PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

FKY Limited

Tilekiln Green, Stansted

June 2023

PLANNING SOLUTIONS FOR:

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

[redacted]

ADMINISTRATION PAGE

Job reference:	10562C
Date:	June 2023
Author:	James Plumb
Telephone:	[redacted]
Email:	[redacted]

Reviewers:	Jacob Cunningham; Aaron Williams
Email:	[redacted]

Issue	Date	Detail of Changes
1	January 2022	Initial issue (10562A)
2	February 2022	Minor amendments (10562A)
3	June 2023	New MAG requirements (10562C)

Stour Valley Business Centre, Brundon Lane, Sudbury, CO10 7GB

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from parked vehicles and artificial lighting within a proposed open logistics centre to be located at Tilekiln Green, Bishop's Stortford, UK. This assessment pertains to the potential impact upon aviation activity associated with London Stansted Airport.

Overall Conclusions

No significant impacts are predicted upon pilots when flying on the 10NM runway approaches and departures, commercial aviation (CA) and general aviation (GA) visual circuits, visual flight routes and the 5km x 5km overhead area. No mitigation is required.

Solar reflections with a 'low potential for temporary after-image' are predicted towards the Air Traffic Control (ATC) Tower. This is the lowest intensity category within industry-standard modelling methodology for glare effects and is consistent with glare commonly encountered from outdoor surfaces. Furthermore, there are mitigating factors that further reduce the overall impact (see Section 6.3). Overall, it is judged that the potential effects are acceptable without further mitigation measures.

This report should be made available to the safeguarding team for London Stansted Airport to understand their position along with any feedback or comments regarding the proposed development.

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. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies (discussed below) in the process of defining its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon aviation activity.

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. Where appropriate, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology[2]. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

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[1] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

[2] 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.

Assessment Conclusions – Aviation

ATC Tower

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards the ATC Tower. Glare of any kind towards an ATC Tower must be carefully evaluated in an operational context. There are mitigating factors that reduce the overall impact. In particular, solar reflections are predicted to occur for a short duration of time throughout the year, will coincide with direct sunlight, and visibility of the reflecting areas would be almost entirely obstructed or completely removed in practice.

Overall, it is judged that the potential effects are acceptable without further mitigation measures.

Runway Approaches and Departures

The analysis has shown that solar reflections are predicted towards the 10NM approach and departure paths for runways 04 and 22.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these runway approaches, which is acceptable in accordance with the associated guidance (Appendix D) and industry best practice for 2-mile approach paths. A low impact is predicted for these approaches, and no mitigation is required.

Visual Circuits

The analysis has shown that solar reflections are predicted towards the left-hand and right-hand GA and CA circuits for runway 04.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards circuits at Stansted Airport. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the circuits. A low impact is predicted, and no mitigation is required.

5km x 5km Overhead Area

The analysis has shown that solar reflections are predicted towards the 5km x 5km overhead area centred upon the proposed development at 2500ft agl.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards the overhead area. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the overhead area. A low impact is predicted, and no mitigation is required.

Visual Flight Routes (VFRs)

The analysis has shown that solar reflections are predicted towards the Audley End, Canfield, Nuthampstead and Puckeridge VFRs.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these VFRs. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the VFRs. A low impact is predicted, and no mitigation is required.

High Level Conclusions – Cumulative Impact

No significant cumulative impacts are predicted upon London Stansted Airport from the proposed development and no mitigation is recommended.

The reflecting areas are each small, and reflections would not be expected to significantly coincide due to spacing between vehicles and varying azimuth and tilt angles, which determine the bearing of reflections. The modelled areas are also conservative in size as the entire parking space in each row have been modelled and not just the area in which the windows would be located.

High-Level Conclusions – Lighting Scheme

Artificial lighting or reflections from artificial lighting is expected to not be significant because reflections of artificial lighting will be of a lower intensity than that associated with reflections from the Sun and there is already existing lighting in the areas surrounding the airport that pilots appropriately manage with on approach to Stansted Airport. The Sun is a far more significant source of light and therefore considering the analysis results for the approach paths and ATC Tower, no significant impacts are predicted because of the lighting scheme. No mitigation is required.

The developer has confirmed that any temporary lighting would be installed to the same principles as the permanent lighting scheme.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 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 parked vehicles and artificial lighting within a proposed open logistics centre to be located at Tilekiln Green, Bishop's Stortford, UK. This assessment pertains to the potential impact upon aviation activity associated with London Stansted Airport.

This report contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 1,000 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.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows[3]:

- 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 this report to refer to both reflection types i.e. glint and glare.

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[3] These definitions are aligned with those of 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 Layout

Figure 1[4] below shows the proposed development site layout.

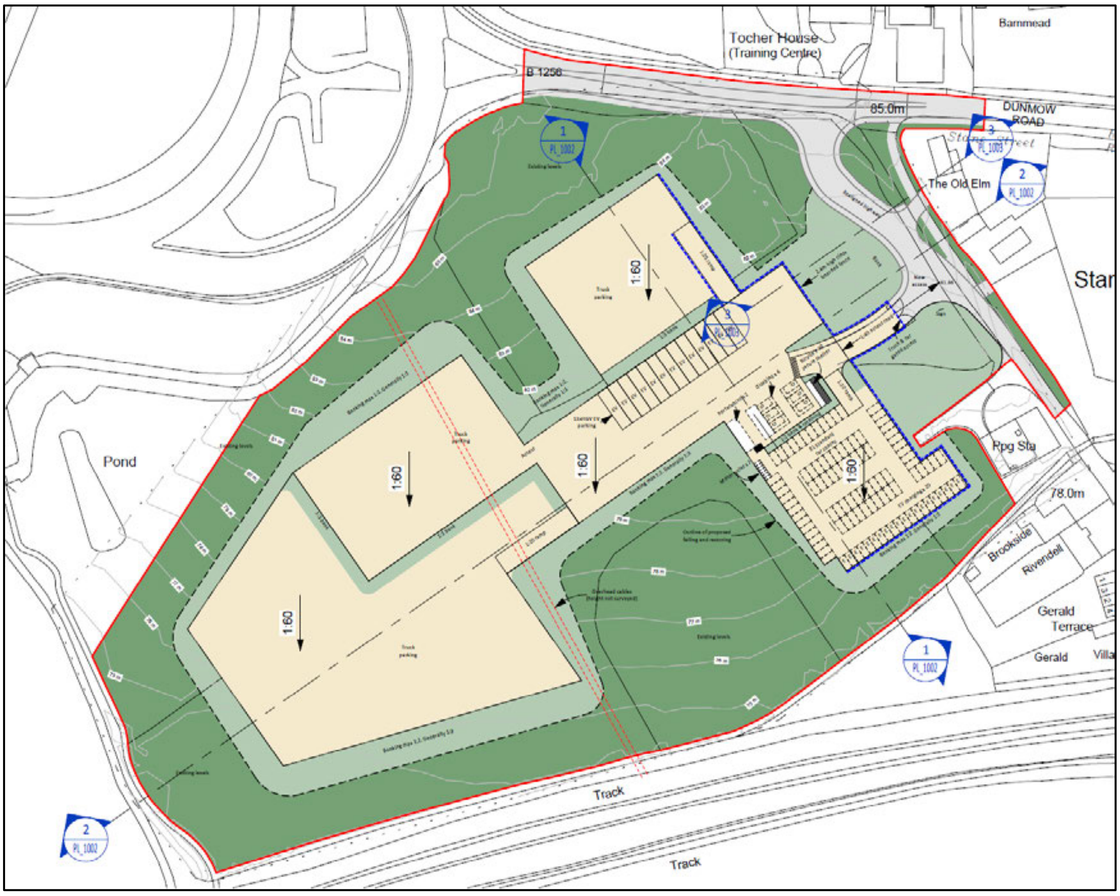

Figure 1 *Proposed development site layout*

[4] Source: 11008PL_1001_E_PROPOSED LAYOUT-A3.pdf

Figure 2 below shows the assessed reflecting areas overlaid onto aerial imagery as the blue rectangles.

Figure 2 *Assessed reflecting areas – aerial imagery*

2.2 Reflector Area Technical Information

The reflector area characteristics for the car parking is presented in Table 1 below.

Modelling Information – Car parking									
Reflector Area	C1	C2	C3	C4	C5	C6	C7	C8	C9
Azimuth angle (°)	56/236		146/326				56/236		146/326
Elevation angle (°)	30/60								
Assessed height (m) above ground level (agl)	1.5								

Table 1 *Reflector area characteristics – Car parking*

The reflector area characteristics for the HGV parking is presented in Table 2 below.

<table>
<tr><th colspan="10">Modelling Information – Truck Parking</th></tr>
<tr><th>Reflector Area</th><th>H1</th><th>H2</th><th>H3</th><th>H4</th><th>H5</th><th>H6</th><th>H7</th><th>H8</th><th>H9</th></tr>
<tr><td>Azimuth angle (°)</td><td>56/236</td><td colspan="8">146/326</td></tr>
<tr><td>Elevation angle (°)</td><td colspan="9">80</td></tr>
<tr><td>Assessed height (m) above ground level (agl)</td><td colspan="9">3</td></tr>
</table>

Table 2 *Reflector area characteristics – Truck Parking*

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendix A and B present a review of relevant guidance and independent studies with regard to glint and glare issues. Much of the information on this topic is in relation to solar photovoltaic developments; however, many of the technical principles are applicable to other smooth reflectors such as windows.

3.2 Background

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

3.3 Methodology

3.3.1 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 this glint and glare assessment 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.

3.3.2 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.

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Aviation Receptors

Stansted Airport is a Civil Aviation Authority (CAA) licenced airport, situated approximately 1.5km north-east of the proposed solar development. It has one ATC Tower and one runway, the details of which are presented below:

- 04/22 measuring 3,049m by 46m (asphalt).

The aerodrome chart for London Stansted Airport[5] is shown in Figure 7, on page 22.

This runway has 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 the approach and departure paths for runway 04/22. Locations have been selected every nautical mile along the extended runway centre line from 50ft above the runway threshold out to a distance of 10 nautical miles. The height of the aircraft is determined by using a 3-degree descent path on approach and 5-degrees on departure.

In addition to the approach and departure paths, receptors have been identified along the Civil Aviation (CA) and General Aviation (GA) circuits at London Stansted Airport, and in a 5km x 5km lattice centred above the proposed development.

Figures 3 to 6, on the following pages, show the assessed aircraft approach paths, circuits, and 5km x 5km lattice relative to the proposed solar development.

[5] NATS AIP, effective 23rd March 2023

Figure 3 *London Stansted Airport approach and departure path receptors*

Figure 4 *London Stansted Airport CA circuit receptors*

Figure 5 *London Stansted Airport GA circuit receptors*

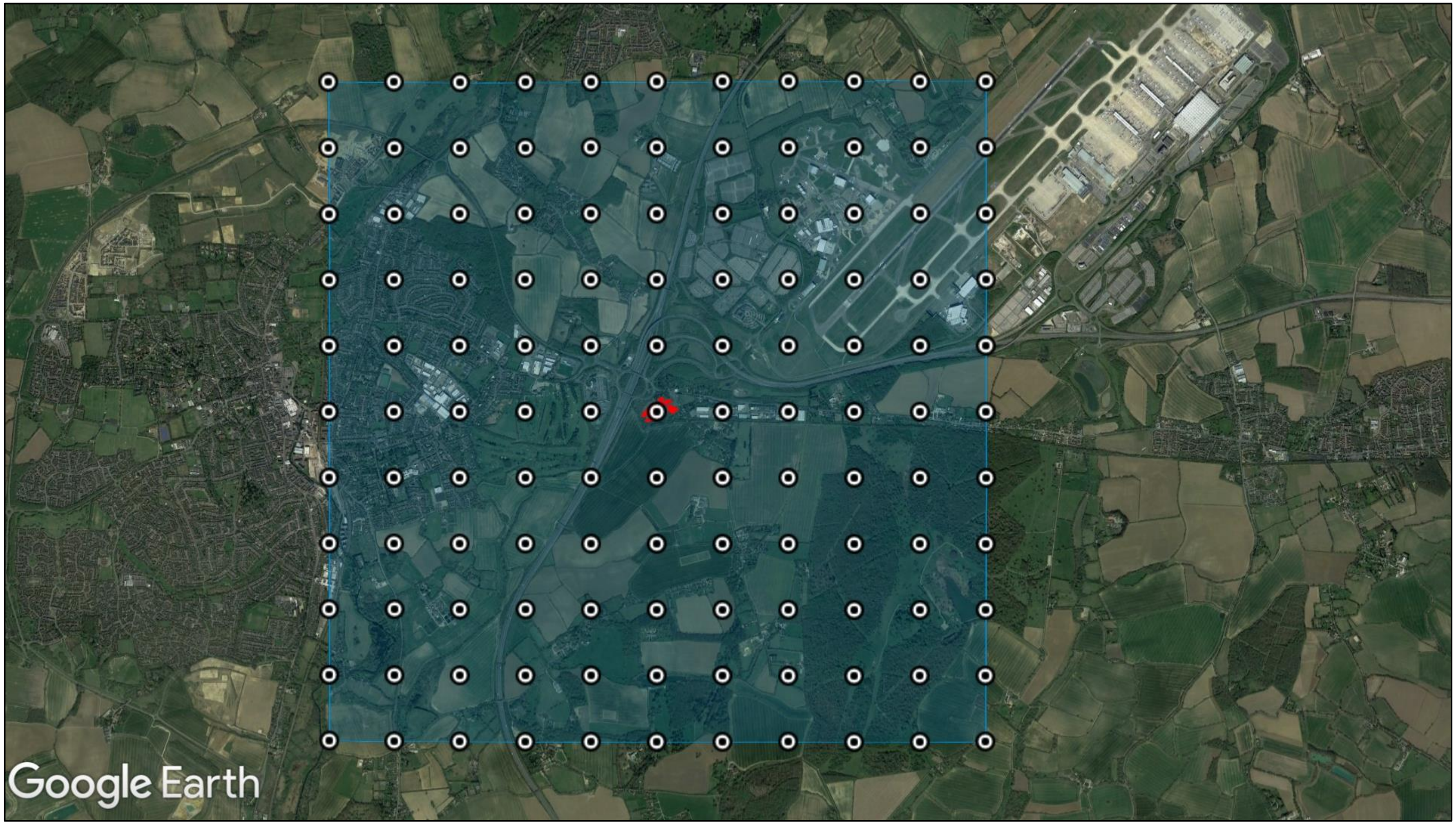

Figure 6 *London Stansted Airport 5km x 5km Overhead Area*

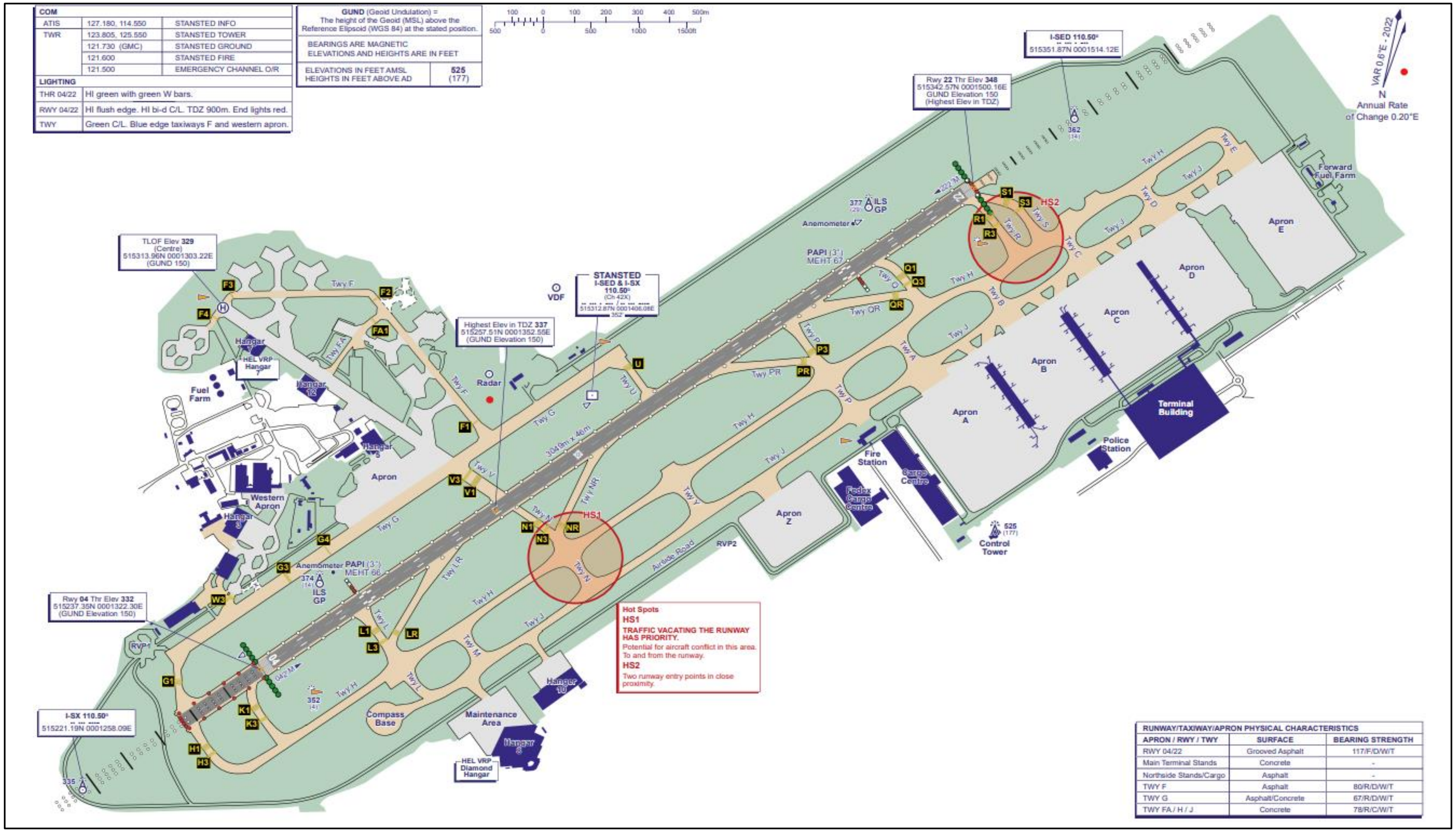

Figure 7 *Aerodrome chart for London Stansted Airport*

4.1.1 Control Zone and Control Areas

The control zone and control areas are areas of controlled airspace around an aerodrome. Figure 10 below shows the Control Zone and Control Areas Chart for London Stansted Airport.

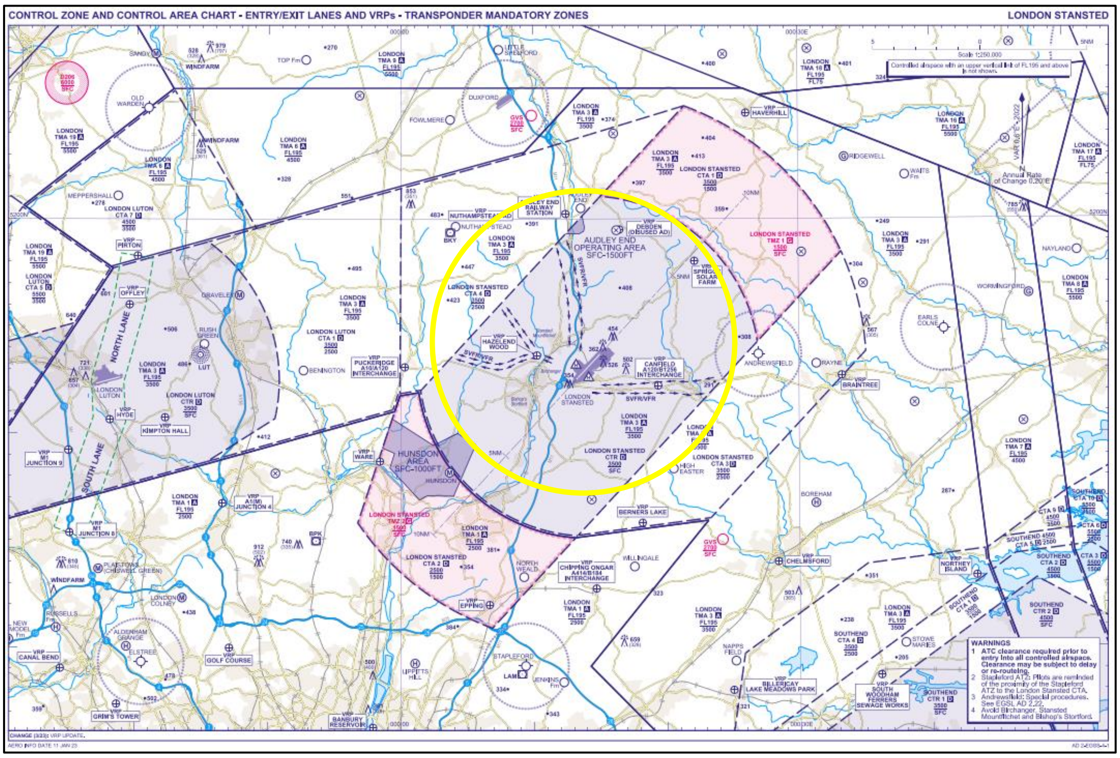

Figure 8 *Control Zone and Control Areas Chart*

The blue arrows (within the yellow circle) illustrate the Visual Flight Routes (VFR) that aircraft follow within the controlled zones and areas at London Stansted Airport.

Four VFR's (Audley End, Canfield, Nuthampstead and Puckeridge) have been assessed at 1,500 feet above mean sea level, and the receptors are shown in Figure 11 on the following page.

