT ANALYSIS RESULTS
LOAD = 150 [LB]

- **Displacement - RIGHT FIXTURES**



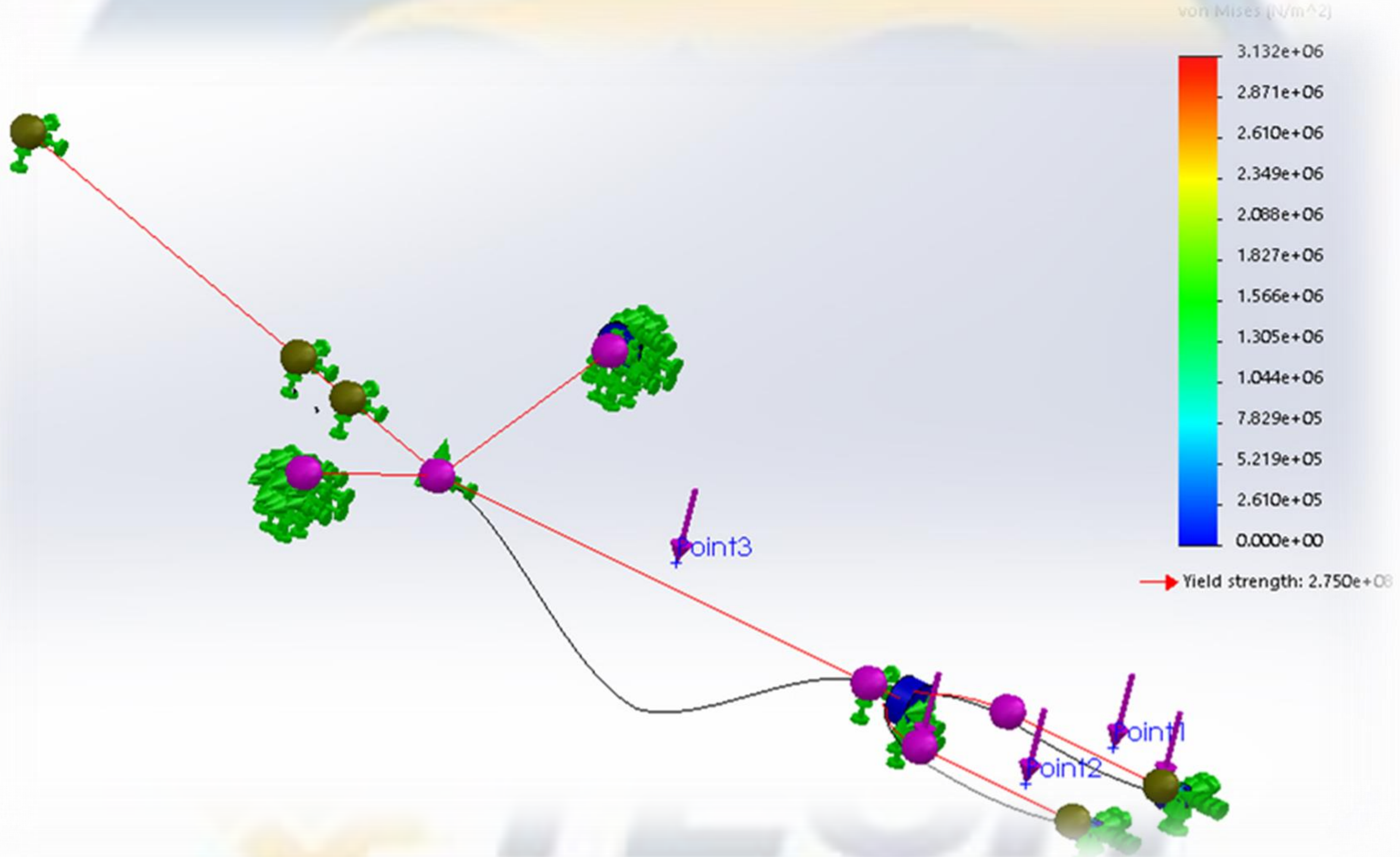
FINITE ELEMENT ANALYSIS
LOAD = 150 [LB]

