Solar Glare Hazard Analysis Tool (SGHAT)

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SAND2015-XXXX

SAND2015-3338PE

Exceptional service in the national interest

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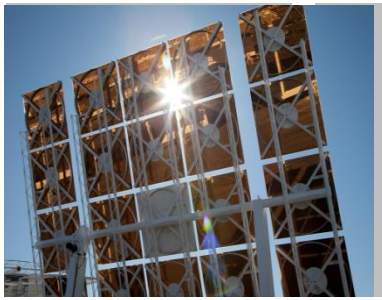

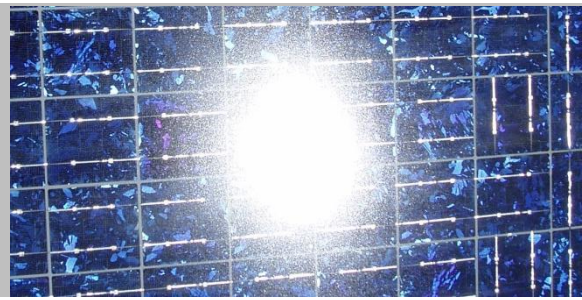

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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SGHAT Overview

- Why do we need it?
- What does it do?
- Improvements and future plans





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

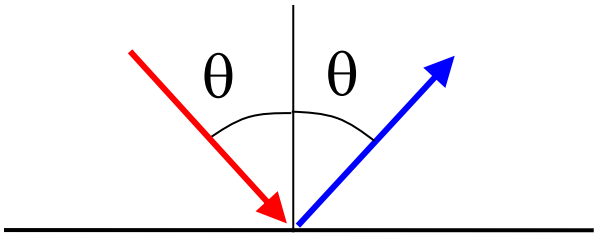
Parabolic Trough Collectors at Kramer Junction, CA

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)

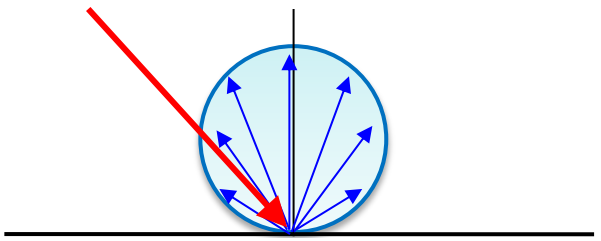
Glare observed from airport traffic control tower at Manchester-Boston Regional Airport (May 2012). The $3.5M array had to be tarped.

