



**Track:** Mini-Track  
**Enviroment/Energy**  
SAND2012-1441C

**Workshop:** 1

**Workshop Title:** Alternative Energy & Airports

**Moderator:** Gail Staba  
Transportation Research  
Board

**Date:** 29 February 2012

## Glare Impacts from Solar Power Plants near Airports

**Presented By:** Clifford K. Ho  
Sandia National Laboratories, Albuquerque, NM

- Introduction
- Solar Glare
- Ocular Hazard Metrics
- Examples of Glare Assessments



- **Glint and glare may cause unwanted visual impacts**
  - Pilots, air-traffic controllers, workers, motorists
- **Potential visual impacts**
  - Distraction
  - After-image (flash blindness)
  - Retinal burn

## Definitions

**Glint:** Momentary flash of light

**Glare:** Continuous source of excessive brightness

## Objective

Develop quantified analysis of glare to reduce uncertainties associated with visual impacts of solar power installations

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# Examples of Glare from Solar Technologies

## Photovoltaics



## Concentrating Solar Power



Heliostats and Central Receiver at Sandia Labs, Albuquerque, NM

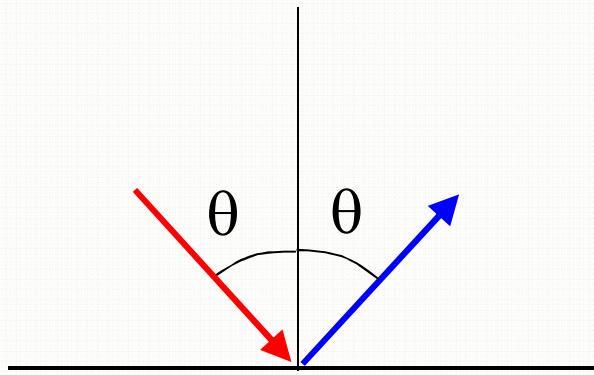


Dish Collectors at Sandia



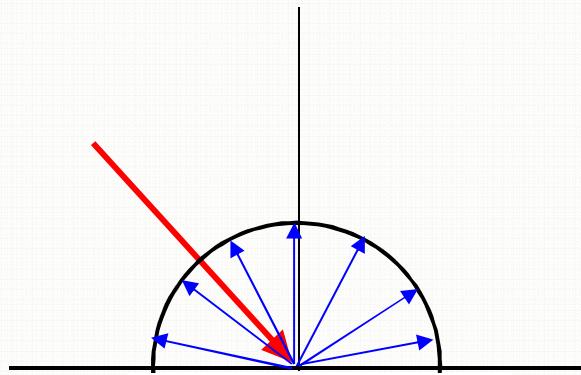
Parabolic Trough Collectors at Kramer Junction, CA

# Types of Reflection



Specular Reflection

(polished surfaces;  
e.g., mirrors, glass)