Strain



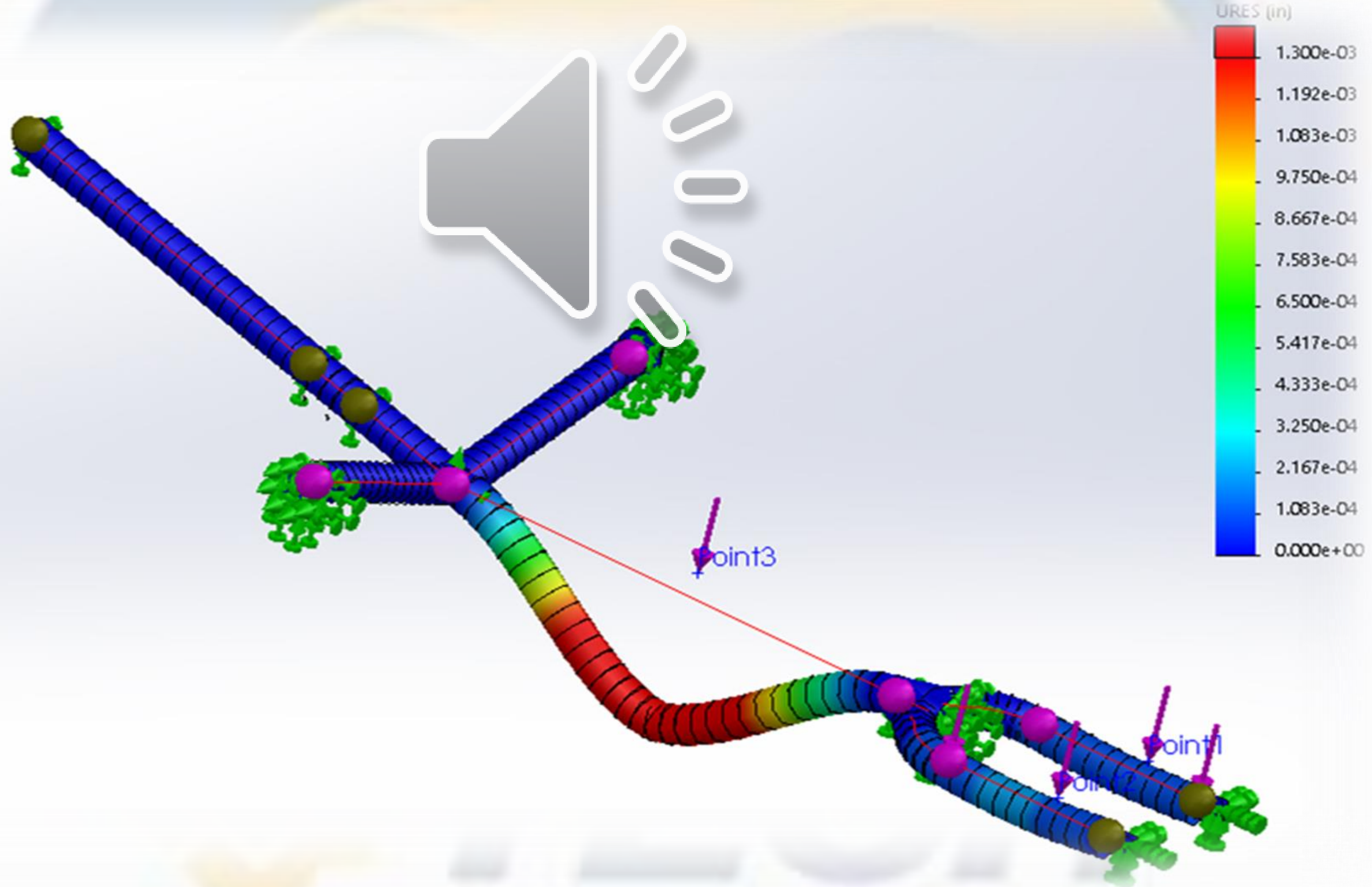
FINITE ELEMENT ANALYSIS
LOAD = 150 [LB]

