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Modeling and Validation of Heliostat Deformation Due to Static Loading

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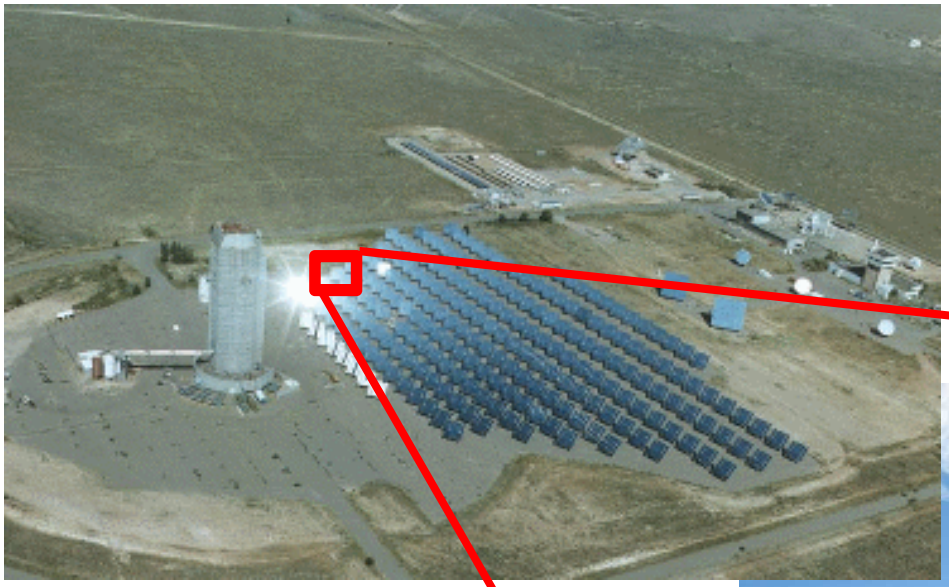
Overview

- Introduction
- Static Displacement Analysis
- Static Displacement Testing
- Results
- Summary

Introduction

- Heliostat field generally comprises ~50% of power tower costs
- Gravity and wind loading impact heliostat optical performance and fatigue
- A validated FEA model can be used to improve designs and reduce costs

Introduction



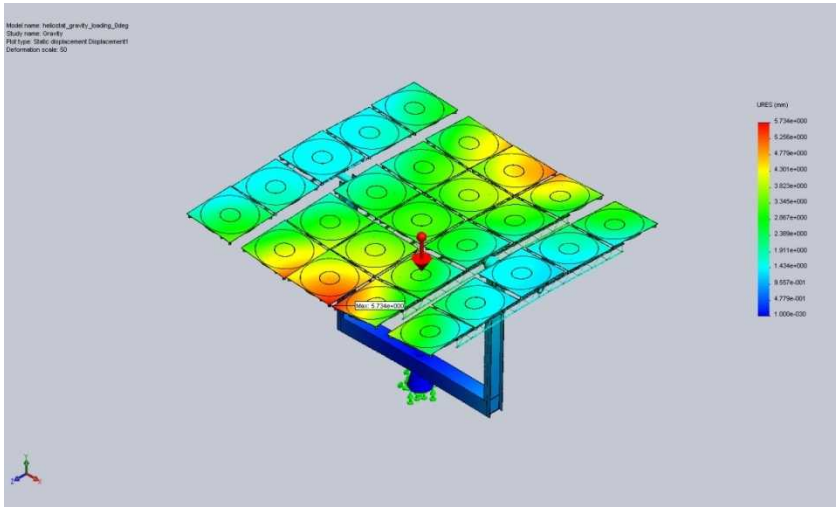
National Solar Thermal Test Facility

Heliostat being tested

Sandia National Laboratories

Objectives

- Static Simulation
  - Simulate displacements for gravity and point loads
- Dynamic Simulations
  - Develop frequency (modal) analysis
- Model Validation
  - Perform static displacement testing to validate static modeling capability



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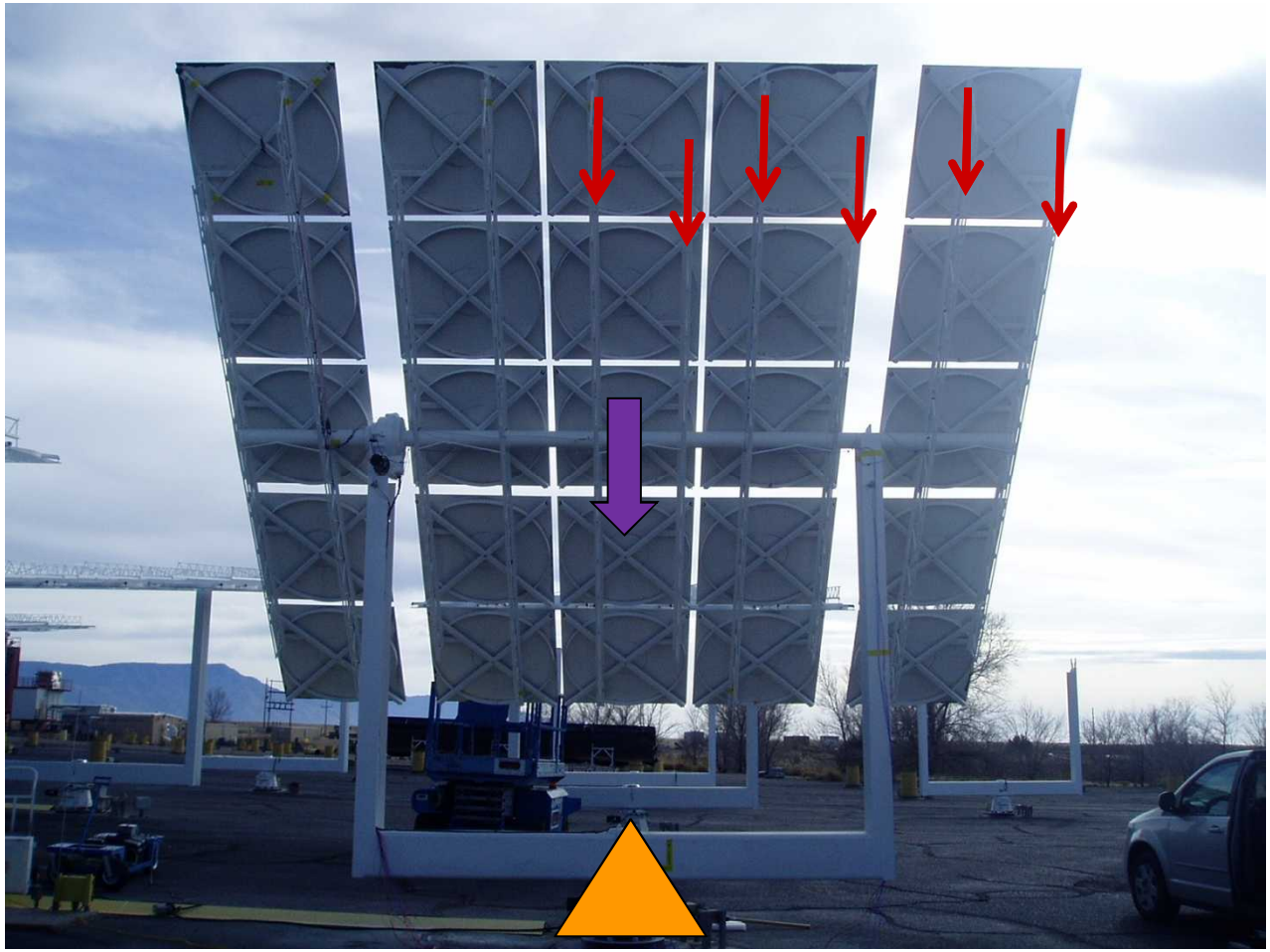
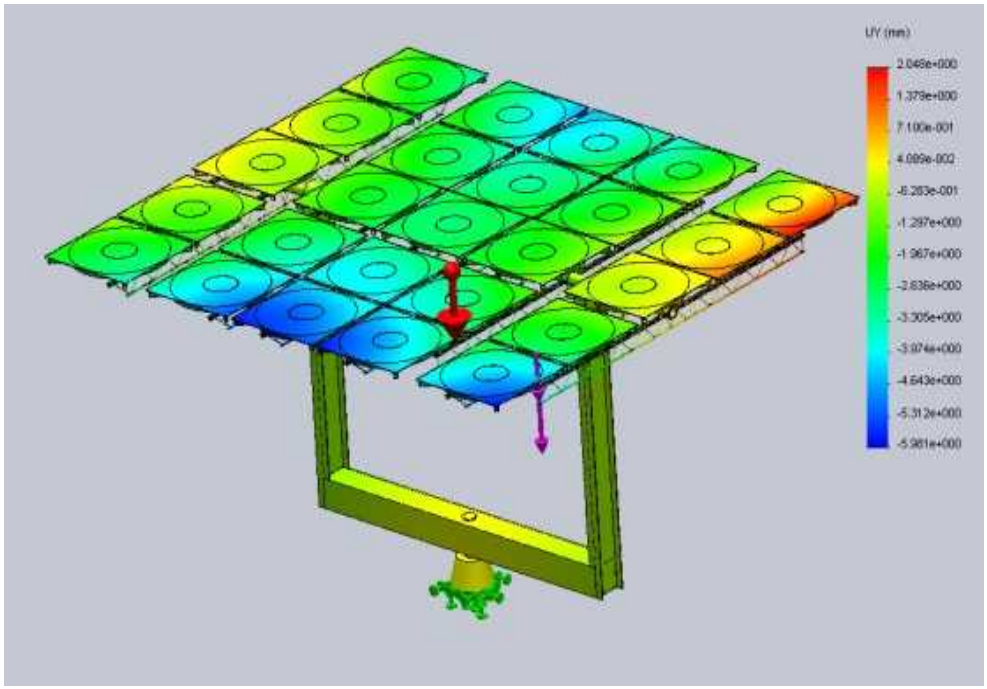
Static Load Scenario



FEA Simulations



- Seven total static simulations
  - Six point loads
  - One gravity
- Constrained at base (Azimuth Motor)
- Approximately 1.8 million solid tetrahedral elements
- Element size of ~28 mm to capture small details
- All simulations exhibited same linear displacement in elastic range

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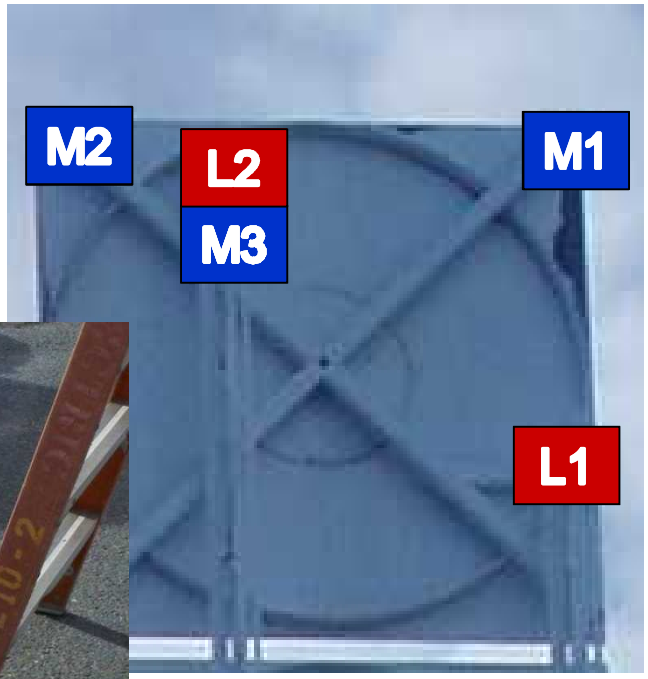
Test Method

- **Static Testing**
  - Suspend weights on NSTF Heliostat and measure displacements
  - Test different displacement measurement techniques for accuracy and repeatability
  - Provide method for static model validation of heliostats

Static Test Scenarios



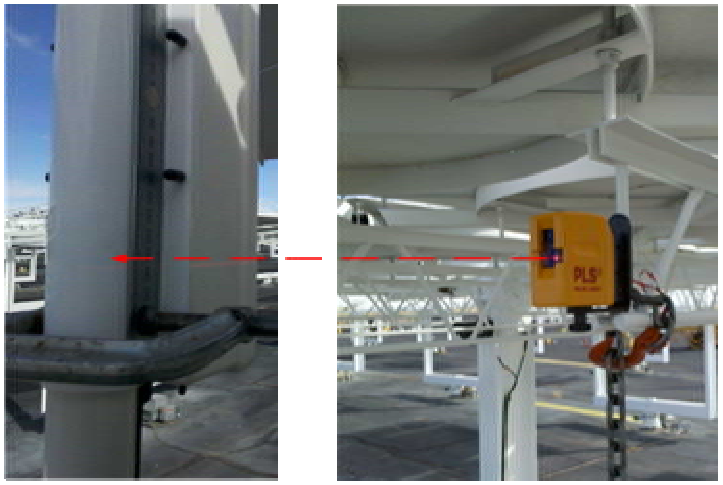
- Three displacement measurement locations per exterior facet
- Two load locations per exterior facet
  - Loads varied from zero to 65 lbs
- Displacements recorded before and after each load

Displacement Measurements

Three Measuring Techniques

String Potentiometer

Leica laser Disto-meter



Laser / Ruler

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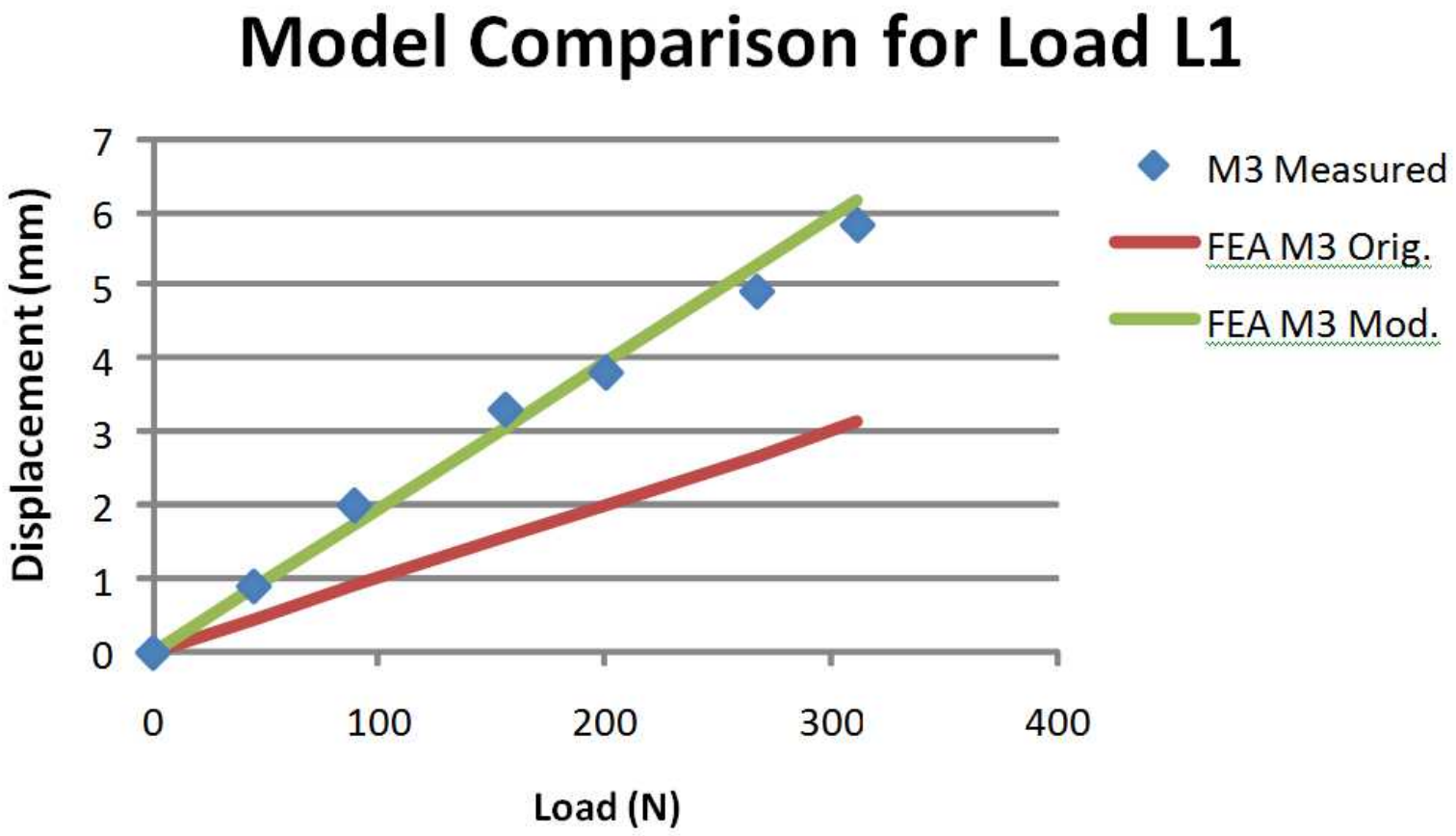
Static Test Results

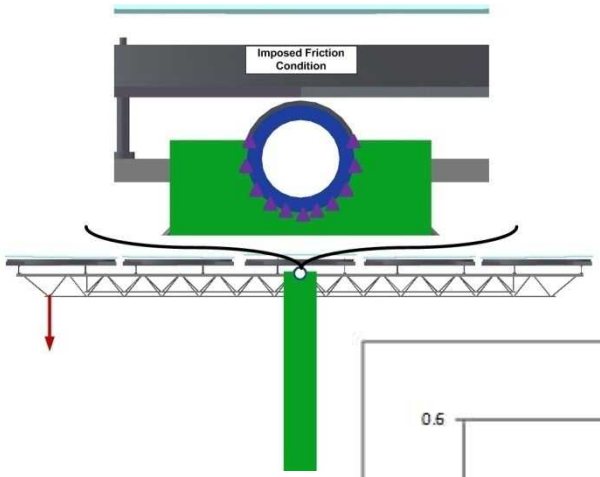


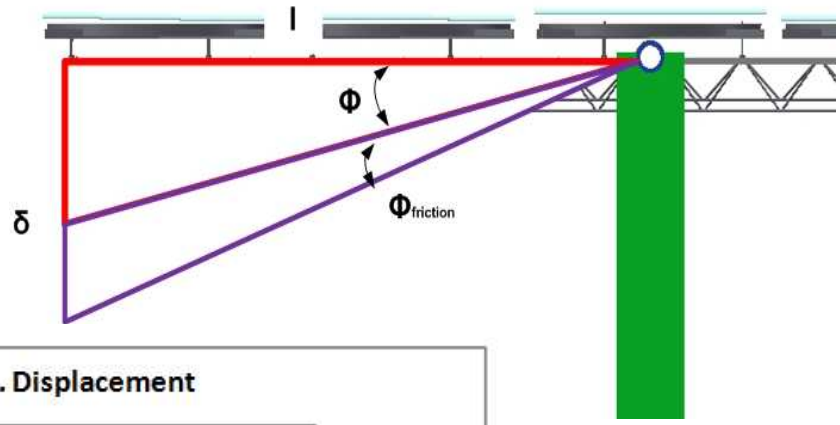
Model Adjustments

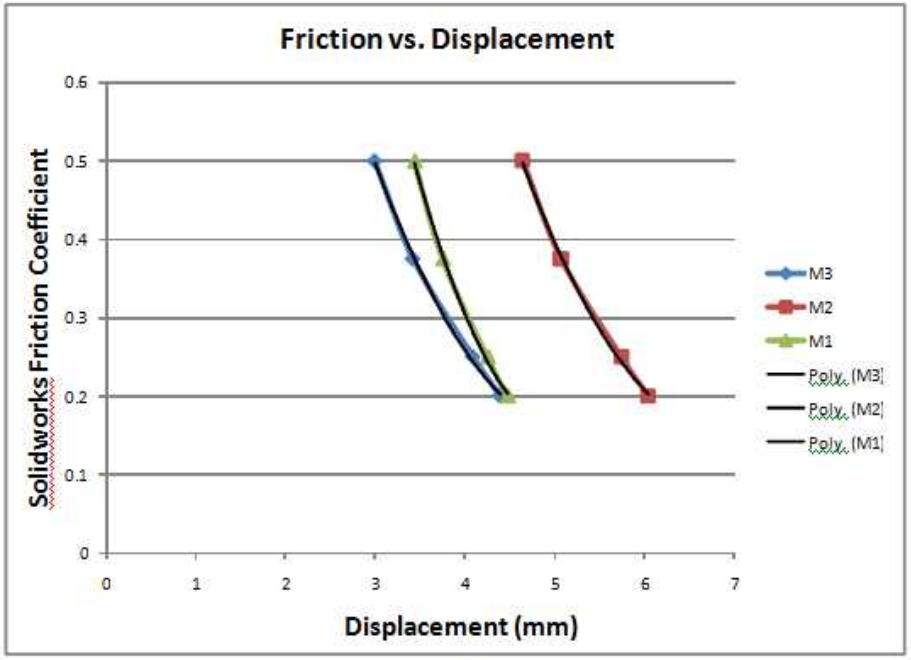
- **Reduced Young's Modulus of steel components by ~ 5%**
  - Material and connections of heliostat assembly may not have been as stiff as default material defined in Solidworks™
- **Special friction condition employed**
  - Kinetic friction constant simulates backlash in gears by adding additional offset in twisting imposed in the torque tube

Friction Condition

$$\delta = l\sin(\phi) + l\sin(\phi_{friction})$$







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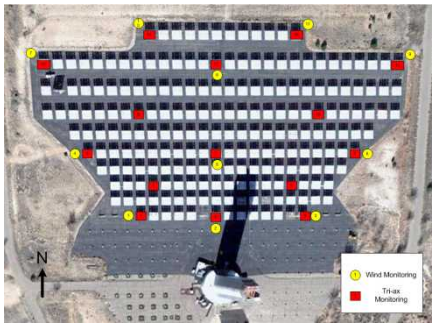
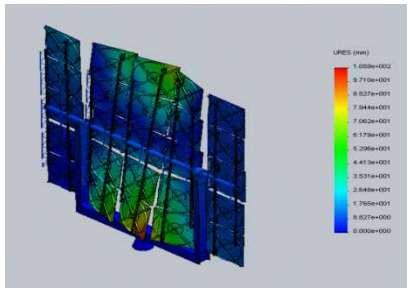
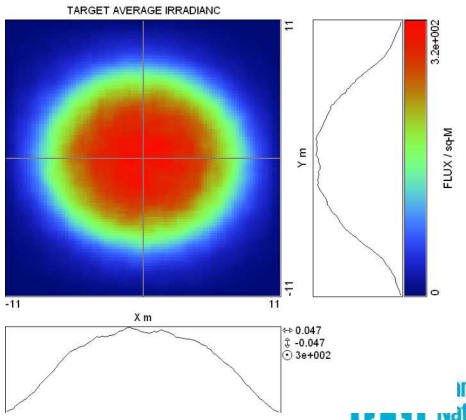
- **Heliostat model was calibrated to match static test results**
- **A simple and repeatable method for heliostat model validation was demonstrated**
  - Static validation via point loading
- **Commercial CAD and simulation software Solidworks was able to simulate static heliostat displacements**

Ongoing Work

- **Utilize model and test results for benchmarking Sandia high-performance computing codes**
- **Monitor and simulate vibration in heliostats due to wind loading**
- **Perform ray tracing on wind deformed models to establish beam quality degradation**







Questions?

Backup Slides

Modeling Goals

- Remodel NSTTF Heliostat using top-down methodology
  - Re-orient heliostat based on azimuth, elevation, and focal length
  - Rebuilds model with no user modification necessary
  - Completely remodeled to add canted and focused facets
- Use model in static and dynamic FEA Analysis
- Ultimately use model for optical ray tracing