

Solar Photovoltaic Glint and Glare Assessment

Workman LLP

Argosy

November 2022

PLANNING SOLUTIONS FOR:

- Solar
- Defence
- Airports
- Telecoms
- Buildings
- Radar
- Railways
- Wind
- Mitigation

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ADMINISTRATION PAGE

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1	April 2022	Initial issue – based on the previous building layout (11319A)
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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from solar panels to be located on the rooftop of a proposed development named Argosy, located approximately 780m northwest of the Air Traffic Control (ATC) Tower at Manchester Airport. The proposed development will consist of one unit, with one section of the rooftop consisting of four solar panel areas and glass roof lights, with an additional section consisting of glass roof lights only. The solar panel areas and glass roof lights¹ require a glint and glare assessment with respect to aviation activity associated with Manchester Airport. The specific receptors assessed within this report include the runway approach paths, the ATC Tower and the nearest visual circuits.

Overall Conclusions

No significant impact upon pilots approaching runway 25L or 25R, or within the visual circuits, is predicted considering the modelled intensity of any visible solar reflection from the assessed solar panel areas (low potential for temporary after-image). In accordance with the associated guidance, no significant impact is predicted, and no mitigation is required.

No impact upon the visual control room within the ATC Tower, or pilots approaching runway 05L or 05R at Manchester Airport is predicted as no solar reflection is possible from the proposed solar panel areas. No mitigation is required.

Solar reflections are predicted from the south west facing rooftop towards the ATC Tower, which consists of glass roof lights. In accordance with the associated guidance and industry best practice, any predicted glare towards an ATC Tower is not acceptable. Pager Power however recommends a pragmatic approach, and recommends that consultation is held with Manchester Airport Group (MAG) to understand their position with respect to the proposed roof lights.

Additional MAG Receptors

Pager Power is aware of additional receptors requested by MAG for new developments requiring glint and glare assessment in the vicinity of their airports. This now includes a request for additional modelling of circuits, extended approach paths, an extended climb out, and an area of airspace above the development at 2,500ft. The analysis in this report is based on the original modelling of the 2-mile approach paths and the ATC Tower, with the additional modelling of the nearest circuits modelled at 1nm width at 1,000ft. The results of the analysis presented in this report give the author strong evidence to show that modelling of the additional receptors requested by MAG would give no stronger intensity than 'low potential for temporary after-image', thus the results would be acceptable considering the associated guidance.

¹ The glass roof lights have similar reflective properties as solar panels and therefore an assessment regarding their impact is presented in Section 8.5 of this report.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. There is no existing planning guidance for the assessment of solar reflections from solar panels towards aviation receptors. Pager Power has, however, produced guidance for glint and glare and solar photovoltaic developments, with the fourth edition originally published in 2020².

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. Solar intensity calculations are then undertaken in line with the Sandia National Laboratories' FAA methodology³. The scenario in which a solar reflection can occur for all receptors is then identified and discussed alongside an operational assessment, and a comparison against the available solar panel reflection studies to determine the overall impact.

² Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

³ Formerly mandatory for on-airfield solar developments in the USA under the FAA's interim policy, superseded in 2021 with a policy that effectively requires individual airports to sign off on their on-airfield development as they see fit.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 54 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems.

Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from solar panels to be located on the rooftop of a proposed development named Argosy, located approximately 780m northwest of the Air Traffic Control (ATC) Tower at Manchester Airport. The proposed development will consist of one unit, with one section of the rooftop consisting of four solar panel areas and glass roof lights, with an additional section consisting of glass roof lights only. The solar panel areas and glass roof lights⁴ require a glint and glare assessment with respect to aviation activity associated with Manchester Airport. The specific receptors assessed within this report include the runway approach paths, the ATC Tower and the nearest visual circuits. This report contains the following:

- Solar development details.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.

Following this, a summary of findings and overall conclusions and recommendations from the desk-based analysis is presented. No site survey has taken place at this stage.

1.2 Pager Power's Experience

Pager Power has undertaken over 900 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

⁴ The glass roof lights have similar reflective properties as solar panels and therefore an assessment regarding their impact is presented in Section 8.5 of this report.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows⁵:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors.
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

The term 'solar reflection' is used in the report to refer to both reflection types i.e. glint and glare.

⁵ These definitions are aligned with the Draft National Policy Statement for Renewable Energy Infrastructure and the Federal Aviation Administration (FAA) in the United States of America.

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Plan

Figure 1⁶ below shows the proposed development site plan. Not aligned north.

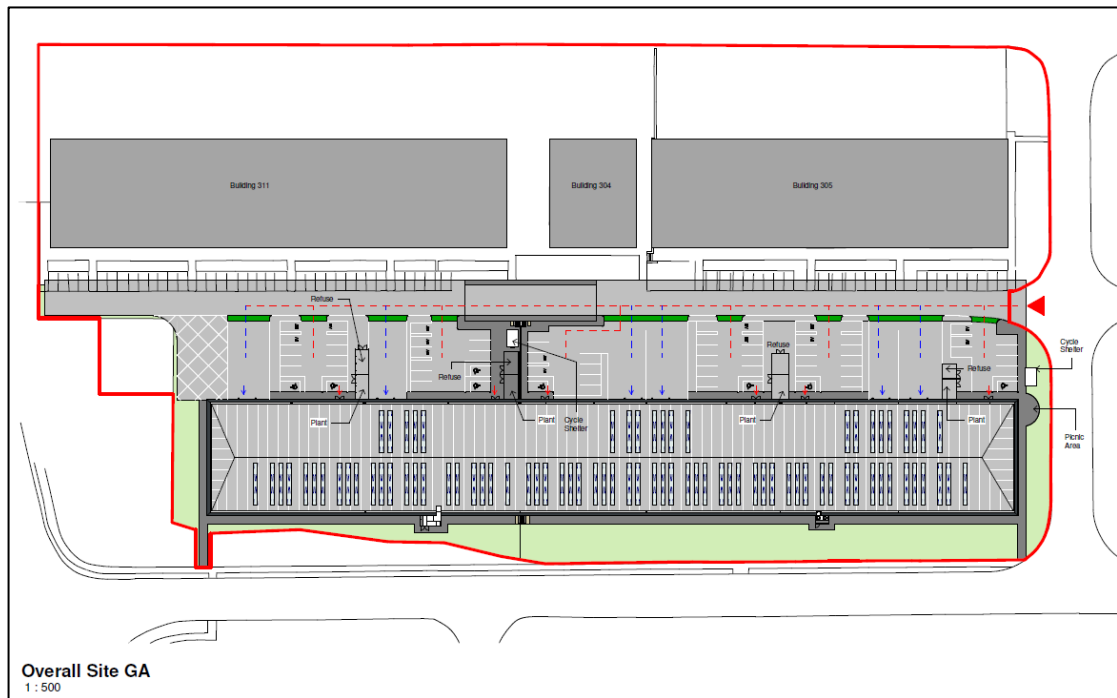


Figure 1 Proposed development site plan

⁶ Source: 020687-RPS-SI-XX-DR-A-5001-P02-Site Layout GA

2.2 Proposed Development Solar Panel Areas

Figure 2⁷ below shows the location of the proposed solar panels on the rooftop (purple areas). The glass roof lights are shown by the vertical light blue areas on either side of the rooftop (discussed further in Section 8.5). Not aligned north.



Figure 2 Proposed development solar panel areas

⁷ Source: 020687-RPS-MB-RO-DR-A-5023-P02-Roof Plan GA - Overall Layout

2.3 Proposed Development Site Plan – Aerial Imagery

Figure 3 below shows the proposed development site plan extrapolated onto aerial imagery showing the individual solar panel areas, as well as the red line boundary.

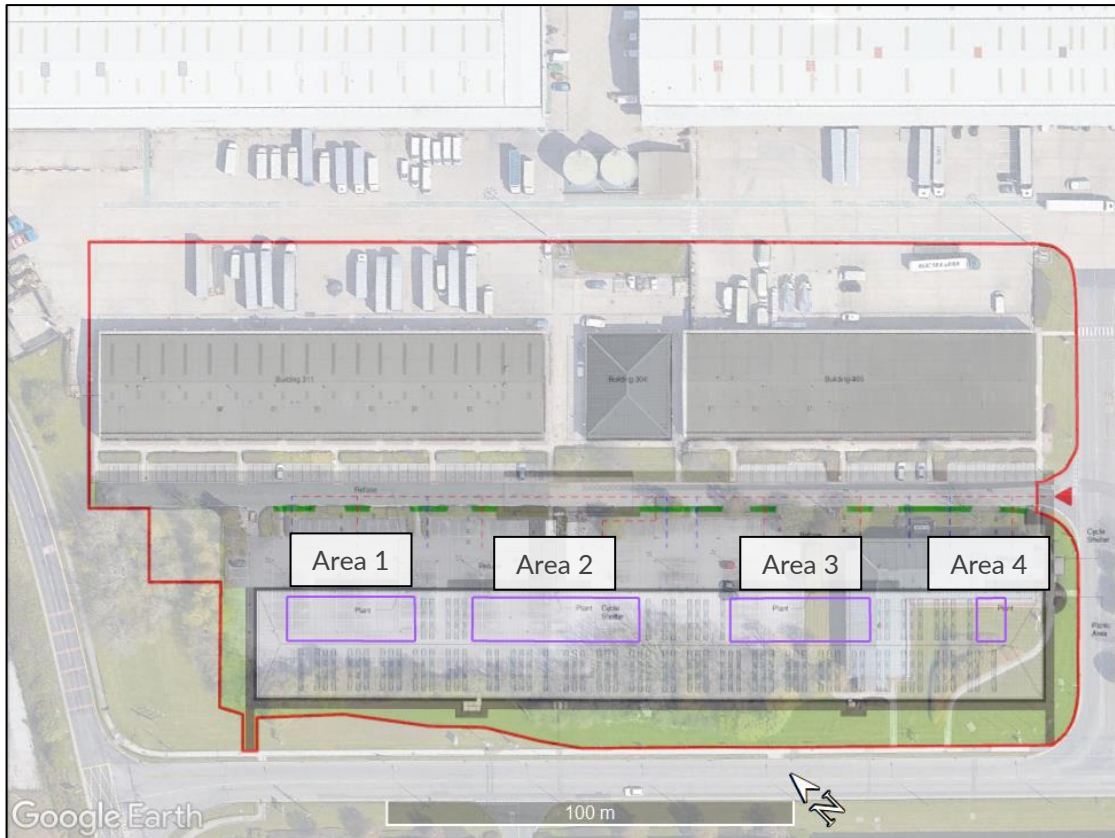


Figure 3 Proposed development site plan – aerial imagery

The reflector areas and technical details used in this assessment are presented in Section 6.

3 MANCHESTER AIRPORT DETAILS

3.1 Overview

The following section presents general details regarding Manchester Airport.

3.2 Airport Information

Manchester Airport is a Civil Aviation Authority (CAA) licensed aerodrome with two runways.

3.3 Runway Details

The runway details are presented below:

- 05L/23R measuring 3,048m by 45m (asphalt);
- 05R/23L measuring 3,050m by 45m (asphalt).

The runways are shown in Figure 4⁸ (aerodrome chart) below.

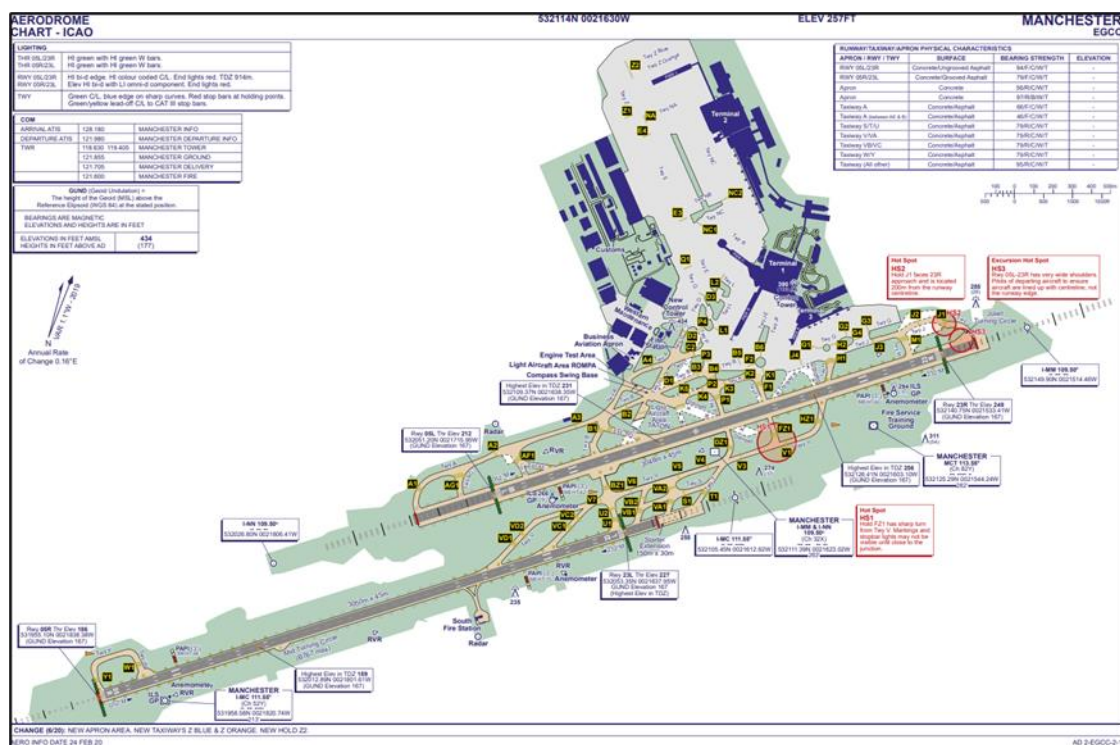


Figure 4 Aerodrome chart – Manchester Airport

⁸ Source: NATS AIP for Manchester Airport (last accessed November, 2022).

The proposed development building footprint relative to Manchester Airport is shown in Figure 5 below.



Figure 5 Location of proposed development relative to Manchester Airport

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels are possible.
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence.
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

4.2 Background

Details of the Sun's movements and solar reflections are presented in Appendix C.

4.3 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for glint and glare assessments is as follows:

- Identify receptors in the area surrounding the solar development.
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations;
- Consider the visibility of the panels from the receptor's location. If the panels are not visible from the receptor then no reflection can occur;
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur;
- Consider both the solar reflection from the solar development and the location of the direct sunlight with respect to the receptor's position;
- Consider the solar reflection with respect to the published studies and guidance – including intensity calculations where appropriate;
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

Within the Pager Power model, the solar development area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor.

4.3.1 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

4.4 Assessment Limitations

Further technical details regarding the methodology of the geometric calculations and limitations are presented in Appendix E and Appendix F.

5 IDENTIFICATION OF RECEPTORS

5.1 Overview

The following section presents the relevant receptors assessed within this report.

5.2 Aviation Receptors

5.2.1 Air Traffic Control Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC Tower. The ATC Tower location is illustrated in Figure 6 below.

Coordinate data taken from the NATS AIP is presented in Appendix G.



Figure 6 ATC Tower location

5.2.2 Airborne Receptors - Approaching Aircraft

Manchester Airport has two operational runways, each with two associated approach paths, one for each bearing. It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for both aircraft approach paths for each runway. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The height of the aircraft is determined by using a 3-degree descent path relative to the runway threshold height. Figure 7 below shows the assessed aircraft approach paths.



Figure 7 Runway approach paths – aerial image

The receptor details for each runway approach are presented in Appendix G.

5.2.3 Aircraft Visual Circuits

When light aircraft arrive or depart from an aerodrome, they may fly in a standard pattern. Manchester Airport requires an assessment of aircraft flying both directions in the visual circuits for 05L, 05R, 23L and 23R. A typical circuit is shown in Figure 8 below.

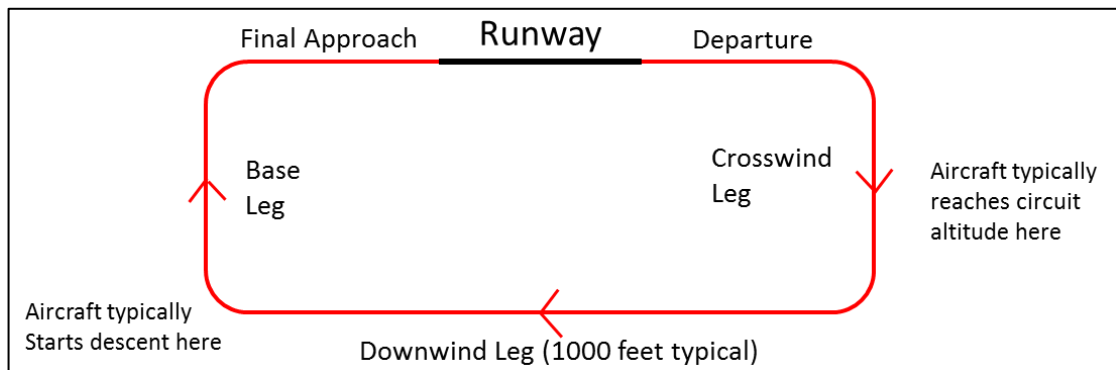


Figure 8 Typical circuit diagram

The way circuits are flown varies from airport to airport, pilot to pilot and aircraft to aircraft. The assessed circuit has the following characteristics:

- Circuit altitude 1,000ft (304.8m) above the lowest runway threshold;
- Circuit originates and terminates at the runway ends⁹;
- The circuit considers an ascent and descent angle of 5°.

It is assumed that aircraft will be at 1,000ft above mean sea level on the base leg.

A circuit width of 1 nautical mile (nm) has been modelled for the 1,000ft circuit.

Figure 9 on the following page shows the circuit paths for Manchester Airport. The red lines show the circuit paths for runway 05L/23R, and the blue lines show the circuit paths for Runway 05R/23L. The proposed development location is also highlighted.

⁹ Runway thresholds.



Figure 9 Circuits paths for runways 05L-23R (red line) and 05R-23L (blue line)

Figure 10 on the following page shows the individual receptor points. In this instance, only the circuits closest to the proposed development have been modelled, with similar or less significant results expected for those circuit paths further from the development. Therefore the runway 05L left-hand/23R right-hand and runway 05R left-hand/23L right-hand circuit paths have been modelled. The detailed receptor points are shown in Appendix G.



Figure 10 Circuits paths for runways 05L-23R (red line) and 05R-23L (blue line)

6 ASSESSED REFLECTOR AREAS

6.1 Reflector Areas

The north east facing rooftop contains four solar panels areas, each of which have been modelled. These areas are shown in Figure 11 below.



Figure 11 Modelled reflector areas

The technical details used in this assessment are presented in Table 1 below.

Technical Details				
Areas	1	2	2	4
Roof azimuth angle	45.2° - north east facing (solar panels and glass roof lights) / 225.2° - south west facing (glass roof lights only)			
Assessed height	9.9m above ground level or 74.9m above mean sea level			
Elevation angle (°)	6			

Table 1 *Technical details*

A number of representative locations are selected within the rooftop areas. The number of modelled reflector points is determined by the size of the reflector area and the assessment resolution. The bounding coordinates for the rooftop areas have been extrapolated from the site plans and can be found in Appendix G. Unit elevation data has been provided by the developer. Ground heights have been taken from Pager Power's database based on OS Panorama data.

A resolution of 1m has been chosen for Pager Power model in this assessment. This means that a geometric calculation is undertaken for each identified receptor every 1m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output.

7 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

7.1 Overview

The Pager Power and Forge models have been used to determine whether reflections are possible. Where solar reflections have been predicted, intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for reference purposes. These calculations are routinely required for solar photovoltaic developments on or near aerodromes.

The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	
Low potential	 Glare beyond 50 deg from pilot line-of-sight
Potential	 Low potential for temporary after-image
Potential for permanent eye damage	 Potential for temporary after-image
	 Potential for permanent eye damage

Table 2 Glare intensity designation

This coding has been used in the table where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology.

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' has been assessed. Surfaces that can be modelled include:

- Smooth glass with an anti-reflective coating (ARC);
- Light textured glass without an anti-reflective coating;
- Light textured glass with an anti-reflective coating;
- Deeply textured glass.

7.2 Summary of Results

The tables in the following subsections summarise the results of the assessment. The predicted glare times are based solely on bare-earth terrain i.e. without consideration of screening from buildings and vegetation. The final column summarises the glare intensity designation defined in the previous sub-section.

The significance of any predicted impact is discussed in the subsequent report sections. The modelling output showing the precise predicted times and the reflecting panel area is shown in Appendix H.

7.3 Geometric Calculation Results Overview – ATC Tower

The results of the geometric calculations for the ATC Tower are presented in Table 3 below.

Receptor	Reflection possible towards ATC Tower? (GMT)		Glare Type (Forge)	Comment
	am	pm		
ATC Tower	No.	No.	n/a	No solar reflections geometrically possible. No impacts predicted.

Table 3 Geometric calculation results overview – ATC Tower

7.4 Geometric Calculation Results Overview – Runway Approaches

The results of the geometric calculations for the runway approach paths are presented in Table 4 below.

Runway	Reflection possible towards the runway approaches? (GMT)		Glare Type (Forge)	Comment
	am	pm		
05L	No.	No.	N/A	No solar reflections geometrically possible. No impacts predicted.
05R				
23R	No.	Yes.		Solar reflections with 'low potential for temporary after-image' are predicted towards the entire 2-mile approach for runway 23R and approximately 1.4 miles of the runway 23L approach path. Low impact is predicted. Discussed further in Section 8.3.
23L				

Table 4 Geometric calculation results overview – runway approaches

7.5 Geometric Calculation Results Overview – Visual Circuit Paths

The results of the geometric calculations for the visual circuit paths are presented in Table 5 below.

Runway	Reflection possible towards the visual circuits? (GMT)		Glare Type (Forge)	Comment
	am	pm		
05L Left-Hand/23R Right-Hand (41-80)	Yes. Points 21-26	Yes. Points 1-20		Solar reflections with 'low potential for temporary after-image' are predicted towards sections of the nearest two circuits that overfly the proposed development. Low impact is predicted. Discussed further in Section 8.4.
05R Left-Hand/23L Right-Hand (121-160)	Yes. Points 17-21	Yes. Points 4-13		

Table 5 Geometric calculation results overview – visual circuit paths

8 GEOMETRIC ASSESSMENT RESULTS DISCUSSION

8.1 ATC Tower

The modelling has shown that solar reflections from the solar panels are not geometrically possible towards the visual control room of the ATC Tower.

No impact is therefore predicted, and no mitigation is required.

8.2 05R and 05L Approach Paths

The modelling has shown that solar reflections from the solar panels are not geometrically possible towards aircraft along the 2-mile approach paths for runways 05L and 05R.

No impact is therefore predicted, and no mitigation is required.

8.3 23L and 23R Approach Paths

The modelling has shown that solar reflections predicted from the solar panels towards pilots along the 2-mile approach paths for runway 23R and 23L will have a maximum intensity of 'low potential for temporary after-image'. This level of glare is acceptable considering the associated guidance and industry best practice.

A low impact is therefore predicted, and no mitigation is required.

8.4 Visual Circuits

For circuit receptors in the runway 05L and 05R left-hand circuits, solar reflections with a maximum of 'low potential for temporary after-image' are predicted from the solar panels. Considering the associated guidance pertaining to approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for circuit paths.

A low impact is therefore predicted, and no mitigation is required.

8.5 Glass Roof Lights

The glass roof lights were assessed for completeness using the same parameters as the solar panels presented in Section 6, with the azimuth angle varied accordingly. The areas assessed are presented in Figure 12 below, whereby the rooftop areas have been assessed as single reflector areas to account for the glass roof lights and solar panel areas on the north east facing rooftop, and the larger number of roof lights on the south western facing rooftop.

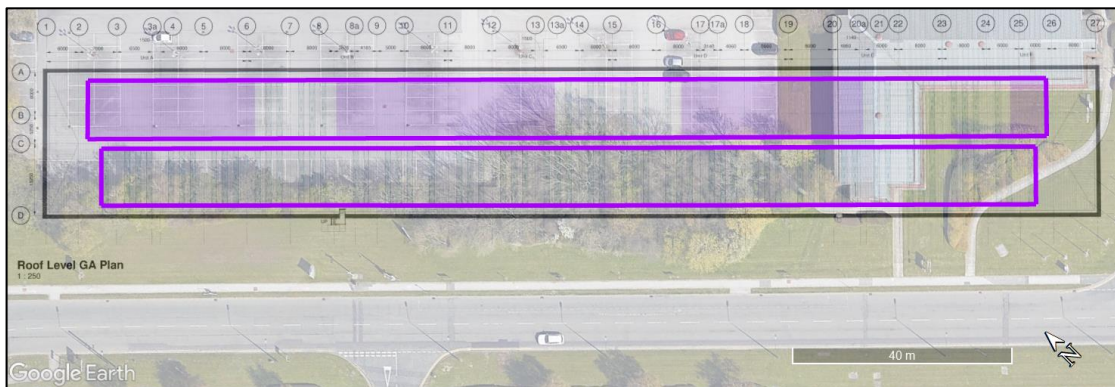


Figure 12 Whole rooftop areas considering solar panel areas and glass roof lights

The modelling has shown that north western panel area assessed as solar panels and roof light combined would produce solar reflections with a maximum of 'low potential for temporary after-image' towards the approach paths, and visual circuits, in keeping with the results for the solar panel areas individually. This level of glare is acceptable considering the associated guidance and industry best practice, and no mitigation is required.

However, whilst the results for the south western facing rooftop area were the same for the approach paths and visual circuits, the analysis showed that the rooftop would also produce solar reflections towards the ATC Tower. The solar reflection chart for this rooftop is presented in Figure 13 on the following page.

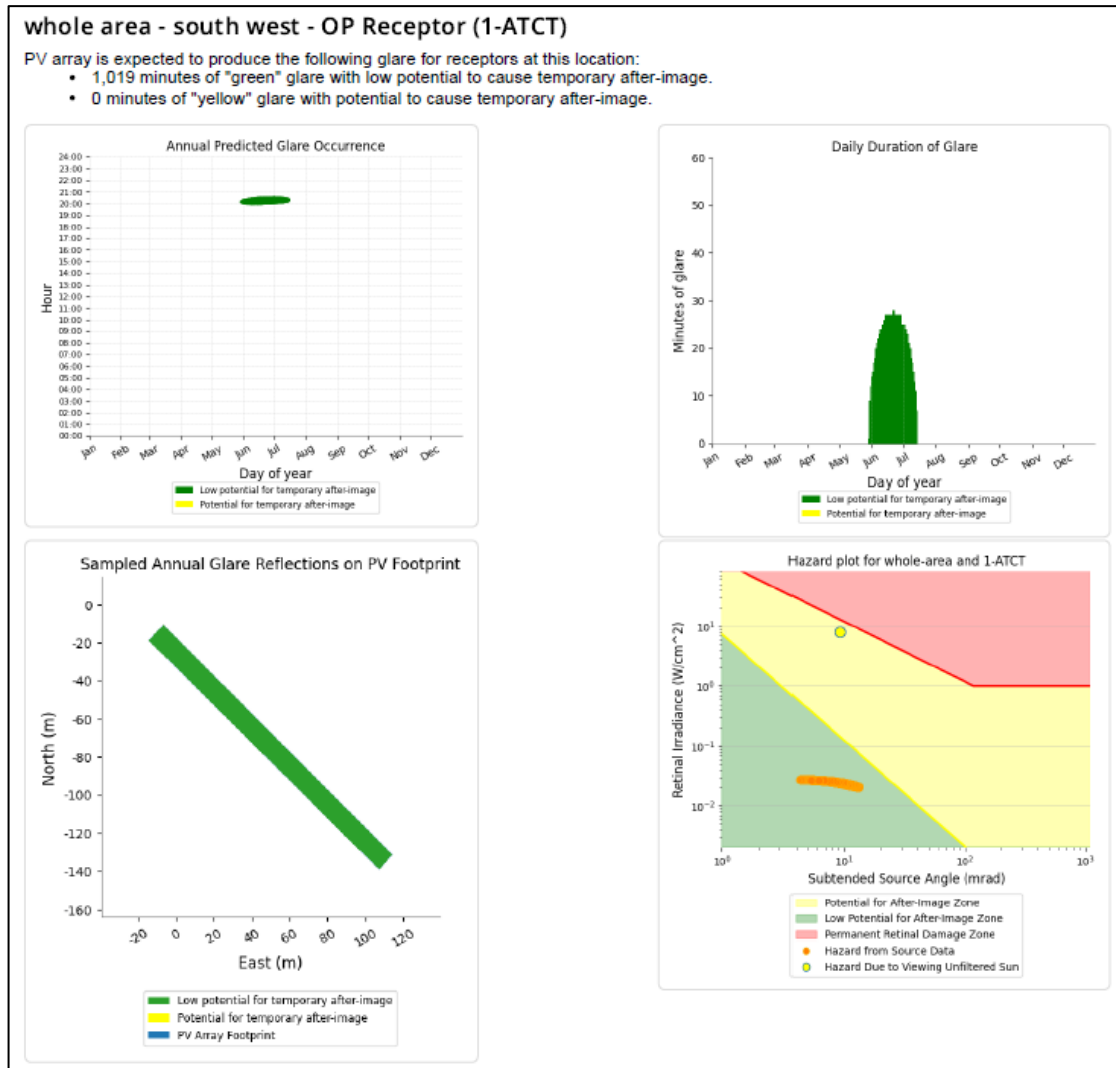


Figure 13 Solar reflection chart for the south west rooftop with respect to the ATC Tower

In accordance with the associated guidance and industry best practice, any predicted glare towards an ATC Tower is not acceptable. Pager Power however recommends a pragmatic approach, especially in this instance whereby the solar reflection would occur for a small percentage of the year (approximately 0.4% of daylight hours¹⁰) and would not originate from an operationally sensitive location. The development will also be replacing an existing car park area, which would have vehicles located within it capable of producing similarly intense reflections; however views from the ATC Tower towards the car park appear unlikely.

Therefore it is recommended that consultation is held with MAG to understand their position with respect to the proposed roof lights.

¹⁰ Assuming, on average, 12 hours of daylight per day per year.

8.6 Additional MAG Receptors

Pager Power is aware of additional receptors requested by MAG for new developments requiring glint and glare assessment in the vicinity of their airports. This now includes a request for additional modelling of circuits, extended approach paths, an extended climb out, and an area of airspace above the development at 2,500ft. The analysis in this report is based on the original modelling of the 2-mile approach paths and the ATC Tower, with the additional modelling of the nearest circuits modelled at 1nm width at 1,000ft. The results of the analysis presented in this report gives the author strong evidence to show that modelling of the additional receptors requested by MAG would give no stronger intensity than 'low potential for temporary after-image', thus the results would be acceptable considering the associated guidance.

9 OVERALL CONCLUSIONS

9.1 Overall Conclusions and Recommendations

No significant impact upon pilots approaching runway 25L or 25R, or within the visual circuits, is predicted considering the modelled intensity of any visible solar reflection from the assessed solar panel areas (low potential for temporary after-image). In accordance with the associated guidance, no significant impact is predicted, and no mitigation is required.

No impact upon the visual control room within the ATC Tower, or pilots approaching runway 05L or 05R at Manchester Airport is predicted as no solar reflection is possible from the proposed solar panel areas. No mitigation is required.

Solar reflections are predicted from the south west facing rooftop towards the ATC Tower, which consists of glass roof lights. In accordance with the associated guidance and industry best practice, any predicted glare towards an ATC Tower is not acceptable. Pager Power however recommends a pragmatic approach, and recommends that consultation is held with MAG to understand their position with respect to the proposed roof lights.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as 'Glint and Glare'.

This is not a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy¹¹ (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

...

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on **neighbouring uses and aircraft safety**;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;*

...

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

¹¹ [Renewable and low carbon energy](#), Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)¹² sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Section 2.52 states:

- '2.52.1 Solar panels may reflect the sun's rays, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.*
- 2.52.2 In some instances, it may be necessary to seek a glint and glare assessment as part of the application. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts. The potential for solar PV panels, frames and supports to have a combined reflective quality should be assessed. This assessment needs to consider the likely reflective capacity of all of the materials used¹³ in the construction of the solar PV farm.*
- 2.52.3 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to be of a non-glare/ non-reflective type and the front face of the panels to comprise of (or be covered) with a non-reflective coating for the lifetime of the permission.*
- 2.52.4 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes and motorists.*
- 2.52.5 There is no evidence that glint and glare from solar farms interferes in any way with aviation navigation or pilot and aircraft visibility or safety. Therefore, the Secretary of State is unlikely to have to give any weight to claims of aviation interference as a result of glint and glare from solar farms.'*

Consultation to determine whether EN-3 provides a suitable framework to support decision making for nationally significant energy infrastructure ended in November 2021. Pager Power is aware that aviation stakeholders were not consulted prior to the publication of the draft policy and understands that they will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the draft policy will change in light of the consultation responses from aviation stakeholders.

Finally, it should be noted that the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

¹² Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Business, Energy & Industrial Strategy, date: September 2021, accessed on: 01/11/2021.

¹³ In Pager Power's experience, the solar panels themselves are the overriding source of specular reflections which have the potential to cause significant impacts upon safety or amenity.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012¹⁴ however the advice is still applicable¹⁵ until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH¹⁶, as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

¹⁴ Archived at Pager Power

¹⁵ Reference email from the CAA dated 19/05/2014.

¹⁶ Aerodrome Licence Holder.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'¹⁷, the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'¹⁸, and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'¹⁹.

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts.

¹⁷ Archived at Pager Power

¹⁸ [Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports](#), Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 08/12/2021.

¹⁹ [Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports](#), Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'²⁰. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- *Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness²¹.*
- *The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.*
- *As illustrated on Figure 16²², flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.*
- *Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location*

²⁰ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

²¹ Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.

²² First figure in Appendix B.

and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:

- A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;
- A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
- A geometric analysis to determine days and times when an impact is predicted.
- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.
- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.
- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this

distance is directly proportional to the size of the array in question²³ but still requires further research to definitively answer.

- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

²³ Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016²⁴ with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

- (a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or
- (b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

- (a) to extinguish or screen the light; and
- (b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.

²⁴ The Air Navigation Order 2016. [online] Available at:
<<https://www.legislation.gov.uk/uksi/2016/765/contents/made>> [Accessed 4 February 2022].

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

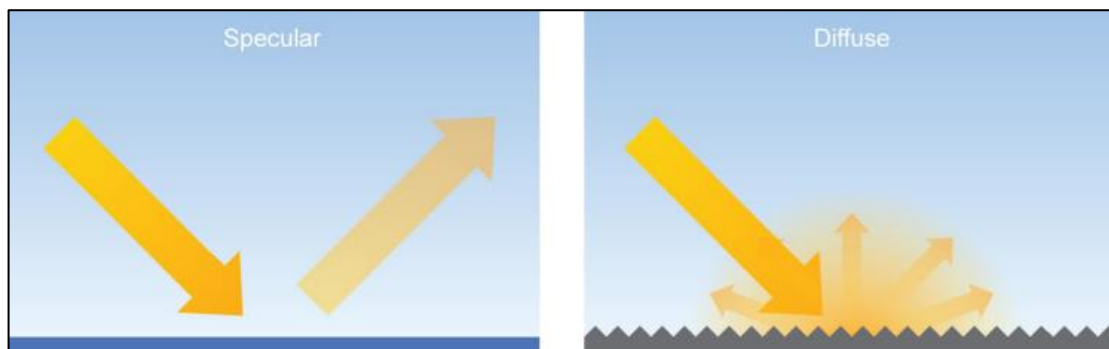
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels and glass. An overview of these studies is presented below.

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance²⁵, illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.



