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# Tower Illuminance Model (TIM): Interactive Real-Time Flyover Simulation Tool to Evaluate Glare and Avian-Flux Hazards

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# Overview

- Background and Objectives
- Tower Illuminance Model
- Glare and Avian Flux Hazard Analyses
- Conclusions

# Background

- Heliostats in standby mode can create adverse glare for pilots
- Concentrated flux in standby locations can harm birds



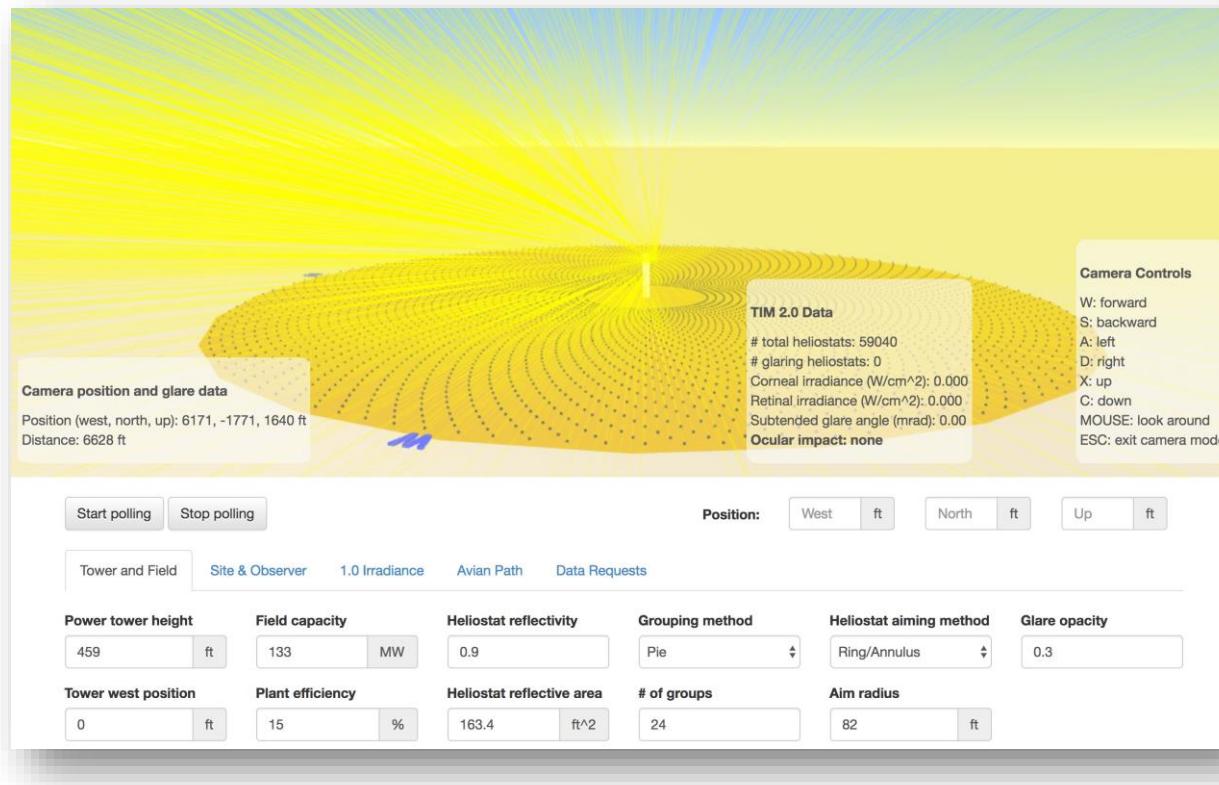
Glare viewed from helicopter over Ivanpah looking NW



MacGillivray Warbler with “Grade 3” solar flux injury found at Ivanpah CSP Plant (Kagan et al., 2014)

# Objectives

- Develop an easy-to-use tool that can evaluate glare and avian flux hazards for different heliostat aiming strategies



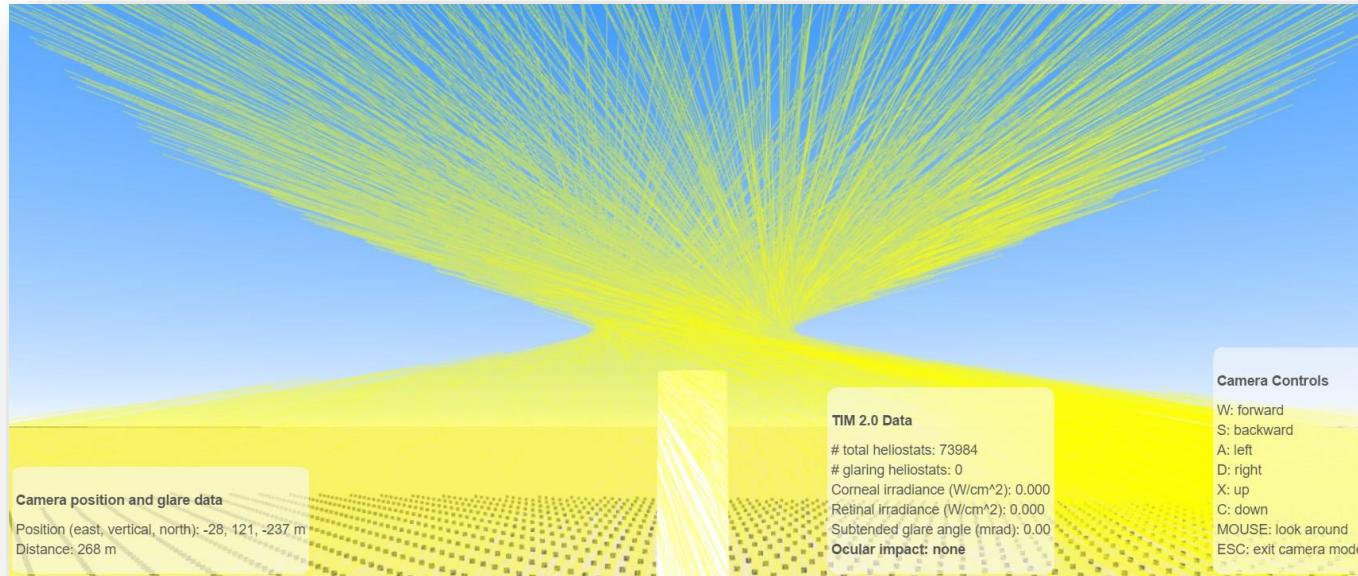
## Tower Illuminance Model (TIM)

