



ACC/AAAE AIRPORT PLANNING,
DESIGN & CONSTRUCTION
SYMPOSIUM

Denver | 29 Feb - 2 Mar 2012

Track: Mini-Track
Environment/Energy

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 Assessments



Examples of Glare from Solar Technologies

Photovoltaics



Concentrating Solar Power



Heliostats and Central Receiver at Sandia Labs, Albuquerque, NM

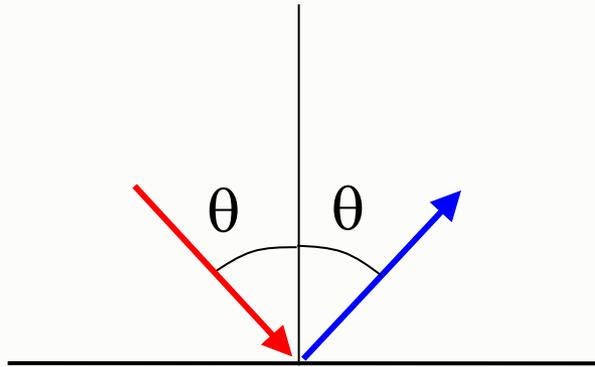


Dish Collectors at Sandia



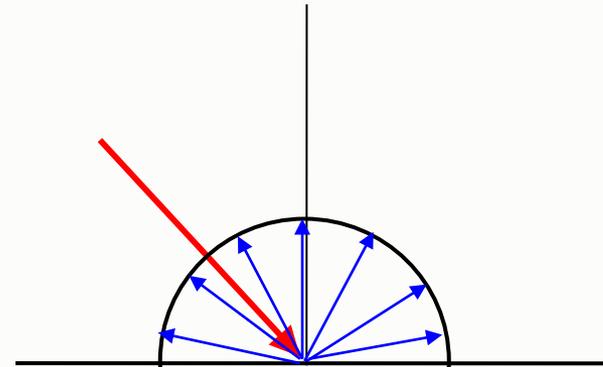
Parabolic Trough Collectors at
Kramer Junction, CA

Types of Reflection



Specular Reflection

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

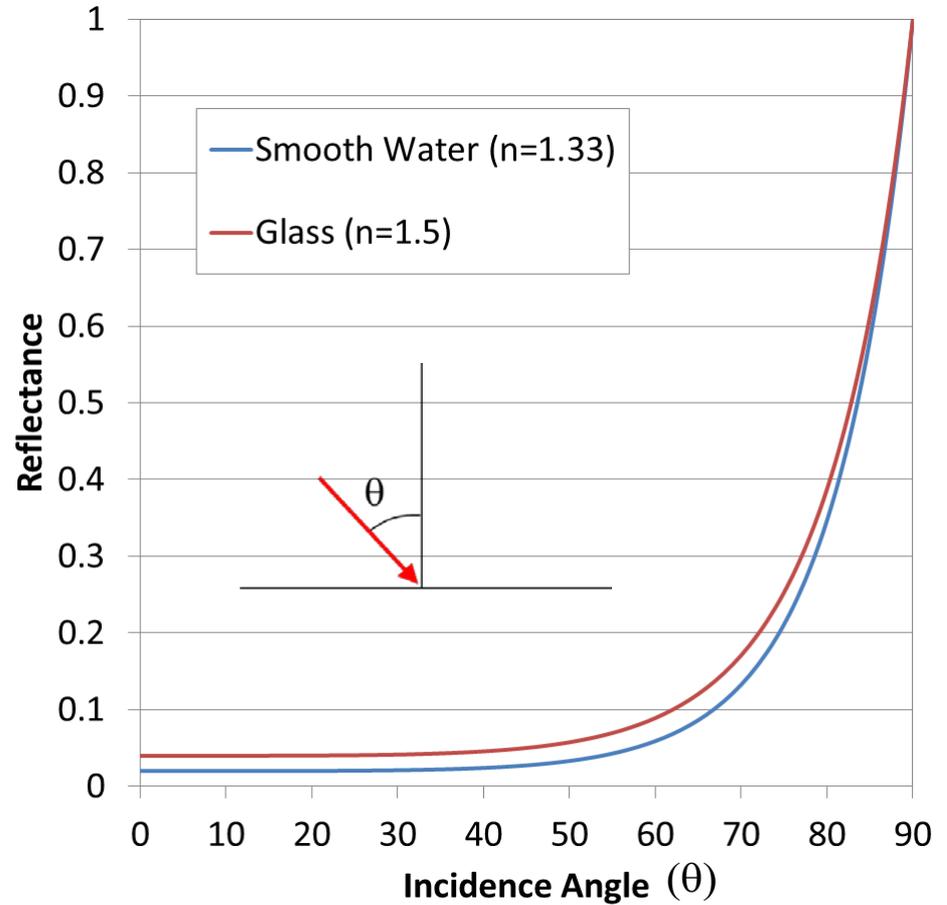
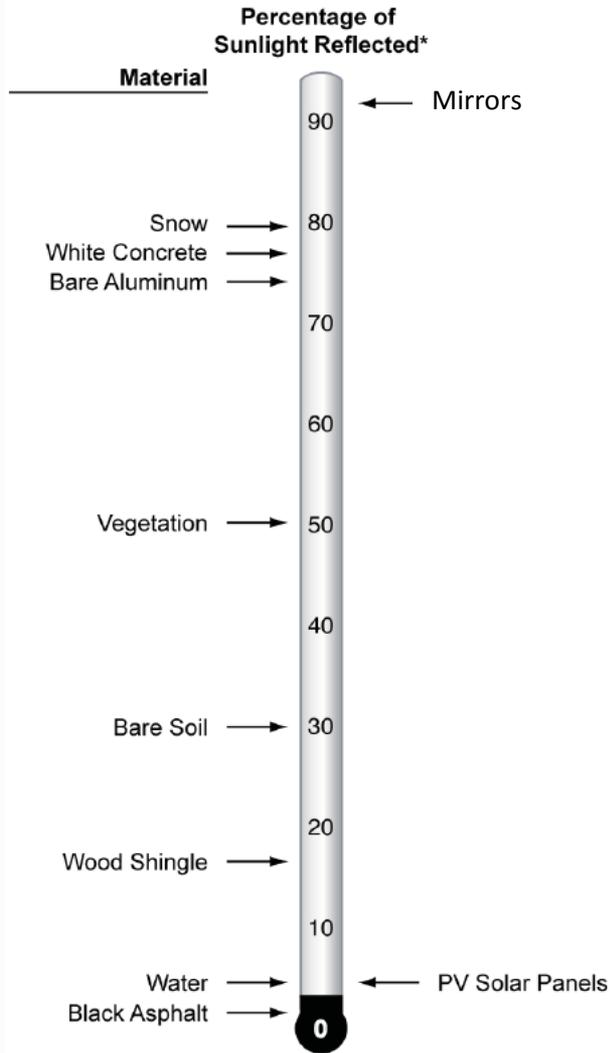


