SAND2014-18267PE

Evaluation of Glare at the Ivanpah Solar Electric Generating System

Exceptional service in the national interest

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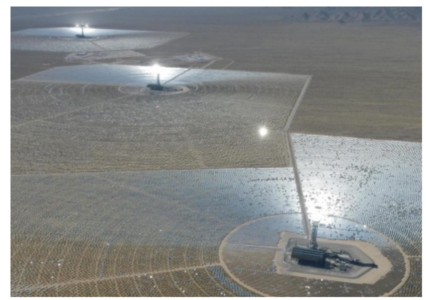

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SAND2014-XXXX

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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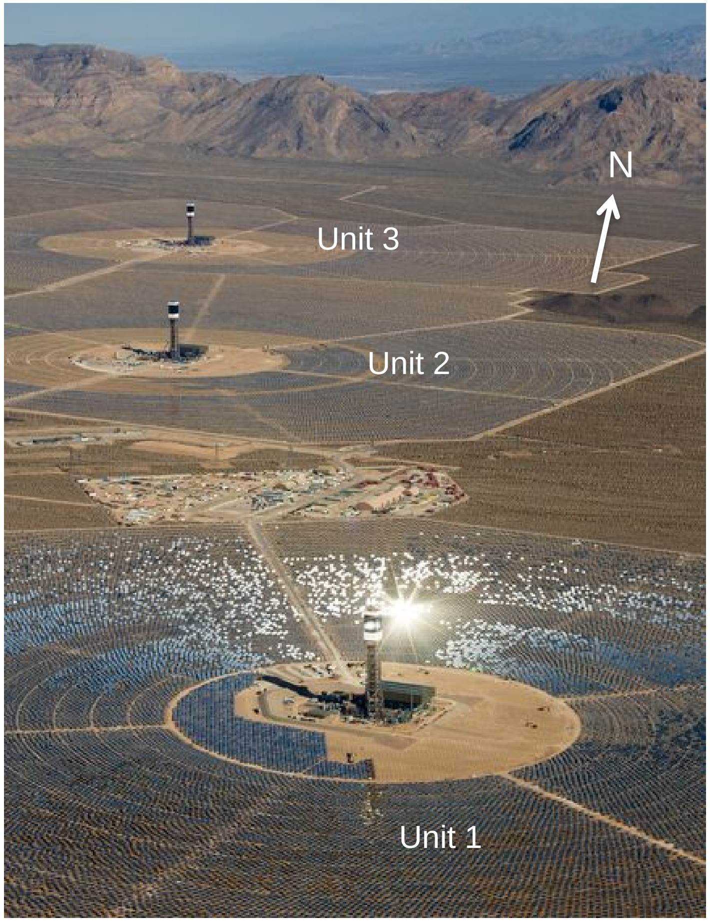
Overview

- Background and Requirements
- Glare Monitoring
  - Aerial Survey
  - Ground Survey
- Mitigation Methods
- Next Steps

Ivanpah Solar Electric Generating System

- Three power tower units
  (377 MW (net) / 392 MW (gross))
  - Unit 1: 126 MW
  - Unit 2: 133 MW
  - Unit 3: 133 MW
  - Each tower 140 m (459 ft) tall
- 173,500 heliostats
  - 2 mirrors/heliostat: 15.2 m^2
- Direct steam receiver (22 m tall x 17 m wide + ~16 m of white shielding)
- Dry-cooling
- 14.2 km^2 (3500 acres) on public desert land in southern California
- Owners: NRG Energy, Google, and Brightsource Energy



Reports of Glare

- ACN: 1109473 (March 10, 2014)
  - “At its brightest neither the pilot nor co-pilot could look in that direction due to the intense brightness. From the pilot’s seat of my aircraft the brightness was like looking into the sun... In my opinion the reflection from these mirrors was a hazard to flight because for a brief time I could not scan the sky in that direction to look for other aircraft.”
- ACN: 1108698 (March 10, 2014)
  - “Daily, during the late morning and early afternoon hours we get complaints from pilots of aircraft flying from the northeast to the southwest about the brightness of this solar farm.”
- ACN: 1156120 (April 16, 2014)
  - “While on the KEPEC3 arrival into LAS we were temporary blinded by bright lights (reflections) from the ground. These reflections, coming from the new solar power station were so bright that any attempt to look outside the plane was met with pain and temporary blindness even when looking back inside.”

Monitoring Requirements

(per TRANS-3, -4, the Heliostat Positioning Plan, and the Power Tower Luminance Monitoring Plan)

Prepared by Environmental Planning Group for CH2MHILL Engineers, Inc., and NRG

Task	Frequency
Evaluate the intensity of the luminance light reflected from the power tower receiver	Within 90 days following commercial operation; after 5 years of operation, after major design changes & following legitimate complaints.
Conduct ground monitoring	At least weekly until static cameras are installed
Conduct aerial monitoring to determine the potential for impacts to aviation	ASAP, after 5 yrs of operation and after changes to the project that affect luminance
Investigate complaints	Within 10 days, as needed

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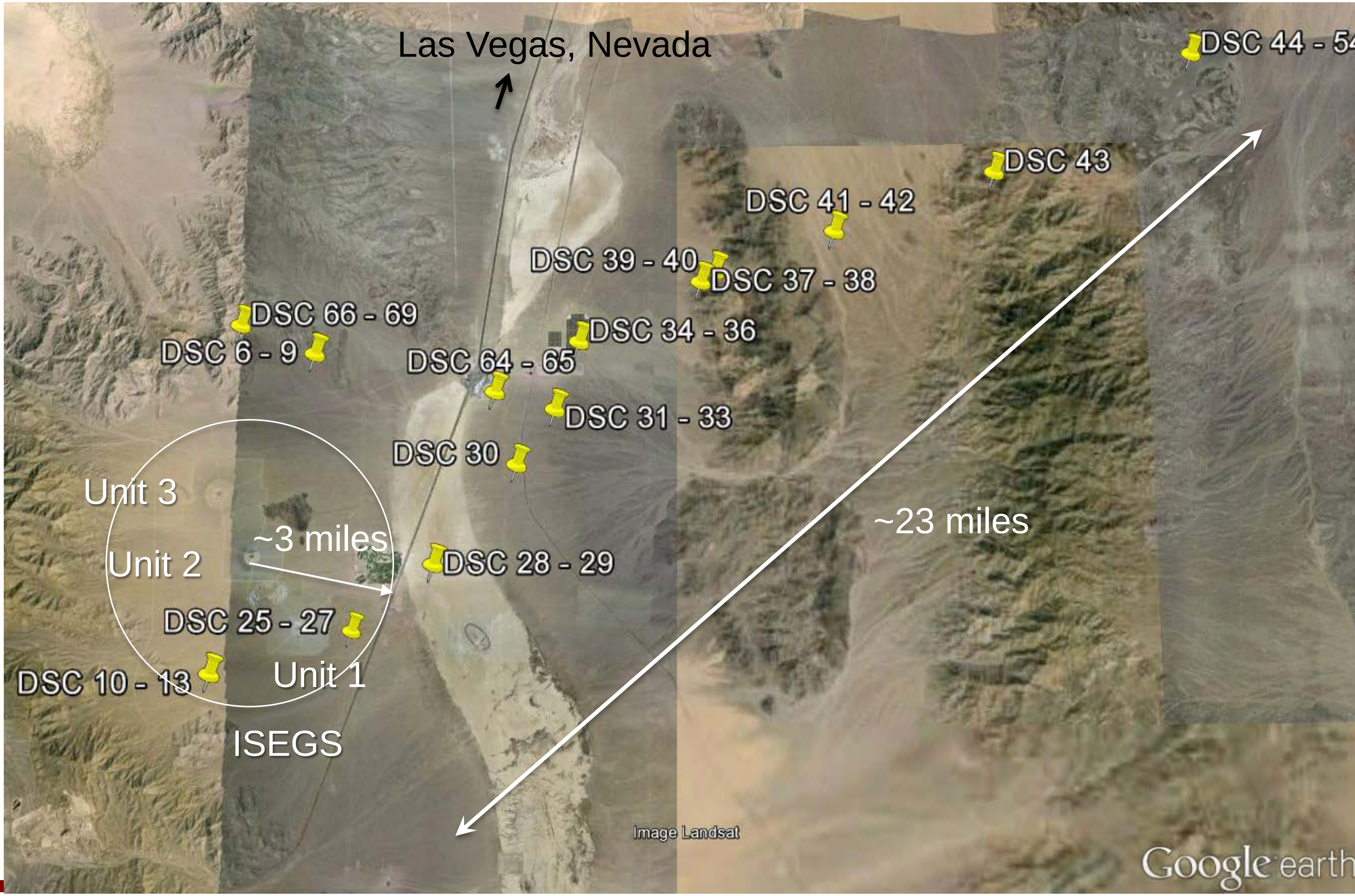
Aerial Survey

Helicopter Survey (April 24, 2014)

Aerial Monitoring Photo Locations

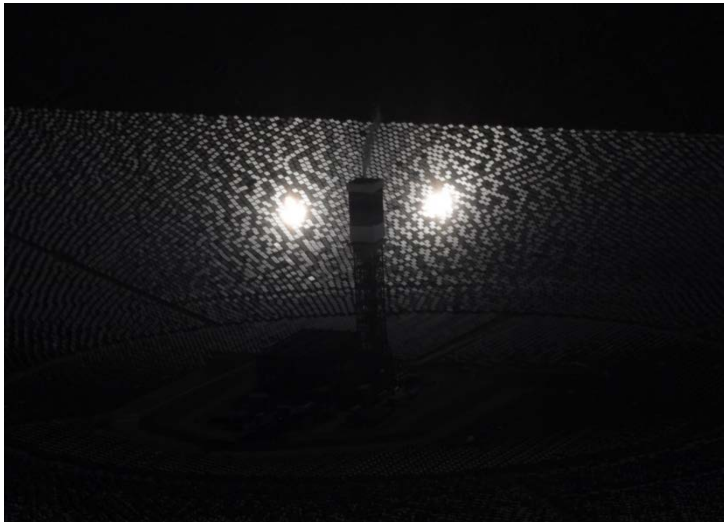


Aerial Glare

April 24, 2014
9:15 – 10:30 AM PDT

Filtered Images of Heliostat Glare

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



Glare from Heliostats in Standby Mode

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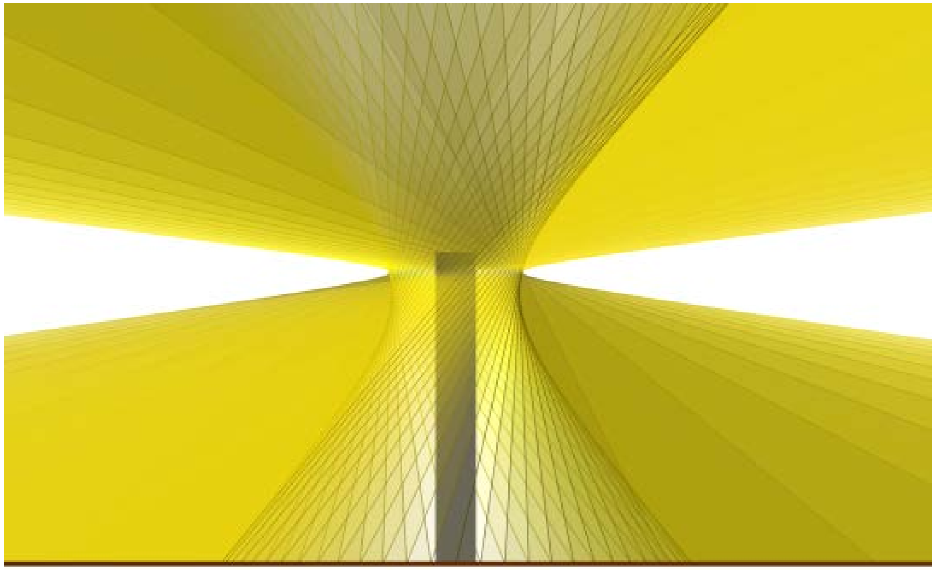
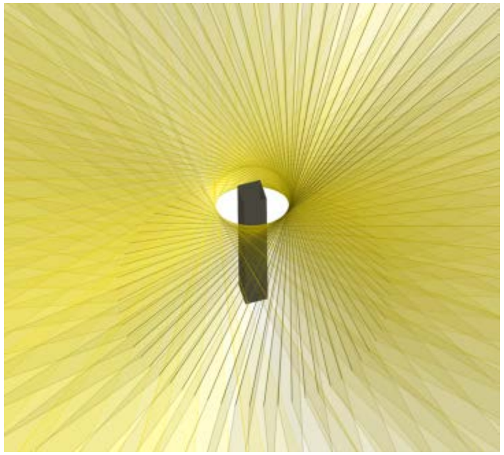
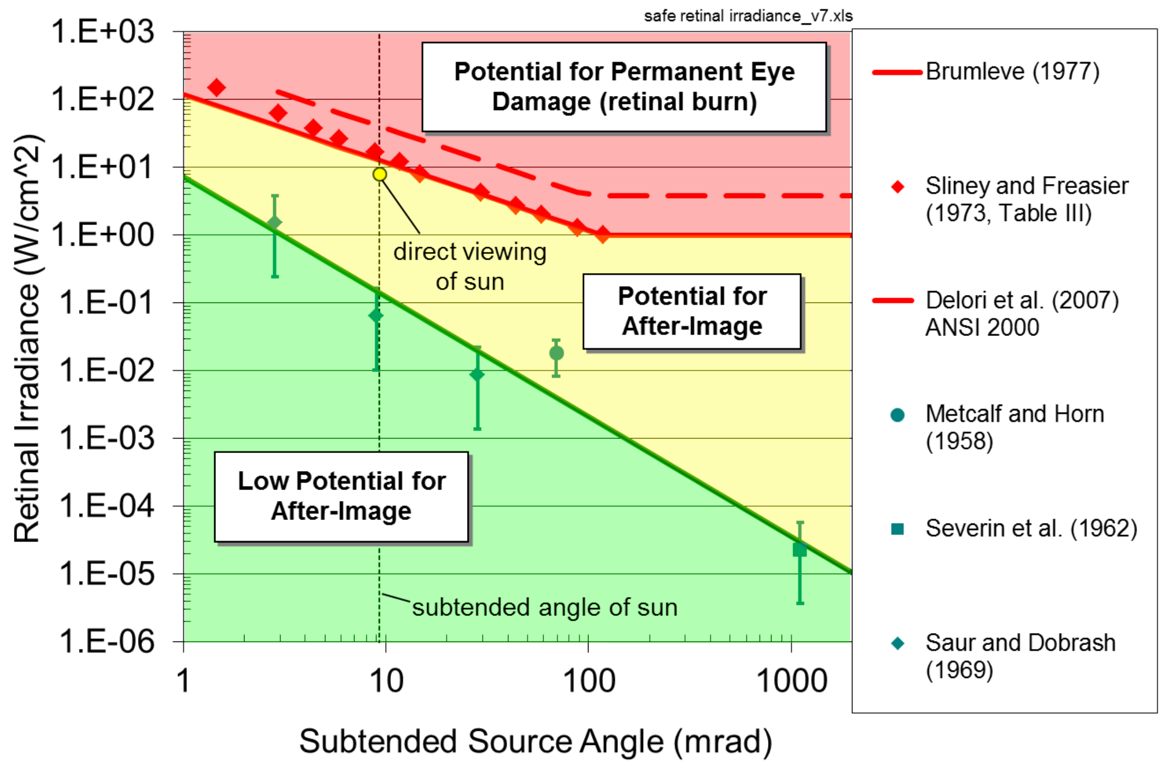




Ocular Hazard Analysis

- Use image of sun and DNI to scale irradiance and subtended angle of glare from heliostats



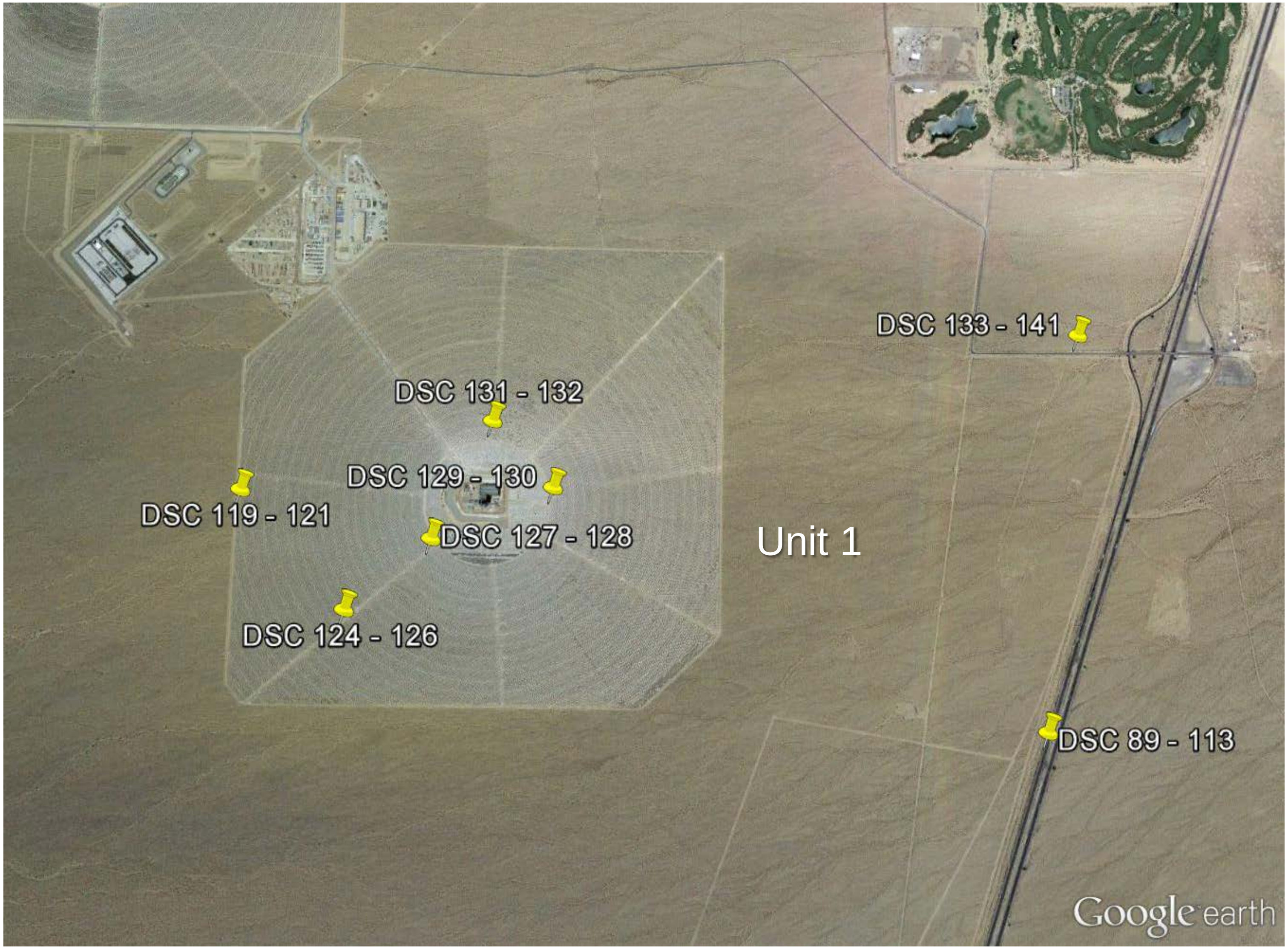
From Ho et. al (2011)

Ocular Hazard Analysis

Image	Tower Unit	Approximate Distance to Glare (miles)	Peak Retinal Irradiance (W/cm^2)	Total Subtended Glare Angle (mrad)	Ocular Impact
DSC 26	1	**1**	6.39	4.13	**Potential for Temporary After-Image**
DSC 28	1 (left)	**3**	5.10	1.60	**Potential for Temporary After-Image**
DSC 28	1 (right)	**3**	2.81	1.90	**Potential for Temporary After-Image**
DSC 08	3	**4**	2.12	3.64	**Potential for Temporary After-Image**
DSC 08	3 v2	**4**	1.98	4.03	**Potential for Temporary After-Image**
DSC 30	1	**6**	2.15	3.47	**Potential for Temporary After-Image**
DSC 65	1	**6**	4.25	1.60	**Potential for Temporary After-Image**
DSC 32	1	**7**	5.45	1.06	Low Potential for After-Image
DSC 34	1	**11**	5.29	0.586	Low Potential for After-Image
DSC 41	3	**15**	1.39	0.760	Low Potential for After-Image
DSC 53	3	**23**	0.112	0.541	Low Potential for After-Image

Ground Survey

Ground Monitoring Photo Locations



Drive-by Video

~12:20 PM (PDT), April 24, 2014

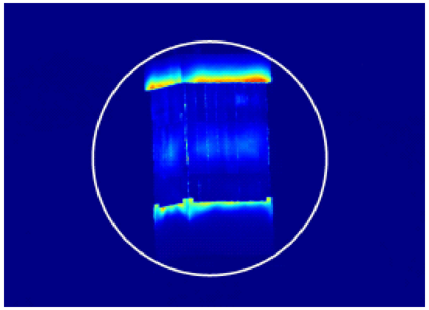
View of Unit 3 Receiver Glare and Rogue Heliostat from I-15

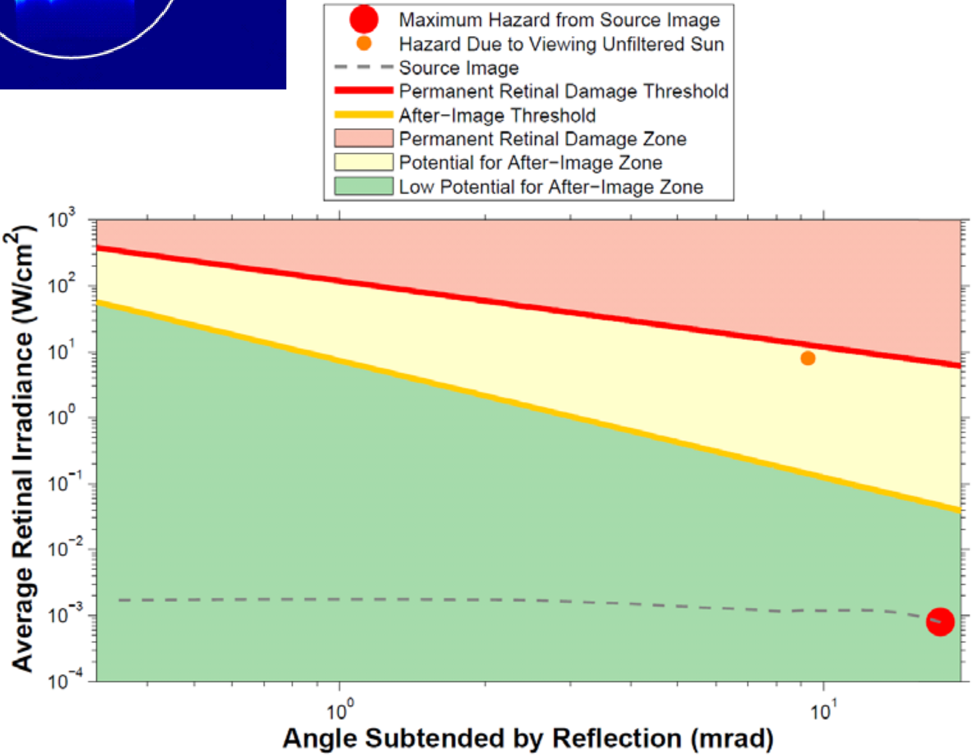
Sandia National Laboratories

~5 miles

Receiver Ocular Hazard Analysis

View of Unit 1 Receiver from I-15 ~1.5 miles away





Summary of Glare Monitoring

- Aerial Monitoring
  - Heliostats in standby mode can cause glare to aerial observers (pilots)
  - Glare from heliostats can cause after-image at far distances (up to 6 miles in our helicopter surveys)
  - Glare was visible from multiple heliostats in standby mode
  - The glare from the illuminated receiver was small compared to the glare from the standby heliostats
- Ground Monitoring
  - Drive-by surveys at three different times of the day did not reveal any ocular hazards
  - All data from receiver glare showed a low potential for after-image