Types of Reflection



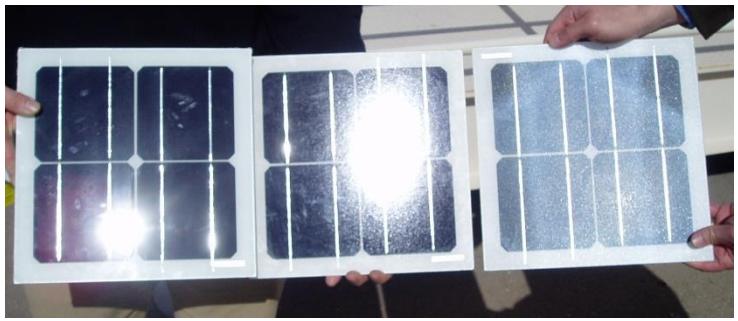
Specular Reflection

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

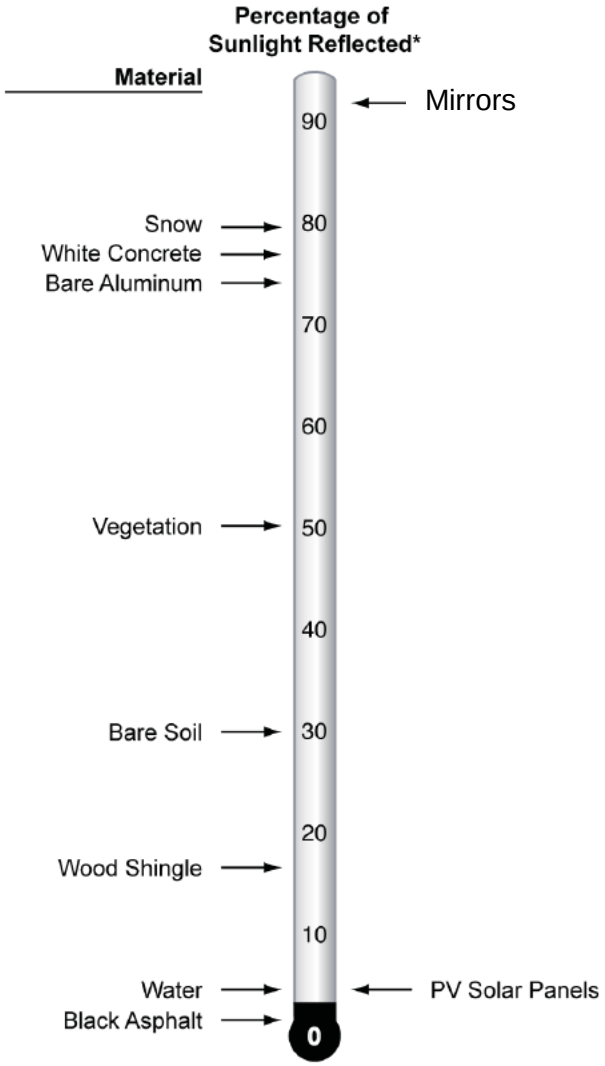


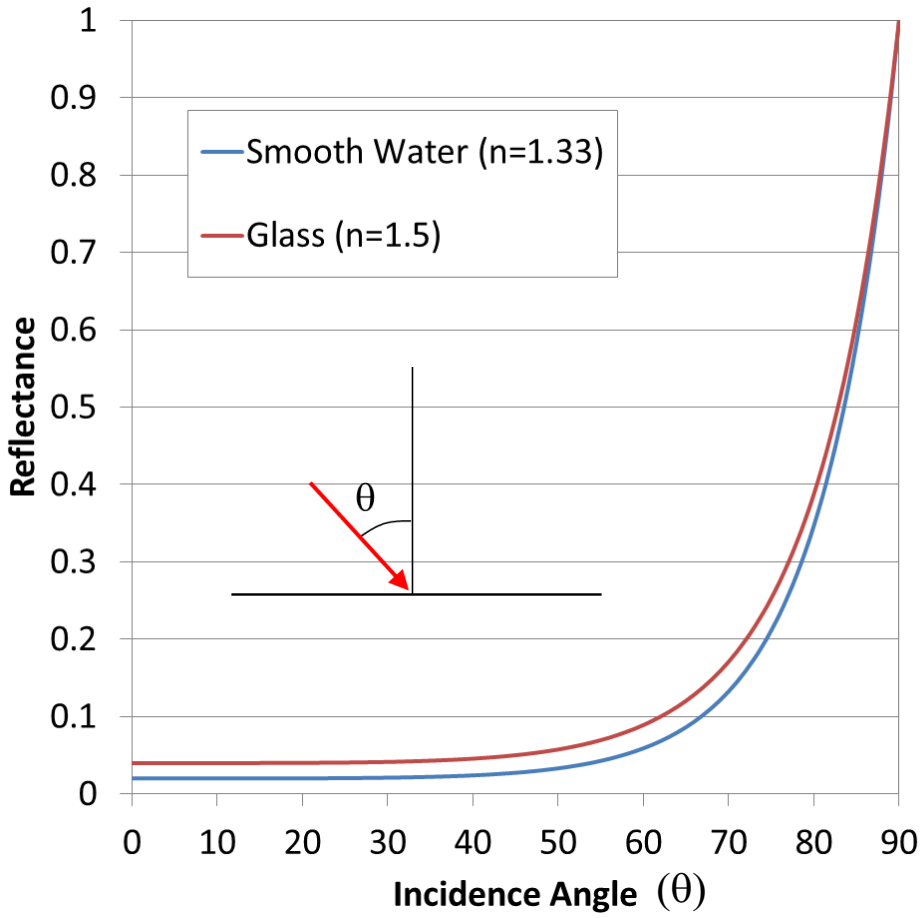
Diffuse Reflection

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



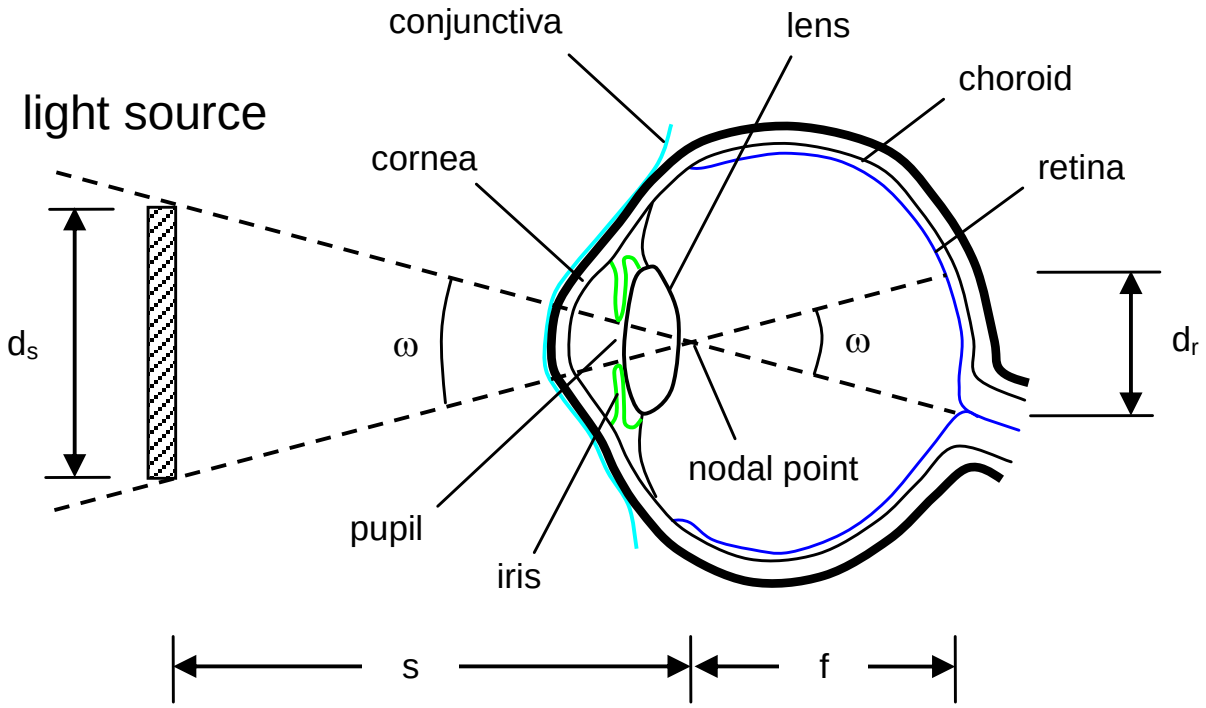
Reflectivity





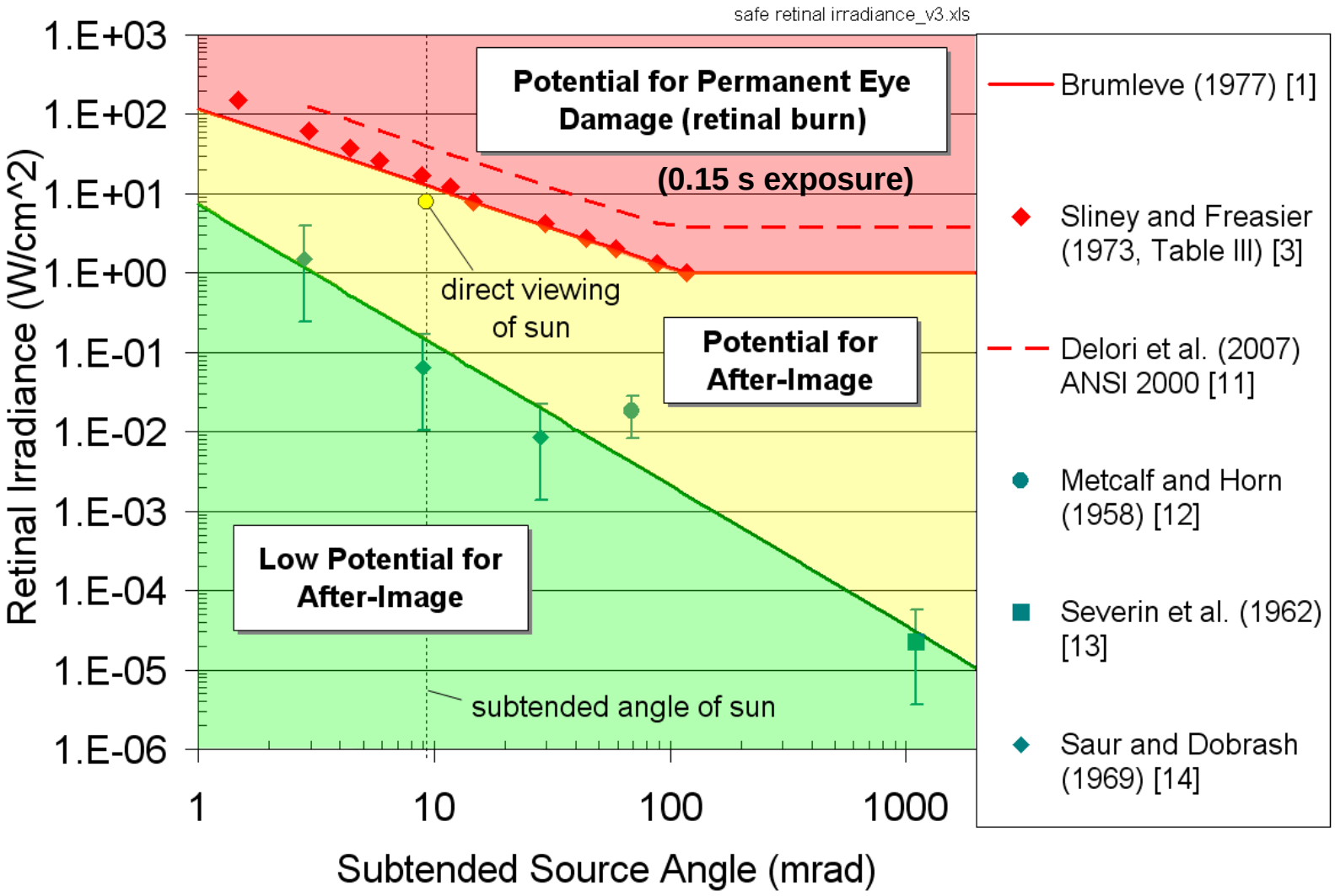
