Solar Turbines
A Caterpillar Company

Summer 2022 Intern Exit Presentation

Design Methods and Lifing Analysis

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- Background
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- Overall Takeaways
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- Questions/Comments

Background

- Hometown: Tucson, AZ
- Undergraduate: University of Arizona
  - BSME ’21
  - Minor in Mathematics
- Graduate: University of Southern California
  - MSME ’22
- Past Experiences
  - Enterprise Preparedness Intern (Raytheon Technologies)
  - Undergraduate Teaching Coordinator (University of Arizona)
  - Virtual Reality Developer (Airy Optics)
- Hobbies: Football, Running/Weight Training/Hiking, Cooking

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ARIZONA

Projects

1. Failure Potential, ANSYS MAPDL Macro
2. Lifing Assessment of Inner Turbine Duct

Project 1

Failure Potential, ANSYS MAPDL Macro

Overview

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- What is the goal?
  - Develop improvements for material interpolation
- Why is failure potential needed?
  - Failure potential is defined as the ratio between the alternating stress and the alternating stress capacity

$$Failure\ Potential = \frac{Alternating\ Stress\ [ksi]}{Alternating\ Stress\ Capacity\ [ksi]}$$

  - The ratio supports analysis by identifying locations of interest for fatigue lifing

Approach

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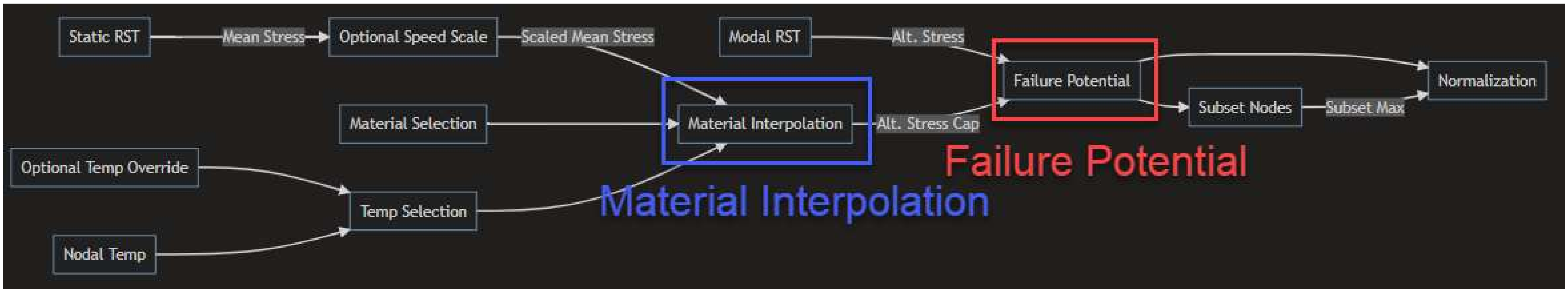

- The macro would take in user input variables:

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} Mean\ Stress\ [ksi] \\ Material \\ Temperature\ [°F] \\ Alternating\ Stress\ [ksi] \end{bmatrix}$$

- Calculate alternating stress capacity as a function of x_1, x_2, x_3
- Produce the following output variable:

$$[Failure\ Potential\ Ratio]$$

Calculating Alternating Stress Capacity

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- Old Method:
  - Hardcoded curves in MAPDL relating mean stress to alternating stress using a polynomial approximation

Cons

- Need to be updated with consideration of new materials
- Subject to user error when entering values
- Inaccuracy due to curve refitting

Calculating Alternating Stress Capacity

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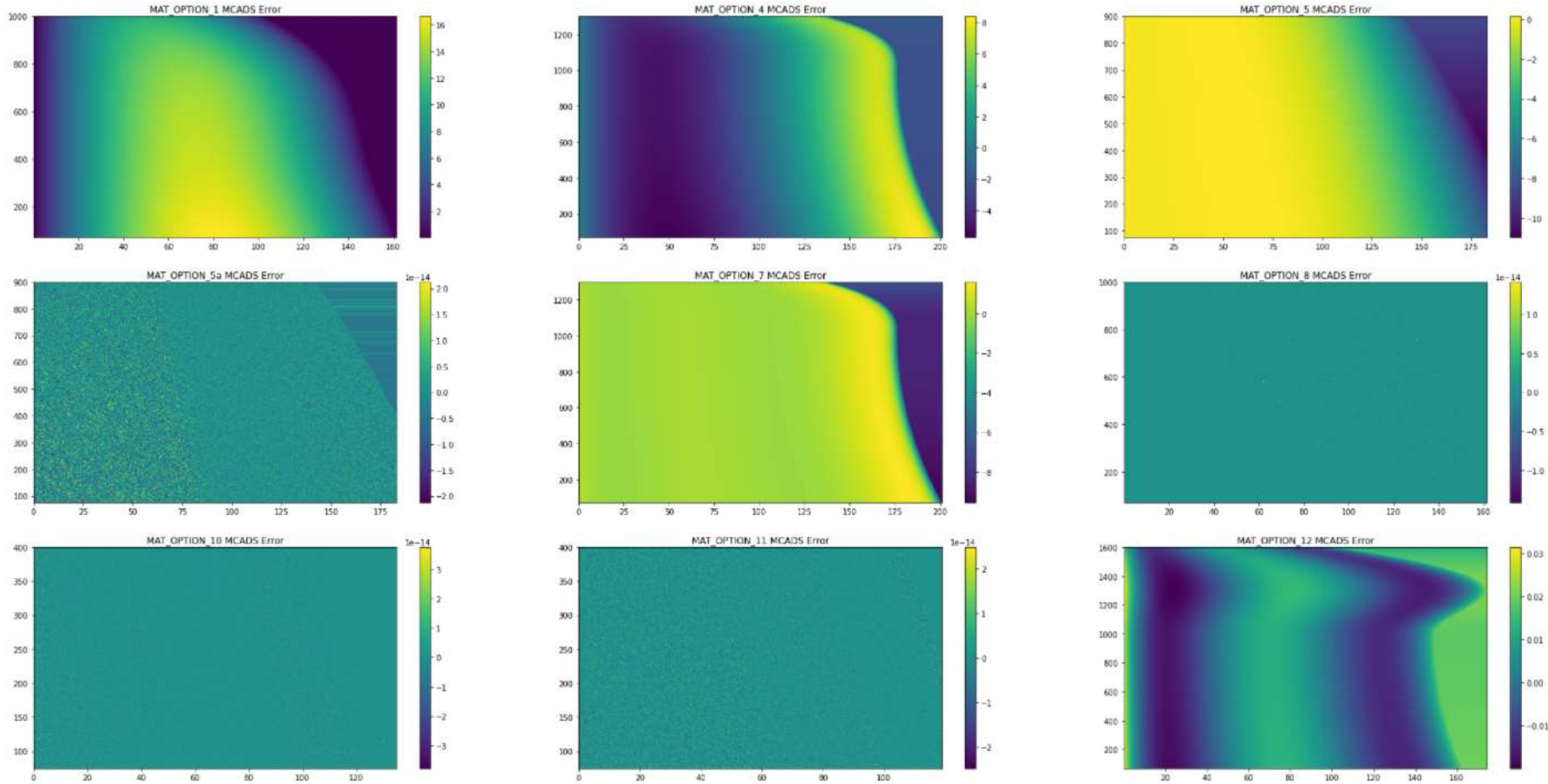