Specular and diffuse reflections

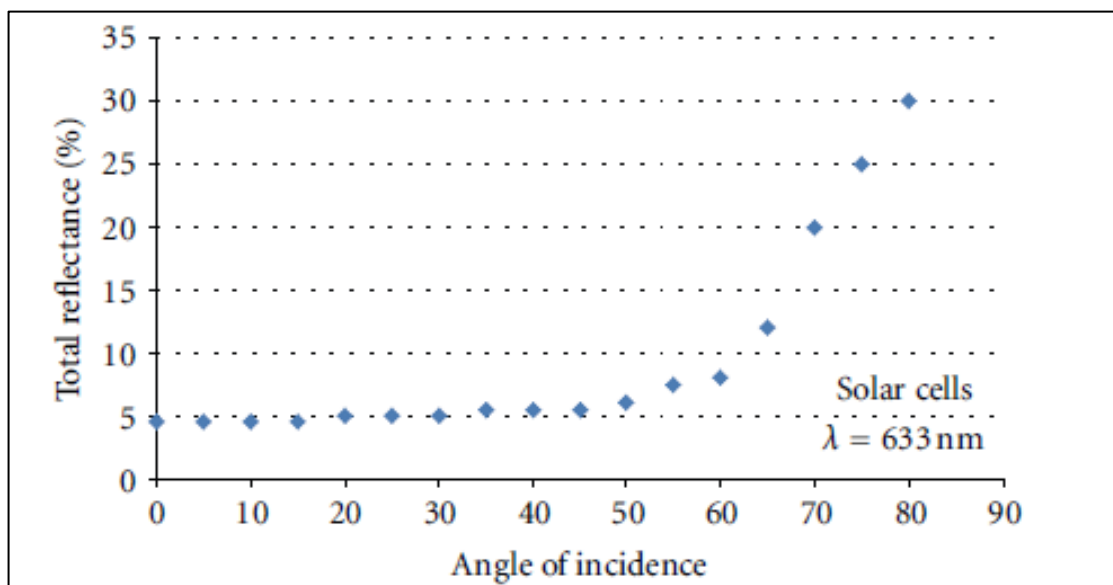
²⁵ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*²⁶. They researched the potential glare that a pilot could experience from a 25-degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

²⁶ Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

FAA Guidance – “Technical Guidance for Evaluating Selected Solar Technologies on Airports”²⁷

The 2018 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected ²⁸
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

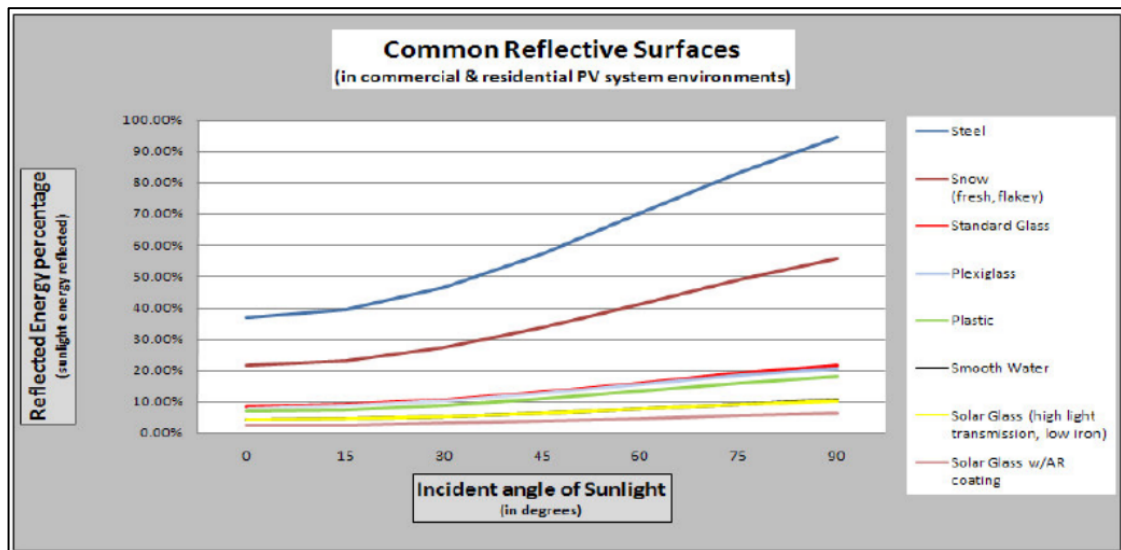
²⁷ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

²⁸ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification²⁹ to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of 'standard glass and other common reflective surfaces'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

²⁹ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time.
- Date.
- Latitude.
- Longitude.

The following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time.
- The Sun rises highest on 21 June (longest day).
- On 21 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector.

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact Significance Definition

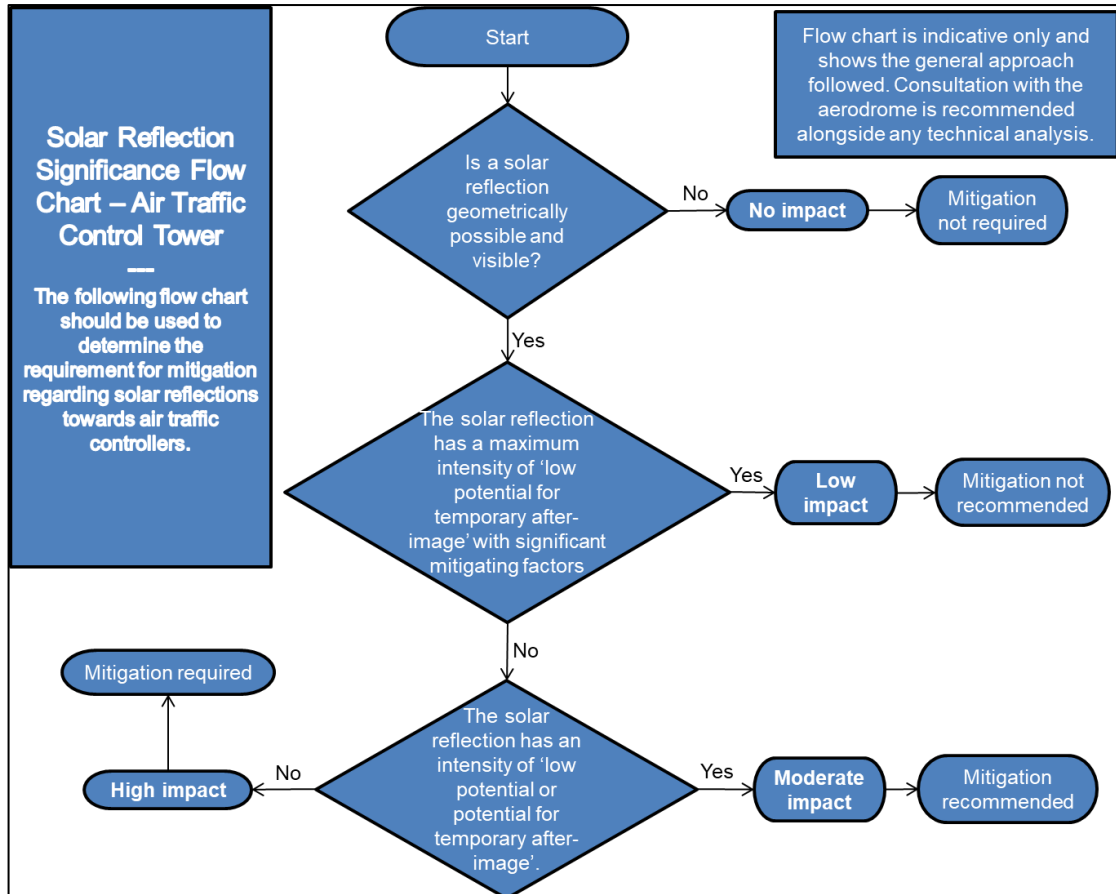
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Assessment Process – ATC Tower

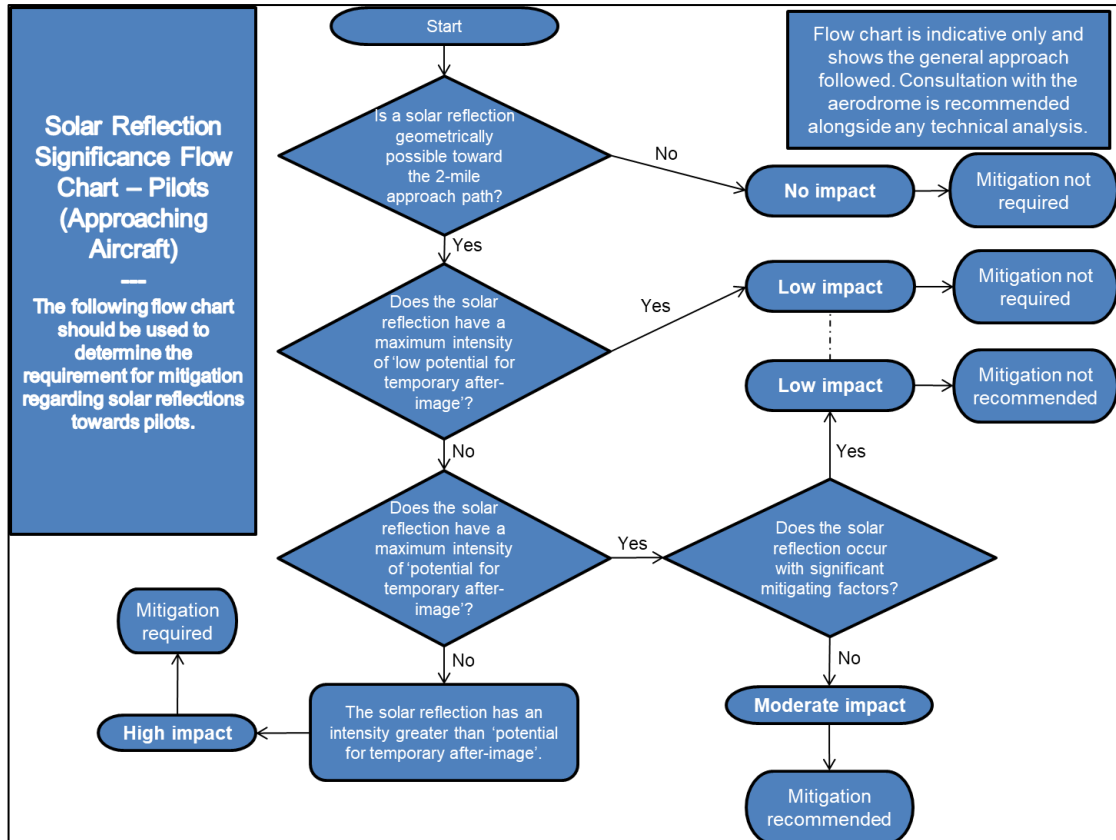
The assessment process for determining the potential impact upon personnel within the ATC Tower is presented below.



ATC Tower mitigation requirement flow chart

Assessment Process for Approaching Aircraft

The assessment process for determining the potential impact upon pilots on an approach path is presented below.



Approaching aircraft receptor mitigation requirement flow chart

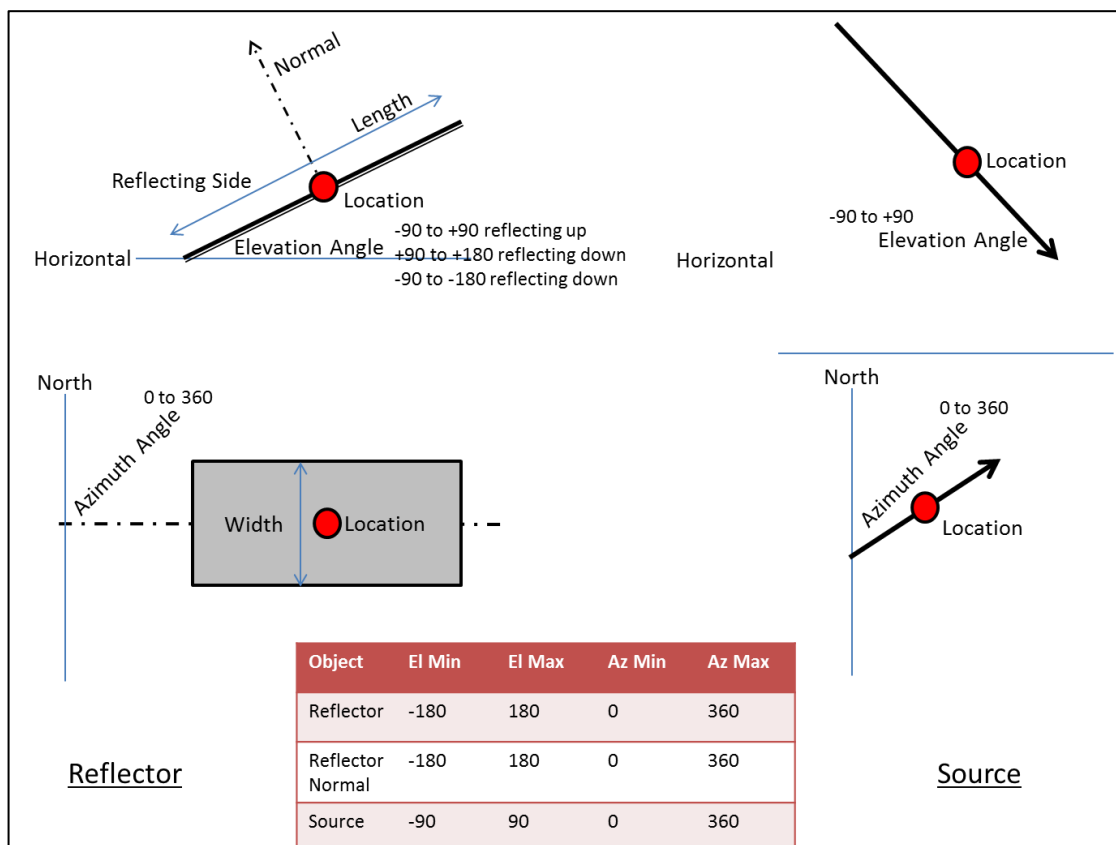
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power's Reflection Calculations Methodology

The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it. The diagram below may be used to aid understanding of the reflection calculation process.



Reflection calculation process

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;
- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
 - The angle between source and normal is equal to angle between normal and reflection;
 - Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

It is assumed that the panel azimuth angle provided by the developer represents the azimuth angle for all of the panels within each solar panel area defined.

Only a reflection from the face of the panel has been considered. The frame or the reverse of the solar panel has not been considered.

The model assumes that a receptor can view the face of every panel within the proposed development area whilst in reality this, in the majority of cases, will not occur. Therefore any predicted solar reflection from the face of a solar panel that is not visible to a receptor will not occur in practice.

A finite number of points within each solar panel area defined is chosen based on an assessment resolution so that a comprehensive understanding of the entire development can be formed. This determines whether a solar reflection could ever occur at a chosen receptor. The model does not consider the specific panel rows or the entire face of the solar panel within the development outline, rather a single point is defined every 'x' metres (based on the resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations.

A single reflection point is chosen for the geometric calculations. This suitably determines whether a solar reflection can be experienced at a receptor location and the time of year and duration of the solar reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

The available street view imagery, satellite mapping, terrain and any site imagery provided by the developer has been used to assess line of sight from the assessed receptors to the modelled solar panel area, unless stated otherwise. In some cases, this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not within the modelling unless stated otherwise. The terrain profile at the horizon is considered if stated.

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge³⁰ and is presented for reference.

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. 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.
4. 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.
5. 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.
6. 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.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the approximate total heights of the PV vertices. For increased accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not 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.
9. 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.
10. 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.
11. 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.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

³⁰ Source: <https://www.forgesolar.com/help/#assumptions>

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

ATC Receptor Details

Receptor	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
ATC Tower	-2.2797167	53.3574000	132.3

ATC Tower receptor details

Approach Receptors for Runway 05L

The table below presents the data for the assessed locations for aircraft on approach to runway 05L.

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
1	-2.2877640	53.3475560	Threshold	79.86
2	-2.2896436	53.3466471	0.1 miles	88.29
3	-2.2915230	53.3457382	0.2 miles	96.73
4	-2.2934024	53.3448293	0.3 miles	105.16
5	-2.2952818	53.3439204	0.4 miles	113.59
6	-2.2971610	53.3430114	0.5 miles	122.03
7	-2.2990402	53.3421024	0.6 miles	130.46
8	-2.3009193	53.3411933	0.7 miles	138.90
9	-2.3027983	53.3402843	0.8 miles	147.33
10	-2.3046772	53.3393752	0.9 miles	155.77
11	-2.3065560	53.3384660	1 mile	164.20
12	-2.3084348	53.3375569	1.1 miles	172.63
13	-2.3103135	53.3366477	1.2 miles	181.07
14	-2.3121921	53.3357385	1.3 miles	189.50
15	-2.3140706	53.3348292	1.4 miles	197.94
16	-2.3159490	53.3339199	1.5 miles	206.37
17	-2.3178274	53.3330106	1.6 miles	214.81
18	-2.3197057	53.3321013	1.7 miles	223.24

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
19	-2.3215839	53.3311919	1.8 miles	231.67
20	-2.3234620	53.3302825	1.9 miles	240.11
21	-2.3253401	53.3293731	2 miles	248.54

Assessed receptor (aircraft) locations on the approach path for runway 05L

Approach Receptors for Runway 23R

The table below presents the data for the assessed locations for aircraft on approach to runway 23R.

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
1	-2.2592806	53.3613194	Threshold	91.14
2	-2.2573996	53.3622276	0.1 miles	99.57
3	-2.2555184	53.3631359	0.2 miles	108.00
4	-2.2536372	53.3640440	0.3 miles	116.44
5	-2.2517559	53.3649522	0.4 miles	124.87
6	-2.2498746	53.3658603	0.5 miles	133.31
7	-2.2479931	53.3667684	0.6 miles	141.74
8	-2.2461116	53.3676765	0.7 miles	150.17
9	-2.2442300	53.3685845	0.8 miles	158.61
10	-2.2423483	53.3694925	0.9 miles	167.04
11	-2.2404666	53.3704005	1 mile	175.48
12	-2.2385847	53.3713084	1.1 miles	183.91
13	-2.2367028	53.3722163	1.2 miles	192.35
14	-2.2348208	53.3731242	1.3 miles	200.78
15	-2.2329387	53.3740321	1.4 miles	209.21
16	-2.2310566	53.3749399	1.5 miles	217.65
17	-2.2291743	53.3758477	1.6 miles	226.08
18	-2.2272920	53.3767555	1.7 miles	234.52
19	-2.2254096	53.3776632	1.8 miles	242.95

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
20	-2.2235271	53.3785709	1.9 miles	251.39
21	-2.2216445	53.3794786	2 miles	259.82

Assessed receptor (aircraft) locations on the approach path for runway 23R.

Approach Receptors for Runway 05R

The table below presents the data for the assessed locations for aircraft on approach to runway 05R.

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
1	-2.3106611	53.3319722	Threshold	71.93
2	-2.3125394	53.3310629	0.1 miles	80.37
3	-2.3144177	53.3301537	0.2 miles	88.80
4	-2.3162959	53.3292443	0.3 miles	97.24
5	-2.3181740	53.3283350	0.4 miles	105.67
6	-2.3200520	53.3274256	0.5 miles	114.10
7	-2.3219300	53.3265162	0.6 miles	122.54
8	-2.3238079	53.3256068	0.7 miles	130.97
9	-2.3256856	53.3246973	0.8 miles	139.41
10	-2.3275633	53.3237878	0.9 miles	147.84
11	-2.3294410	53.3228783	1 mile	156.27
12	-2.3313185	53.3219687	1.1 miles	164.71
13	-2.3331960	53.3210591	1.2 miles	173.14
14	-2.3350734	53.3201495	1.3 miles	181.58
15	-2.3369507	53.3192399	1.4 miles	190.01
16	-2.3388279	53.3183302	1.5 miles	198.45
17	-2.3407051	53.3174205	1.6 miles	206.88
18	-2.3425821	53.3165108	1.7 miles	215.31
19	-2.3444591	53.3156010	1.8 miles	223.75
20	-2.3463360	53.3146912	1.9 miles	232.18

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
21	-2.3482129	53.3137814	2 miles	240.62

Assessed receptor (aircraft) locations on the approach path for runway 05R

Approach Receptors for Runway 23L

The table below presents the data for the assessed locations for aircraft on approach to runway 23L.

No.	Longitude (°)	Latitude (°)	Distance from RWY Threshold	Assessed Altitude (m amsl)
1	-2.2772083	53.3481528	Threshold	84.43
2	-2.2753284	53.3490614	0.1 miles	92.86
3	-2.2734484	53.3499700	0.2 miles	101.30
4	-2.2715683	53.3508786	0.3 miles	109.73
5	-2.2696881	53.3517872	0.4 miles	118.17
6	-2.2678078	53.3526957	0.5 miles	126.60
7	-2.2659275	53.3536042	0.6 miles	135.03
8	-2.2640471	53.3545126	0.7 miles	143.47
9	-2.2621666	53.3554211	0.8 miles	151.90
10	-2.2602860	53.3563295	0.9 miles	160.34
11	-2.2584054	53.3572378	1 mile	168.77
12	-2.2565246	53.3581462	1.1 miles	177.21
13	-2.2546438	53.3590545	1.2 miles	185.64
14	-2.2527629	53.3599628	1.3 miles	194.07
15	-2.2508820	53.3608710	1.4 miles	202.51
16	-2.2490009	53.3617792	1.5 miles	210.94
17	-2.2471198	53.3626874	1.6 miles	219.38
18	-2.2452386	53.3635956	1.7 miles	227.81
19	-2.2433573	53.3645037	1.8 miles	236.25
20	-2.2414759	53.3654118	1.9 miles	244.68
21	-2.2395944	53.3663199	2 miles	253.11

Assessed receptor (aircraft) locations on the approach path for runway 23L

The Runway 05R Right-Hand/23L Left-Hand Circuit

The table below presents the data for the assessed locations for aircraft circuiting the right-hand side of runway 05R or the left-hand side of the runway 23L circuit.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
1	-2.27721	53.34815	56.69
2	-2.27390	53.34975	81.44
3	-2.27059	53.35136	106.20
4	-2.26727	53.35296	130.95
5	-2.26329	53.35320	155.70
6	-2.25905	53.35294	180.45
7	-2.25546	53.35197	205.20
8	-2.25277	53.34999	229.95
9	-2.25009	53.34801	254.70
10	-2.24784	53.34596	279.45
11	-2.24829	53.34343	304.21
12	-2.24873	53.34090	328.96
13	-2.25154	53.33913	353.71
14	-2.25485	53.33753	378.46
15	-2.25816	53.33593	383.13
16	-2.26147	53.33433	383.13
17	-2.26479	53.33273	383.13
18	-2.26810	53.33112	383.13
19	-2.27141	53.32952	383.13
20	-2.27472	53.32792	383.13
21	-2.27803	53.32632	383.13
22	-2.28134	53.32472	383.13
23	-2.28465	53.32312	383.13
24	-2.28796	53.32152	383.13
25	-2.29127	53.31991	383.13

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
26	-2.29459	53.31831	383.13
27	-2.29790	53.31671	383.13
28	-2.30121	53.31511	366.21
29	-2.30468	53.31383	341.45
30	-2.30892	53.31410	316.70
31	-2.31316	53.31437	291.95
32	-2.31606	53.31610	267.20
33	-2.31874	53.31808	242.45
34	-2.32142	53.32006	217.70
35	-2.32227	53.32236	192.95
36	-2.32182	53.32489	168.19
37	-2.32059	53.32717	143.44
38	-2.31728	53.32877	118.69
39	-2.31397	53.33037	93.94
40	-2.31066	53.33197	69.19

Assessed receptor (aircraft) locations on the 05R Right-Hand/23L Left-Hand circuit

The Runway 05R Left-Hand/23L Right-Hand Circuit

The table below presents the data for the assessed locations for aircraft circuiting the left-hand side of runway 05R or the right-hand side of the runway 23L circuit.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
41	-2.27721	53.34815	56.69
42	-2.27390	53.34975	81.44
43	-2.27059	53.35136	106.20
44	-2.26727	53.35296	130.95
45	-2.26605	53.35523	155.70
46	-2.26560	53.35776	180.45
47	-2.26645	53.36007	205.20
48	-2.26913	53.36204	229.95

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
49	-2.27181	53.36402	254.70
50	-2.27471	53.36576	279.45
51	-2.27895	53.36602	304.21
52	-2.28319	53.36629	328.96
53	-2.28666	53.36502	353.71
54	-2.28997	53.36341	378.46
55	-2.29328	53.36181	383.13
56	-2.29659	53.36021	383.13
57	-2.29991	53.35861	383.13
58	-2.30322	53.35701	383.13
59	-2.30653	53.35541	383.13
60	-2.30984	53.35380	383.13
61	-2.31315	53.35220	383.13
62	-2.31646	53.35060	383.13
63	-2.31977	53.34900	383.13
64	-2.32308	53.34740	383.13
65	-2.32639	53.34580	383.13
66	-2.32971	53.34420	383.13
67	-2.33302	53.34259	383.13
68	-2.33633	53.34099	366.21
69	-2.33914	53.33923	341.45
70	-2.33958	53.33670	316.70
71	-2.34003	53.33417	291.95
72	-2.33778	53.33211	267.20
73	-2.33510	53.33014	242.45
74	-2.33241	53.32816	217.70
75	-2.32882	53.32719	192.95
76	-2.32458	53.32692	168.19

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
77	-2.32059	53.32717	143.44
78	-2.31728	53.32877	118.69
79	-2.31397	53.33037	93.94
80	-2.31066	53.33197	69.19

Assessed receptor (aircraft) locations on the 05R Left-Hand/23L Right-Hand circuit

The Runway 05L Right-Hand/23R Left-Hand Circuit

The table below presents the data for the assessed locations for aircraft circuiting the right-hand side of runway 05L or the left-hand side of the runway 23R circuit.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
81	-2.25928	53.36132	75.90
82	-2.25610	53.36286	99.69
83	-2.25291	53.36440	123.49
84	-2.24973	53.36594	147.28
85	-2.24818	53.36801	171.08
86	-2.24775	53.37044	194.87
87	-2.24789	53.37277	218.67
88	-2.25047	53.37467	242.46
89	-2.25305	53.37657	266.26
90	-2.25562	53.37848	290.05
91	-2.25938	53.37909	313.85
92	-2.26345	53.37934	337.64
93	-2.26719	53.37893	361.44
94	-2.27038	53.37739	383.13
95	-2.27356	53.37585	383.13
96	-2.27675	53.37431	383.13
97	-2.27993	53.37277	383.13
98	-2.28312	53.37123	383.13
99	-2.28630	53.36969	383.13

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
100	-2.28949	53.36815	383.13
101	-2.29267	53.36661	383.13
102	-2.29586	53.36507	383.13
103	-2.29904	53.36353	383.13
104	-2.30223	53.36200	383.13
105	-2.30541	53.36046	383.13
106	-2.30860	53.35892	383.13
107	-2.31178	53.35738	373.96
108	-2.31497	53.35584	350.16
109	-2.31643	53.35374	326.37
110	-2.31686	53.35131	302.57
111	-2.31664	53.34899	278.78
112	-2.31406	53.34709	254.98
113	-2.31148	53.34519	231.19
114	-2.30890	53.34329	207.39
115	-2.30511	53.34272	183.59
116	-2.30103	53.34247	159.80
117	-2.29732	53.34294	136.00
118	-2.29413	53.34448	112.21
119	-2.29095	53.34602	88.41
120	-2.28776	53.34756	64.62

Assessed receptor (aircraft) locations on the 05L Right-Hand/23R Left-Hand circuit

The Runway 05L Left-Hand/23R Right-Hand Circuit

The table below presents the data for the assessed locations for aircraft circuiting the left-hand side of runway 05L or the right-hand side of the runway 23R circuit.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
121	-2.25928	53.36132	75.90
122	-2.25610	53.36286	99.69
123	-2.25291	53.36440	123.49
124	-2.24973	53.36594	147.28
125	-2.24601	53.36641	171.08
126	-2.24193	53.36615	194.87
127	-2.23814	53.36559	218.67
128	-2.23556	53.36368	242.46
129	-2.23298	53.36178	266.26
130	-2.23040	53.35988	290.05
131	-2.23018	53.35756	313.85
132	-2.23061	53.35513	337.64
133	-2.23208	53.35304	361.44
134	-2.23526	53.35150	383.13
135	-2.23845	53.34996	383.13
136	-2.24163	53.34842	383.13
137	-2.24482	53.34688	383.13
138	-2.24800	53.34534	383.13
139	-2.25119	53.34380	383.13
140	-2.25437	53.34226	383.13
141	-2.25756	53.34072	383.13
142	-2.26074	53.33918	383.13
143	-2.26393	53.33764	383.13
144	-2.26711	53.33611	383.13
145	-2.27030	53.33457	383.13

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
146	-2.27348	53.33303	383.13
147	-2.27667	53.33149	373.96
148	-2.27985	53.32995	350.16
149	-2.28359	53.32953	326.37
150	-2.28767	53.32979	302.57
151	-2.29142	53.33040	278.78
152	-2.29400	53.33230	254.98
153	-2.29658	53.33420	231.19
154	-2.29916	53.33610	207.39
155	-2.29929	53.33844	183.59
156	-2.29886	53.34087	159.80
157	-2.29732	53.34294	136.00
158	-2.29413	53.34448	112.21
159	-2.29095	53.34602	88.41
160	-2.28776	53.34756	64.62

Assessed receptor (aircraft) locations on the 05L Left-Hand/23R Right-Hand circuit

Reflector Area Data

Area 1

ID	Longitude	Latitude	ID	Longitude	Latitude
1	-2.29091	53.36332	3	-2.29069	53.36305
2	-2.29058	53.36312	4	-2.29103	53.36325

Reflector area data – area 1

Area 2

ID	Longitude	Latitude	ID	Longitude	Latitude
5	-2.29043	53.36303	7	-2.29010	53.36270
6	-2.28999	53.36277	8	-2.29054	53.36296

Reflector area data – area 2

Area 3

ID	Longitude	Latitude	ID	Longitude	Latitude
9	-2.28976	53.36263	11	-2.28950	53.36235
10	-2.28939	53.36241	12	-2.28987	53.36256

Reflector area data – area 3

Area 4

ID	Longitude	Latitude	ID	Longitude	Latitude
13	-2.28912	53.36225	15	-2.28915	53.36214
14	-2.28904	53.36220	16	-2.28923	53.36218

Reflector area data – area 4



APPENDIX H – DETAILED PAGER POWER MODELLING RESULTS

Overview

The Pager Power charts for the receptors are shown on the following pages. Each chart shows:

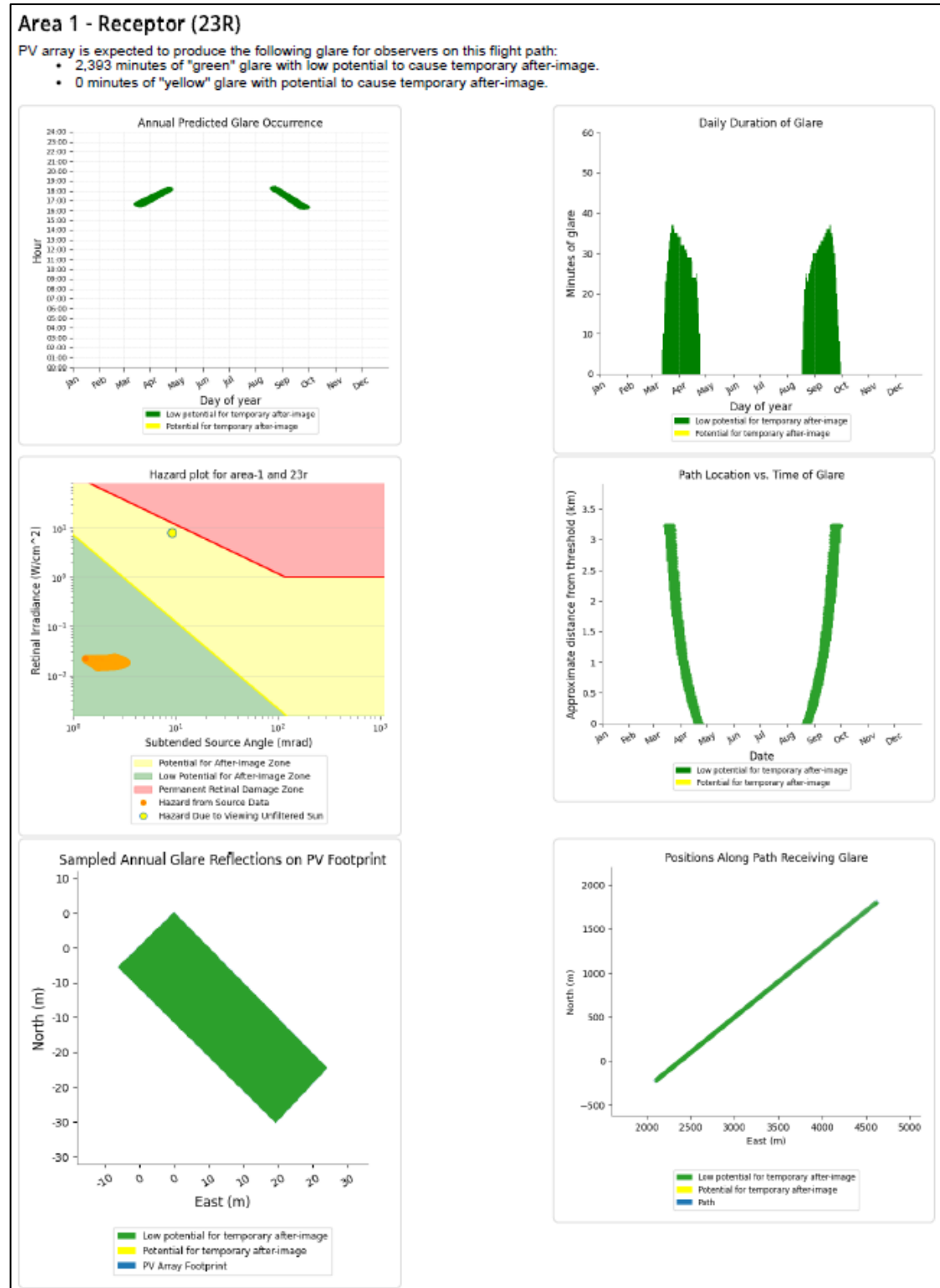
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Areas shown in orange are those where the Sun is obscured by terrain at the visible horizon and therefore no solar reflection could occur. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas only;
- The red and yellow lines show sunrise and sunset times respectively.

Each Forge chart shows:

- The reflection date/time graph – top left image. The chart shows the time at which glare at the corresponding intensities can occur;
- Duration of glare – top right image. The chart shows the duration for the corresponding glare intensities;
- Glare intensity graph – middle left image. Shows you the intensity of glare produced and the categorisation it falls within;
- Glare intensity graph – middle right image. Location on the approach path glare can be experienced over the year;
- The reflecting areas – bottom left image. Indicative only;
- Position on approach path receiving the associated glare intensity – bottom right image.