Adapted from ACRP Synthesis 28 "Investigating Safety Impacts of Energy Technologies on Airports and Aviation"

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)

New Federal Policy

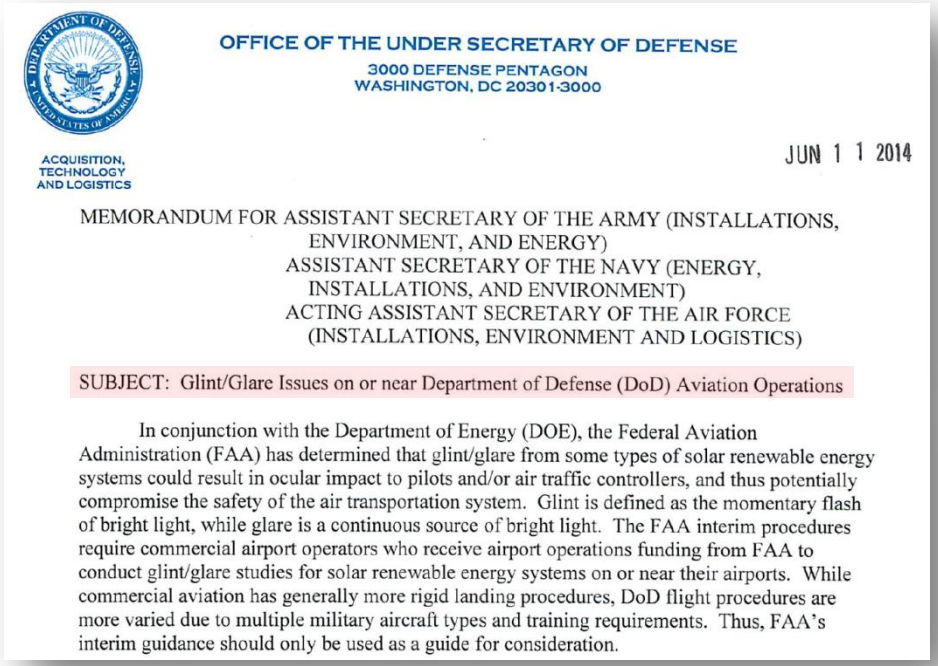
- U.S. Department of Transportation, Federal Aviation Administration (78 FR 63276, October 23, 2013)
  - "...the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated 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

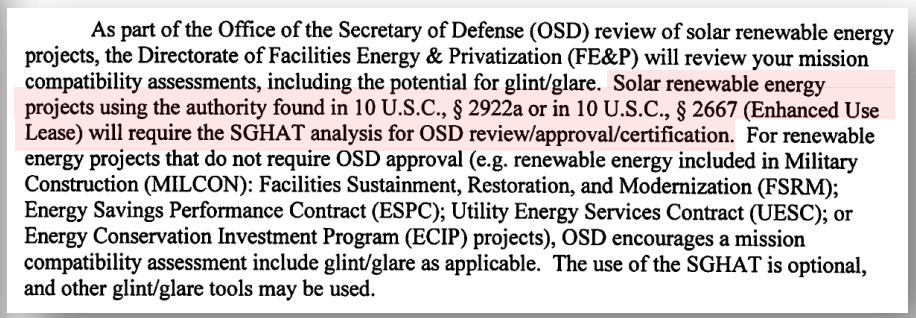
ACQUISITION, TECHNOLOGY AND LOGISTICS

JUN 1 1 2014

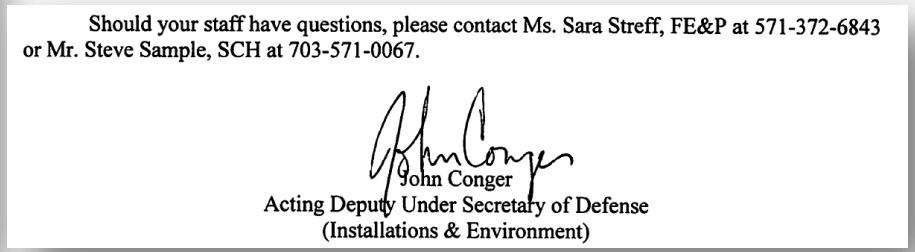
MEMORANDUM FOR ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENVIRONMENT, AND ENERGY)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS, AND ENVIRONMENT)
ACTING ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND LOGISTICS)

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)

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)

SGHAT Overview

Sandia National Laboratories

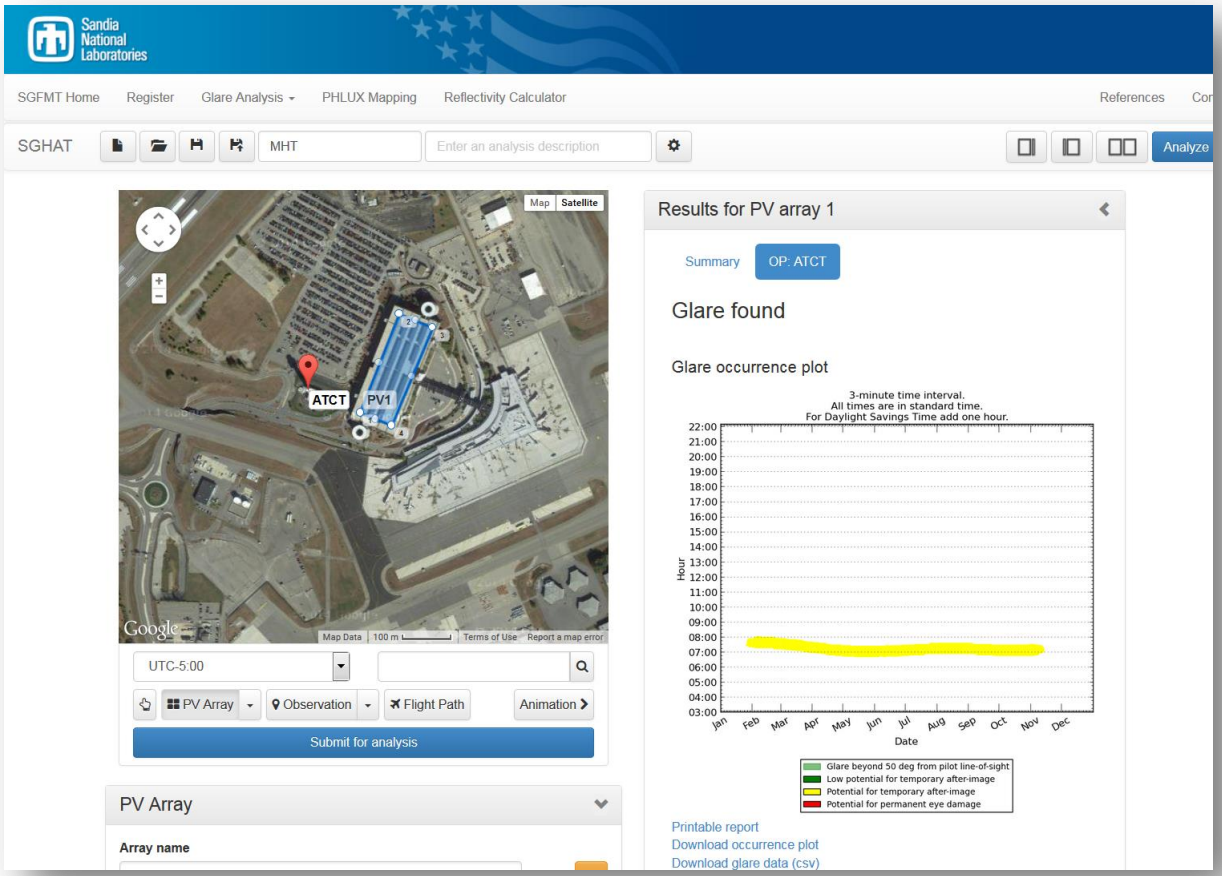
- Why do we need it?
- What does it do?
- Improvements and future plans