Stress



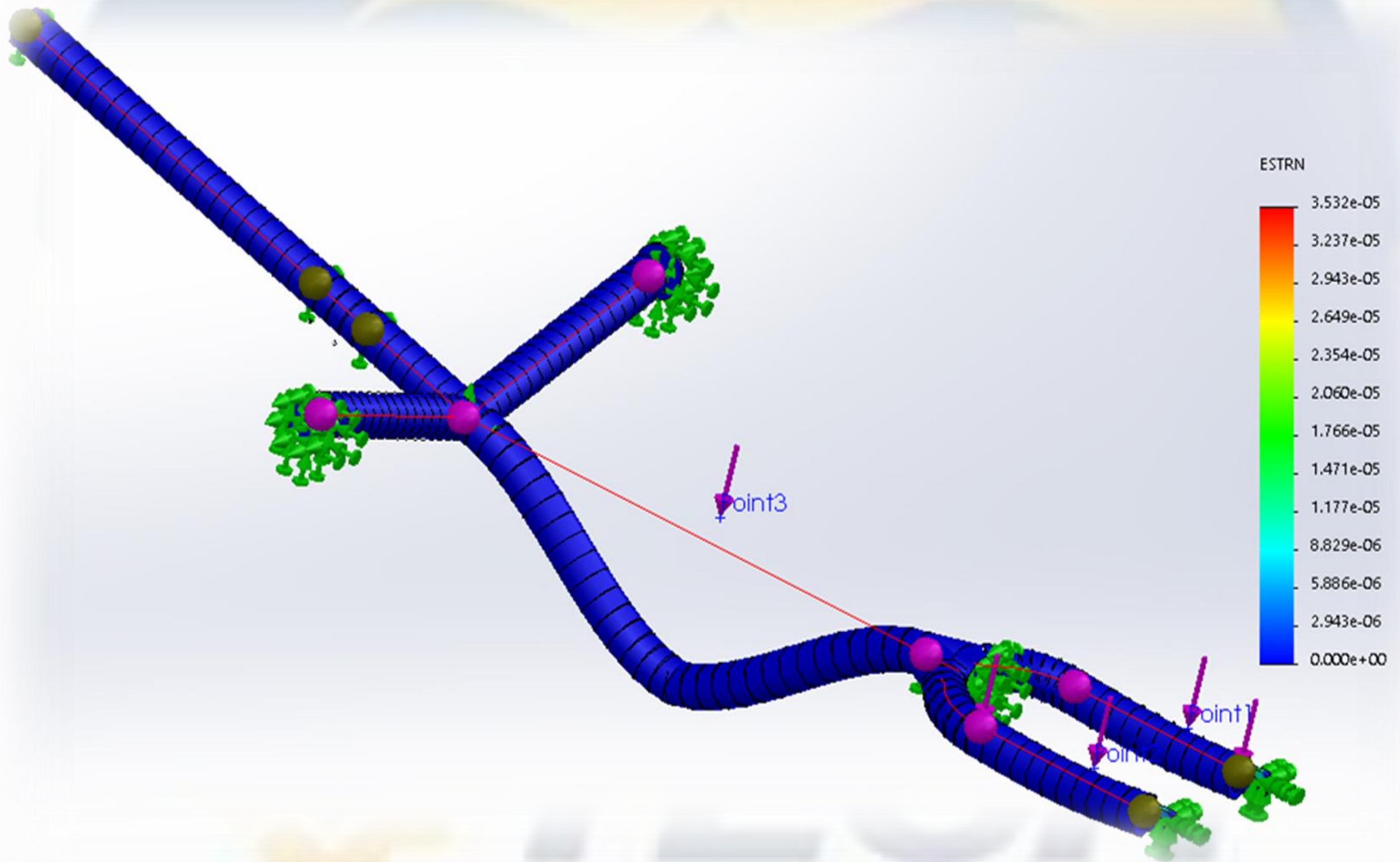
FINITE ELEMENT ANALYSIS
LOAD = 250 [LB]