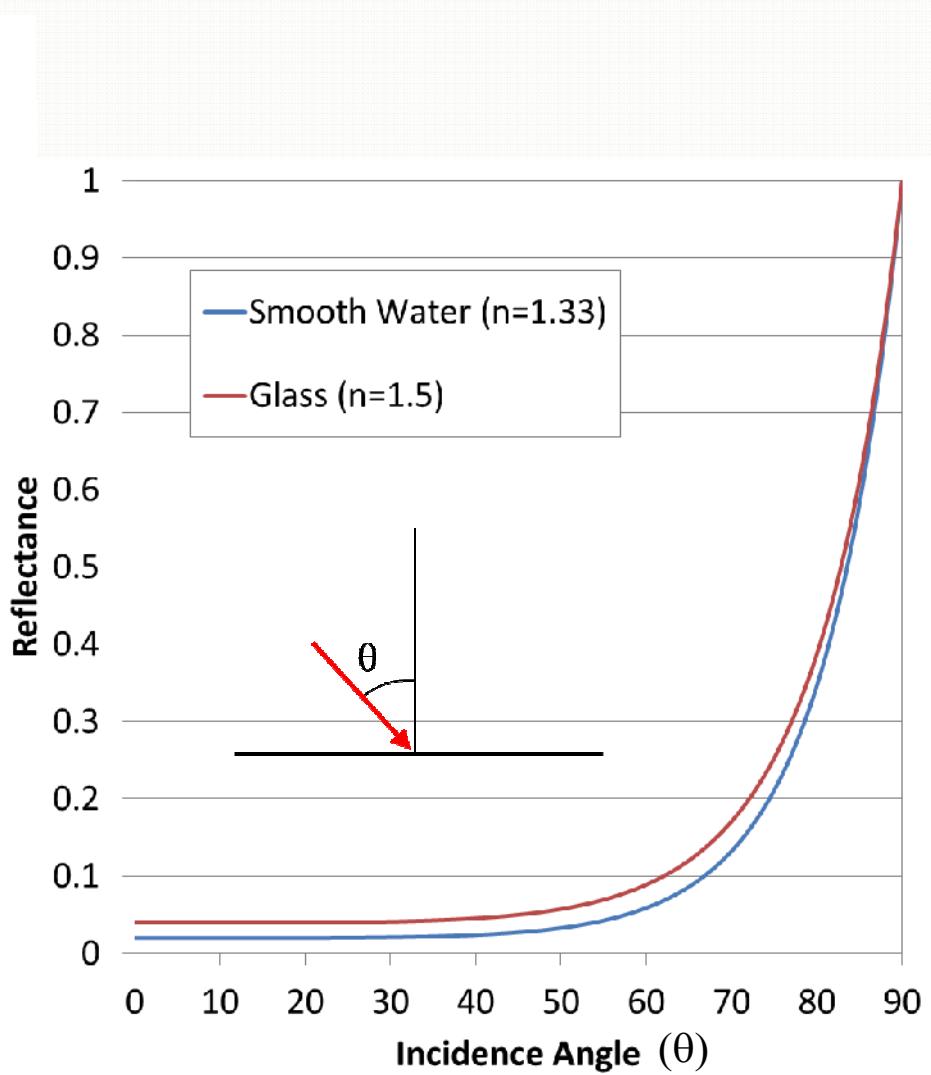
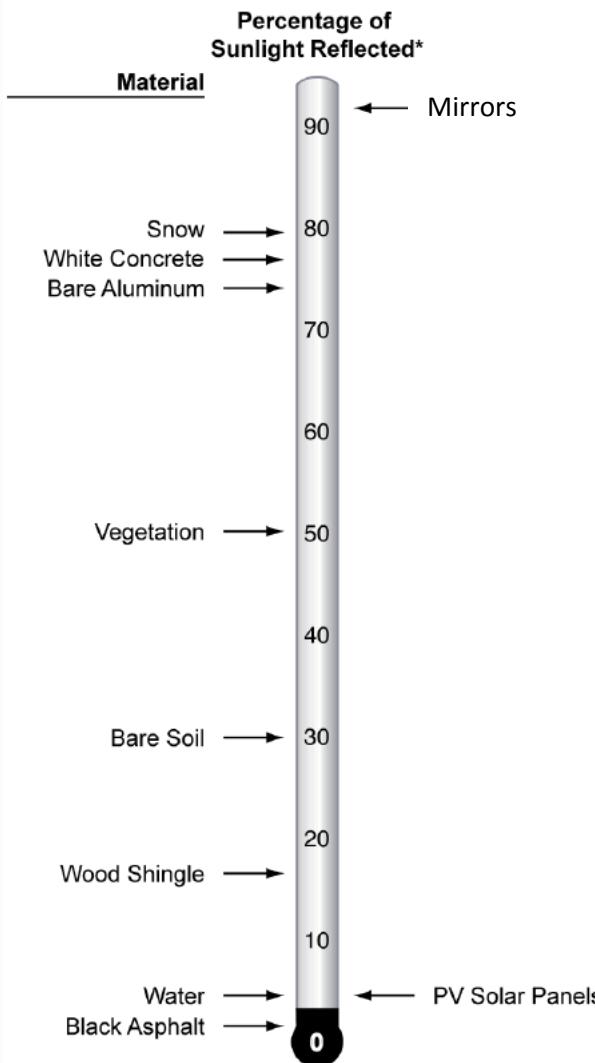


Diffuse Reflection

(rough surfaces; e.g.,  
receivers, pavement, snow)



