Solar Energy Compatibility with DoD Operations

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Exceptional service in the national interest

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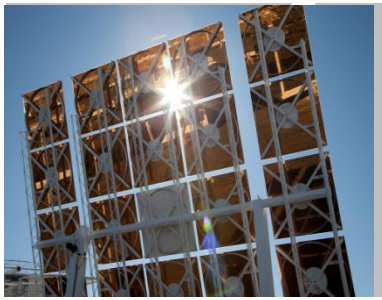

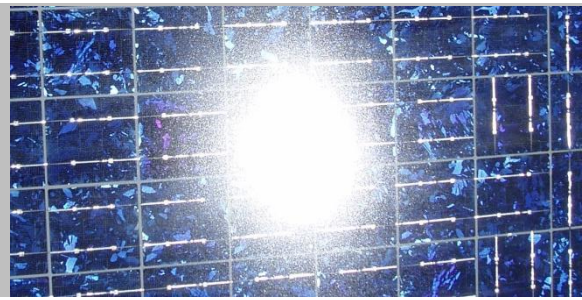

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Overview

- Introduction
- Glint and Glare Analysis
- Thermal Emissions Analysis
- Summary

Introduction

- Multiple agencies are interested in evaluating potential safety impacts from emerging energy technologies
  - DoD
    - Impact on operations and training missions
  - FAA
  - California Energy Commission
    - Solar power plant Applications for Certification
  - National Academies – Transportation Research Board
    - Synthesis Report on “Investigating Safety Impacts of Energy Technologies on Airports and Aviation”

Introduction

- Funded by DOE, DoD, and private industry to address compatibility issues with solar energy
  - Glint and glare from photovoltaics (PV) and concentrating solar power (CSP)
    - Glare can cause negative visual impacts for pilots and air-traffic controllers
  - Infrared emissions
    - Heated objects can interfere with infrared sensors

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Glint and Glare

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

Definitions

Glint: Momentary flash of light

Glare: Continuous source of excessive brightness

Road sign on Massachusetts State Route 2

Examples of Glare from Solar Technologies

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Photovoltaics

Concentrating Solar Power

Heliostats and Central Receiver at Sandia Labs, Albuquerque, NM

Dish Collectors at Sandia

Parabolic Trough Collectors at Kramer Junction, CA

Examples of Glare from Solar Technologies

Glare observations from C-12 cockpit at Kramer Junction, CA
(from Air Force Flight Test Center 412 TW at Edwards AFB, approval #13166)

Glare observed from airport traffic control tower at Manchester-Boston Regional Airport (May 2012). The $3.5M array had to be tarped.

New Federal Policy

- U.S. Department of Transportation, Federal Aviation Administration
  (78 FR 63276, October 23, 2013)
  - "...the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated airport."
  - "All sponsors of federally-obligated airports who propose to install or to permit others to install solar energy systems on the airport must attach the SGHAT report, outlining solar panel glare and ocular impact, for each point of measurement to the Notice of Proposed Construction Form 7460-1."

U.S. Department of Transportation

Federal Aviation Administration

DoD Memo on Glare

- DoD issued guidance in June 2014 requiring the use of SGHAT for renewable energy projects near DoD Aviation Operations

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION, TECHNOLOGY AND LOGISTICS

JUN 1 1 2014

MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENVIRONMENT, AND ENERGY)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS, AND ENVIRONMENT)
ACTING ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND LOGISTICS)

SUBJECT: Glint/Glare Issues on or near Department of Defense (DoD) Aviation Operations

In conjunction with the Department of Energy (DOE), the Federal Aviation Administration (FAA) has determined that glint/glare from some types of solar renewable energy systems could result in ocular impact to pilots and/or air traffic controllers, and thus potentially compromise the safety of the air transportation system. Glint is defined as the momentary flash of bright light, while glare is a continuous source of bright light. The FAA interim procedures require commercial airport operators who receive airport operations funding from FAA to conduct glint/glare studies for solar renewable energy systems on or near their airports. While commercial aviation has generally more rigid landing procedures, DoD flight procedures are more varied due to multiple military aircraft types and training requirements. Thus, FAA's interim guidance should only be used as a guide for consideration.

As part of the Office of the Secretary of Defense (OSD) review of solar renewable energy projects, the Directorate of Facilities Energy & Privatization (FE&P) will review your mission compatibility assessments, including the potential for glint/glare. Solar renewable energy projects using the authority found in 10 U.S.C., § 2922a or in 10 U.S.C., § 2667 (Enhanced Use Lease) will require the SGHAT analysis for OSD review/approval/certification. For renewable energy projects that do not require OSD approval (e.g. renewable energy included in Military Construction (MILCON): Facilities Sustainment, Restoration, and Modernization (FSRM); Energy Savings Performance Contract (ESPC); Utility Energy Services Contract (UESC); or Energy Conservation Investment Program (ECIP) projects), OSD encourages a mission compatibility assessment include glint/glare as applicable. The use of the SGHAT is optional, and other glint/glare tools may be used.

Should your staff have questions, please contact Ms. Sara Streff, FE&P at 571-372-6843 or Mr. Steve Sample, SCH at 703-571-0067.