Absolute error as large as 7-8 ksi at high stress & temperatures

Calculating Alternating Stress Capacity

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- New Method:
  - Interpolation of data stored as a table that is produced using two curves from Luna MPD (Tensile Strength vs Temperature & Alternating Stress vs Mean Stress)

Pros

- Directly pulling and reading information from Luna MPD, not subjected to user input error
- Greater scalability to potential future materials
- Greater accuracy in approximation of alternating stress capacity

Calculating Alternating Stress Capacity

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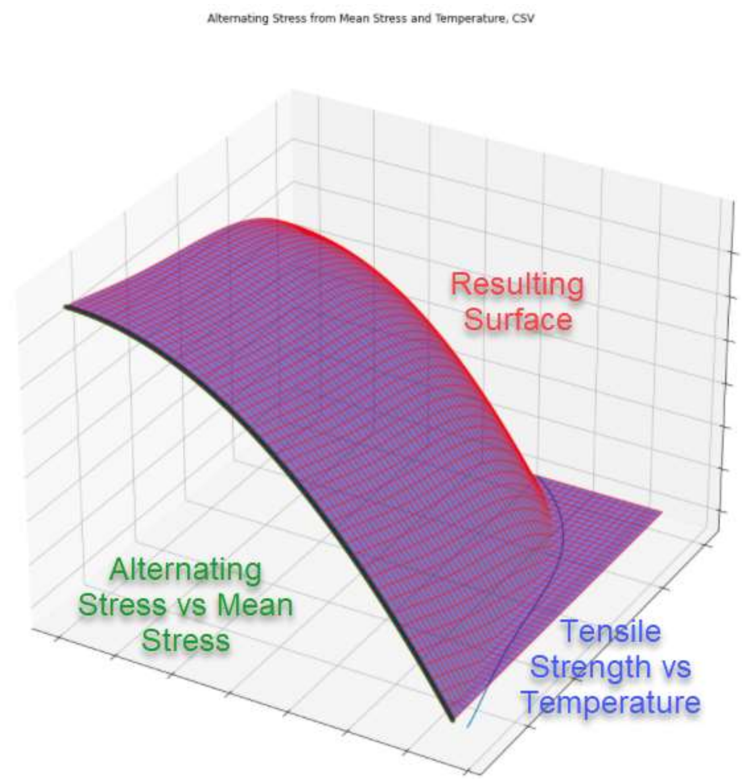
- Resulting plot of .csv data



Calculating Alternating Stress Capacity

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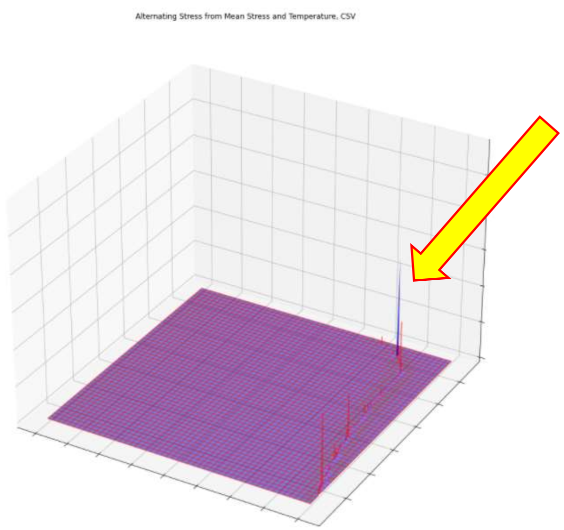
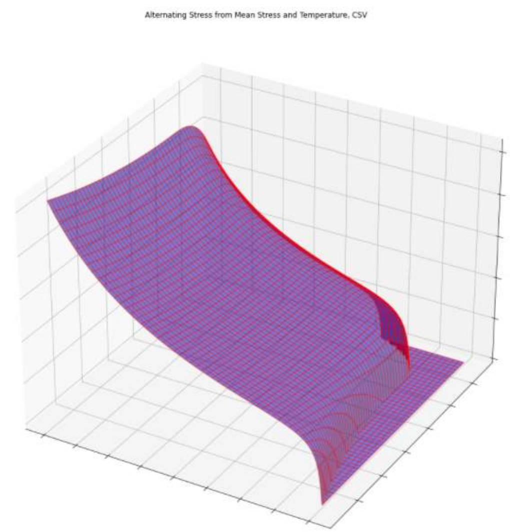
- Previous implementation observed large discontinuities