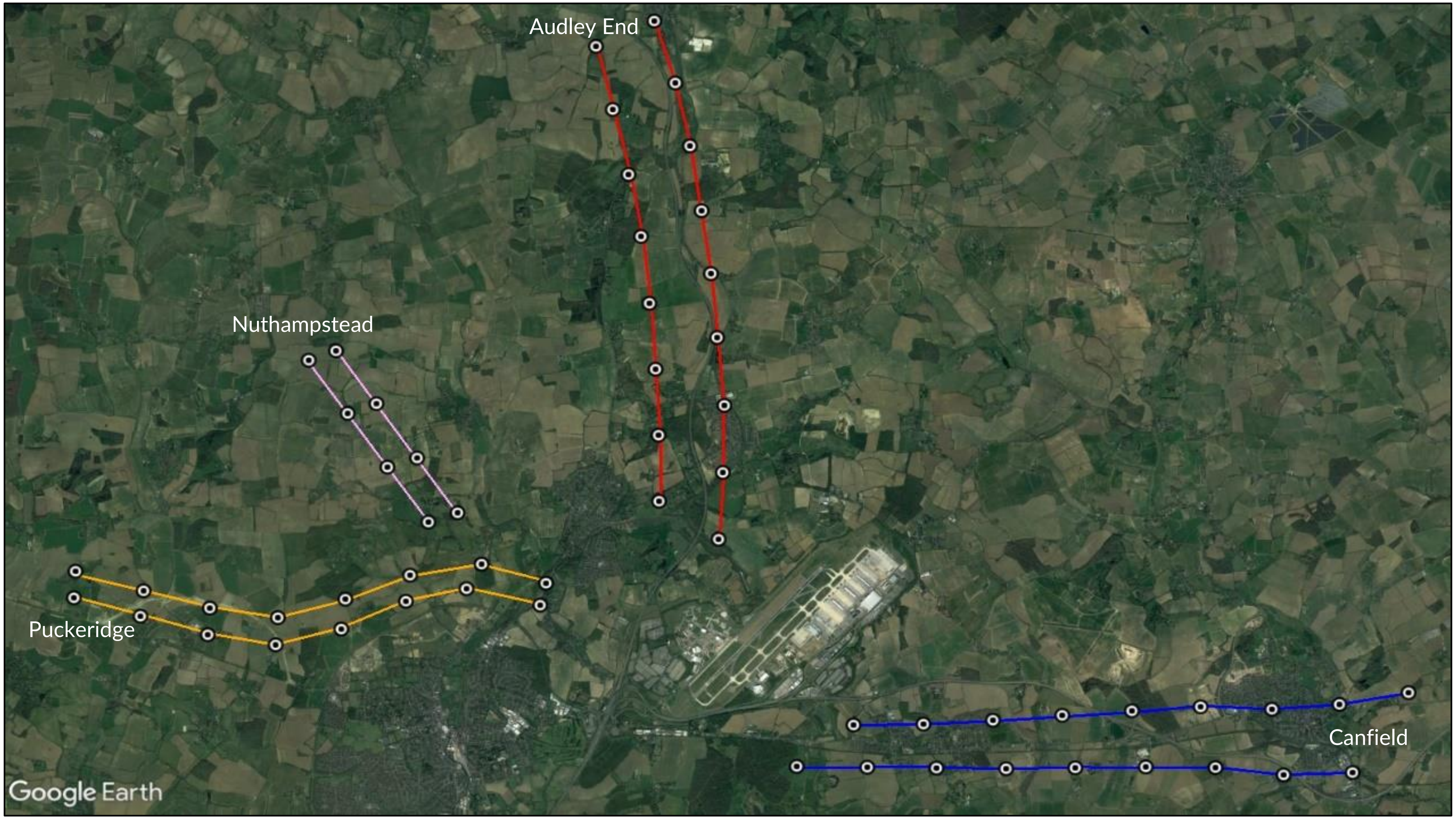

Figure 9 *Visual Flight Routes for London Stansted Airport*

4.1.2 ATC Tower Details

London Stansted Airport has one ATC Tower, which is 63m tall and located approximately 1.13km south of the runway 22 threshold. The location of the ATC Tower is shown in Figure 8 below, and a ground-based view of the ATC Tower is shown in Figure 9 below.

Figure 10 *Location of the ATC Tower within London Stansted Airport*

Figure 11 *Ground-based view of the ATC Tower at London Stansted Airport (visual control room circled)*

5 ASSESSMENT DETAILS

5.1 Assessment Parameters

Solar reflections are most significant when they are specular rather than diffuse i.e. reflections from a smooth mirror-like surface are more noticeable than scattered reflections from rougher surfaces.

The most reflective elements of a vehicle are considered to be the glass windows. In particular, in the context of visibility to an aircraft, the windscreen and/or rear window are likely to be the two most significant reflectors, in that order[6].

For modelling purposes, the car parking spaces have been assessed considering reflectors with vertical elevations of 30 degrees (representing a windscreen) and 60 degrees (representing a rear window). Similarly, the HGV/truck parking spaces have been assessed considering reflectors with vertical elevations of 80 degrees (representing a windscreen).

Motorcycles/cycles have not been taken forward technical modelling as the predicted effects would be less significant than that of windscreens from parked HGV's or cars.

The azimuth angles and parking layout for the assessed cars have been extrapolated from the site imagery and the HGV/truck azimuth angles and parking layout is indicative. This azimuth angles consider that vehicles would be aligned with the bays and could face either direction. The height above ground level of the reflective elements of the car parking and HGV parking spaces has been taken as 1.5m and 3m respectively.

It is not practical to model every feasible configuration of reflectors possible, given that vehicles vary in height and design. It is also unlikely that all spaces will be in use at all times, or that all vehicles will be perfectly aligned with the bays. Furthermore, the entire extents of each parking area have been modelled; however, in practice the windscreens of the assessed areas will occupy a small fraction of the modelled areas. The approach taken within the modelling is considered conservative and robust.

5.2 Reflector Areas

5.2.1 Reflector Areas

A resolution of 2m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 2m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the parking layouts have been extrapolated from the site plans. The data can be found in Appendix G.

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[6] The flatter angle of a windscreen means it is more likely to produce a visible reflection to an airborne location.

The assessed reflector areas are shown in Figure 12 below. Areas C1 to C9 are for the car parking and areas H1 to H9 are for the truck (HGV) parking.

Figure 12 *Assessed reflector areas*

6 GLINT AND GLARE ASSESSMENT RESULTS

6.1 Overview

The Pager Power and Forge model has been used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. 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 3 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	'Glare beyond 50 degrees from pilot's field-of-view'
'Green'	'Low potential for temporary after-image'
'Yellow'	'Potential for temporary after-image'
'Red'	'Potential for permanent eye damage'

Table 3 *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' is assessed. This is the most reflective surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

- Smooth glass with an anti-reflective coating;
- Light textured glass without an anti-reflective coating;
- Light textured glass with an anti-reflective coating; or
- Deeply textured glass.

If significant glare is predicted, modelling of less reflective surfaces could be undertaken.

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 predicted impact considering the level of predicted screening based on a desk-based review of the available imagery. 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 areas are shown in Appendix H.

6.2 Geometric Calculation Results – Aviation

The results of the geometric calculations are presented in Table 4 below.

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
ATC Tower	Solar reflections are geometrically possible		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible	Low impact	No (see Section 6.3)
Runway 04 10NM Approach	Solar reflections are geometrically possible between the threshold and 10 nautical miles from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this approach path	Low impact	No
Runway 22 10NM Approach	Solar reflections are geometrically possible between the threshold and 10 nautical miles from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this approach path	Low impact	No
Runway 04 10NM Departure	Solar reflections are geometrically possible between the threshold and 10 nautical miles from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this departure path	Low impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
Runway 22 10NM Departure	Solar reflections are geometrically possible between the threshold and 10 nautical miles from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this departure path	Low impact	No
Runway 04/22 CA Circuits	Solar reflections are geometrically possible towards sections of the left-hand and right-hand circuits for runway 04		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of these circuits	Low impact	No
Runway 04/22 GA Circuits	Solar reflections are geometrically possible towards sections of the left-hand and right-hand circuits for runway 04		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of these circuits	Low impact	No
5km x 5km Overhead Area	Solar reflections are geometrically possible towards sections of the overhead area		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards the overhead area	Low impact	No
Visual Flight Routes	Solar reflections are geometrically possible towards sections of Audley End, Canfield, Nuthampstead and Puckeridge VFRs		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards the visual flight routes	Low impact	No

Table 4 *Geometric analysis results – Aviation*

Figures 13 to 15 below and on the following page show all receptors where 'green' glare is predicted to be possible. Figure 13 shows the visual flight routes, Figure 14 shows the 5km x 5km overhead area, whilst in Figure 15, receptors on the approach and departure paths are shown on the light blue line and receptors on the white lines are those on the CA and GA circuits.

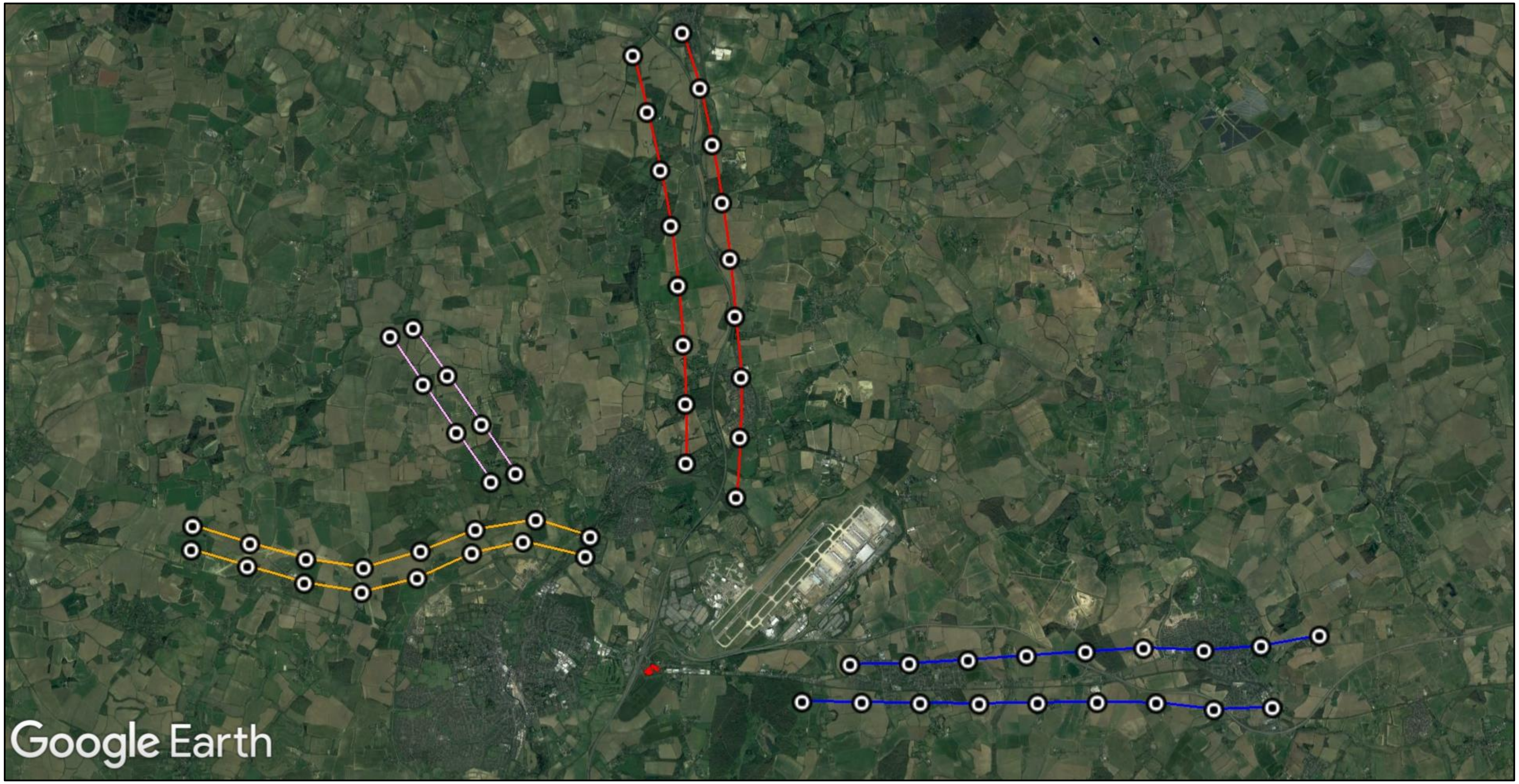

Figure 13 *Receptors where 'green' glare is predicted on the visual flight routes*

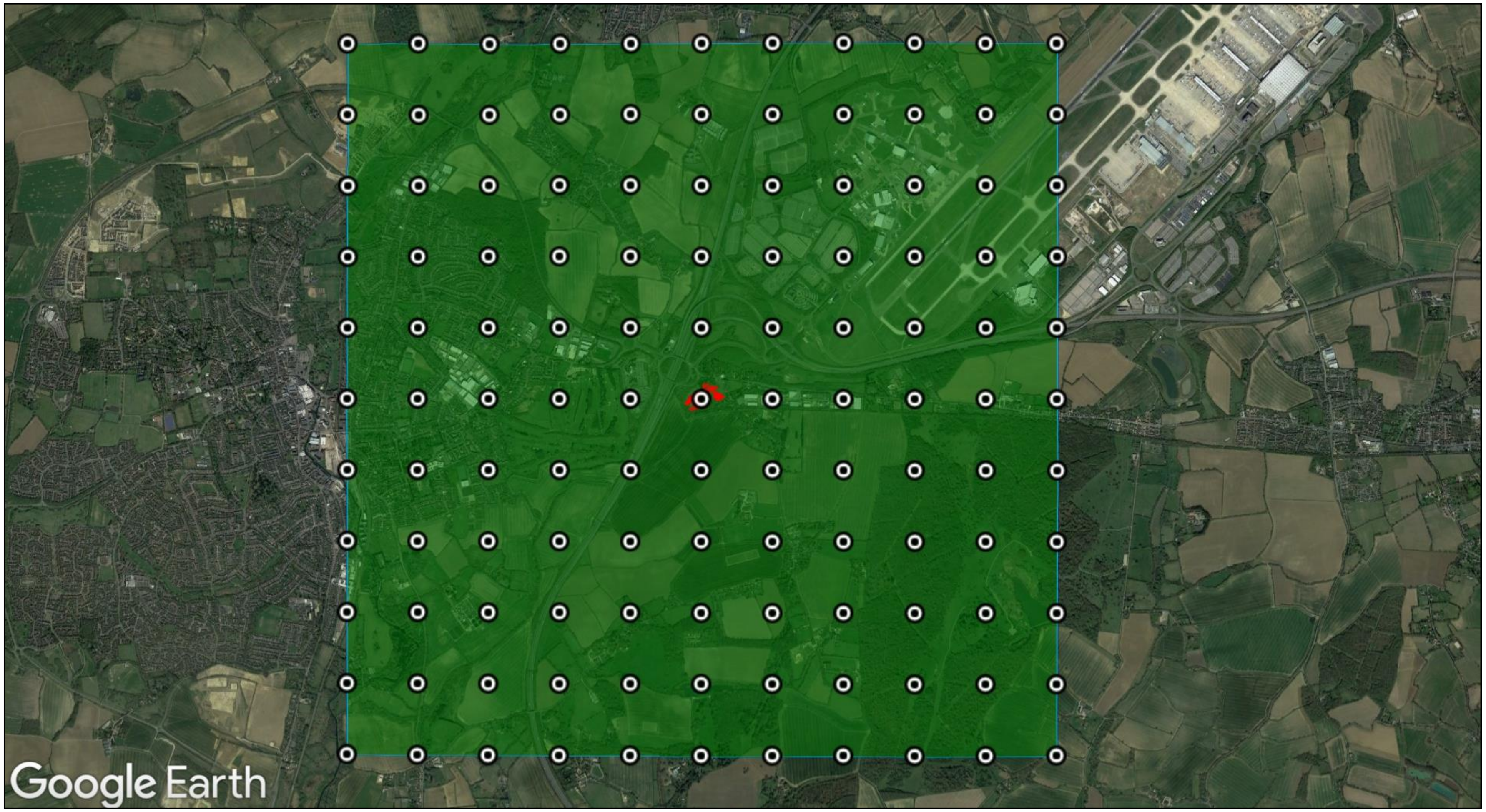

Figure 14 *Receptors where 'green' glare is predicted for the 5km x 5km overhead area*

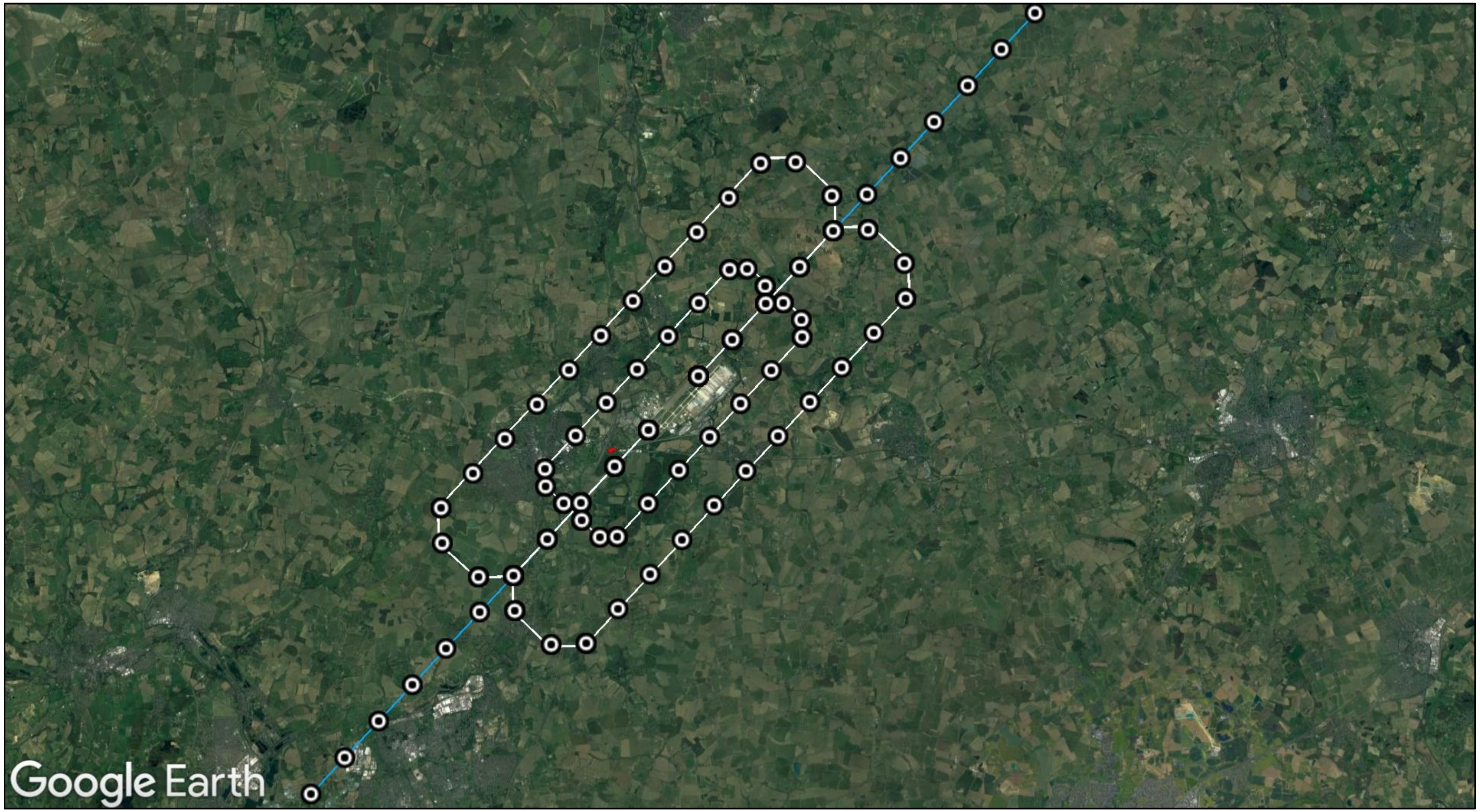

Figure 15 *Receptors where 'green' glare is predicted for approach paths and visual circuits*

6.3 ATC Tower

The modelling has shown that solar reflections are geometrically possible towards the ATC Tower. Solar reflections are predicted to originate from areas C3 to C6, C9, and H2 to H9. This is based on the modelling assumption that all the areas of the proposed development are visible.

Following an initial review of the available imagery, as shown in Figures 16 and 17 on the following pages, views of the reflecting panels are considered possible; however, there is existing vegetation and dwellings offering potential screening adjacent to the B1256 and A120. Therefore, detailed screening analysis has been undertaken to determine more accurately the level of visibility of the reflecting areas.

Figure 16 *Reflecting areas relative to the ATC Tower*

Figure 17 *Viewpoint of London Stansted Airport ATC tower towards the reflecting areas*

The Forge glare intensity modelling results for areas C3 and H2, are shown in Figures 18 to 20 below and on the following page. Full Forge glare modelling results for the ATC Tower are shown in Appendix H.

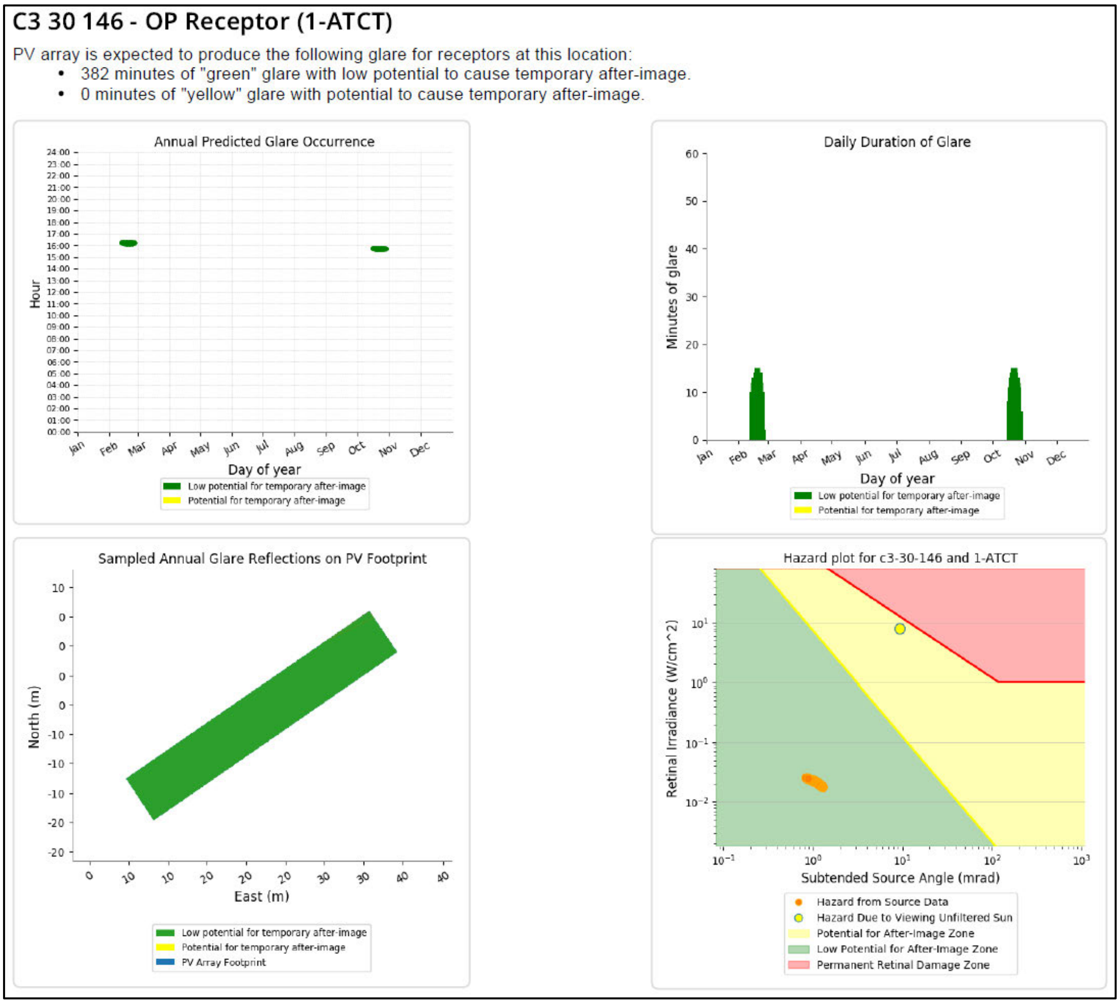

Figure 18 *Forge glare intensity modelling results*[7] *– Reflector area C3, 30-degree tilt (front windscreens), and parking orientation 146 degrees azimuth*

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[7] The terms 'PV array or PV footprint' within these figures are standard text contained within Forge modelling results which refer to solar photovoltaic panel areas because the majority of solar glint and glare studies are for solar photovoltaic developments.

