ARUP

MIMWEP | Cardiff and Vale College (CAVC)

Advanced Technology Centre

Glint and Glare Study for Cardiff Airport

Reference: VG0101-ARP-XX-XX-RP-Y-00013

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Executive Summary

Arup have undertaken a Glint and Glare assessment in line with current CAA/FAA guidance to assess any potential impact of the proposed solar photovoltaic (SPV) installation associated with the Cardiff and Vale College, Advanced Technology Centre development located to the north-east of Cardiff Airport (CWL).

A geometric assessment has been undertaken to establish when and where reflected sunlight from the SPV panels has the potential to enter the cockpit of an aircraft or intersect with a ground viewing position. Geometric modelling does not quantify the risk of glint and and/or glare.

The assessment has assumed the SPV array will cover the whole of identified roof areas and makes no allowance for gaps and spaces for other rooftop mounted services therefor representing a worst case scenario.

It must be noted that this assessment has been taken based on the Arup designed performance specification for the SPV array which will be developed by a specialist contractor. Should there be any deviations from the specification in the final design, the final design will need to be assessed to confirm the validity of the results of this assessment as summarised below.

The geometric modelling indicates:

- Reflected sunlight from the proposed SPV installations is unlikely to impact the Air Traffic Control Tower (ATCT).
- Reflected sunlight from the proposed SPV installations is unlikely enter the aircraft on final approach to RWY12 and RWY30.

Whilst the geometric modelling indicates there is potential for reflected sunlight to enter the cockpit of aircraft on visual approach circuits to both runways, the potential impact is not considered significant due to duration, proximity and likelihood of occurrence.

Based on the findings of the geometric assessment, limitations of the Solar Gare Hazard Analysis Tool (SGHAT) and current recommendations from the FAA, a SHGAT assessment is not considered nessesary.

Based on the findings of the assessment no mitigation measures are deemed nessesary.

1. Introduction

1.1 Scope of Report

Arup was commissioned to carry out a glint and glare study to assess any potential impact of the proposed solar photovoltaic (SPV) installation associated with the Cardiff and Vale College, Advanced Technology Centre development located to the north-east of Cardiff Airport (CWL).

This document provides a detailed site-specific analysis of the potential for reflected sunlight from the proposed SPV installation and whether this could constitute a risk to airport operations.

The analysis has been undertaken to address several questions and/or scenarios posed by the Head of Airfield Operations at Cardiff Airport, during the meeting on 14 November 2023, to identify any potential impact on airport operations.

This document details the methodology and findings of the assessment.

1.2 The Project

Cardiff and Vale College (CAVC), Advanced Technology Centre is proposed to be constructed on land adjacent to Port Road, to the north-east of Cardiff airport as illustrated in Figure 4.

The development comprises a 3 storey teaching block to the south of the site with two double height workshop wings extending to the east. The surrounding landscape will comprise areas of parking, hard standing, landscaped areas and multi-use games areas (MUGAs).

SPV panels are proposed to be installed on the roof of the main building and the south-facing pitched roofs of the workshop wings. Further details of the proposed SPV installation are provided in section 1.4.

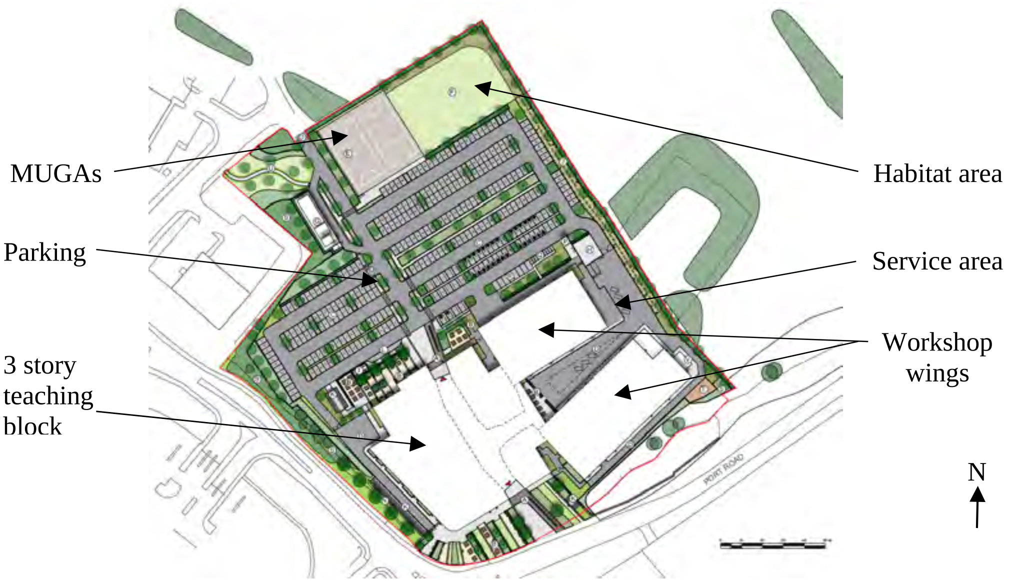
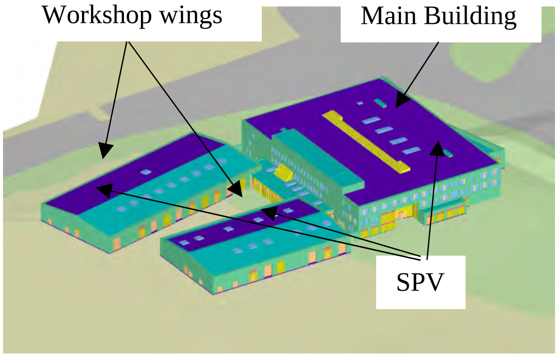