- Realized that these discontinuities arose since the stress range was not being scaled

Previous



Updated



Calculating Alternating Stress Capacity

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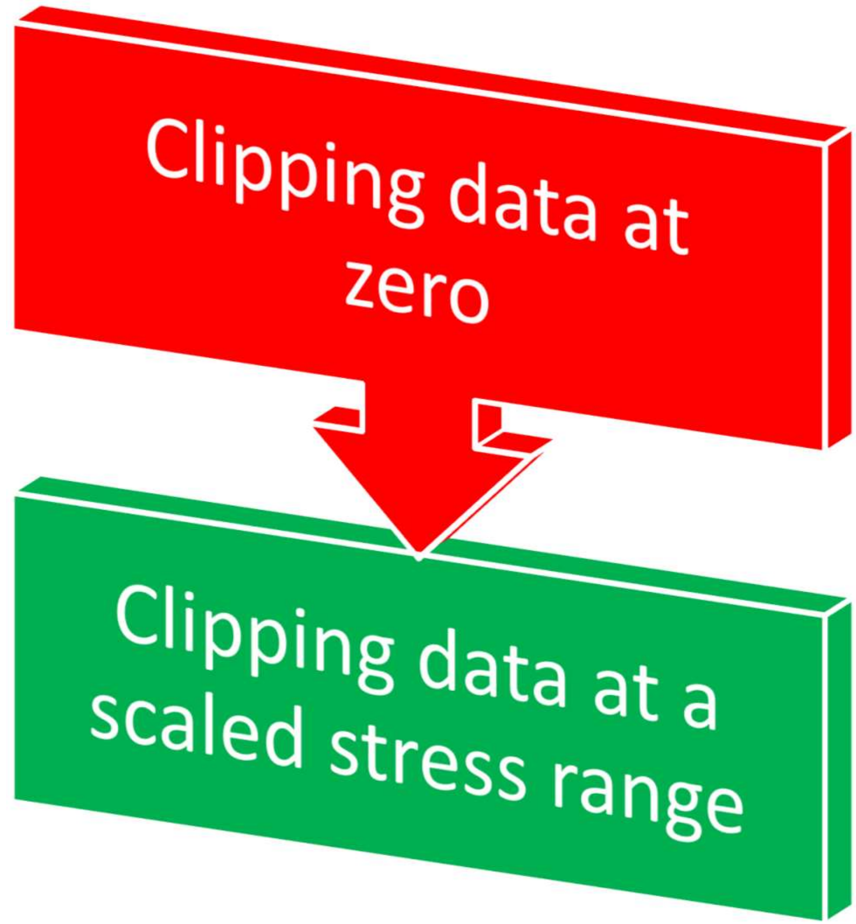
- Curves were observing these spikes along the maximum stress values
- Implement a method to clip the data at scaled maximum and minimum stress values



Calculating Alternating Stress Capacity

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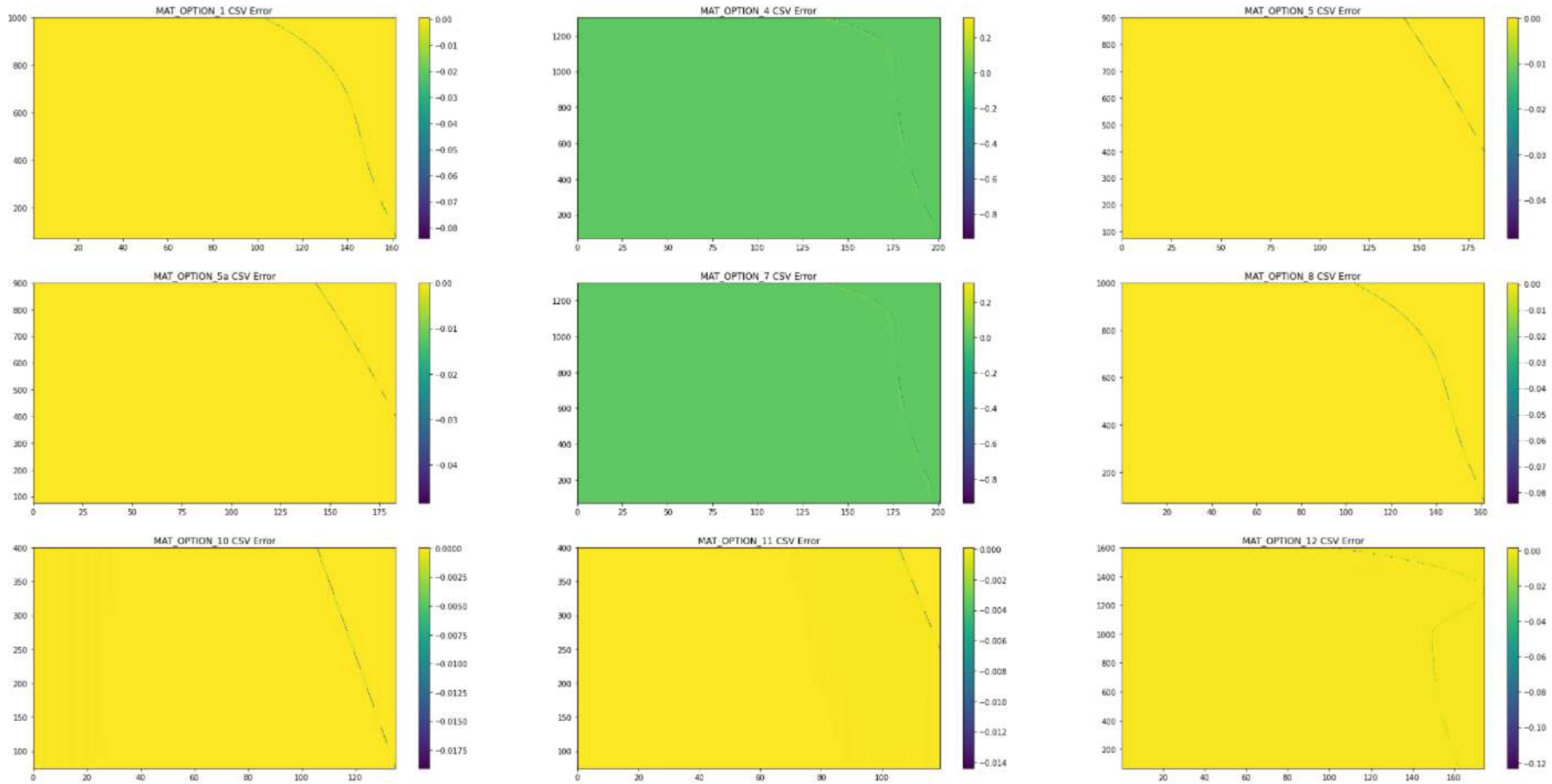

Maximum absolute error ~0.8

Project 2

Tiered Lifing Analysis of Inner Inter Turbine Duct (ITD)

Overview

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- What is the problem?
  - The Turbine Mechanical Design team requires analytical guidance to perform a material selection between two nickel-based superalloys
- How does my role with DMLA support this challenge?
  - Provided a lifing assessment of the Inner Turbine Duct (ITD) for both materials

Project Intake

General

- Talk with design team
- Clarify design intent
- Define details
  - Geometry
  - Thermals
  - Boundary Conditions

Inner Inter Turbine Duct (ITD)

- Update full load steady state and transient model using two materials
- Cold geometry
- Analysis may drive a design decision about the material selection of the ITD
- Compare results to previous model

- Geometry type: 3D cyclically symmetric – multi-component assembly
- Geometry source: design engineering
- Material property details: nickel alloy
- Time domain: multiple time points (e.g. zero-max-zero, pseudo transient, transient)
- Boundary condition sources: existing model
- Engine Section: Turbine – Power
- Component: Inner and Outer Turbine Ducts

- Acceptance Criteria
  - Project intake review completed
  - Peer review 1 completed
  - Peer review 2 completed
  - Cycle expansion and damage calculation completed
  - Peer review 3 completed
  - Documentation uploaded

Steady State Analysis Setup

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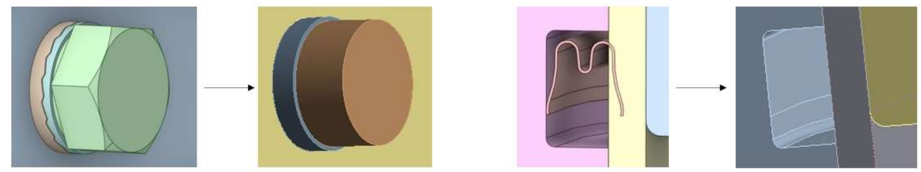
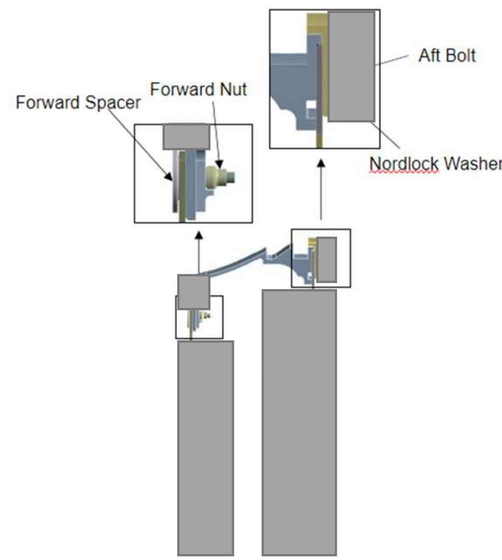
- Re-orient and simplify geometry



- Set materials, pull from central database through linked xml file in ANSYS working files

Component	Material	Material ID
Forward Shield		
Forward Bolt		
Forward Discourager		
Forward Spacer		
Forward Nut		
Inner Inter Turbine Duct		
Aft Discourager		
Aft Bolt		
Nordlock Washer		
Aft Shield		



Steady State Analysis Setup

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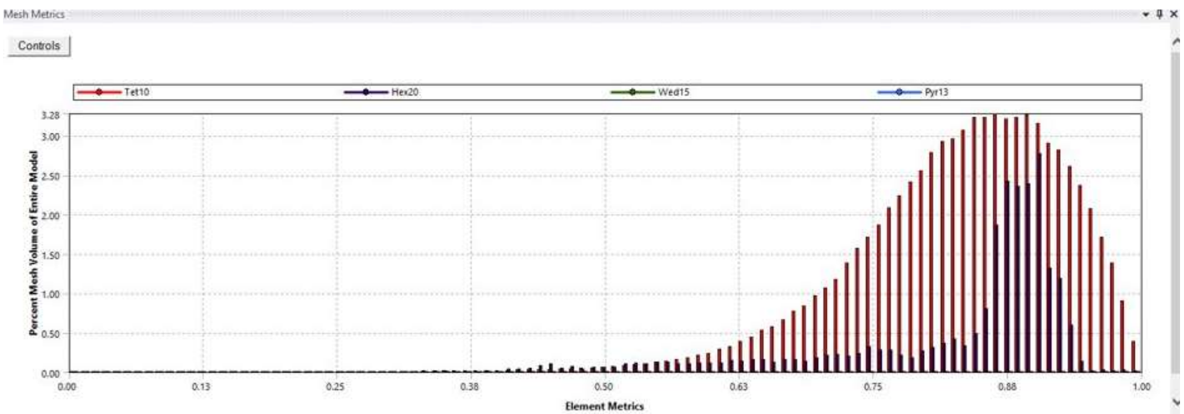
- Mesh controls, tried to mimic those from previous analysis
- Overall good mesh, no errors



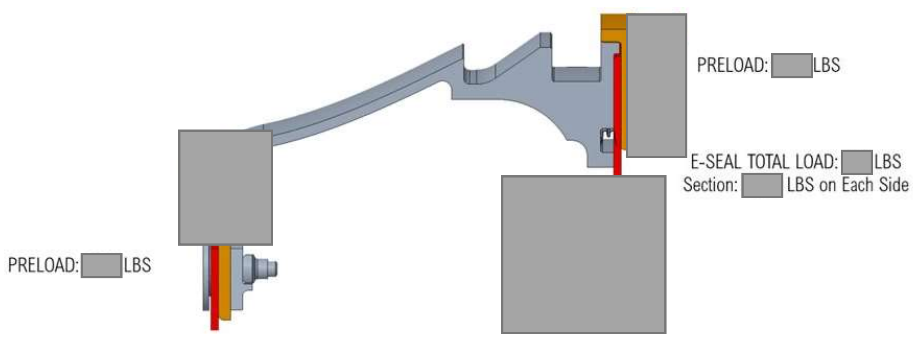
SUMMARIZE SHAPE TESTING FOR ALL SELECTED ELEMENTS

<<<<<< SHAPE TESTING SUMMARY >>>>>>
<<<<<< FOR ALL SELECTED ELEMENTS >>>>>>

Element count	
384	COMBIN14
125	SURF156
482	PRETS179
22890	SOLID186
536978	SOLID187
Total 560859	

Test	Number tested	Warning count	Error count	Warn+Err %
Aspect Ratio	559868	87	0	0.02 %
Parallel Deviation	22890	2	0	0.01 %
Maximum Angle	559868	53	0	0.01 %
Jacobian Ratio	560859	6	0	0.00 %
Warping Factor	22890	82	0	0.36 %
Any	560859	196	0	0.03 %

- Preload



Steady State Analysis Setup

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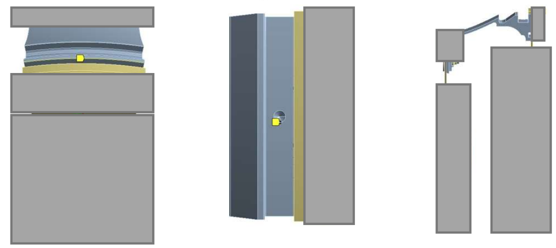
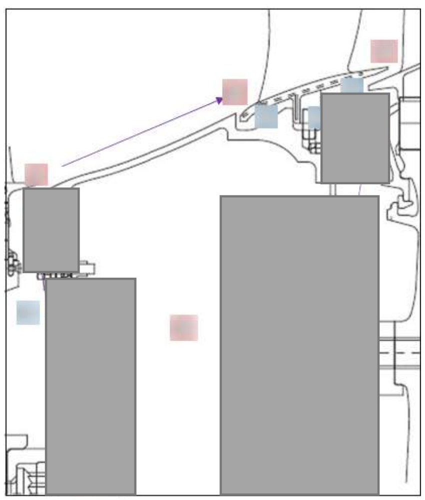
- Displacement Constraints

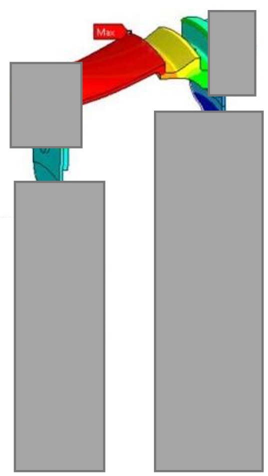
- Axial - Tangential - Radial



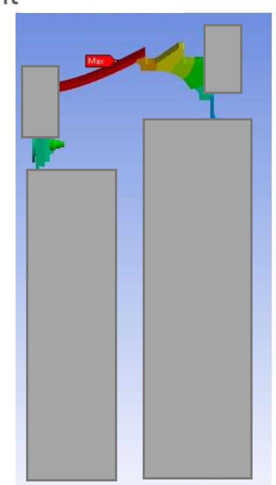
- Pressure and Temperatures from Heat Transfer



- Previous



- Current



Peer Review 1

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General

- Geometry simplifications
- Mesh summary
- FLSS Boundary conditions
  - Preloads
  - Displacement constraints
  - Symmetry
  - Contact
  - Pressure
  - Temperatures
- Deformation
- Stress Decomposition