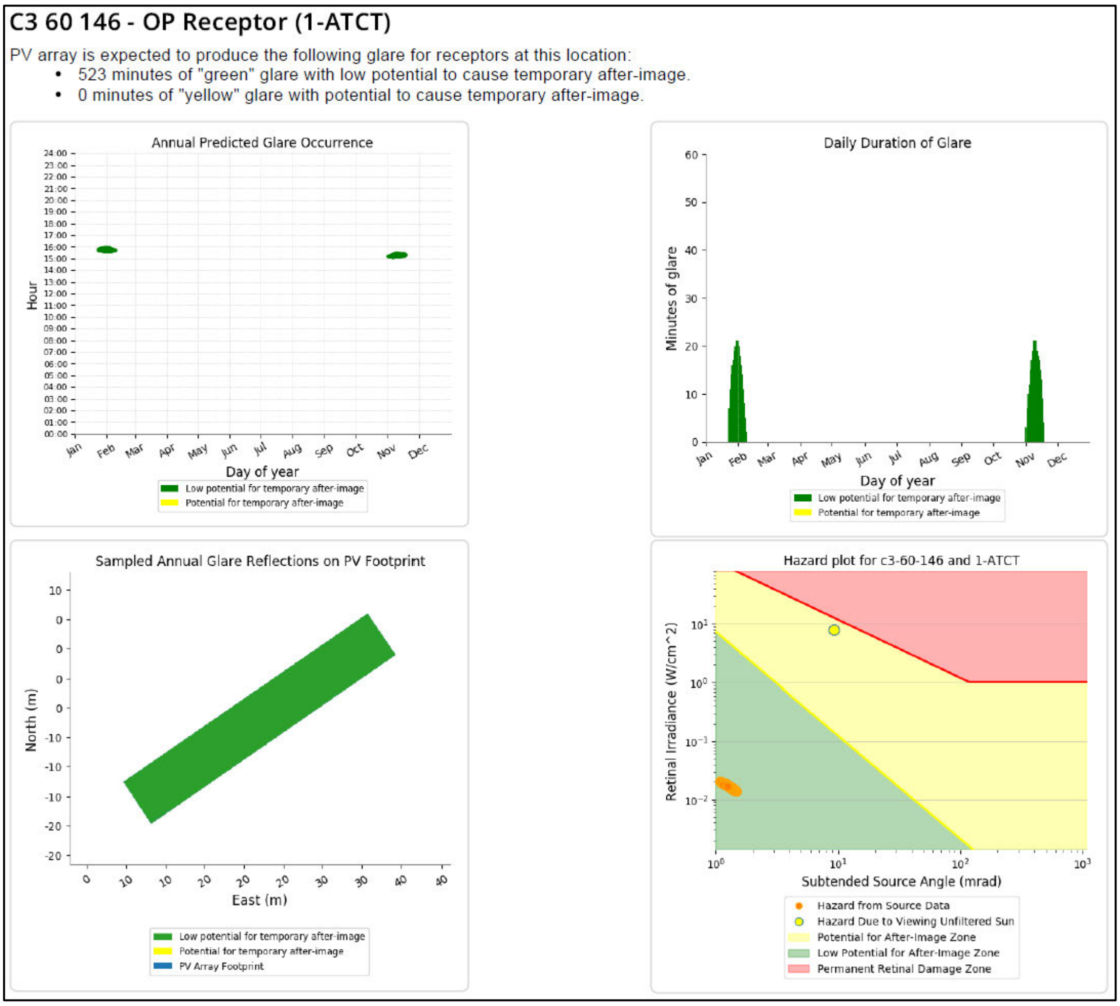

Figure 19 *Forge glare intensity modelling results - Reflector area C3, 60-degree tilt (back windscreens), and parking orientation 146 degrees azimuth*

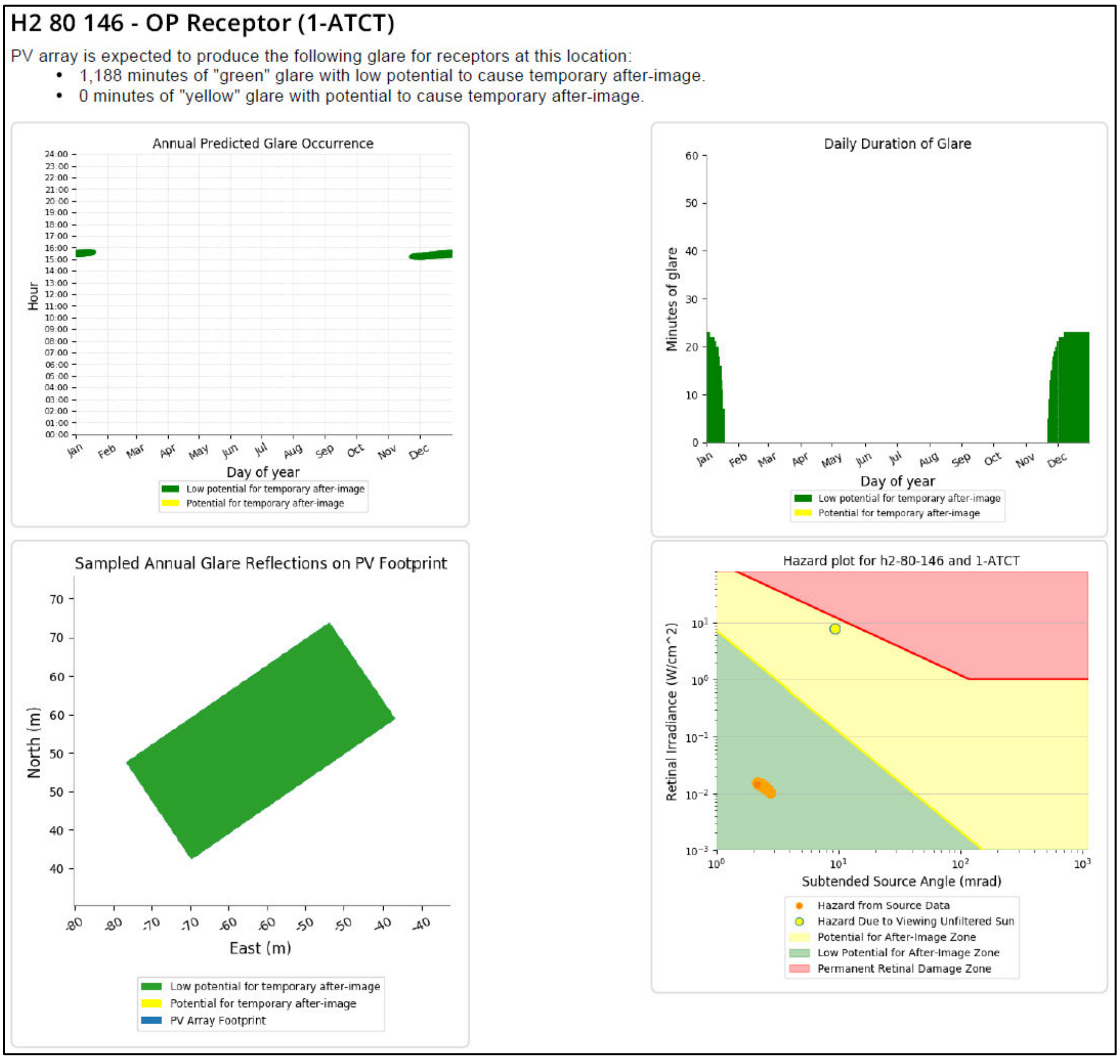

Figure 20 *Forge glare intensity modelling results - Reflector area H2, 80-degree tilt (front windscreens), and parking orientation 146 degrees azimuth*

The results of the Pager Power modelling for the ATC Tower, are shown in Figures 21 and 22 below.

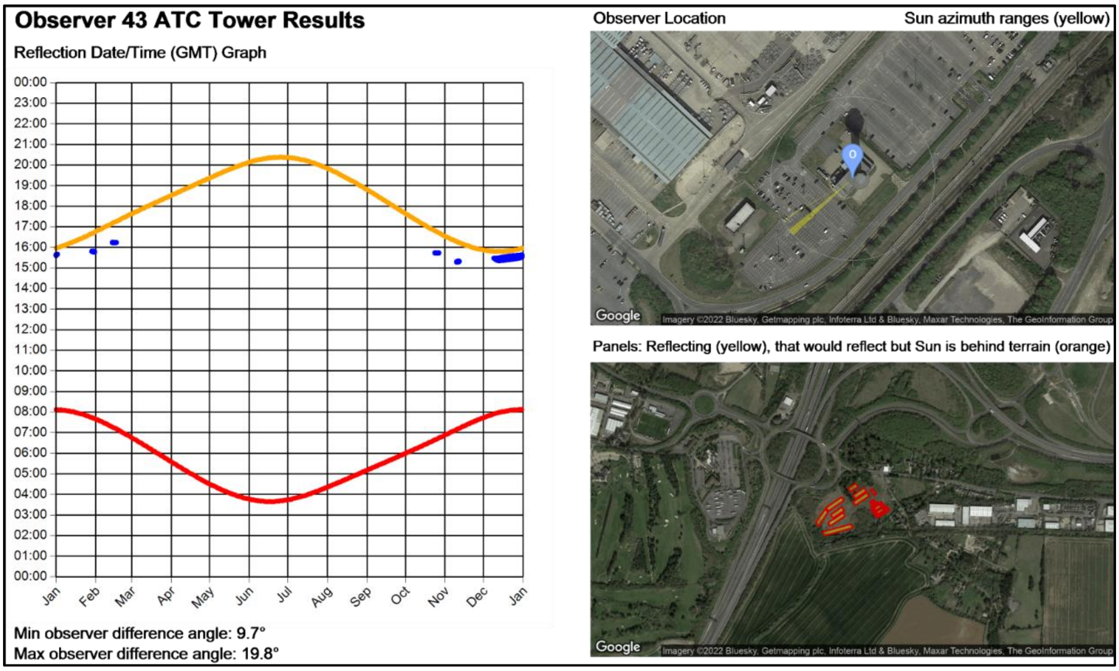

Figure 21 *Pager Power modelling results – ATC Tower*

Figure 22 *Reflecting areas*[8] *(yellow radial icons) – Pager Power modelling results for ATC Tower*

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[8] Reflecting areas are C3 to C6, C9, and H2 to H9. No solar reflections are geometrically possible for areas C1, C2, C7, C8, and H1; however, are shown within the figure for reference.

6.3.1 Detailed Screening Analysis

Detailed screening analysis has been undertaken for three representative locations within each of the reflecting areas. The result of the analysis has concluded that, when considering a height of 3m for existing screening in the form of vegetation and dwellings and a height of 3m for the assessed reflecting areas, visibility would be limited to areas C6, H4 to H7 and H9. Furthermore, it is possible that visibility of the reflecting areas would not be possible, following a site survey when considering the existing environment or the structure/orientation of the vehicles.

Further details are presented in Appendix I. Should glare be visible towards the ATC Tower, the impact significance is considered in the following subsection on a conservative basis.

6.3.2 Impact Significance

Glare of any kind towards an ATC tower was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[9] for on-airfield solar. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally. There is no formal guidance for glint and glare with respect to windscreens from parked vehicles and is a technical point of reference only.

Reflection generated from cars is significantly different compared to solar panels because a vehicle's reflective surfaces are often curved while a solar panel surface is flat. Therefore, the predicted solar reflections will be scattered and not all the predicted reflected sun light will reach the observer in the ATC tower.

Also, a worst-case scenario was considered. In such scenario, the following is assumed:

- The car park is considered to be full of reflecting vehicles at all orientations. Therefore, the impact predicted will overestimate the number and duration of solar reflections from the vehicles parked within the car park;
- Not all vehicles have same height, and some (taller vehicles) might be screening others.

Pager Power recommends a pragmatic approach to consider glare in an operational context. Relevant considerations include:

- The time of day at which glare is predicted;
- The duration of any predicted glare;
- The location of the source of glare relative to the runway thresholds;
- The intensity of the predicted glare;
- The level of predicted effect relative to existing sources of glare.

In the case of the proposed development:

- The ATC Tower is operational 24 hours; therefore, predicted reflections could be experienced.

[9] This guidance has since been superseded and airports are tasked with determining safety requirements themselves.

- The maximum duration of glare[10] would be for area H5 with orientation 146 degrees[11], the duration of glare at the ATC tower is 1,213 minutes in total per year and would occur between mid-November and mid-January between 3.00pm and 3.50pm. This represents a small proportion of time compared to average daylight hours in any one year (0.462%[12]). The maximum duration would be for less than 25 minutes on the days when the glare is possible.
- The separation distance between an observer and the nearest reflecting panel is over 3.85km.
- The reflecting panel areas are relatively small at approximately 1.02% of an observer's horizontal field of view[13].
- ATC personnel looking towards runway threshold 04 will be looking in the direction of the reflecting areas.
- The intensity of the predicted glare originating from reflecting areas is categorised as having a 'low potential for a temporary after-image'. This is the lowest categorisation of glare intensity; however, any glare towards an ATC Tower must be evaluated in context.
- Solar reflections will occur within approximately 2hrs of sunset i.e. when the Sun is low in the sky beyond the reflecting areas. Therefore, an observer will likely have a view of the sun within the same viewpoint of the reflecting areas. The Sun is a far more significant source of light. Figure 23 on the following page shows a representative viewpoint of an observer within the ATC tower towards the reflecting areas at a time and date when solar reflections could occur.
- The proposed development would introduce a new source of reflective surface; however, there are existing reflective surfaces in the form of parked vehicles that are potentially located closer to the ATC Tower with equal or greater reflectivity as shown by Figure 24 on page 44. The reflecting areas would represent approximately 0.93%[14] of the total vehicle parking areas identified surrounding Stansted Airport[15].
- The weather would have to be clear and sunny at the specific times when the glare was possible to be experienced.

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[10] Based upon the Forge modelling results.
[11] Assuming the entire area is visible, all vehicles are parked in that orientation, and that the reflecting area is smooth flat glass.
[12] Based on 4380 daylight hours per year.
[13] 2.15 degrees azimuth / 210 degrees azimuth field of view.
[14] 8159.4 square metres (areas C3 to C6, C9, and H2 to H9) / 879848.7 square metres (from 316 areas identified)
[15] The areas shown within the figure represent parking spaces for vehicles identified following a review of the available imagery.

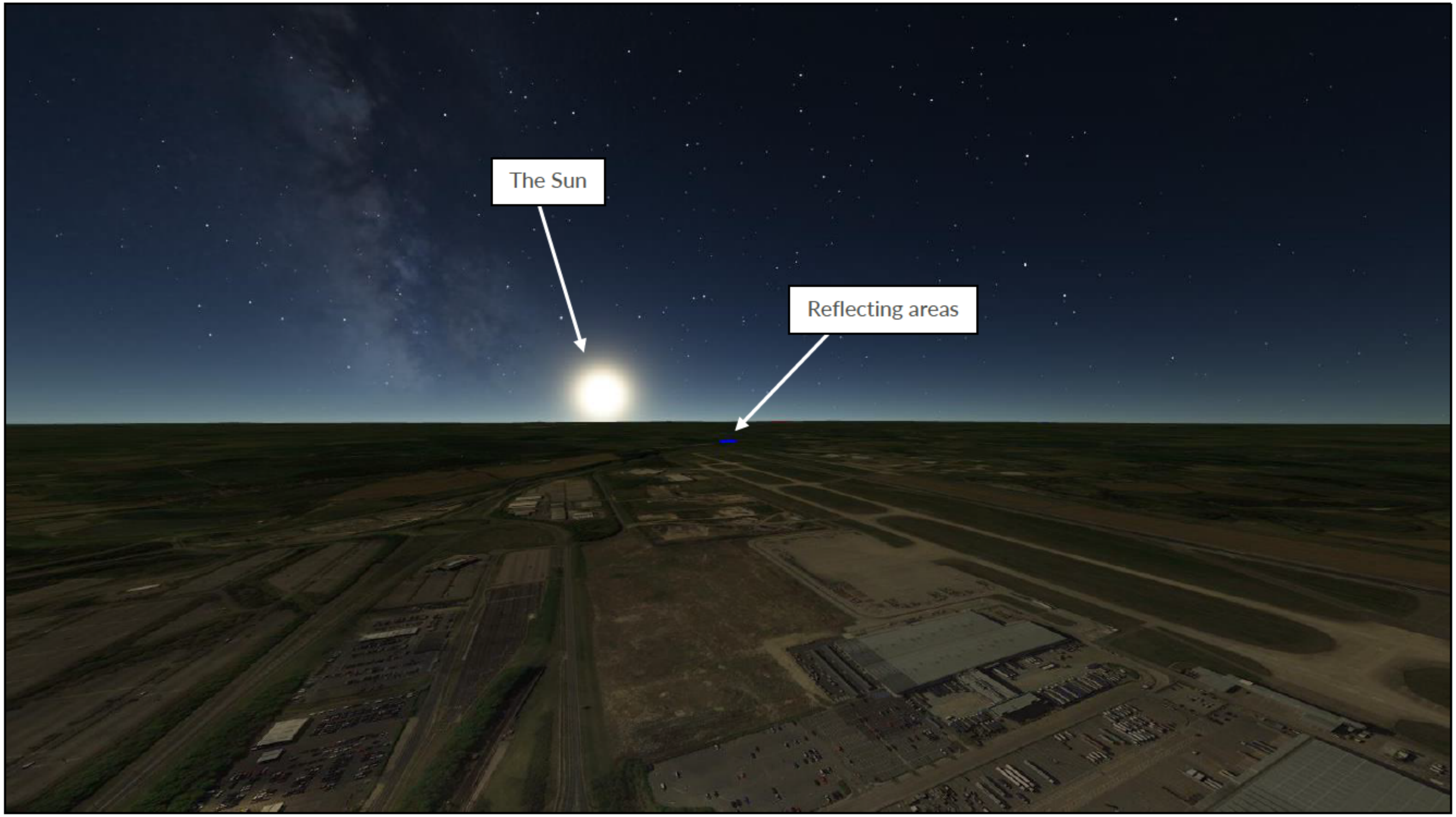

Figure 23 ATC viewpoint[16] *towards reflecting panels at 3.20pm UTC on the 1st of December 2022 – aerial image*

Figure 24 *Vehicle parking spaces (purple areas) with the potential to cause solar reflections towards the ATC tower and reflecting areas within the proposed development*

7 HIGH-LEVEL ASSESSMENT OF CUMULATIVE EFFECTS

7.1 Overview

The proposed development includes 18 separate modelled areas spread across the site, each of which represent several separate vehicle windscreens and windows.

The cumulative impact of the proposed development upon aviation activity is considered below, with reference to modelling results contained in section 6.2.

7.2 Assessment

In Pager Power's experience, significant cumulative impacts are not predicted for this development with regard to glint and glare effects. This is due to the reflections being predicted not to coincide to produce significant effects, for the following reasons:

- The individual windscreen and car window areas are small and the intensity of reflections are very low;
- The reflective areas of cars in a car park are typically spaced quite far apart, compared to their size, and would therefore be expected to produce a 'twinkling' effect, where reflections are distinct between windscreens;
- The modelled areas have varied azimuth and tilt angles, meaning that they would not be expected to produce reflections towards the same receptors concurrently. Instead, reflections would be separate and transient, with few instances of concurrent reflections;
- There are many surrounding car parking areas which are far larger than this proposed development. Solar reflections from this proposed development would be of a similar or lesser intensity to existing sources of glare in the surrounding area, such as other car parks nearby, including the airport's own carparks.

7.3 Conclusions

No significant cumulative impacts are predicted upon London Stansted Airport from the proposed development and no mitigation is recommended.

The reflecting areas are each small, and reflections would not be expected to significantly coincide due to spacing between vehicles and varying azimuth and tilt angles, which determine the bearing of reflections.

8 HIGH-LEVEL ASSESSMENT OF THE LIGHTING SCHEME

8.1 Overview

The external lighting scheme for the proposed development is presented in Figure 25[17] below. The lighting scheme proposes 38 led lamps to be situated in and around the proposed development. The lighting will be situated within hooded lanterns with light directed downwards rather than sideways or upwards.

> *"The proposed lighting design complies fully with all stipulated aviation standards by providing no upward light (light emitted above the horizontal position) whilst also complying with the source intensity limiting Glare index through the use of specifically designed optics (lens's) that distribute light evenly without high peak intensities at gamma angles above 70 degrees."*[18]

The developer has also committed that any temporary construction lighting would be installed to the same principles as this permanent lighting scheme.

