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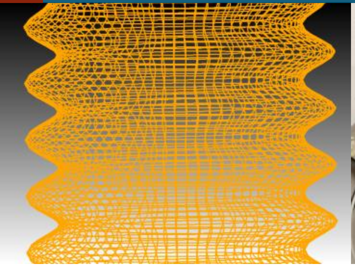
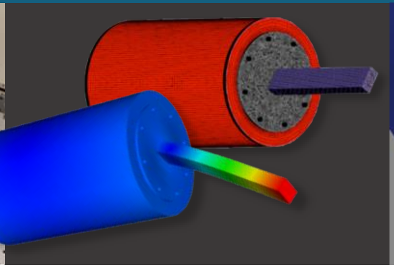
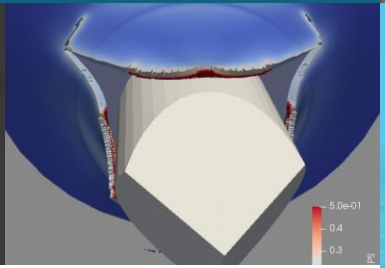
Parameterized Friction Modeling With Optimized User Constructs







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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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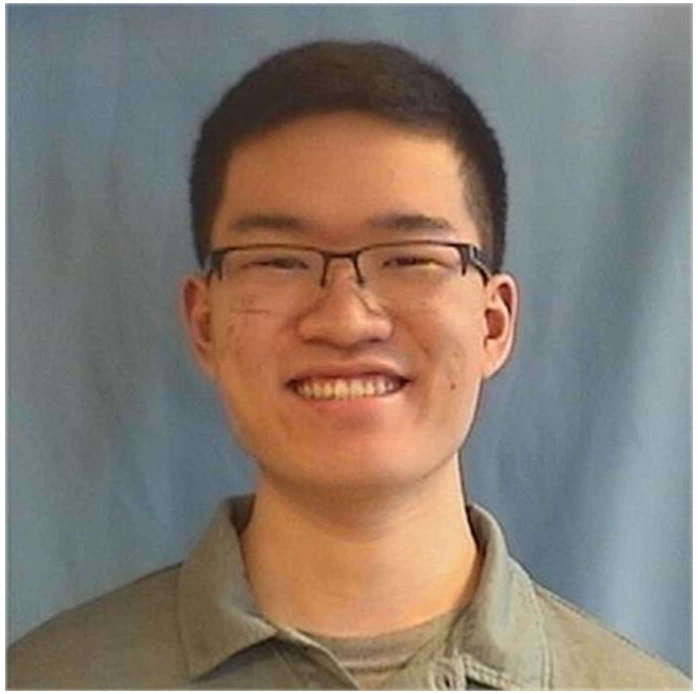
Our Team



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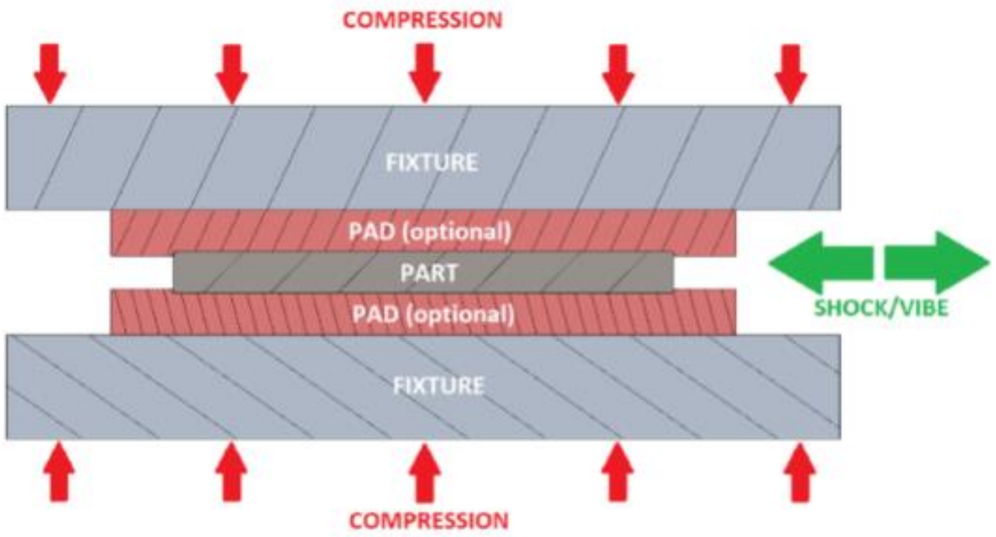
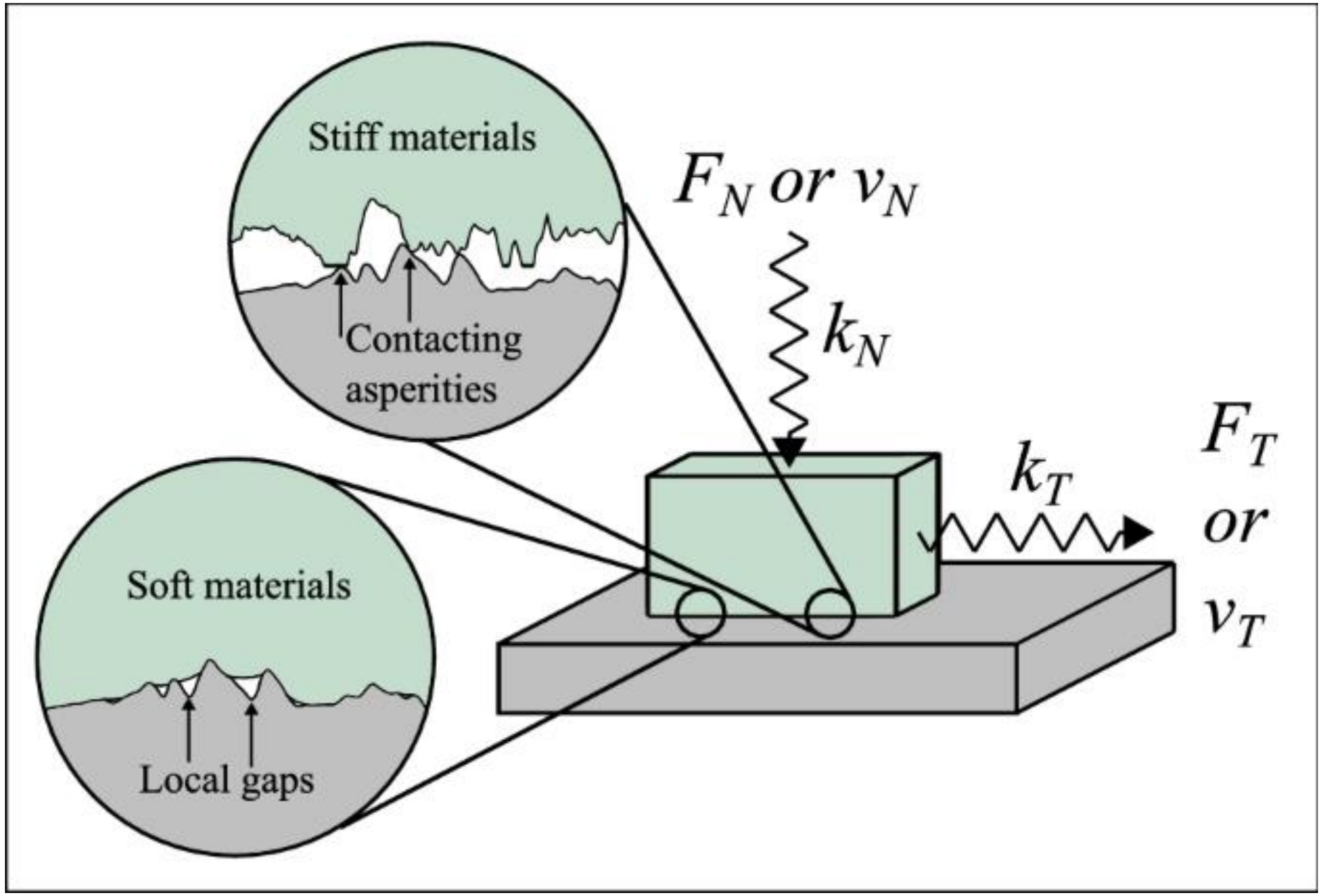
Problem