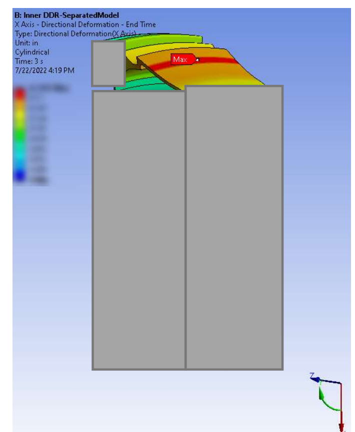
Inner Inter Turbine Duct (ITD)

- Geometry simplifications are standard and were accepted, one thing to note is the importance of re-orienting updated geometry in SpaceClaim before beginning Mechanical analysis
- Mesh was good, first exposure to accessing the .db file in Classic
- Boundary conditions accepted, symmetry was done using cyclic symmetry tree item, discussion to implement commands but cyclic was working
- Performed comparison of reaction loads to hand calculations
- Results
  - Deformation, similar in magnitude and direction as previous
  - Stress decomposition, driven by thermals

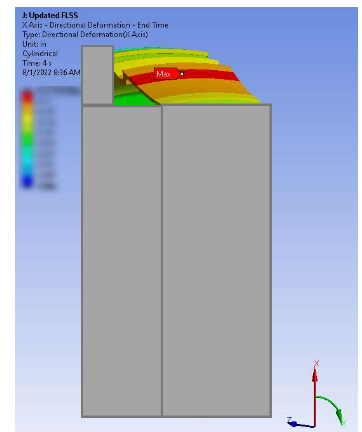
	[illegible]				
Component	Preload [ksi]	Pressure [ksi]	Thermal [ksi]	Total [ksi]	Dominant
Aft Shield Top	[illegible]	[illegible]	[illegible]	[illegible]	
Aft Discourager	[illegible]	[illegible]	[illegible]	[illegible]	
ITD Location 1	[illegible]	[illegible]	[illegible]	[illegible]	
ITD Location 2	[illegible]	[illegible]	[illegible]	[illegible]	
Forward Discourager	[illegible]	[illegible]	[illegible]	[illegible]	
Forward Shield Top	[illegible]	[illegible]	[illegible]	[illegible]	

Signed Equivalent Stress

Previous



Current



Steady State Analysis Results

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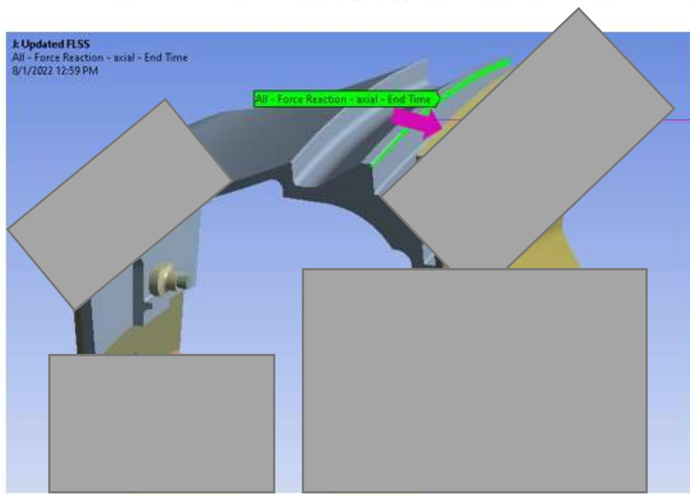
- Verified with excel load calculations

PT Static Blowoff Loads										
Location	Pressure/Load ID	Load Direction (+1/-1)	R_{outer}	R_{inner}	A_{piston}	P	Load	Area Check	Interface Check	Component Blowoff Load
Fwd Shield Interface	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Yes	[illegible]
Fwd Cavity	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Gaspath Surface	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Stage 3 Inner Shroud Cavity	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Stage 3 Nozzle Slot	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Interturbine Diaphragm Cavity	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Interturbine Diaphragm Interface	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Yes	
Forward Cavity	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Flow Discouarger Steps	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Interturbine Diaphragm Cavity	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Interturbine Duct Inner Duct Interface	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Yes	
Windage Shield Forward Face	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Intertubrine Duct Inner Duct Interface	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Yes	
Interturbine Diaphragm Aft Face	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Flow Discourager Steps	[illegible]	-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

3% difference



Transient Analysis Setup

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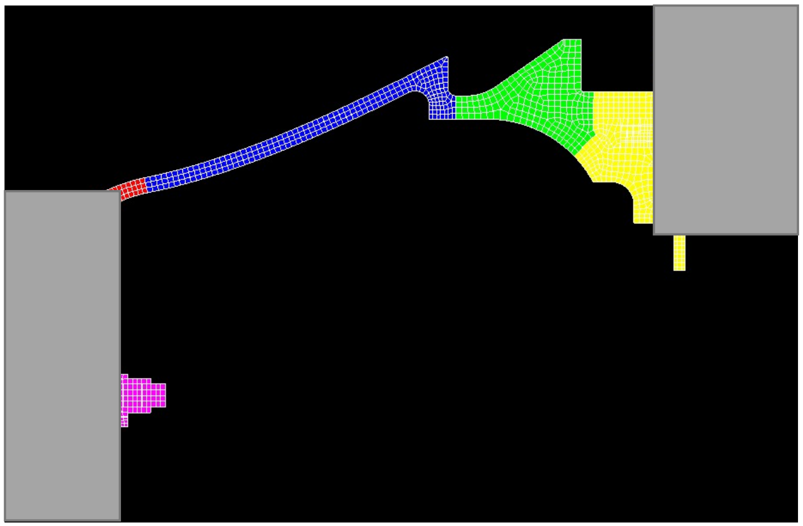
- Create temperature maps from heat transfer transient results for each component
- These maps were created for 148 points that were a result of the time point down selection tool
- Analyzes temperature deltas across bulk regions of interest