Runway Approach Path – 23R

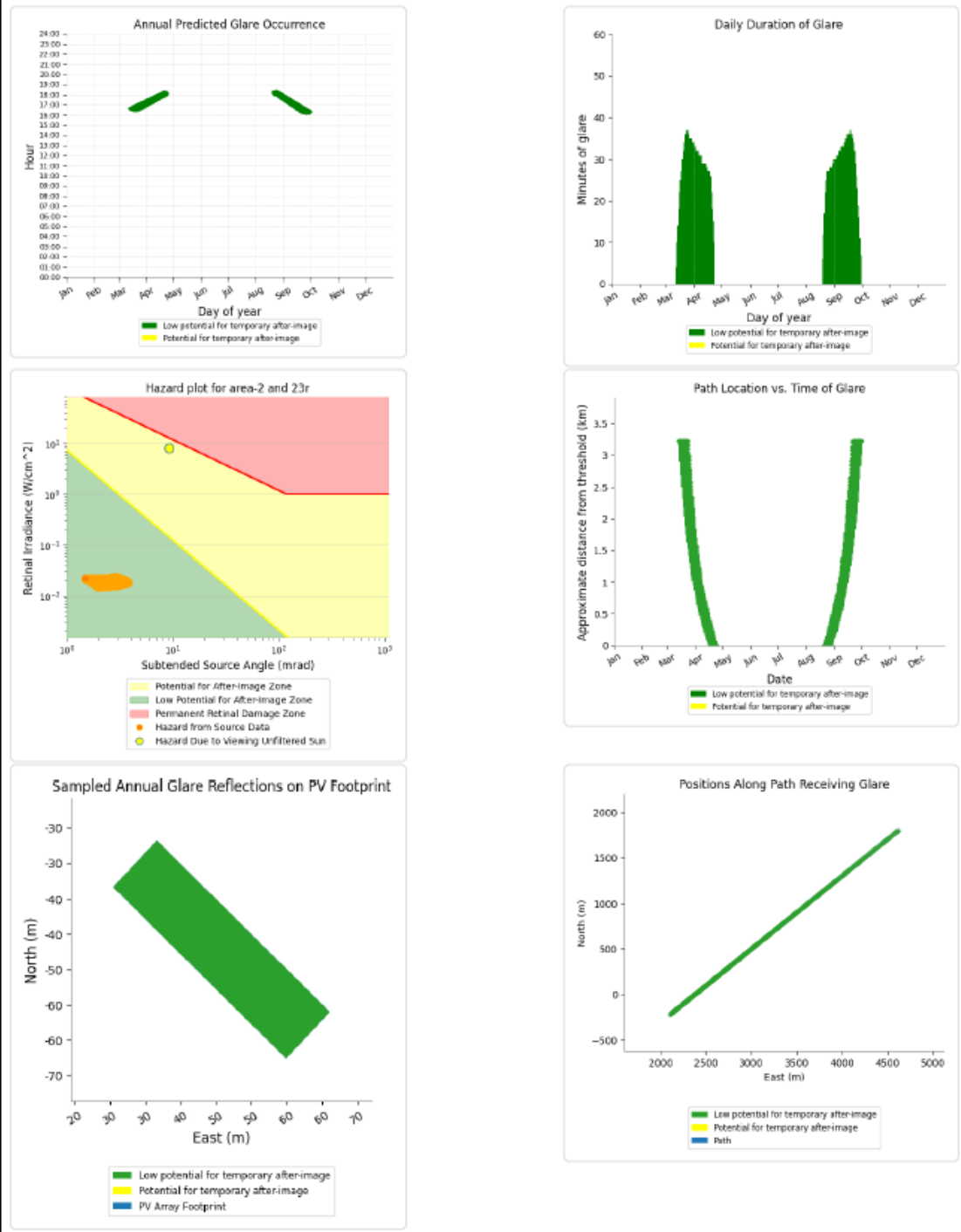
The Forge and Pager Power solar reflection charts for the runway 23R approach path are presented below.



Area 2 - Receptor (23R)

PV array is expected to produce the following glare for observers on this flight path:

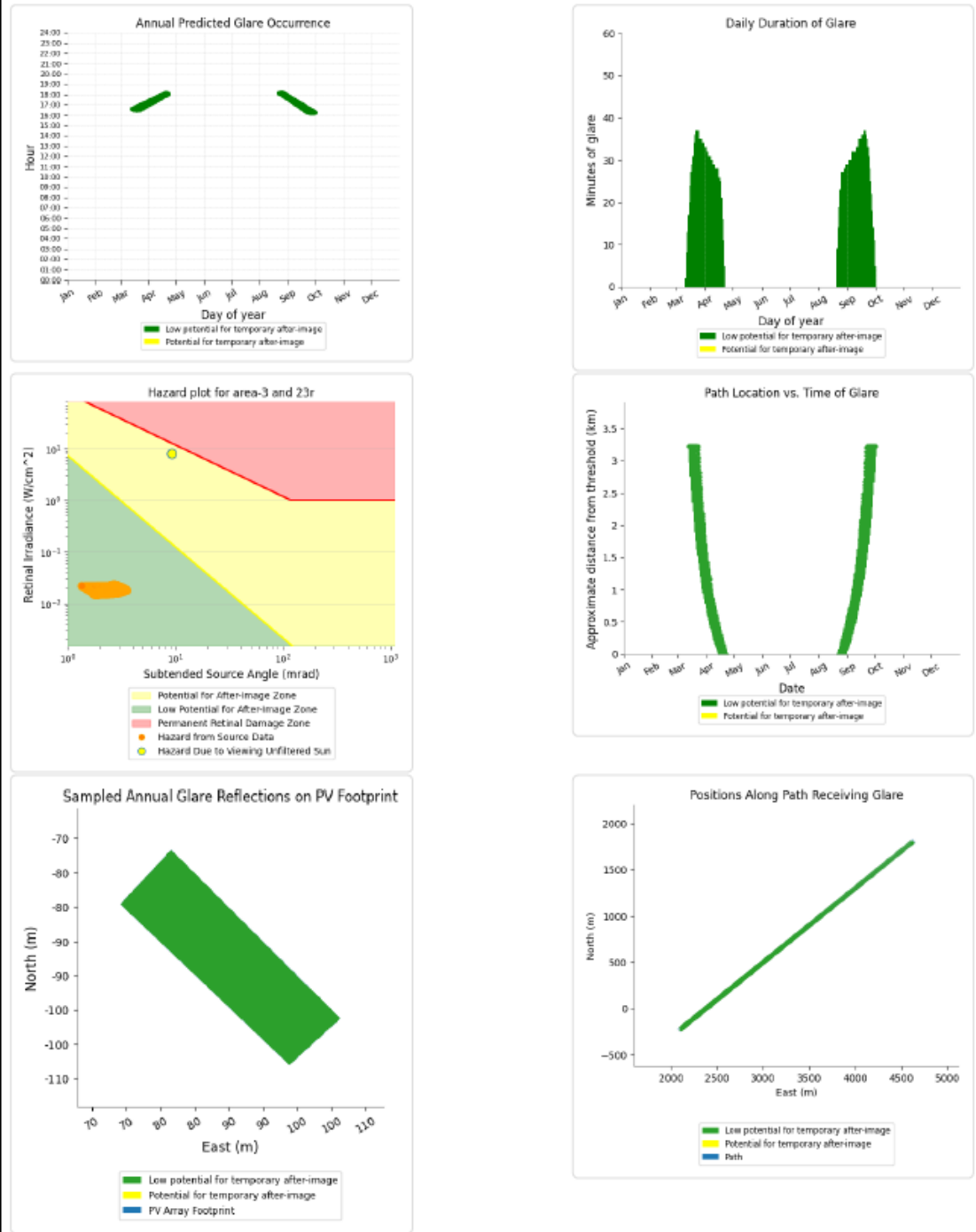
- 2,411 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 3 - Receptor (23R)

PV array is expected to produce the following glare for observers on this flight path:

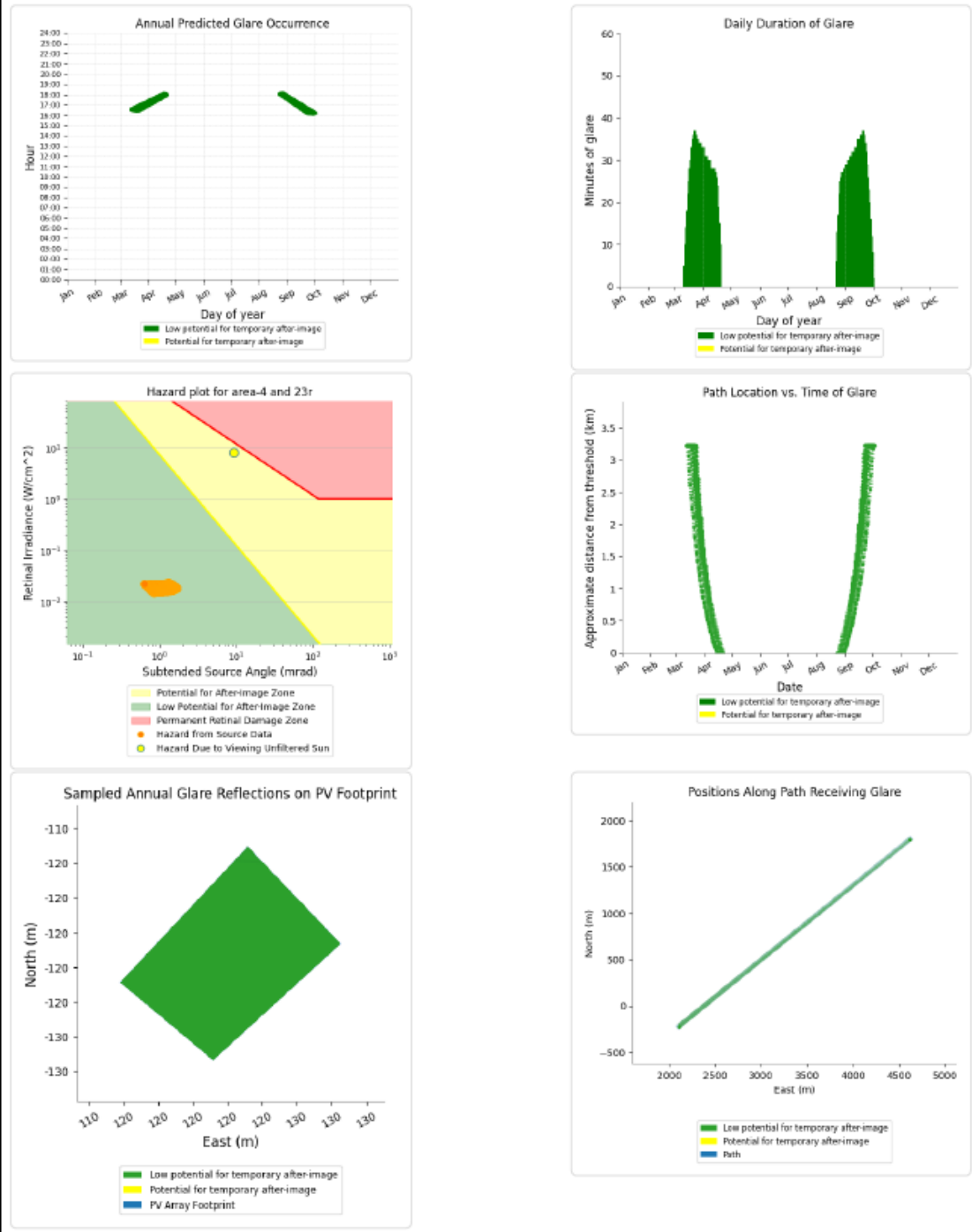
- 2,359 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 4 - Receptor (23R)

PV array is expected to produce the following glare for observers on this flight path:

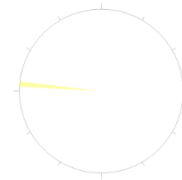
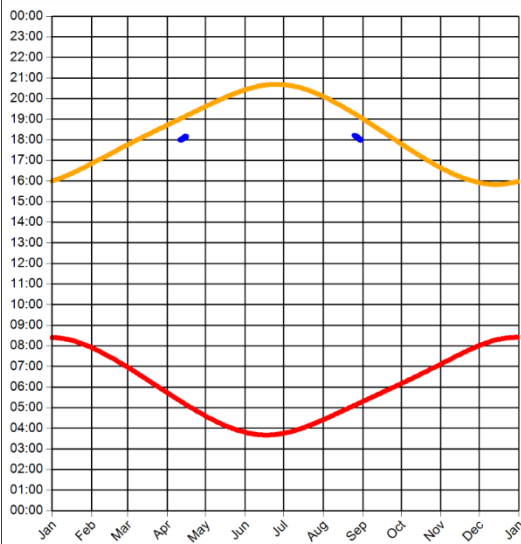
- 2,295 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Observer Runway 23R - 01 Results

Sun azimuth range is 273.1° - 276.8° (yellow)

Reflection Date/Time (GMT) Graph

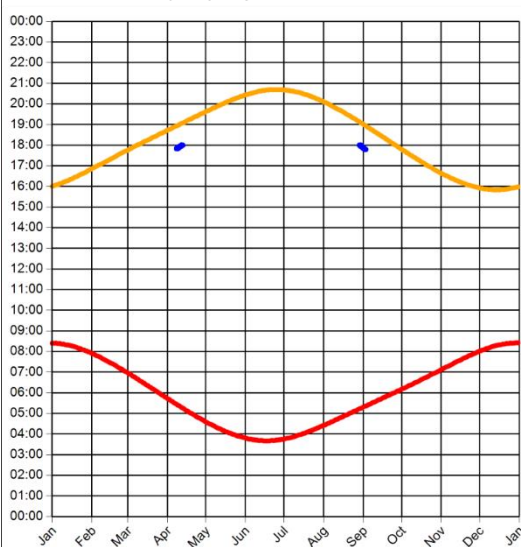


Observer Runway 23R - 02 Results

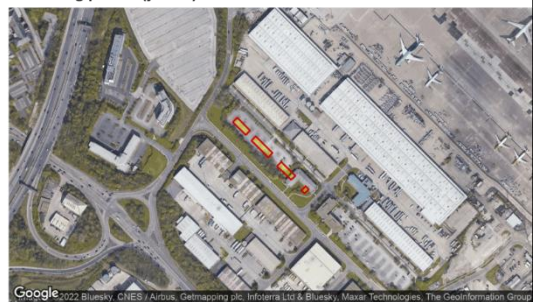
Observer Location

Sun azimuth range is 270.2° - 273.7° (yellow)

Reflection Date/Time (GMT) Graph

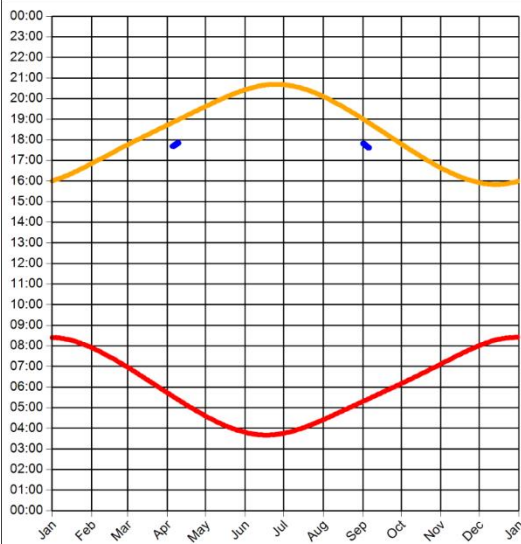


Reflecting panels (yellow)



Observer Runway 23R - 03 Results

Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 267.6° - 271.1° (yellow)

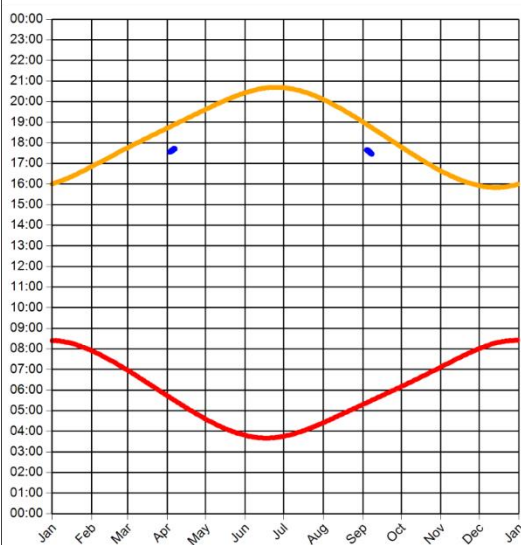


Reflecting panels (yellow)



Observer Runway 23R - 04 Results

Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 265.4° - 268.6° (yellow)

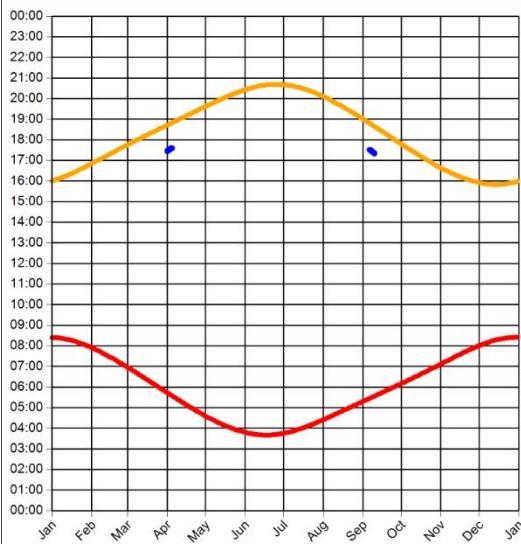


Reflecting panels (yellow)



Observer Runway 23R - 05 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 263.4° - 266.7° (yellow)

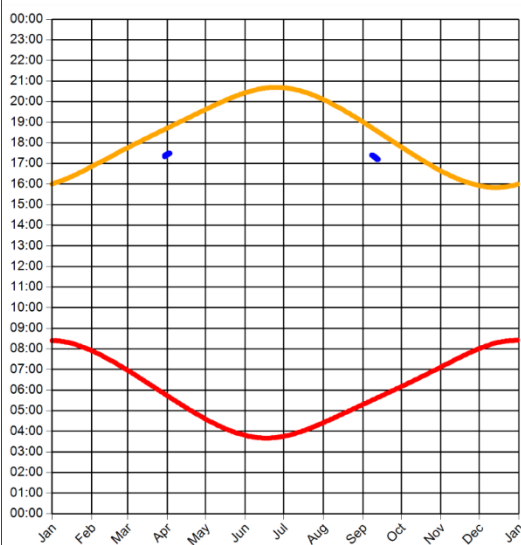


Reflecting panels (yellow)

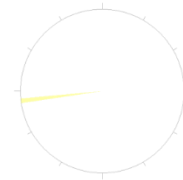


Observer Runway 23R - 06 Results

Reflection Date/Time (GMT) Graph

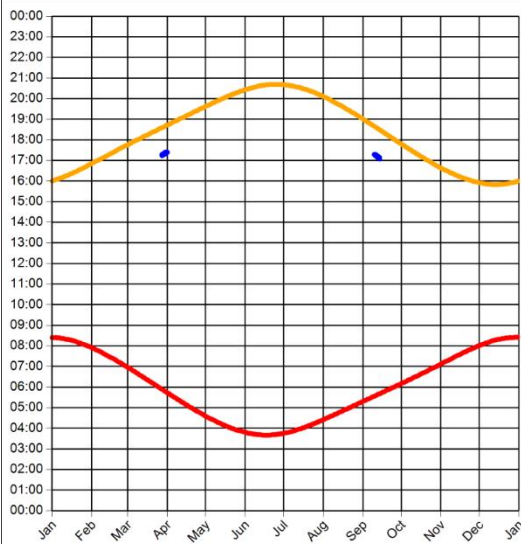


Sun azimuth range is 261.5° - 264.8° (yellow)



Observer Runway 23R - 07 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 259.9° - 263.1° (yellow)