- Many systems hold components in place through clamping
- Friction is notoriously difficult to model
- Determining required clamping often takes many cycles of destructive testing



Compliant Friction Modeling

- Micro scale surface features change friction coefficients
- True surface area increases as compression increases
- Compliant materials deform and “fill” voids from surface features
- FEA required for simulation



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Our Project

Model

- Build a 3D model in SolidWorks
- Mesh using CUBIT
- Simulate in SIERRA under different conditions

Build design advisor

- Import user conditions
- Determine successes and failures
- Find regions of success, failure and uncertainty

Test and verify

- Test at simulated points
- Test at high preloads based on prediction function
- Input test data into design advisor for comparison

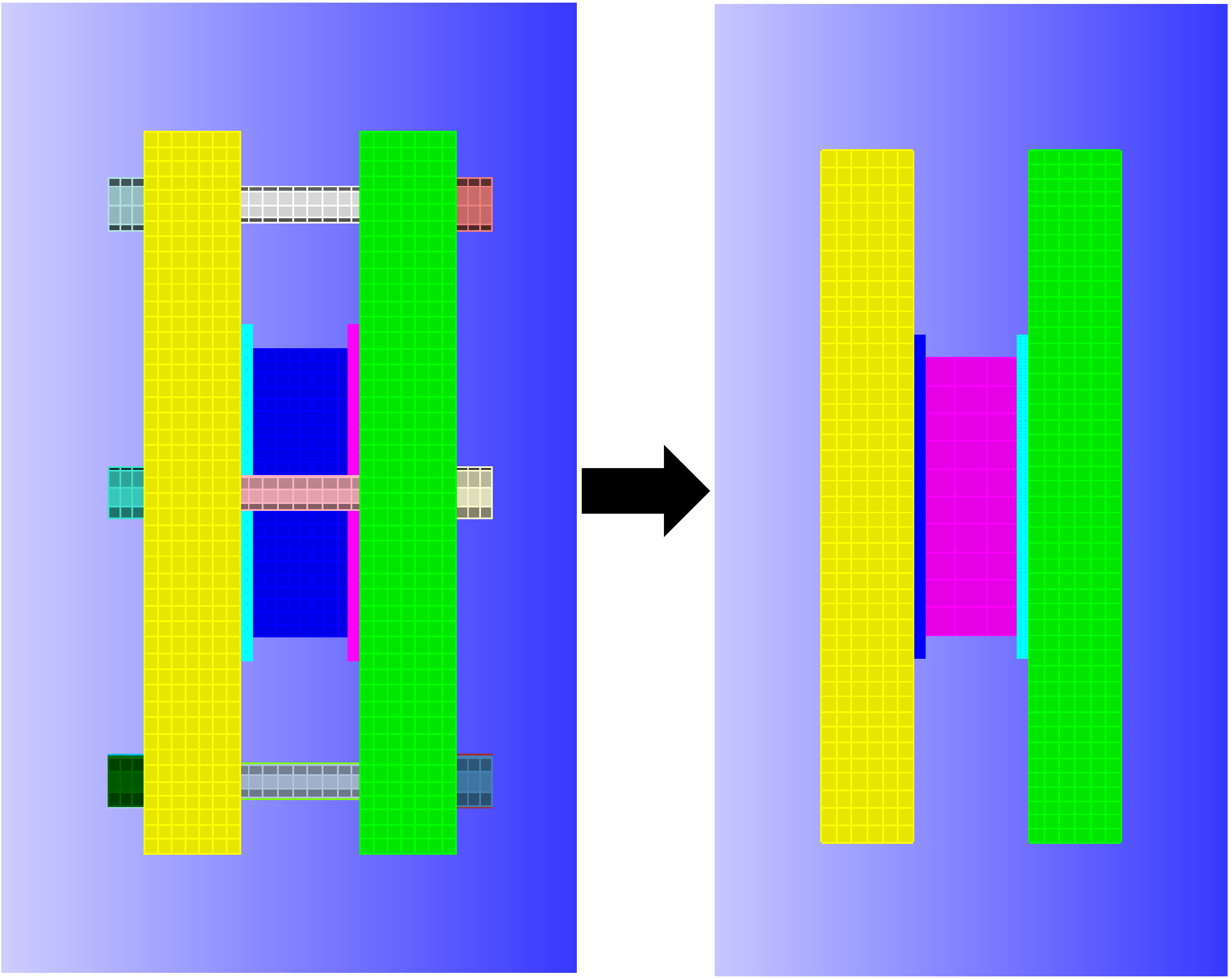
Simulation & Modeling

Simulation Parameters

- Efficiency of simulations were paramount
- Pad deformation is critical to the validity of the simulations
- Hundreds of simulations required
  - Sweep over geometries, pad materials, and compressions
  - Automated through Python scripts

Simplified Geometry

- Model on right was used for bulk simulations
- Verified against the exact model for stress distribution
- Allowed for 3x timestep size



Simulation Steps

Apply compression

- Uniform force across the top plate
- Force increases with cycloidal ramp
- Time to settle

