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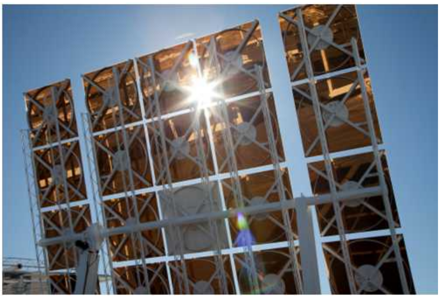

Avian Solar-Flux Hazards Stakeholder Meeting

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SAND2016-XXXX

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Overview

- Background and Goals
- Approach and Meeting Objectives
- Discussion
- Wrap-Up and Actions

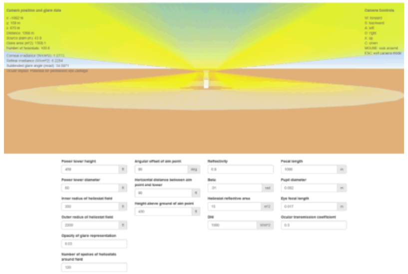
Background

- Recent reports of birds being burned and killed by solar flux at CSP plants have drawn a significant amount of attention and negative publicity
  - US Fish & Wildlife released a study conducted in 2013 suggesting that birds were being killed by concentrated sunlight at a rate of one bird every two minutes

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

Goals

- DOE is funding work to address avian flux hazards
  - Develop models and tools to quantify flux from heliostat aiming strategies
  - Mitigate impacts of avian (and glare) hazards
  - Optimize operational performance



Tower Illuminance Model

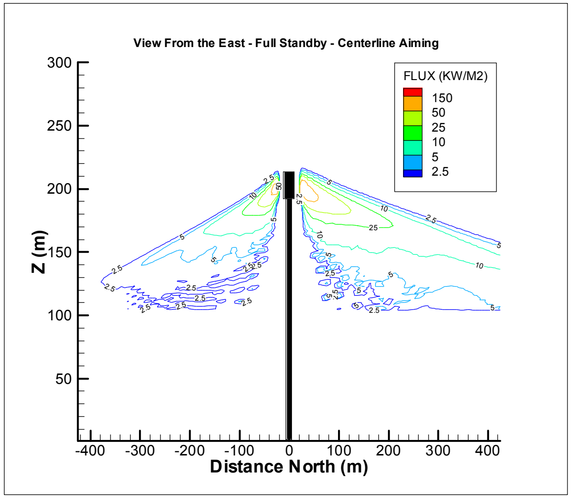


Photo and model of high-flux regions causing solar glare and avian hazards at Ivanpah Solar Electric Generating System

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Approach

Sandia National Laboratories

1. Identify metrics for safe solar flux levels

2. Develop tools to model solar flux in air space around power tower
   - Case studies: Ivanpah and NSTTF at Sandia (for validation)

3. Compare alternative heliostat standby-aiming strategies
   - Minimize solar flux according to metrics in (1) above
   - Minimize impact on plant operations

Ivanpah Solar Electric Generating System

National Solar Thermal Test Facility (NSTTF)

Tower Illuminance Model

Meeting Objectives

1. Discuss and identify metrics for safe solar flux level
2. Discuss standby heliostat aiming strategies
3. Discuss operational strategies and performance impacts for longer heliostat slew times to the receiver