Diffuse Reflection

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



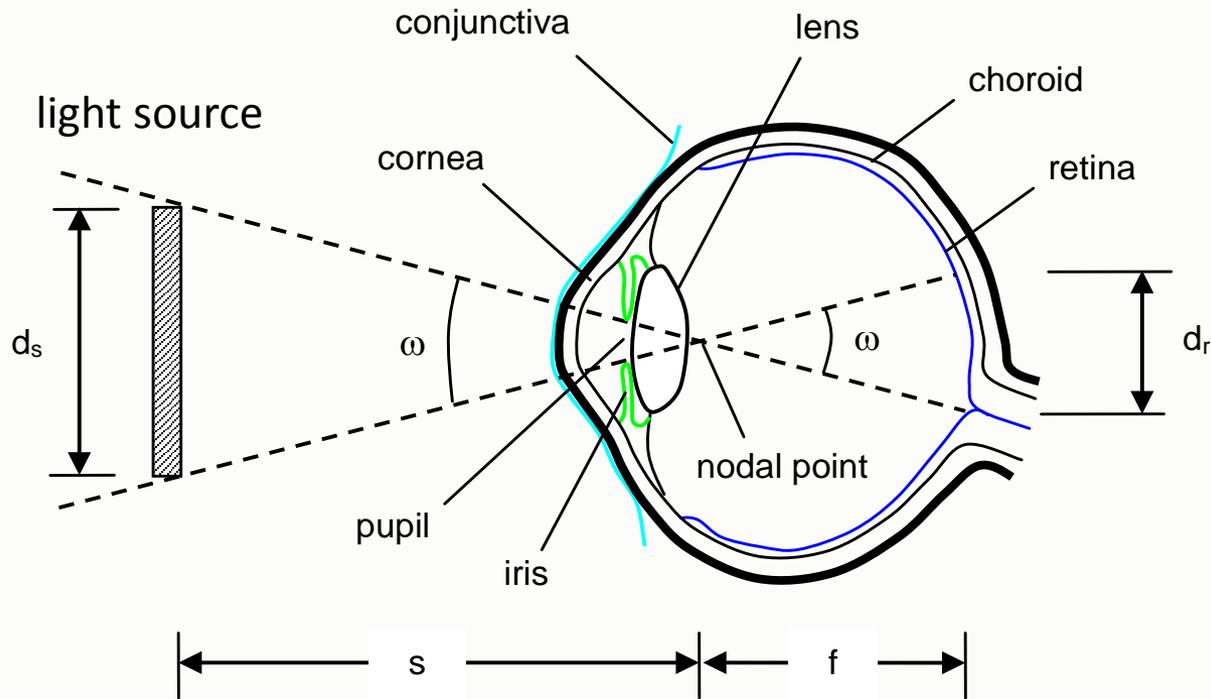
Reflectivity



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

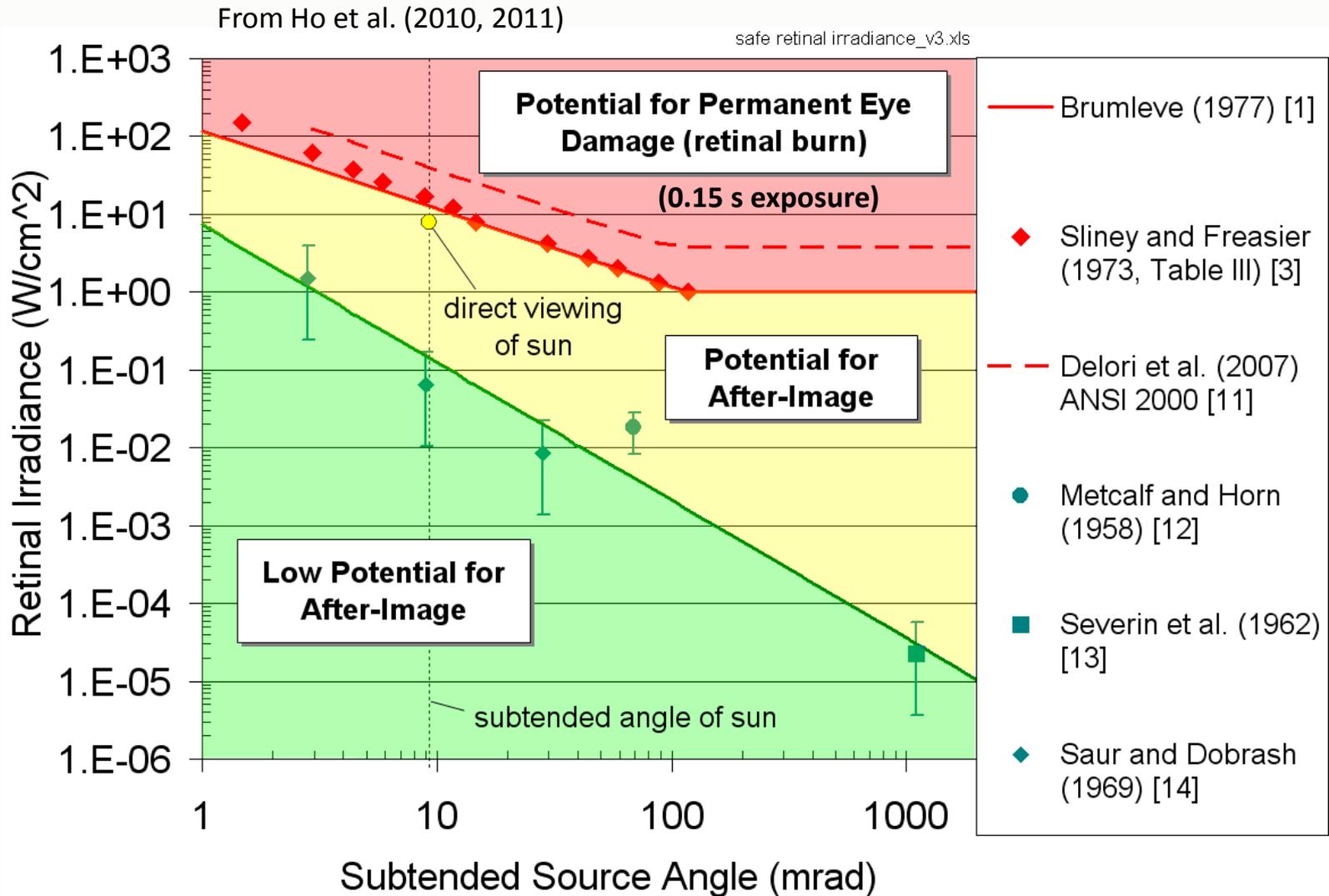
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- Need to calculate
 - Power entering eye
 - Function of irradiance at the cornea (front of eye)
 - Subtended angle of glint/glare source