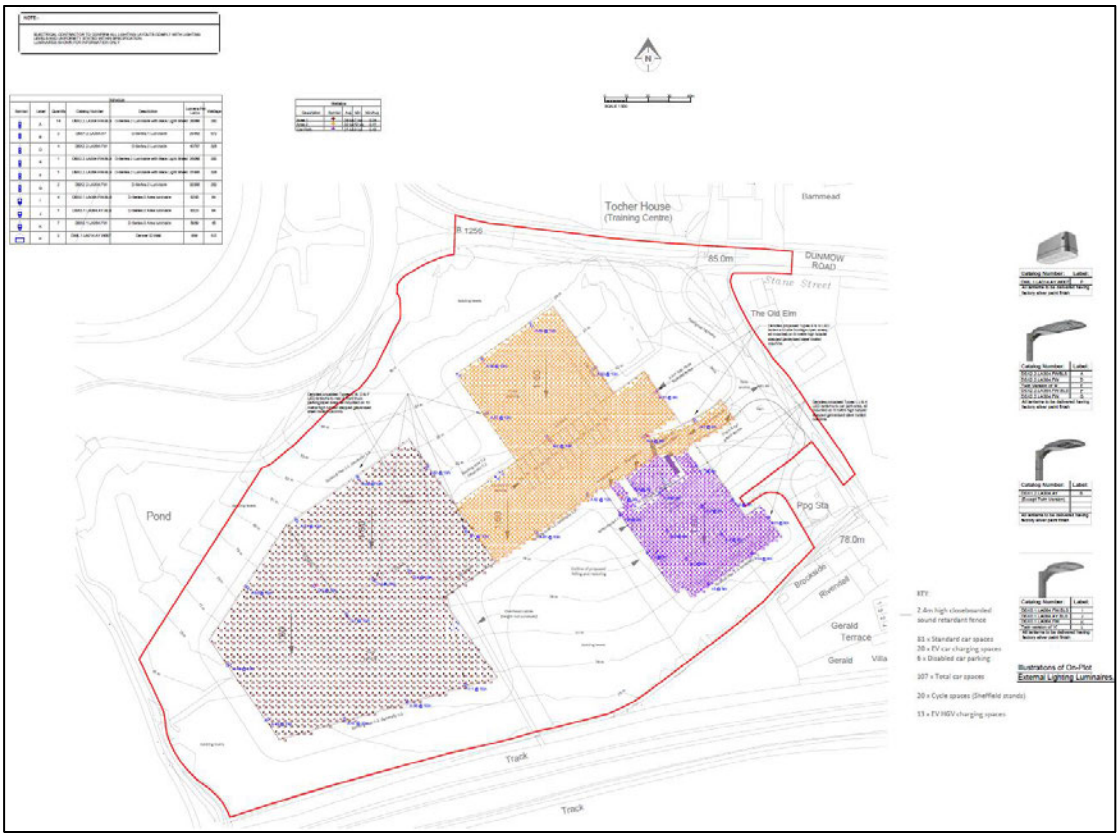

Figure 25 *Lighting Scheme*

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[17] Source: 10398-EXT-01B External Lighting Lux Level Plot.pdf

[18] Source: 10398- External Lighting Strategy - 12.10.21doc.pdf

9 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

9.1 Assessment Conclusions – Aviation

9.1.1 ATC Tower

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards the ATC Tower. Glare of any kind towards an ATC Tower must be carefully evaluated in an operational context. There are mitigating factors that reduce the overall impact. In particular, solar reflections are predicted to occur for a short duration of time throughout the year, will coincide with direct sunlight, and visibility of the reflecting areas would be almost entirely obstructed or completely removed in practice.

Overall, it is judged that the potential effects are acceptable without further mitigation measures.

9.1.2 Runway Approaches and Departures

The analysis has shown that solar reflections are predicted towards the 10NM approach and departure paths for runways 04 and 22.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these runway approaches, which is acceptable in accordance with the associated guidance (Appendix D) and industry best practice for 2-mile approach paths. A low impact is predicted for these approaches, and no mitigation is required.

9.1.3 Visual Circuits

The analysis has shown that solar reflections are predicted towards the left-hand and right-hand GA and CA circuits for runway 04.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards circuits at Stansted Airport. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the circuits. A low impact is predicted, and no mitigation is required.

9.1.4 5km x 5km Overhead Area

The analysis has shown that solar reflections are predicted towards the 5km x 5km overhead area centred upon the proposed development at 2500ft agl.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards the overhead area. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the overhead area. A low impact is predicted, and no mitigation is required.

9.1.5 Visual Flight Routes (VFRs)

The analysis has shown that solar reflections are predicted towards the Audley End, Canfield, Nuthampstead and Puckeridge VFRs.

It is predicted that solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these VFRs. Considering the associated guidance for approach paths which state that this level of glare is acceptable, it can be reliably presumed that this level of glare intensity is acceptable for the VFRs. A low impact is predicted, and no mitigation is required.

9.2 High Level Conclusions – Cumulative Impact

No significant cumulative impacts are predicted upon London Stansted Airport from the proposed development and no mitigation is recommended.

The reflecting areas are each small, and reflections would not be expected to significantly coincide due to spacing between vehicles and varying azimuth and tilt angles, which determine the bearing of reflections. The modelled areas are also conservative in size as the entire parking space in each row have been modelled and not just the area in which the windows would be located.

9.3 High Level Conclusions – Lighting Scheme

Artificial lighting or reflections from artificial lighting is expected to not be significant because reflections of artificial lighting will be of a lower intensity than that associated with reflections from the Sun and there is already existing lighting in the areas surrounding the airport that pilots appropriately manage with on approach to Stansted Airport. The Sun is a far more significant source of light and therefore considering the analysis results for the approach paths and ATC Tower, no significant impacts are predicted because of the lighting scheme. No mitigation is required.

The developer has confirmed that any temporary lighting would be installed to the same principles as the permanent lighting scheme.

9.4 Overall Conclusions

No significant impacts are predicted upon pilots when flying on the 10NM runway approaches and departures, commercial aviation (CA) and general aviation (GA) visual circuits, visual flight routes and the 5km x 5km overhead area. No mitigation is required.

Solar reflections with a 'low potential for temporary after-image' are predicted towards the Air Traffic Control (ATC) Tower. This is the lowest intensity category within industry-standard modelling methodology for glare effects and is consistent with glare commonly encountered from outdoor surfaces. Furthermore, there are mitigating factors that further reduce the overall impact (see Section 6.3). Overall, it is judged that the potential effects are acceptable without further mitigation measures.

This report should be made available to the safeguarding team for London Stansted Airport to understand their position along with any feedback or comments regarding the proposed development.

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, 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.

The information pertains largely to effects from solar panels – however this is relevant from a technical perspective because solar panels and glass windows are similar in the context of specular reflections.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[19] (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.'

[19] 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)[20] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[21] However, solar panels may reflect the sun's rays at certain angles, 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.

3.10.94 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

3.10.95 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

3.10.96 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

3.10.97 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 3.10.125-127 state:

3.10.125 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

3.10.126 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

3.10.127 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence.

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[20] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 05/04/2023.

[21] *Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.*

In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 3.10.149-150 state:

3.10.149 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, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

3.10.150 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; though, this is still unlikely to be welcomed by aviation stakeholders, who 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 final issue of the policy will change in light of further consultation responses from aviation stakeholders.

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

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, 2012[22] however the advice is still applicable[23] 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.

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[22] Archived at Pager Power

[23] Reference email from the CAA dated 19/05/2014.

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 ALH[24], 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. 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'[25], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System

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[24] Aerodrome Licence Holder.
[25] Archived at Pager Power

Projects on Federally Obligated Airports'[26], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[27].

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. 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.

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[26] 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.

[27] 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.

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'[28]. 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 blindness[29].
- 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 16[30], 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 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

[28] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[29] 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.
[30] First figure in Appendix B.

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 question[31] 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.

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[31] 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 2016[32] 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

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[32] 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

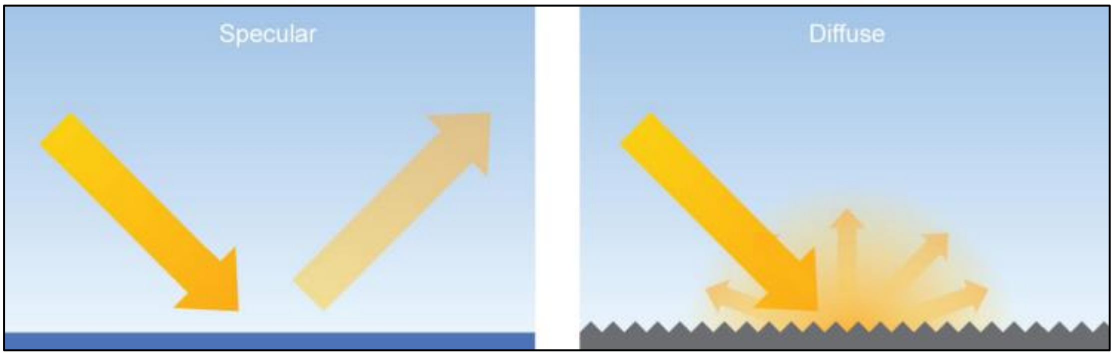
Overview

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 guidance[33], 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

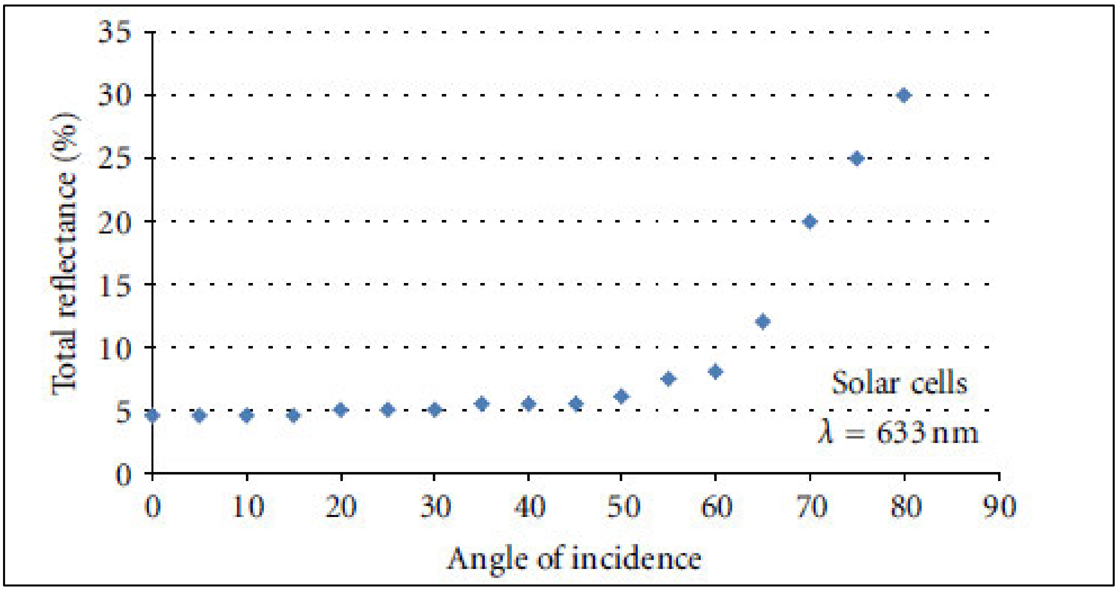
[33] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[34]". 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.

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[34] 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"[35]

The 2010 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[36]
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).

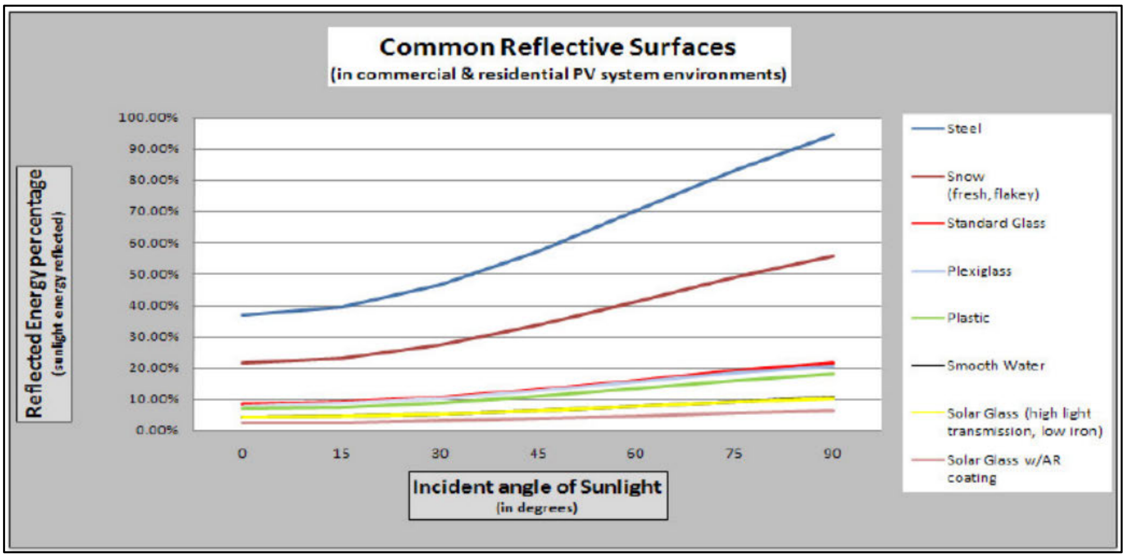
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[35] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.
[36] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[37] 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.

[37] 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).

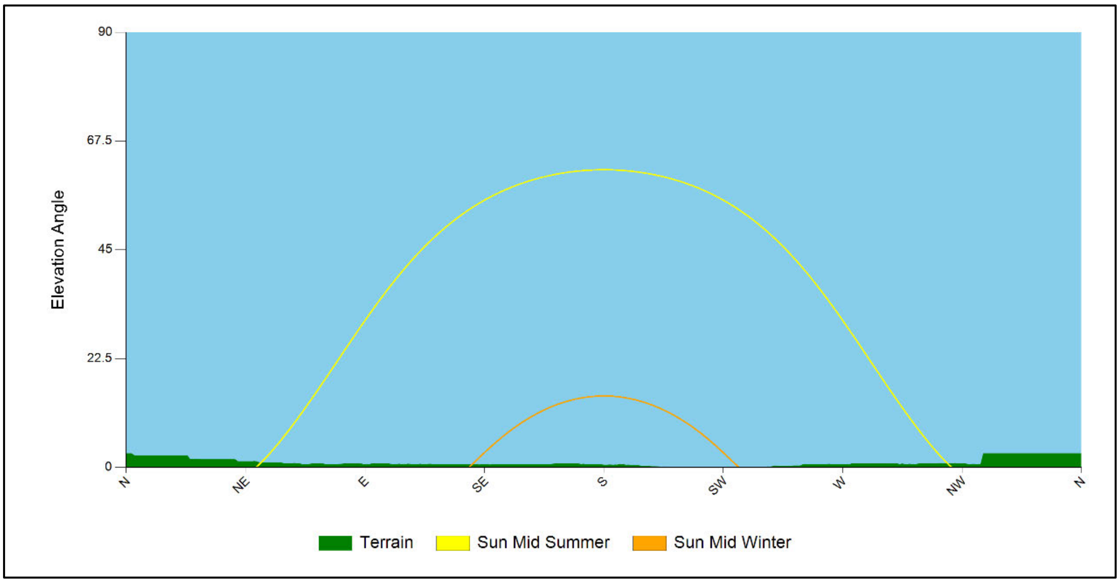
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

The following is true at the location of the proposed 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. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from the development location.



Sunrise and sunset curves

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

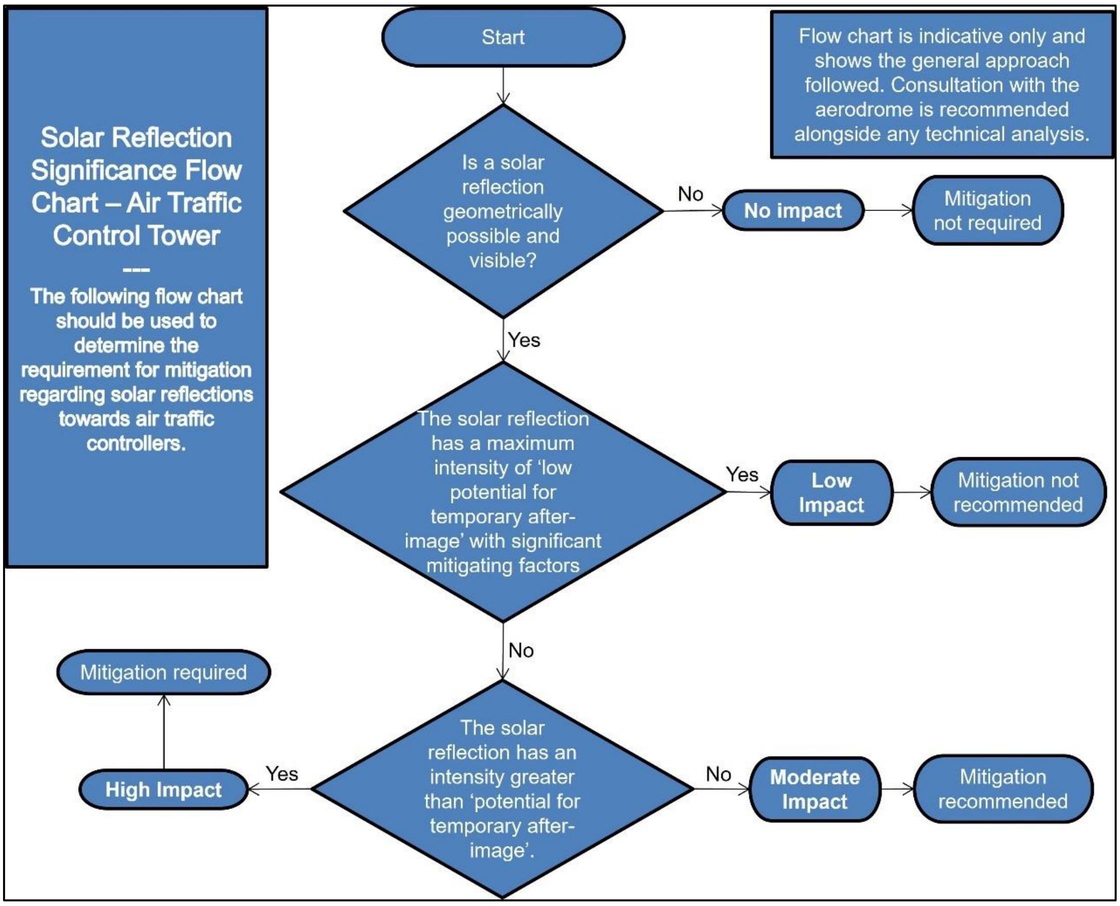
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation
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

Impact Significance Determination for ATC Towers

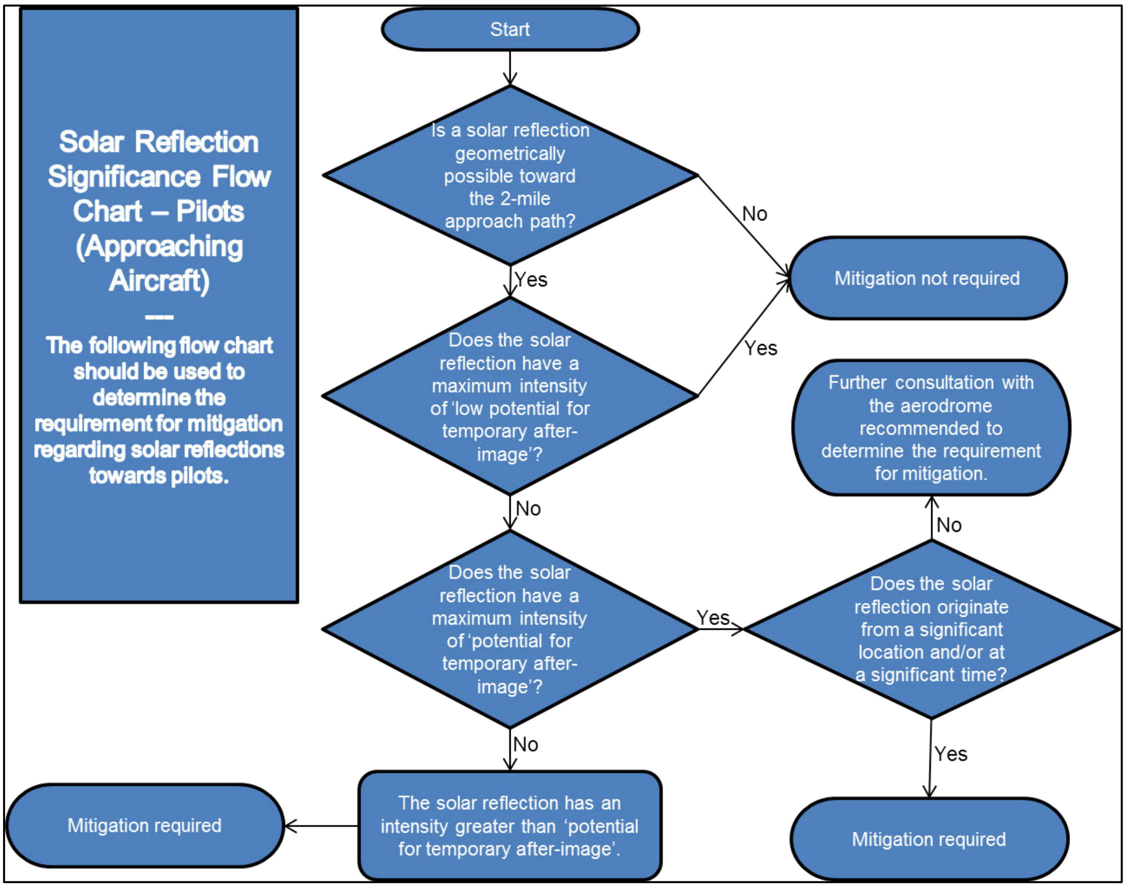
The flow chart presented below has been followed when determining the mitigation requirement for ATC Towers.



ATC Tower receptor mitigation requirement flow chart

Impact Significance Determination for Approaching Aircraft

The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



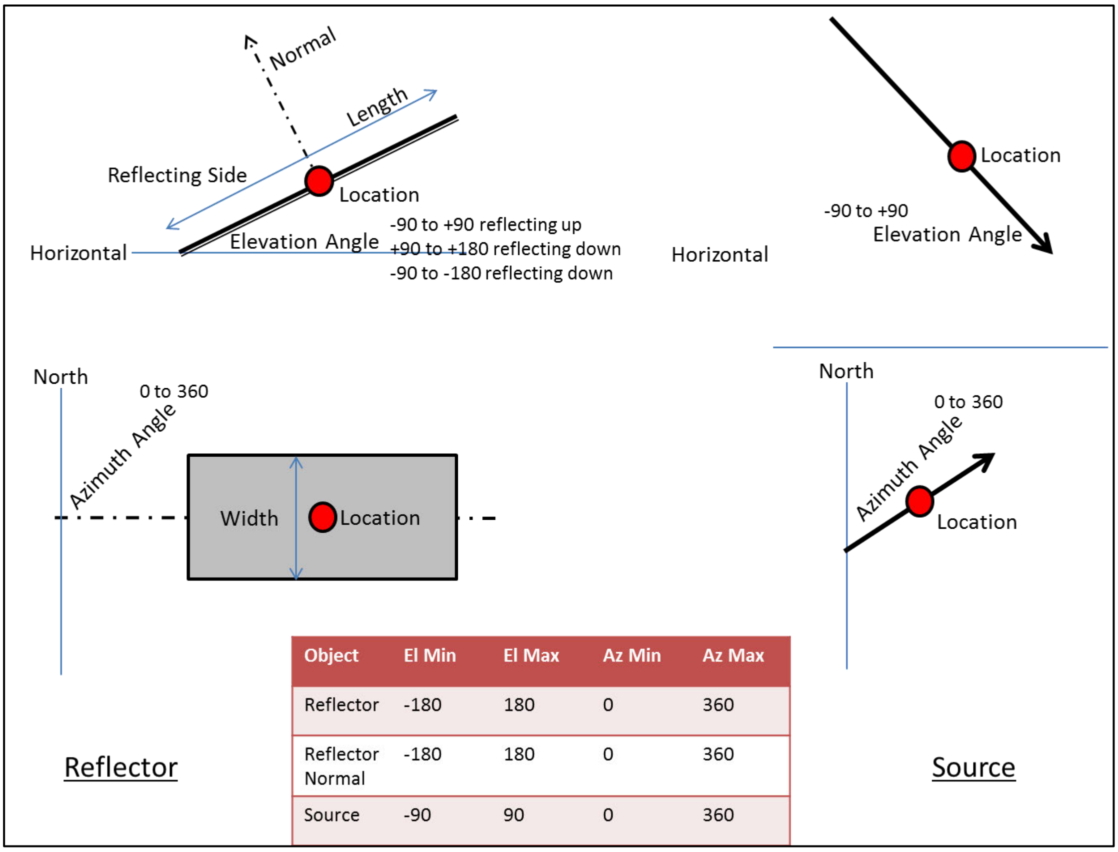
Approaching aircraft receptor mitigation requirement flow chart

APPENDIX E – 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.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

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

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[38].