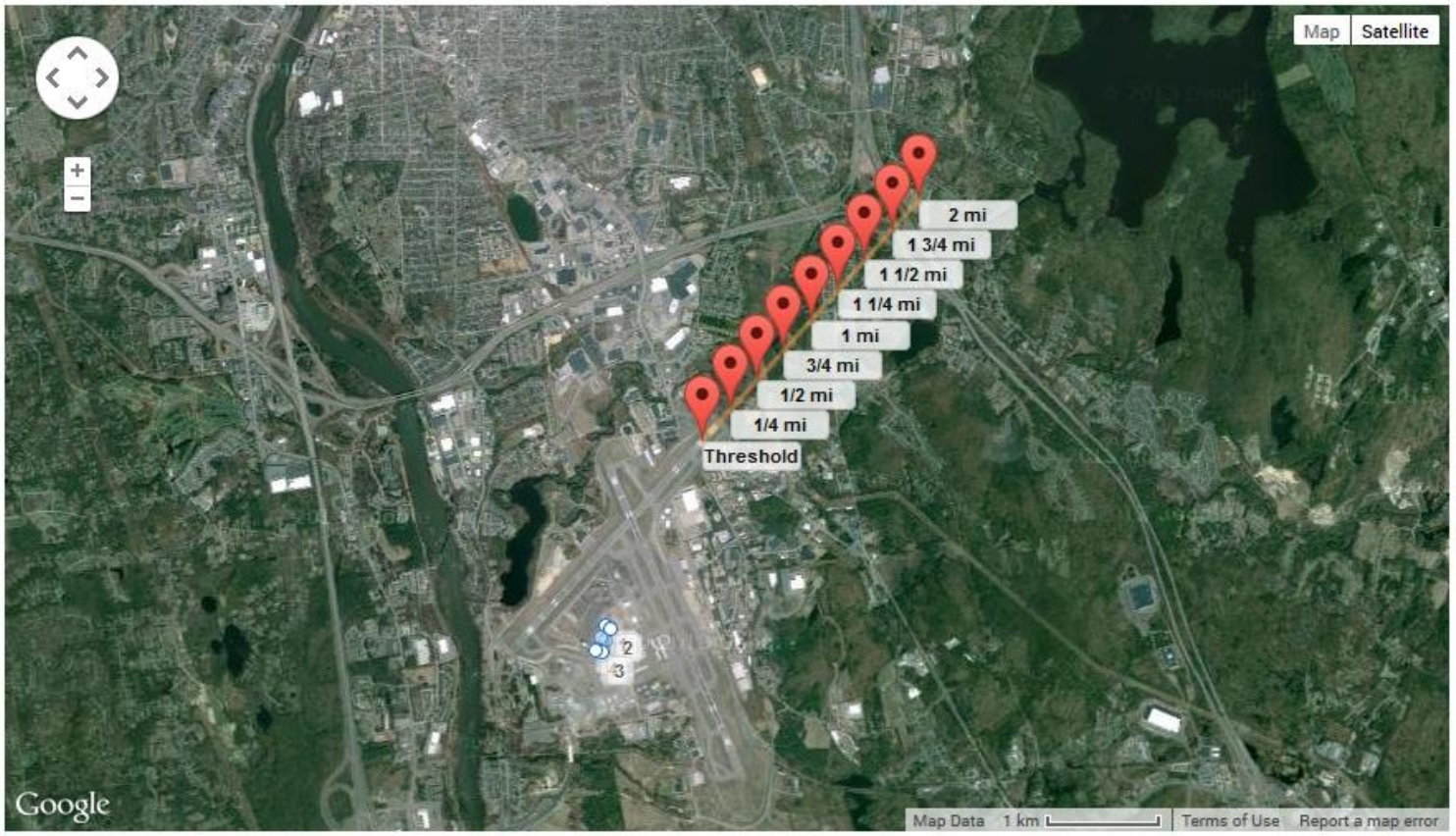
Solar Glare Hazard Analysis Tool

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



- Uses interactive Google Maps
- Very fast annual simulations

Approach to Runway 24



Observation points approaching Runway 24 from the northeast.

Data Entry for PV Tilt/Orientation, Reflectance, DNI, and Elevations

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PV Array

Array name

PV array 1

Description

Axis tracking

None

Module surface material

Smooth glass without ARC

Panel tilt

20 deg

☑ Reflectivity varies with incidence angle (view data)

Orientation (Calculate declination)

110 deg

☐ Correlate slope error to module surface type (view data)

Rated power

530 kW

Slope error

10 mrad

Vertices click to expand/collapse

id	Latitude	Longitude	Ground Elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
1	42.92791	-71.44084	222.41	75	297.41
2	42.92964	-71.43996	223.02	75	298.02
3	42.92944	-71.4393	223.79	75	298.79
4	42.92771	-71.44021	222.41	75	297.41