Displacement



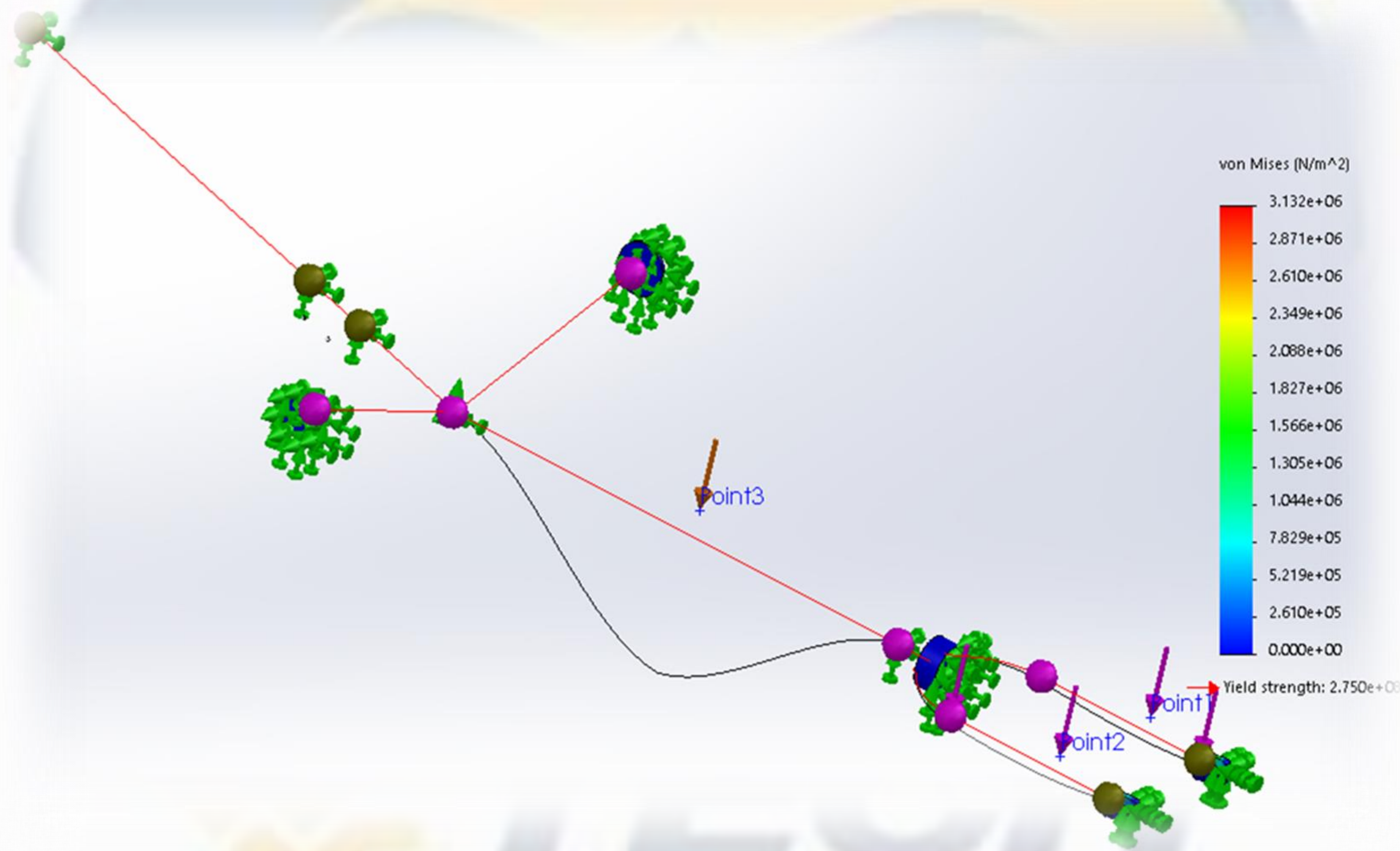
FINITE ELEMENT ANALYSIS
LOAD = 250 [LB]

