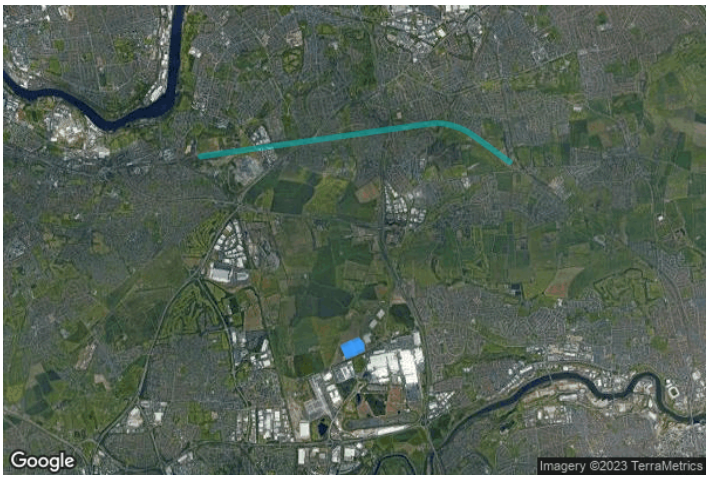
FORGESOLAR GLARE ANALYSIS

Project: **IAMP Sunderland rooftop**
Site configuration: **NT15611 Envision giga plant variation Railway**

Created 12 Jun, 2023
Updated 14 Jun, 2023
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 1 MW to 5 MW
Site ID 92614.9902

Ocular transmission coefficient 0.5
Pupil diameter 0.002 m
Eye focal length 0.017 m
Sun subtended angle 9.3 mrad
PV analysis methodology V2



Summary of Results No glare predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy	Peak Luminance
	°	°	min	hr	min	hr	kWh	cd/m^2
PV array 1	2.124	156.0	0	0.0	0	0.0	-	0
PV array 10	2.124	156.0	0	0.0	0	0.0	-	0
PV array 11	2.124	336.0	0	0.0	0	0.0	-	0
PV array 12	2.124	336.0	0	0.0	0	0.0	-	0
PV array 13	2.058	156.0	0	0.0	0	0.0	-	0
PV array 14	2.058	156.0	0	0.0	0	0.0	-	0
PV array 15	2.058	336.0	0	0.0	0	0.0	-	0
PV array 16	2.058	336.0	0	0.0	0	0.0	-	0
PV array 17	2.124	336.0	0	0.0	0	0.0	-	0
PV array 18	2.058	156.0	0	0.0	0	0.0	-	0
PV array 2	2.124	156.0	0	0.0	0	0.0	-	0
PV array 3	2.124	336.0	0	0.0	0	0.0	-	0
PV array 4	2.124	336.0	0	0.0	0	0.0	-	0
PV array 5	2.058	156.0	0	0.0	0	0.0	-	0
PV array 6	2.058	156.0	0	0.0	0	0.0	-	0
PV array 7	2.058	336.0	0	0.0	0	0.0	-	0
PV array 8	2.058	336.0	0	0.0	0	0.0	-	0
PV array 9	2.124	156.0	0	0.0	0	0.0	-	0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Railway	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.920410	-1.483984	39.40	28.50	67.90
2	54.920643	-1.484150	38.71	28.50	67.21
3	54.921222	-1.481919	38.65	28.50	67.15
4	54.920987	-1.481755	38.66	28.50	67.16

Name: PV array 10
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921225	-1.481923	38.65	15.50	54.15
2	54.921435	-1.482075	39.00	15.50	54.50
3	54.922005	-1.479874	38.32	15.50	53.82
4	54.921789	-1.479712	38.08	15.50	53.58

Name: PV array 11
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921435	-1.482076	38.97	15.50	54.47
2	54.921655	-1.482243	38.59	15.50	54.09
3	54.922231	-1.480044	38.26	15.50	53.76
4	54.922006	-1.479874	38.32	15.50	53.82