# Reflectivity

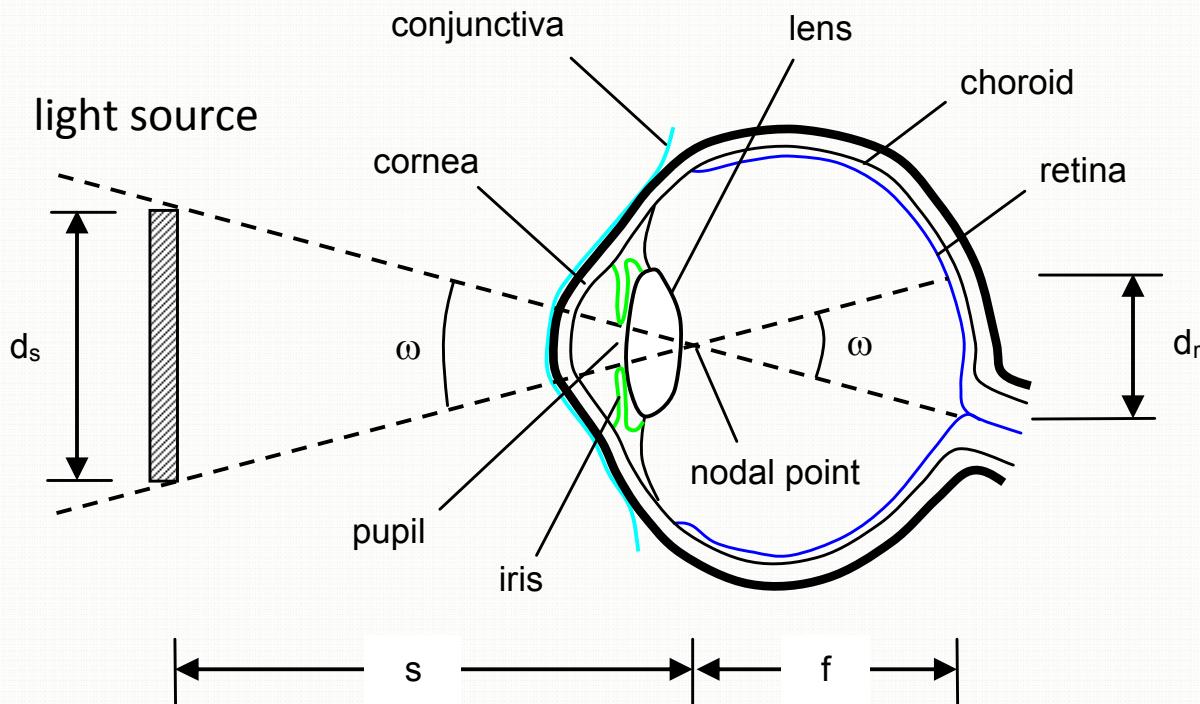


Adapted from ACRP Synthesis 28 "Investigating Safety Impacts of Energy Technologies on Airports and Aviation"

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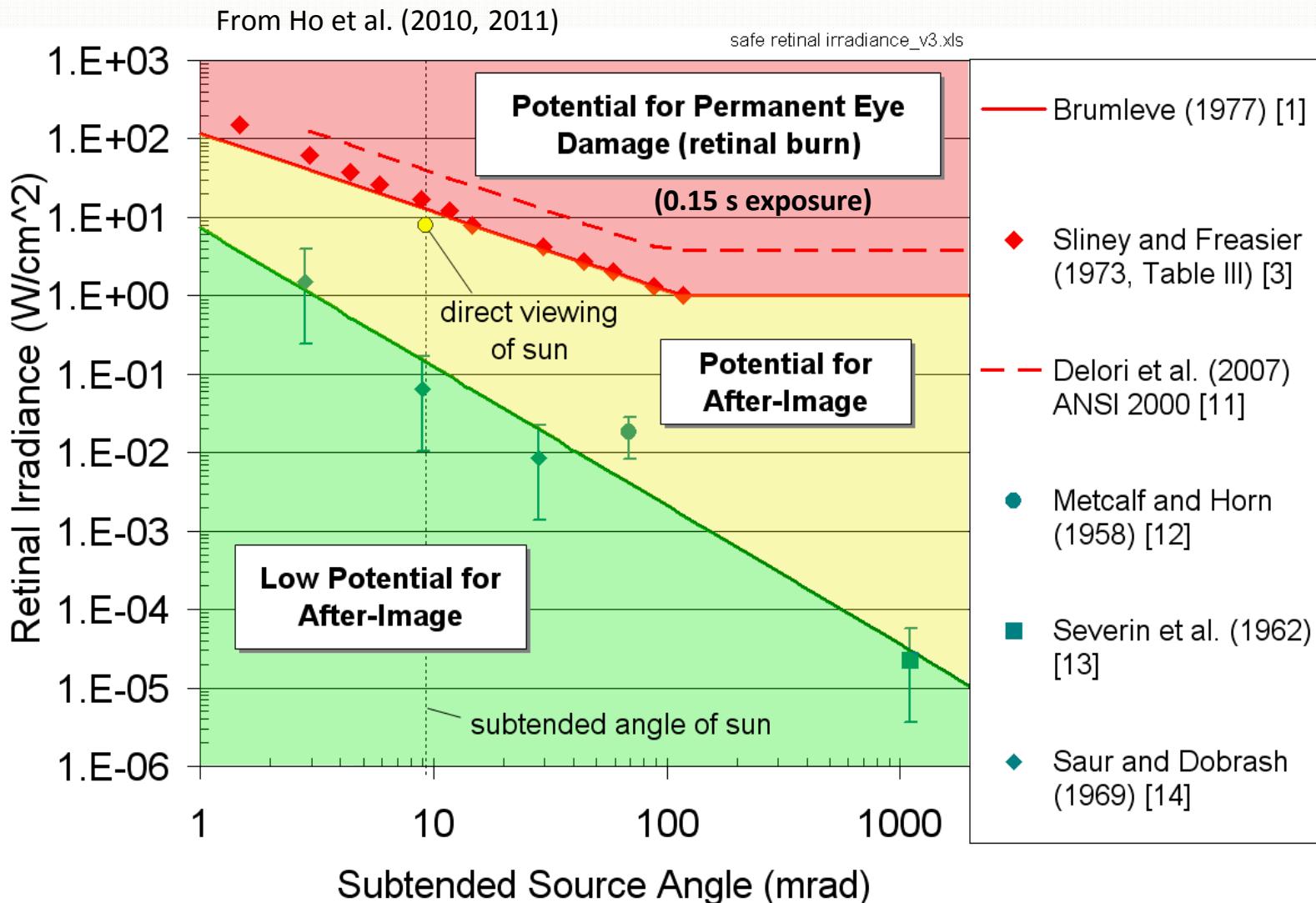