Transient Analysis Setup

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- For each time step needed to import temperature map and scale the pressure using the PCD value from that step as well as the full load steady state PCD

$$F_{PCD\ Scale} = \frac{(PCD_{Time} - 14.7)}{(PCD_{FLSS} - 14.7)}$$

- Ensure that the preload conditions translate through to the end of analysis

Peer Review 2

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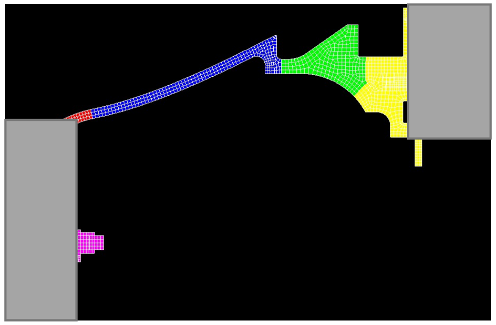
General	Inner Inter Turbine Duct (ITD)

- Transient Boundary conditions
  - Time point down selection
  - Transient scaling pressure
- Model Checks
- Reference Stress
- Damage Calculations

- Compiled heat transfer cycle sheet for engine conditions and resulting thermal points to determine temperature deltas across areas of interest
- Determined 148 time points of interest
- Included full load steady state conditions and final point



- Scaled pressure using PCD values from heat transfer cycle sheet

$$F_{PCD\ Scale} = \frac{(PCD_{Time} - 14.7)}{(PCD_{FLSS} - 14.7)}$$

- Next Steps: Utilize lifing tools for further analysis

Transient Analysis Results

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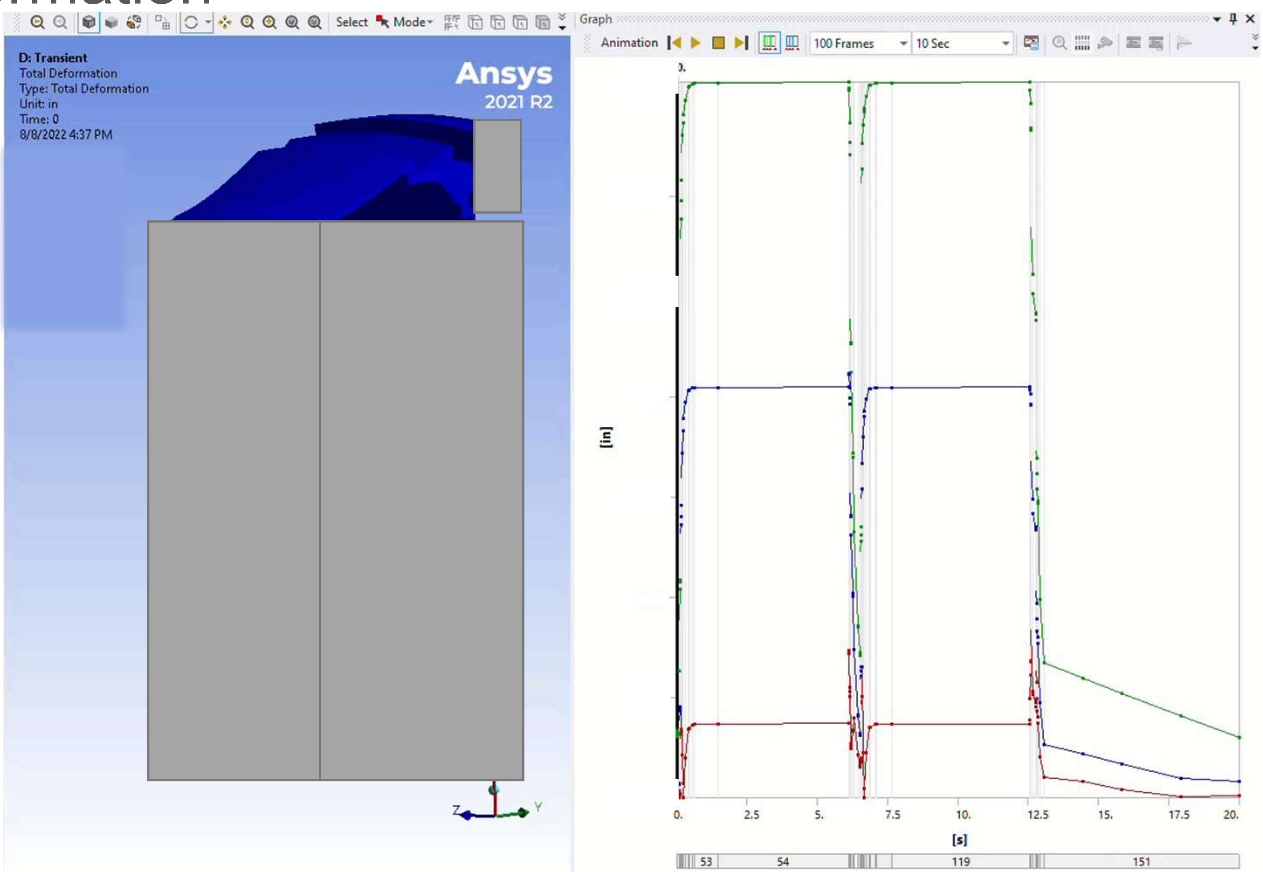
- Total Deformation