Name: PV array 12
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921655	-1.482243	38.59	14.50	53.09
2	54.921873	-1.482434	38.67	14.50	53.17
3	54.922444	-1.480215	37.92	14.50	52.42
4	54.922231	-1.480043	38.26	14.50	52.76

Name: PV array 13
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921928	-1.482474	38.60	14.50	53.10
2	54.922156	-1.482654	38.33	14.50	52.83
3	54.922723	-1.480417	37.36	14.50	51.86
4	54.922501	-1.480248	37.73	14.50	52.23

Name: PV array 14
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922156	-1.482654	38.33	15.50	53.83
2	54.922385	-1.482825	38.07	15.50	53.57
3	54.922951	-1.480594	37.15	15.50	52.65
4	54.922723	-1.480416	37.36	15.50	52.86

Name: PV array 15
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922385	-1.482825	38.07	15.50	53.57
2	54.922624	-1.483006	37.78	15.50	53.28
3	54.923181	-1.480760	37.21	15.50	52.71
4	54.922951	-1.480594	37.15	15.50	52.65

Name: PV array 16
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922623	-1.483005	37.78	14.50	52.28
2	54.922843	-1.483175	37.53	14.50	52.03
3	54.923400	-1.480941	36.60	14.50	51.10
4	54.923181	-1.480760	37.21	14.50	51.71

Name: PV array 17
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922444	-1.480215	37.92	14.50	52.42
2	54.922570	-1.479737	37.23	14.50	51.73
3	54.922249	-1.479490	37.97	14.50	52.47
4	54.922121	-1.479961	38.30	14.50	52.80

Name: PV array 18
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922501	-1.480248	37.73	14.50	52.23
2	54.922839	-1.480507	37.55	14.50	52.05
3	54.922952	-1.480030	37.72	14.50	52.22
4	54.922626	-1.479780	37.23	14.50	51.73

Name: PV array 2
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.920644	-1.484150	38.71	29.50	68.21
2	54.920854	-1.484324	38.92	29.50	68.42
3	54.921436	-1.482075	38.97	29.50	68.47
4	54.921222	-1.481920	38.65	29.50	68.15

Name: PV array 3
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.920854	-1.484324	38.89	29.50	68.39
2	54.921081	-1.484487	38.81	29.50	68.31
3	54.921653	-1.482242	38.59	29.50	68.09
4	54.921435	-1.482075	38.97	29.50	68.47

Name: PV array 4
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921081	-1.484484	38.75	28.50	67.25
2	54.921297	-1.484664	39.34	28.50	67.84
3	54.921873	-1.482434	38.70	28.50	67.20
4	54.921654	-1.482242	38.59	28.50	67.09

Name: PV array 5
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921351	-1.484707	39.36	28.50	67.86
2	54.921587	-1.484875	39.12	28.50	67.62
3	54.922154	-1.482652	38.37	28.50	66.87
4	54.921928	-1.482474	38.58	28.50	67.08

Name: PV array 6
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921587	-1.484875	39.11	29.50	68.61
2	54.921809	-1.485057	39.19	29.50	68.69
3	54.922385	-1.482825	38.18	29.50	67.68
4	54.922155	-1.482653	38.33	29.50	67.83

Name: PV array 7
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.921809	-1.485057	39.13	29.50	68.63
2	54.922057	-1.485235	39.57	29.50	69.07
3	54.922621	-1.483004	37.78	29.50	67.28
4	54.922385	-1.482825	38.08	29.50	67.58

Name: PV array 8
Axis tracking: Fixed (no rotation)
Tilt: 2.058°
Orientation: 336.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.922057	-1.485234	39.57	28.50	68.07
2	54.922267	-1.485407	39.54	28.50	68.04
3	54.922843	-1.483175	37.61	28.50	66.11
4	54.922622	-1.483004	37.78	28.50	66.28

Name: PV array 9
Axis tracking: Fixed (no rotation)
Tilt: 2.124°
Orientation: 156.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.920987	-1.481755	38.66	14.50	53.16
2	54.921224	-1.481924	38.65	14.50	53.15
3	54.921788	-1.479712	38.08	14.50	52.58
4	54.921565	-1.479536	38.05	14.50	52.55

