Part Design and Optimization

Modest Introduction

By: Elliot Bushman

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(Not Good at ANSYS)🤫

External Integration

Car — What other subsystems is this one reliant upon or are reliant upon it, what external factors or subteams should I consider?

System — How does this part and subsystem play into subteam goals, how can this be done better?

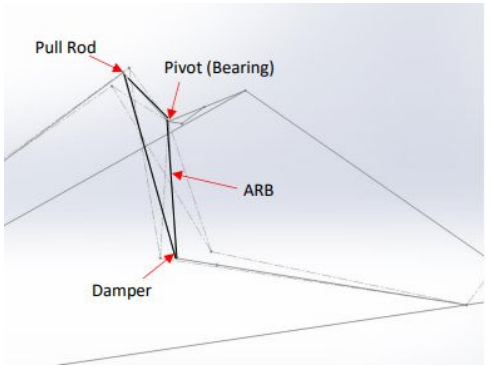
Subsystem — What role does this system play, how does it have to package, etc.?

Part — Consider interfaces and purpose in subsystem

Ex: Car -> Controls System -> Steering System -> Steering Column

Approaching Model for a New Part

1. Purpose and Integration
    a. bolts, cables, bearings, other parts
2. Statics
    a. Relative positioning and motion of multiple interface
    b. What forces and will each interface see and how will they be accounted for
3. Dynamics
    a. What path will it take, potential for interference?
    b. Will motion change magnitude and orientation of forces?
    c. How many cycles will occur over life?
4. Manufacturing
    a. Machining, casting, printing, layup?



Internal Integration

1 Select Hardware

Fits within package of assembly
Sufficiently load ratings
Easy assembly and maintenance

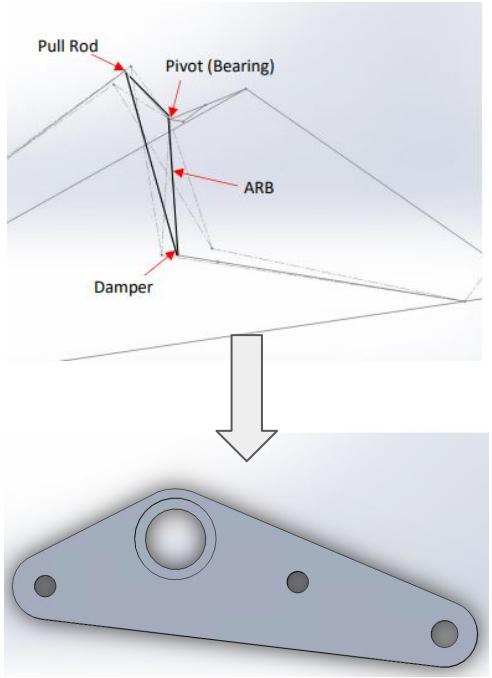
2 Model

Accommodate critical hardware specs
Interfaces will all necessary components
Achieves function
Manufacturable

3 Assembly

Check all interfaces and connections
Interference and clearance assessment
Dynamics

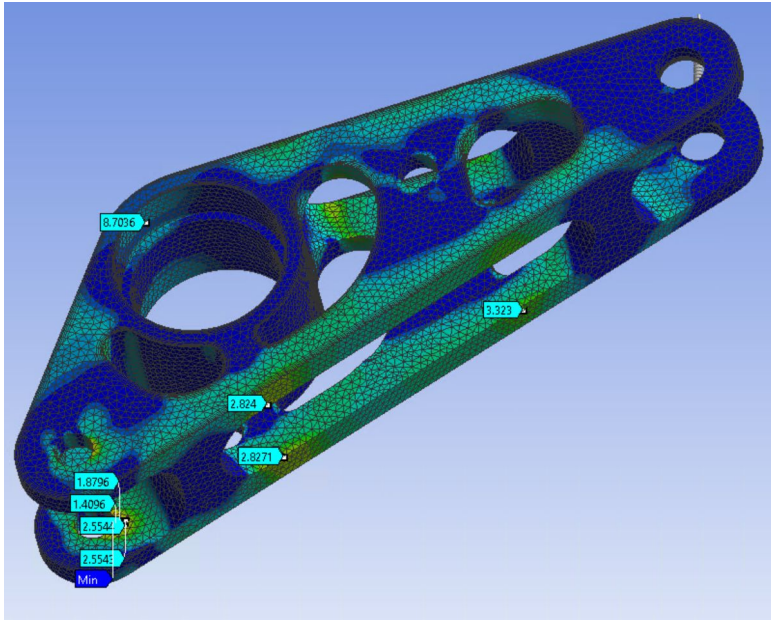
4 Simulation



Ansys

Deformation + Factor of Safety + Fatigue / Cycle Analysis → Verify Part Integrity