Ryan Goerl, NRG

Overview

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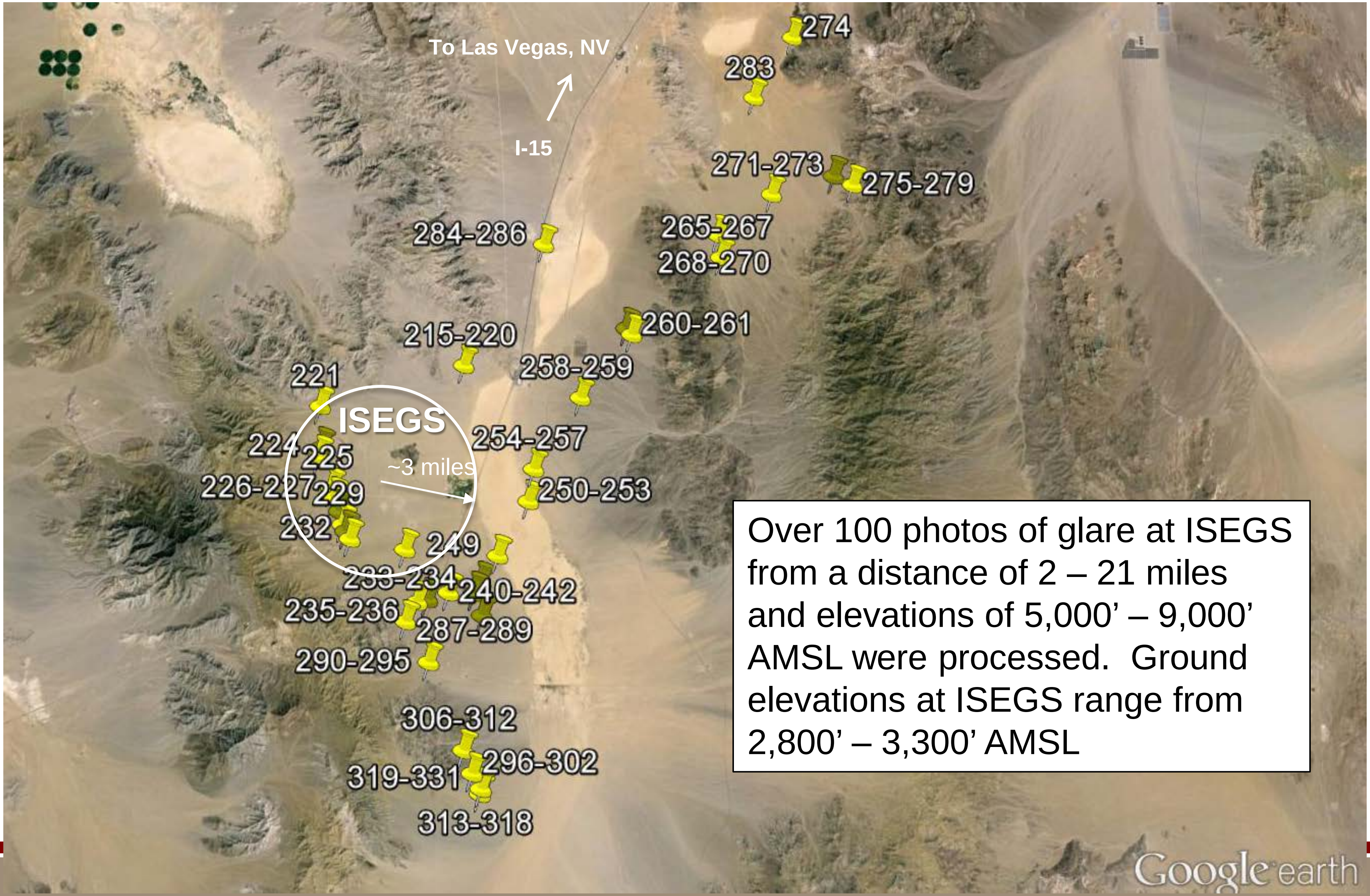
Suggested Mitigation Methods

- Limit the number of heliostats in standby mode
  - Predict need for standby heliostats based on cloud cover or other factors
  - Position some heliostats vertically in proper azimuth position to reduce time to slew to target
  - Bring heliostats up to standby position near receiver sequentially only as needed
- Incorporate a glare shield near the receiver for heliostats in standby mode
  - Perhaps the shield can serve as a preheater for the water
- Increase the number of aim points near the receiver during standby and have adjacent heliostats point to different locations to disperse the visible glare

Evaluation of New Heliostat Standby Strategies (July 22, 2014)

Aerial Monitoring Photo Locations

July 22, 2014 (~11:00 AM – 12:50 PM)

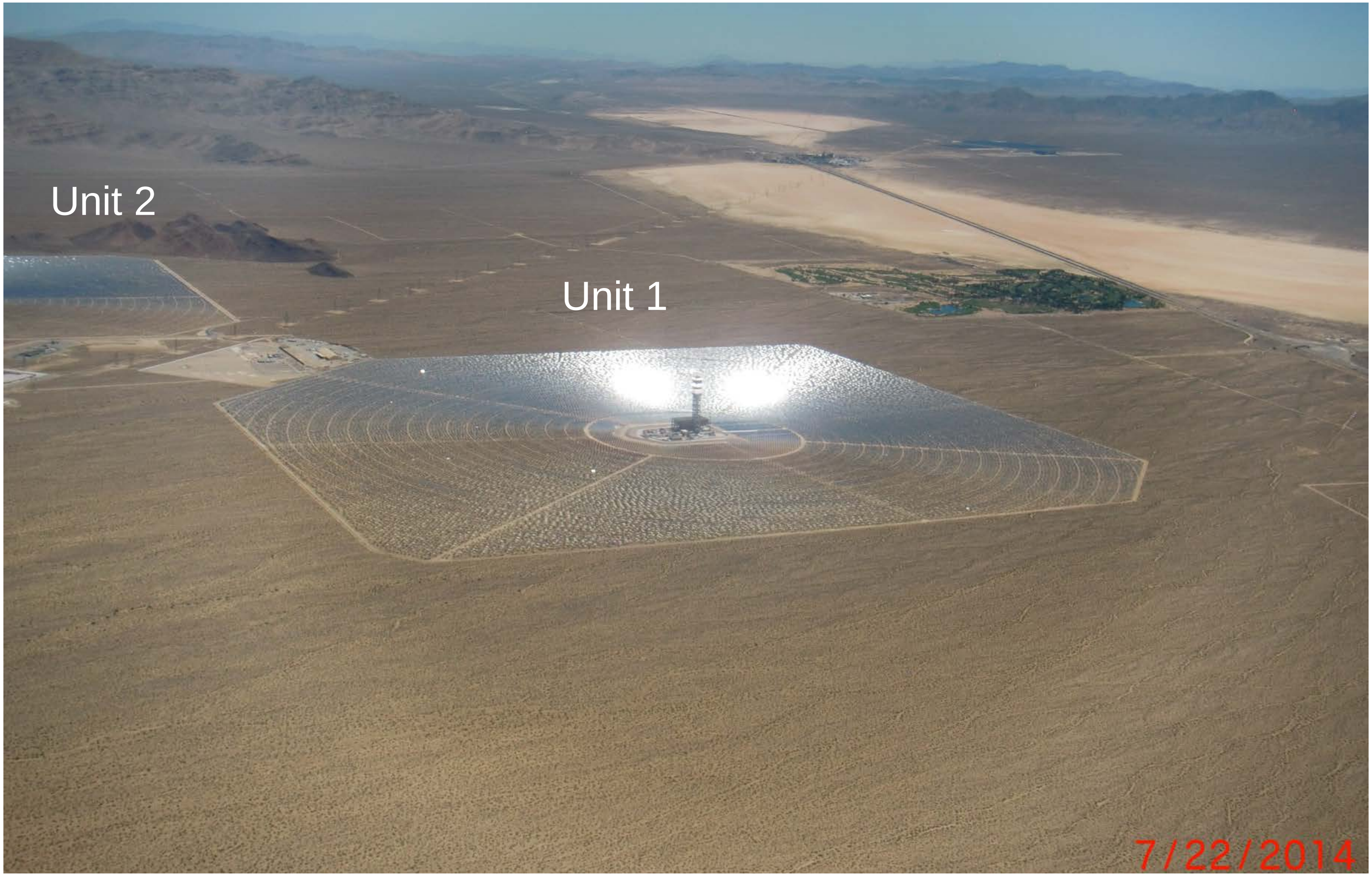


Aerial Glare Photographs

Looking Southeast, ~1 – 4 miles away
11:20 AM (PDT), July 22, 2014

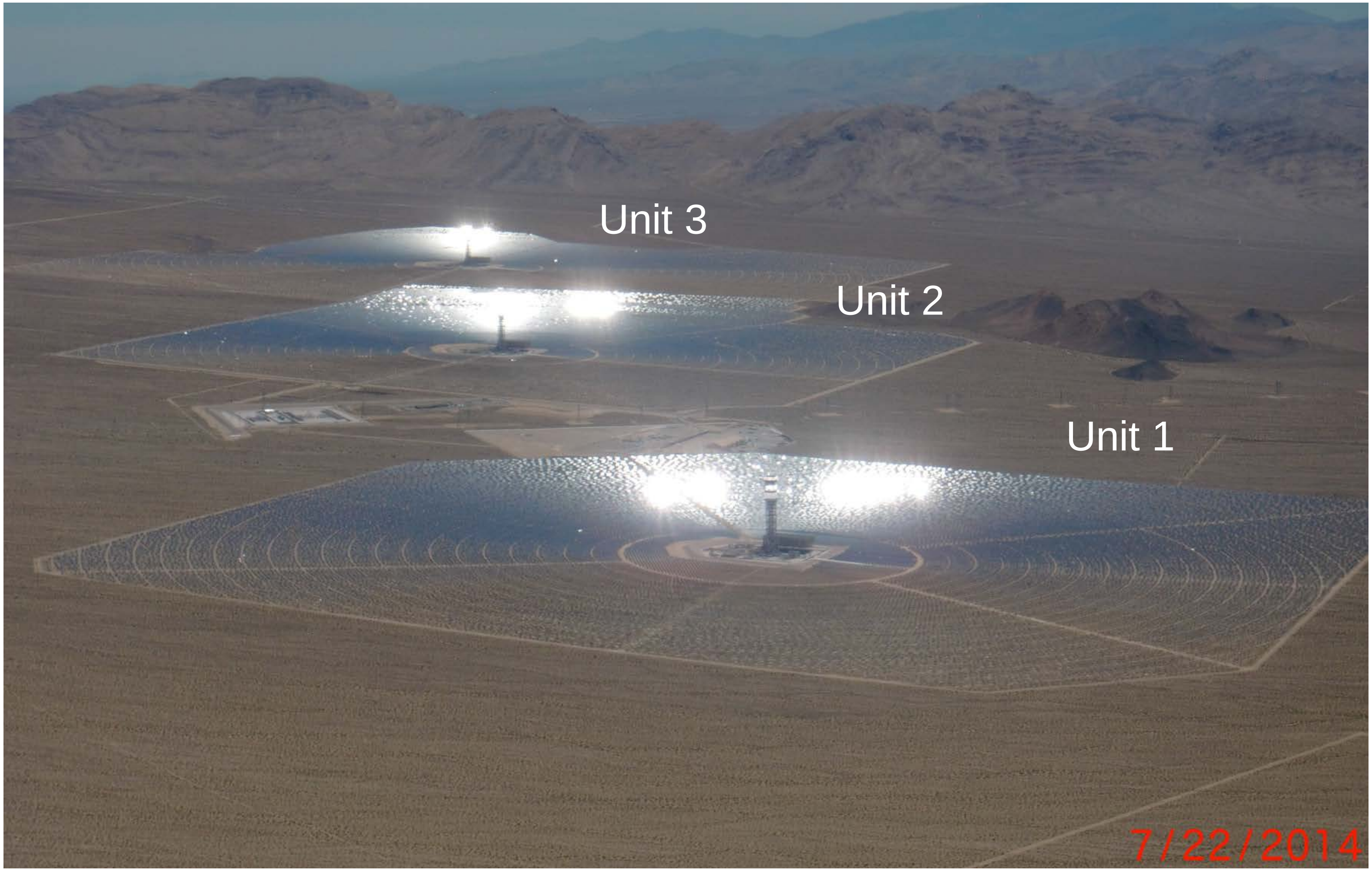
Aerial Glare Photographs

Looking Northeast, ~2 – 3 miles away
11:29 AM (PDT), July 22, 2014



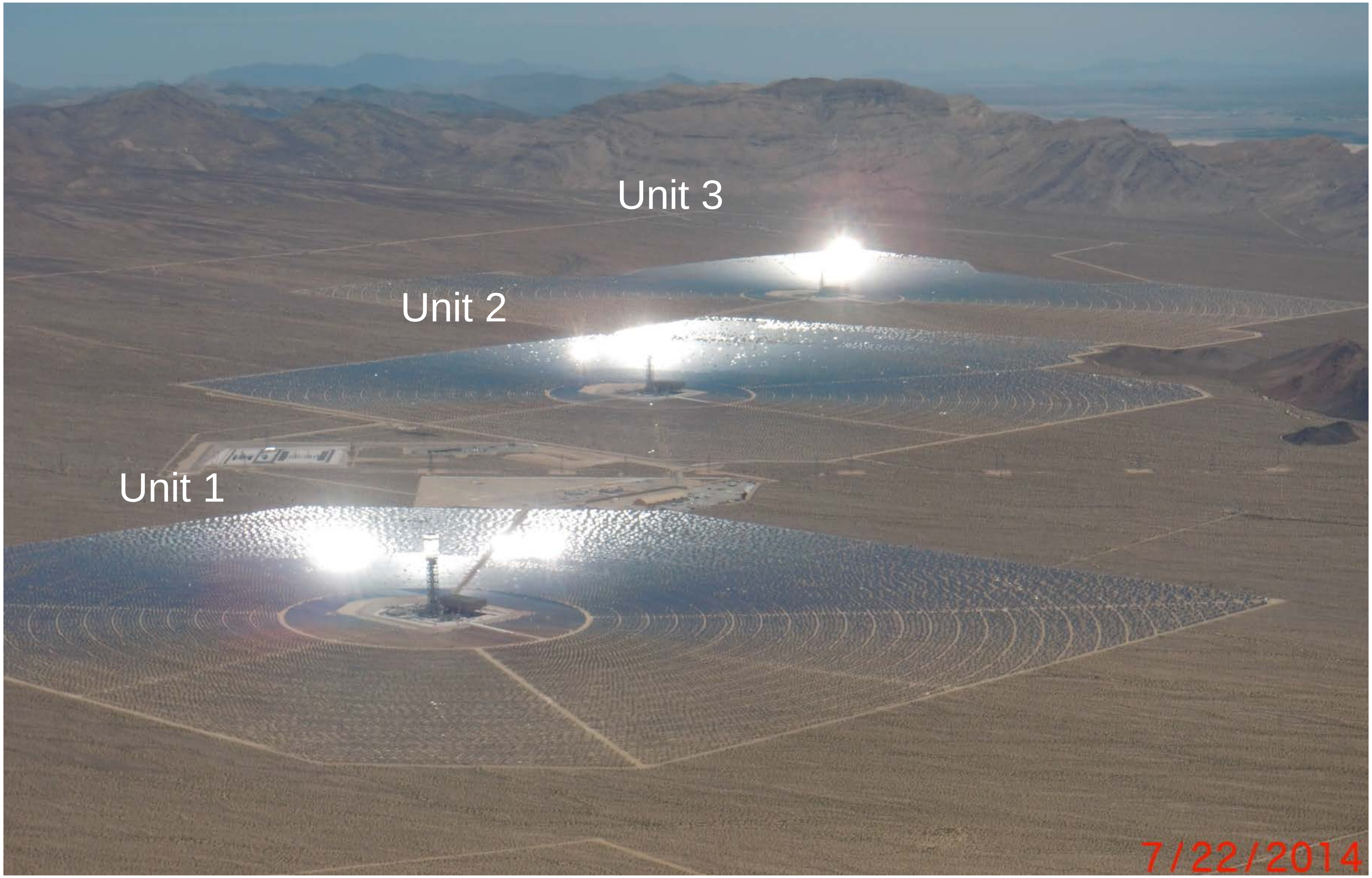
Aerial Glare Photographs

Looking North/Northwest, ~5 – 6 miles away
11:33 AM (PDT), July 22, 2014



Aerial Glare Photographs

Looking Northwest, ~3 – 5 miles away
11:38 AM (PDT), July 22, 2014

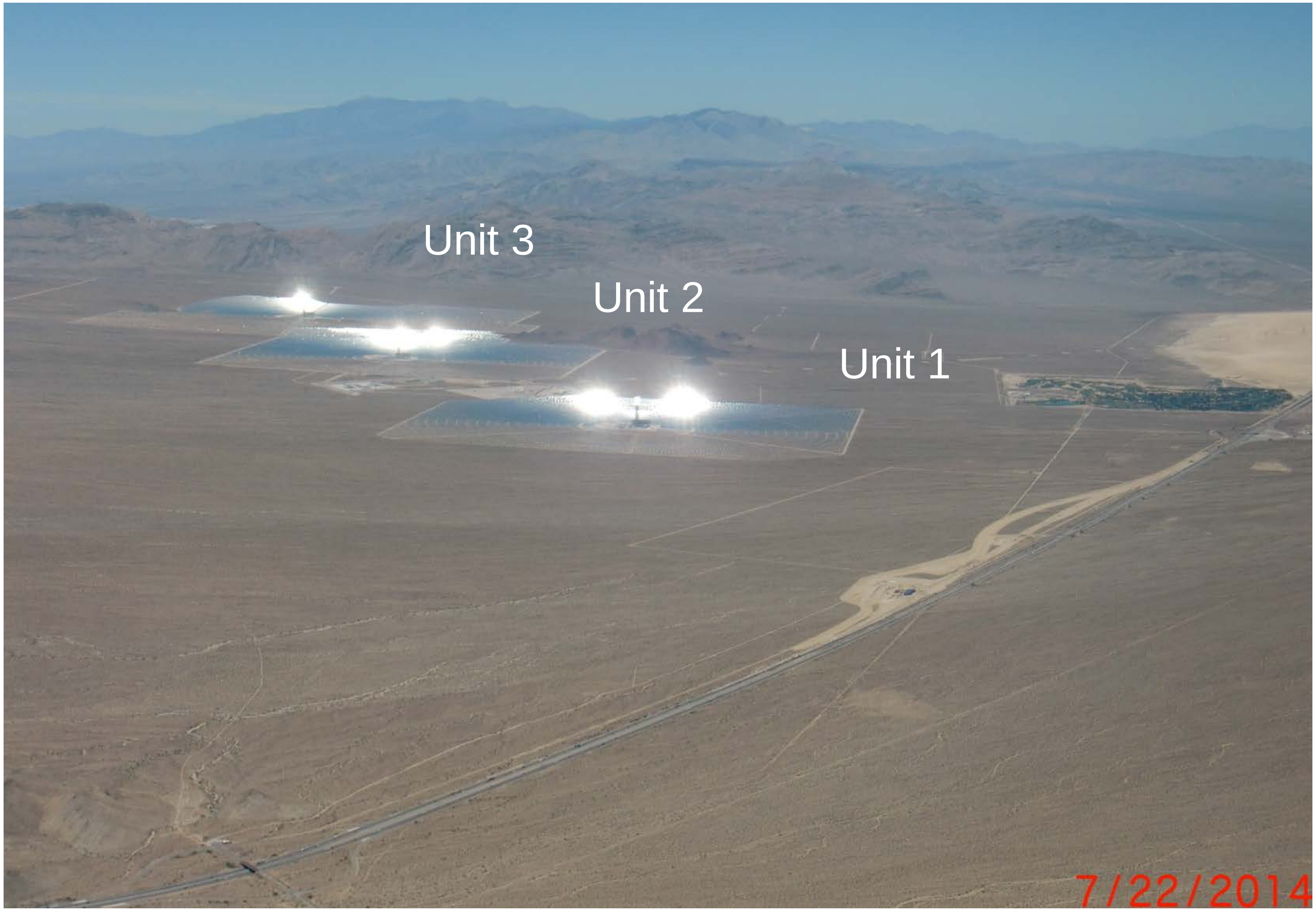


Aerial Glare Photographs