John Conger
Acting Deputy Under Secretary of Defense
(Installations & Environment)

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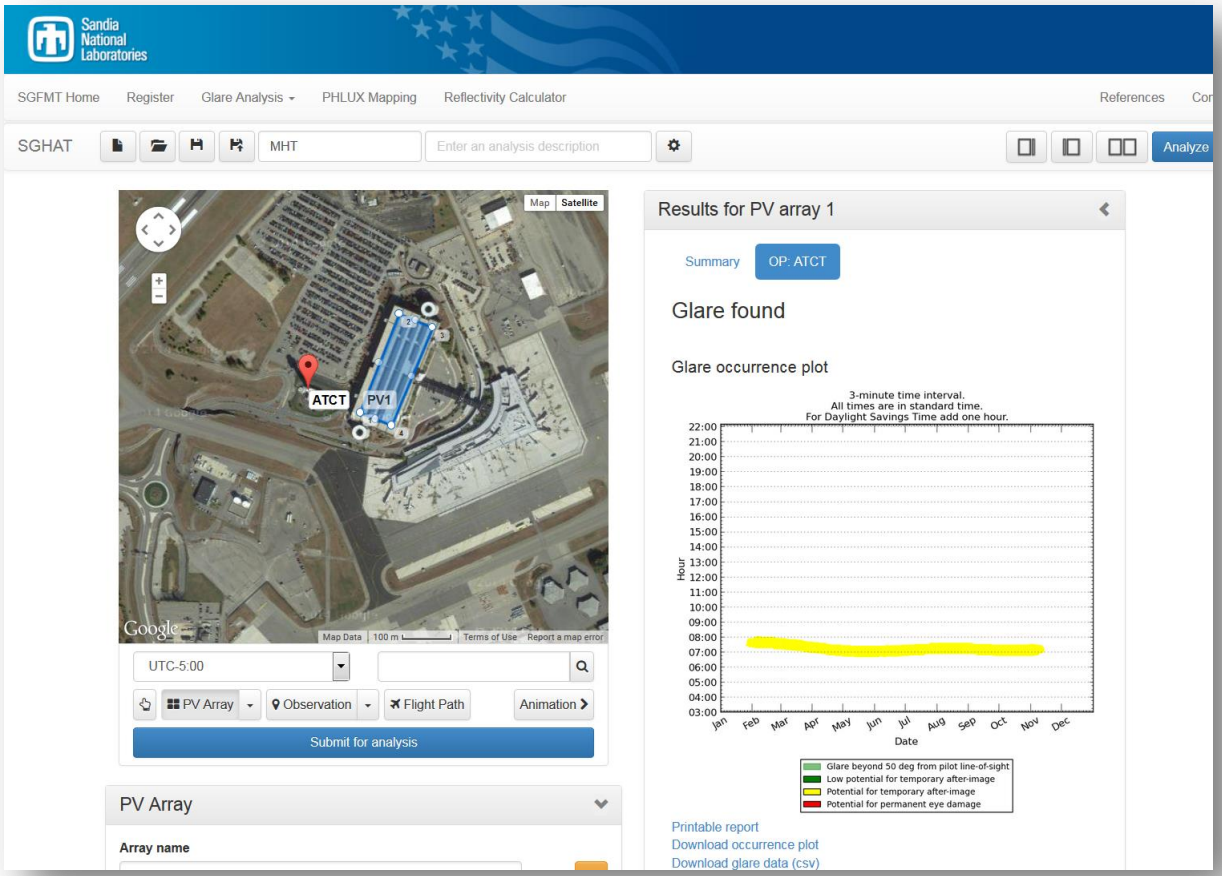
PV Glare

Solar Glare Hazard Analysis Tool

- Free web-based software that predicts impacts of glare and annual energy production from photovoltaic arrays



- Uses interactive Google Maps
- Very fast annual simulations

SGHAT Used at DoD Sites

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- 106th Rescue Wing
- 374th Civil Engineer Squadron
- AF/A3O-BA (Bases & Ranges)
- Air Force Material Command
- Andersen Air Force Base (Guam)
- Eglin AFB
- Eielson Air Force Base (AK)
- Fairchild AFB
- Fort Detrick (Army, Maryland)
- Hanscomb AFB
- Hickam Air Force Base (HI)
- Joint Base Anacostia Boling
- Laughlin AFB
- Naval Air Station Fort Worth
- Reserve Base
- Naval AS Pensacola
- Naval Facilities Engineering Command Midwest
- Nellis AFB
- Osan Air Base (South Korea)
- Patuxent River Naval Air Station
- Pearl Harbor Naval Station
- Travis AFB
- Tyndall AFB
- USAF Air Mobility Command
- USAF CEC, Strategic Asset Util.
- Wake Island Airfield
- Yokota Air Base (Japan)

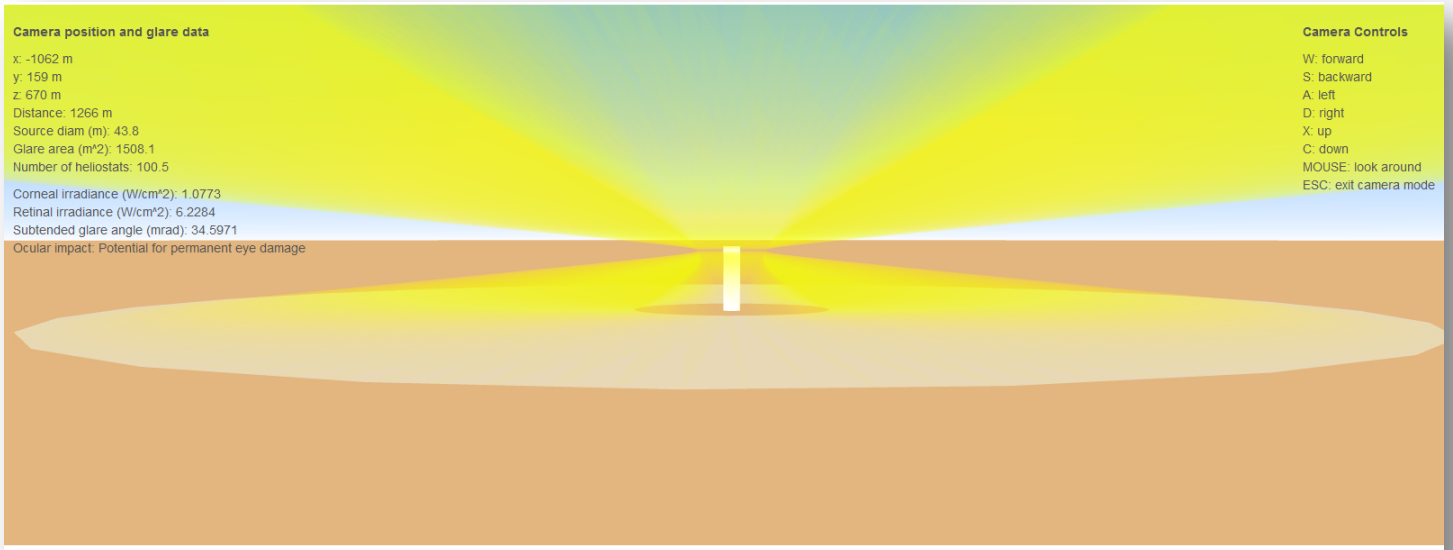
CSP Glare

Glare from Heliostats in Standby Mode

Heliostats in standby mode at the Ivanpah Solar Electric Generating System caused glare to pilots