Strain



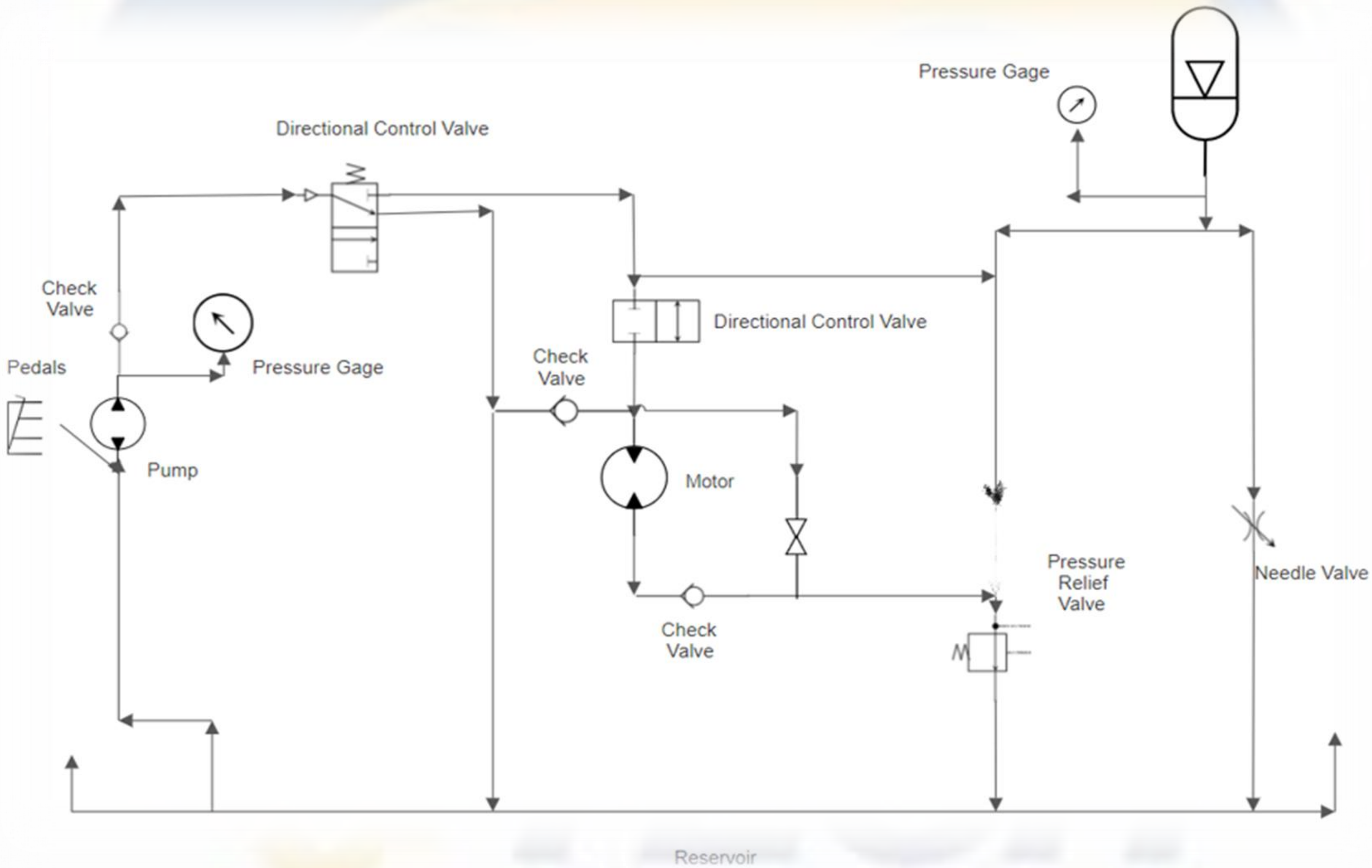
FINITE ELEMENT ANALYSIS
LOAD = 250 [LB]