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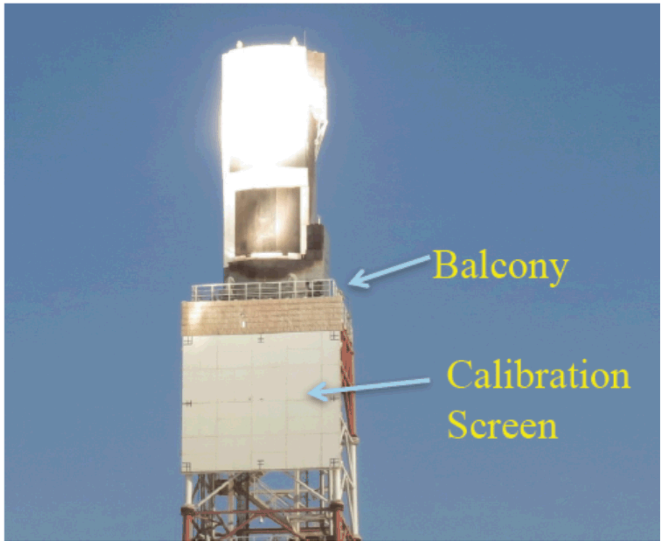
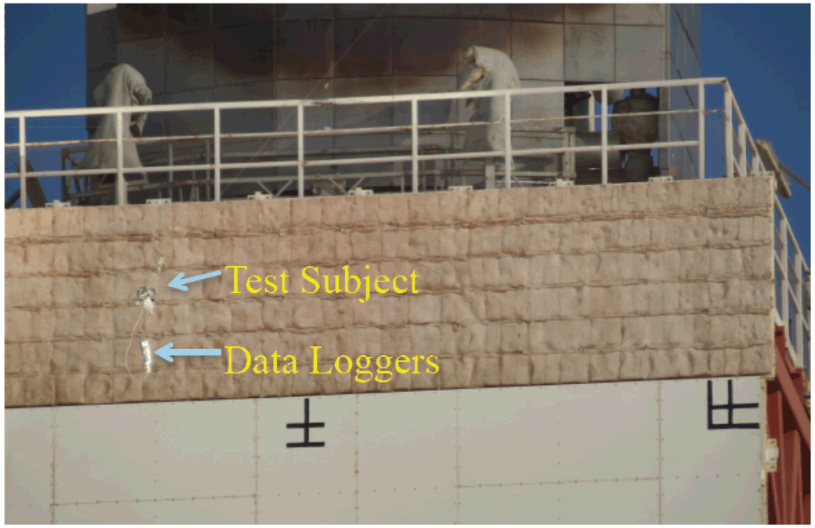
Solar Energy Development Center
(Negev Desert, Southern Israel)

- Tests conducted with bird carcasses exposed to different flux levels (Santolo, 2012)
  - "no observable effects on feathers or tissue were found in test birds where solar flux was below 50 kW/m^2 with exposure times of up to 30 seconds."
  - California Energy Commission analytical study found that "a threshold of safe exposure does not exist above a solar flux density of 4 kW/m^2 for a one-minute exposure"





Discussion – Objective 1

- Any additional information regarding safe flux levels for birds?
- Any additional observations from industry (Ivanpah, Crescent Dunes)?
- Comments on CEC model?
  - 4 kW/m^2 for up to 60 seconds
- Comments on Santolo study?
  - 50 kW/m^2 for up to 30 seconds
- Consensus?

Meeting Objectives

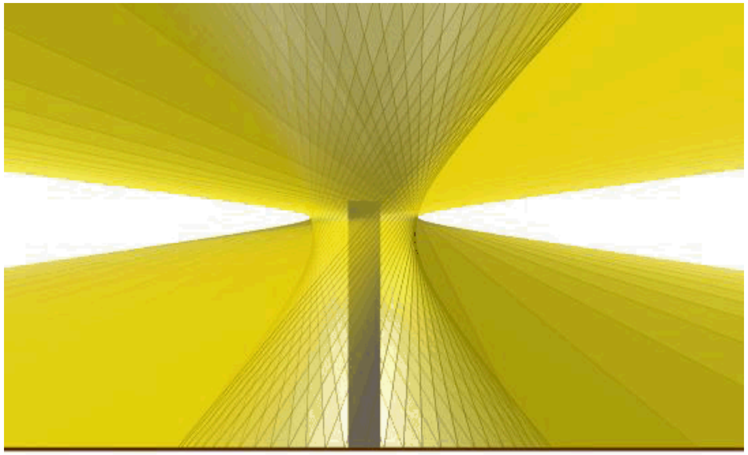
1. Discuss and identify metrics for safe solar flux level