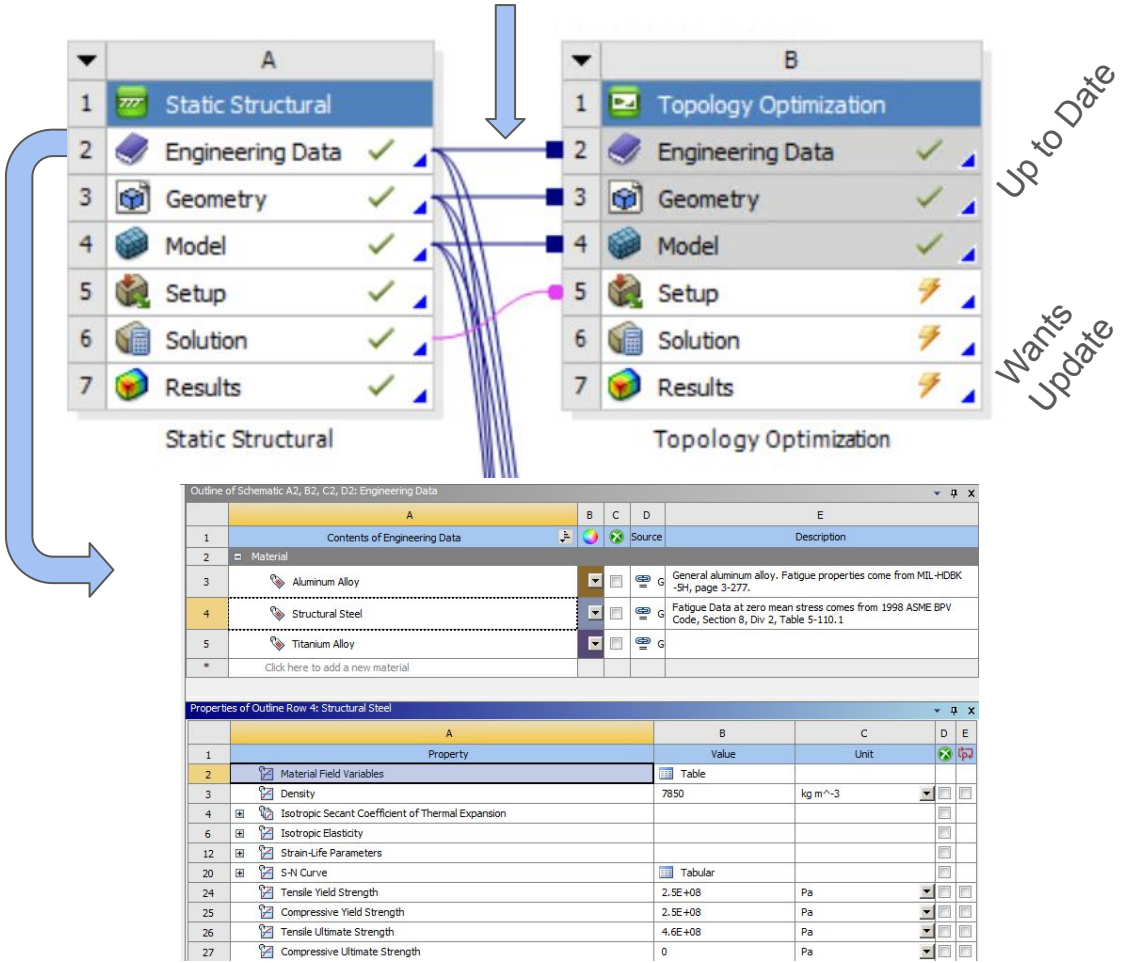
Topology Optimization + Iterations → Optimize Weight / Strength



The Workbench

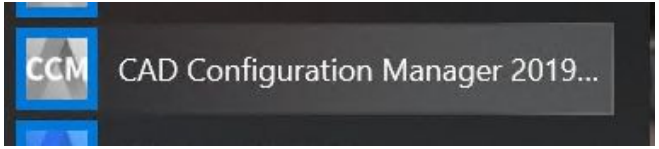
1. Type of analysis
2. Simulation environment parameters
   a. material properties
3. Model Being analyzed
   a. Import from Solidworks
4. Preparing model for simulation
   a. Mesh and connections
5. How exists in space
   a. supports, forces,
6. Result of simulation
7. Interpreting the solution

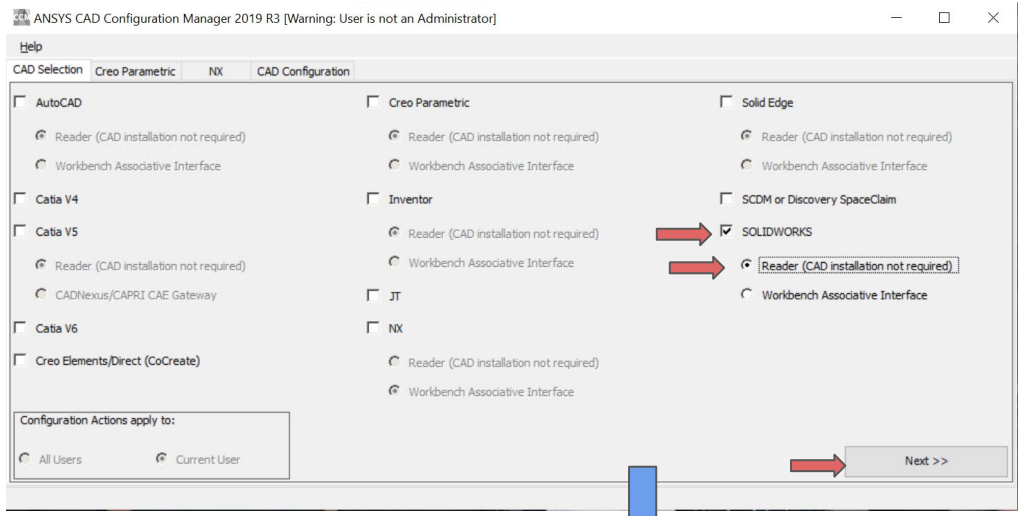
Link multiple analysis or results for second analysis