Stress



HYDRAULIC COMPONENTRY

HYDRAULIC CIRCUIT



HYDRAULIC COMPONENT SELECTION

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AIQT3100 Accumulator	
Specifications	
Type	Bladder
Port Size	3/4" NPT
Max Pressure	3000
Size	1 Quart
Weight	9.5 Lbs

Eaton 26003-LZG Gear Pump	
Specifications	
Type	Gear
Direction	Bi-Directional
Displacement	9.5 cm^3/r .58 in^3/r
Inlet Port	1.0625-12 UN-2B
Mount	2 bolt
Max Pressure	3000 PSI
Min RPM	750
Max RPM	3600 RPM
Output	7.8 GPM @ 3600 RPM

Eaton 26703-DAA Drive Motor	
Specifications	
Type	Gear
Direction	Bi-Directional
Displacement	10.2 cm^3/r .62 in^3/r
Inlet Port	1.0625-12 UN-2B
Mount	2 bolt
Max Continuous Pressure	3000 PSI

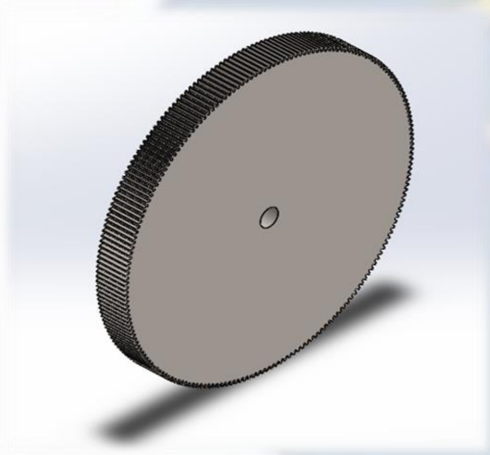
GEAR RATIOS AND FILL RATE CALCULATIONS

Eaton 26003-LZG Gear Pump	
Specifications	
Type	Gear
Direction	Bi-Directional
Displacement	9.5 cm^3/r .58 in^3/r
Inlet Port	1.0625-12 UN-2B
Mount	2 bolt
Max Pressure	3000 PSI
Min RPM	750
Max RPM	3600 RPM
Output	7.8 GPM @ 3600 RPM

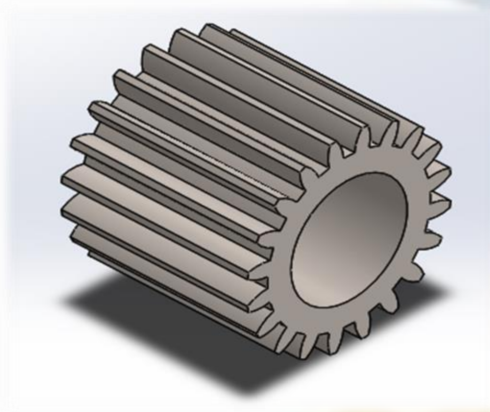
- **With the given pump, our team decided that a 10:1 gear ratio would work best for our design.**
- **This is based off of the average human pedal speed which is between 60-80 rpm.**

GEAR RATIO AND CALCULATIONS

GEAR RATIOS AND FILL RATE CALCULATIONS CONT.



Large Pump Gear



Small Pump Gear

- **Gears were to be made of 4043 Molybdenum steel, with teeth hardened using pack carburizing hardening techniques**
- **200 tooth large gear, 20 tooth small gear**
- **These gears were going to be made using a water jet, allowing us to create a gear special to our vehicle. Significantly cutting purchase costs.**

GEAR RATIOS AND FILL RATE CALCULATIONS CONT.

Calculations Used

Fill rate w/o proportioning valve

$$GPM\ @\ Input\ RPM = \frac{Input\ RPM \cdot Pump\ GPM\ output}{Max\ Pump\ RPM}$$

$$GPM\ to\ \frac{Quarts}{sec} = GPM\ @\ Input\ RPM \cdot \frac{4\ quarts}{1\ gallon} \cdot \frac{1\ min}{60\ sec}$$

$$Seconds\ to\ fill\ 1\ quart = \frac{1\ quart}{\frac{Quarts}{Second}}$$

Fill Rate w/o Proportioning Valve

RPM input	Seconds to fill 1 quart [sec]
750	9.2311
800	8.6708

- **Again, the calculations are based off of the gear ratio of 60-80 rpm.**
- **A 10:1 gear ratio will give us 600-800 input rpm to the gear pump, with the minimum input rpm being 750.**
- **Calculations based on direct flow with no proportioning valve. Proportioning valve will decrease the fill rate of the accumulator**

WRAP UP

FUTURE WORK

If time and opportunity were permitted this year:

- **Begin frame fabrication and mount hydraulic components**
- **Test and evaluate vehicle**
- **Make corrections to components or design if necessary**
- **Perform time trials of NFPA challenges**
- **Promote engineering and hydraulic power through presentation and demonstration at surrounding high schools**

All of the materials, components, hardware, and consumables are readily available for next year's WVU Tech Fluid Power Club. They can continue with this design or completely redesign. Regardless they have a substantial head start in regards to money, assets, and information.

CHALLENGES

- **Covid 19**
  - **Barred from school since 13 Mar 2020**
  - **Half the team had to return to Spain**
  - **Cancellation of Dr. Nuemann's visit to campus on 25-27 March.**
- **Local Constraints**
  - **We share a small fabrication lab with WVU Tech's Baja Team, Aero Team, Bridge Design Team, Concrete Canoe Team, and the senior projects of all graduating engineering seniors. Not to mention technology and engineering labs that must be taught in this same lab. Therefore, time must be scheduled and distributed.**
  - **Lab time was scarce before Covid 19, was nonexistent after 13 March 2020**

OPPPORTUNITIES

- The COVID 19 setback will not define the success or failure of this year's team.
- We are extremely disappointed that we could not fabricate a project we've worked on all year.
- Next year's team is ahead of the curve and ready to pick up where we left off.
- 2019-20 was WVU Tech Fluid Power Club's first chartered year, and we are gaining members.
- We have a working relationship with several local high schools were we will showcase fluid power and spur interest in STEM related industries.
- As the Fluid Power Club grows, hopefully, our school, student body, and infrastructure will grow. This will allow more students to showcase their abilities on a national level
- Thank you to the NFPA, Sponsors, Mentors, and Advisors for all you do to help small schools and rural students make a positive impact on the engineering community.
- See you in 2021!

ACKNOWLEDGEMENTS

Special Thanks to the NFPA and the generous sponsors of this competition.

- **SunSource**
- **Bimba Manufacturing Company**
- **Danfoss Power Solutions**

Sincere appreciation to the mentors and advisors:

Dr. Uwe Neumann	**Vice President Bosch Rexroth/Team Mentor**
Dr. Paul Steranka	**WVU Tech Dean of Engineering**
Dr. Yogen Panta	**WVU Tech Associate Professor/Team Advisor**
Dr. Bernhard Bettig	**WVU Tech Chair of Mechanical Engineering**
Dr. Winnie Fu	**WVU Tech Chair of Technology**
Austin Yeater	**Technical Advisor/ Senior M.E. student**

2019 Fluid Power Team

WVU Institute of Technology Student Government Association