2. Discuss standby heliostat aiming strategies

3. Discuss operational strategies and performance impacts for longer heliostat slew times to the receiver

Ivanpah Solar

- 390 MW_e direct steam power-tower plant (3 towers)
- Standby heliostats aimed along a ring around the receiver
- Tried spreading the aim points to reduce flux (and glare)



Crescent Dunes

(Tonopah, Nevada)

- 110 MW_e molten-salt power tower
- In January 2015, 3,000 heliostats were aimed at standby points above receiver
  - 115 bird deaths in 4 hours
  - SolarReserve spread the aim points to reduce peak flux to < 4 kW/m^2
    - Reported zero bird fatalities in months following change

Figure 1 – The halo created by the reflected light of 3,000 heliostats which caused the bird mortalities.

Images from http://cleantechnica.com

Discussion – Objective 2

- What “baseline” standby heliostat aiming strategy should be implemented in our models?
- What alternative aiming strategies can be considered?
- How do standby heliostat aiming strategies differ for direct-steam and molten-salt power tower plants?
  - Have the issues been truly solved at Crescent Dunes?
  - Can Ivanpah accommodate larger slew times to the receiver to reduce flux levels?

Meeting Objectives

1. Discuss and identify metrics for safe solar flux level

2. Discuss standby heliostat aiming strategies

3. Discuss operational strategies and performance impacts for longer heliostat slew times to the receiver

Discussion – Objective 3

- What heliostat slew rates (elevation, azimuthal) are typical?
  - NSTTF heliostats: 24 deg/min for both axes
  - Ivanpah, Crescent Dunes, Gemasolar?
- Will spreading the standby aim points (increasing the slew time to receiver) impact operational performance?
  - If so, how?
  - Is there a correlation between the time it takes for standby heliostats to reach the receiver and energy production or start-up time?

Overview

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Meeting Objectives

1. Discuss and identify metrics for safe solar flux level
   - Consensus?
   - Actions?
2. Discuss standby heliostat aiming strategies
   - Baseline vs. alternative strategies?
3. Discuss operational strategies and performance impacts for longer heliostat slew times to the receiver
   - Impact of slew time on energy production/start-up time?

Actions

BACKUP SLIDES

Avian Solar-Flux Hazards Stakeholder Meeting

Agenda

Organizers:

Cliff Ho, Sandia National Laboratories, ckho@sandia.gov

Tim Wendelin, National Renewable Energy Laboratory, tim.wendelin@nrel.gov

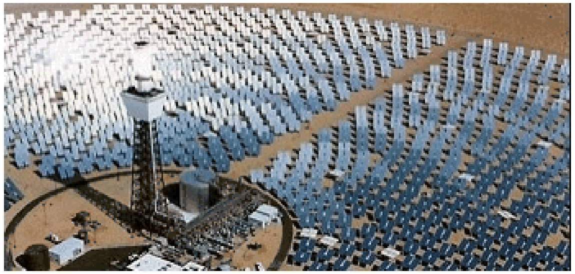
Introduction (Cliff/Tim) (15 min)

- Participants introduce themselves
- Present DOE project goals and scope
  - Brief statement of SOPO Milestones & Deliverables