Looking West/Southwest, ~7 – 8 miles away
11:48 AM (PDT), July 22, 2014

Aerial Glare Photographs

Looking North/Northwest, ~6 – 9 miles away
12:31 PM (PDT), July 22, 2014



Unit 1 – Looking North/Northwest ~3 – 4 miles away

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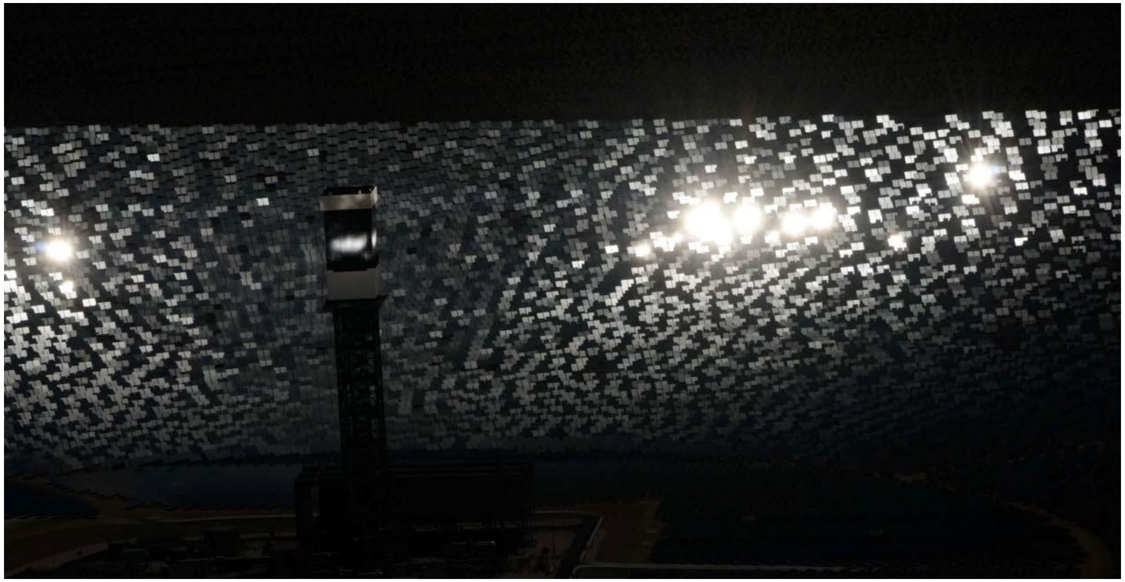


~11:31 AM (PDT)

DSC237 (no filters),
1/3200s – f/32
Brightest points are saturated

DSC235 (~60X filtering),
1/3200s – f/32
No saturation

Unit 2 – Looking North/Northwest ~5 miles away

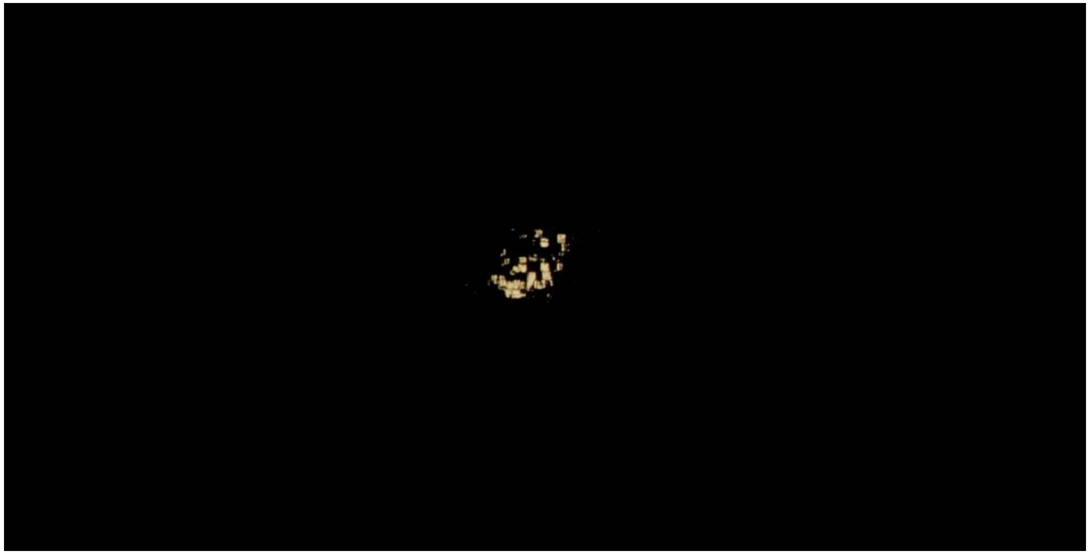
~11:30 AM (PDT)