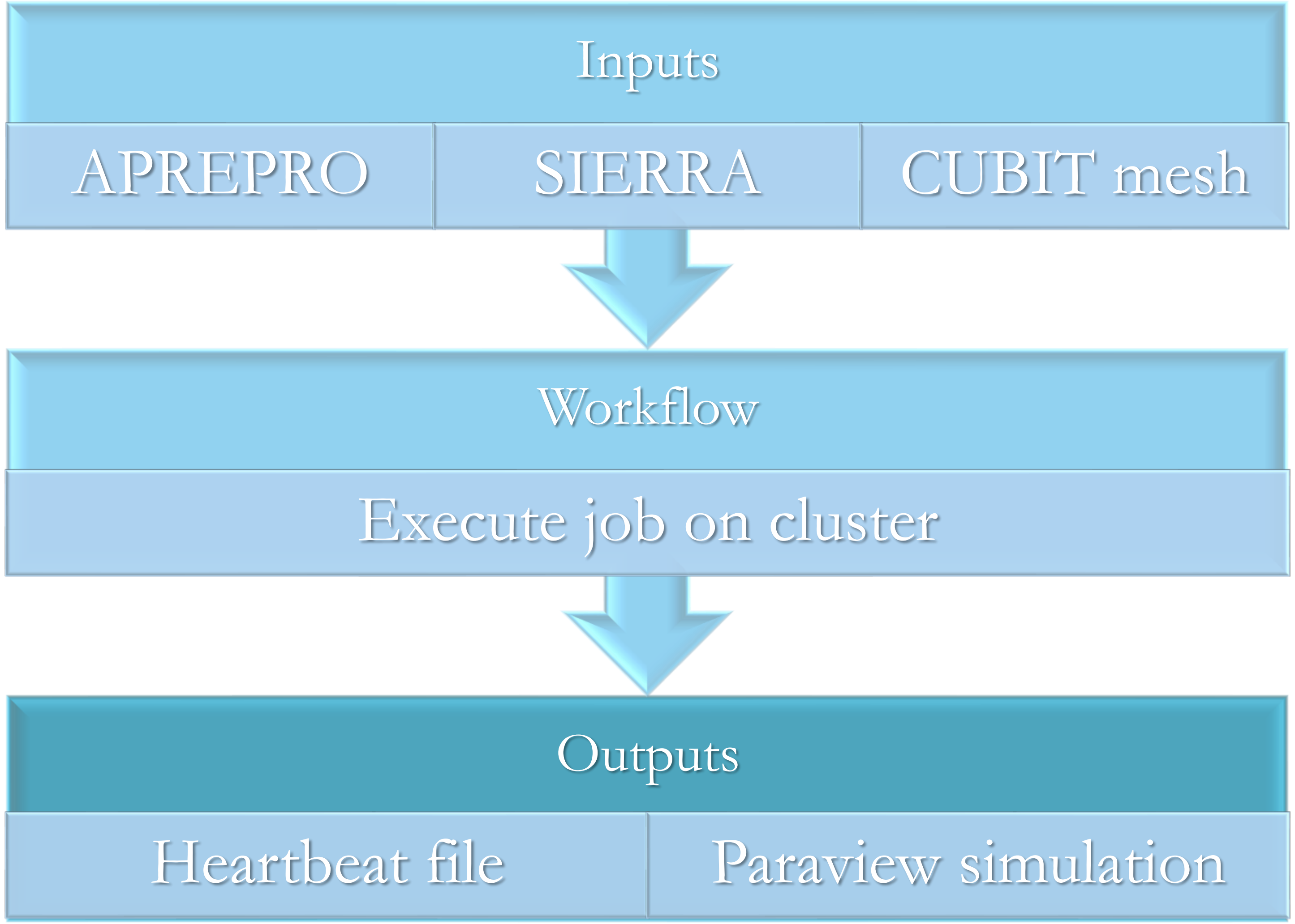
Apply shock

- 2ms Haversine pulse
- Allow it to dissipate

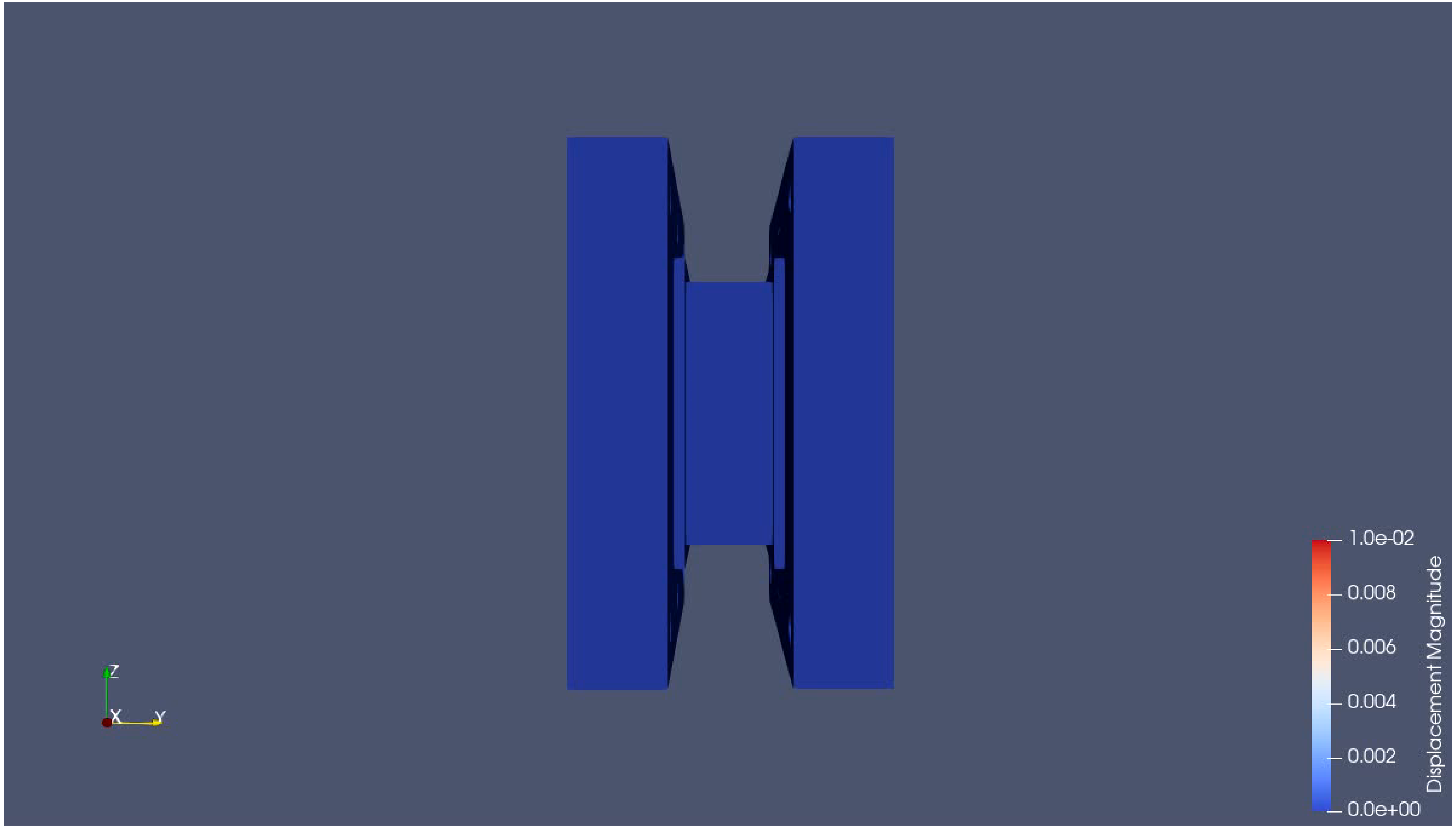
Output data

- Position data
- Acceleration data
- Element death

Simulation Workflow



Simulation Results



Design Advisor

Design Advisor Simplified Overview

Inputs

- Simulated data
- User input data
- User fail criteria
- Requested output graphs

Data processing

- Import principal simulation data
- Determine maximal successes & minimal fails from failure criteria