Tower Illuminance Model

Sandia has developed a 3D tool that allows users to “fly” around a power tower plant to determine the irradiance and potential ocular hazards from heliostat glare at any location



Power tower height: 459 ft	Angular offset of aim point: 90 deg	Reflectivity: 0.9	Focal length: 1000 m
Power tower diameter: 60 ft	Horizontal distance between aim point and tower: 90 ft	Beta: .01 rad	Pupil diameter: 0.002 m
Inner radius of heliostat field: 350 ft	Height above ground of aim point: 430 ft	Heliostat reflective area: 15 m^2	Eye focal length: 0.017 m
Outer radius of heliostat field: 2200 ft		DNI: 1000 W/m^2	Ocular transmission coefficient: 0.5
Opacity of glare representation: 0.03			
Number of spokes of heliostats around field: 120			

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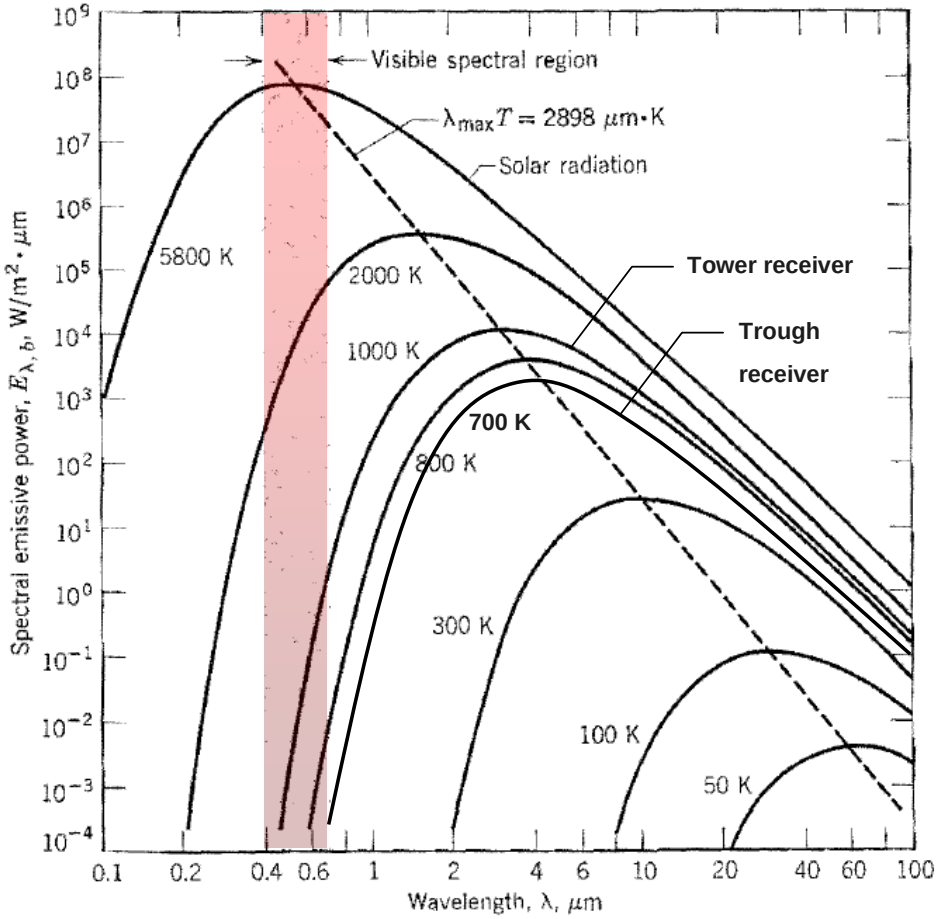
Infrared Emissions