Route Receptors

Name: Railway
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	54.954083	-1.527031	48.86	2.75	51.61
2	54.958699	-1.470874	23.27	2.75	26.02
3	54.959225	-1.464437	27.18	2.75	29.93
4	54.959610	-1.459394	26.46	2.75	29.21
5	54.959649	-1.457801	26.05	2.75	28.80
6	54.959595	-1.455886	25.09	2.75	27.84
7	54.959352	-1.453729	24.76	2.75	27.51
8	54.958927	-1.451498	24.87	2.75	27.62
9	54.958577	-1.450052	24.55	2.75	27.30
10	54.958163	-1.448644	24.61	2.75	27.36
11	54.957177	-1.446133	25.02	2.75	27.77
12	54.954232	-1.439106	22.24	2.75	24.99
13	54.953158	-1.436498	23.00	2.75	25.75

Glare Analysis Results

Summary of Results No glare predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy	Peak Luminance
	°	°	min	hr	min	hr	kWh	cd/m²
PV array 1	2.124	156.0	0	0.0	0	0.0	-	0
PV array 10	2.124	156.0	0	0.0	0	0.0	-	0
PV array 11	2.124	336.0	0	0.0	0	0.0	-	0
PV array 12	2.124	336.0	0	0.0	0	0.0	-	0
PV array 13	2.058	156.0	0	0.0	0	0.0	-	0
PV array 14	2.058	156.0	0	0.0	0	0.0	-	0
PV array 15	2.058	336.0	0	0.0	0	0.0	-	0
PV array 16	2.058	336.0	0	0.0	0	0.0	-	0
PV array 17	2.124	336.0	0	0.0	0	0.0	-	0
PV array 18	2.058	156.0	0	0.0	0	0.0	-	0
PV array 2	2.124	156.0	0	0.0	0	0.0	-	0
PV array 3	2.124	336.0	0	0.0	0	0.0	-	0
PV array 4	2.124	336.0	0	0.0	0	0.0	-	0
PV array 5	2.058	156.0	0	0.0	0	0.0	-	0
PV array 6	2.058	156.0	0	0.0	0	0.0	-	0
PV array 7	2.058	336.0	0	0.0	0	0.0	-	0
PV array 8	2.058	336.0	0	0.0	0	0.0	-	0
PV array 9	2.124	156.0	0	0.0	0	0.0	-	0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Railway	0	0.0	0	0.0

PV: PV array 1 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m²
Railway	0	0.0	0	0.0	0

PV array 1 and Route: Railway

No glare found

PV: PV array 10 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 10 and Route: Railway

No glare found

PV: PV array 11 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 11 and Route: Railway

No glare found

PV: PV array 12 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 12 and Route: Railway

No glare found

PV: PV array 13 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 13 and Route: Railway

No glare found

PV: PV array 14 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 14 and Route: Railway

No glare found

PV: PV array 15 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 15 and Route: Railway

No glare found

PV: PV array 16 no glare found

Receptor results ordered by category of glare

Railway	0	0.0	0	0.0	0

PV array 16 and Route: Railway

No glare found

PV: PV array 17 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 17 and Route: Railway

No glare found

PV: PV array 18 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 18 and Route: Railway

No glare found

PV: PV array 2 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 2 and Route: Railway

No glare found

PV: PV array 3 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 3 and Route: Railway

No glare found

PV: PV array 4 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 4 and Route: Railway

No glare found

PV: PV array 5 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 5 and Route: Railway

No glare found

PV: PV array 6 no glare found

Receptor results ordered by category of glare

Railway	0	0.0	0	0.0	0

PV array 6 and Route: Railway

No glare found

PV: PV array 7 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 7 and Route: Railway

No glare found

PV: PV array 8 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 8 and Route: Railway

No glare found

PV: PV array 9 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Railway	0	0.0	0	0.0	0

PV array 9 and Route: Railway

No glare found

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.
Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.

Default glare analysis parameters and observer eye characteristics (for reference only):

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians