Low-Cost Heliostat for Modular Systems

Subcontractor:

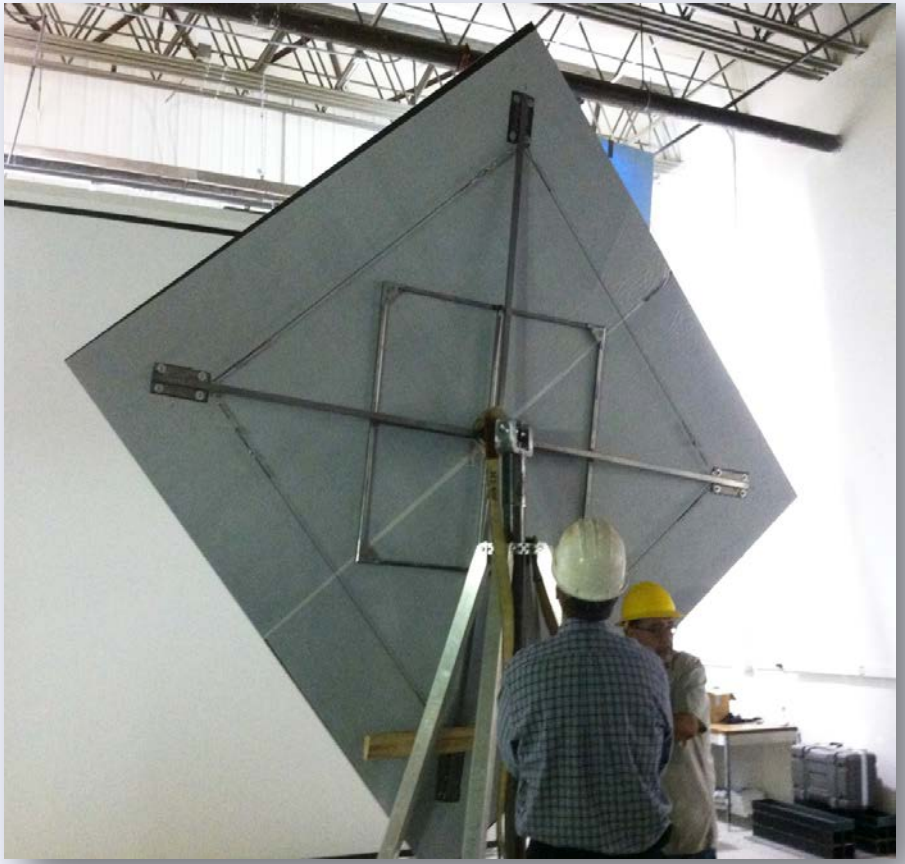
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Principal Investigator:

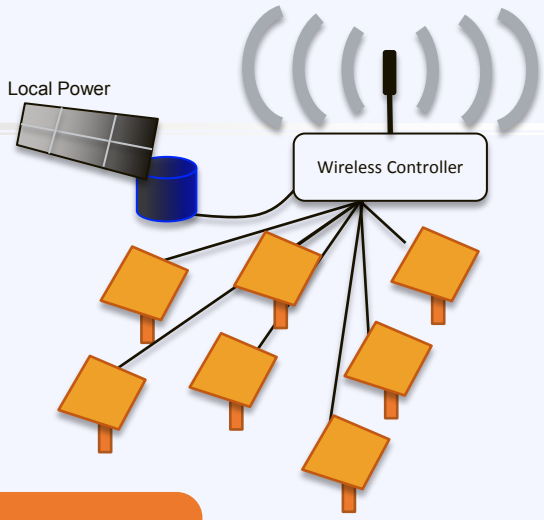
Chuck Kutscher

Start Date:

October 1, 2012



Development Approach

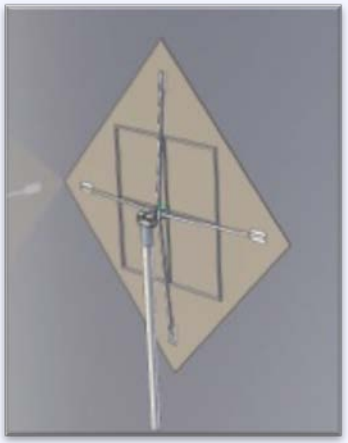


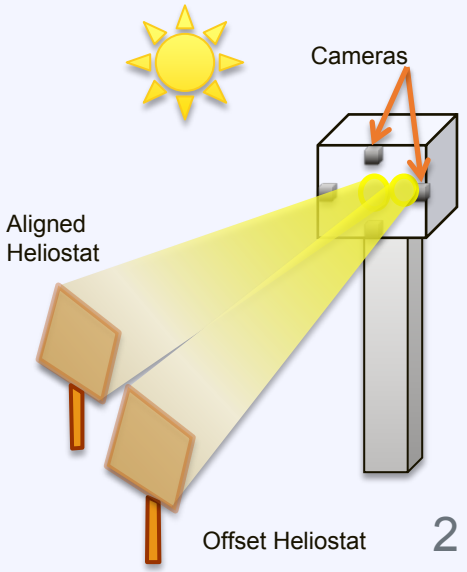
Task 1.
Material-Efficient Heliostat Design

Task 2.
Wireless Communication and Control System

Task 3.
Image-Based Closed Loop Tracking Algorithm

Low-Cost ($75/m^2) Heliostat Field

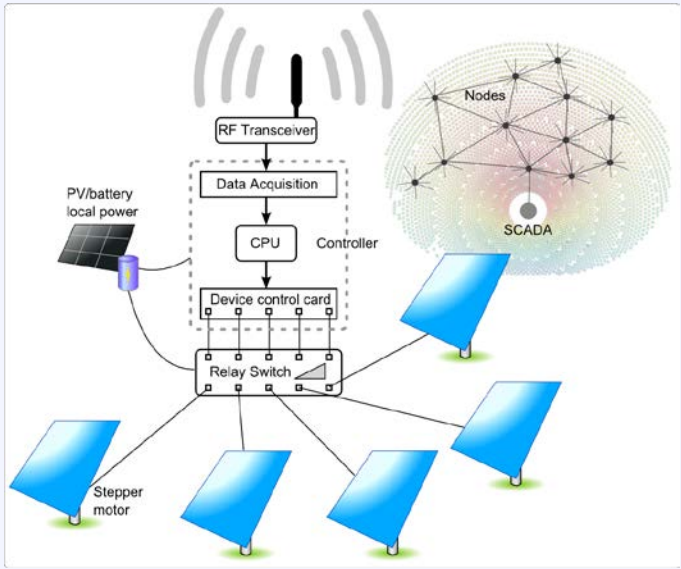




SunShot U.S. Department of Energy

Task Objectives

- Specific goals:
  - Task 1: Low-cost structure with no greater than 4.0 mrad image error at wind speeds up to 12 m/s (26.8 mph)
  - Task 2: Wireless, locally-powered communication and control system that decreases these cost aspects by at least 20%
  - Task 3: Autonomous optical calibration and tracking technique

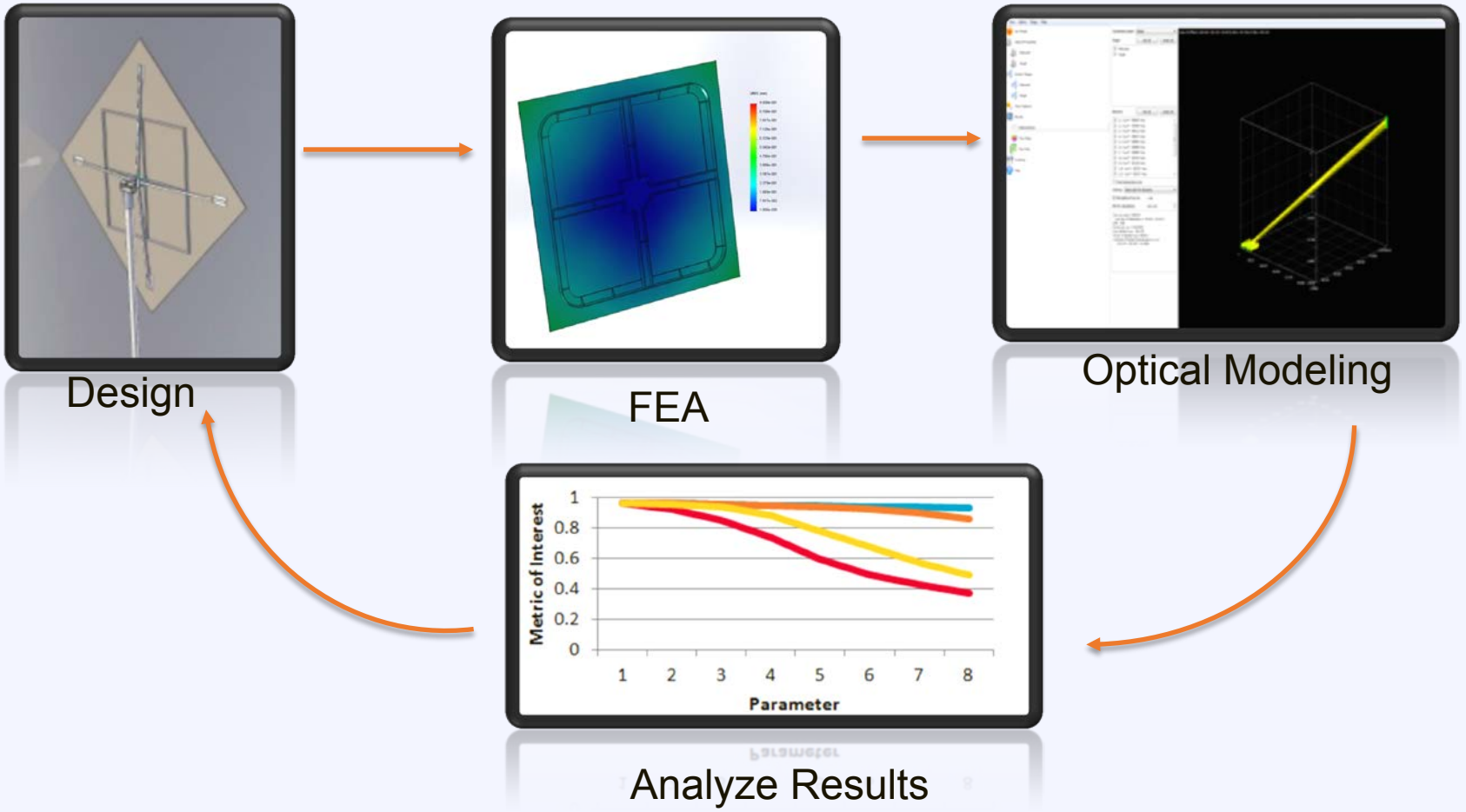


Project Innovation

- Structure
  - Cable drive that minimizes motor torque and cost
  - Glass integrated structural design lowers material usage
- Wireless Control
  - Reduction in field wiring and associated costs
- Image-Based Tracking
  - Centralized sensor bank minimizes number of high cost components
  - Deployed low-cost orientation sensors

Task 1: Collector prototype development and testing (Judy Netter, Allison Gray NREL)

Methodology and Approach

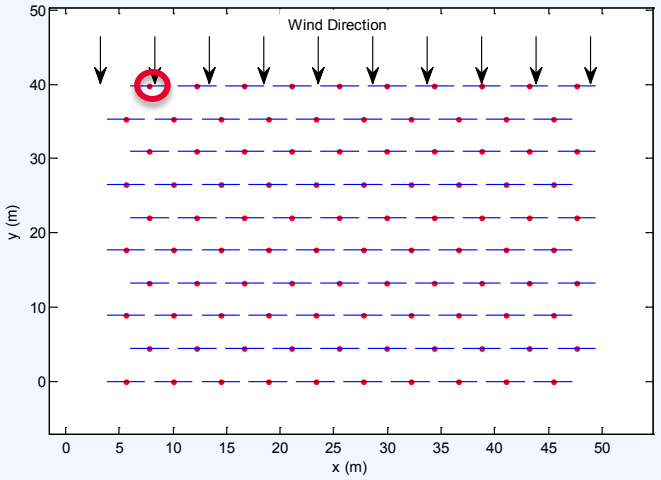


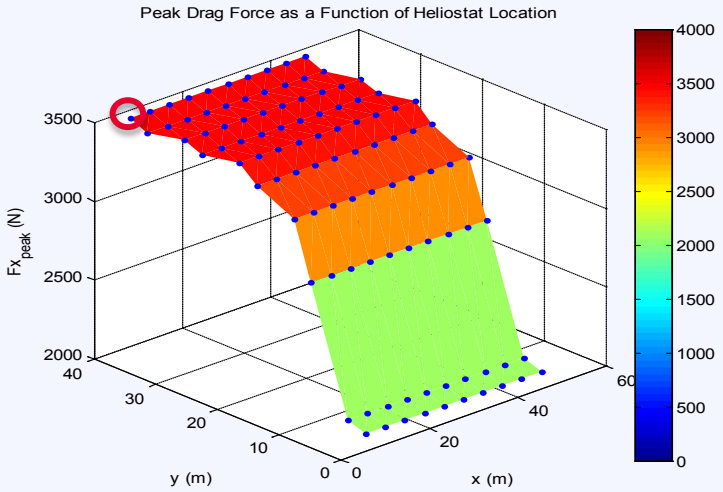
Task 1: Collector prototype development and testing (Judy Netter, Allison Gray NREL)

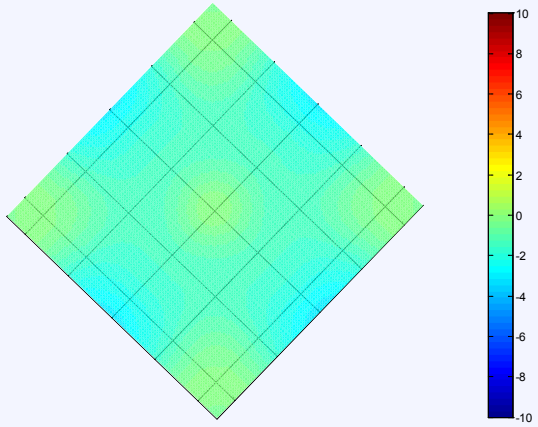
Heliostat Surface Errors

- Changes in surface deflections in 35 mph wind conditions were analyzed
  - RMS error of 2.64 mrad was determined while heliostat is in its peak drag orientation
  - RMS error of 0.51 mrad was determined for this design while the heliostat is in its peak lift orientation

Modeled Field Layout



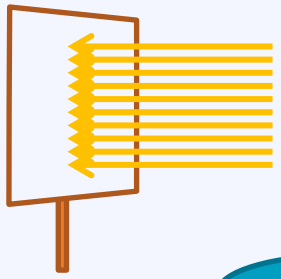




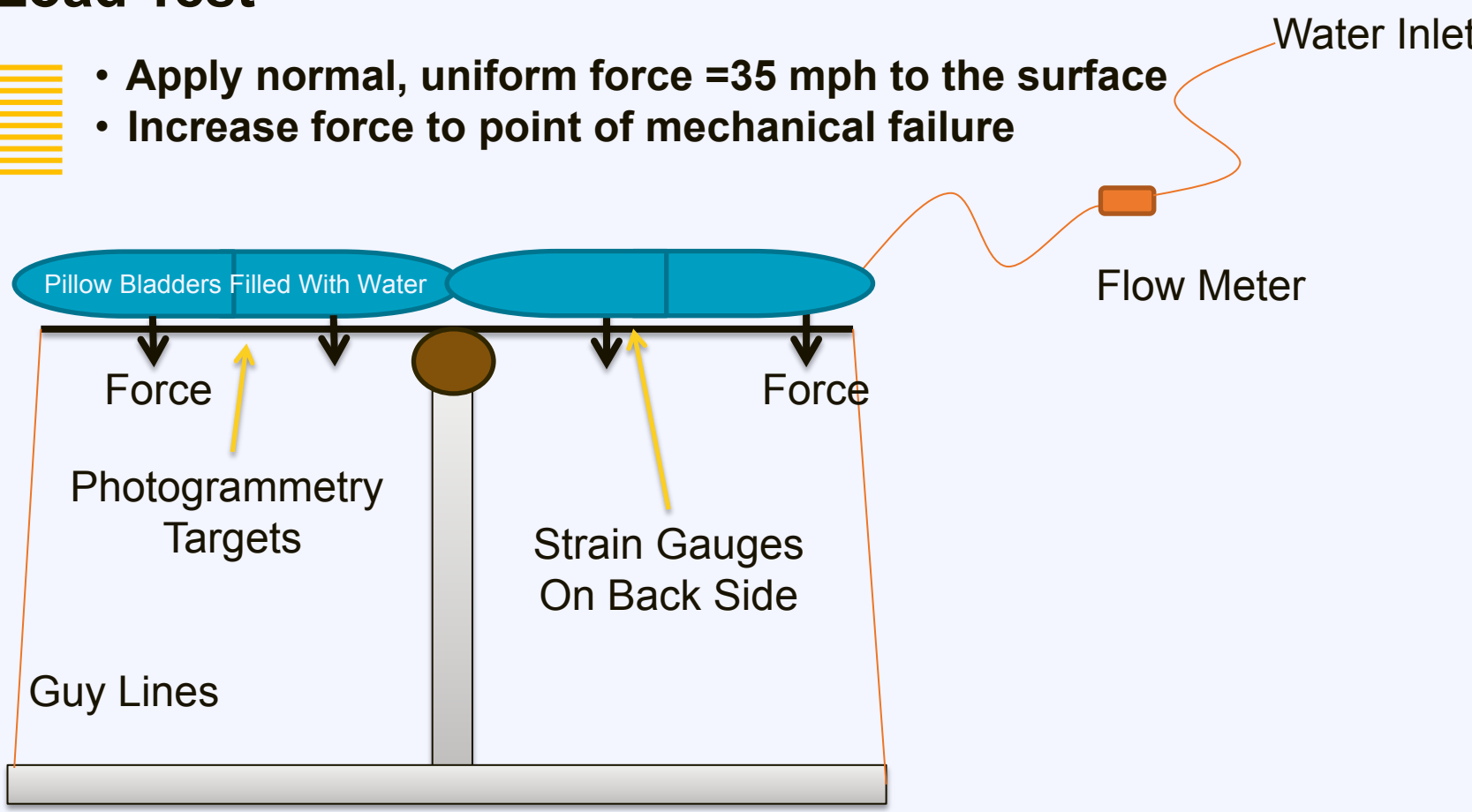
Deflection results for an isolated heliostat in a field experiencing 35 mph winds in a peak drag load orientation.

Task 1: Collector prototype development and testing (Judy Netter, Allison Gray NREL)

Wind Load Test



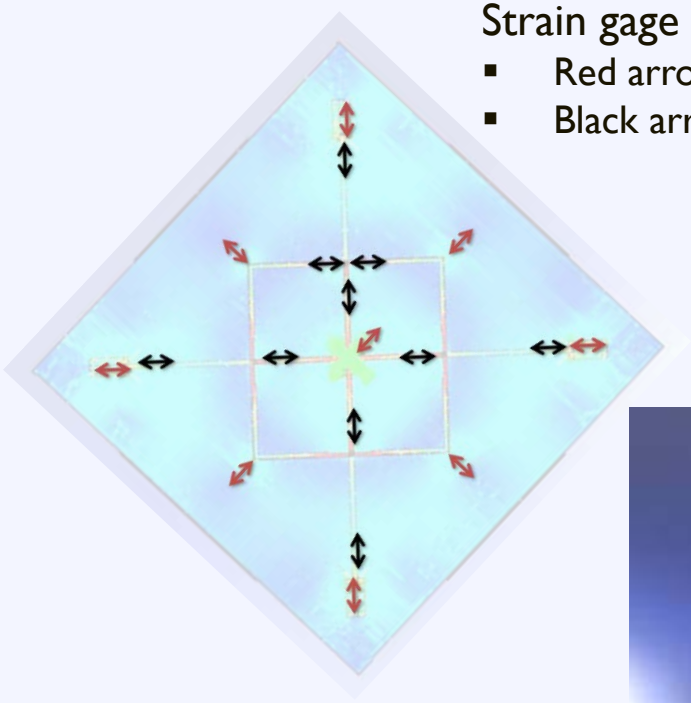
- **Apply normal, uniform force =35 mph to the surface**
- **Increase force to point of mechanical failure**



Filled Water Bladders Apply Uniform Load in Stow Position

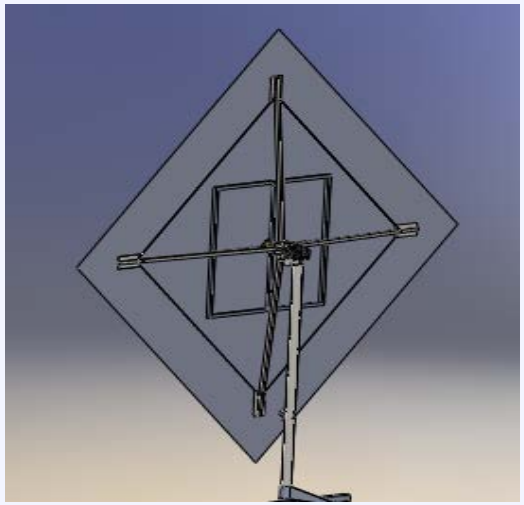
Task 1.1: Collector prototype development and testing (Judy Netter, Allison Gray NREL)

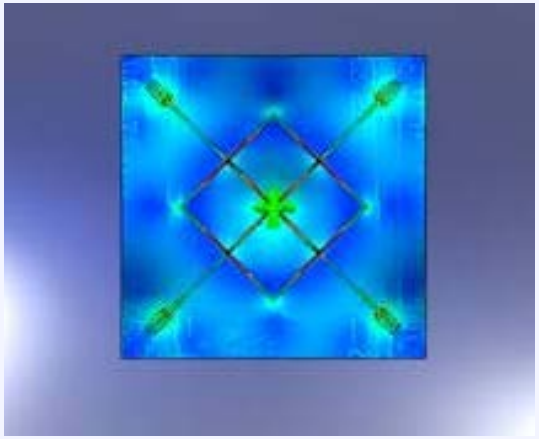
Preparation for Strain Gage Tests



Strain gage placement

- Red arrows – on mirror back surface
- Black arrows- steel back structure

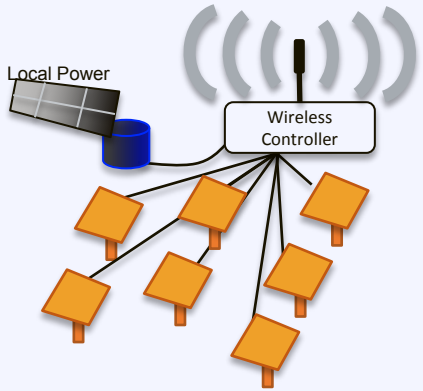


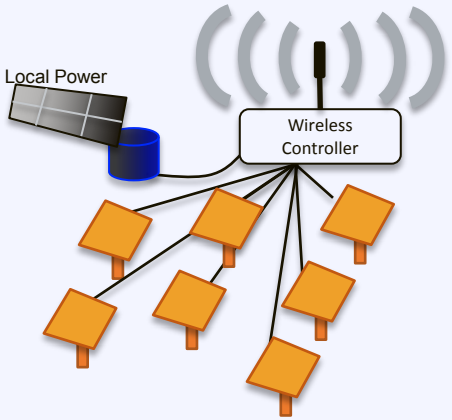


Regions of increased strain are shown in green.

Task 2: Wireless Control
(Tim Wendelin, Guangdong Zhu, Ben Ihas NREL)

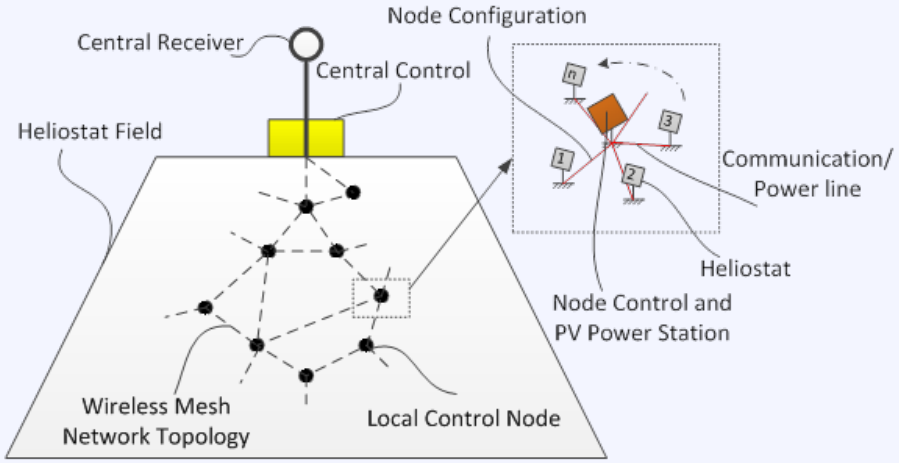
- 20% reduction in power/communications results in \$17-\$18/m^2 as a starting point.
- Other benefits of wireless control
  - ✓Reduction of field preparation
  - ✓Reduction of heliostats installation
  - ✓Reduction of O&M cost
  - ✓Increase in communication reliability





Task 2: Wireless Control (Tim Wendelin, Guangdong Zhu, Ben Ihas, NREL)

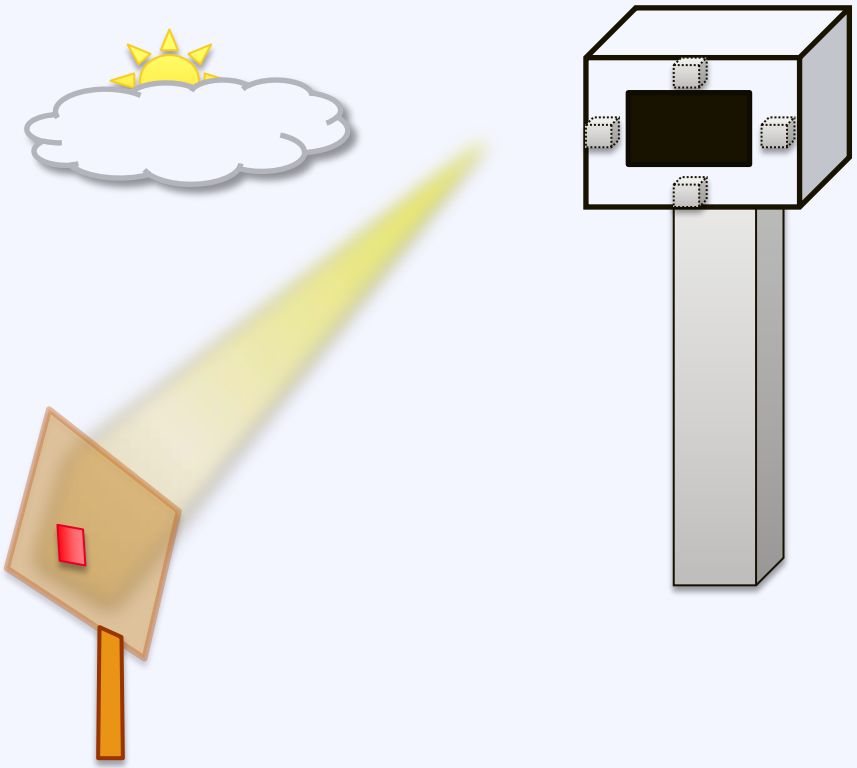
- Additional Staff: Mike Wood, Willbros Engineers
- Results:
  - Finalized the contract with Willbros and had kick-off meeting.
  - Initiated mesh shared node conceptual design



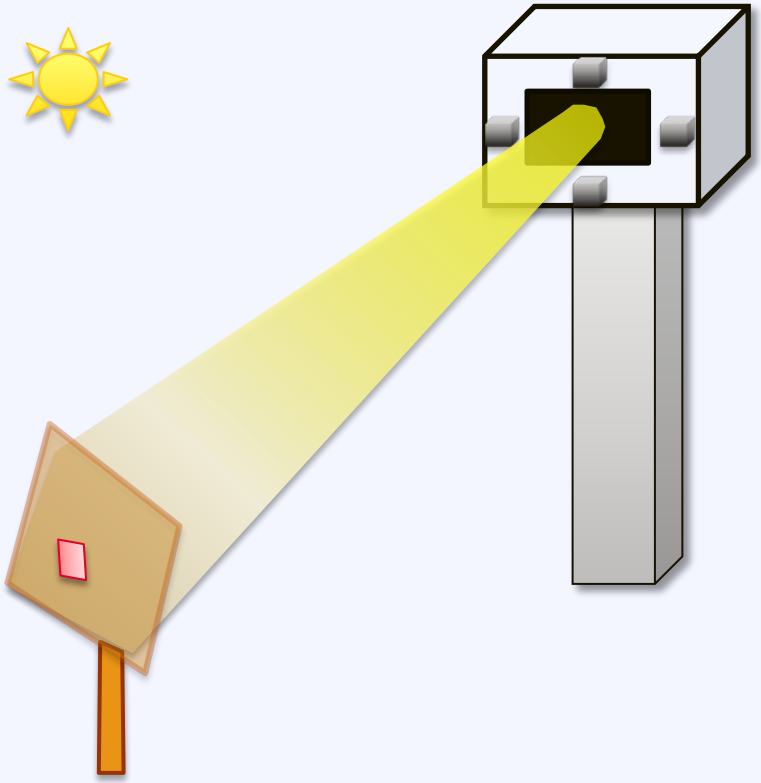
Task 3: Image-Based Tracking and Calibration (Ben Ihas, NREL)

Hybrid Control Approach

Low-Light: Low-Cost Onboard Orientation Sensor for Rough-tune

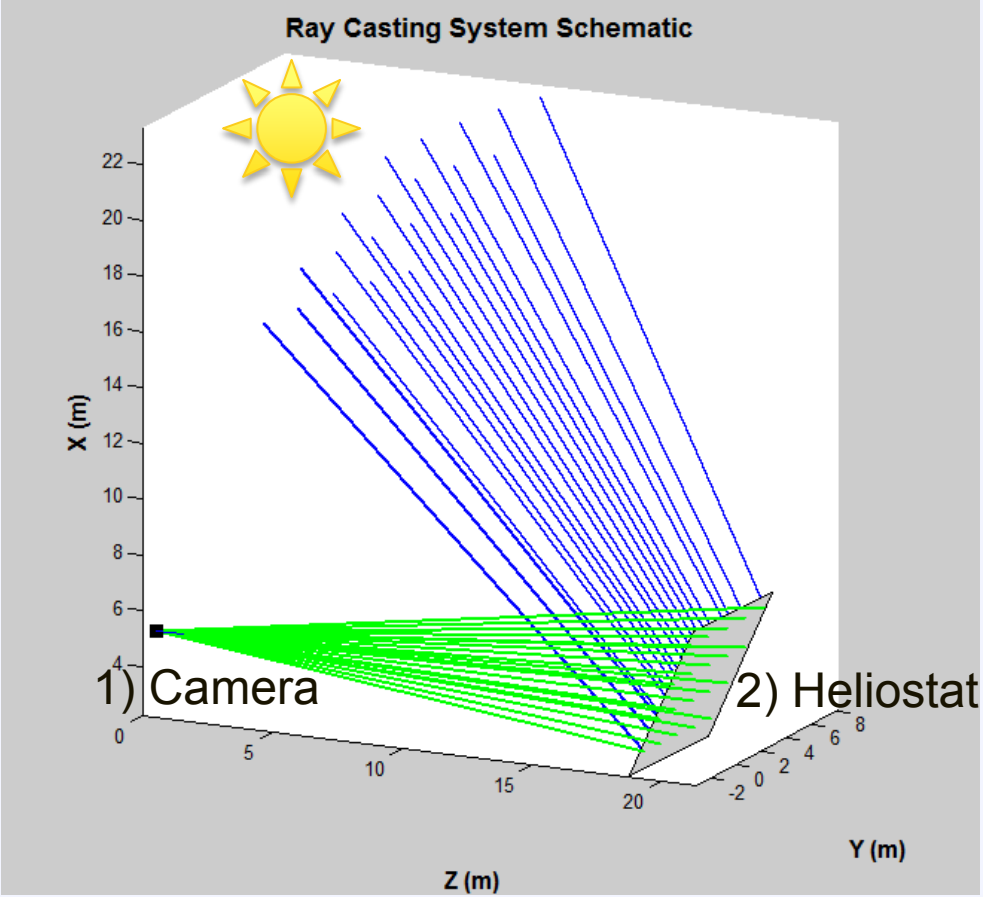


On-Sun Tracking: Image Sensors on Receiver Fine-tune



Task 3: Image-Based Tracking and Calibration (Ben Ihas, NREL)

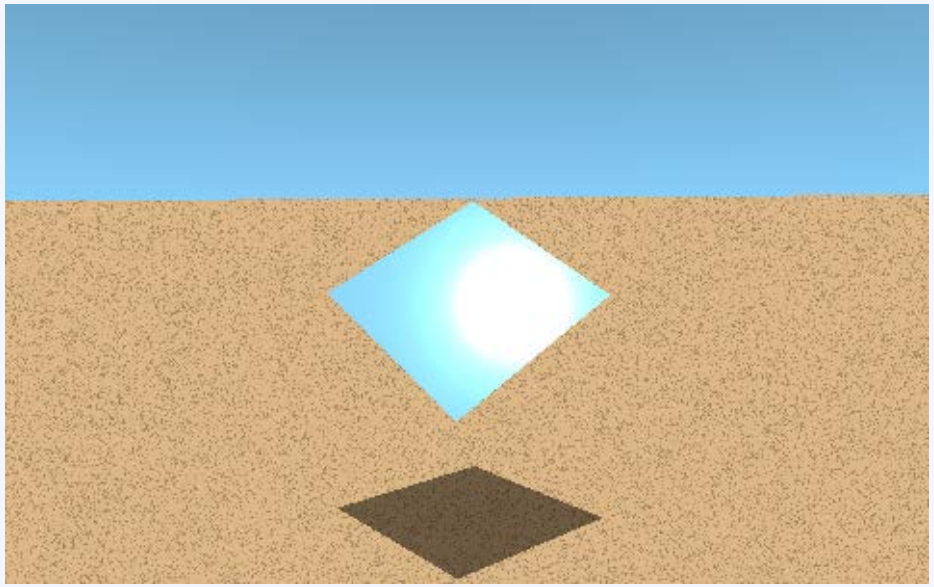
Ray Casting Model Design



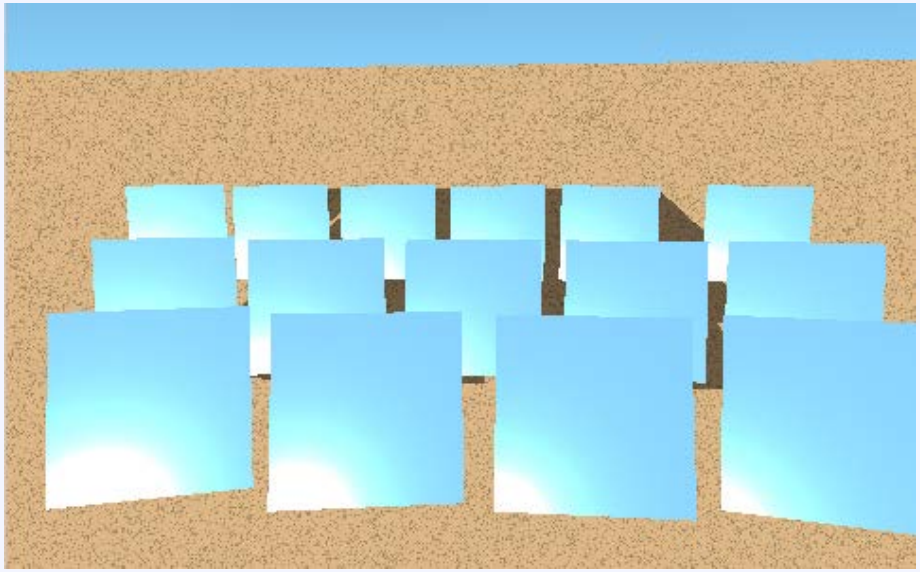
Schematic of Modeled Objects

Task 3: Image-Based Tracking and Calibration (Ben Ihas, NREL)

Results – Example Ray Casting Model Output



Single “Heliostat”



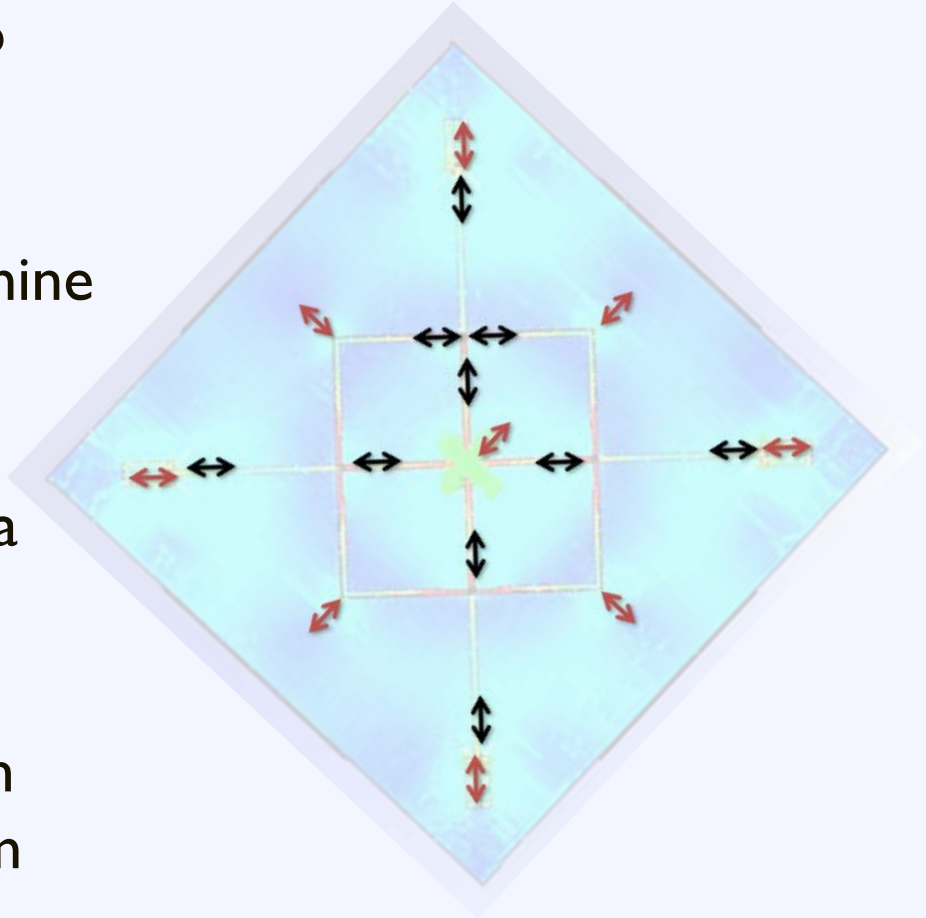
…Easily Expandable to Full-field

Challenges and Barriers

- Optimum heliostat size
- Drive mechanics compatibility with wireless communication and image-based tracking
  - Consistently sending meaningful signals to the heliostat
- Robust automatic heliostat recognition
  - Identify each heliostat regardless of lighting conditions
  - Handling image sensor saturation events
- Sensor layout optimization
  - Where must sensors be positioned?
- Transient handling
  - Maintaining accurate orientation despite loss of raw signal

Future Work

- Complete wind load testing to validate numerical models
- Employ a cost optimization method with DFMA to determine the lowest-cost heliostat size based on different scenarios
- Improve structure and design a cable drive system
- Develop a secure transceiver shared-node conceptual design for the wireless control system
- Incorporate into power tower simulations



Strain Gauge Map

Patents and Publications

- Kutscher, C., M. Wagner, A. Gray, G. Zhu, and T. Wendelin, "A Review of the State-of-the-Art of Heliostat Technology," submitted to the journal *Solar Energy*, under review.

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