- **Meeting Objectives** (Cliff/Tim) (5 min)
  - Discuss metrics for safe solar flux level
  - Discuss standby heliostat aiming strategies
  - Discuss operational strategies and performance impacts for longer heliostat slew times to the receiver
- **Present NREL/Sandia approach** (Tim) (10 min)
- **General Discussion on Objective 1**. (Cliff, all) (30 min)
  - Present summary of previous information/data assumptions and analysis
  - Goal:
    - Arrive at some practical consensus regarding a quantifiable metric(s) for safe solar flux levels in this analysis.
  - Open for discussion
- **General Discussion on Objective 2**. (Cliff, all) (30 min)
  - Present summary of previous information/data assumptions and analysis
  - Goal
    - Gather information on existing and new aiming strategies for incorporating into flux/performance analysis.
  - Open for discussion
- **General Discussion on Objective 3**. (Cliff, all) (30 min)
  - Present summary of previous information/data assumptions and analysis
  - Goals:
    - Gather information on how existing and new aiming strategies (e.g., increased slew times) might impact performance.
    - Agree on the metric/approach for evaluating impact on performance.
  - Open for discussion
- **Wrap-up** (Cliff, Tim, all) (15 min)
  - Summary of Objective results and lessons learned
  - Summary of action items and next steps
  - Adjourn

Solar One (Daggett, California)

- 10 MW_e direct-steam pilot demonstration project
- 40 weeks of study from 1982 to 1983 (McCrary et al. 1984, 1986)
  - 70 documented bird deaths
    - 81% from collisions (mainly heliostats)
    - 19% from burns
  - Impact on local bird population was considered minimal
  - Nearly all observed incinerations ("small flashes of light within the standby points, accompanied by a brief trail of white vapor") involved aerial insects rather than birds



Barn Swallow

White-Throated Swift

Solar Energy Development Center
(Negev Desert, Southern Israel)

- Solar demonstration facility with a 6 MW_{th} heliostat field and power tower
- No bird singeing was reported in four years of operation while following U.S. Fish & Wildlife Service protocols of four surveys per week over 20 m transects

Ivanpah Solar Electric Generating System

(Ivanpah, California)

- 390 MW_e direct steam power-tower plant (3 towers)
- Kagan et al. (2014) found 141 bird fatalities Oct 21 – 24, 2013
  - 33% caused by solar flux
  - 67% caused by collisions or predation
- H.T. Harvey and Associates found 703 bird fatalities in first year at ISEGS
  - Study estimated 3500 bird fatalities accounting for search efficiency and scavengers removing carcasses
- ISEGS has since implemented new heliostat aiming strategies and bird deterrents

Cause	Number of Detections				
	Winter	Spring	Summer	Fall	Total
Singed	27	100	42	147	316
Collision	14	15	10	45	84
Other*	5	5	2	3	15
Unknown	51	82	61	94	288
Total	**97**	**202**	**115**	**289**	**703**

* Includes detections in ACC buildings without evidence of singeing or collision effects.

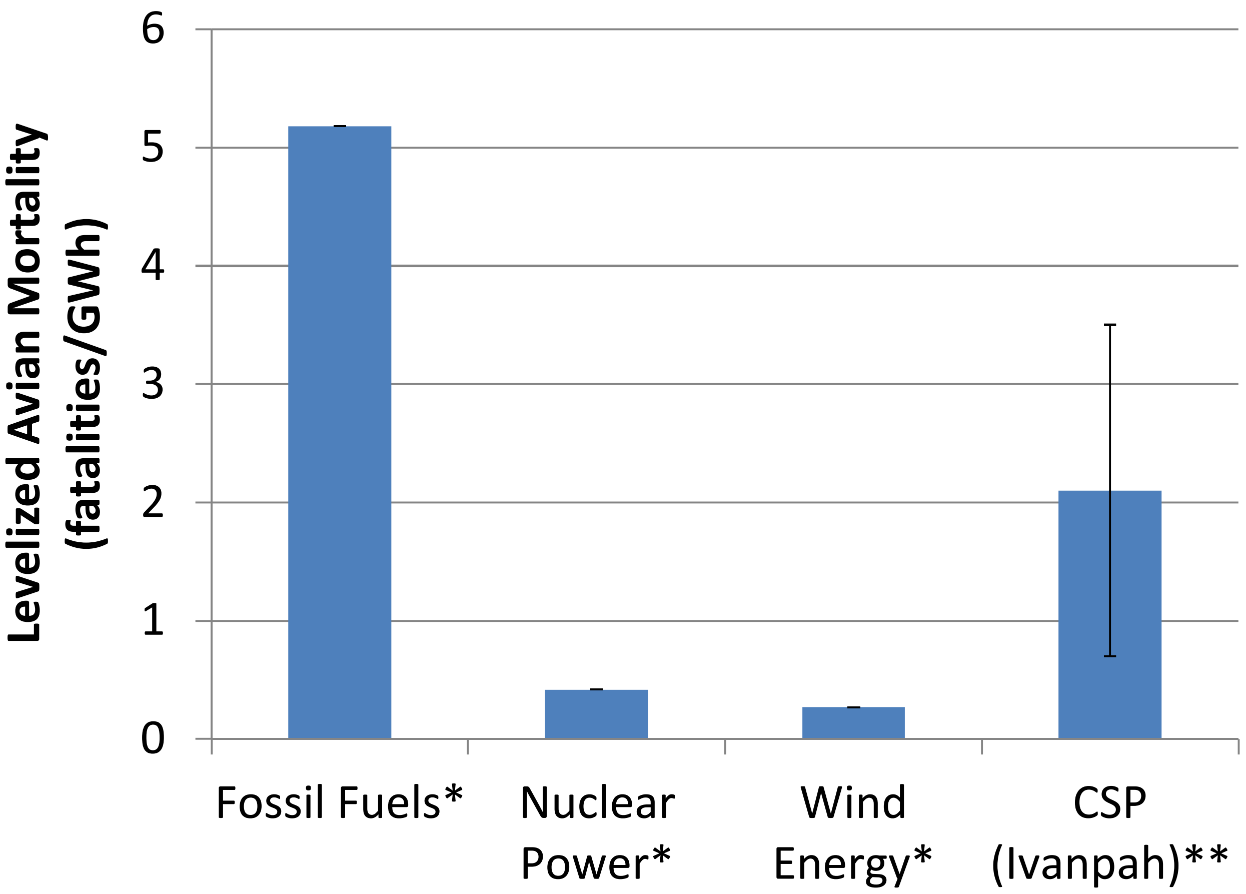
H.T. Harvey and Associates, 2013 - 2014

Gemasolar Thermosolar Plant

(Andalusia, Spain)

- 20 MW_e molten-salt power tower plant
- 14-month study revealed no avian fatalities in vicinity of tower (Dept. of Zoology, U. Granada)