Analysis configuration

Height units ○ feet ◉ meters

Time interval 1 min

Sun angle 9.3 mrad

Peak DNI 1000 W/m^2

DNI varies? ☑

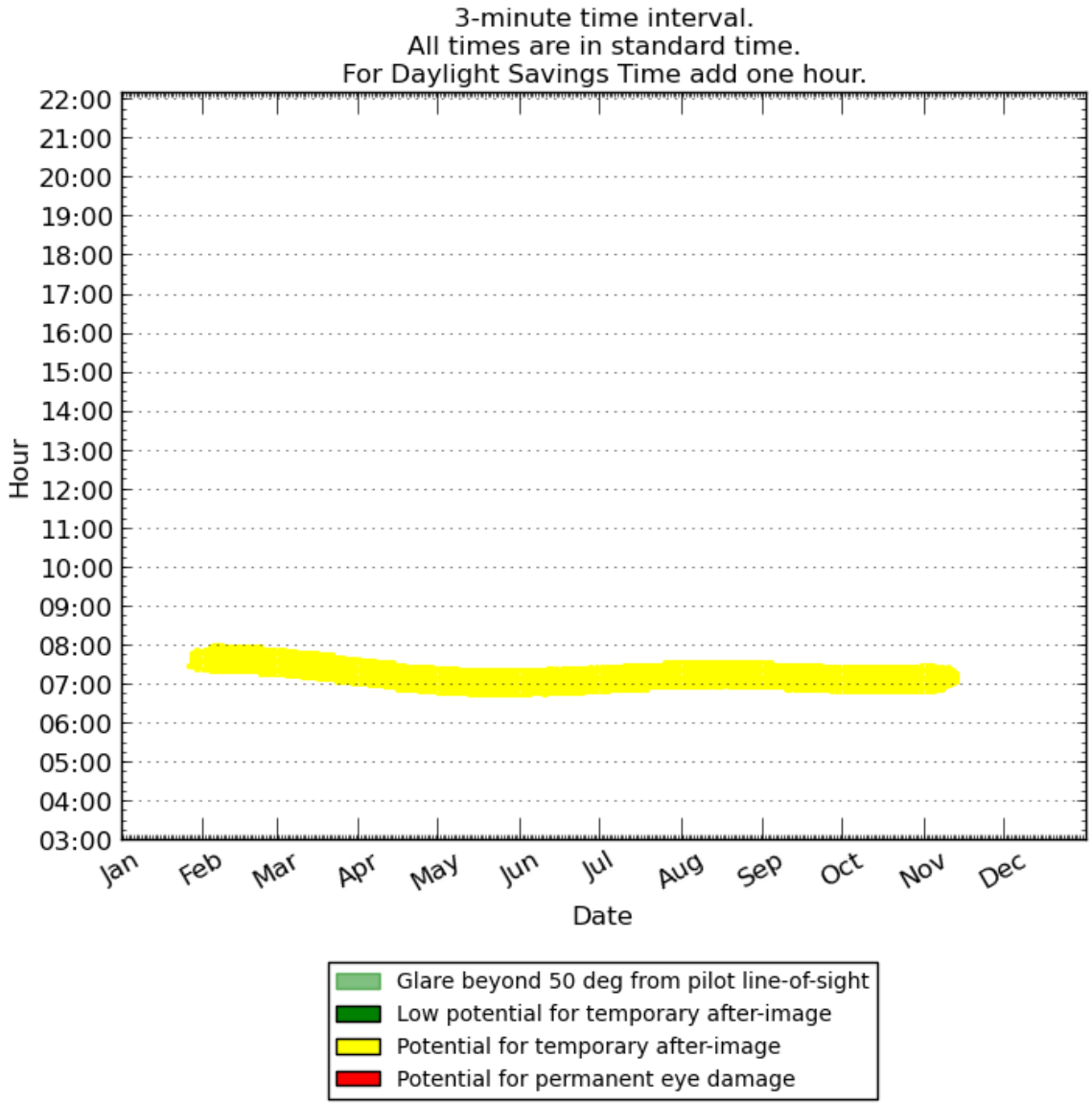
Ocular transmission coefficient 0.5

Pupil diameter 0.002 m

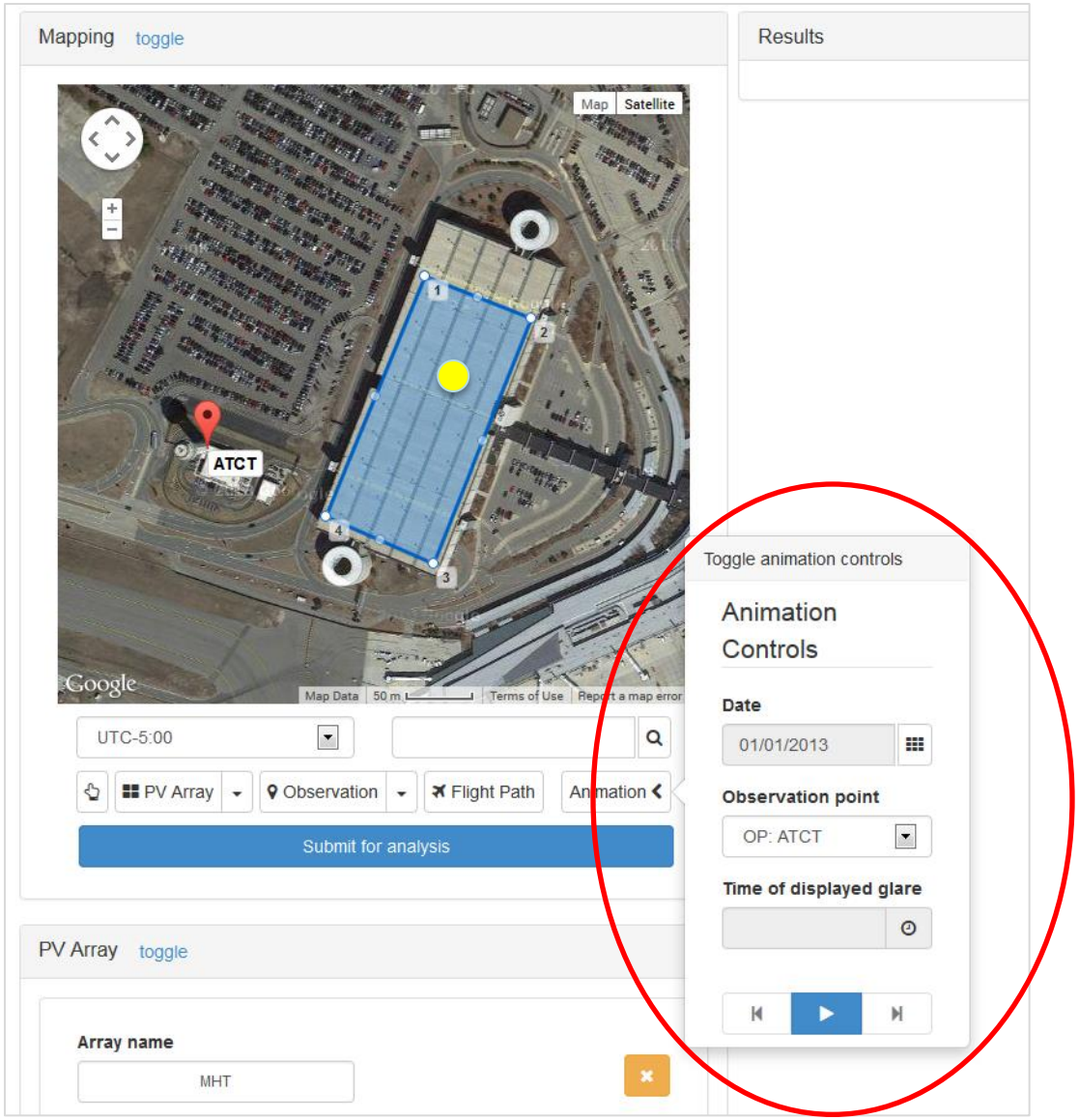
Eye focal length 0.017 m

Okay

Glare Occurrence Plot



Glare Animation Feature



Mitigation of glare while maximizing energy production

Azimuthal Angle (degrees)	Elevation Angle (degrees)	Relative Annual Energy Production
180	43	100.0%*
200	20.6	93.9%**
120	40	88.9%
120	50	87.2%
110	20.6	82.4%
110	30	85.0%
110	40	84.7%
120	60	83.7%
110	50	82.8%
130	70	81.5%
100	30	80.9%
100	20	80.8%
100	40	79.9%
110	60	79.3%
120	70	78.3%
100	50	77.6%
90	20	77.5%
210	80	76.9%
90	30	76.4%
220	80	75.8%
90	40	74.5%
110	70	74.2%
100	60	74.1%
130	80	74.0%
90	50	71.8%
120	80	71.3%
100	70	69.2%
90	60	68.1%
110	80	67.7%
90	70	63.4%
100	80	63.2%
90	80	57.8%

- Use SGHAT to identify PV array configurations that produce no glare
- Choose design that maximizes energy production

*Maximum energy production; produces glare to ATCT
**Current configuration; produces glare to ATCT

SGHAT Overview

Sandia National Laboratories

- Why do we need it?
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SGHAT Enhancements since 1.0

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- 2013 Q3:
  - Flight path analysis tool
  - Component persistence (save site configurations on server)
  - Updated look-back algorithm to account for elliptical beam spread
- 2013 Q4:
  - Editable flight path elevation
  - Expanded .csv output
  - Vary panel reflectivity based on panel material type
- 2014 Q1:
  - Multiple PV arrays per analysis
  - Generate glare hazard plots for selected day
  - Account for glare visibility along flight paths
  - Editable viewing angle restriction along flight paths
  - Single- and dual-axis tracking with angle limit

SGHAT Enhancements since 1.0 (cont.)

- 2014 Q3
  - Account for pilot line-of-sight in flight path results (light green glare)
- 2015 Q1
  - Correlate slope error with panel surface material
- In-progress
  - Optimization tool
  - Project-based layout
  - Vertical surface analysis
  - Improved glare prediction "envelope" algorithm

Developed simplified block-space analysis for PAX River in December 2015

AFRL SGHAT Evaluation (April 3, 2014)