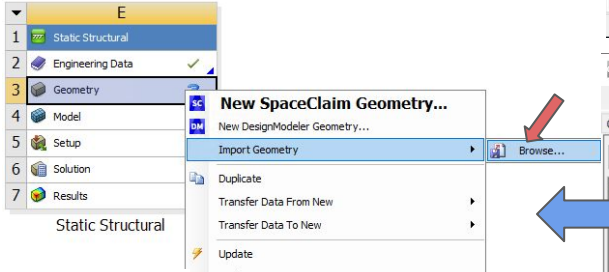


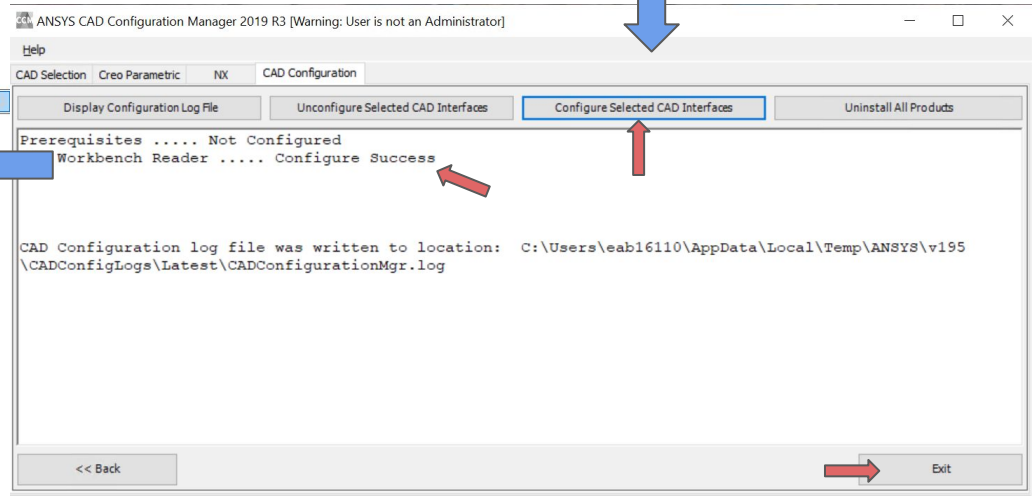
Import a Solidworks Model

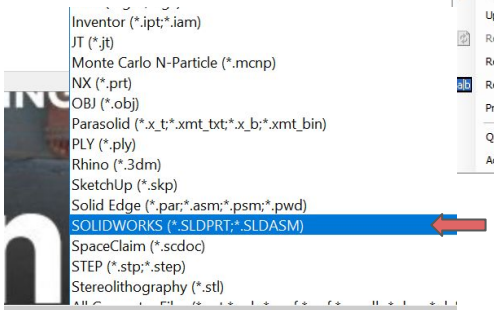
This process creates a “linked” model so Ansys will read latest version of SW file