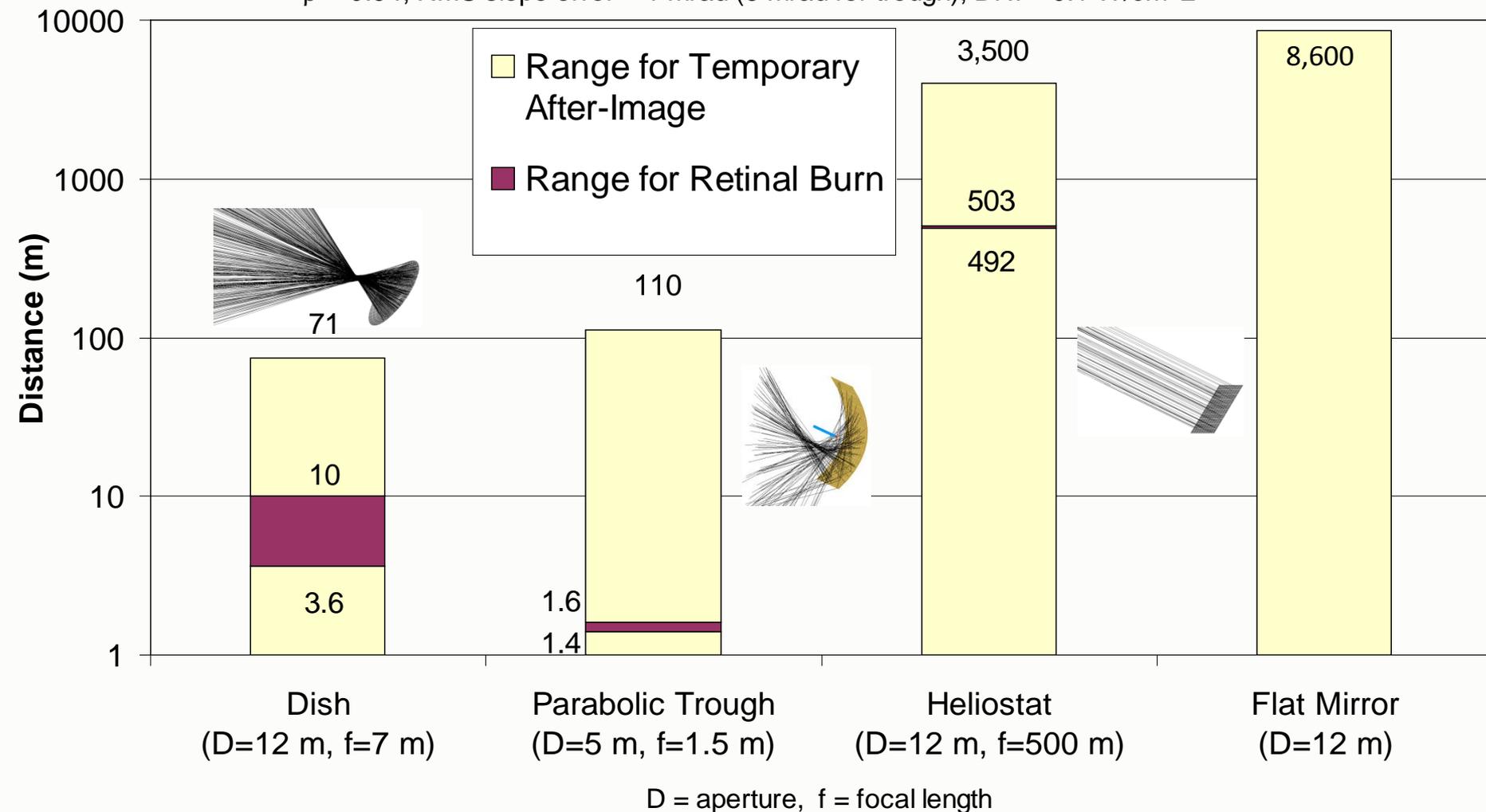
Potential Ocular Impacts



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

Potential Ocular Impacts as a Function of Distance

$\rho = 0.94$, RMS slope error = 1 mrad (5 mrad for trough), DNI = 0.1 W/cm²



www.sandia.gov/glare

The screenshot shows a Mozilla Firefox browser window displaying the Sandia National Laboratories website. The address bar shows the URL <https://share.sandia.gov/glare/>. The page header includes the Sandia National Laboratories logo and navigation links: About, Mission Areas, Newsroom, Careers, Doing Business, Education, Contact Us. There are also links for Employee Locator, Index, Site Map, and a search bar.

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.