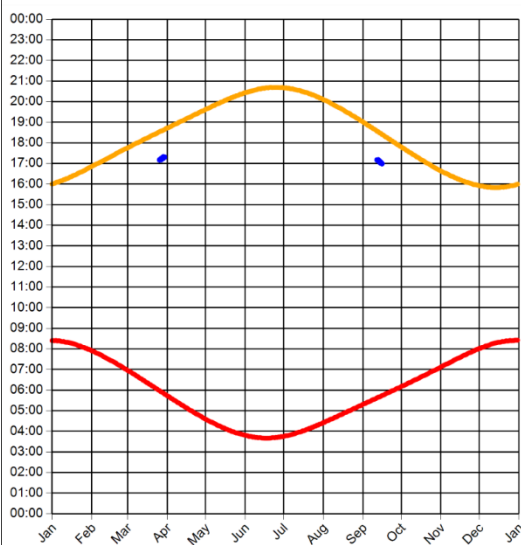


Reflecting panels (yellow)

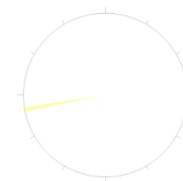


Observer Runway 23R - 08 Results

Reflection Date/Time (GMT) Graph

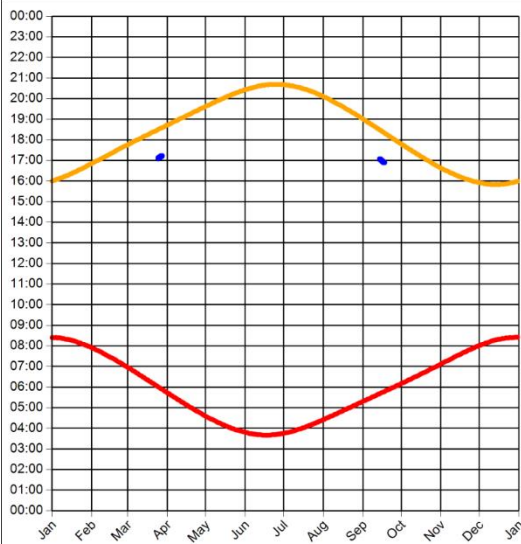


Sun azimuth range is 258.3° - 261.4° (yellow)



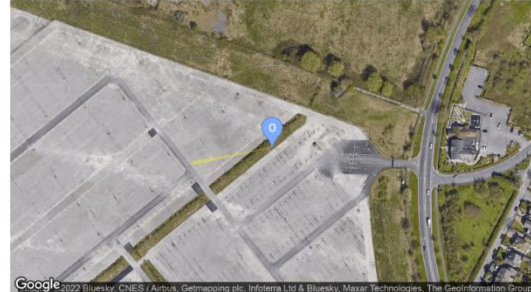
Observer Runway 23R - 09 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 257° - 259.8° (yellow)

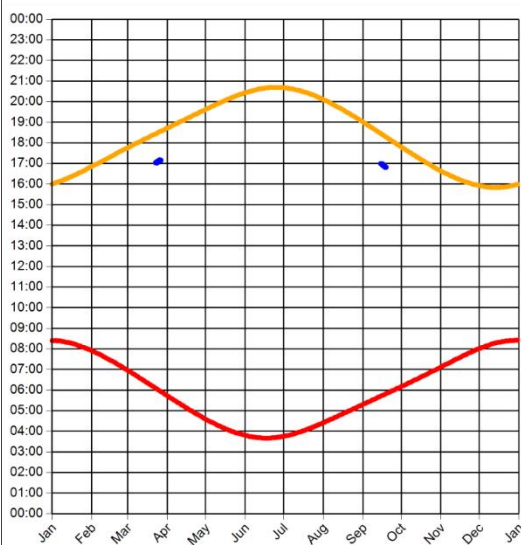


Reflecting panels (yellow)



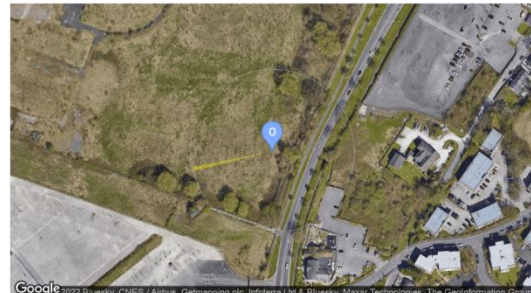
Observer Runway 23R - 10 Results

Reflection Date/Time (GMT) Graph

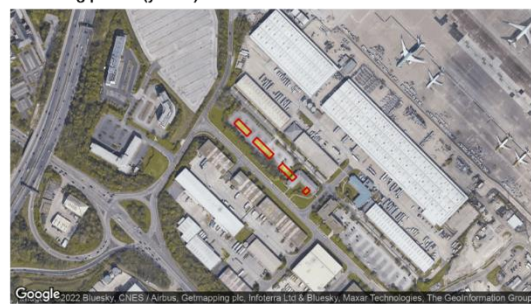


Observer Location

Sun azimuth range is 255.7° - 258.7° (yellow)

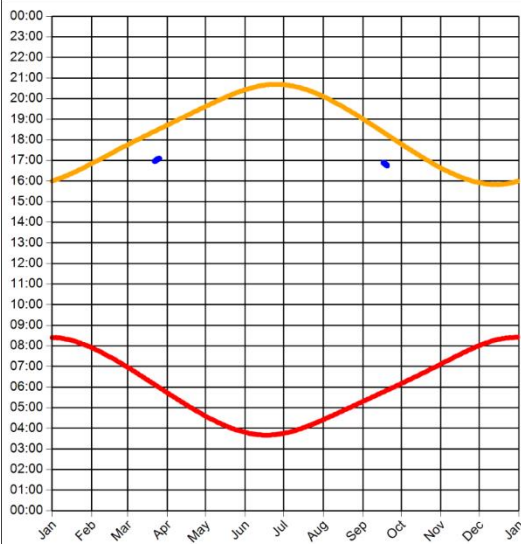


Reflecting panels (yellow)



Observer Runway 23R - 11 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 254.6° - 257.6° (yellow)

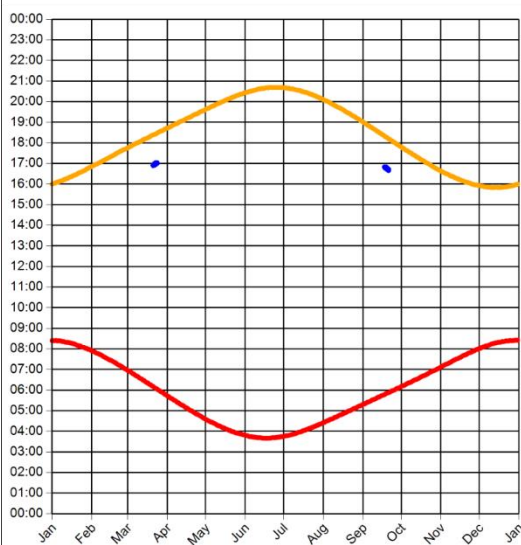


Reflecting panels (yellow)



Observer Runway 23R - 12 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 253.6° - 256.2° (yellow)



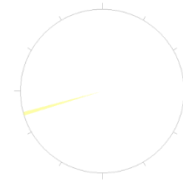
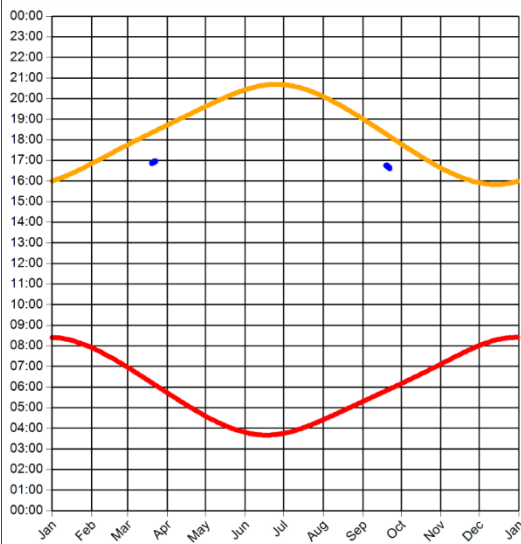
Reflecting panels (yellow)



Observer Runway 23R - 13 Results

Sun azimuth range is 252.6° - 255.2° (yellow)

Reflection Date/Time (GMT) Graph

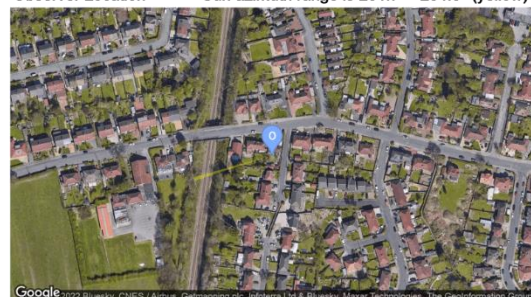
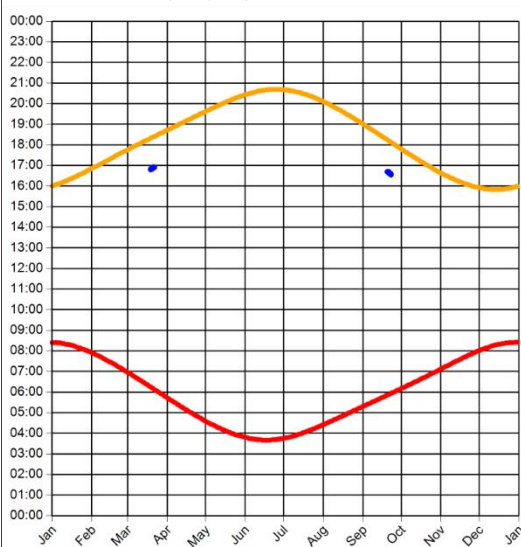


Observer Runway 23R - 14 Results

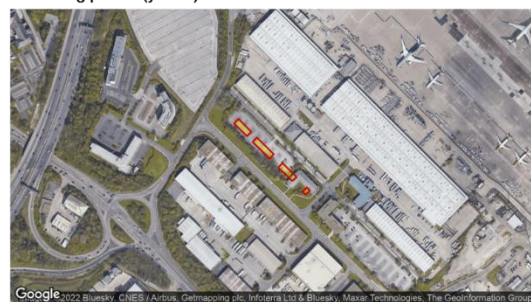
Observer Location

Sun azimuth range is 251.7° - 254.3° (yellow)

Reflection Date/Time (GMT) Graph

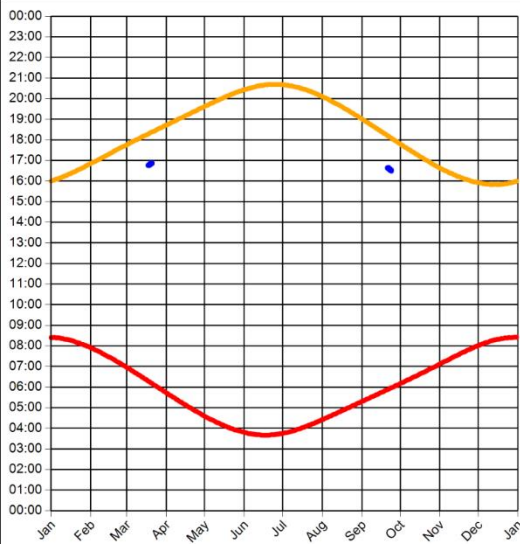


Reflecting panels (yellow)



Observer Runway 23R - 15 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 14.2°
Max observer difference angle: 15°

Observer Location Sun azimuth range is 250.9° - 253.4° (yellow)

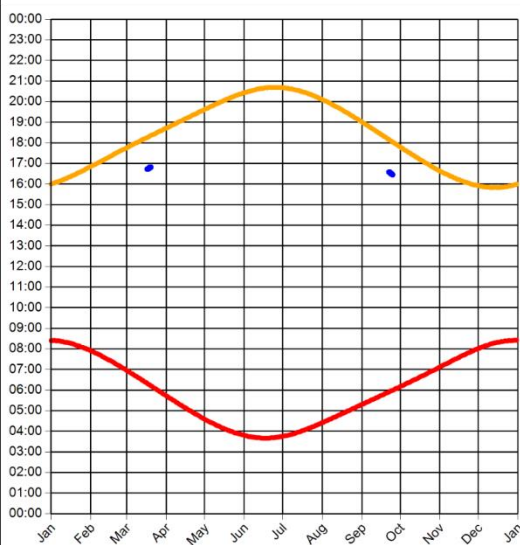


Reflecting panels (yellow)



Observer Runway 23R - 16 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 14.4°
Max observer difference angle: 15.1°

Observer Location Sun azimuth range is 250.1° - 252.5° (yellow)

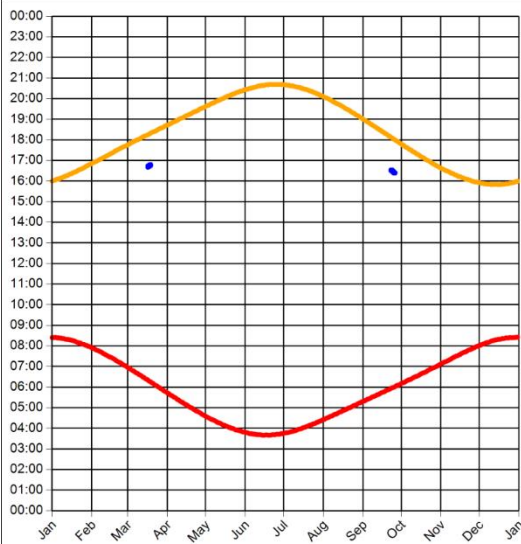


Reflecting panels (yellow)



Observer Runway 23R - 17 Results

Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 249.5° - 251.7° (yellow)

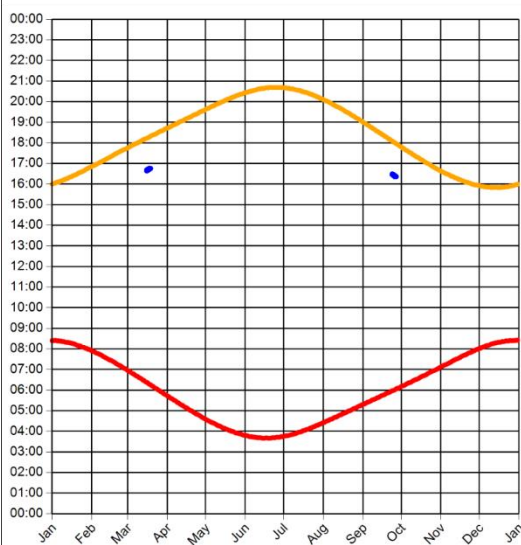


Reflecting panels (yellow)



Observer Runway 23R - 18 Results

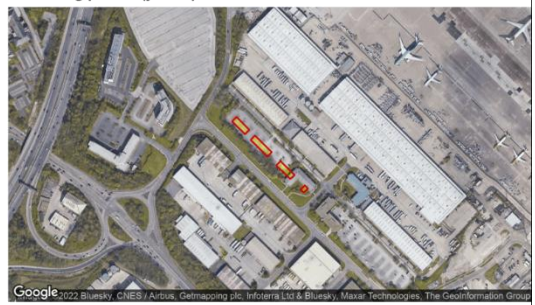
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 248.8° - 251.2° (yellow)



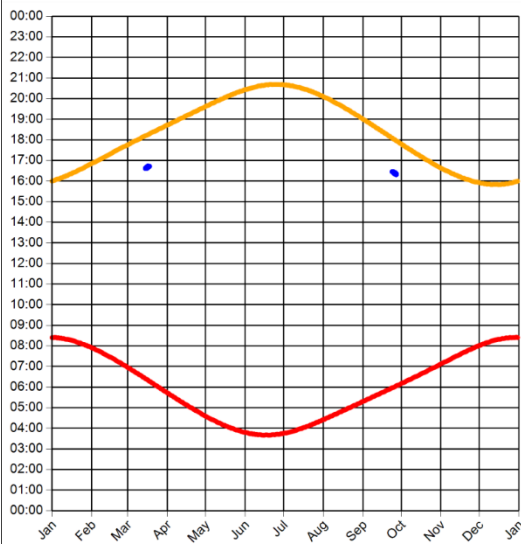
Reflecting panels (yellow)



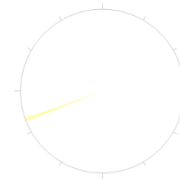
Observer Runway 23R - 19 Results

Sun azimuth range is 248.2° - 250.6° (yellow)

Reflection Date/Time (GMT) Graph



Min observer difference angle: 14.8°
Max observer difference angle: 15.5°

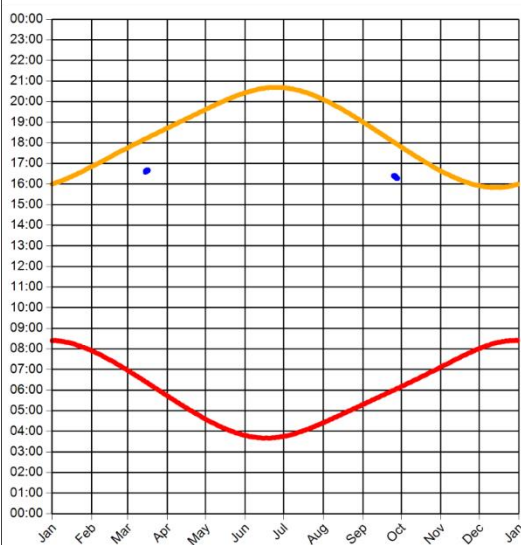


Observer Runway 23R - 20 Results

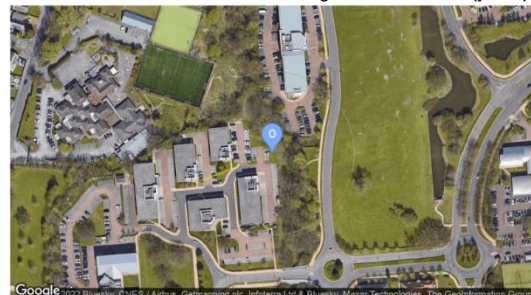
Observer Location

Sun azimuth range is 247.6° - 249.8° (yellow)

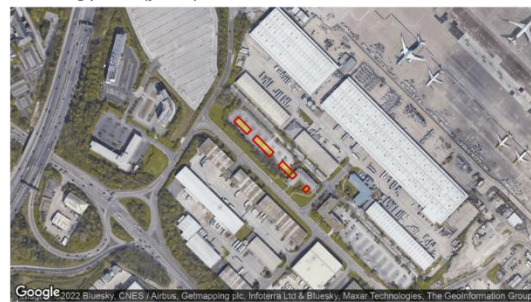
Reflection Date/Time (GMT) Graph



Min observer difference angle: 14.9°
Max observer difference angle: 15.7°

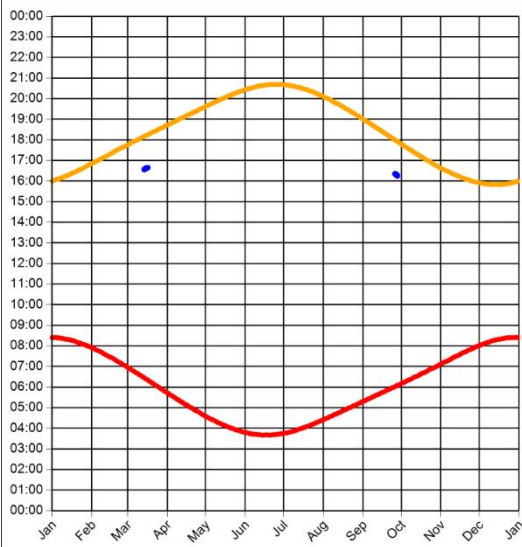


Reflecting panels (yellow)



Observer Runway 23R - 21 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 15.1°
Max observer difference angle: 15.7°

Observer Location

Sun azimuth range is 247.1° - 249.3° (yellow)



Reflecting panels (yellow)



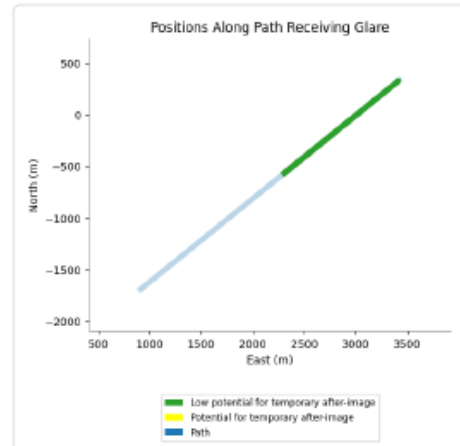
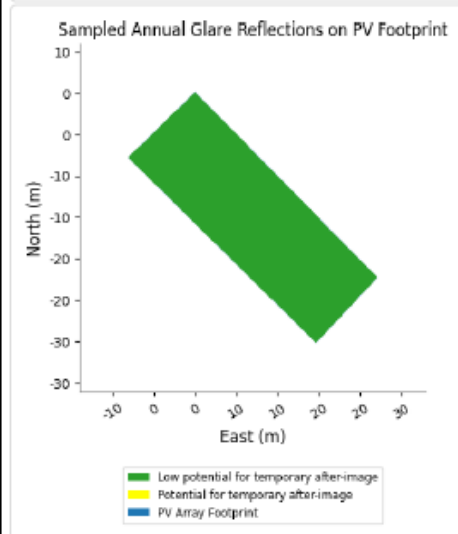
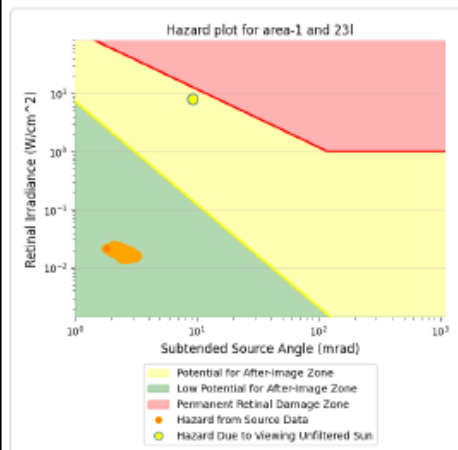
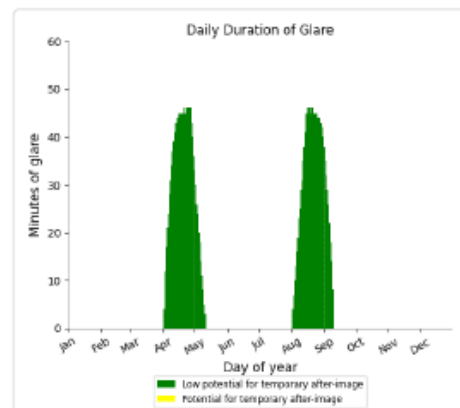
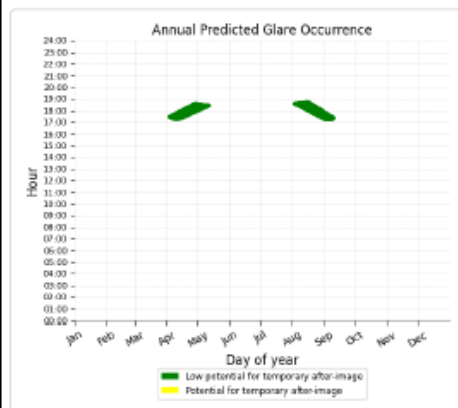
Runway Approach Path – 23L

The Forge and Pager Power solar reflection charts for the runway 23L approach path are presented below.

Area 1 - Receptor (23L)

PV array is expected to produce the following glare for observers on this flight path:

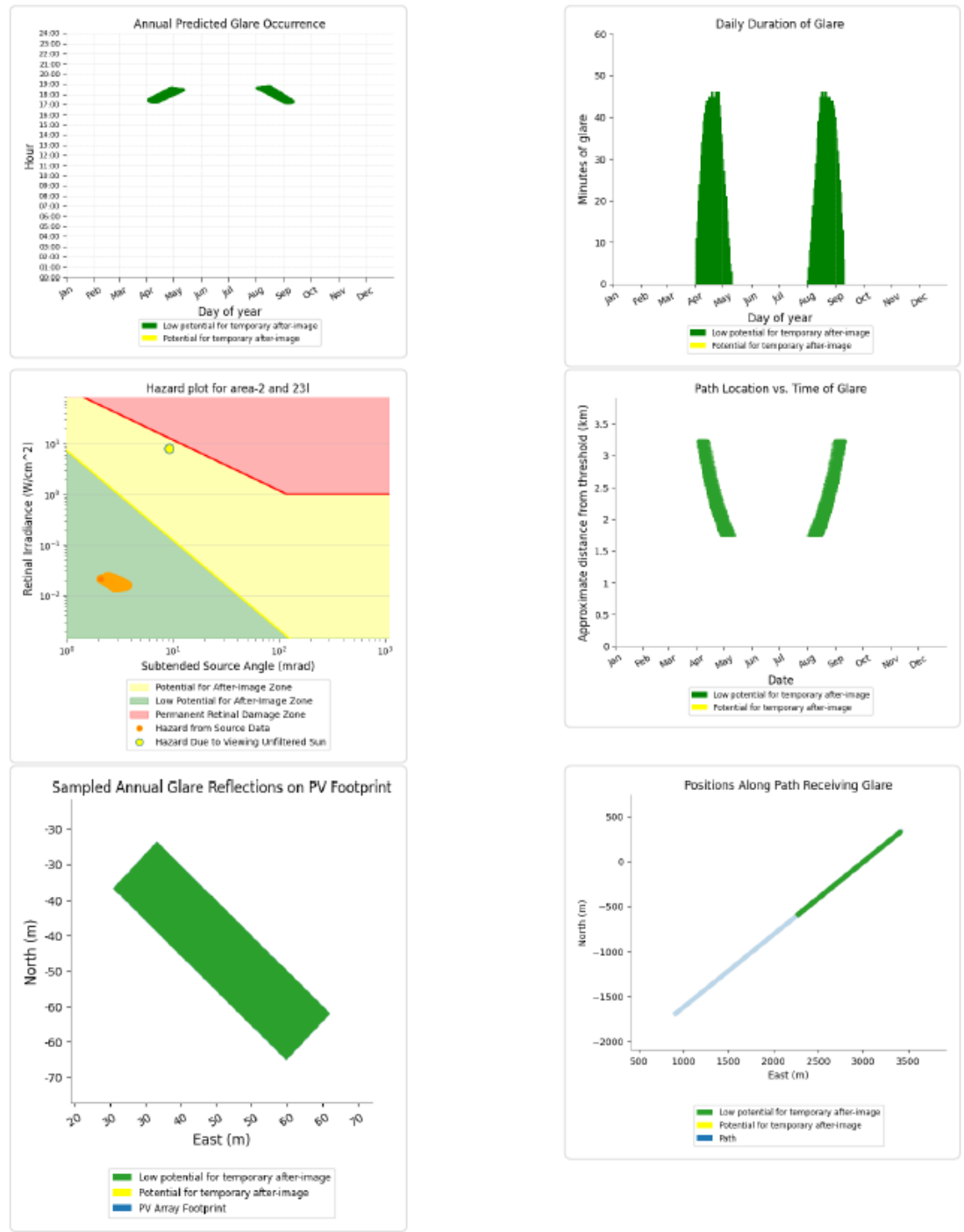
- 2,548 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 2 - Receptor (23L)

PV array is expected to produce the following glare for observers on this flight path:

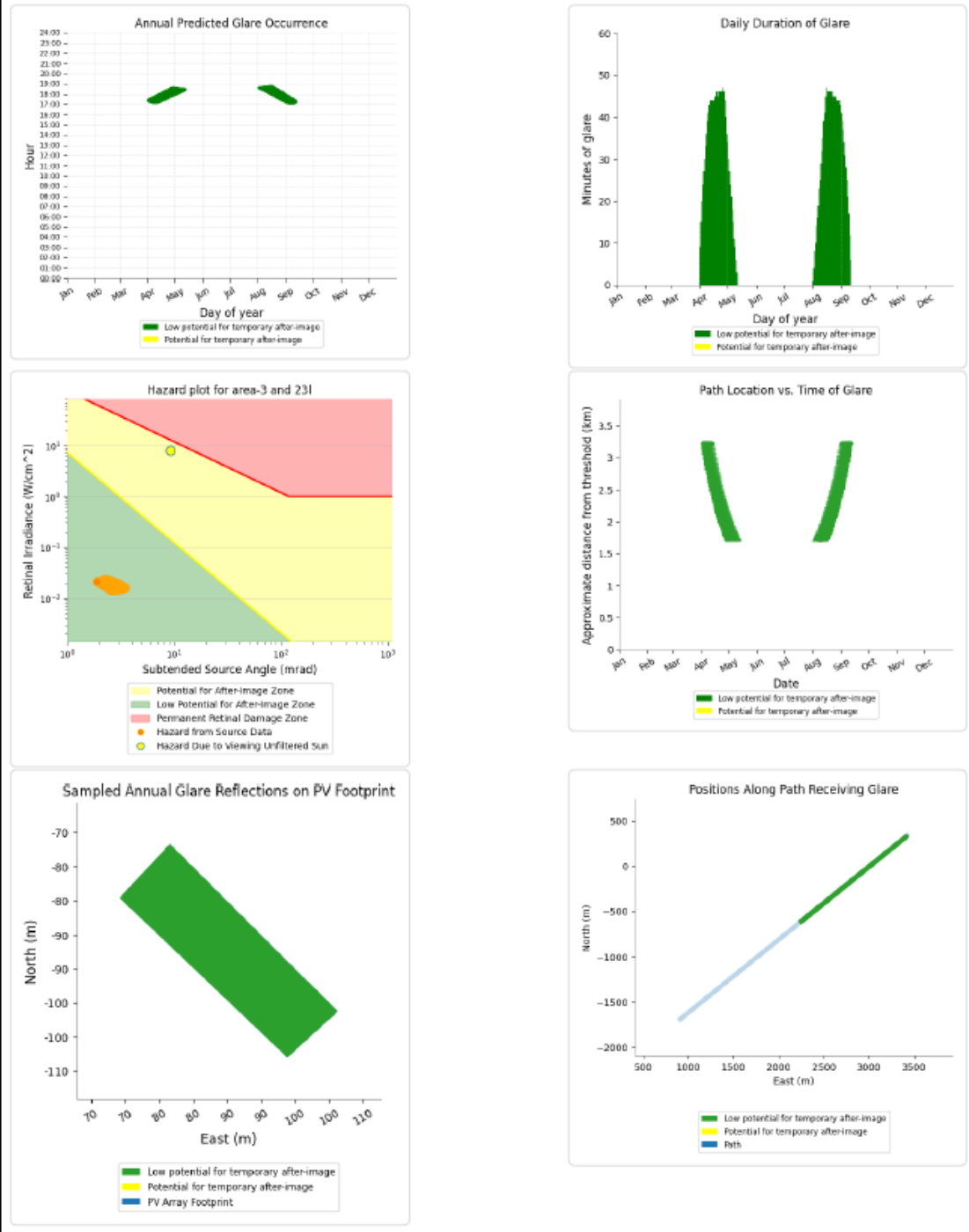
- 2,630 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 3 - Receptor (23L)

PV array is expected to produce the following glare for observers on this flight path:

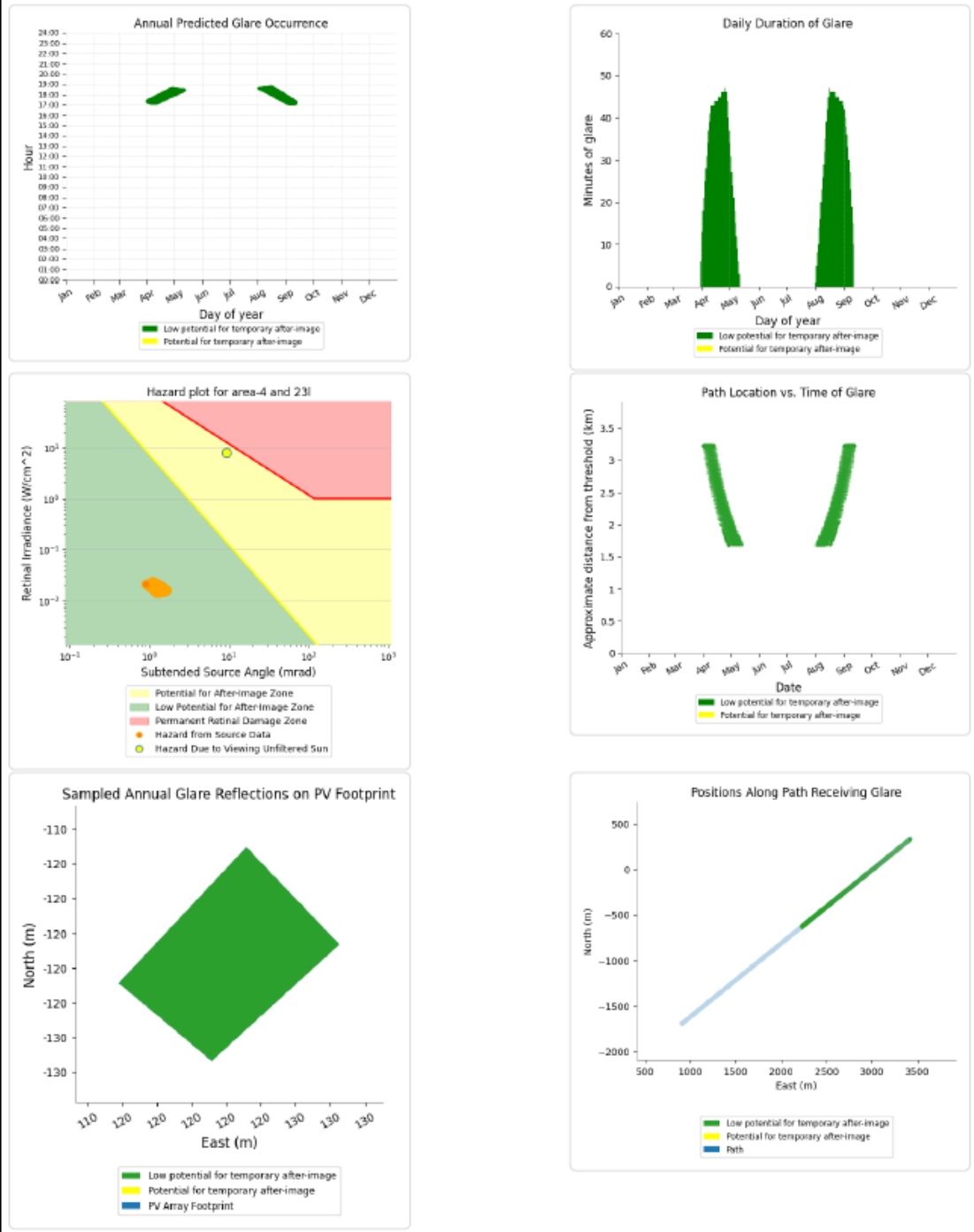
- 2,713 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 4 - Receptor (23L)

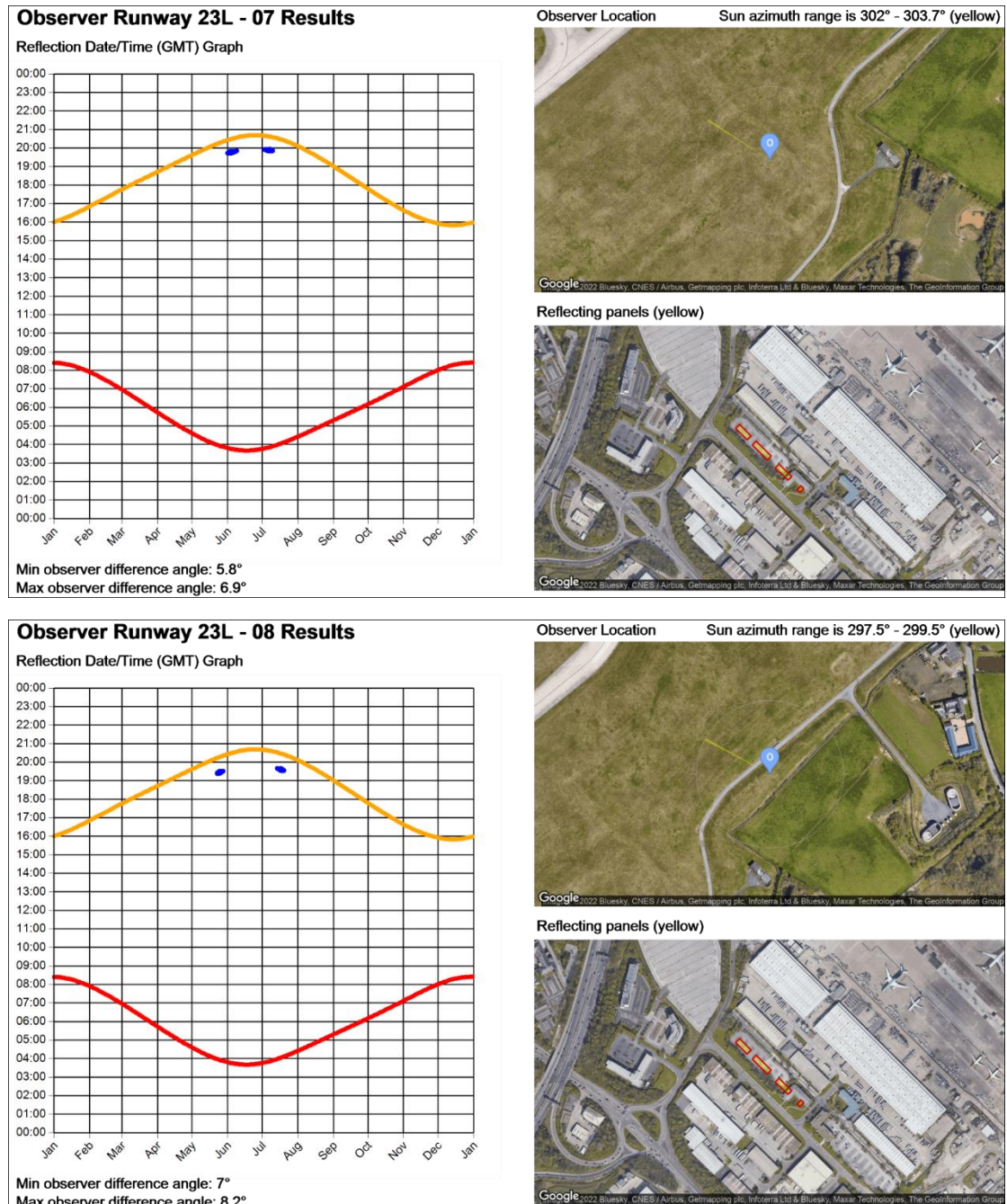
PV array is expected to produce the following glare for observers on this flight path:

- 2,755 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



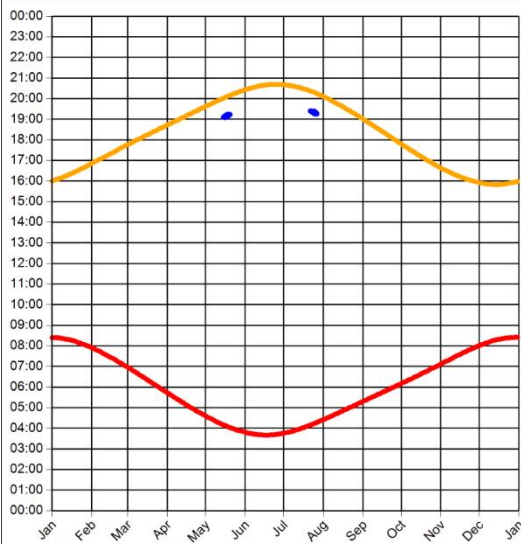
Observer Runway 23L - 01-06

No valid reflections found.



Observer Runway 23L - 09 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 293.2° - 295.6° (yellow)

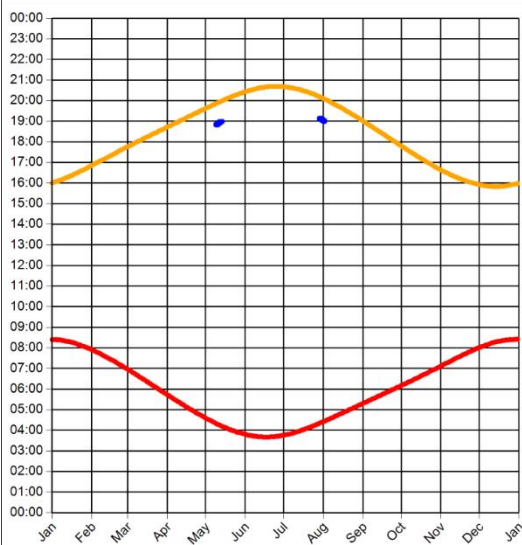


Reflecting panels (yellow)



Observer Runway 23L - 10 Results

Reflection Date/Time (GMT) Graph

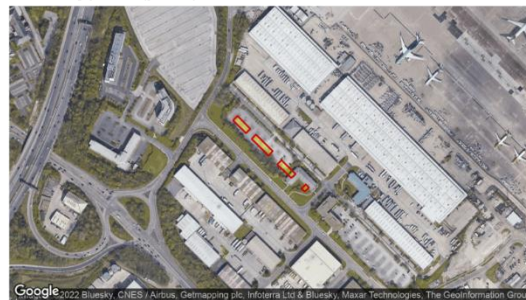


Observer Location

Sun azimuth range is 289.3° - 291.9° (yellow)

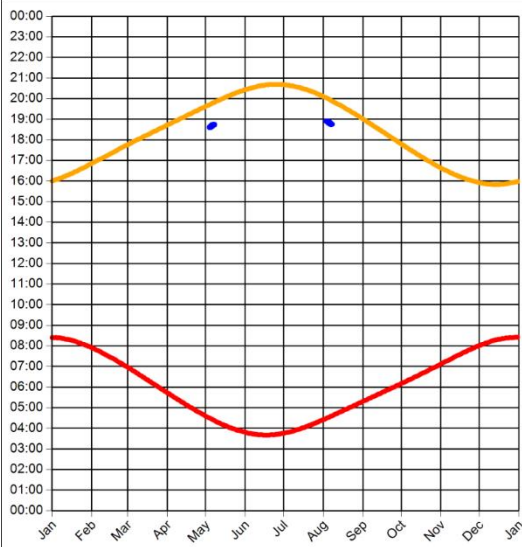


Reflecting panels (yellow)



Observer Runway 23L - 11 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 285.7° - 288.3° (yellow)

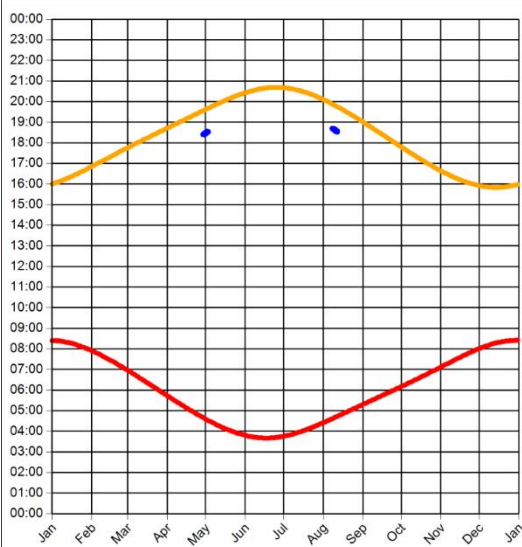


Reflecting panels (yellow)



Observer Runway 23L - 12 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 282.3° - 285° (yellow)

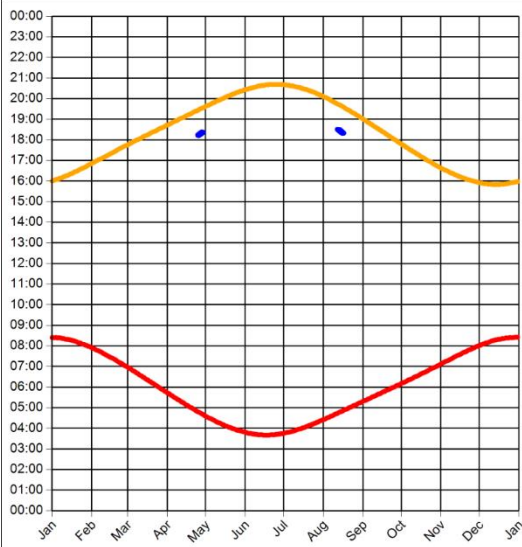


Reflecting panels (yellow)



Observer Runway 23L - 13 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 279.3° - 282.2° (yellow)

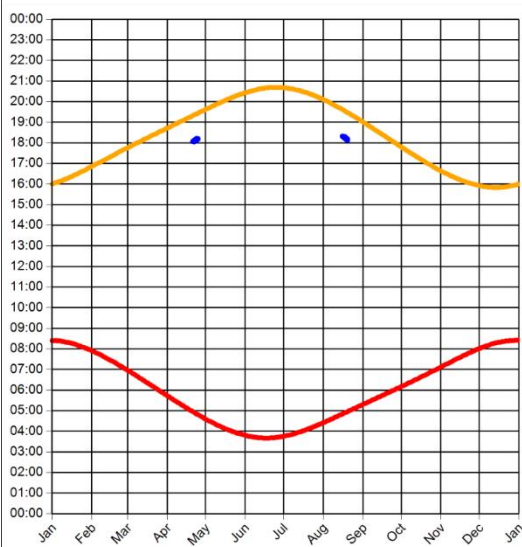


Reflecting panels (yellow)



Observer Runway 23L - 14 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 276.5° - 279.4° (yellow)

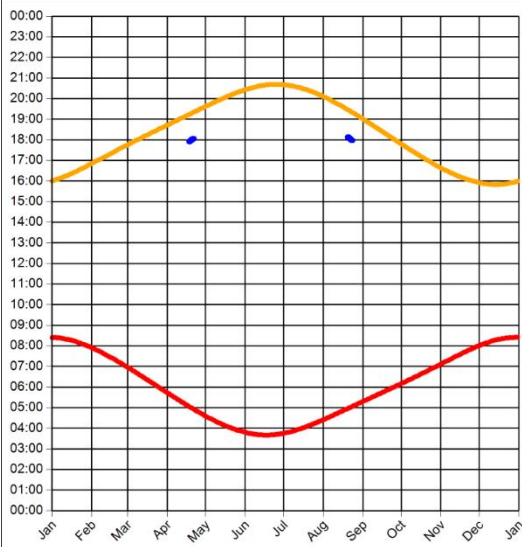


Reflecting panels (yellow)



Observer Runway 23L - 15 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 274° - 276.8° (yellow)

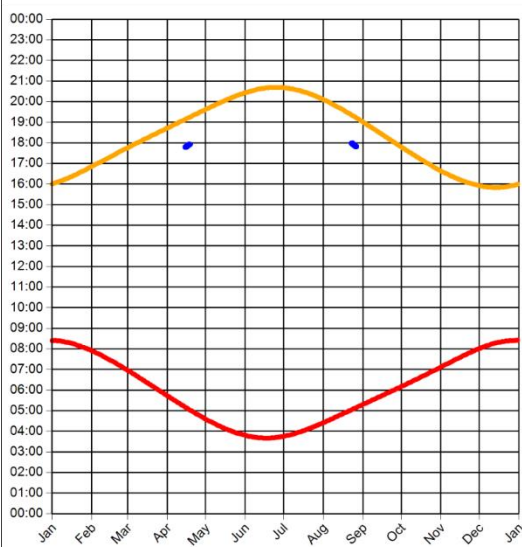


Reflecting panels (yellow)



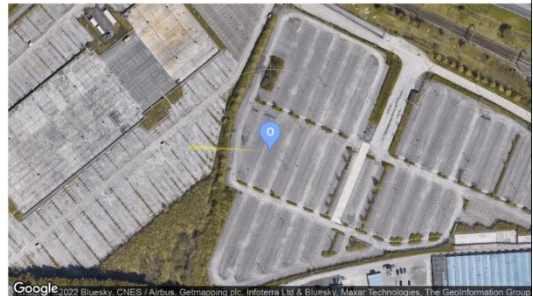
Observer Runway 23L - 16 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 271.7° - 274.5° (yellow)

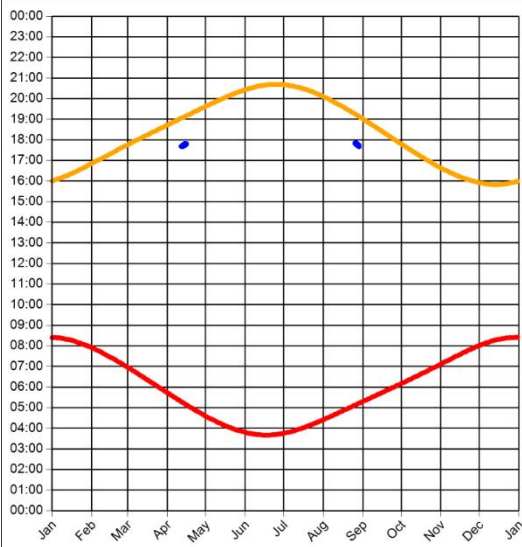


Reflecting panels (yellow)



Observer Runway 23L - 17 Results

Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 269.6° - 272.3° (yellow)

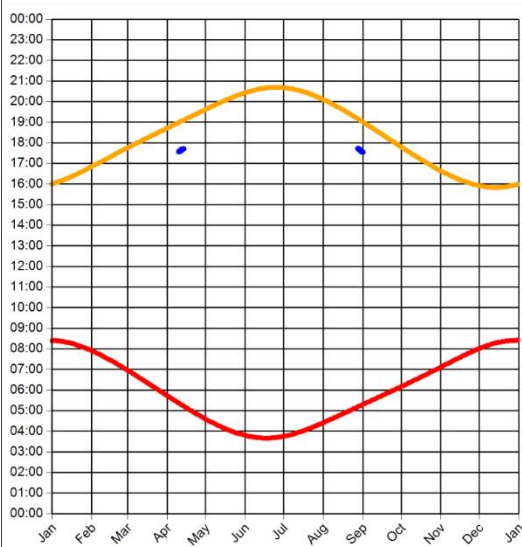


Reflecting panels (yellow)



Observer Runway 23L - 18 Results

Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 267.6° - 270.5° (yellow)

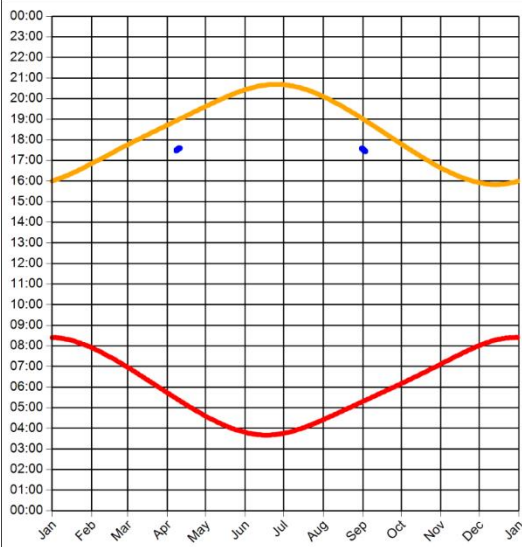


Reflecting panels (yellow)



Observer Runway 23L - 19 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 265.9° - 268.4° (yellow)

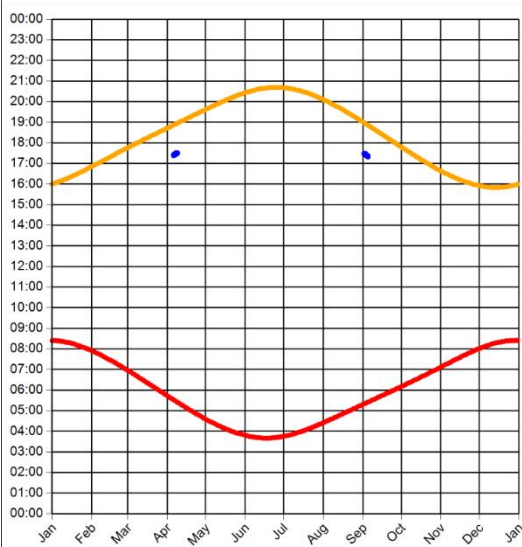


Reflecting panels (yellow)



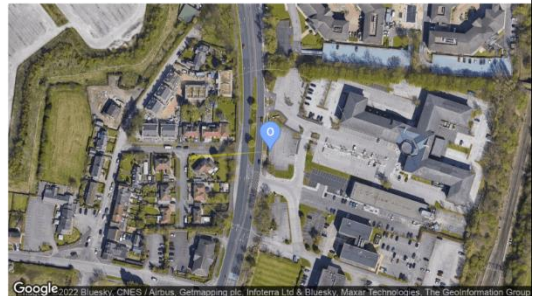
Observer Runway 23L - 20 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 264.3° - 266.8° (yellow)

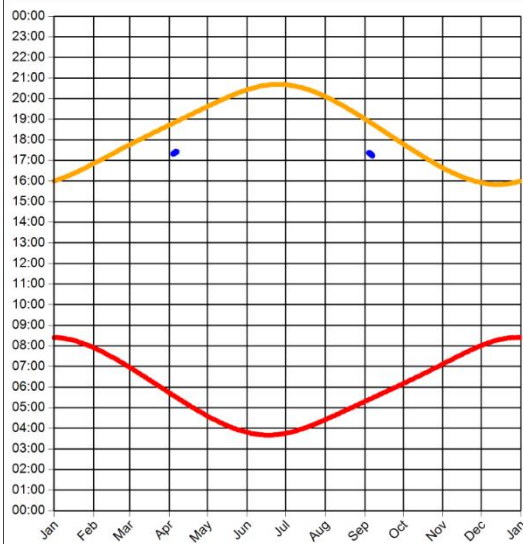


Reflecting panels (yellow)



Observer Runway 23L - 21 Results

Reflection Date/Time (GMT) Graph

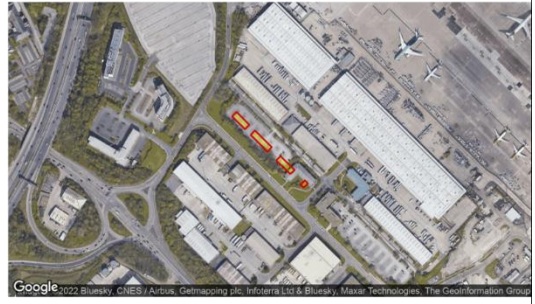


Min observer difference angle: 15°
Max observer difference angle: 16°

Observer Location Sun azimuth range is 262.7° - 265.2° (yellow)



Reflecting panels (yellow)



Visual Circuits

The charts for the visual circuits can be supplied upon request.



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