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

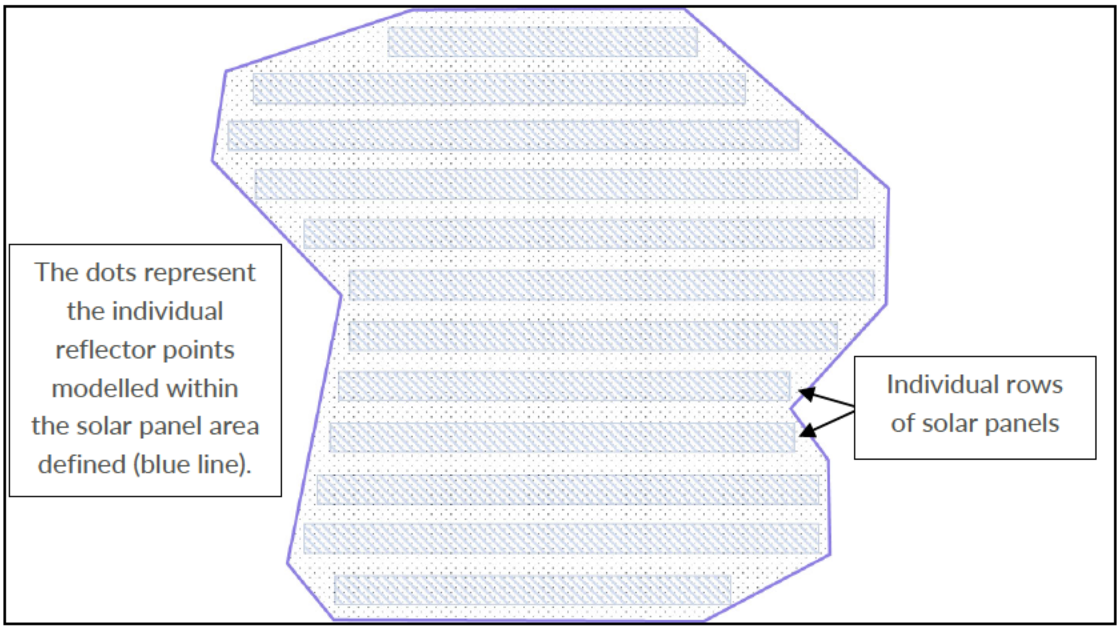
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the 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 assessment resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure below which illustrates this process.

[38] UK only.



Solar panel area modelling overview

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 Forge[39] 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 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 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 total heights of the coordinates outlined in the Google map. For more 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.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

[39] Source: https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

ATC Receptor Details

The co-ordinates and overall altitude of the ATC Tower has been extrapolated from available maps and imagery. The ground height has been taken from Pager Power's database[40] based on the co-ordinates of the ATC Tower. The details are presented in the table below.

Longitude (°)	Latitude (°)	Ground Height Altitude (m) (amsl)	ATC Tower Observer Height[41] (m)	Overall Assessed Height (m)
0.25458	51.88531	94.94	63.00	157.94

ATC Tower receptor details

Runway Details

The table below presents the runway details for Stansted Airport. Full receptor details can be provided upon request.

Runway	Longitude (°)	Latitude (°)	Threshold Altitude (ft) (amsl)
04/22	0.22286	51.87704	332.3
	0.25004	51.89516	347.6

Runway details for Stansted Airport

Modelled Reflector Areas

The modelled reflector areas are presented in the tables below.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20334	51.87023	3	0.20350	51.87017
2	0.20341	51.87026	4	0.20343	51.87014

Modelled Reflector Data – Area C1

[40] Based on OS Panorama 50m DTM
[41] Estimated based on the available imagery.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20346	51.87028	3	0.20362	51.87022
2	0.20353	51.87031	4	0.20355	51.87019

Modelled Reflector Data – Area C2

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20339	51.87008	3	0.20379	51.87019
2	0.20375	51.87023	4	0.20343	51.87004

Modelled Reflector Data – Area C3

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20354	51.87002	3	0.20392	51.87007
2	0.20384	51.87015	4	0.20362	51.86995

Modelled Reflector Data – Area C4

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20367	51.86990	3	0.20406	51.86995
2	0.20397	51.87003	4	0.20375	51.86983

Modelled Reflector Data – Area C5

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20373	51.86975	3	0.20438	51.86997
2	0.20434	51.87001	4	0.20377	51.86971

Modelled Reflector Data – Area C6

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20338	51.87000	3	0.20373	51.86976
2	0.20344	51.87002	4	0.20366	51.86973

Modelled Reflector Data – Area C7

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20388	51.87021	3	0.20415	51.87005
2	0.20394	51.87023	4	0.20409	51.87002

Modelled Reflector Data – Area C8

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20409	51.87002	3	0.20428	51.87005
2	0.20424	51.87009	4	0.20413	51.86998

Modelled Reflector Data – Area C9

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20336	51.87061	3	0.20367	51.87048
2	0.20347	51.87066	4	0.20355	51.87043

Modelled Reflector Data – Area H1

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20220	51.87066	3	0.20271	51.87072
2	0.20259	51.87083	4	0.20233	51.87055

Modelled Reflector Data – Area H2

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20245	51.87044	3	0.20315	51.87057
2	0.20302	51.87068	4	0.20257	51.87033

Modelled Reflector Data – Area H3

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20246	51.87023	3	0.20330	51.87042
2	0.20317	51.87054	4	0.20258	51.87012

Modelled Reflector Data – Area H4

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20104	51.87004	3	0.20198	51.87027
2	0.20185	51.87038	4	0.20116	51.86993

Modelled Reflector Data – Area H5

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20128	51.86982	3	0.20198	51.86995
2	0.20186	51.87006	4	0.20141	51.86970

Modelled Reflector Data – Area H6

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20114	51.86956	4	0.20192	51.86987
2	0.20138	51.86966	5	0.20203	51.86977
3	0.20139	51.86965	6	0.20126	51.86945

Modelled Reflector Data – Area H7

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20051	51.86956	3	0.20113	51.86989
2	0.20100	51.87000	4	0.20064	51.86944

Modelled Reflector Data – Area H8

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	0.20084	51.86925	3	0.20245	51.86939
2	0.20232	51.86951	4	0.20097	51.86914

Modelled Reflector Data – Area H9

APPENDIX H – DETAILED MODELLING RESULTS

Overview

The Pager Power charts for receptors are shown on the following pages. Further modelling charts can be provided upon request. 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 reflection date/time graph – left hand side of image. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas;
- The sunrise and sunset curves throughout the year (red and yellow lines).

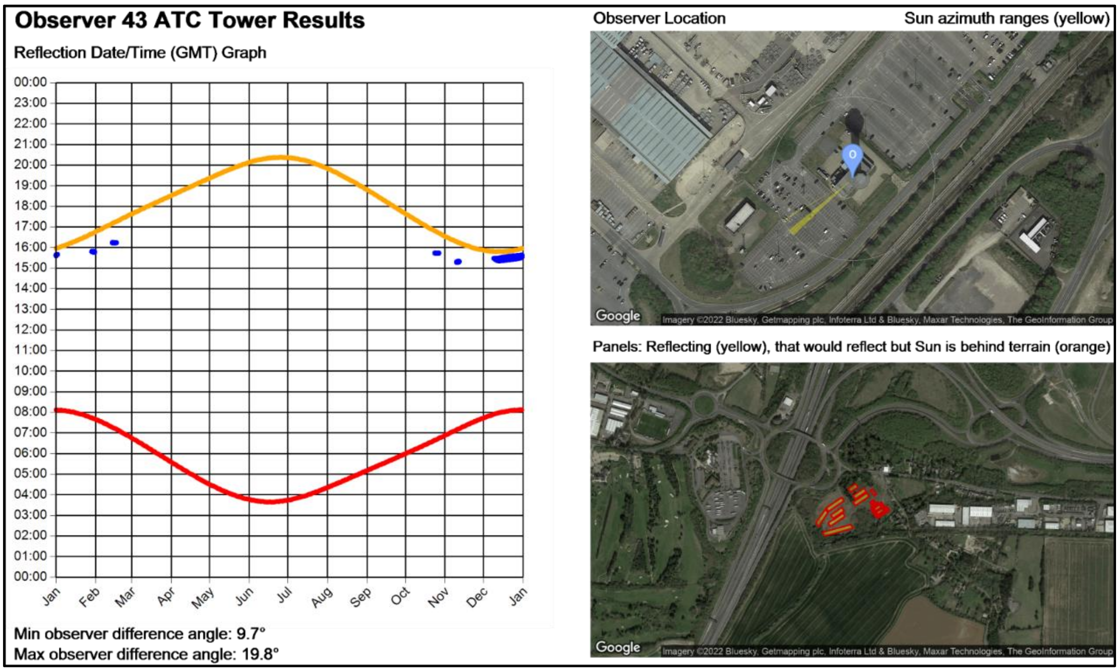
The Forge charts for the receptors are shown on the following pages. Each chart shows:

- The annual predicted solar reflections;
- The daily duration of the solar reflections;
- The location of the proposed development where glare will originate;
- The calculated intensity of the predicted solar reflections.

Full modelling results can be provided upon request.

ATC Tower

Pager Power

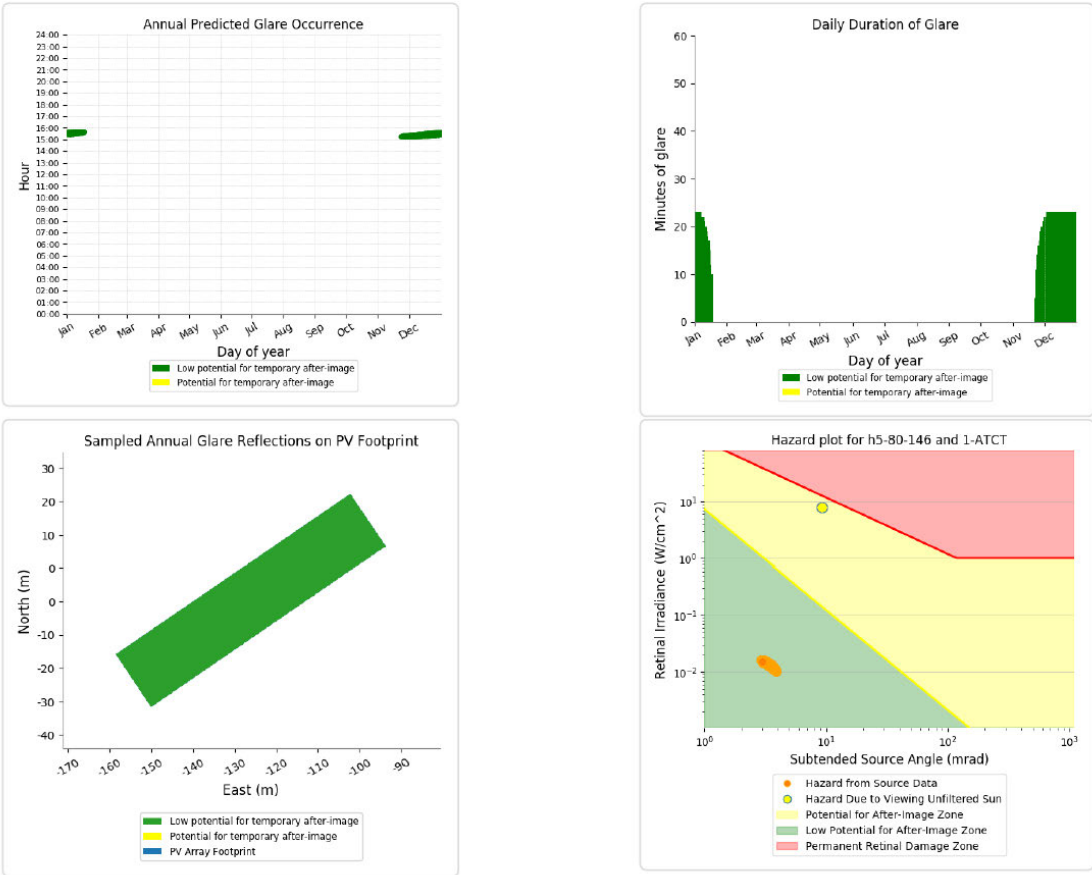


Forge

H5 80 146 - OP Receptor (1-ATCT)

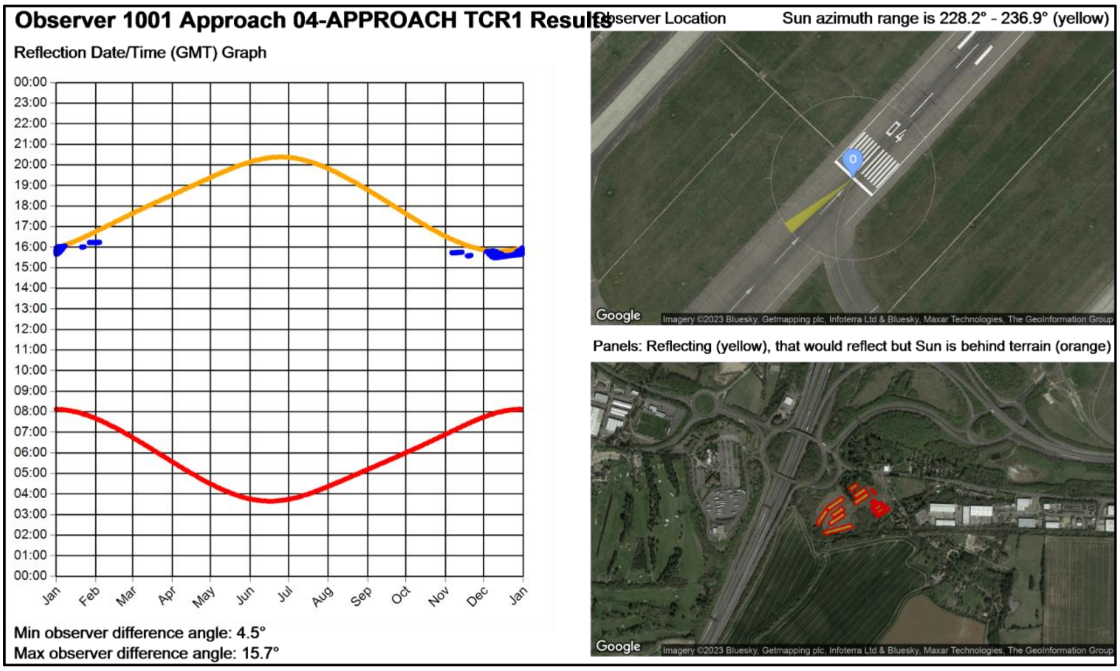
PV array is expected to produce the following glare for receptors at this location:

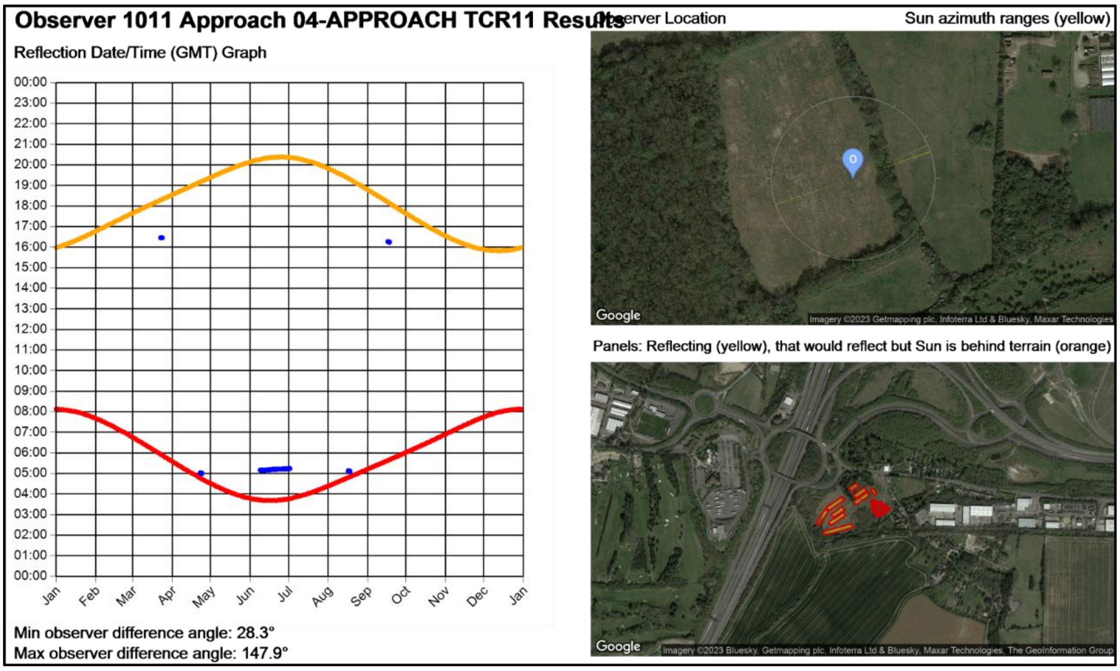
- 1,213 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

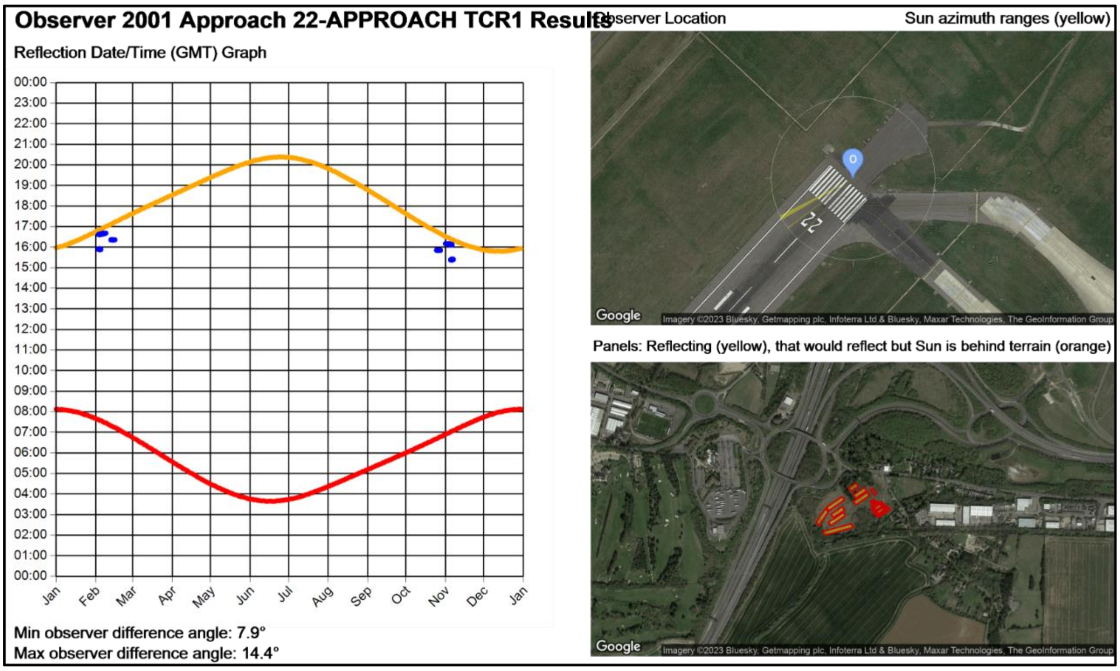


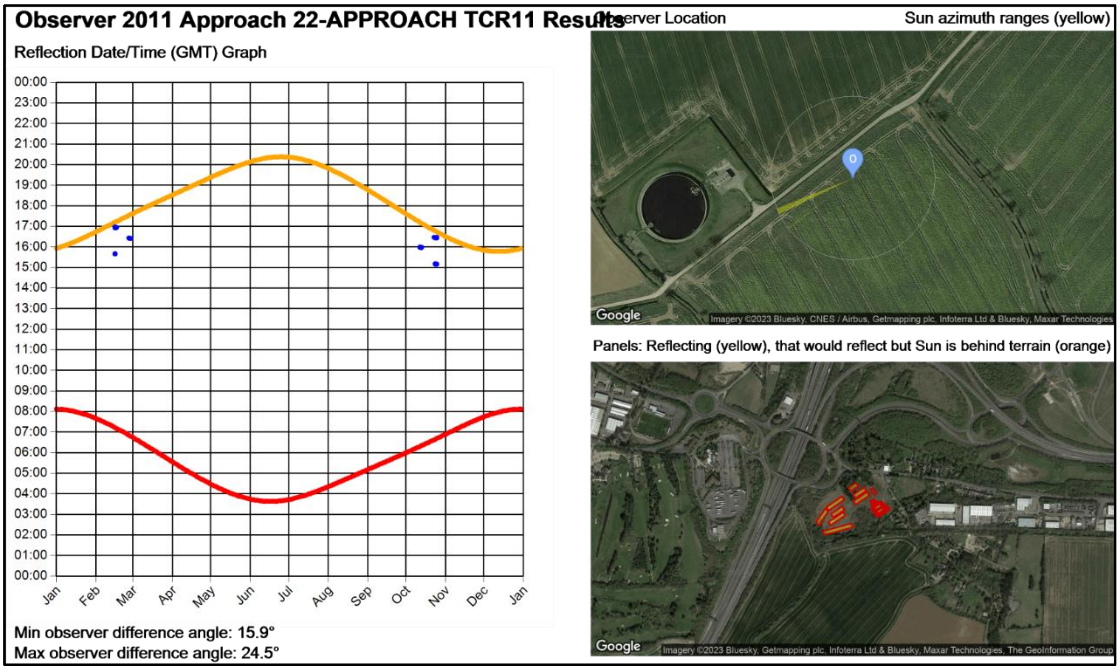
Approach Paths

Pager Power






Observer 2001 Approach 22-APPROACH TCR1 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 7.9°
Max observer difference angle: 14.4°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

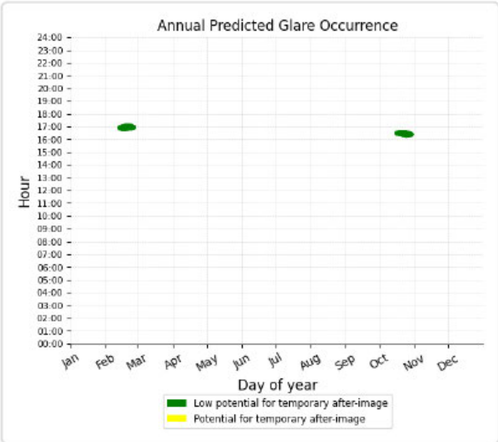

Observer 2011 Approach 22-APPROACH TCR11 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 15.9°
Max observer difference angle: 24.5°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

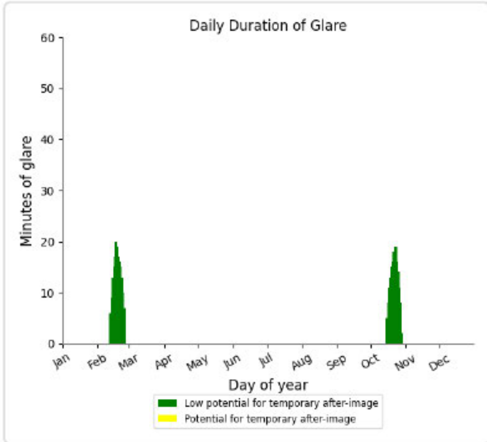
Forge

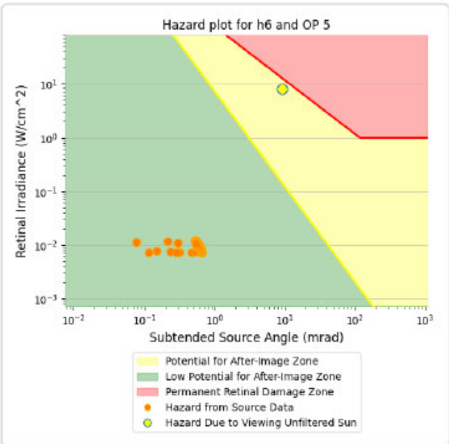
H6 and OP 5

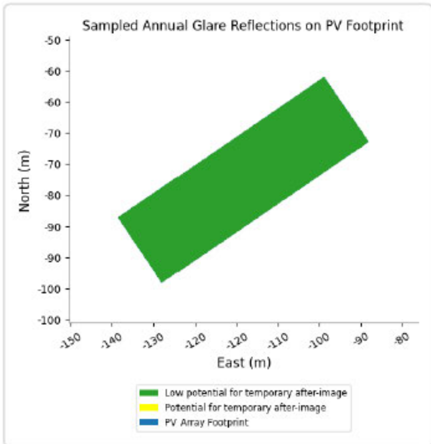
Yellow glare: none

Green glare: 391 min.



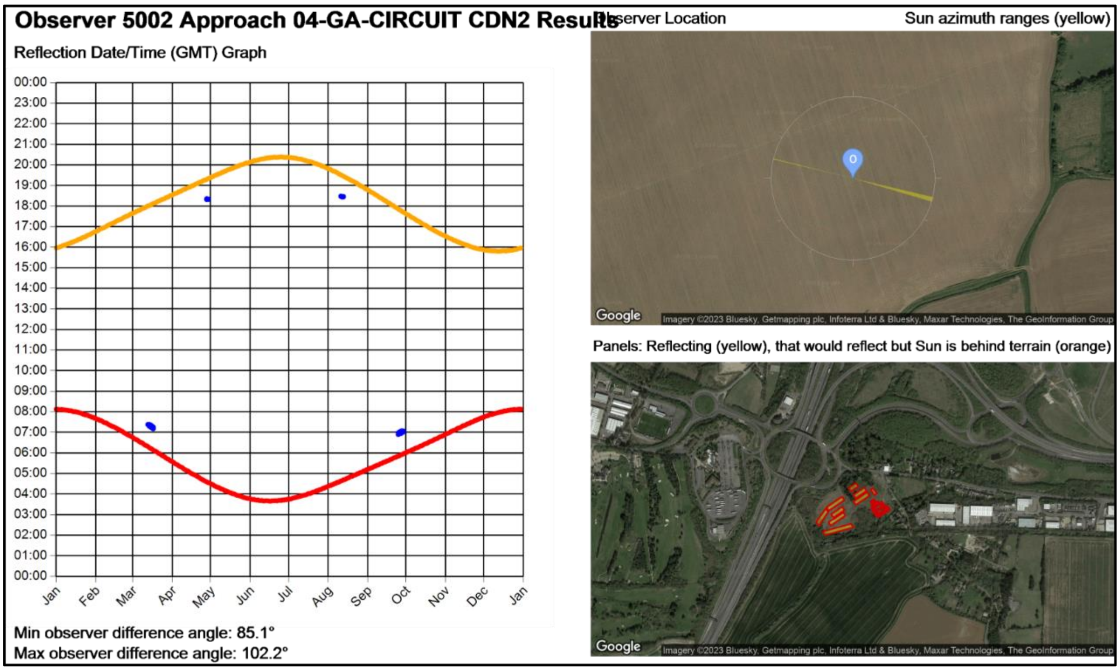


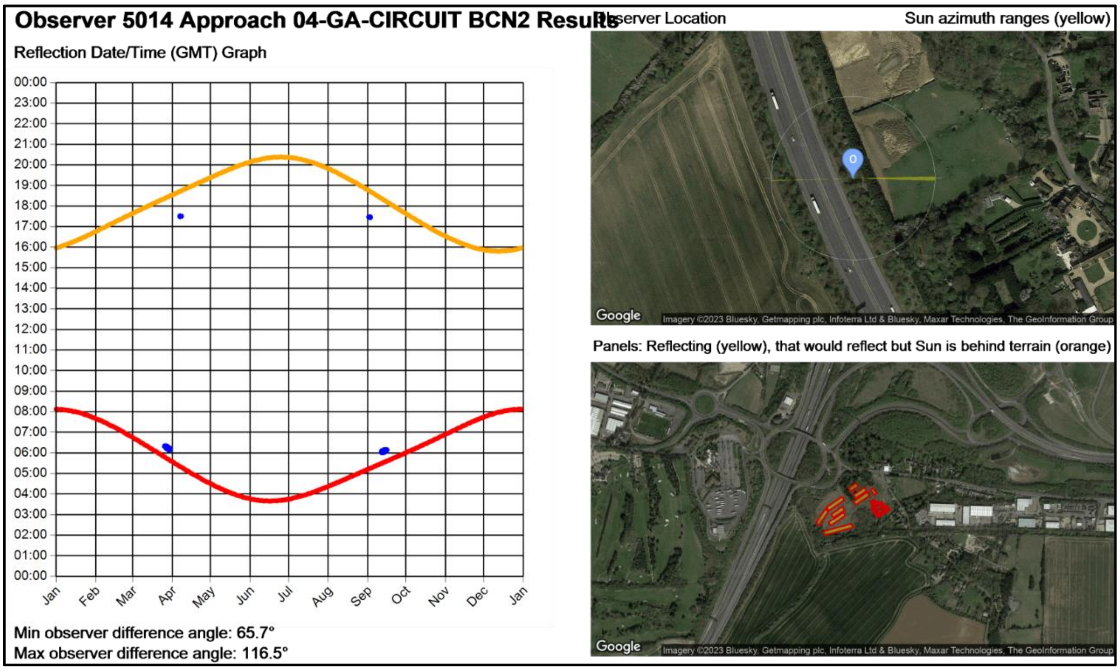


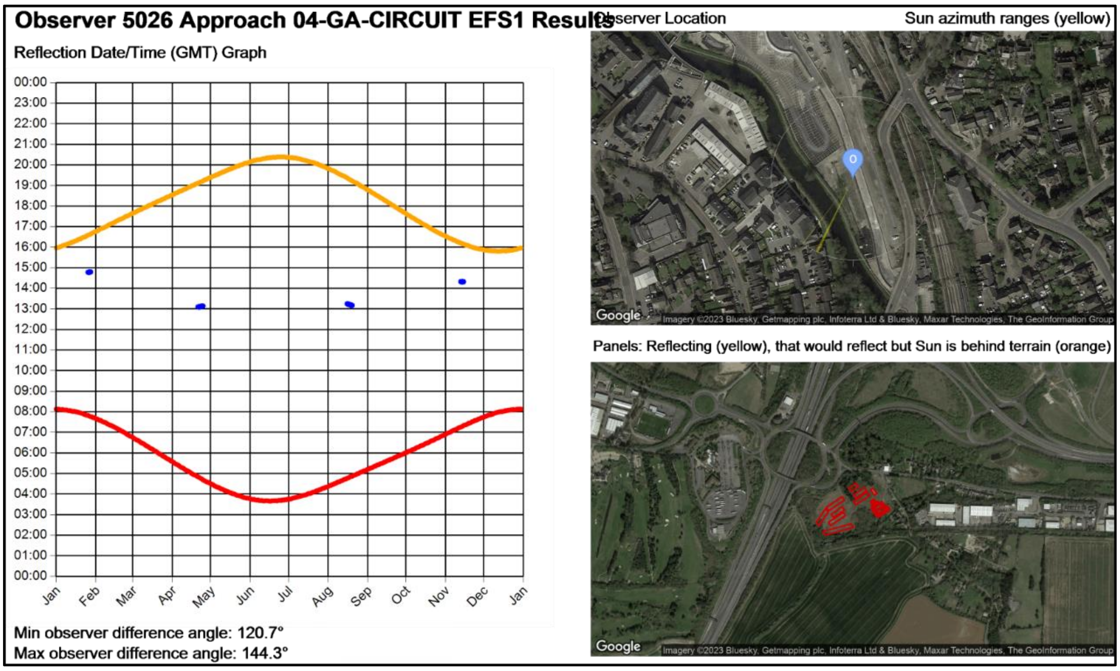


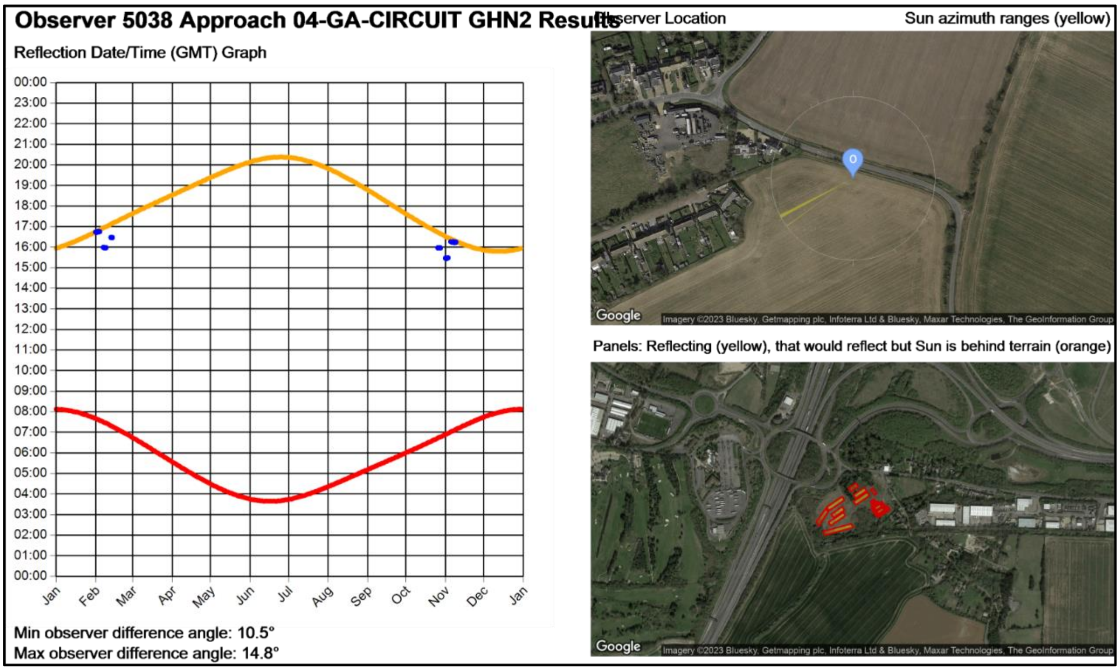
GA and CA Circuits

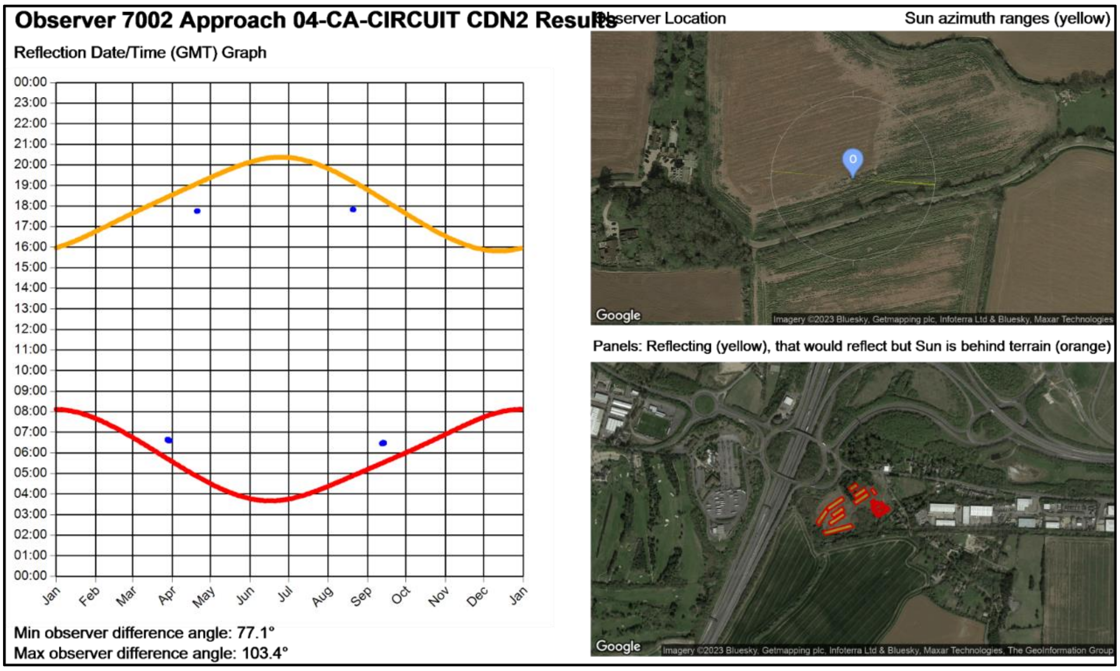
Pager Power

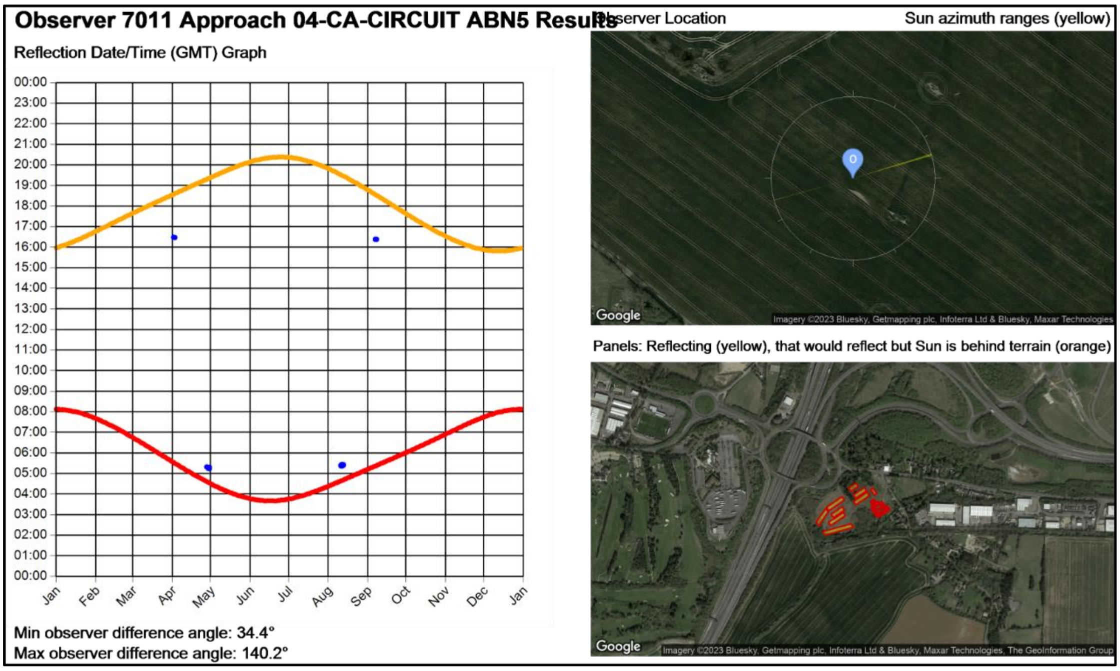


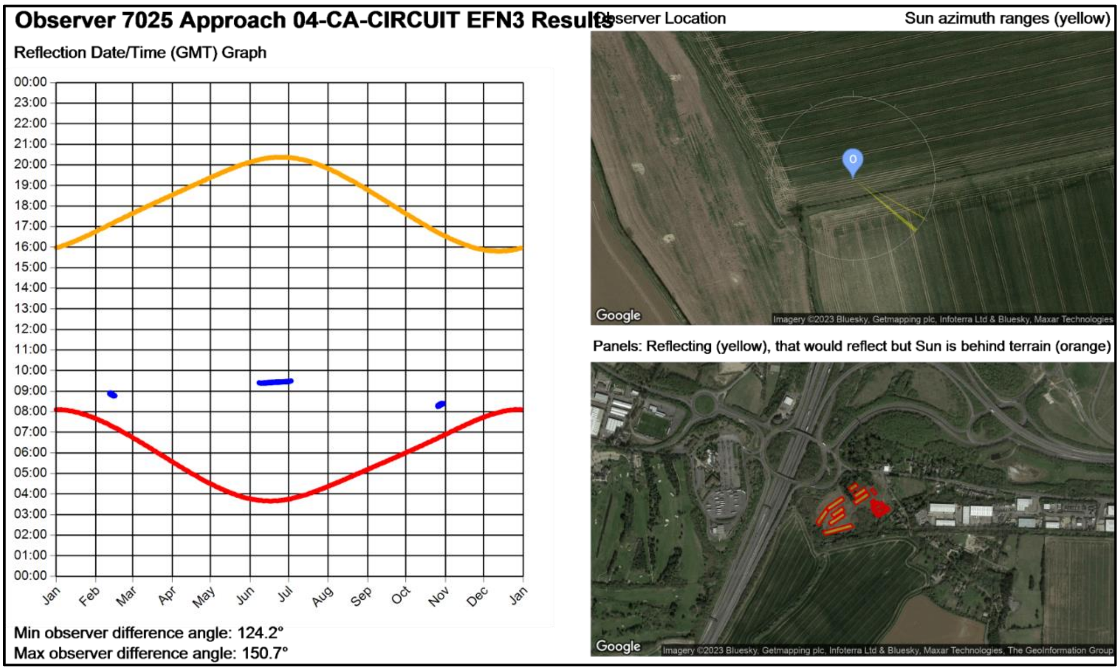


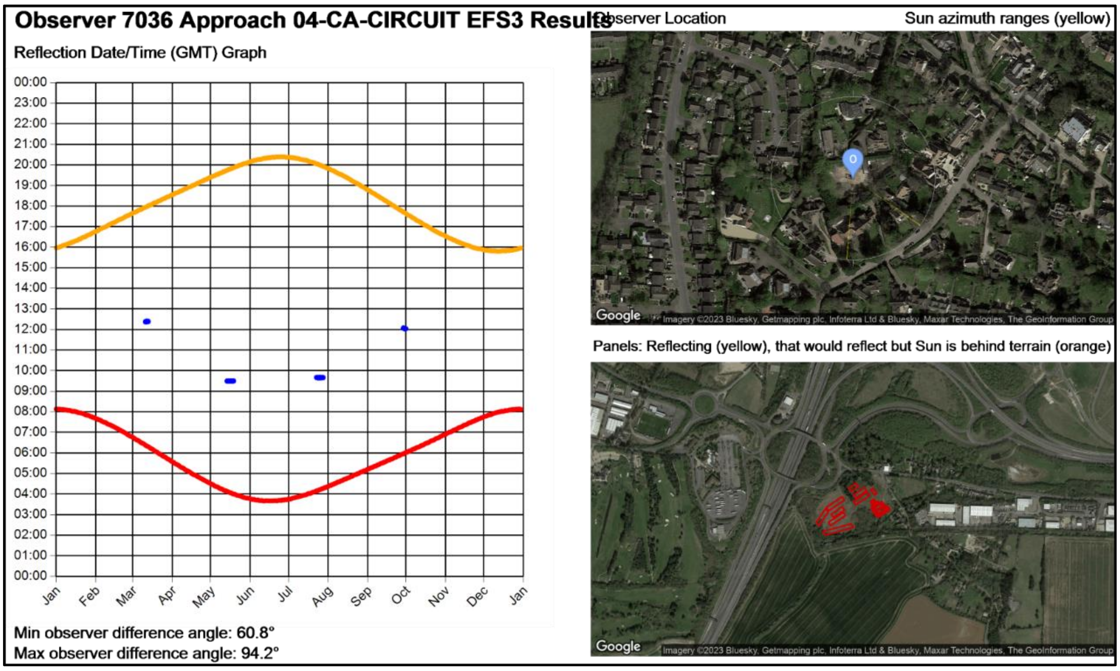

Observer 5026 Approach 04-GA-CIRCUIT EFS1 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 120.7°
Max observer difference angle: 144.3°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

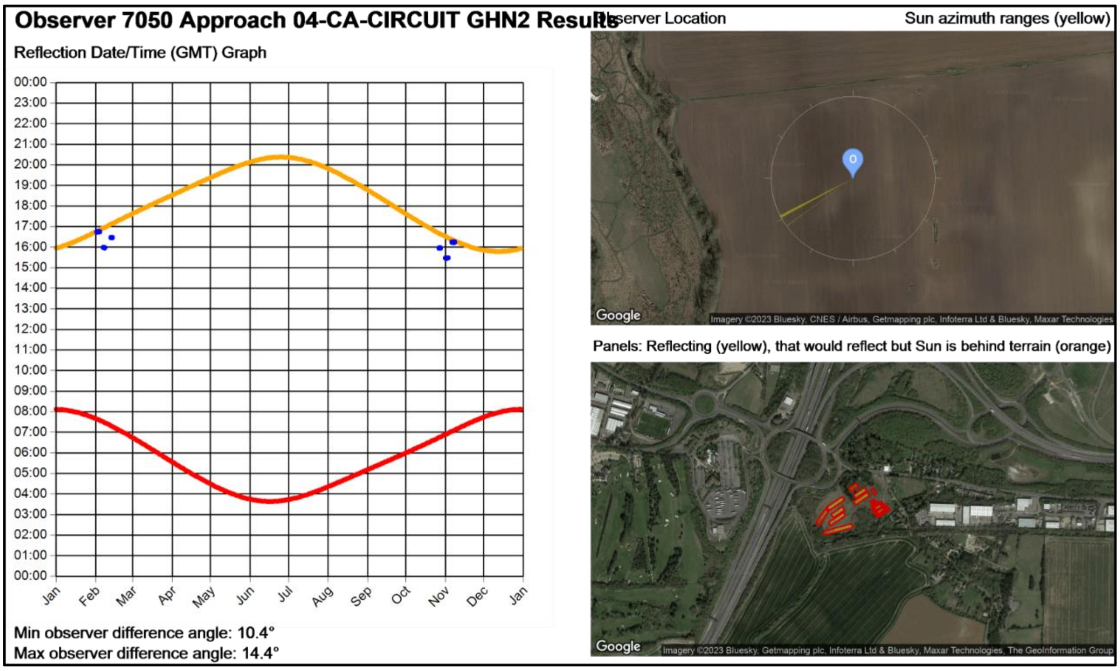

Observer 5038 Approach 04-GA-CIRCUIT GHN2 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 10.5°
Max observer difference angle: 14.8°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