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# Tower Illuminance Model

- Interactive 3D simulation of irradiance from alternative heliostat aiming strategies
- Customizable values to specify tower and heliostat field
- Real-time reporting of glare and avian flux hazards as a function of location and time



# TIM User Interface

**Camera position and glare data**

Position (west, north, up): 0, -3280, 1640 ft  
Distance: 3668 ft

Corneal irradiance (W/cm<sup>2</sup>): 0.000  
Retinal irradiance (W/cm<sup>2</sup>): 0.000  
Subtended glare angle (mrad): 0.00  
Ocular impact: none

X: up  
C: down  
MOUSE: look around  
ESC: exit camera mode

**Position:** West ft North ft Up ft

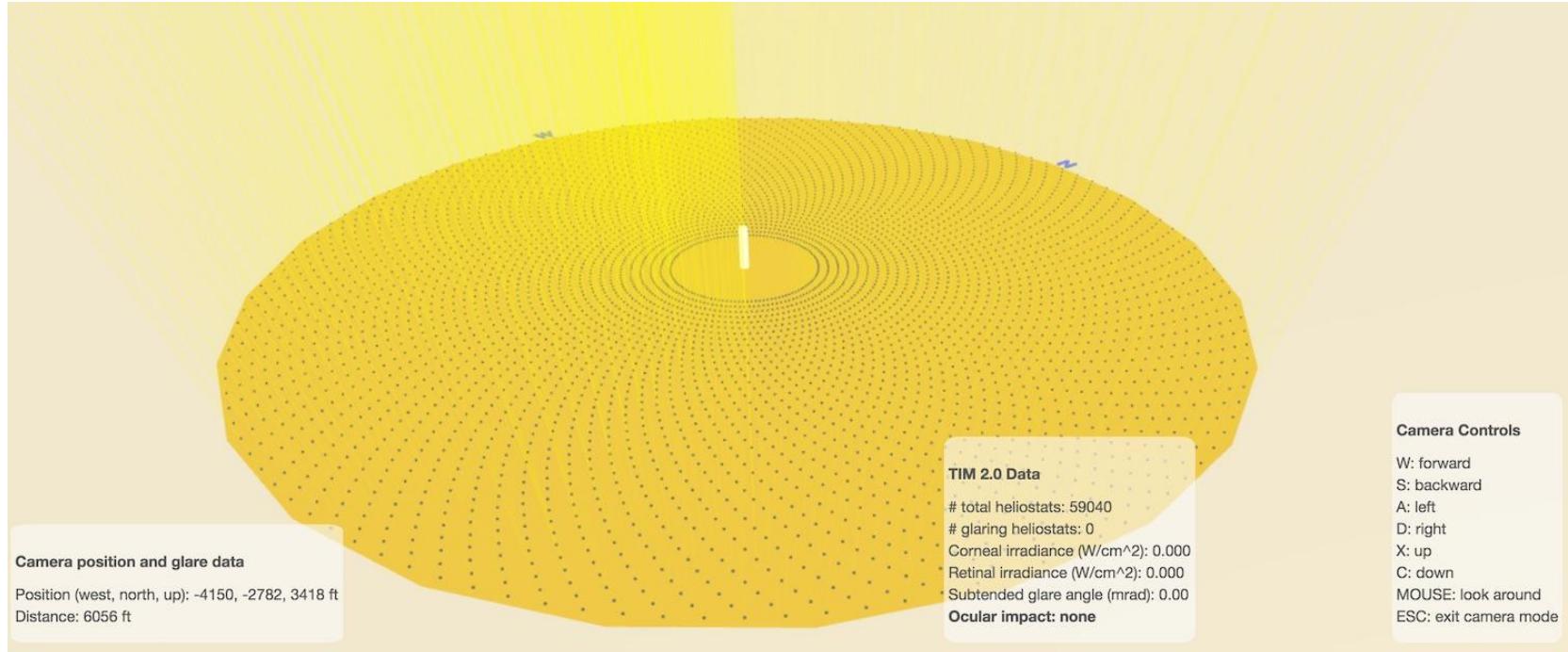
**Start polling** **Stop polling**

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**Tower and Field** **Site & Observer** **1.0 Irradiance** **Avian Path** **Data Requests**

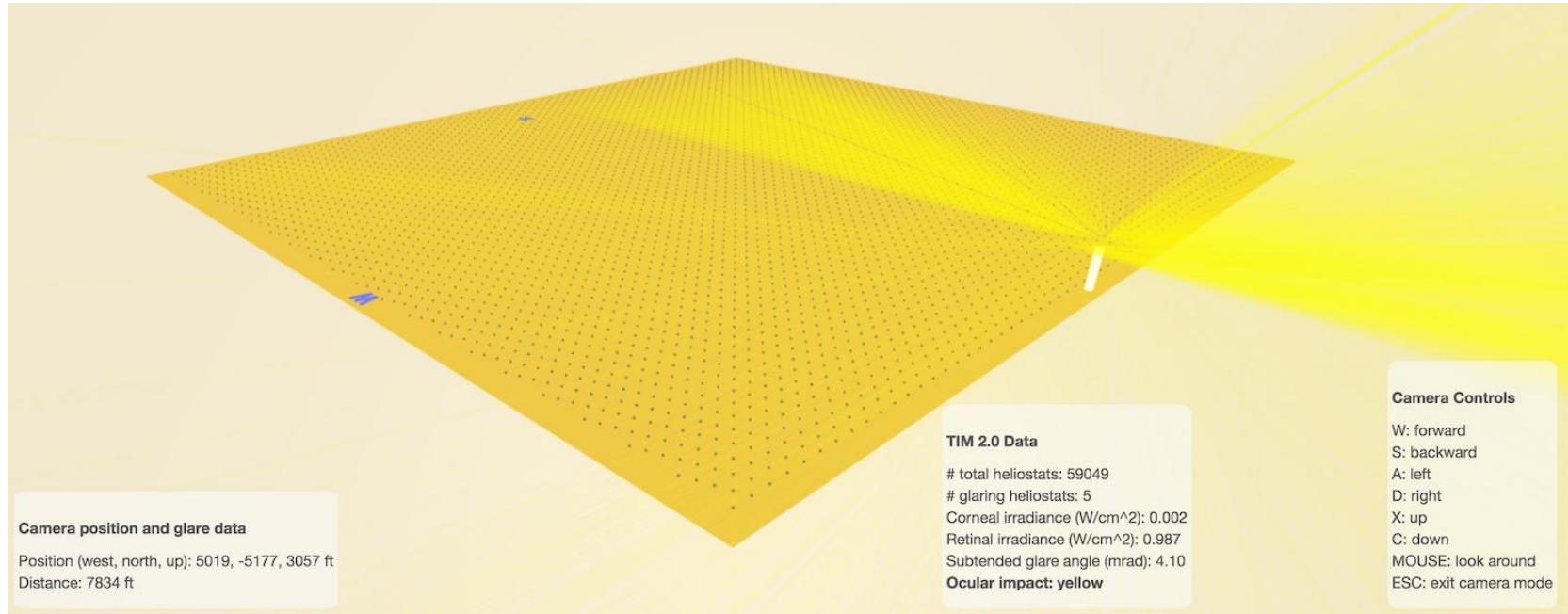
<b>Power tower height</b> 459 ft	<b>Field capacity</b> 133 MW	<b>Heliostat reflectivity</b> 0.9	<b>Grouping method</b> Pie	<b>Heliostat aiming method</b> Ring/Annulus	<b>Glare opacity</b> 0.5
<b>Tower west position</b> 0 ft	<b>Plant efficiency</b> 15 %	<b>Heliostat reflective area</b> 163.4 ft <sup>2</sup>	<b># of groups</b> 24	<b>Aim radius</b> 82 ft	
<b>Tower north position</b> 0 ft	<b>Inner radius of field</b> 500 ft	<b>Heliostat focal length</b> 2732 ft		<b>Maximum aim radius</b> 82 ft	
<b>Tower diameter</b> 60 ft	<b>Outer radius of field</b> 3220 ft	<b>Beta</b> 0.025 rad		<b>Aim height</b> 400 ft	
				<b>Maximum aim height</b> 400 ft	
				<b>Aim ring direction</b> Clockwise	

# Example: Circular Field Layout



- Tower centrally-located
- ~60,000 heliostats in radial layout

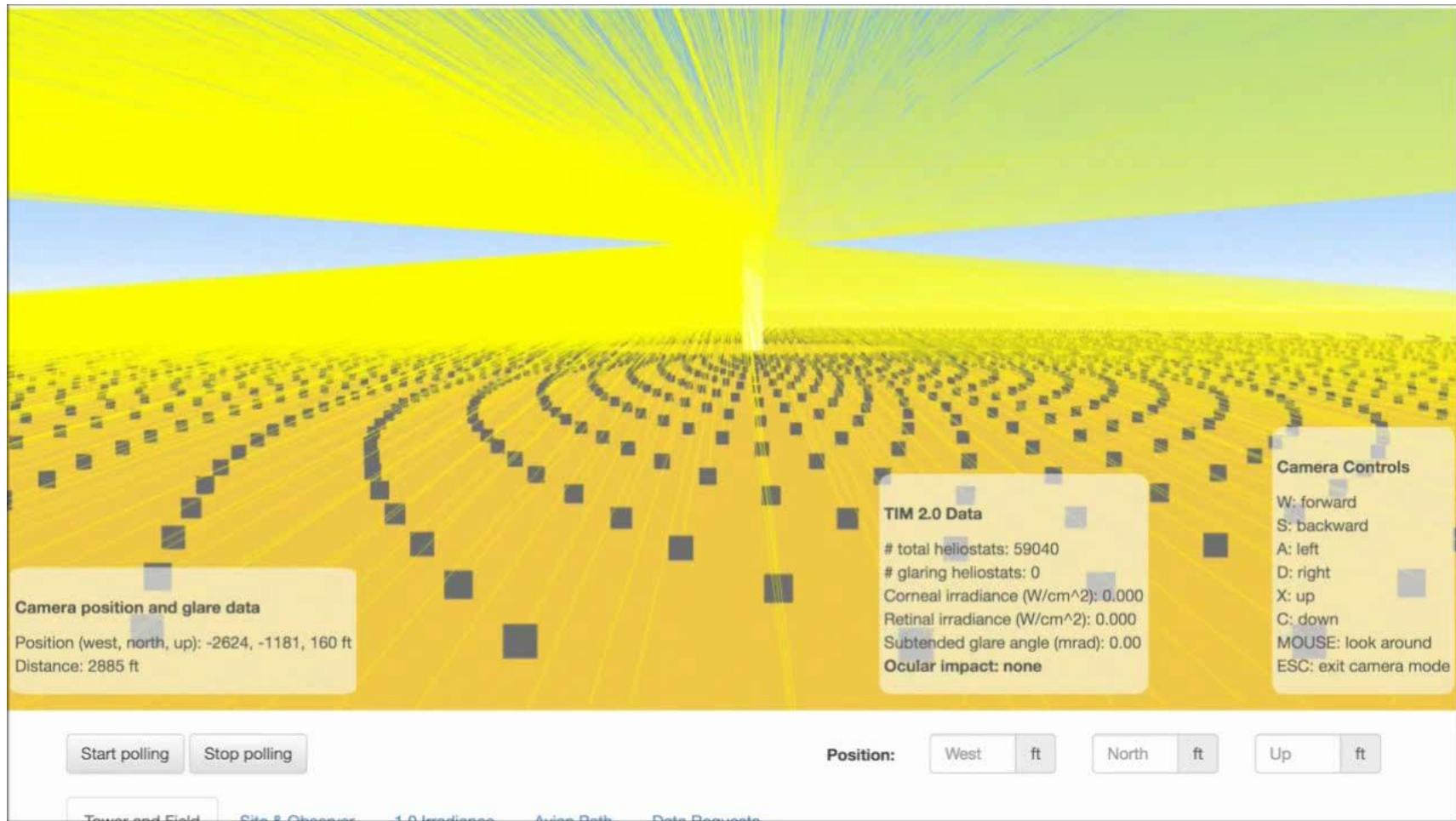
# Example: Rectangular Field Layout



- Polar/directional field
- Heliostats in grid layout

# TIM – 3D Field Navigator

- Use keyboard buttons to "fly" through heliostat field
- Glare data updates based on user location

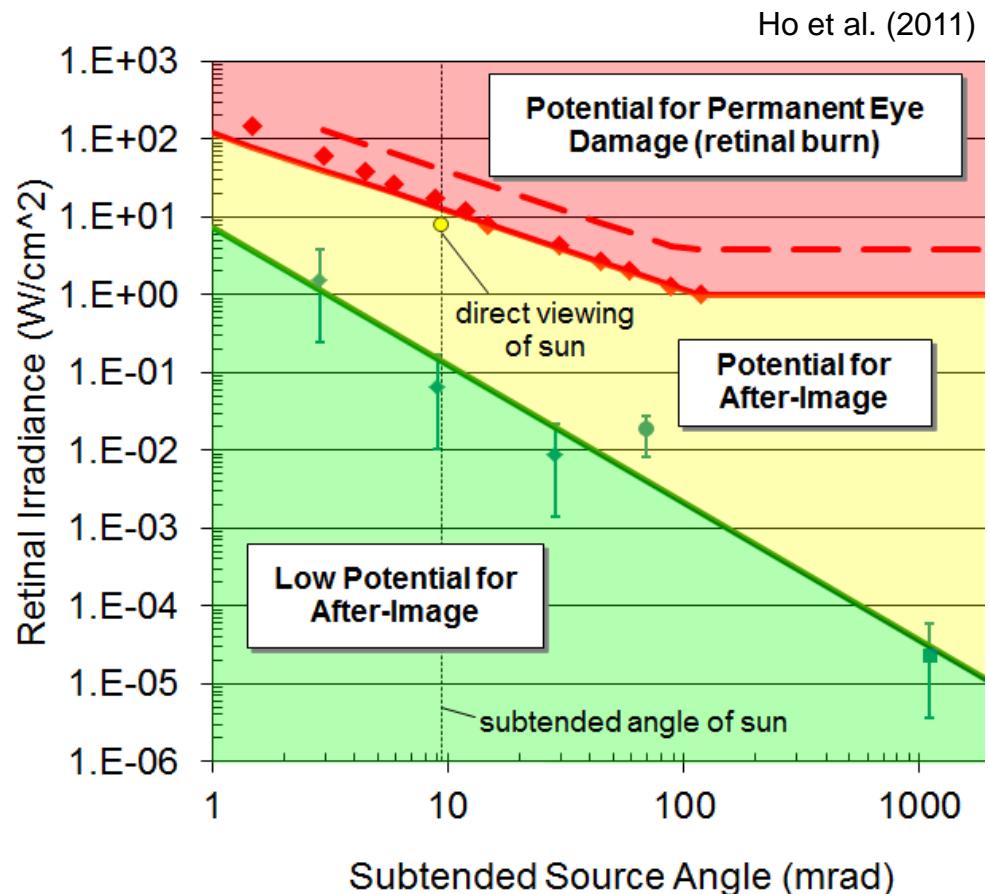


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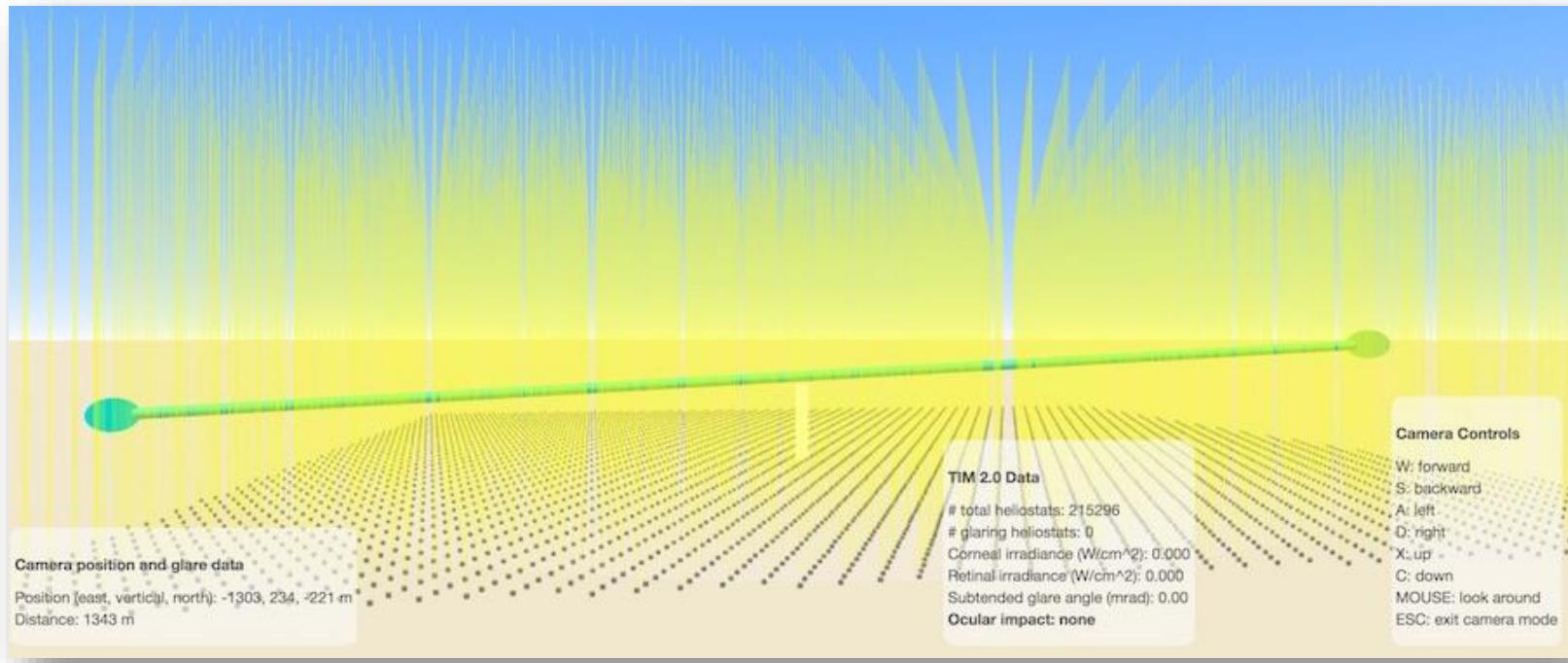
# Glare Analyses

- Determines irradiance and glare impact from heliostats
- Analytical model for speed and qualitative results
- Sub-second results for >50,000 heliostat reflections



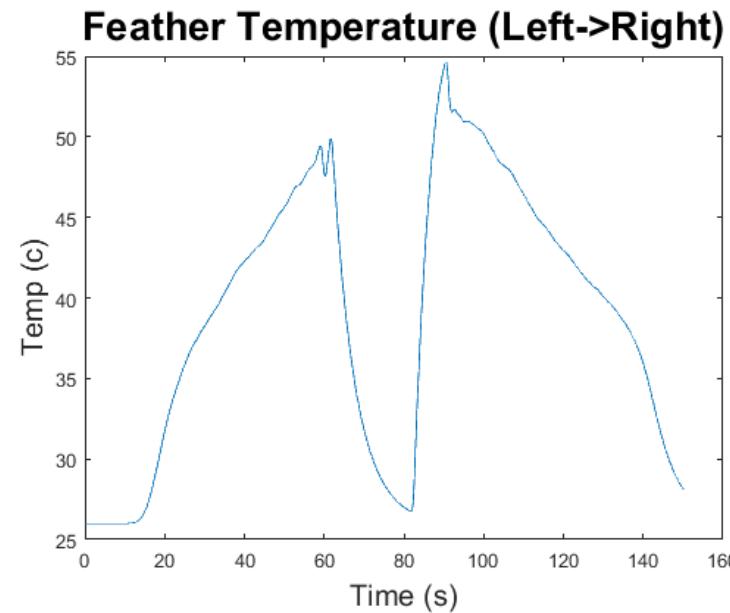
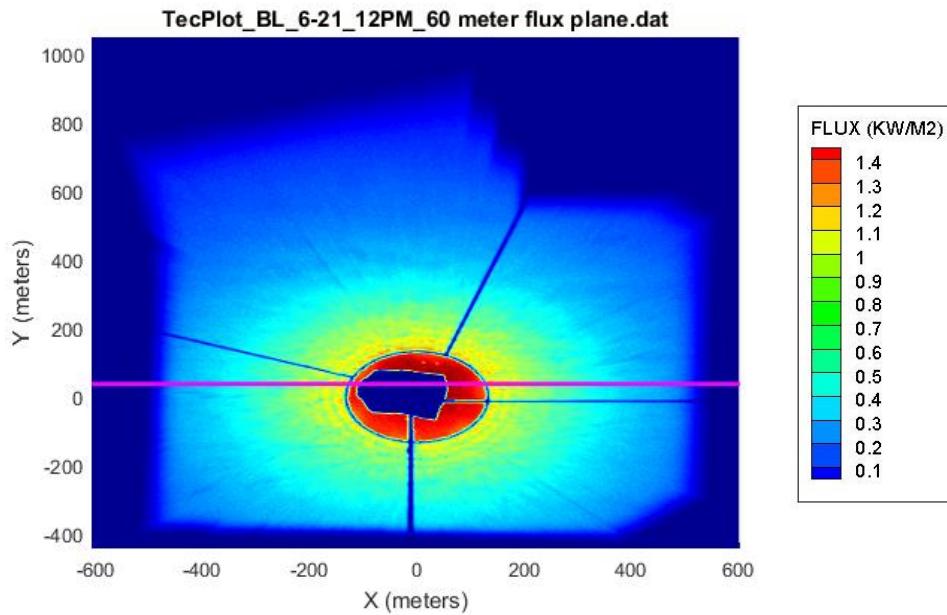
# TIM Avian-Flux Hazard Simulation

- Simulates bird traveling through airspace above heliostats
- User specifies start and end points



# TIM Avian-Flux Simulation

- TIM calculates irradiance and bird feather temperatures along path
  - Solves energy balance



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# Conclusions

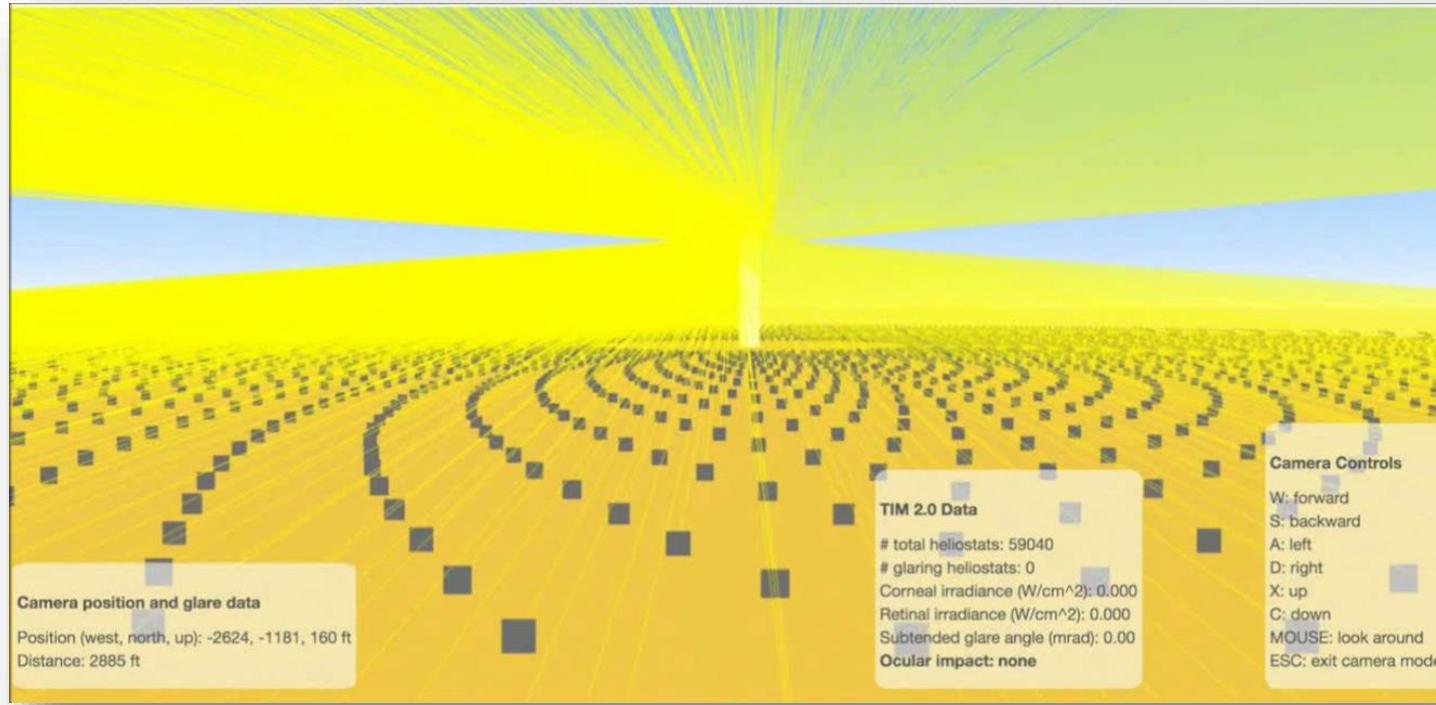
- Tower Illuminance Model (TIM) provides interactive real-time analyses of irradiance, glare, and avian flux hazards for different heliostat aiming strategies
  - Irradiance based on validated analytical models of heliostat beams
  - Glare hazard based on empirical data of ocular impact
  - Avian flux hazards based on bird feather temperature
- TIM can be used to evaluate alternative heliostat standby aiming strategies to minimize glare and avian-flux hazards
- Validation with Soltrace currently being performed

# Team / Collaborators

- **Sandia**
  - Cliff Ho (PI), Luke Horstman (avian hazard modeling), Julius Yellowhair (optical modeling)
- **NREL**
  - Tim Wendelin (flux modeling, avian hazards)
- **Sims Industries**
  - Cianan Sims (TIM)
- **CSP Industry**
  - NRG/Ivanpah
    - Doug Davis, George Piantka, Tim Sisk, William Dusenbury
- **DOE**
  - Chris Nichols, Daniel Boff, Michele Boyd



# Questions?

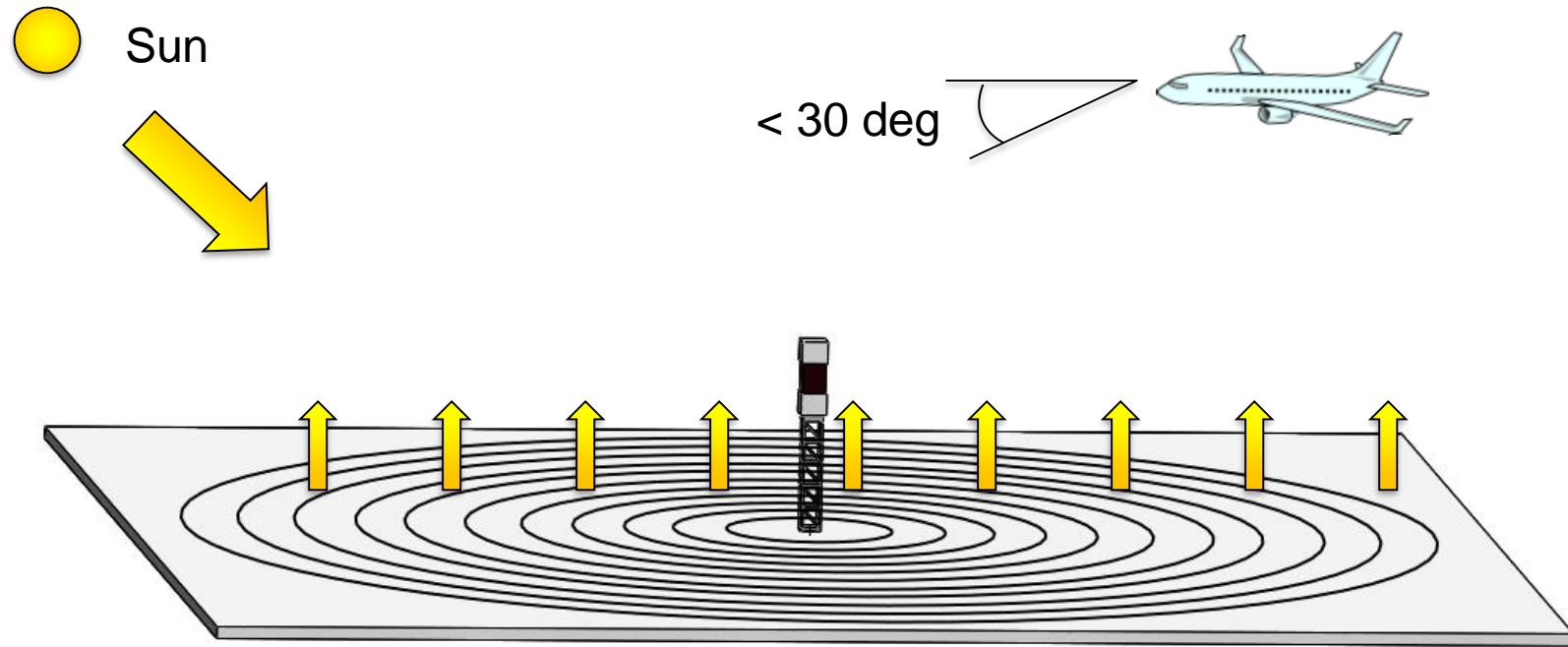


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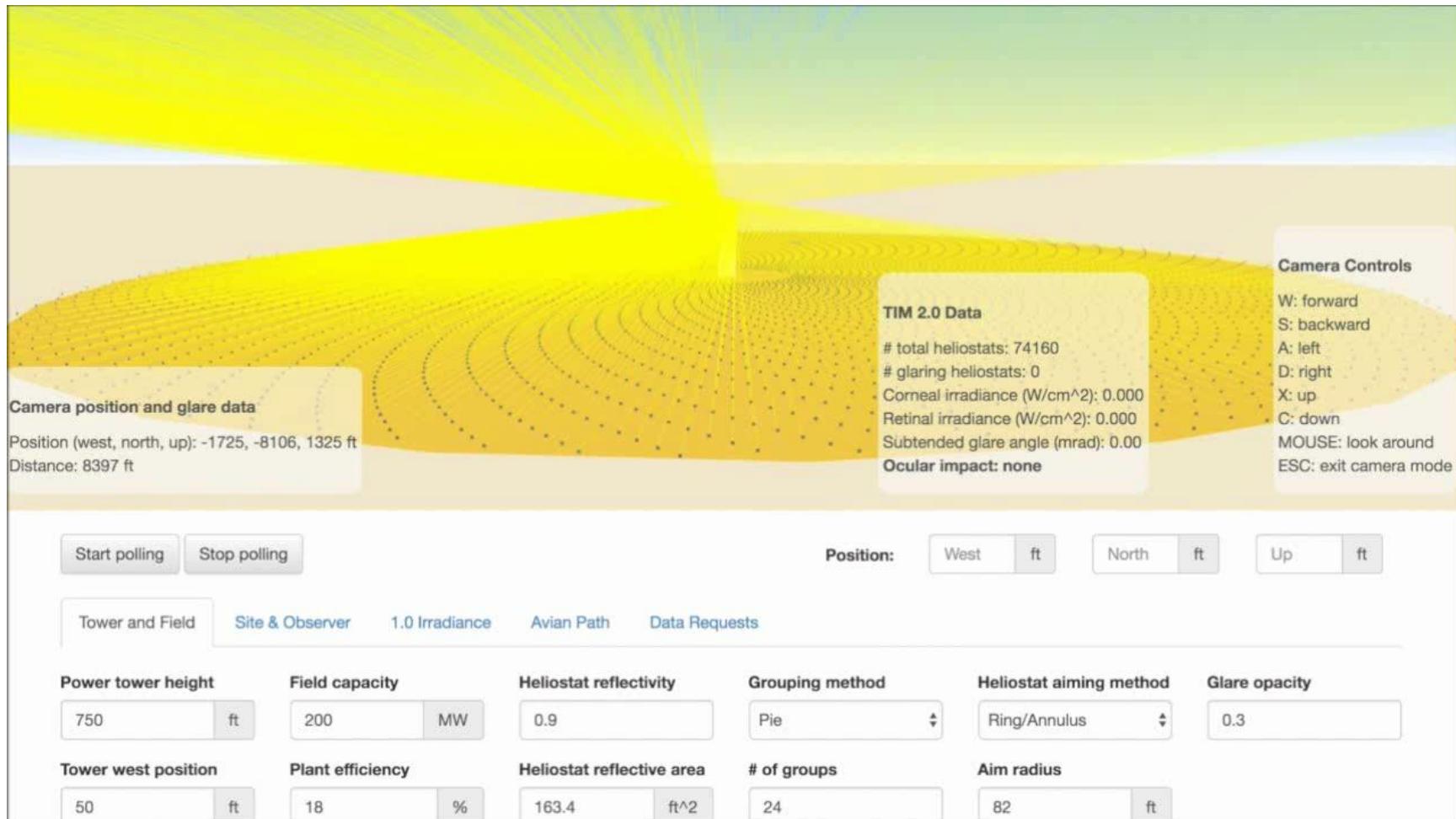
# **BACKUP SLIDES**

# Up-Aiming Strategy

- Up-Aiming can eliminate glare and avian flux hazards, but it increases heliostat travel time to receiver

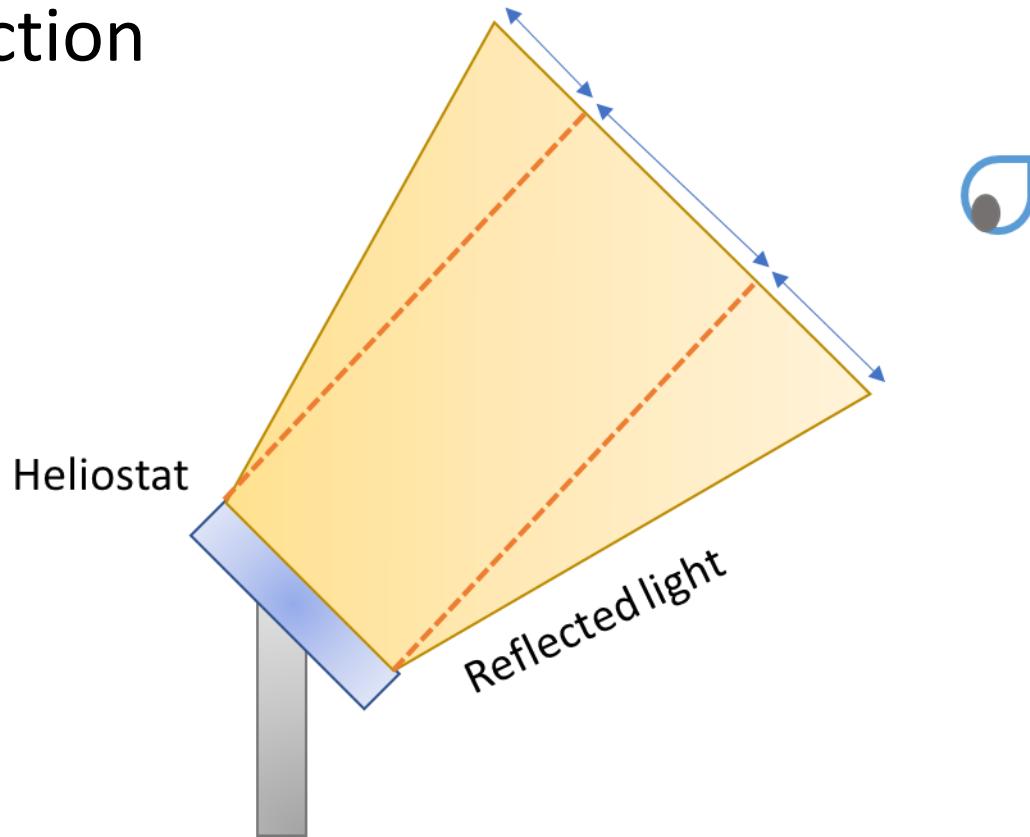


# TIM Alternative Aiming



# Glare Prediction – Slope Error

- TIM considers beam scatter due to heliostats
- Each heliostat reflection modeled as conical projection



# Validation of TIM

- Validation with Soltrace currently being performed

Baseline Irradiance Along West-East Transect (12 PM @ 787 ft.)