# Retinal Irradiance



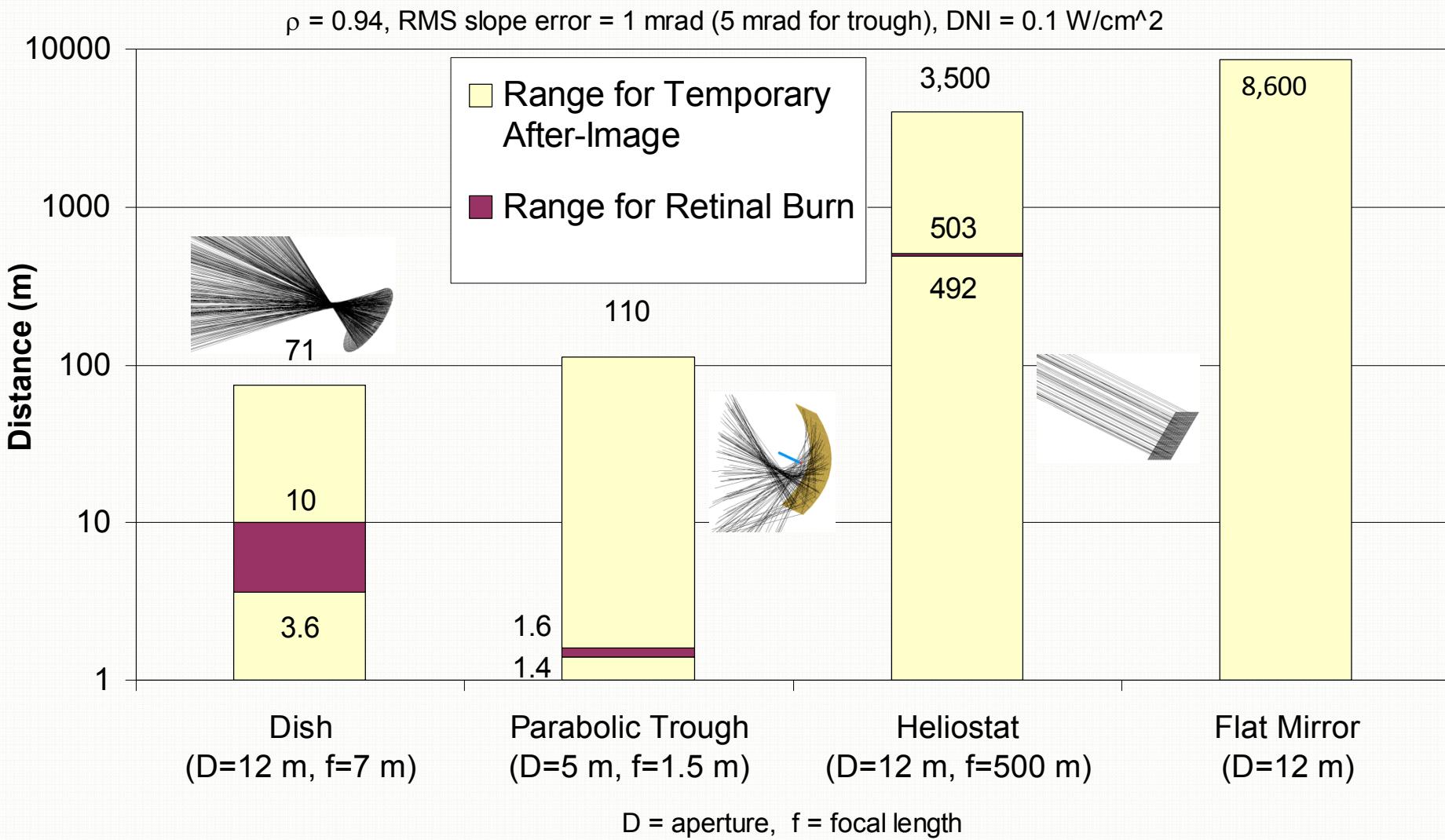
- Need to calculate
  - Power entering eye
    - Function of irradiance at the cornea (front of eye)
  - Subtended angle of glint/glare source

# Potential Ocular Impacts



Equations and analysis methods detailed in Ho et al. (2010, 2011)

# Potential Ocular Impacts as a Function of Distance



# Web-Based Glare Tool

www.sandia.gov/glare

Sandia National Laboratories: Solar Glare and Flux Mapping Tools - Mozilla Firefox

File Edit View History Bookmarks Tools Help

sanda.gov https://share.sandia.gov/glare/

Sandia National Laboratory https://share.sandia.gov/glare/ Employee Locator | Index | Site Map

Search  Go

**Solar Glare and Flux Mapping Tools**

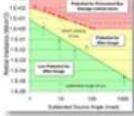
Measurement of reflected solar irradiance is receiving significant attention by industry, military, and government agencies to assess potential impacts of glint and glare from growing numbers of solar power installations around the world. In addition, characterization of the incident solar flux distribution on central receivers for concentrating solar power applications is important to monitor and maintain system performance.