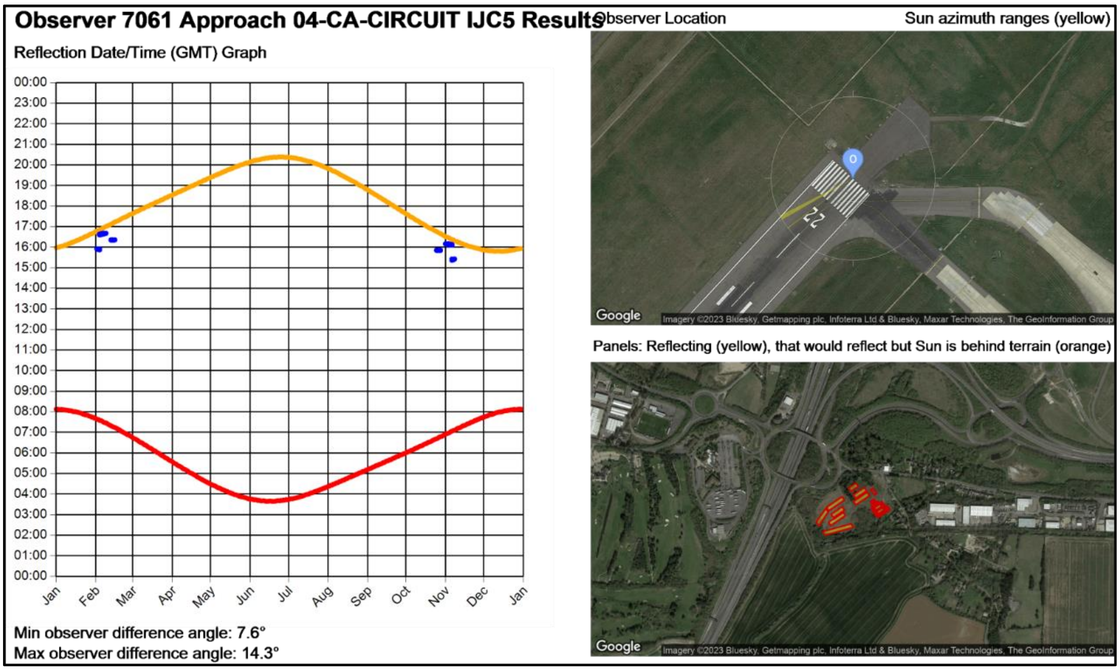

Observer 7002 Approach 04-CA-CIRCUIT CDN2 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 77.1°
Max observer difference angle: 103.4°
Observer Location
Sun azimuth ranges (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 7011 Approach 04-CA-CIRCUIT ABN5 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 34.4°
Max observer difference angle: 140.2°
Observer Location
Sun azimuth ranges (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 7025 Approach 04-CA-CIRCUIT EFN3 Results
Reflection Date/Time (GMT) Graph
00:00 23:00 22:00 21:00 20:00 19:00 18:00 17:00 16:00 15:00 14:00 13:00 12:00 11:00 10:00 09:00 08:00 07:00 06:00 05:00 04:00 03:00 02:00 01:00 00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 124.2°
Max observer difference angle: 150.7°
Observer Location
Sun azimuth ranges (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 7036 Approach 04-CA-CIRCUIT EFS3 Results
Reflection Date/Time (GMT) Graph
00:00 23:00 22:00 21:00 20:00 19:00 18:00 17:00 16:00 15:00 14:00 13:00 12:00 11:00 10:00 09:00 08:00 07:00 06:00 05:00 04:00 03:00 02:00 01:00 00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 60.8°
Max observer difference angle: 94.2°
Observer Location
Sun azimuth ranges (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 7050 Approach 04-CA-CIRCUIT GHN2 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 10.4°
Max observer difference angle: 14.4°
Observer Location
Sun azimuth ranges (yellow)
Google
Imagery ©2023 Bluesky, CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2023 Bluesky, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group

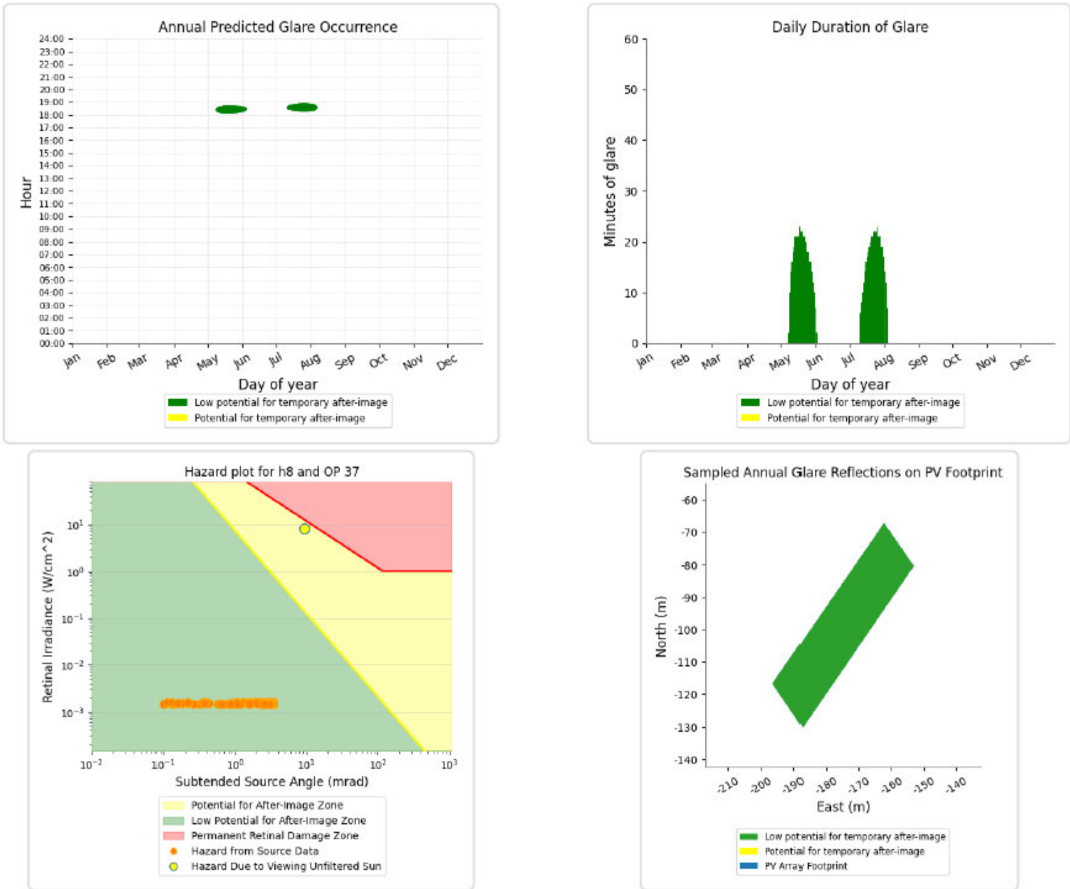

Observer 7061 Approach 04-CA-CIRCUIT IJC5 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 7.6°
Max observer difference angle: 14.3°
Observer Location
Sun azimuth ranges (yellow)
22
Google
Imagery ©2023 Bluesky, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2023 Bluesky, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies, The GeoInformation Group

Forge

H8 and OP 37

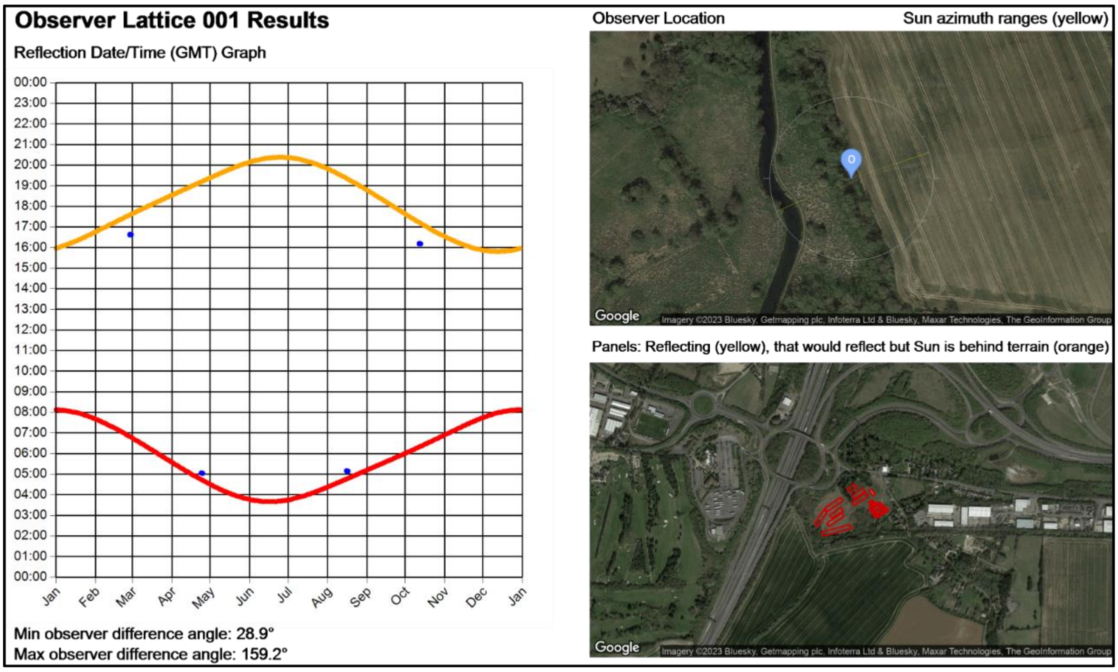
Yellow glare: none

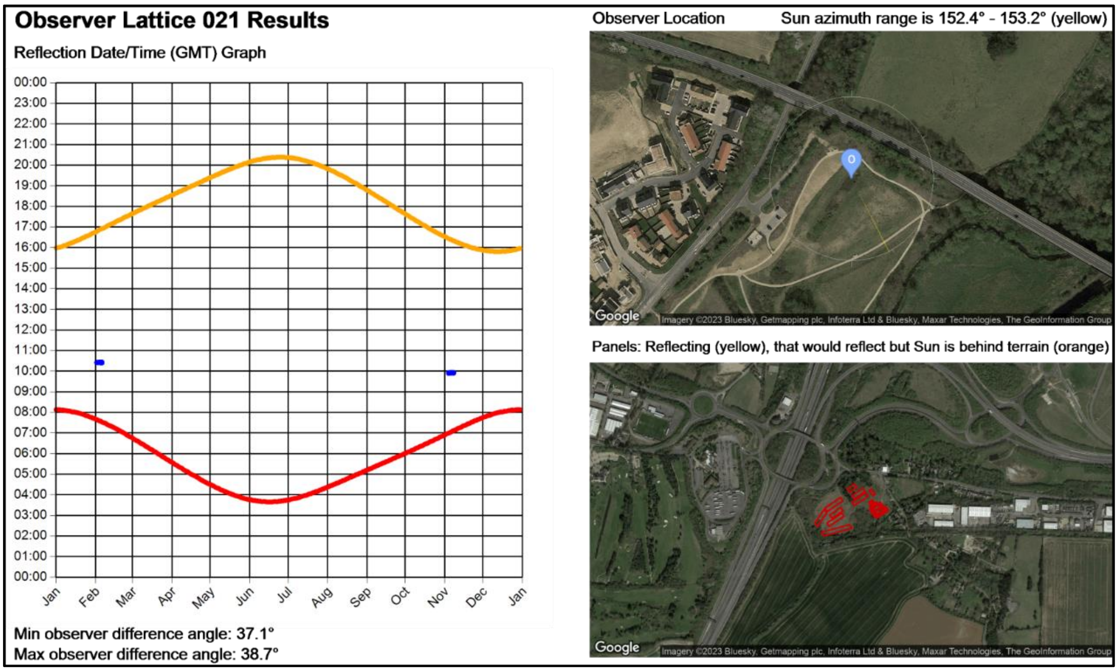
Green glare: 847 min.

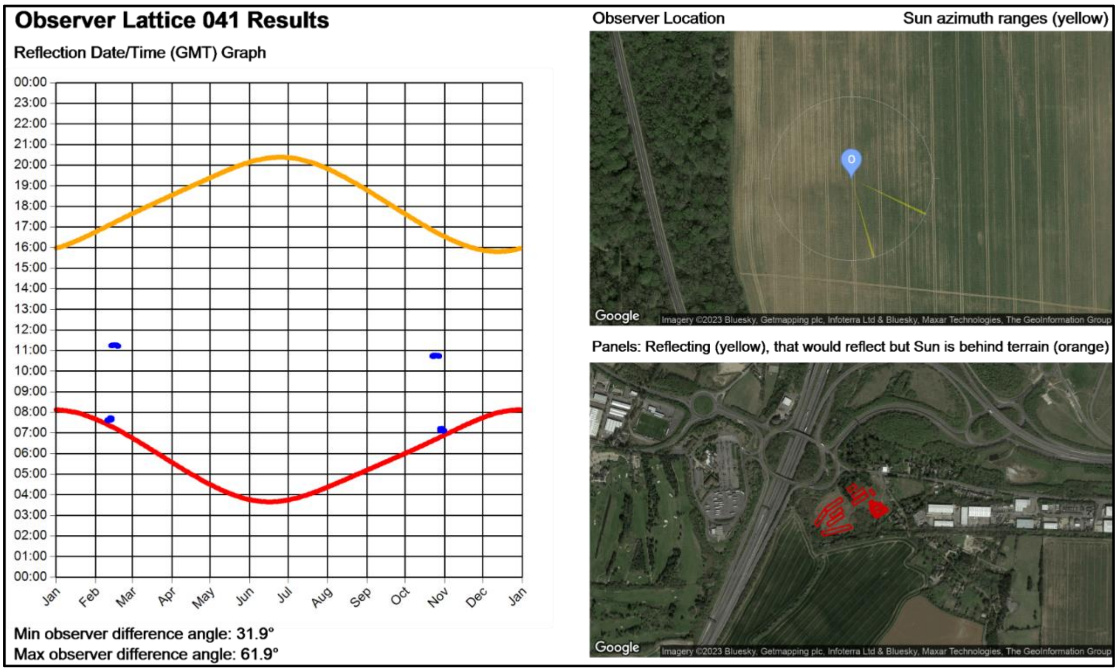


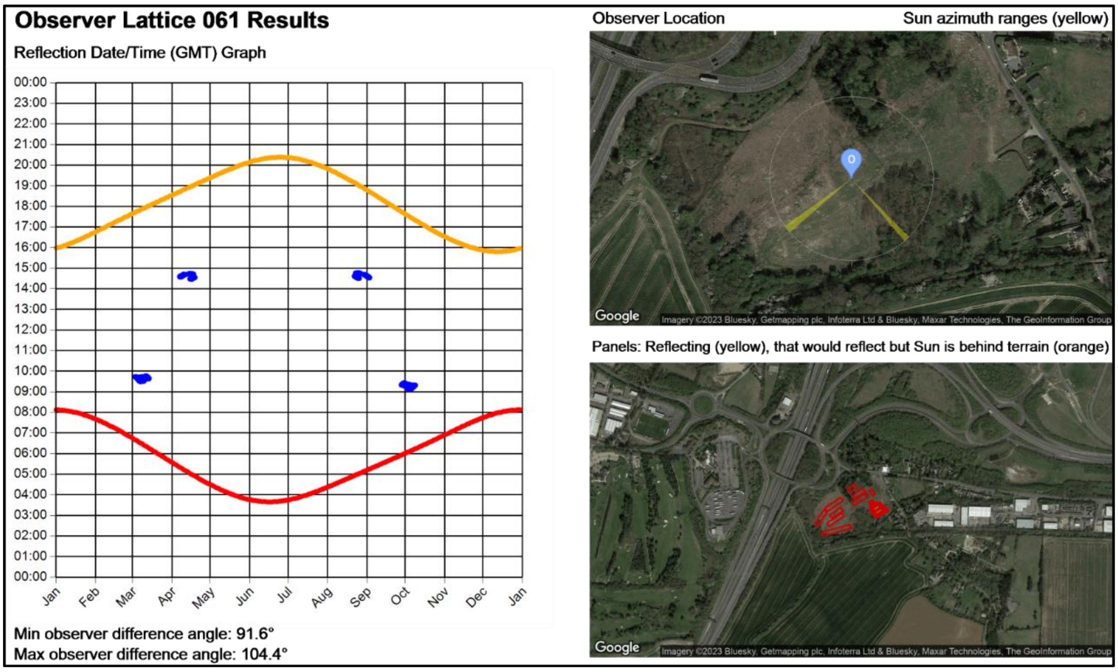
5km x 5km Overhead Area

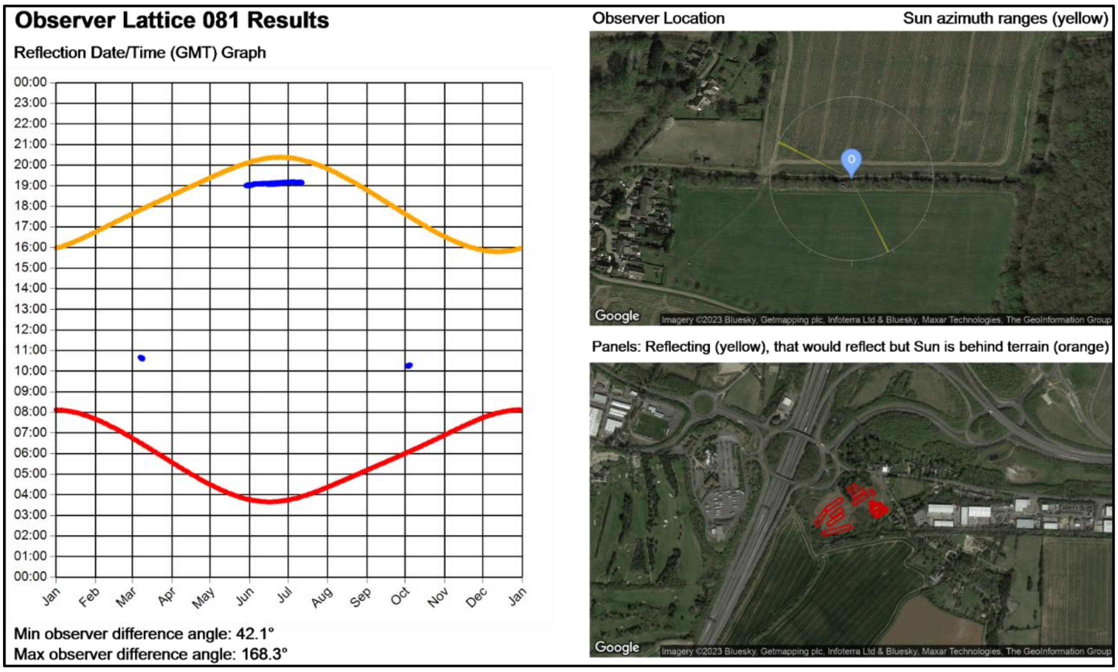
Pager Power

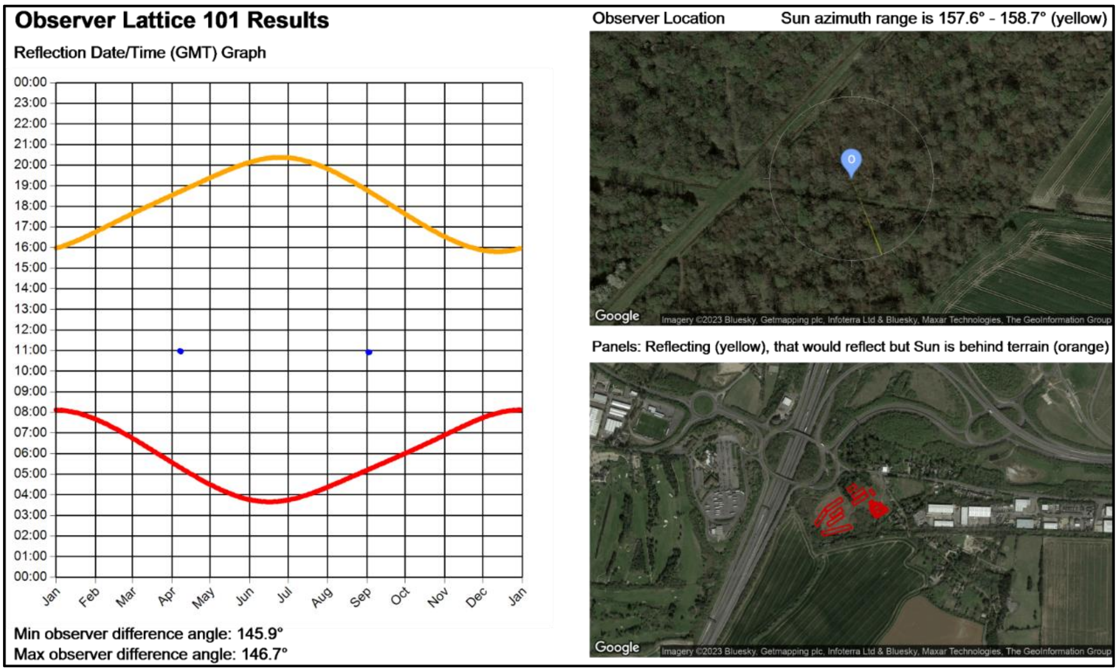


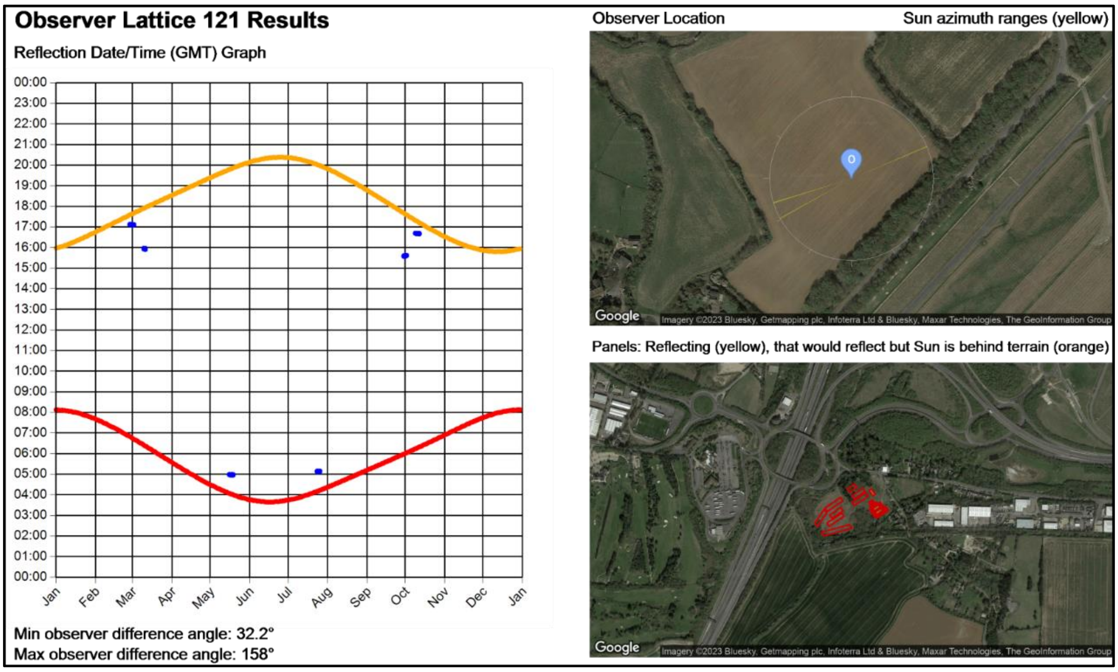



Observer Lattice 041 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 31.9°
Max observer difference angle: 61.9°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Lattice 061 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 91.6°
Max observer difference angle: 104.4°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Lattice 081 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 42.1°
Max observer difference angle: 168.3°
Observer Location
Sun azimuth ranges (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Lattice 101 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 145.9°
Max observer difference angle: 146.7°
Observer Location
Sun azimuth range is 157.6° - 158.7° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google



Observer Lattice 121 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 32.2°
Max observer difference angle: 158°
Observer Location
Sun azimuth ranges (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Forge

H1 and OP 15

Yellow glare: none

Green glare: 1,354 min.