DSC238 (no filters),
1/3200s – f/32
Brightest points are saturated

DSC236 (~60X filtering),
1/3200s – f/32
No saturation

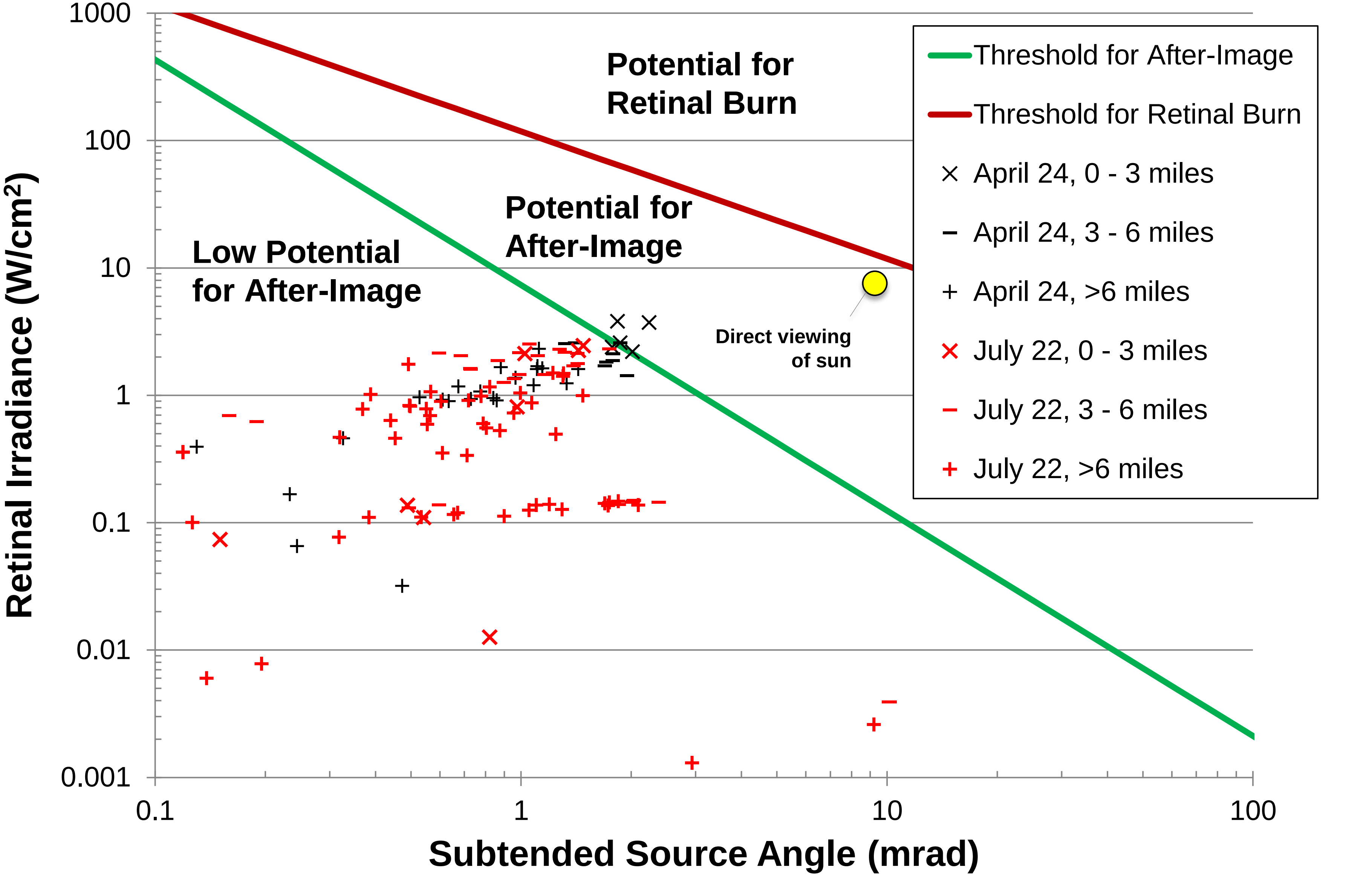
Unit 3 – Looking North/Northwest, ~7 miles away

~11:32 AM (PDT)
DSC239 (no filters),
1/3200s – f/32
Brightest points are
saturated



~11:38 AM (PDT)
DSC246 (~4096X
filter), 1/3200s – f/32
No saturation

Ocular Hazard Analysis



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Next Steps

Sandia National Laboratories

- Hold meeting with CEC, NRG, Brightsource, Sandia, and other stakeholders to review results and discuss path forward
  - New standby aiming strategies?
  - New standby procedures?
  - Possibility of glare shields?
  - Reduce number of standby heliostats that face directly toward the sun; these produce the most glare
- Implement new aiming strategies
  - Perform additional flyovers to characterize impact
- Identify optimal solution
  - Revise Heliostat Positioning Plan for review and approval
  - Implement solution for proposed Palen project

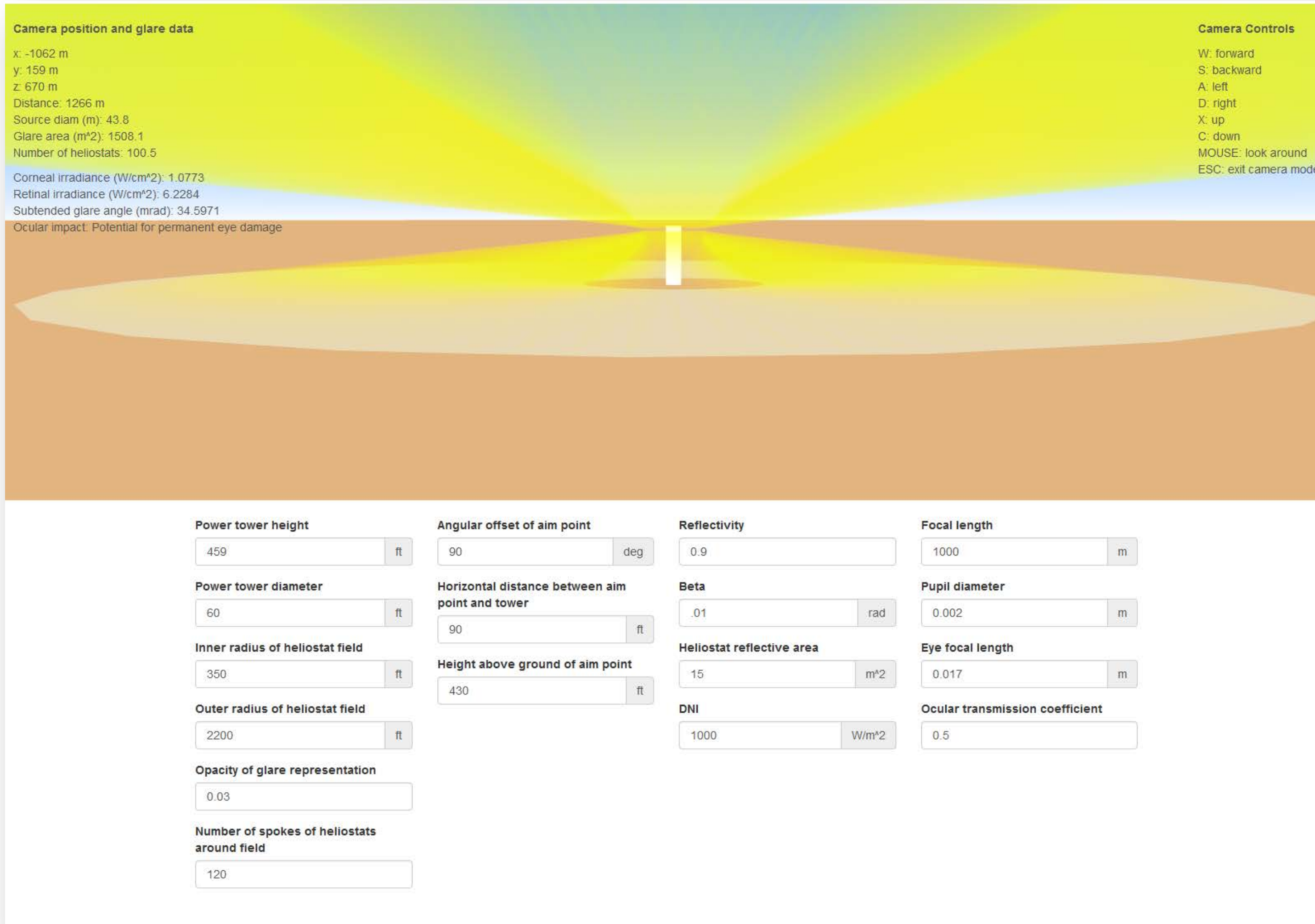
Acknowledgments

- Funding from DOE SunShot Soft Costs Program
- Matt Binner (pilot, Airworks LV)
- Jason Slavin (SNL, data processing)
- Philip Spinks (NRG, data collection)

Backup Slides

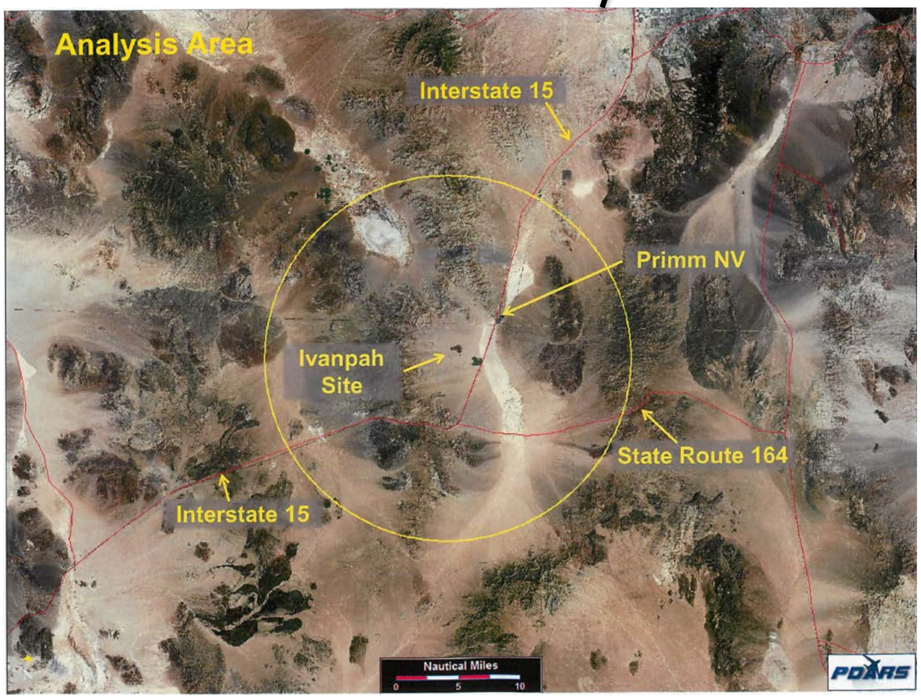
Next Steps – Tower Illuminance Model

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

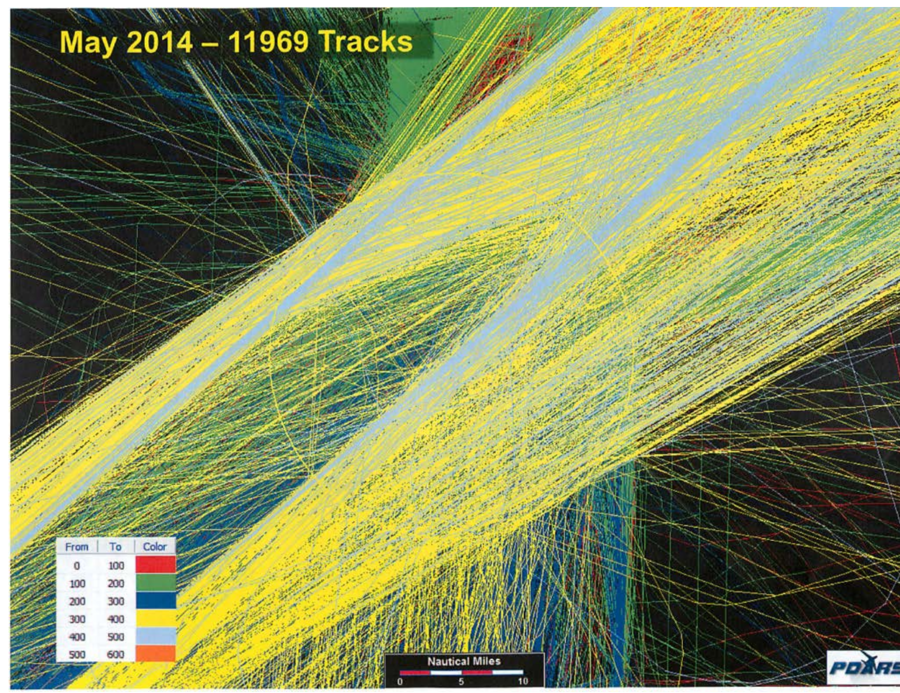


Flight Path Analysis near ISEGS

Las Vegas, Nevada



FAA evaluated number of flight paths within 15 nautical miles of ISEGS (Docket 09-AFC-07C, TN 202585)



Nearly 12,000 flights in May 2014

Ocular Hazard Analysis

Sandia National Laboratories

Sampling from over 100 glare images

Image	DNI (W/m^2)	Tower Unit	Approximate Distance to Glare Source (miles)	Average Retinal Irradiance (W/cm^2)	Total Subtended Glare Angle (mrad)	Ocular Impact
DSC 0233	1000	1	1.9	2.118	1.024	Low Potential for After-Image
DSC 0221	1000	3	2.4	0.810	0.976	Low Potential for After-Image
DSC 0224	1000	2	2.8	0.137	0.489	Low Potential for After-Image
DSC 0229	1000	1	3	1.766	1.428	Low Potential for After-Image
DSC 0250	1000	1	4.2	2.518	1.054	Low Potential for After-Image
DSC 0218	1000	3	4.5	2.037	0.685	Low Potential for After-Image
DSC 0240	1000	2	5.2	1.450	1.158	Low Potential for After-Image
DSC 0304	1000	2	6.5	0.985	0.777	Low Potential for After-Image
DSC 0252	1000	3	6.6	1.751	0.492	Low Potential for After-Image
DSC 0258	1000	1	7.2	1.493	1.221	Low Potential for After-Image
DSC 0289	1000	3	7.3	0.139	1.195	Low Potential for After-Image
DSC 0291	1000	2	7.3	0.137	1.101	Low Potential for After-Image
DSC 0305	1000	3	8.1	0.634	0.440	Low Potential for After-Image
DSC 0306	1000	1	8.7	0.137	2.092	Low Potential for After-Image
DSC 0285	1000	2	9.7	0.553	0.803	Low Potential for After-Image
DSC 0260	1000	1	9.9	0.821	0.498	Low Potential for After-Image
DSC 0264	1000	3	10	1.013	0.388	Low Potential for After-Image
DSC 0265	1000	1	14	0.590	0.554	Low Potential for After-Image
DSC 0271	1000	3	16.8	0.119	0.671	Low Potential for After-Image
DSC 0272	1000	1	16.9	0.110	0.384	Low Potential for After-Image
DSC 0282	1000	2	18.9	0.357	0.119	Low Potential for After-Image
DSC 0280	1000	3	19	0.467	0.320	Low Potential for After-Image
DSC 0274	1000	3	21	0.110	0.534	Low Potential for After-Image