This website provides tools to analytically and empirically quantify glare from reflected light and determine the potential impact (e.g., temporary flash blindness, retinal burn). In addition, tools are being developed that will evaluate the irradiance distribution on a central receiver. Empirical results are based on digital photographs uploaded by the user. Instructions are included in each of the links below.

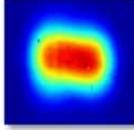
**Empirical Glare Analysis**  
Upload Glare Photos



**Analytical Glare Analysis**



**Flux Mapping Analysis**  
Upload Receiver Photos



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Done

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# Glare Example: Heliostat Flyover

National Solar Thermal Test Facility  
Albuquerque, NM  
November 10, 2010



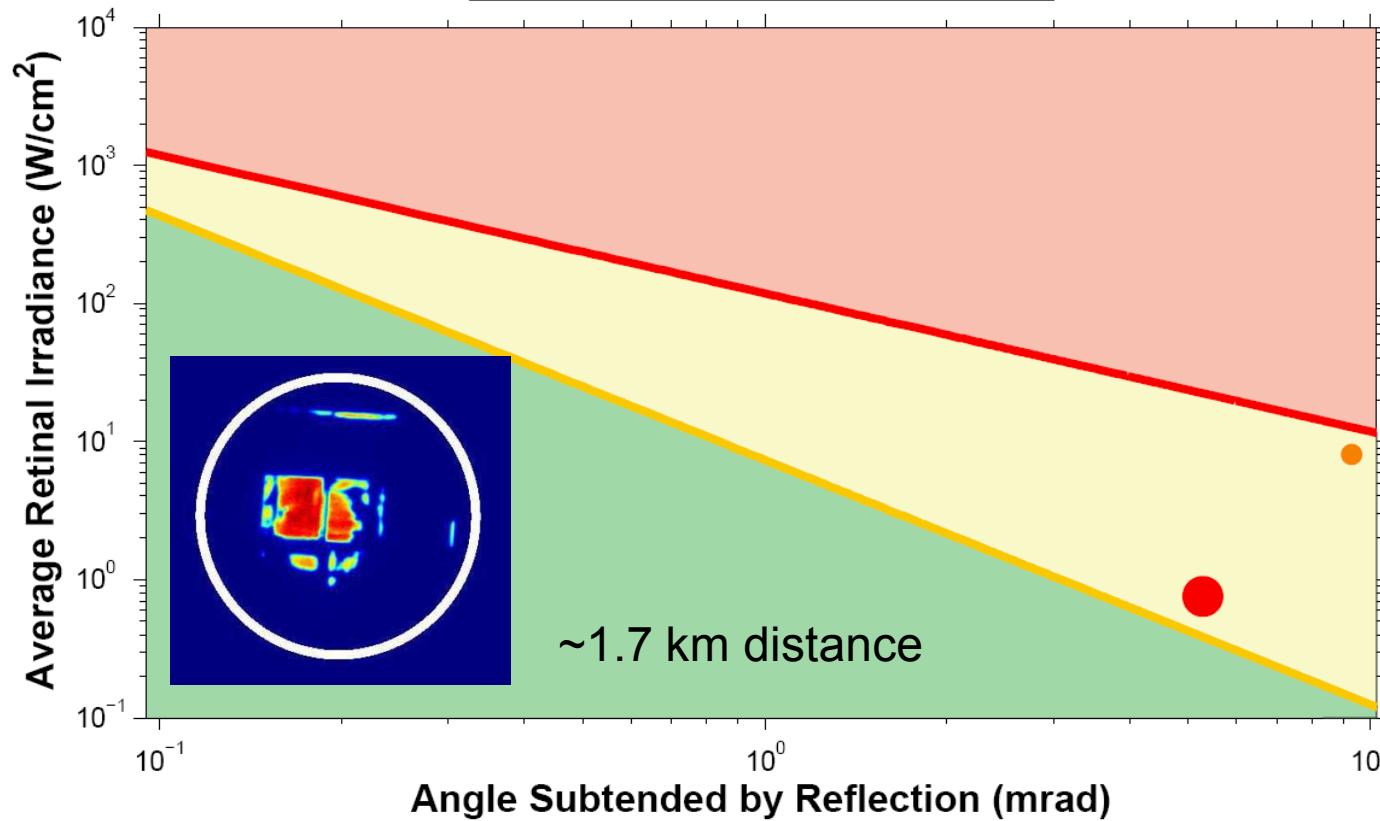
Heliostats aimed in “standby” position 30 m to the east of top of tower