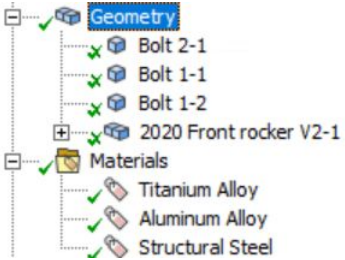


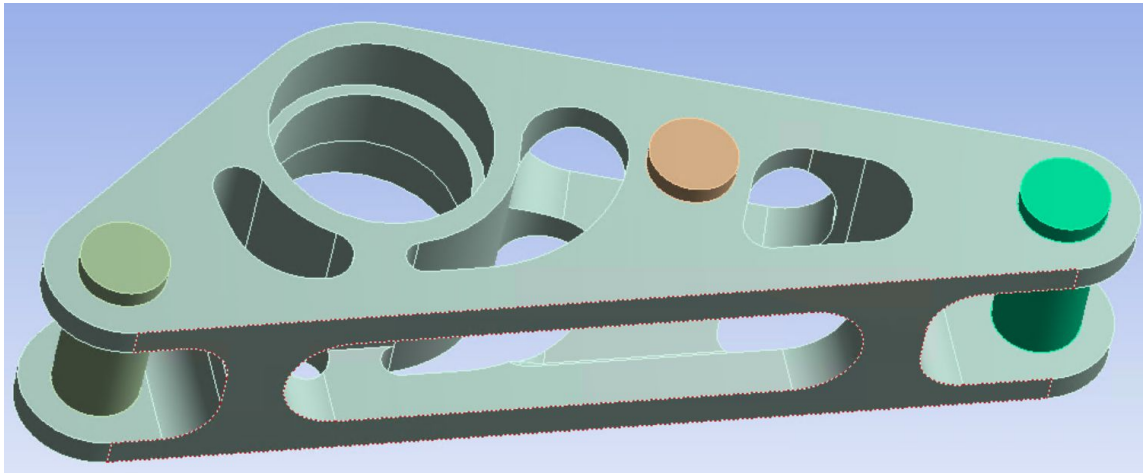






Connections



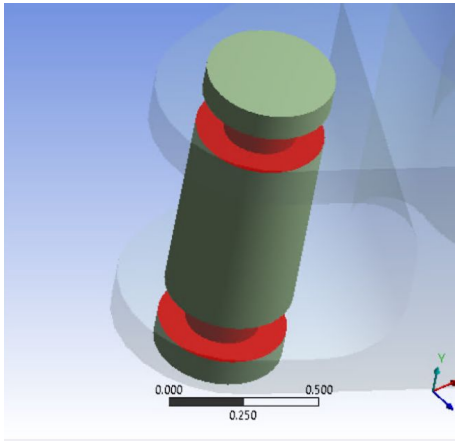


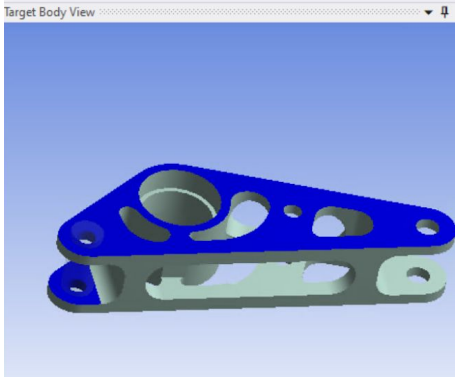
- Simplified hardware make forces applications easier and more representative
- Apply material for each body
  - hardware should always be steel or titanium unless suspect it may fail or deflect
-

Connections

Scope	
Scoping Method	Geometry Selection
Contact	6 Faces
Target	6 Faces
Contact Bodies	Bolt 1-1
Target Bodies	2020 Front rocker V2-1
Protected	No
Definition	
Type	Frictionless
Scope Mode	Manual
Behavior	Program Controlled
Trim Contact	Program Controlled
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Stabilization Damping Factor	0.
Pinball Region	Program Controlled
Time Step Controls	None
Geometric Modification	
Interface Treatment	Add Offset, No Ramping
Offset	0. in
Contact Geometry Correction	None

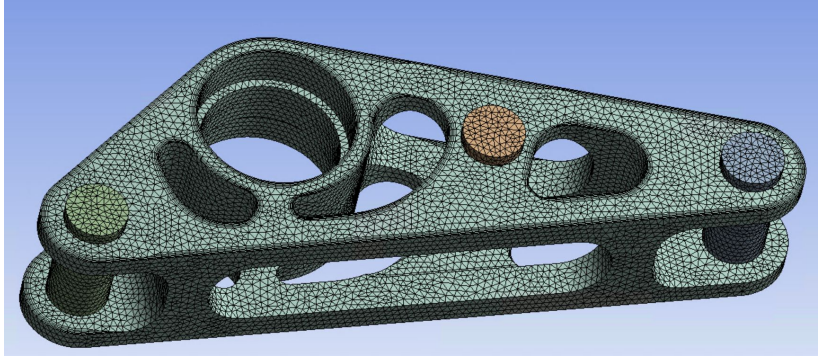
⇦ Frictionless connections are not the most representative but they are simpler to model



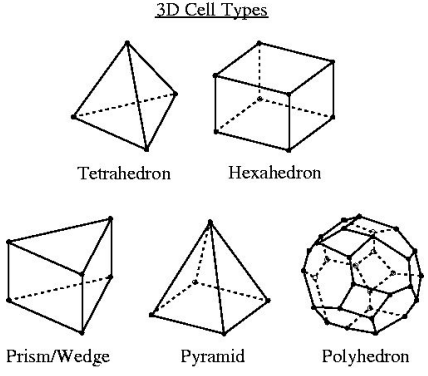


Consider how the bolt transfers force to the part and if the bolt itself applies and forces?

Bolt Pretension



- Different bodies will require different mesh qualities
- Inflation is your friend
- Sometimes less is more
  - troubleshooting
  - rapid changes
- Check the convergence of the mesh to ensure representative results

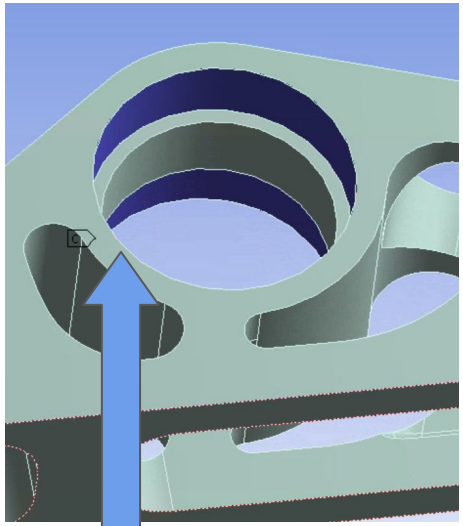


Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	5.e-002 in
Advanced	
Defeature Size	Default
Behavior	Soft

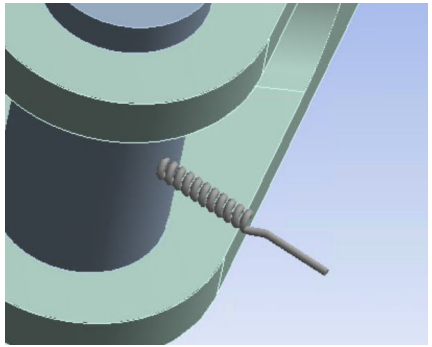
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizi...	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Di...	5.9562 in
Average Surface ...	0.34648 in²
Minimum Edge L...	8.4136e-004 in
Quality	
Inflation	
Use Automatic In...	Program Controlled
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Lay...	5
Growth Rate	1.2
Inflation Algorit...	Pre
View Advanced ...	No
Advanced	
Statistics	

Support

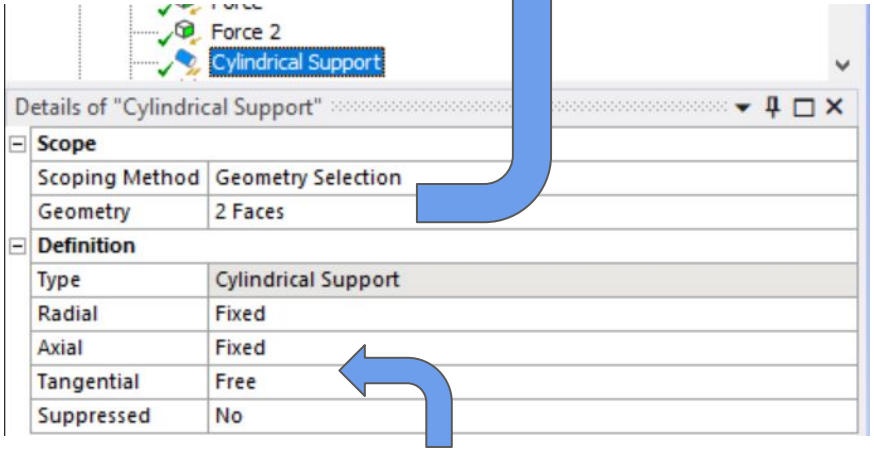
Troubleshooting Friend



- Consider how the part is fixed in the car
  - Bearing, pin, bolt, mount?
  - How does this restrict freedom of part?
- Another place where including multiple bodies useful to give better representation of real work
  - ex: bond a body representing the bearing and fix it



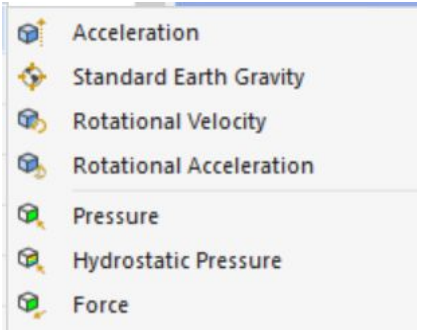
(In this case my spring is my last constraint hindering tangential motion)



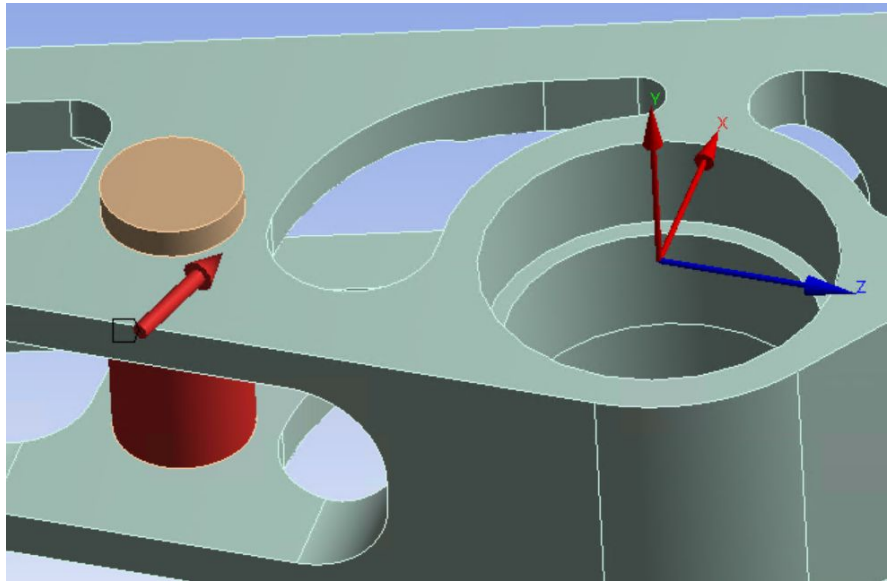
Constrains to 1 DOF!

Force

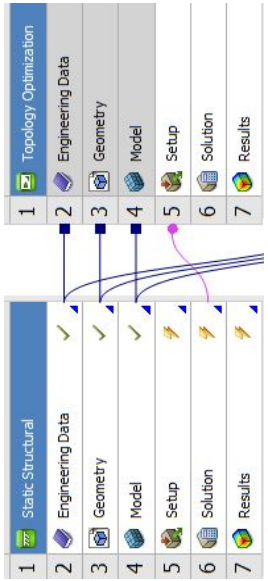
- Consider all of the possible ways forces will be applied to the part
  - Including non intended
- Custom ording can make converting forces to vectors for Ansys much easier
- Will the part have multiple loading cases?
- Can all of the loads be represented by simple point forces?



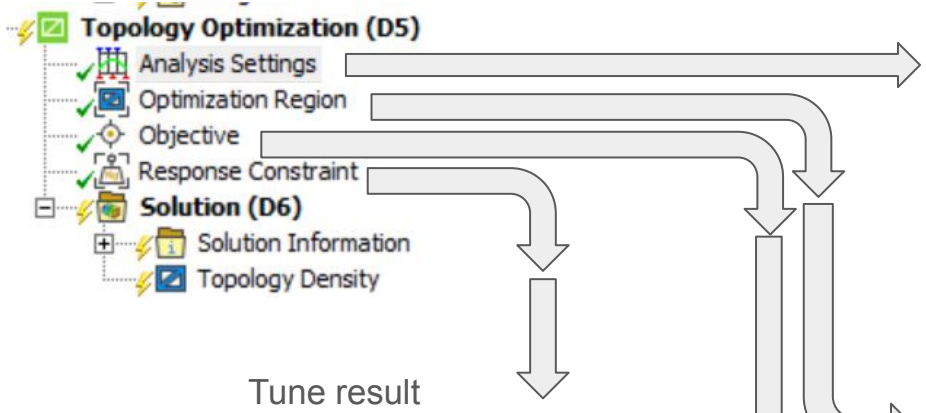
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Components
Coordinate System	Bearing Orgin 1
X Component	57.905 lbf (ramped)
Y Component	0. lbf (ramped)
Z Component	19.532 lbf (ramped)
Suppressed	No



Topology Optimization



Setup derived from static



Process direction

Definition	
Maximum Number Of Iterations	500.
Minimum Normalized Density	1.e-003
Convergence Accuracy	0.1 %
Penalty Factor (Stiffness)	3.
Region of Manufacturing Constraint	Include Exclusions
Region of Min Member Size	Exclude Exclusions
Region of AM Overhang Constraint	Exclude Exclusions
Solver Controls	
Solver Type	Program Controlled
Output Controls	
Analysis Data Management	

Tune result

Scope	
Scoping Method	Optimization Region
Optimization Region Selection	Optimization Region
Definition	
Type	Response Constraint
Response	Mass
Define By	Constant
Percent to Retain	65 %
Suppressed	No

What's is being optimized

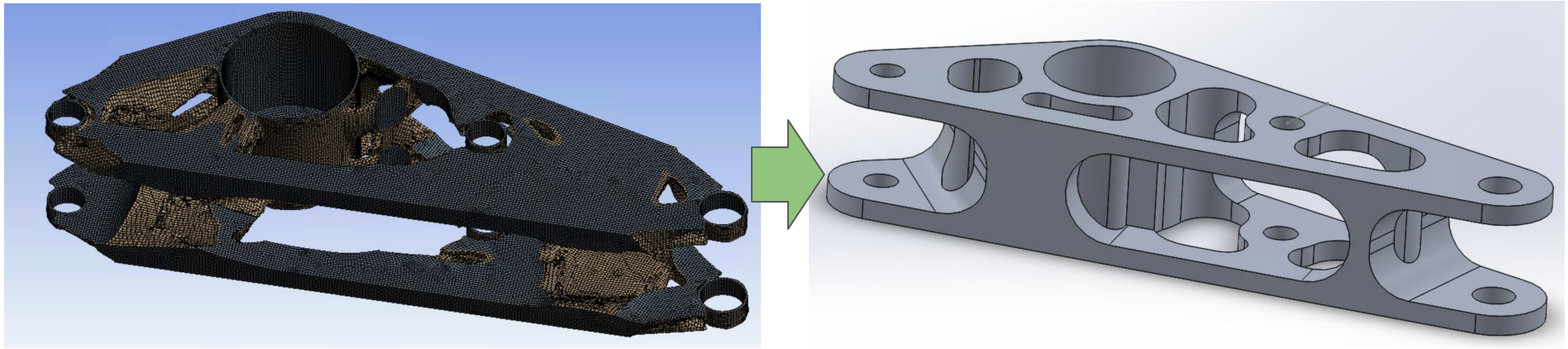
Design Region	
Scoping Method	Geometry Selection
Geometry	1 Body
Exclusion Region	
Define By	Geometry Selection
Geometry	No Selection
Optimization Option	
Optimization Type	Topology Optimization - Density Based

What's the objective(s)

Enabled	Response Type	Goal	Formulation	Environment Name	Weight	Multiple Sets	Start Step	End Step	Step	Start Mode	End Mode	Mo
☑	Compliance	Minimize	Program Controlled	All Forces in Plane	N/A	Enabled	1	1	1	N/A	N/A	N/

Topology Optimization

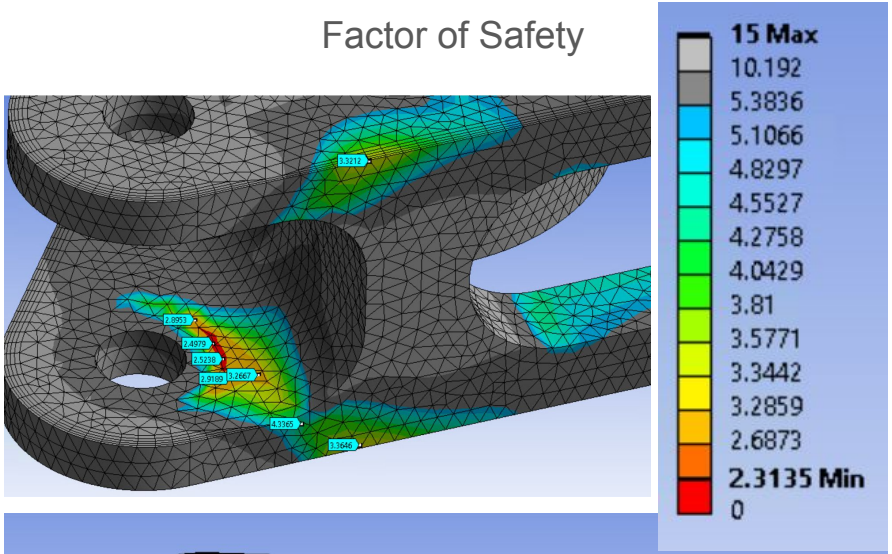
This result should act as guiding force for removing bulk from part

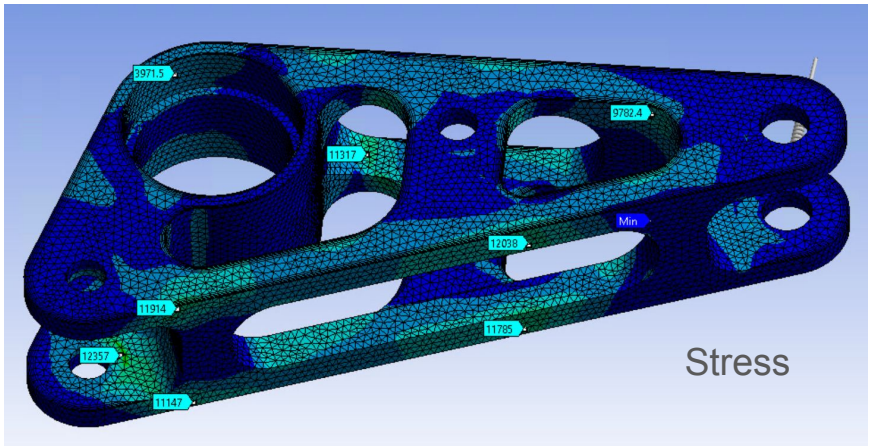


Static Structural

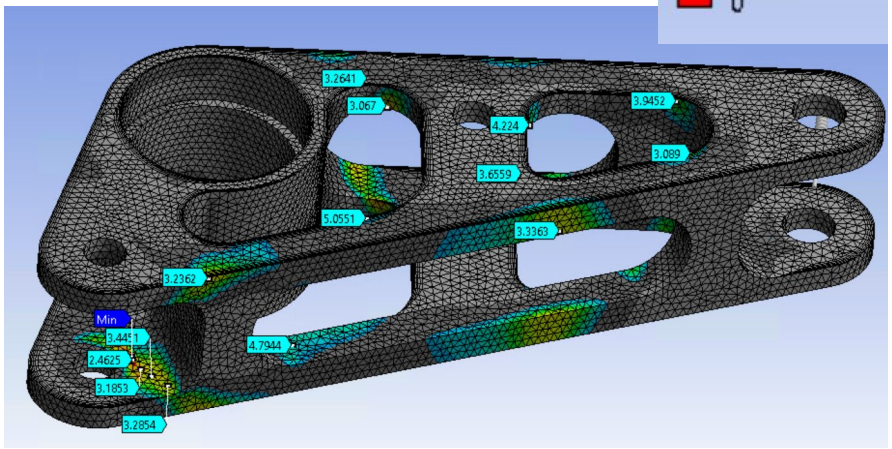
- Results should be interpreted based off particular needs
  - Min FOS around >2.5
  - Deflection can cause host of failures
- Usually better to have a part not fail than save a couple grams, keep weight saving in perspective
- Consider how representative simulation especially without validation
- Typically want to perform multiple analysis for different scenarios

Factor of Safety





Stress

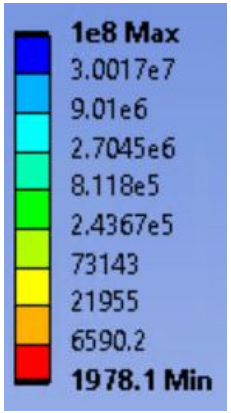


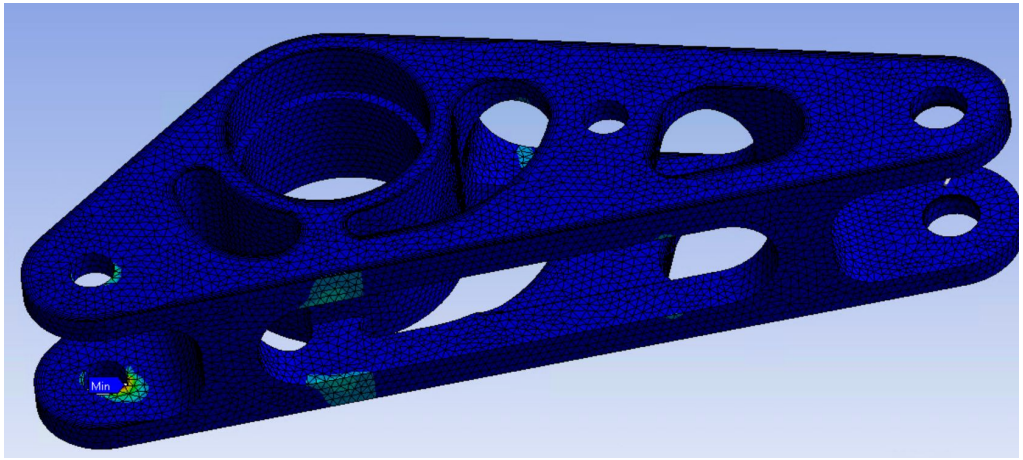
Fatigue Tool

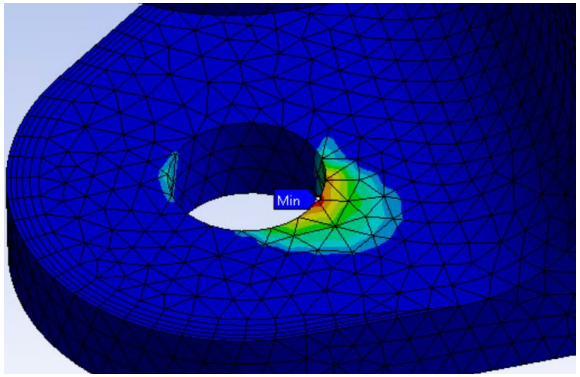
- How many cycles does this part see?
  - Talk to DAQ!
- Again FOS >2.5
- Does one particular area withstand significantly less cycles?
- Formula car drives relatively short time

This tells me that the bolt is going to wear on its mounting surfaces

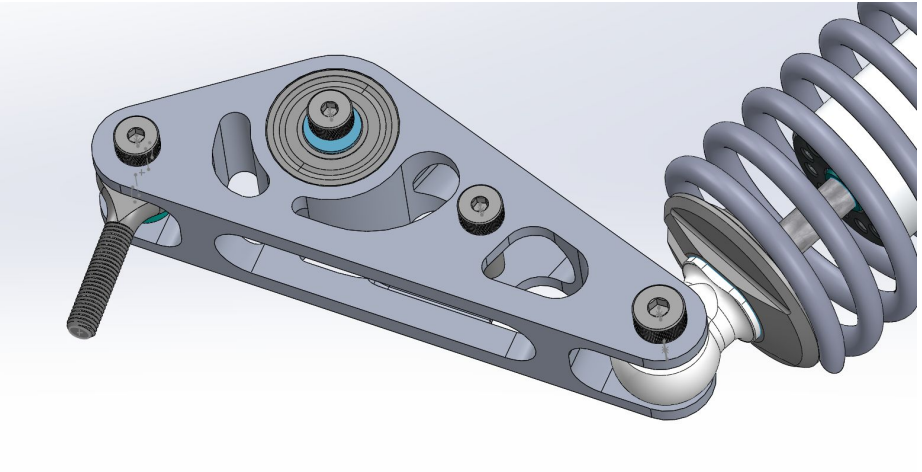
Domain	
Domain Type	Time
Materials	
Fatigue Strength Factor (Kf)	0.9
Loading	
Type	Fully Reversed
Scale Factor	1.
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	None
Stress Component	Equivalent (von-Mises)
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles







Result



Your done, psyc. go back to start

- Does it still fit into subsystem?
- Hardware requirements same?
- Is it manufacturable?

Document your process!

Open Discussion & Questions

Thank you!