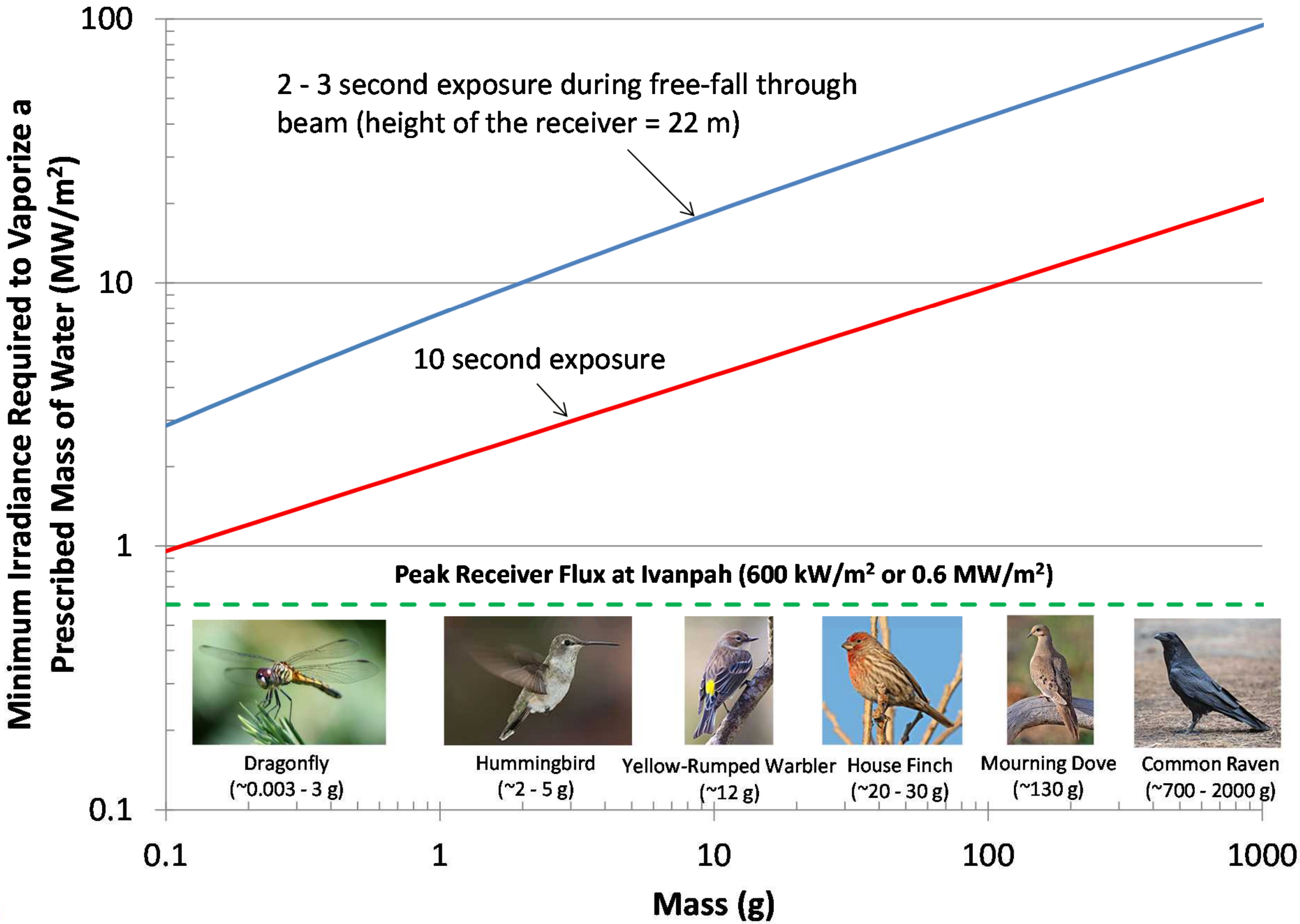
Levelized Avian Mortality for Energy (LAME)



*Sovacool (2009)

**During first year of operation at Ivanpah (2013 – 2014) before mitigation measures and deterrents were implemented

Feasibility of Bird Vaporization



Overview

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- Avian Mortality at CSP Facilities
- Mitigation Measures
- Conclusions

Deterrents

- Acoustic
  - Painful or predatory sounds
- Visual
  - Intense lights and decoys
- Tactile
  - Bird spikes, anti-perching devices
- Chemosensory
  - Grape-flavored powder drinks (methyl anthranilate)

- Ivanpah has implemented these deterrents and seen a ~70% reduction in bat and bird deaths (personal communication, Doug Davis, NRG, 8/3/15)

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Conclusions

- Recent reports of extreme numbers of birds being killed by concentrated sunlight at CSP plants appear to be misinformed and inflated
- The large number of "streamers," or smoke plumes, observed and attributed to vaporization of birds is likely caused by insects flying into the concentrated flux
- Complete vaporization of birds flying into concentrated solar flux is highly improbable
- Safe irradiance levels for birds have been reported to range from 4 kW/m^2 to 50 kW/m^2
- Mitigation measures and bird deterrents can be used

Modeling Approach

- NREL/Sandia model and tool development for solar flux analysis and operational performance impacts of different standby heliostat aiming stragies

Flux Hazard Analysis

- Create model of baseline power tower design (Ivanpah) in both SolarPILOT and SolTrace.
  - Heliostat geometry, positions and tower height from NRG.
- Create model of NSTTF in SolarPILOT and SolTrace (model previously established in SolTrace).
  - Validate model using Sandia flux mapping tools