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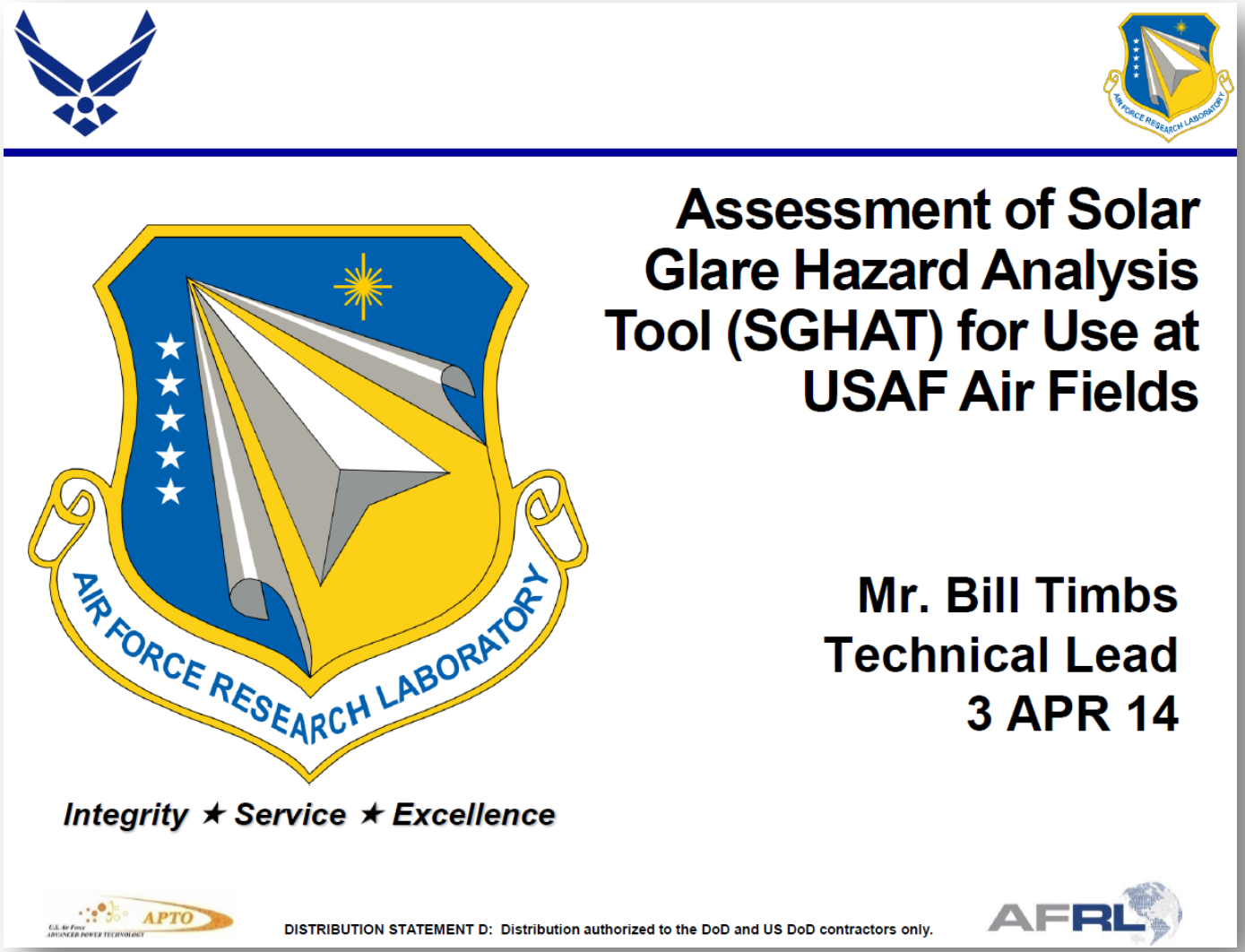

Air Force Tiger Team Report (Oct. 2014)

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Table 1
Solar PV Compatibility Project Recommended Implementation Actions

Recommendation/Tasks	Staff/CME Requirement (person hours)	Contract Requirement (dollars)
1. SGHAT Modifications		
a. Establish capability to conduct block air space analysis of project site against multiple flight paths.		$64,000
b. Provide for import of batch files containing approach paths and closed loop patterns for block air space analysis		32,000
c. Advanced flight path drawing tool		32,000
d. Expand account permission beyond current limit to four project locations, eight observation points, and two flight paths		8,000
e. Establish customizable analysis options, permitting user to segment ocular hazards analysis or effective energy production calculations to optimize processing speed.	40	32,000
Add user control for saving project reviews.	60	
f. Incorporate AF required security protocols for user access to saved project reviews.		
g. Develop shared component database and superuser access, providing restricted access to selected users	80	
h. Investigate Fee Based Review Service Options		
i. Facilitate Contract Agreements and liaison/oversight	100	
j. Organize and staff User Technical Advisory Committee for modification guidance		
k. Provide periodic briefs to designated Management Committee	40	
2. Migrate and Operationalize Enhanced SGHAT		
a. Provide for SGHAT Hosting using virtualized servers and balancing	60	8,200
b. Provide Technical Support and Maintenance for SGHAT Program	40	24,000
c. Updating and upgrading of existing features. Development of minor features, maintenance and bug fixes	20	40,800
3. SGHAT User Reach-back and Support		
a. Prepare AF SGHAT User's Manual Supplement for special instructions and integration of modification features.	80	
b. Operate SGHAT User Hotline/Mailbox	90	
c. Coordinate Processing Que	40	
4. Prepare and Maintain On-line Training Module	200	
5. Develop and Apply Prototype Glint/Glare Areawide Analysis as AICUZ Study Element	160	
6. Support in the adoption and implementation of selected recommendations	100	
a. Coordination with DoD Siting Clearinghouse		
b. Integration of Glint/Glare Policy in AICUZ Program		
Total	870	$240,000

Solar PV Compatibility Project Revised Draft Final Tiger Team Report (8 Oct 2014) Page 24 of 24

Munsterman et al. (2014)

Conclusions

- Glint and Glare can cause unwanted visual impacts
  - Analytical models and safety metrics have been developed
  - Models have been validated with test data
  - Web tool has been developed
- SGHAT predicts when and where glare will occur from a prescribed PV array at user-defined observation points/paths
  - Google Maps is used for easy user interface
  - SGHAT can be used to produce analyses and reports to satisfy new federal (FAA, DoD) requirements for solar installations near airports
- SGHAT predicts annual energy production
  - Systems can be quickly optimized to mitigate glare while maximizing energy production
- Expected to save costs and increase public safety
  - FAA, DoD, regulatory agencies, airports, solar energy industries, consumers, cities, businesses, residences

Acknowledgments

- DOE Solar Technologies Soft Costs Subprogram
- Bill Petrak and Chris Hugunin, FAA
- Sandia Colleagues
  - Cianan Sims, Contractor (Programmer)
  - Julius Yellowhair, Ph.D., SMTS
  - James Yuan, SMTS
  - Evan Bush and Andrew Sharp, Students
  - Victoria Smith, Steve Arroyo, Jim Muntz (9329 – SNL Server/Software Support)

Questions?

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Backup Slides

FAA Flight Simulator Tests

- Impact of angle and duration of glare