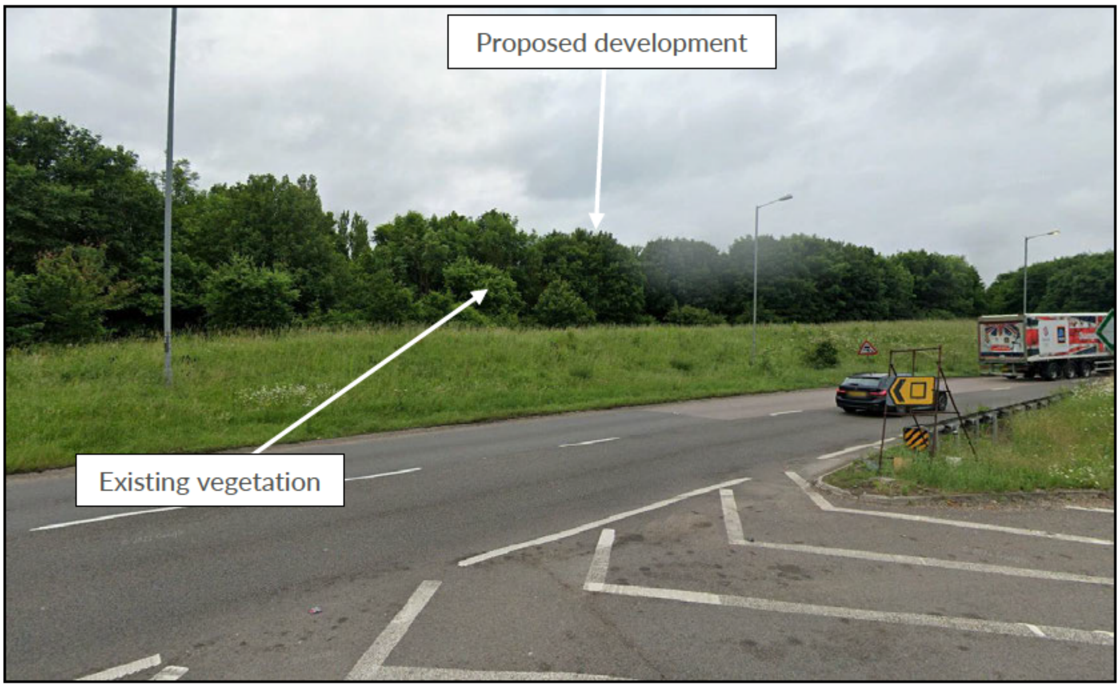
APPENDIX I – SCREENING ANALYSIS

Screening Assessment Overview

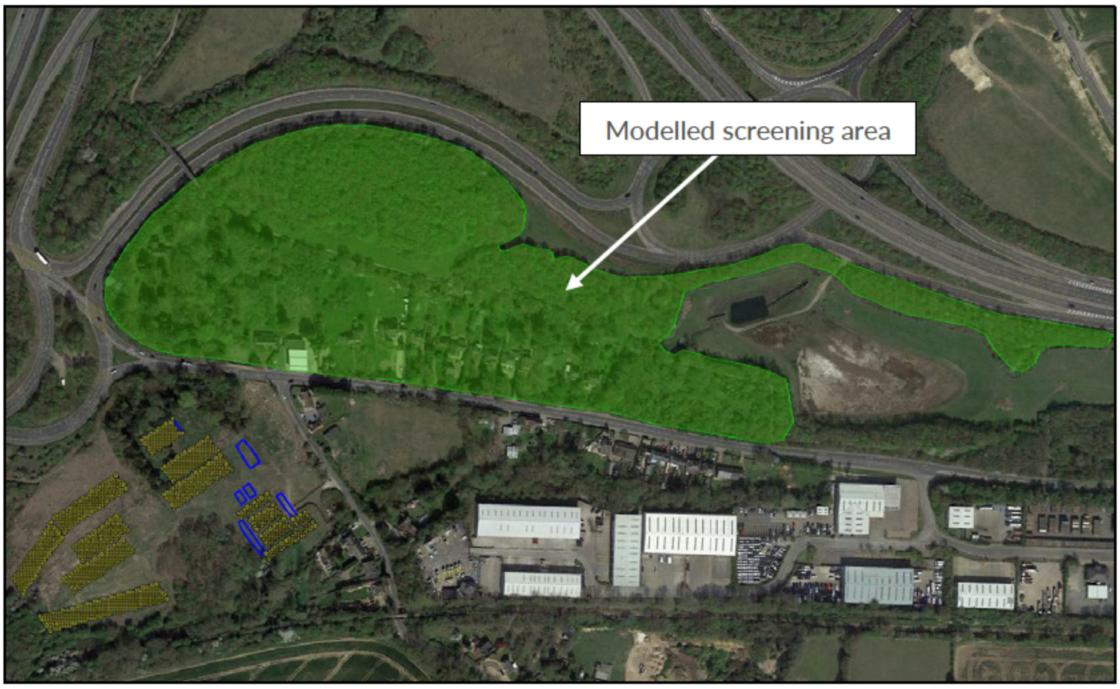
For the ATC Tower detailed screening analysis has been undertaken to determine the level of visibility of the reflecting areas.

Following a review of the available imagery, as shown in the figures below and on the following page, screening in the form of existing vegetation and dwellings has been identified. The reflecting areas based on bare earth terrain (yellow radial icons), for the ATC Tower, are shown within the last figure.

Existing vegetation adjacent to the B1256

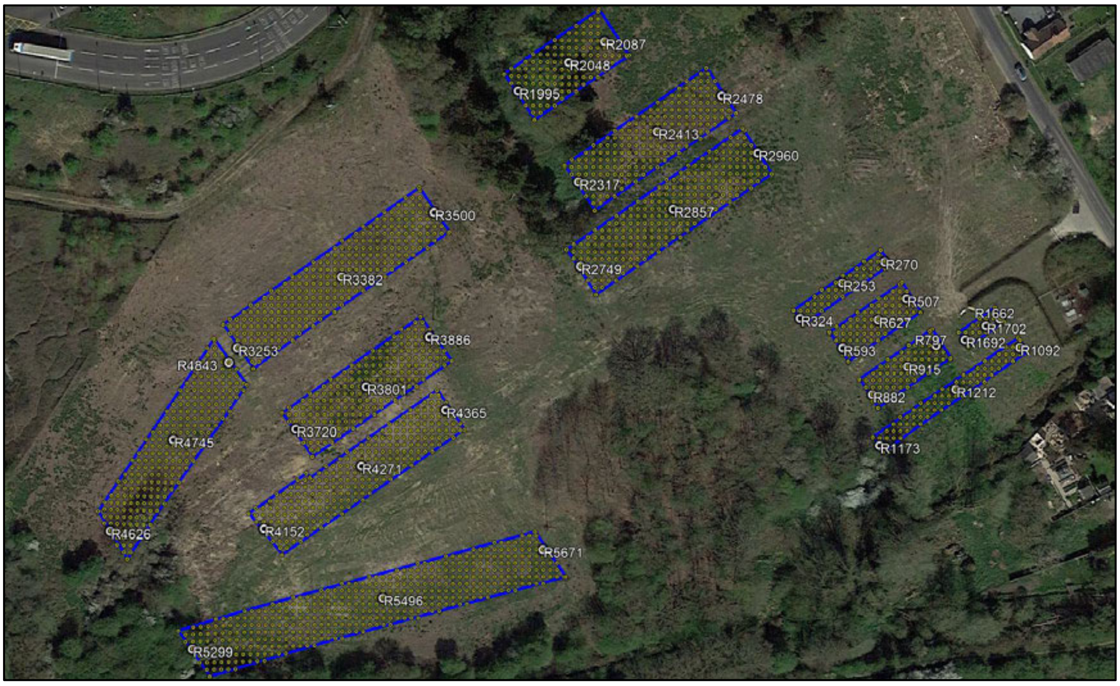


Existing vegetation adjacent to the A120 Priory Wood Roundabout



Location of identified screening (green area) and reflecting areas (yellow radial icons) for the ATC tower based on bare earth terrain

As described in Appendix F, the glint and glare model does not account for terrain or vegetation screening (i.e. bare earth terrain) between a receptor and the modelled reflectors and therefore assumes that all of the reflectors are visible to each modelled receptor on a conservative basis[42]. The purpose of detailed screening analysis is to further determine the visibility when considering potential screening in the form of existing vegetation and dwellings. A line of sight profile has been carried out for three representative locations within each of the reflecting areas. The location of the assessed locations, indicated by the labelled white radial icons, is shown in the figure below.



Assessed locations for ATC line of sight

A screening height of 3m (throughout the defined screening area) has been chosen on a conservative basis. Furthermore, a height of 3m has been assumed for all the assessed representative locations. An altitude of 160.02m[43] has been considered for the ATC Tower within the line of sight assessment; however, the viewing height of personnel within the ATC Tower is possibly less than this figure.

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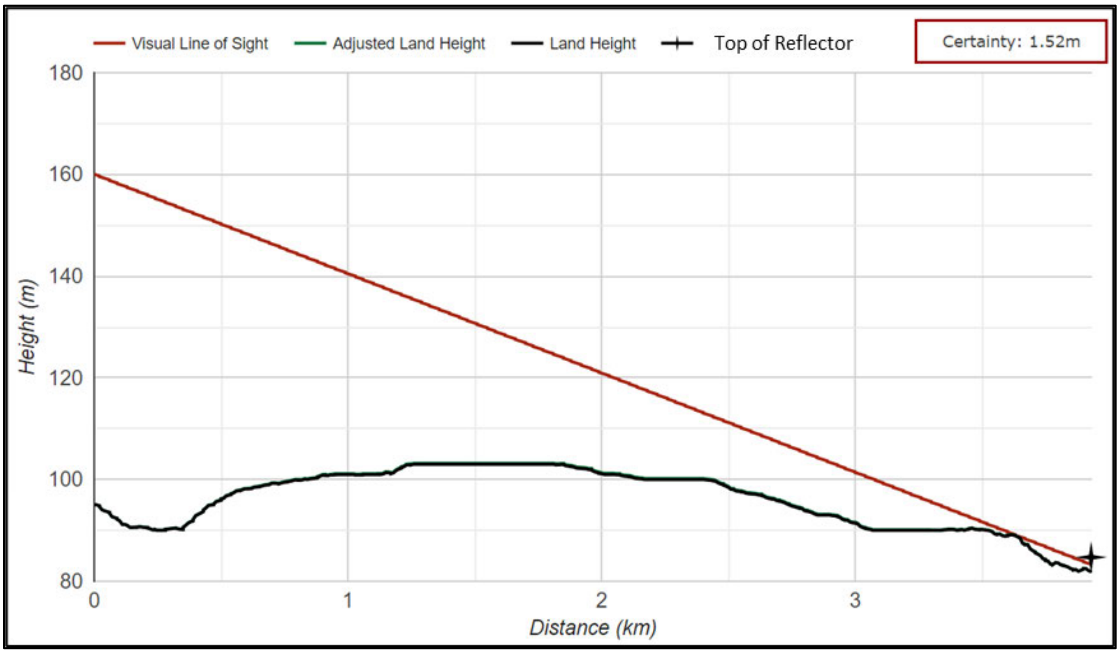
[42] Note: The Pager Power model does account for screening of the Sun by the terrain; however, does not account for screening in the form of terrain, dwellings, or buildings between a receptor and a reflector point and assumes visibility is possible.

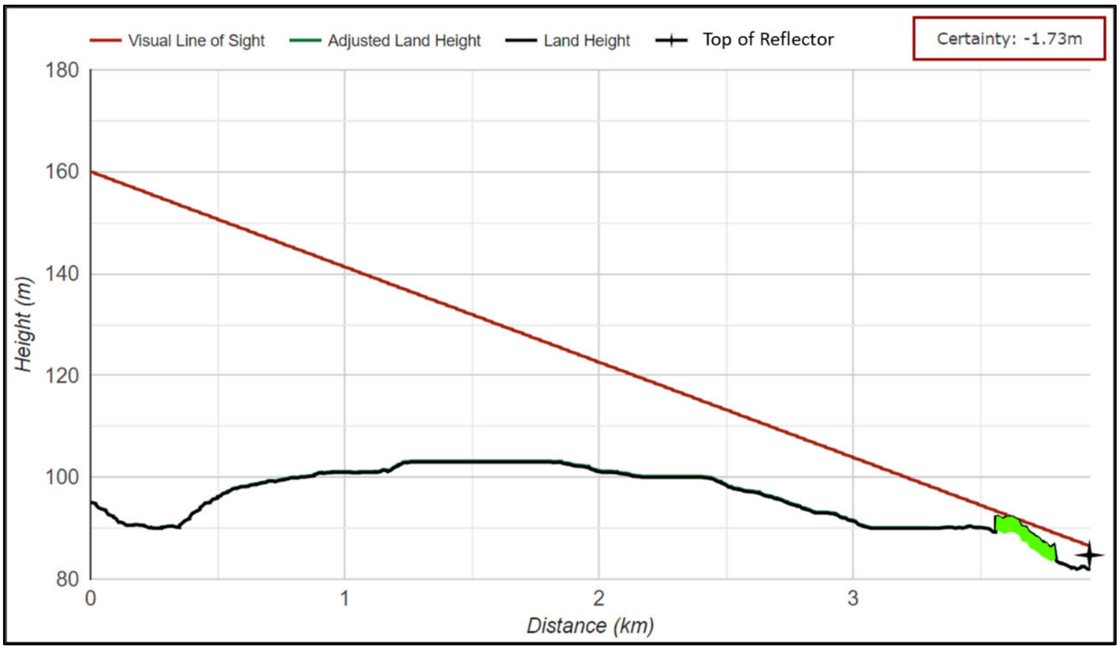
[43] Source: NATS AIP. 525 feet i.e. 160.02m. Ground height of 94.95m based on OSGB terrain data + 65.07m height agl.

An example of a line of sight profile is shown in the figure below. Due to the number of points assessed, all have not been included within the report. The cross represents the maximum height of the assessed reflector point. The box labelled 'Certainty' shows the amount by which the reflector point is visible, in the case of the example below this figure is 1.52m. This result is shown for reference purposes, in the case of the figure below **no screening has been considered**.



Screening profile calculation chart – ATC Tower *and* assessed point R2048 (within area H2) *without consideration of screening*

The figure on the following page shows the result of the line of sight profile when **a screening height of 3m has been considered**. The green outlined area represents illustrates the location of the proposed screening along the terrain profile. The box labelled 'Certainty' shows the amount by which the reflector point is visible, in the case of the example below this figure is -1.73m. Therefore, the reflector point is not visible by a vertical distance of 1.73m.



Screening profile calculation chart – ATC Tower and 3m existing screening for assessed point R2048 (within area H2)

The location of the blocking point is shown by the flag icon (within the identified screening area) within the figure below.

Screening analysis overview – ATC Tower and point R2048 (within area H2)

Screening Analysis Results

Screening Height at 3m

The table below shows the results of the screening analysis for the assessed locations. Of the 38 assessed locations within the reflecting areas, only 9 were considered visible.

Area	Reflector Point	Longitude (°)	Latitude (°)	Certainty
C3	R324	0.20342	51.87006	-0.92
C3	R270	0.20378	51.87020	-1.38
C3	R253	0.20360	51.87015	-1.25
C4	R627	0.20375	51.87005	-0.91
C4	R593	0.20361	51.86998	-0.65
C4	R507	0.20386	51.87011	-1.03
C5	R915	0.20388	51.86993	-0.55
C5	R882	0.20373	51.86986	-0.19
C5	R797	0.20400	51.86999	-0.72
C6	R1212	0.20408	51.86987	-0.55
C6	R1173	0.20377	51.86974	0.17
C6	R1092	0.20435	51.86999	-0.86
C9	R1702	0.20420	51.87004	-0.97
C9	R1692	0.20411	51.87000	-0.85
C9	R1662	0.20426	51.87006	-1.03
H2	R2087	0.20261	51.87075	-1.61
H2	R2048	0.20246	51.87069	-1.73
H2	R1995	0.20226	51.87063	-1.72
H3	R2478	0.20308	51.87062	-1.3
H3	R2413	0.20282	51.87053	-0.61

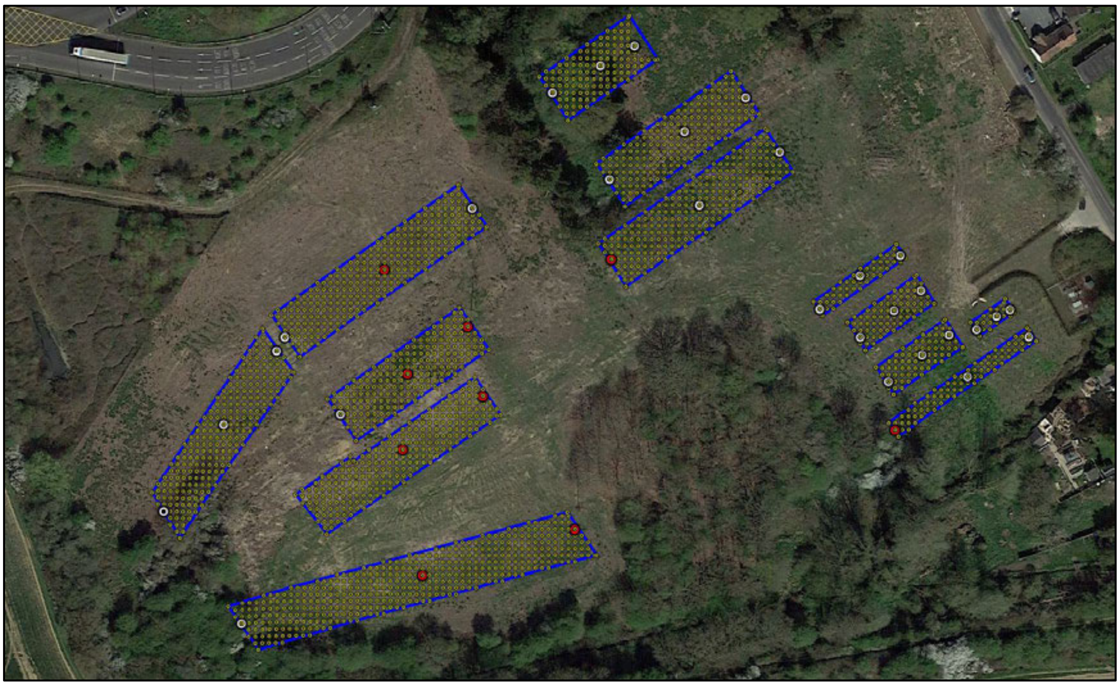
Area	Reflector Point	Longitude (°)	Latitude (°)	Certainty
H3	R2317	0.20251	51.87040	-0.33
H4	R2960	0.20324	51.87047	-0.66
H4	R2857	0.20290	51.87034	-0.42
H4	R2749	0.20251	51.87019	0.17
H5	R3500	0.20192	51.87033	-0.64
H5	R3382	0.20154	51.87016	0.05
H5	R3253	0.20109	51.86998	-0.23
H6	R3886	0.20189	51.87001	0.65
H6	R3801	0.20164	51.86988	0.3
H6	R3720	0.20134	51.86977	-0.65
H7	R4365	0.20196	51.86982	0.55
H7[44]	R4271	0.20160	51.86968	0.61
H8	R4843	0.20106	51.86995	-0.33
H8	R4745	0.20083	51.86975	-1
H8	R4626	0.20056	51.86952	-2.25
H9	R5671	0.20236	51.86946	1.39
H9	R5496	0.20169	51.86933	0.05
H9	R5299	0.20089	51.86920	-1.73

Line of sight results for ATC Tower and reflecting areas

[44] One of the reflector points, R4152, within area H7 did not output a line of sight result.

Screening Assessment Conclusions

The modelling has shown that based on existing screening at a height of 3m visibility is considered possible for areas C6, H4 to H7 and H9. The level of visibility to area C6 may not be possible as the level of certainty is at most 0.17m when considering a height of 3m for the reflector point, in practice the windscreen is likely to be located on cars at a height of approximately 1.5m. For the reflector points that were deemed visible by the analysis i.e. within areas H4 to H7 and H9, the average level of visibility is approximately 0.5m[45]. Furthermore, it is possible that following a site survey and in practice when considering the existing environment or the structure/orientation of the trucks, visibility of the reflecting areas would not be possible. The figure below shows the locations that are considered visible based upon a height of 3m for the assessed existing screening and a height of 3m for the reflector points.



Screening assessment results – Visible locations (red radial icons)

[45] Average of certainty for reflector points R2749 (area H4), R3382 (area H5), R3886 and R3801 (area H6), R4365 and R4271 (area H7), R5671 and R5496 (area H9).

PAGERPOWER
Urban & Renewables

Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +[redacted]