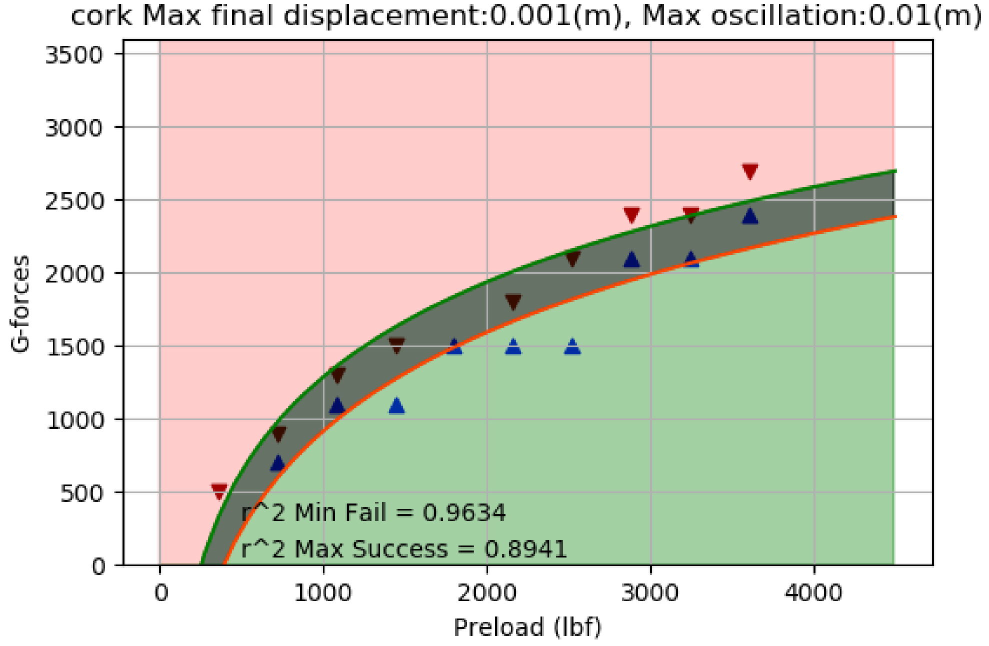
Optional data processing

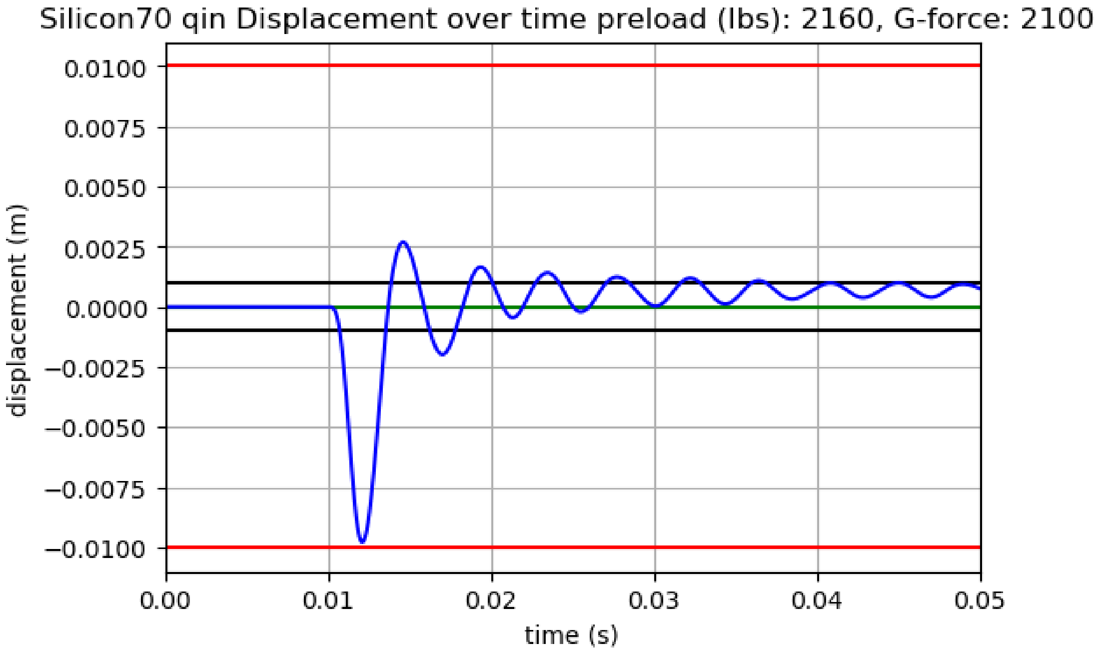
- Check additional requested graphs
- Import secondary simulation data
- Apply failure criteria

Outputs

- Plot best fit success & failure functions
- Plot failure criteria against displacement
- Save all figures to host computer

Design Advisor Outputs





Displacement Over Time

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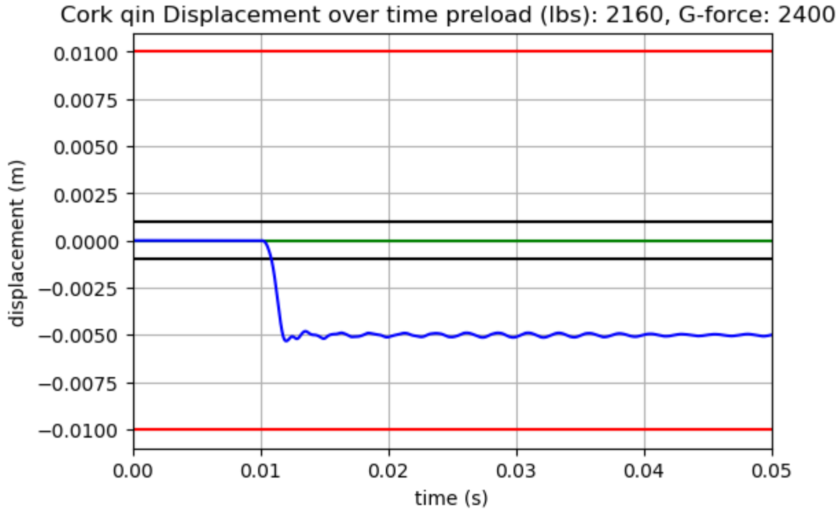

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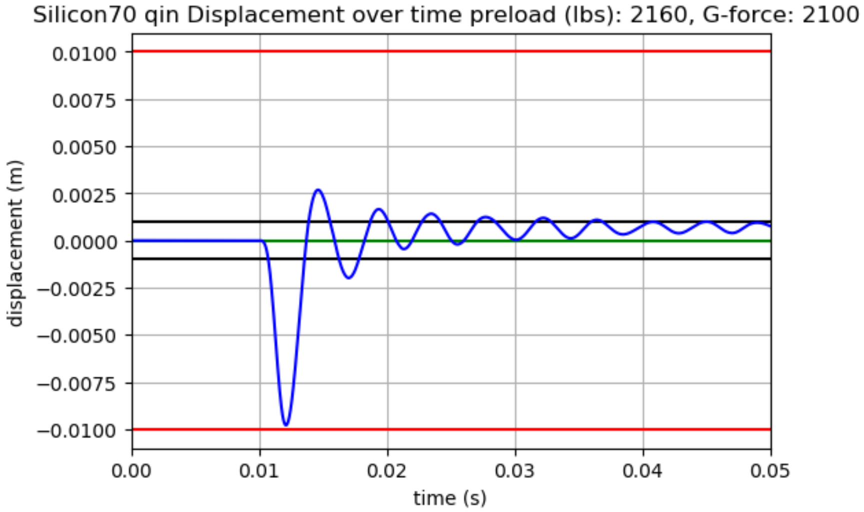

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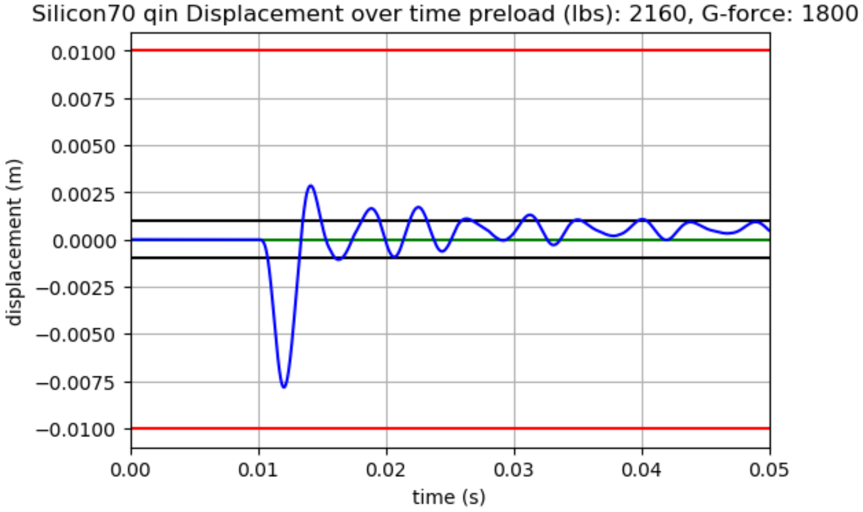