Flux Hazard Analysis

- Obtain/establish relevant information/parametric data from industry/stakeholder workshop
  - Baseline/novel aiming strategies.
  - Heliostat control capabilities (slew rates, aiming algorithms/capabilities)
  - Metrics for safe solar flux levels (I_{haz}, $V > I_{haz}$)
  - Performance metrics

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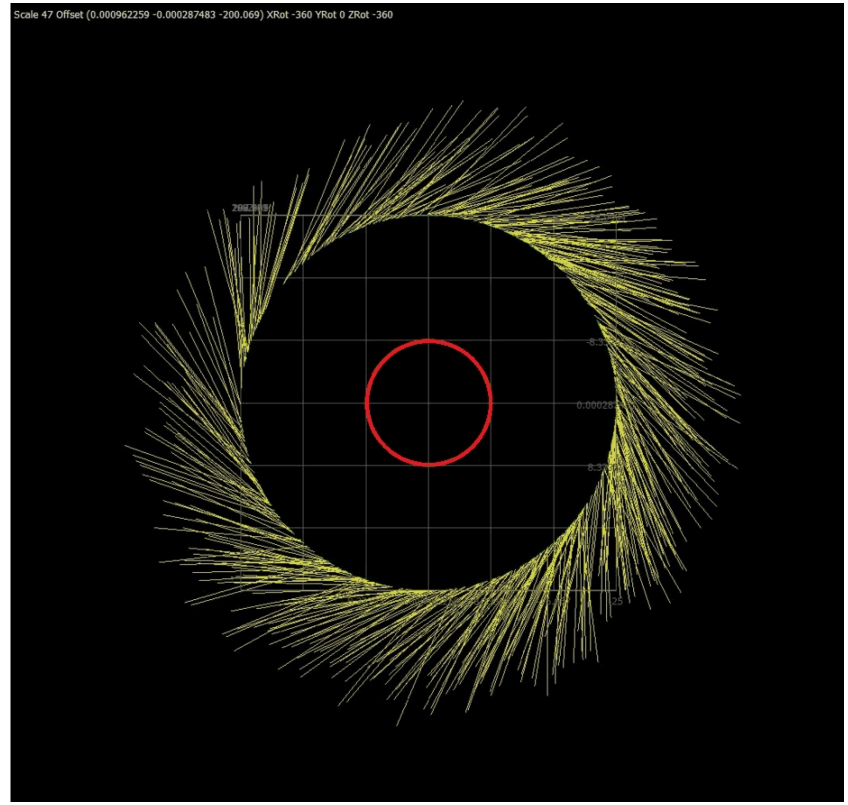

Flux Hazard Analysis

- Apply methodology to Ivanpah and NSTTF fields for analyzing baseline cases both operational and standby.
  - Generate volumetric flux maps for both operational and standby cases for representative days of the year.
  - Calculate ratio of airspace volume with flux greater than I_{haz} , $V > I_{haz}$

$$\frac{V_{>Ihaz,Alternate}}{V_{>Ihaz,Baseline}}$$

- Apply methodology to Ivanpah and NSTTF fields for analyzing alternate standby aiming strategies.
  - Goal: $\frac{V_{>Ihaz,Alternate}}{V_{>Ihaz,Baseline}} < 0.1$

Flux Hazard Analysis

- Evaluate successful aiming strategies for impact on annual performance
  - Quantify time from standby to operational for representative days of the year and for both baseline and alternative standby aiming strategies.
  - Use the Solar Advisor Model to quantify annual performance impact of alternative vs baseline cases with the goal of realizing a ratio of Annual Output (MW-hours): $\frac{E_{Alternate}}{E_{Baseline}} = 1.0$
- Provide both input and output data from methodology for validation of the enhanced Tower Illuminance Model (TIM)