Transient Analysis Results

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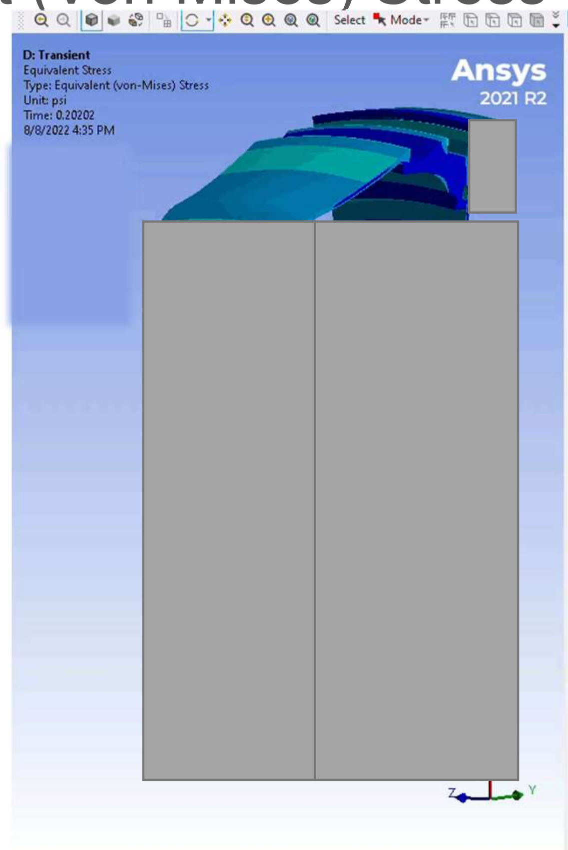
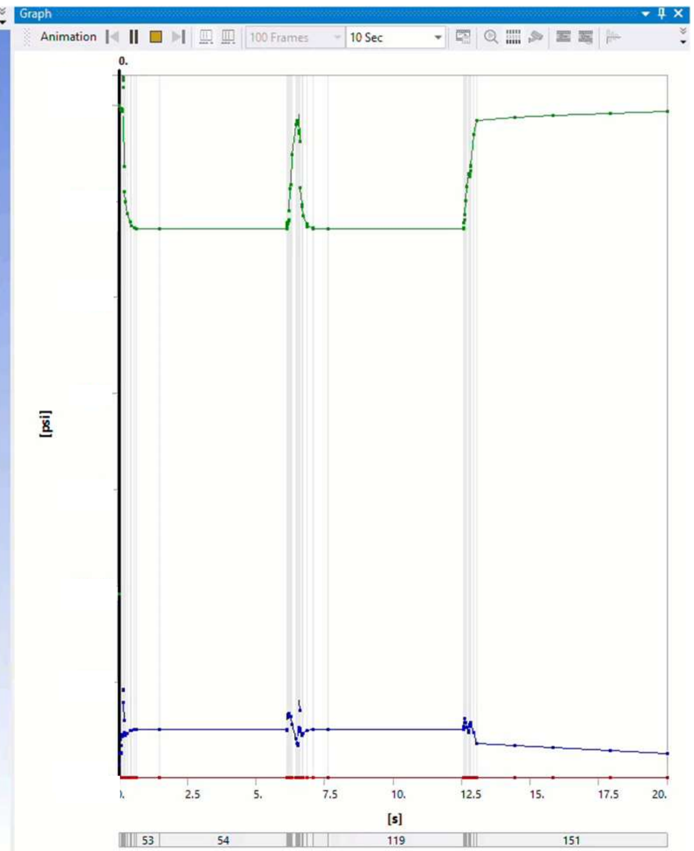
- Equivalent (Von Mises) Stress





Overall Takeaways

1. School to Industry Transition
2. Roadblocks/Challenges

School to Industry Transition

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- Applying engineering principles in real life applications
- Larger emphasis on software support but “Hand Calculations” are great for sanity checks and verification
- Learning doesn’t end when you graduate

School to Industry Transition

- People posses a wealth of knowledge
  - Sometimes make it difficult for someone to come along early in the process and break down the information in another’s head for their use
  - For a first time ANSYS user I faced many challenges with convergence
  - Resulted in me outlining a number of the suggestions for dealing with nonlinear convergence issues for future use of new team members

Roadblocks/Challenges

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- 1st time exposure to ANSYS
  - Ansys training website
  - Team members
  - Good ole Google
- Balancing my time and working while solutions are being evaluated and macros are being ran
  - Plays in good with DMLA structure because time can be committed to create presentations
- Most everything you need is avalible….finding it, that's the challenge

Acknowledgements

- DMLA Team
  - Victor Siordia
  - Eric Blankenship
  - Brandon Killian
  - Jose Elias Ledesma Nieto
  - Will Blattman
  - Tyler Holmes
  - Estevan Negrete
  - Artemio Sanchez Gomez
  - Octavio Garcia Villazana
  - Antonio Barajas
  - Anna Wei
- NPI/GTPE Internship Leadership
  - Dan Reitz
  - Hyun Kim
  - Kiara Sanchez
  - Gwendolyn Royal
  - Brandon Killian
  - Megan Waller
  - David Wahlstrom
  - Megan Hand
- Project Support
  - Ray Alvarez
  - Jonathan Ortiz
- Southwest Research Institute
- All of my fellow interns and the NGRE!