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- Empirical Glare Analysis**
Upload Glare Photos
- Analytical Glare Analysis**
- Flux Mapping Analysis**
Upload Receiver Photos

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Glare Example: Heliostat Flyover

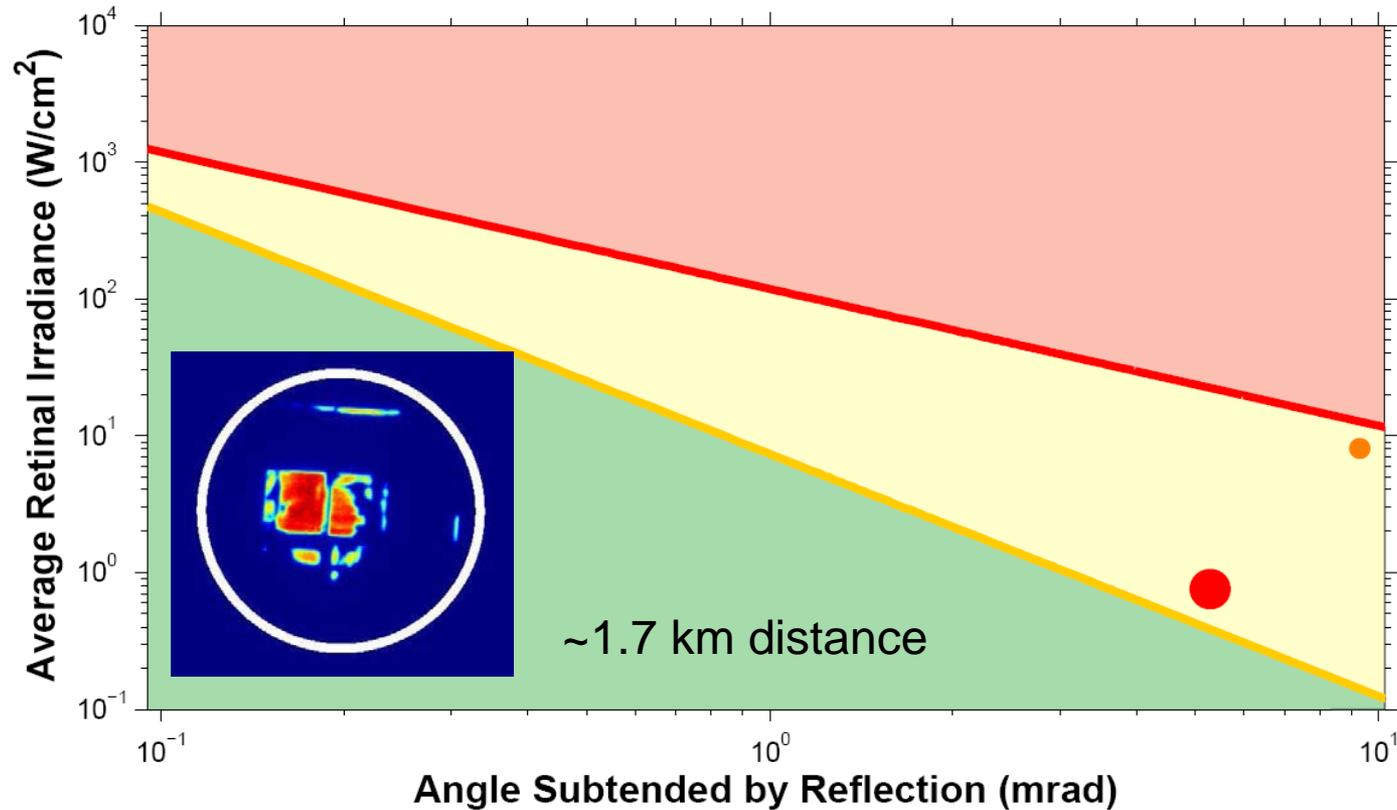
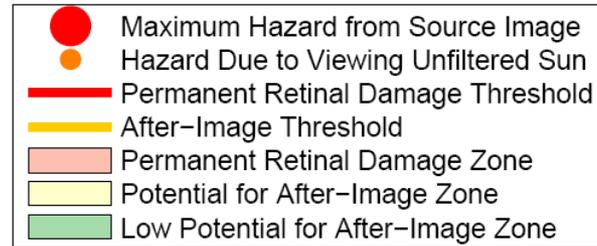
National Solar Thermal Test Facility
Albuquerque, NM
November 10, 2010

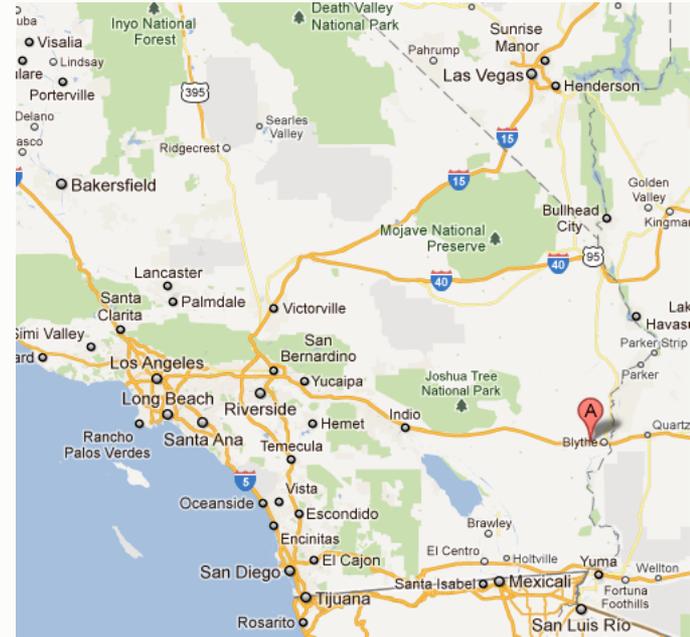


Heliostats aimed in “standby” position 30 m to the east of top of tower

Heliostat Glare Analysis

From Ho (2011)





Glare Assessment Example:

BLYTHE SOLAR POWER PROJECT

[CALIFORNIA ENERGY COMMISSION SUPPLEMENTAL STAFF ASSESSMENT PART 2](#)

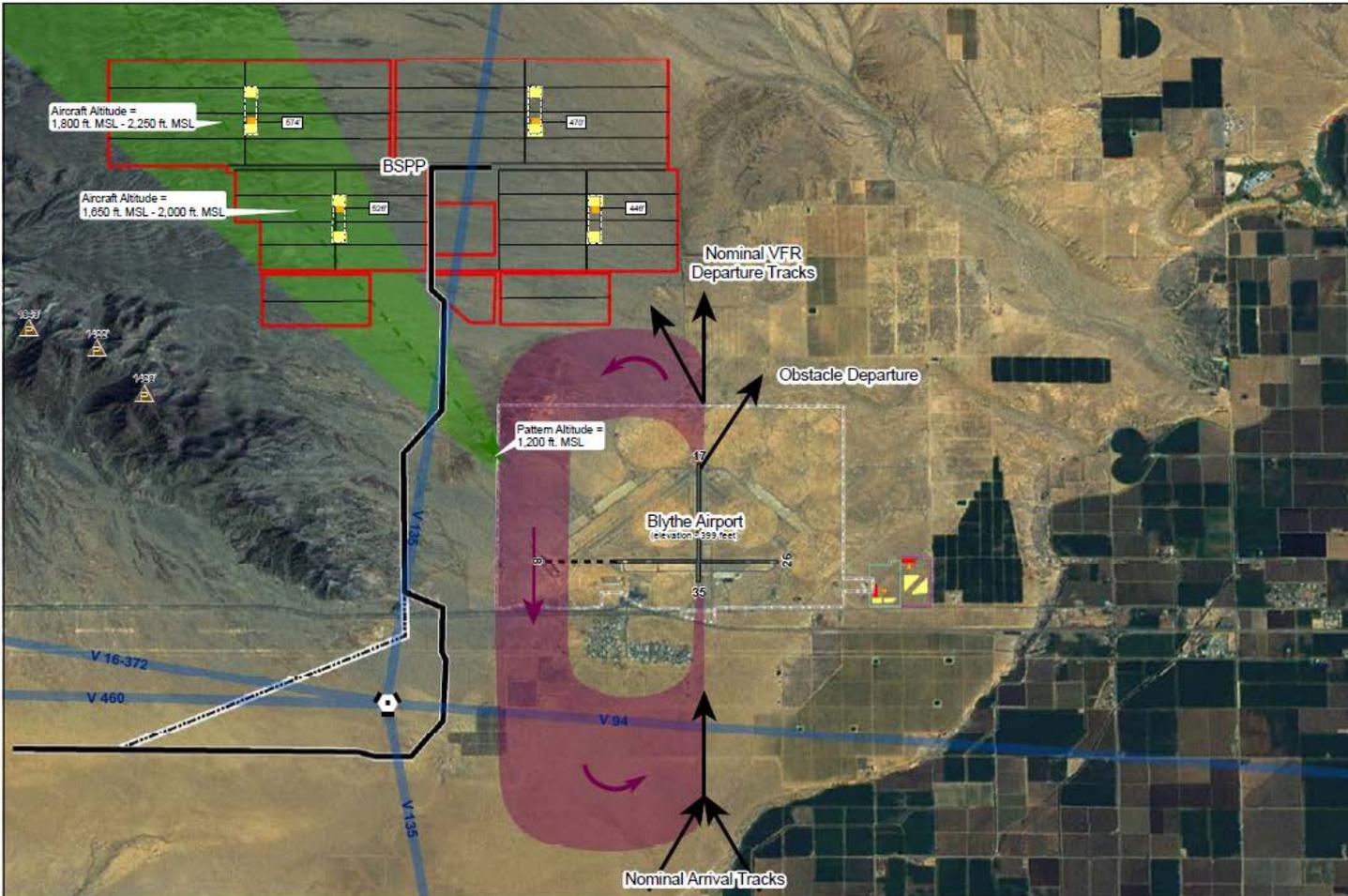
Blythe Airport Glare Analysis

California Energy Commission

LEGEND

- Facility Footprint
- Mirror Arrays*
- Power Block
- Evaporation Ponds
- Air-Cooled Condenser
- Cooling Towers
- Transmission Line
- Potential Alternate Transmission Line Route
- Blythe I Power Plant (operating)
- Blythe II Power Plant (approved, not yet built)
- Victor Airways
- Runway
- Proposed Runway Extension
- Airport Property Line
- Generator Exhaust Stack
- Elevation Peaks
- Ground Elevation, MSL
- Blythe VORTAC
- Nominal Traffic Pattern Entry
- Traffic Pattern
- Direction of Flight

Note: MSL = Above mean sea level
 *Mirror troughs are oriented north-south within each mirror array cell.



Source: Federal Aviation Administration, Airport/Facility Directory, SW, 08 APR 2010 to 03 JUN 2010, p. 73; Riverside County Airport Land Use