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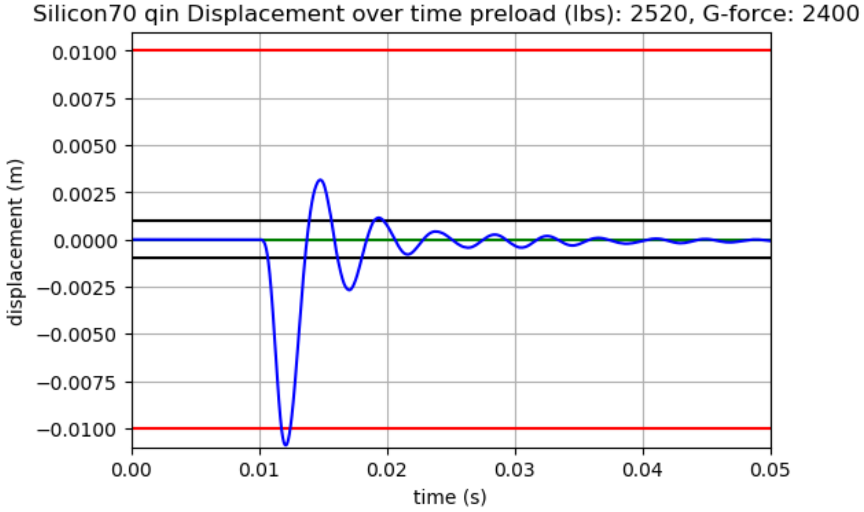
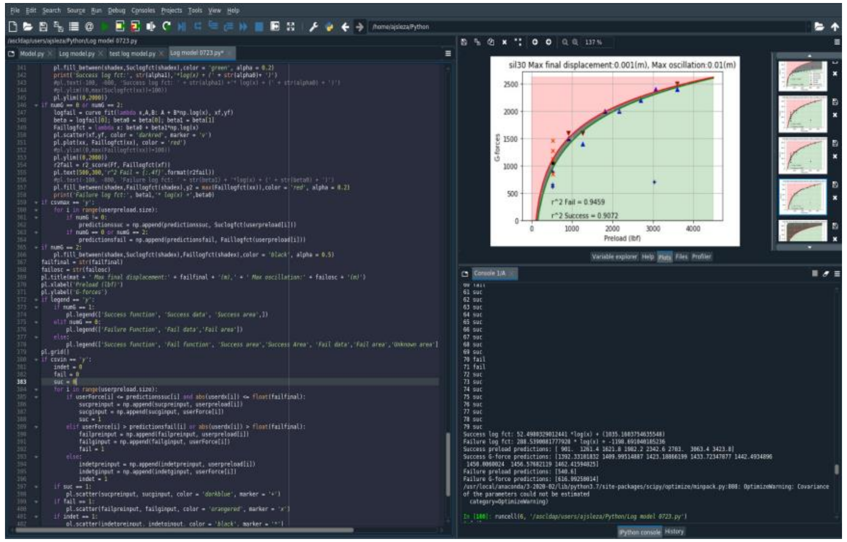
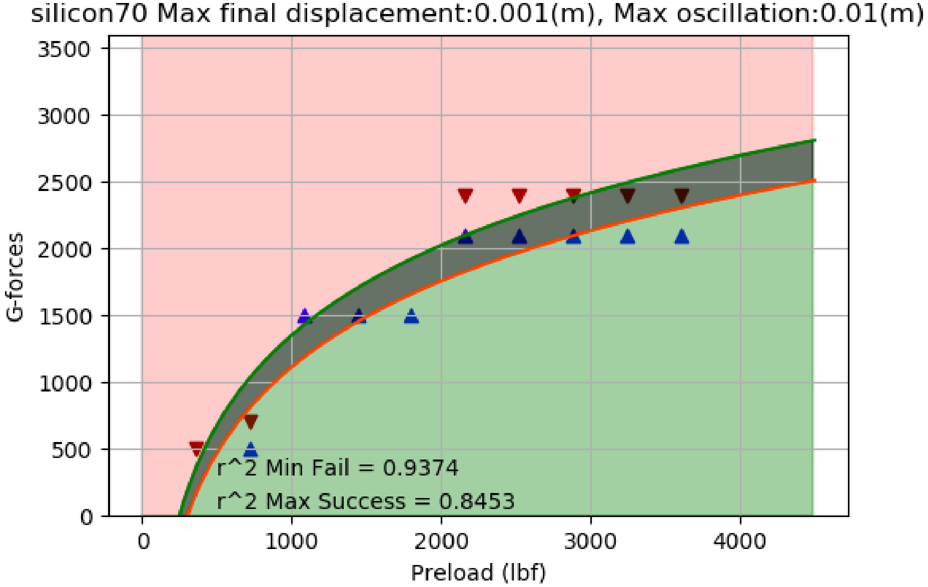
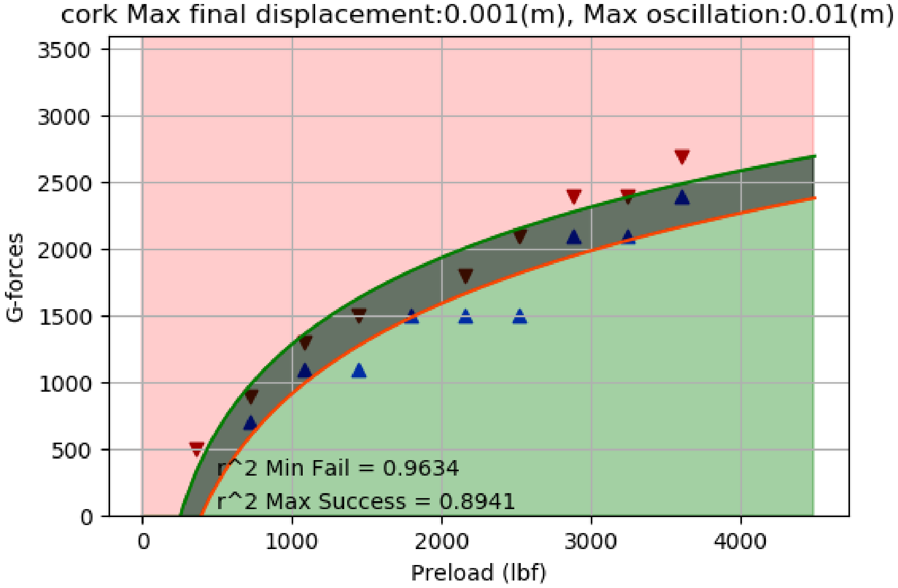
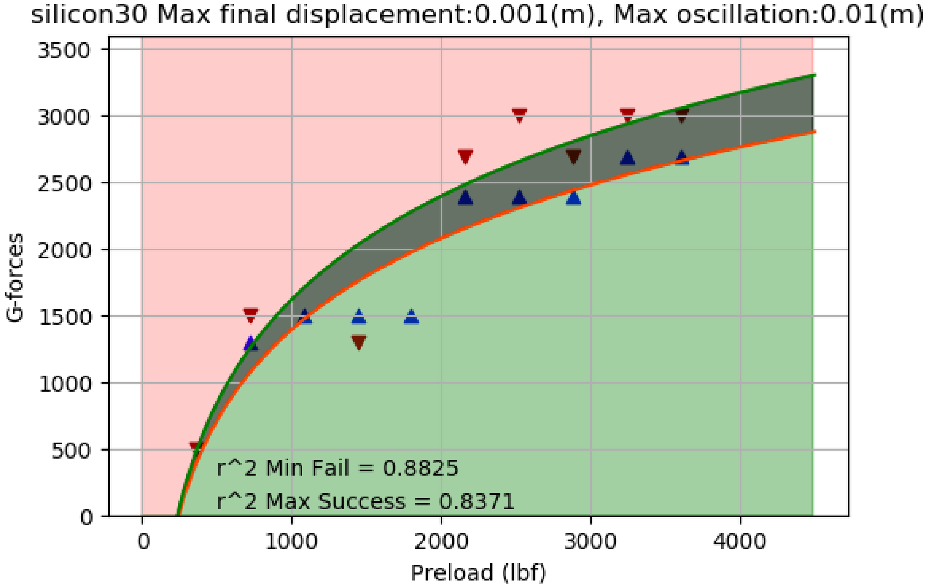