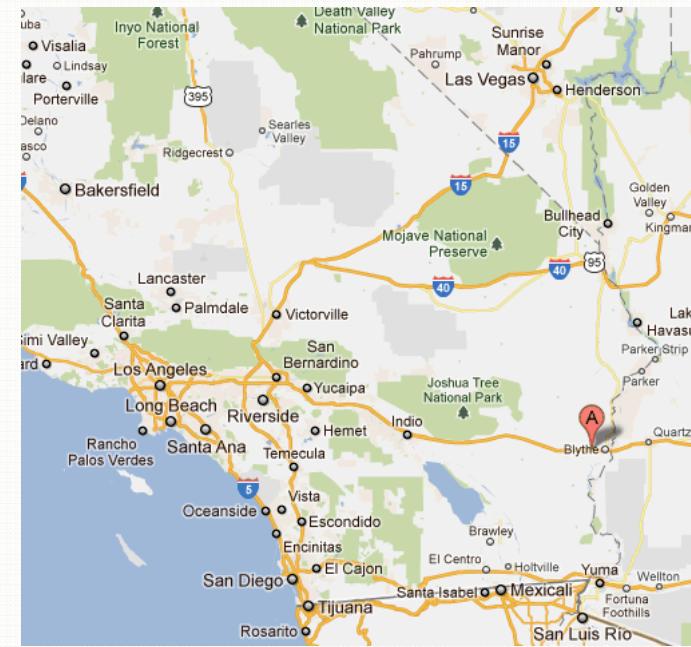
# Heliostat Glare Analysis

From Ho (2011)



- Maximum Hazard from Source Image
- Hazard Due to Viewing Unfiltered Sun
- Permanent Retinal Damage Threshold
- After-Image Threshold
- Permanent Retinal Damage Zone
- Potential for After-Image Zone
- Low Potential for After-Image Zone





Glare Assessment Example:

# BLYTHE SOLAR POWER PROJECT

CALIFORNIA ENERGY COMMISSION SUPPLEMENTAL STAFF ASSESSMENT PART 2

# Blythe Airport Glare Analysis

California Energy Commission

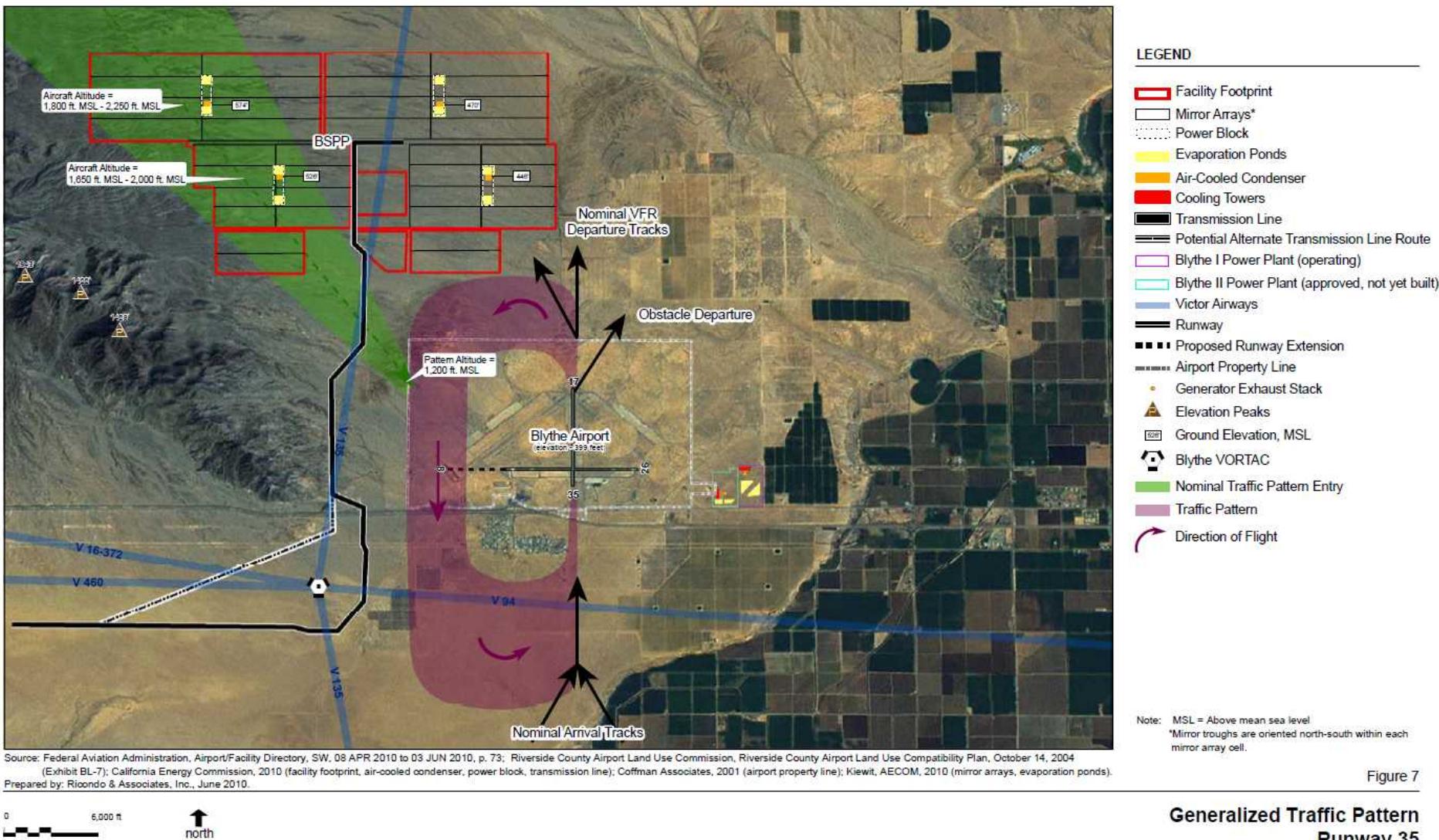
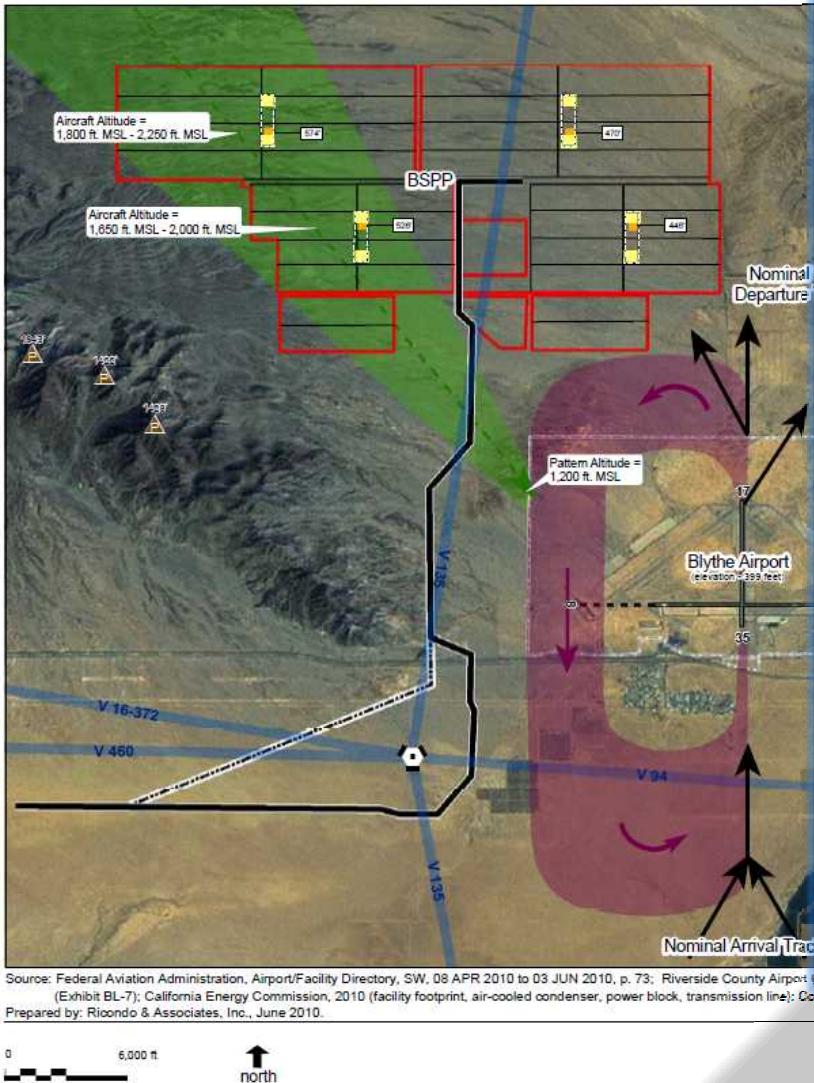


Figure 7

Generalized Traffic Pattern  
Runway 35

# Blythe Airport Glare Analysis

California Energy Commission



## Glare Assessment Process:

1. Identify conditions when glare may be visible by pilots
  - Flight patterns, time/date, solar plant operations
2. If glare conditions exists, identify potential ocular impact
3. If glare is likely to cause ocular impact, identify mitigation measures

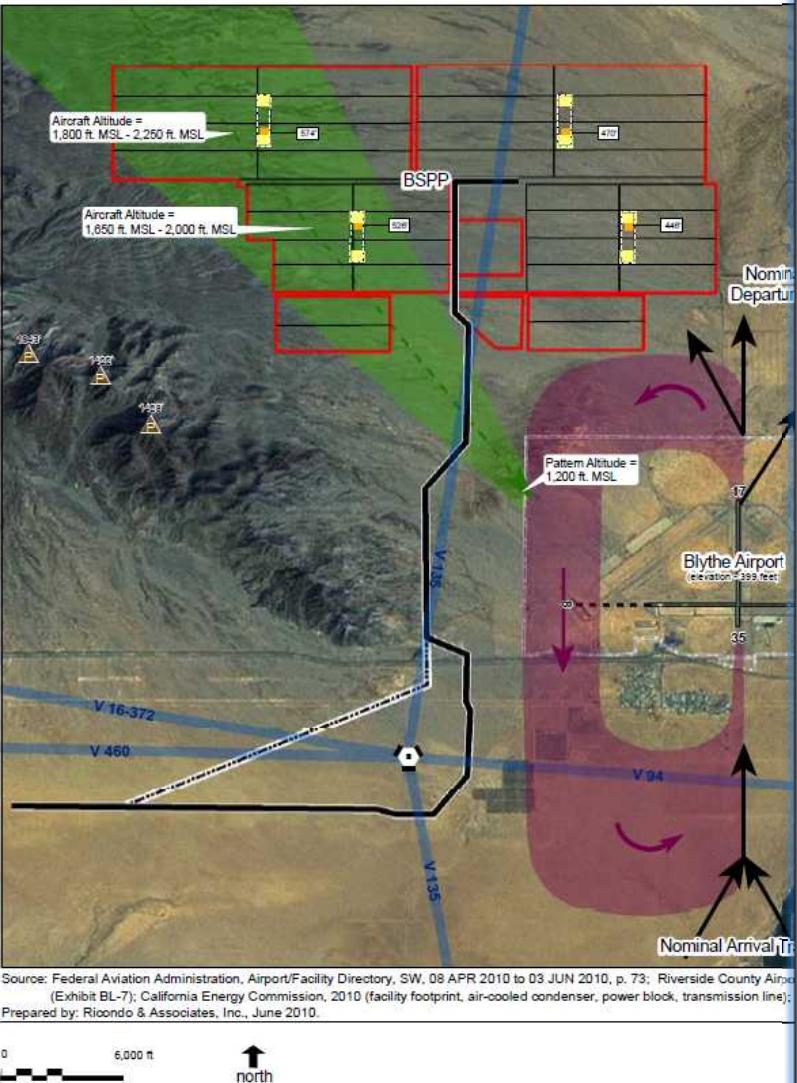
Figure 7

Generalized Traffic Pattern  
Runway 35

# Blythe Airport Glare Analysis

California Energy Commission

- Staff Assessment identified several scenarios where glare may impact pilots
- Mitigations were proposed
  - Barriers and screens
  - Pilot notification
  - Stow procedures
- Based on assessment and hearings, the Commission decided that the project could be licensed



Source: Federal Aviation Administration, Airport/Facility Directory, SW, 08 APR 2010 to 03 JUN 2010, p. 73; Riverside County Airport (Exhibit BL-7); California Energy Commission, 2010 (facility footprint, air-cooled condenser, power block, transmission line); Prepared by: Rioondo & Associates, Inc., June 2010.

# **CONCLUSIONS**

- **Glint and glare can cause unwanted visual impacts**
  - Analytical models and safety metrics have been developed to quantify glint and glare from different solar technologies
  - These methods can be used to assess impact of glare near airports
- **Identification and quantification of potential impacts will help agencies to develop appropriate mitigations, measures, and/or requirements**
  - California Energy Commission
  - Air Force
  - FAA
  - Transportation Research Board/ACRP



# **BACKUP SLIDES**

# Examples of Airports with Solar PV

- Denver International Airport (8 MW)
- San Francisco International Airport (500 kW)
- Oakland International Airport (1.7 MW)
- Fresno Yosemite International Airport (2 MW)
- San Antonio Airport (235 kW)
- Charlotte Douglas Int. Airport (306 kW)



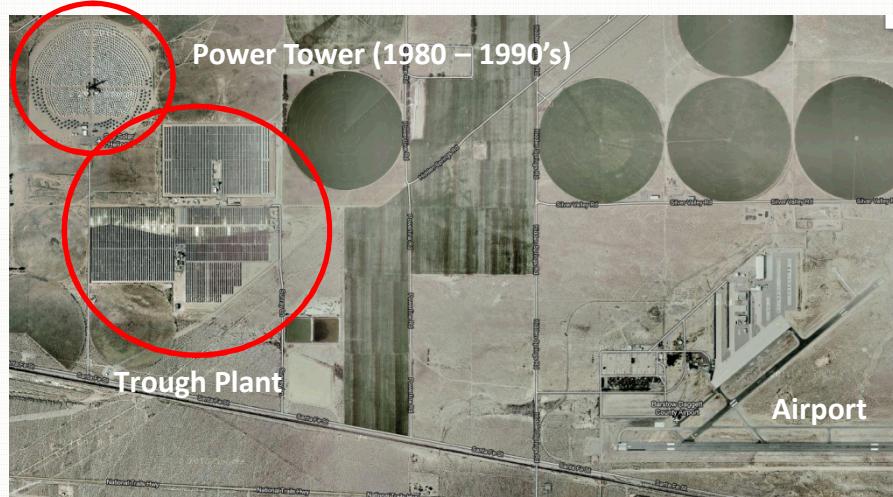
Denver International Airport



Oakland International Airport

# Airports near Concentrating Solar Power Plants

- Barstow Daggett County Airport
  - Parabolic trough plant (~1 mile away)
  - Power tower (1980's – 1990's)
- Las Vegas International Airport
  - Parabolic trough plant (~15 miles away)



Barstow Daggett County Airport



Nevada Solar One (looking SE;  
LV airport is ~15 miles to the NW)