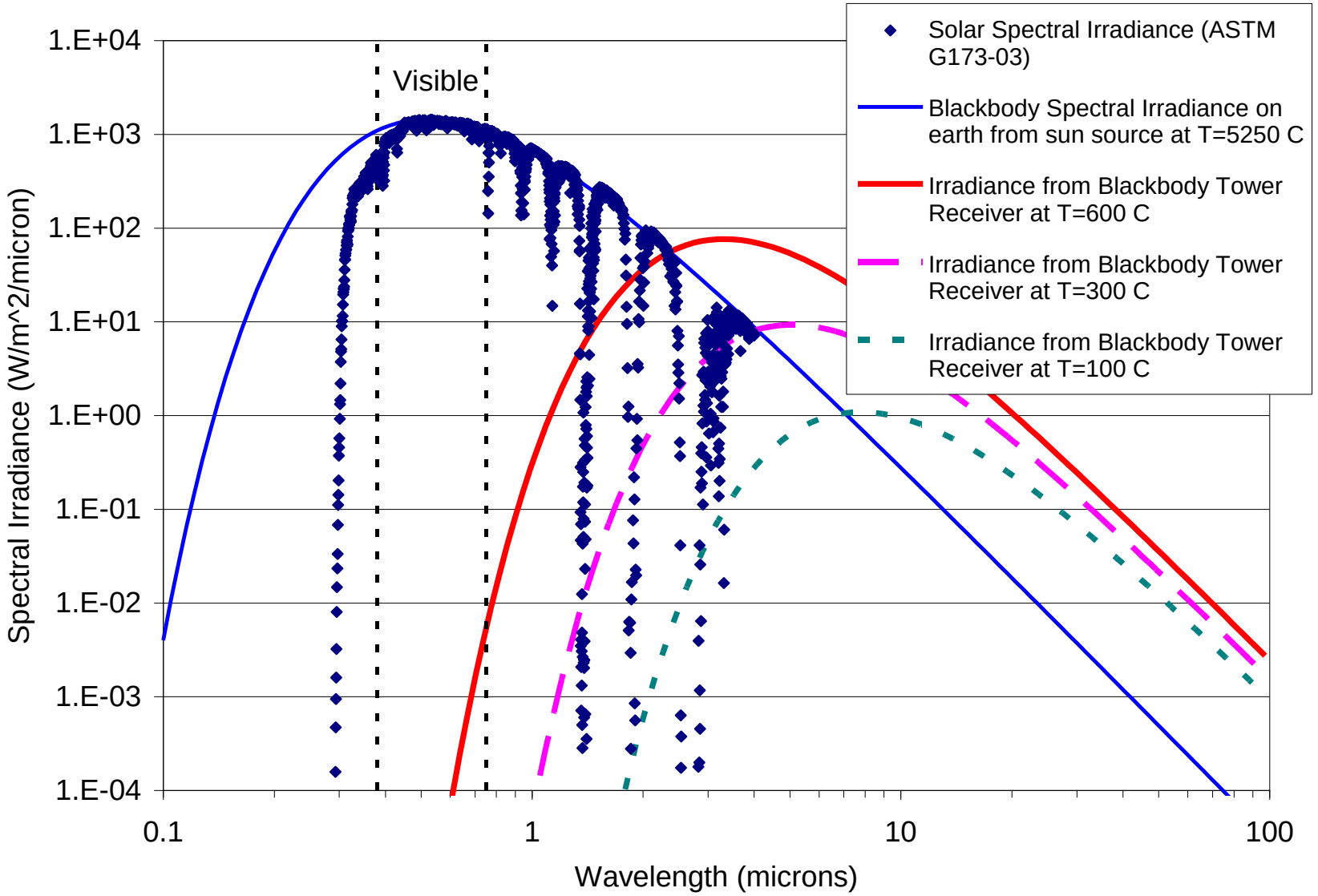
- Heated objects can emit infrared radiation that may interfere with infrared sensors

Spectral Emissive Power

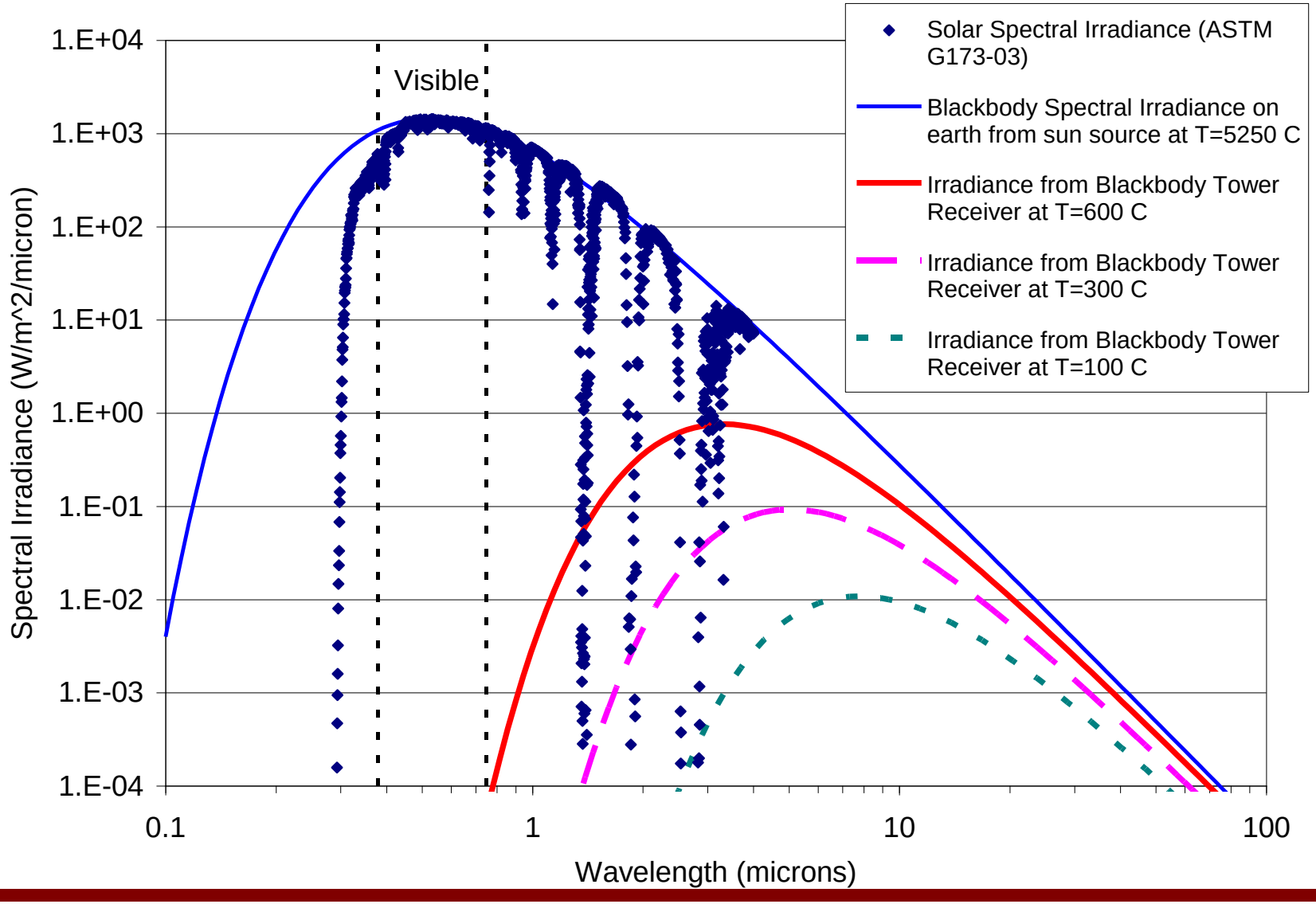


Spectral blackbody emissive power as a function of wavelength and temperature (adapted from Incropera and DeWitt, 1985).

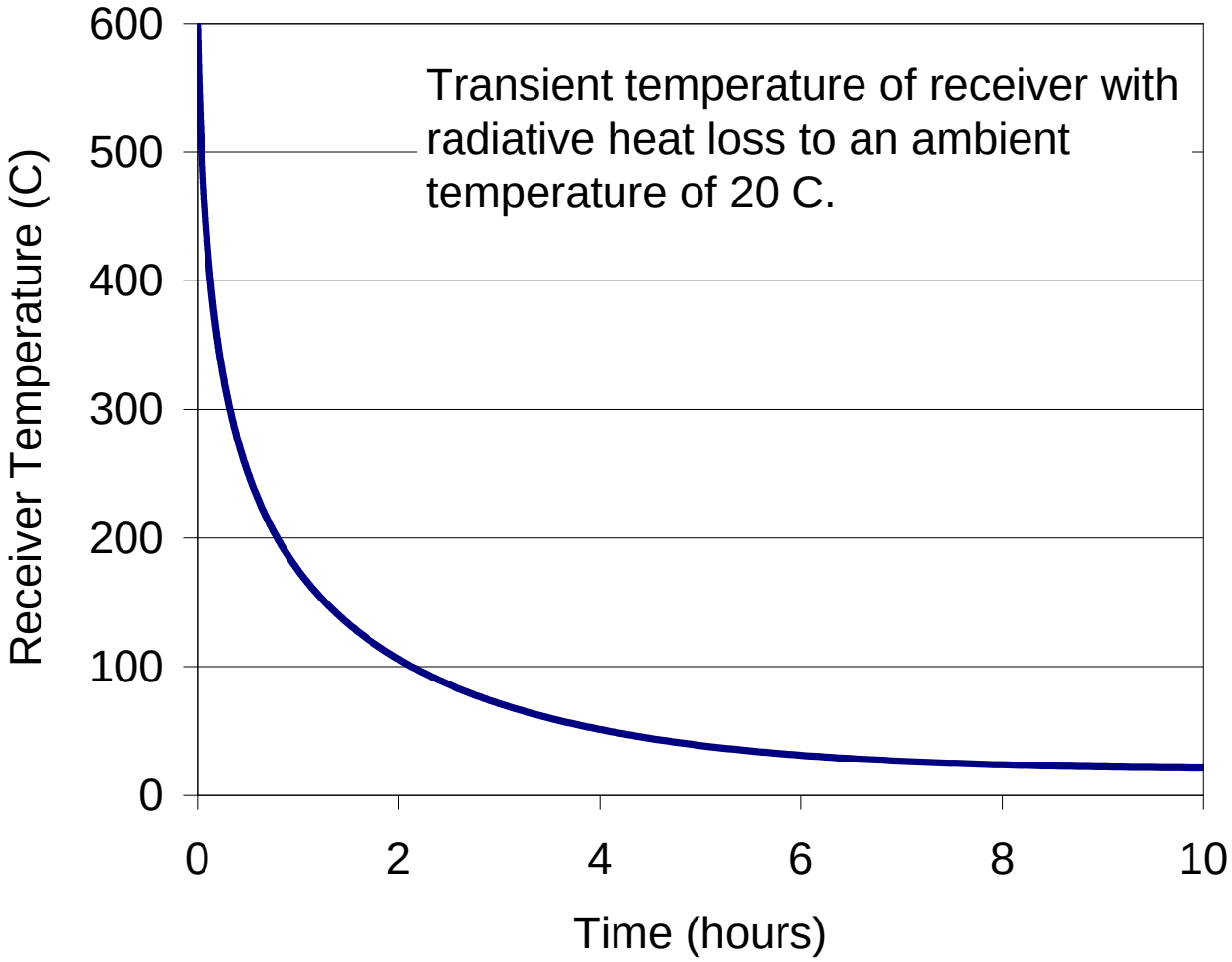
Example of Irradiance Received from Power Tower Receiver at 100 m



Example of Irradiance Received from Power Tower Receiver at 1,000 m



Transient Receiver Temperatures



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Summary

- Glint and glare can cause unwanted visual impacts
  - Analytical models and safety metrics have been developed to quantify glint and glare
  - Models have been validated with test data
  - Software tools have been developed
    - SGHAT (PV glare)
    - TIM (CSP glare)
- Infrared emissions from heated objects can interfere with infrared sensors
  - Excel spreadsheet has been developed to determine spectral irradiance from “hot sources”
    - Dependent on temperature, distance, and configuration

Air Force White Papers

- Series of white papers covering renewable energy technologies (PV, CPV, CSP, etc.)
  - Potential impacts include the following:
    - Ground-based and airborne radar interference
    - Radio frequency interference
    - Glare impact on pilots and sensors
    - Infrared emissions (“thermal signature”)
    - Overflight restrictions
    - Sonic overpressure

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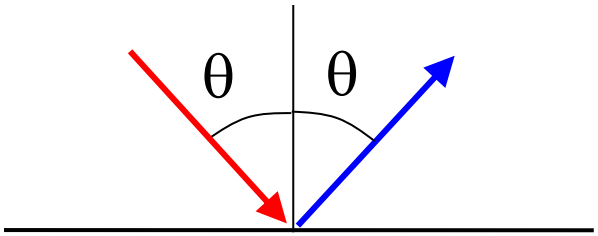
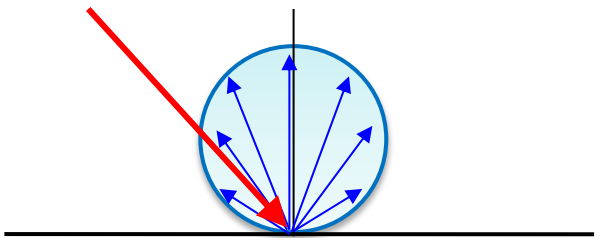
Backup Slides

Types of Reflection



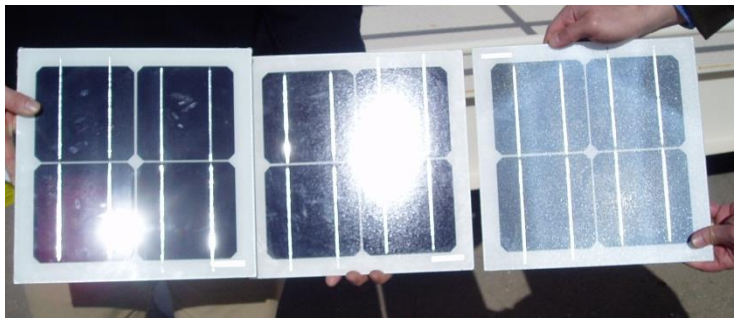
Specular Reflection

Polished Surfaces
(e.g., mirrors,
smooth glass)

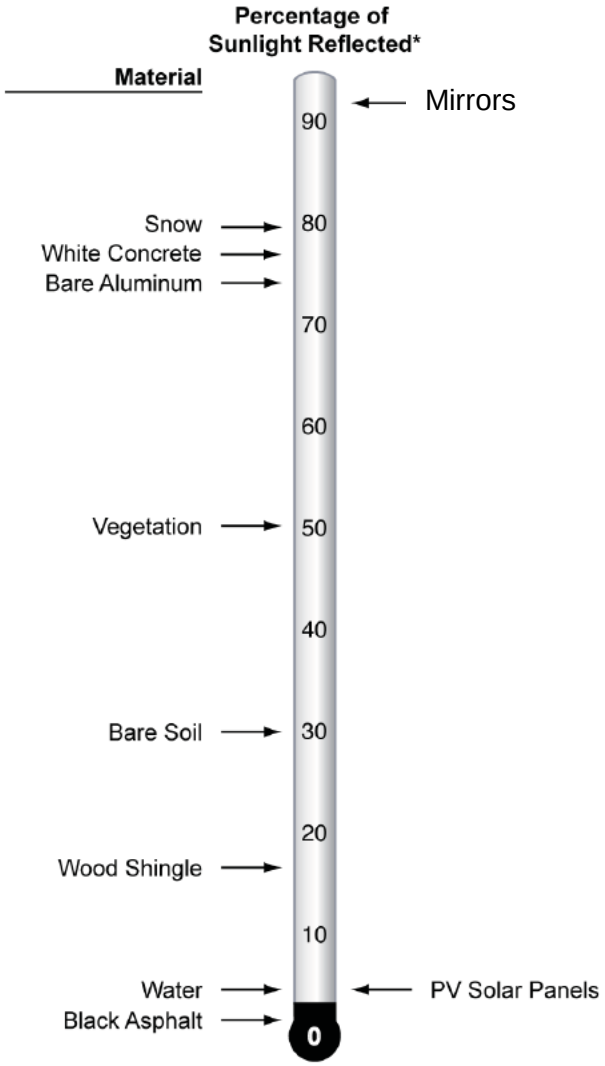


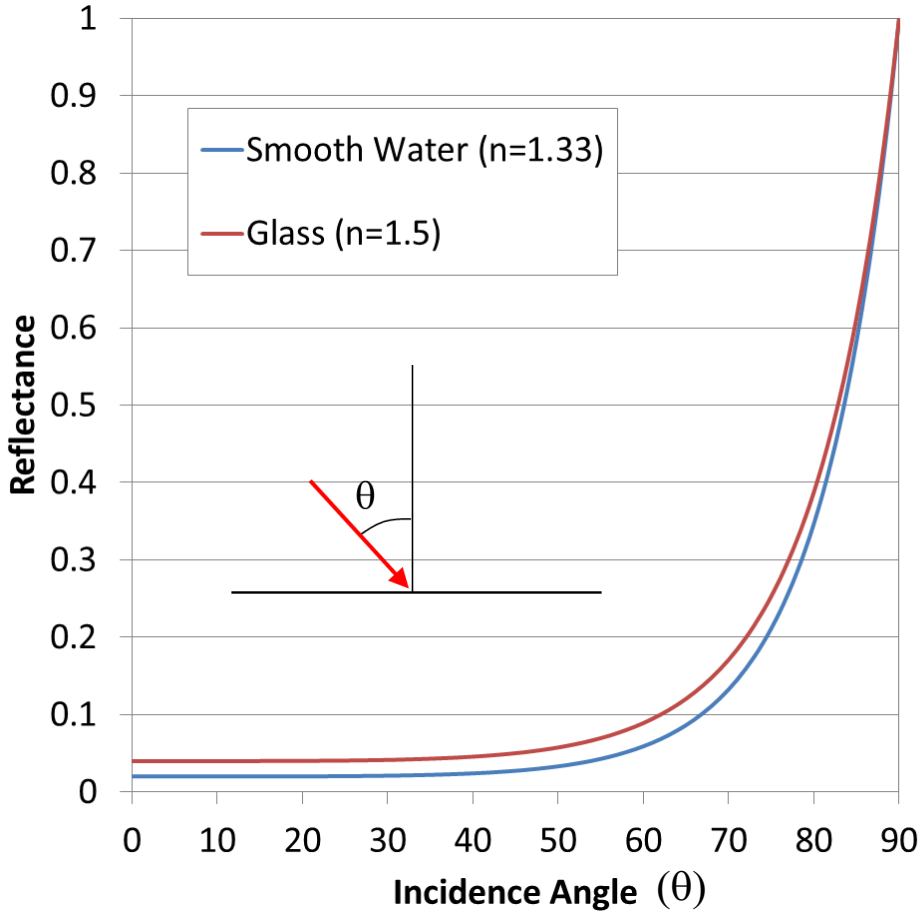
Diffuse Reflection

Rough Surfaces
(e.g., receivers, textured
glass, snow, pavement)



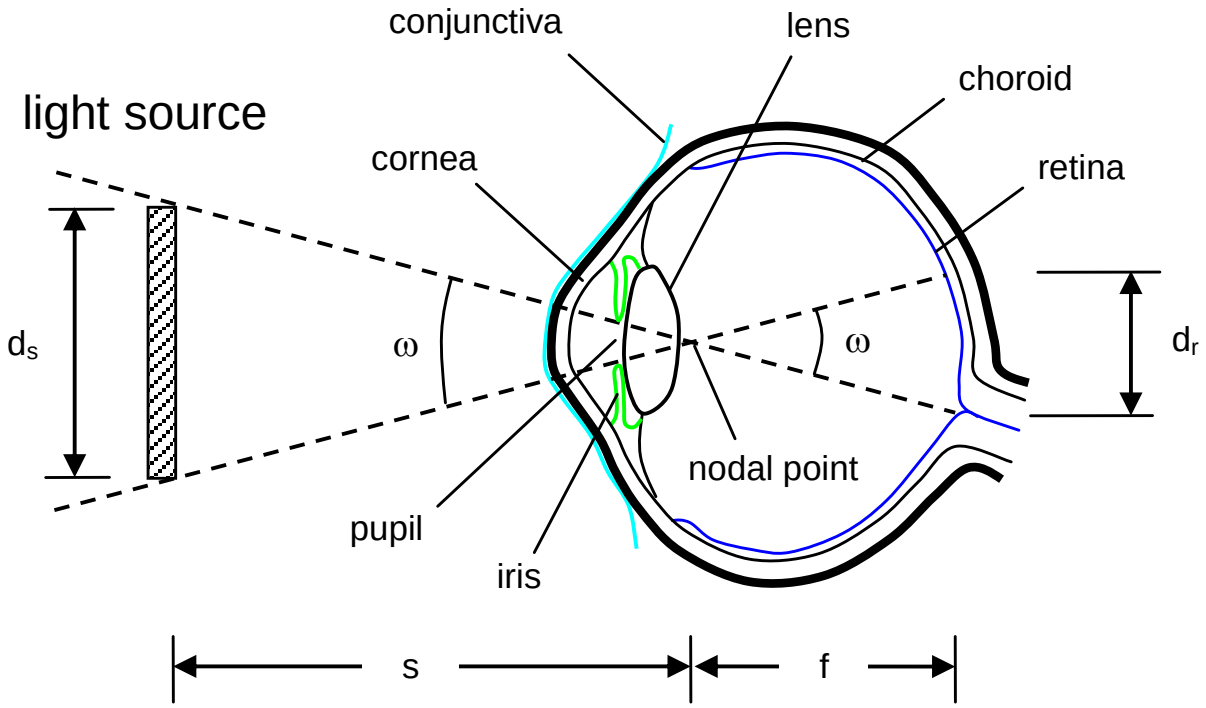
Reflectivity





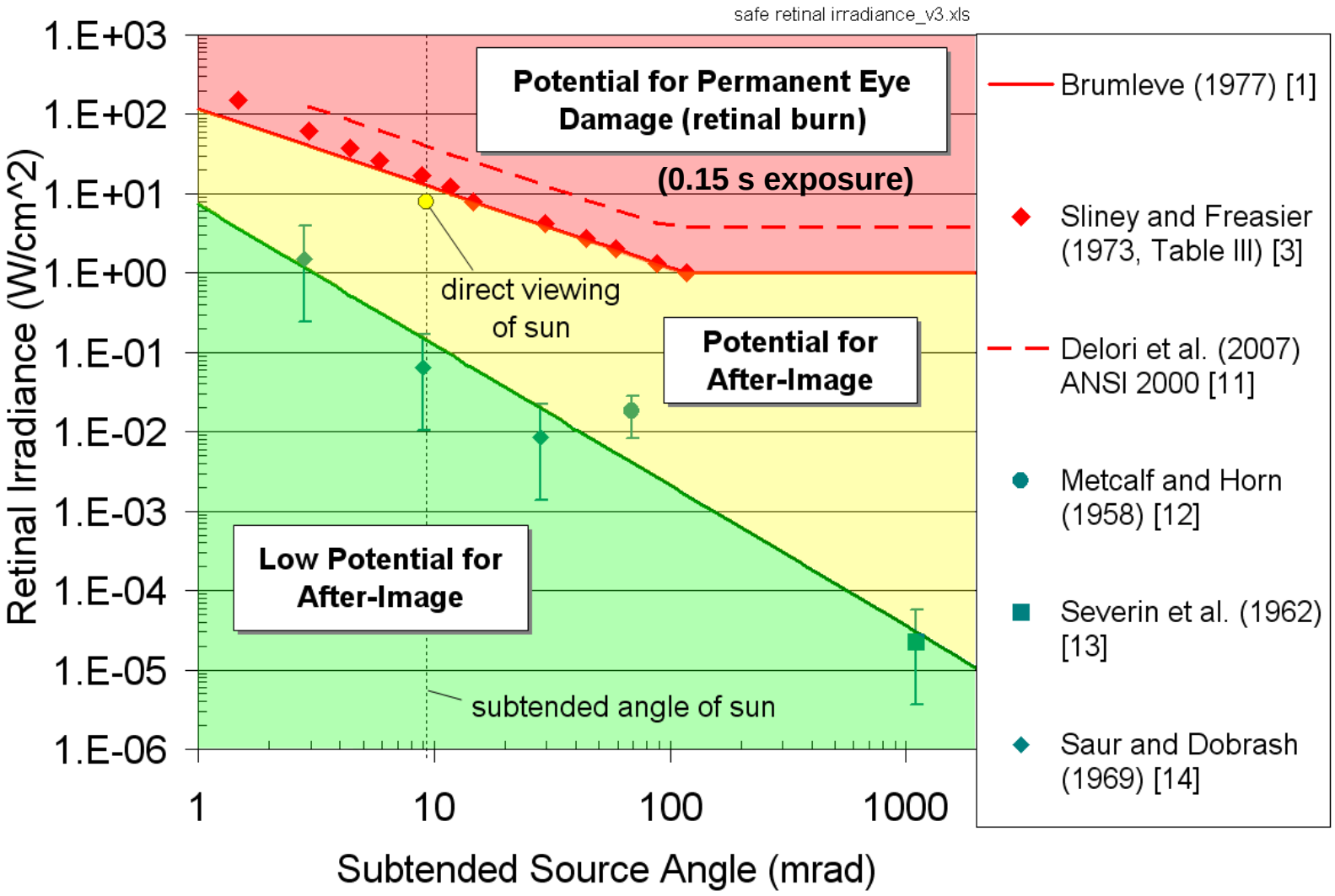
Adapted from ACRP Synthesis 28 "Investigating Safety Impacts of Energy Technologies on Airports and Aviation"