Design Advisor



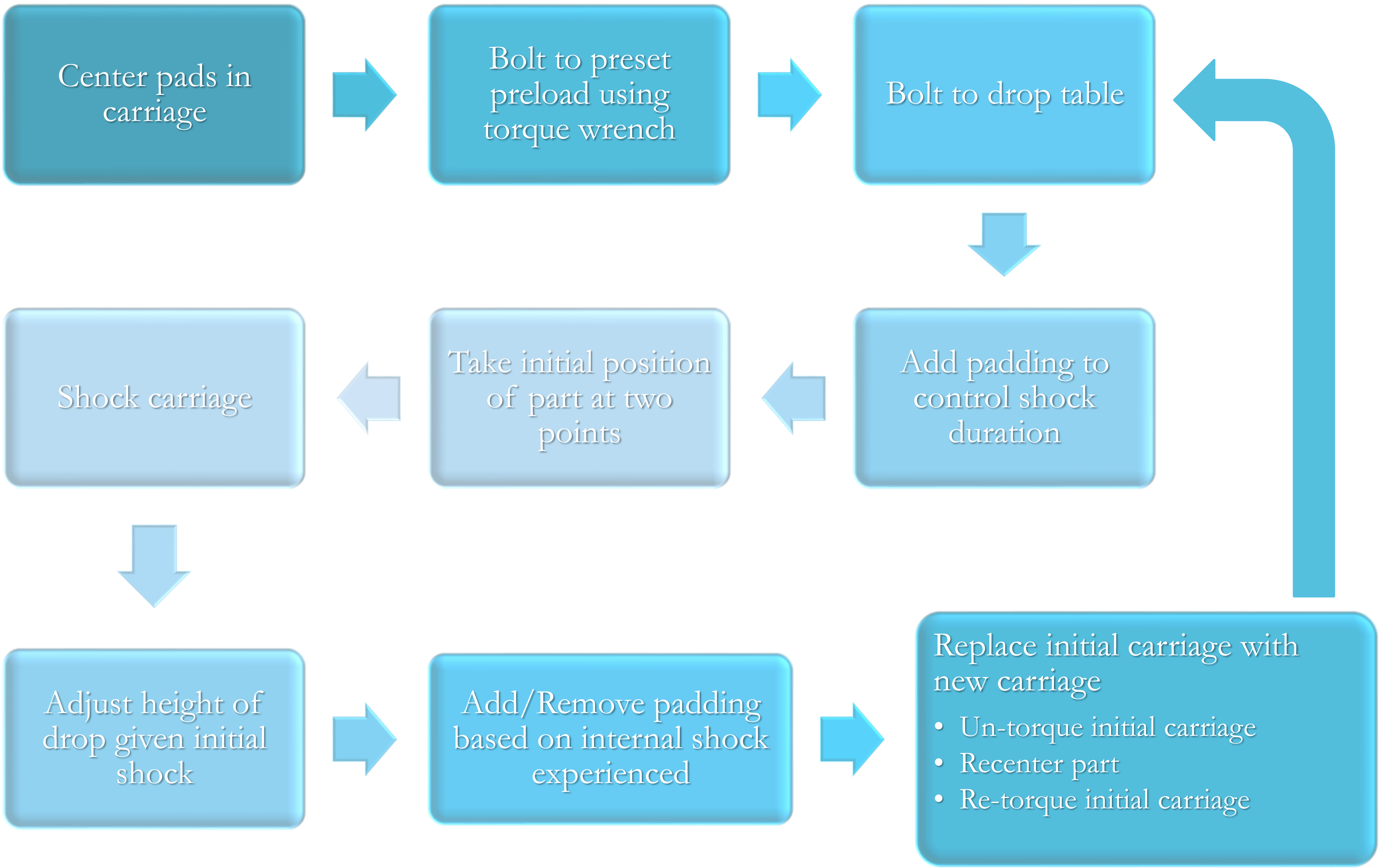






Verification & Testing

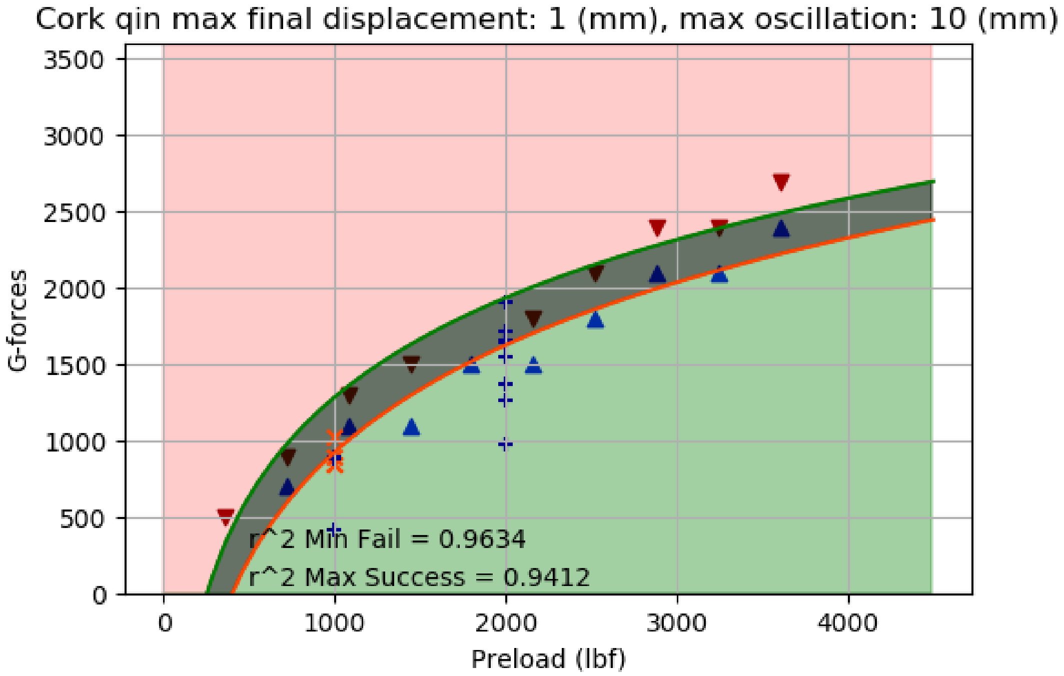
Test Methodology

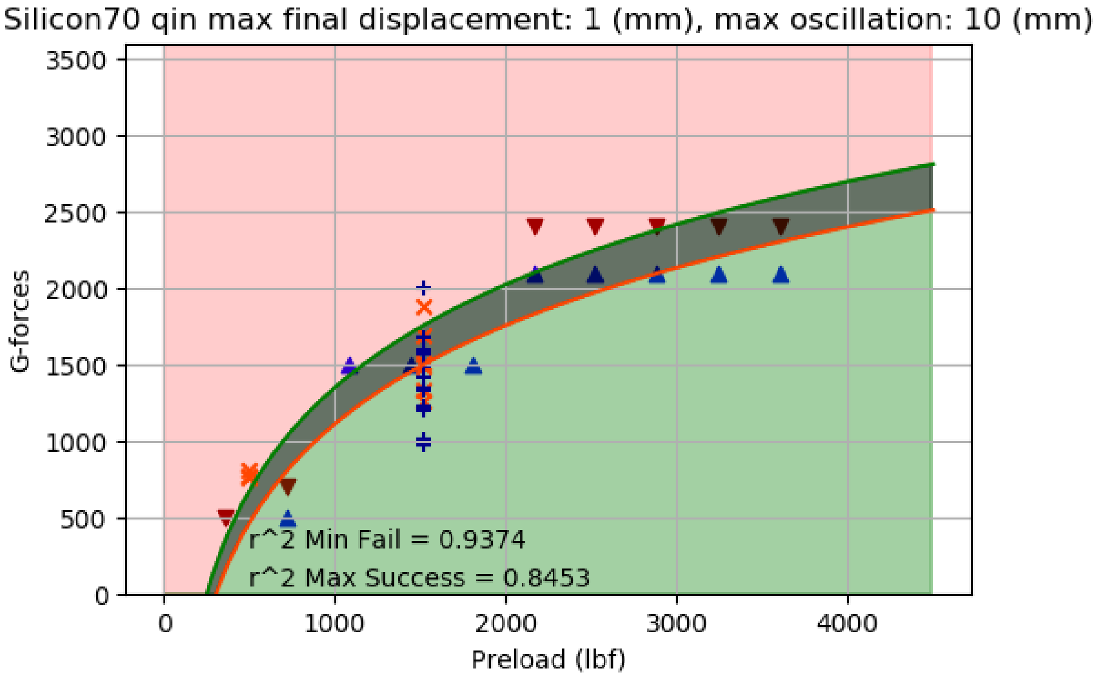


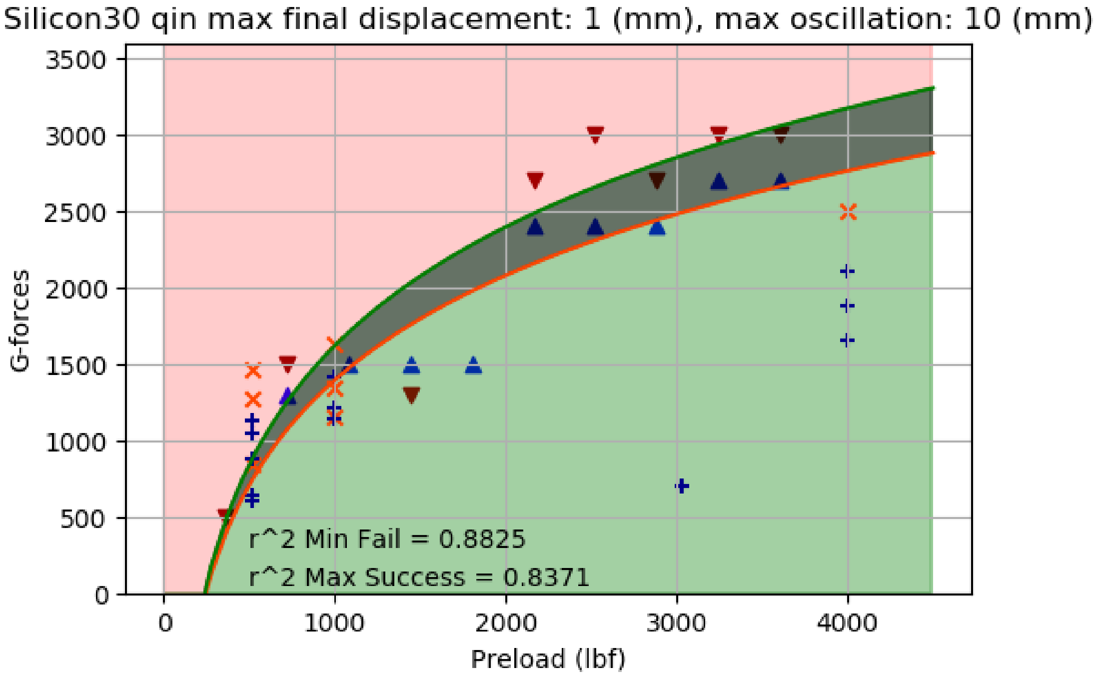
Data Collection

- High speed video
  - Displacement over time
  - Pad deformation and slip
- Accelerometers
  - Part kinematics
  - Time dependent, quantitative data
- Digital Calipers
  - Precise final displacement

Test Results







Limitations & Future Research

Limitations

Simulation Limitations

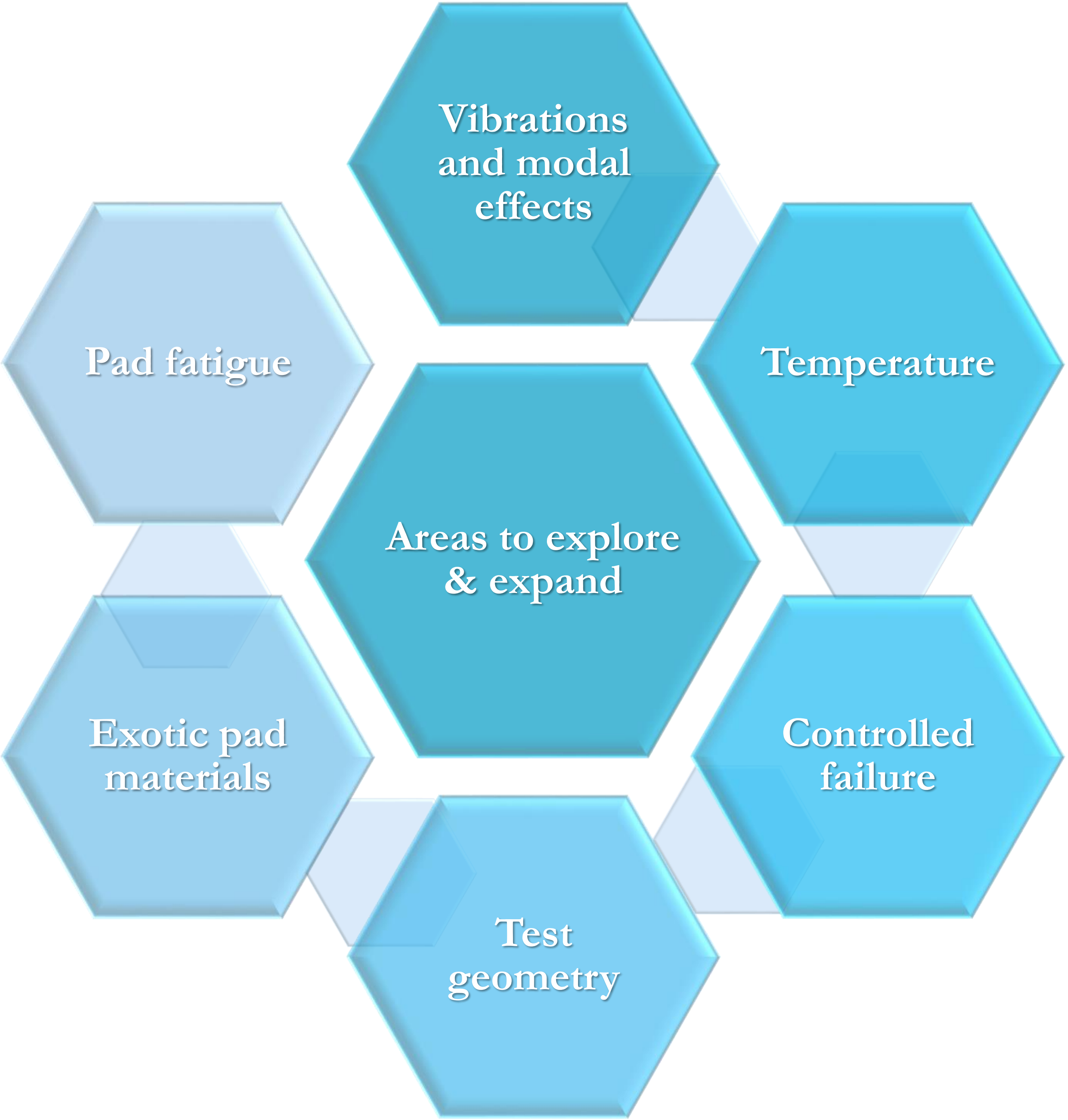
- More rotation in plates than observed in testing
- μ_s changes based on compression
- Deterministic simulation of stochastic process

Advisor Limitations

- Maximum success point dependent on range swept
- Oscillations do not always terminate in time
- Cannot predict specific displacements

Test Limitations

- Pulsed shock duration is inconsistent
- Bolts lose compression after shock
- Shock amplitude is inconsistent and infeasible to predict a priori


Vibrations and modal effects
Temperature
Controlled failure
Test geometry
Exotic pad materials
Pad fatigue
Areas to explore & expand

Q&A

Acknowledgments

- NOMAD team
  - Debby Fowler
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  - Neal Hubbard
  - Ramon Reyes
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References

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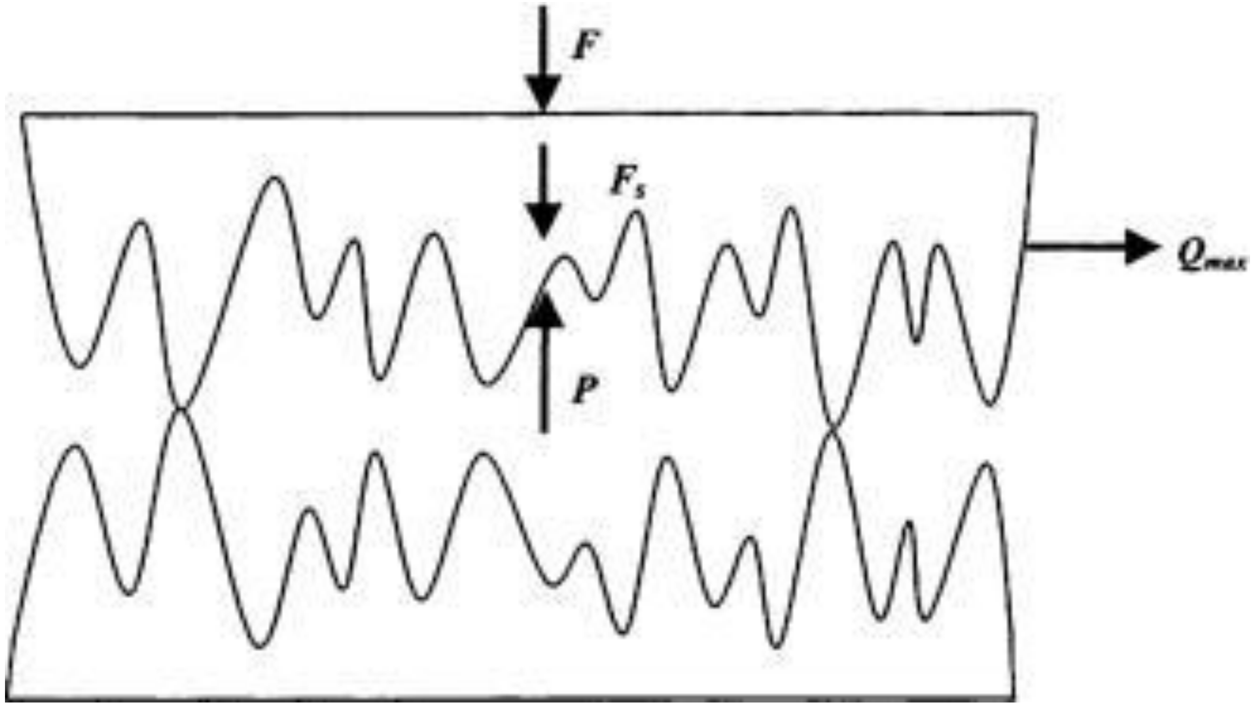
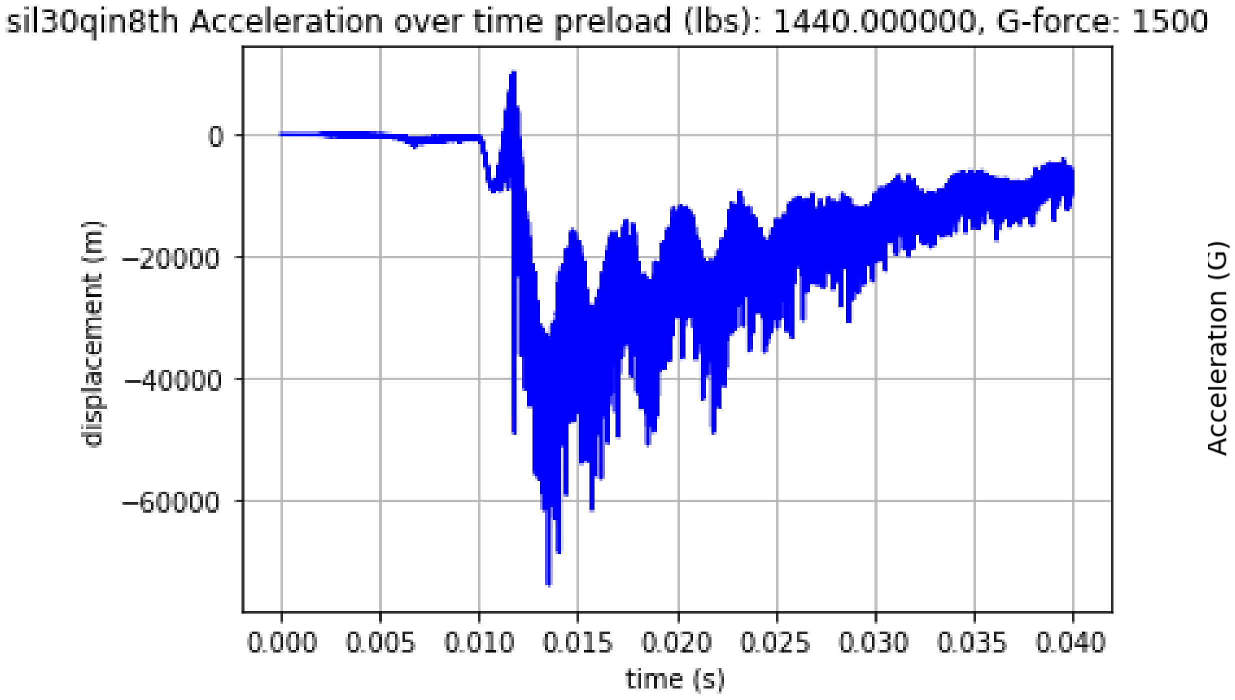
Friction Modeling With Rigid Materials

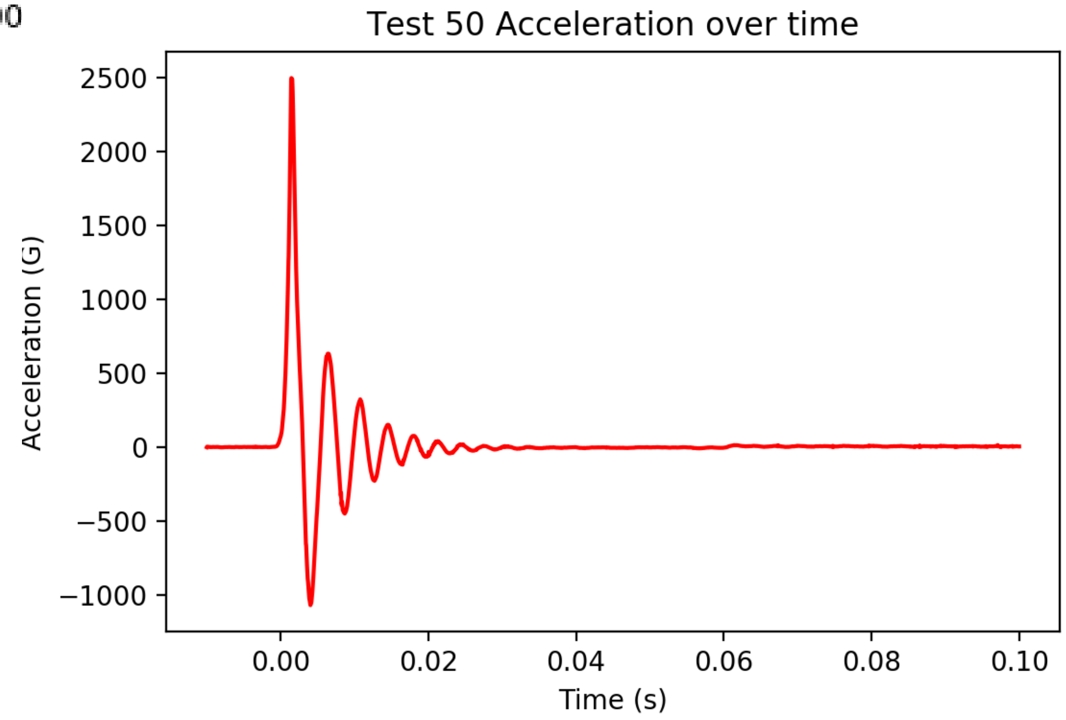
- Dependent on micro and nano scale surface features
- True surface area changes friction coefficient
- Compression independent
- FEA often required for simulation



[2]

Simulation Acceleration VS Test Acceleration





Design Considerations & Central Questions

- Will a shock displace a compressed part?
- What are the failure conditions?
- How much compression is there?
- How large is the shock?
- How long is the shock?
- What is the pad material?
- What is the pad geometry?