Commission, Riverside County Airport Land Use Compatibility Plan, October 14, 2004 (Exhibit BL-7); California Energy Commission, 2010 (facility footprint, air-cooled condenser, power block, transmission line); Coffman Associates, 2001 (airport property line); Kiewit, AECOM, 2010 (mirror arrays, evaporation ponds).
 Prepared by: Ricondo & Associates, Inc., June 2010.



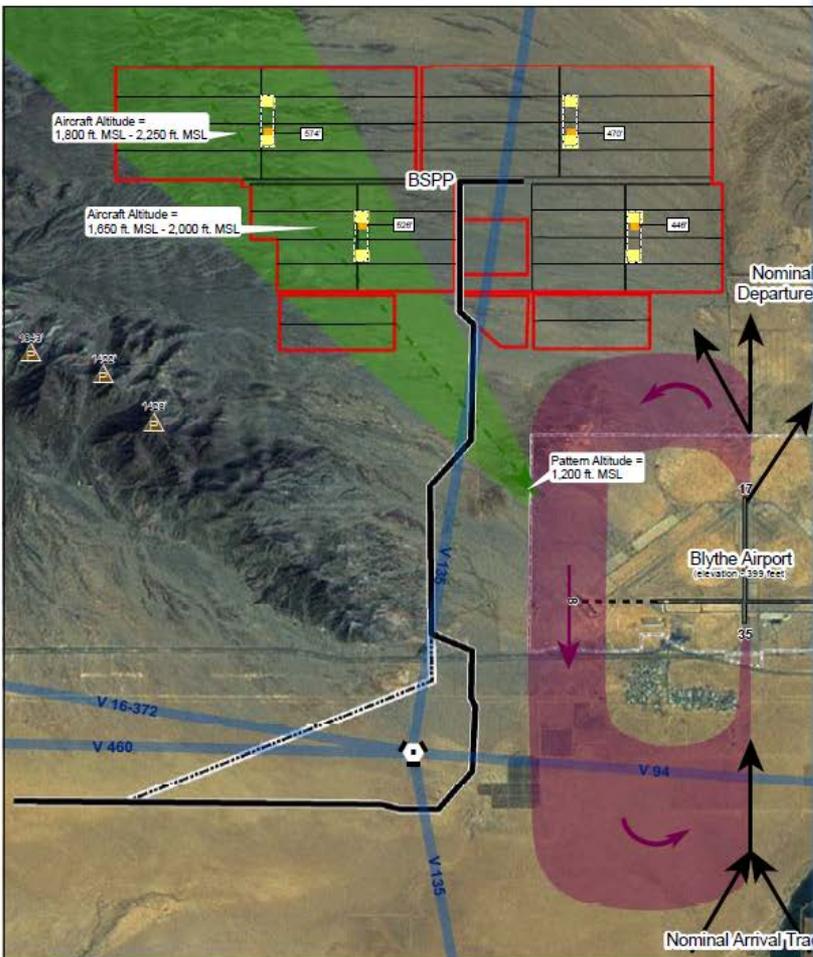
Figure 7

Generalized Traffic Pattern Runway 35

June 2010

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 exist, identify potential ocular impact
3. If glare is likely to cause ocular impact, identify mitigation measures

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); Coffman Associates, 2001 (airport property line); Kiewit, AECOM, 2010 (mirror arrays, evaporation ponds). Prepared by: Ricordo & Associates, Inc., June 2010.

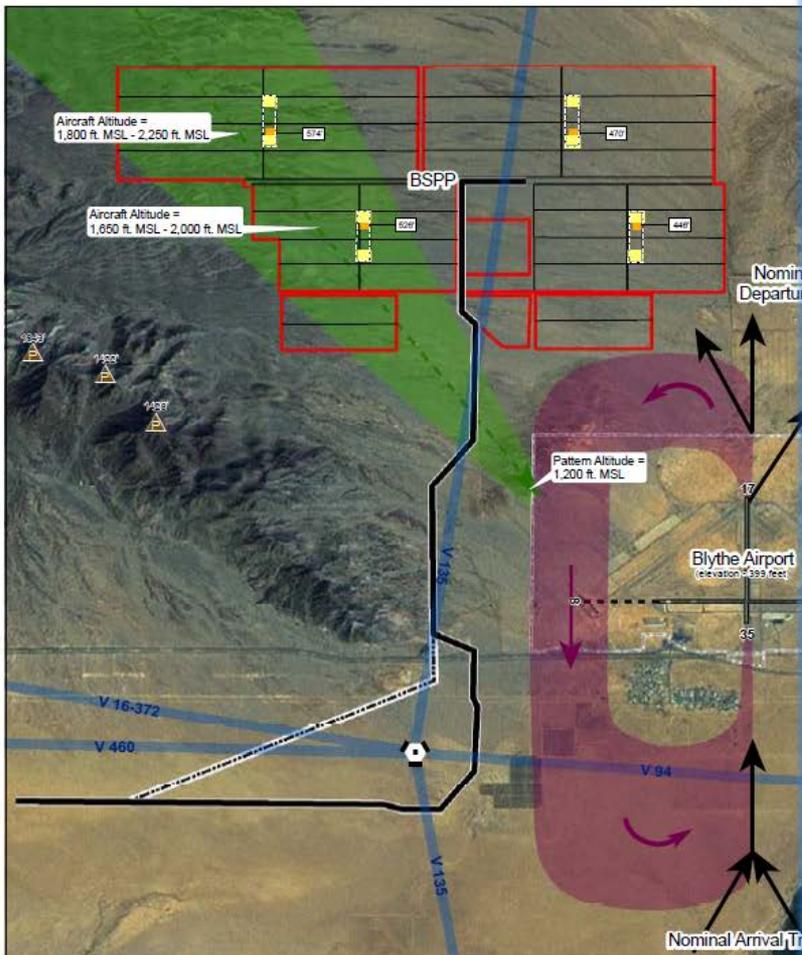
Figure 7



Generalized Traffic Pattern
Runway 35

Blythe Airport Glare Analysis

California Energy Commission



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: Ricordo & Associates, Inc., June 2010.

- 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

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)



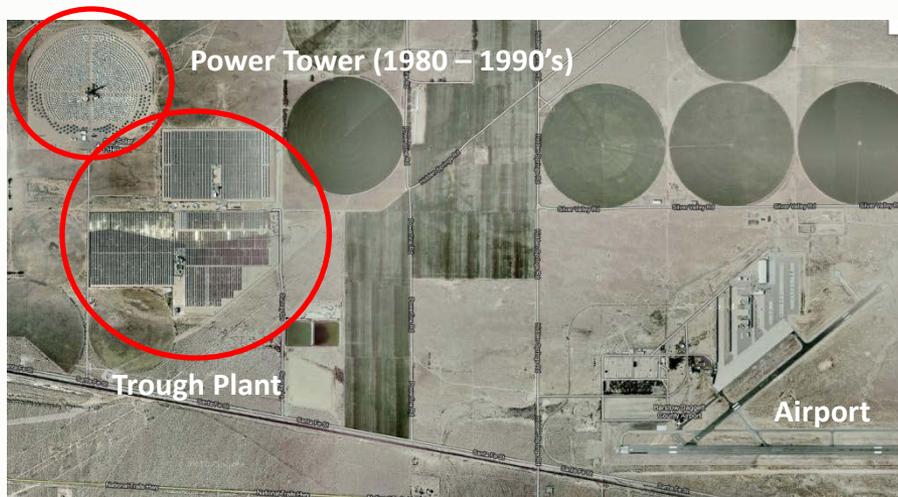
Denver International Airport



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)