Impact of Light Entering the Eye



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

Potential Ocular Impacts



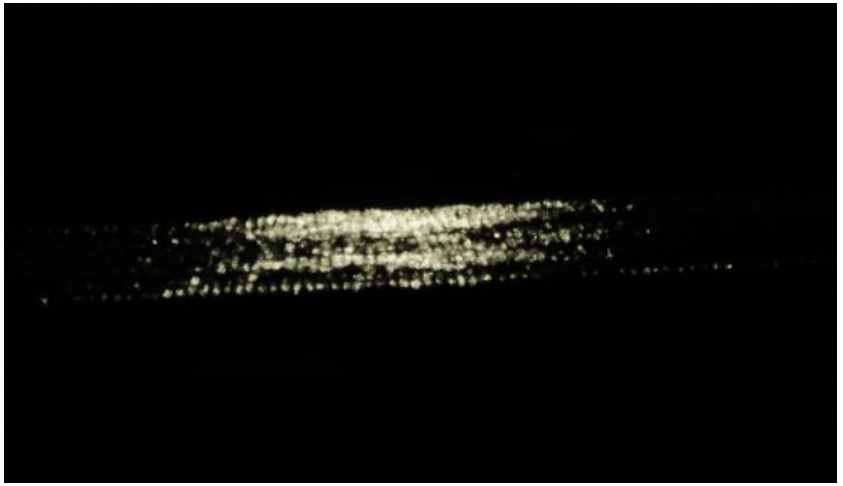
Equations and analysis methods detailed in Ho et al. (2010, 2011)

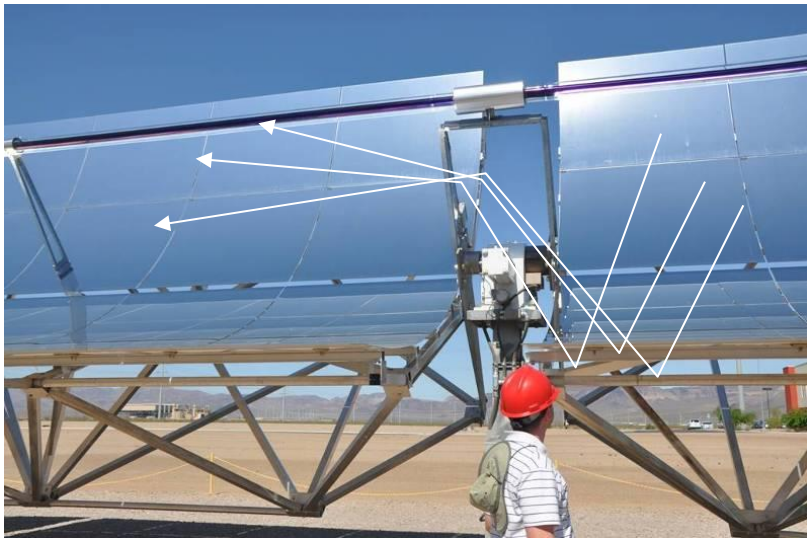
SGHAT – Ongoing and Future Work

- FAA flight simulator tests
  - Impact of angle and duration of glare
- Incorporate tracking modules and curved surfaces for CSP
- Add features to simulate glare from buildings and vertical surfaces
- Work with PV manufacturers to mitigate glare and maximize energy capture
  - Surface texturing or coatings

Decreasing ocular impact / increasing energy absorption

Concentrated Glare from Troughs





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Heliostat Glare at Ivanpah CSP Plant

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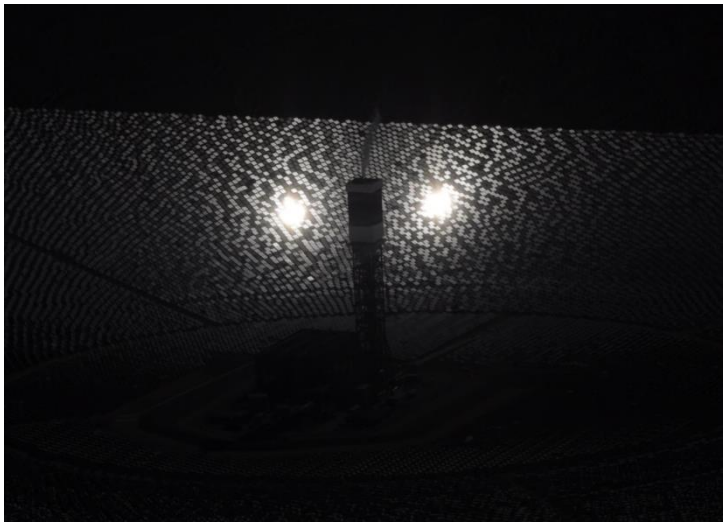
Looking Northeast at Unit 1, 9:10 AM PDT (~3 miles away from glare)



Methods to Mitigate Glare

- Observer uses screens or shades
  - May not be practical for pilots or controllers
  - ABQ Airport uses double shades to block sun
- Proper design and siting of solar installations
  - SGHAT (for PV)
  - TIM (for CSP)
- Reduce glare via anti-reflective coatings and glass texturing
  - Good for PV modules
  - Not applicable for mirrors and receivers used in concentrating solar power