Figure 1 Landscape plan



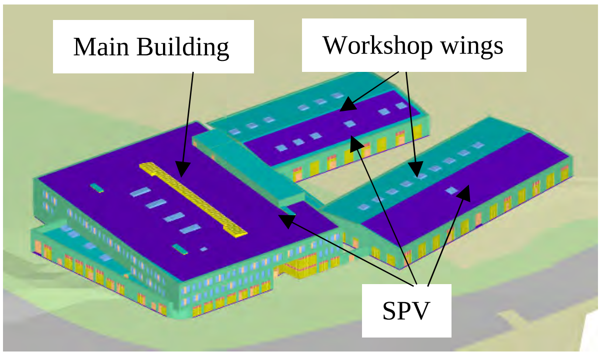


Figure 2 North-west view of site model

Figure 3 South-east view of site model

1.3 Site & Context

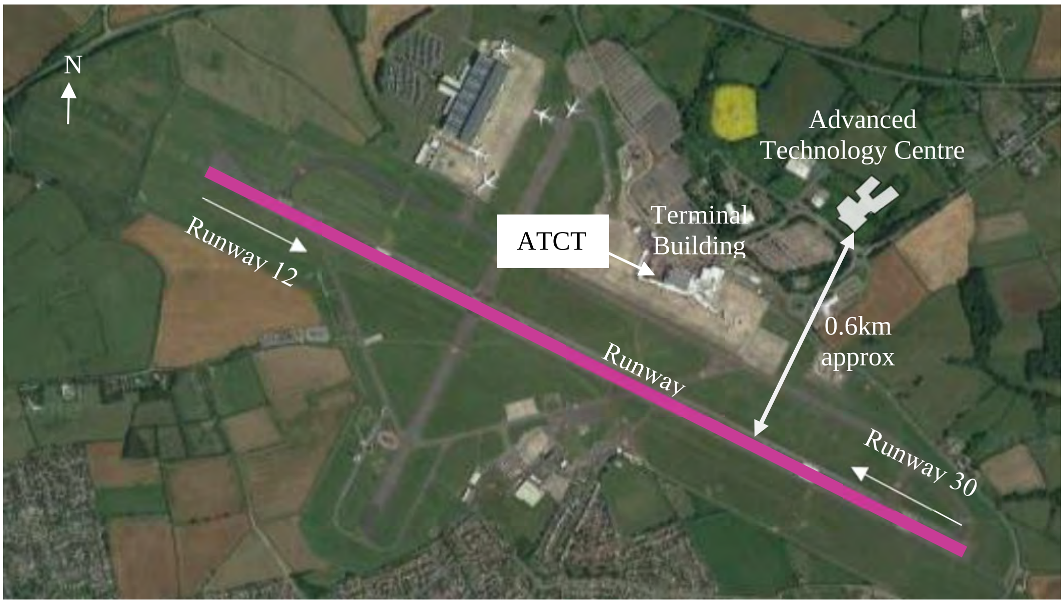


Figure 4 Area Plan (Image from Google Maps)

The airport is located 15.7 km (8.5nm) south-west of Cardiff as defined in documentation available from AIS UK Aeronautical Information Service.

The airport operates a single runway designated as runway 12 (RWY12) or runway 30 (RWY30) based on compass direction.

The air traffic control tower (ATCT) is located to the north of the runway. The height (AMSL) of ATCT is 86.48m.

The airport operational hours are 24 hours/day, 365 days per year.

1.4 Proposed SPV Installation

The proposed SPV array will be mounted on the roofs of the Advanced Technology Centre development, situated to the north-east of the airport at latitude/longitude coordinates 51.400°/-3.332°, approximately 0.6km (0.32 nautical miles) north of the runway.

The proposed SPV will be installed on the roof of the main building and southernly facing pitched roofs of the two workshop wings. Figure 5 illustrates the proposed SPV layout and divides the proposed SPV area into three parts (Part 1, Part 2, Part 3) based on the geometric properties:

- Part 1 - SPV panels are mounted on the main building roof (height of 11.25m) with a tilt of 20° above horizontal and an orientation of 148° anticlockwise from due south. Although the proposed area of SPV panels will not cover the whole roof and will be coordinated around other rooftop services, for the purpose of this assessment it has been assumed that SPV panels may be installed anywhere on the roof therefore presenting a worst case scenario.
- Part 2 - SPV panels are mounted on the south facing pitched roof of the workshop wing (height of 6.3m) with a tilt of 6° above horizontal and an orientation of 148° anticlockwise from due south.
- Part 3 - SPV panels are mounted on the south facing pitched roof of the workshop wing (height of 6.3m) with a tilt of 6° above horizontal and an orientation of 134° anticlockwise from due south.

The assessment has been undertaken assuming a smooth glass SPV panel coating.

Should there be any deviations from the assumed SPV panel orientations, tilts and coatings, the findings of this assessment will be invalidated.

Figure 5 Proposed SPV area and layout (indicated in purple)

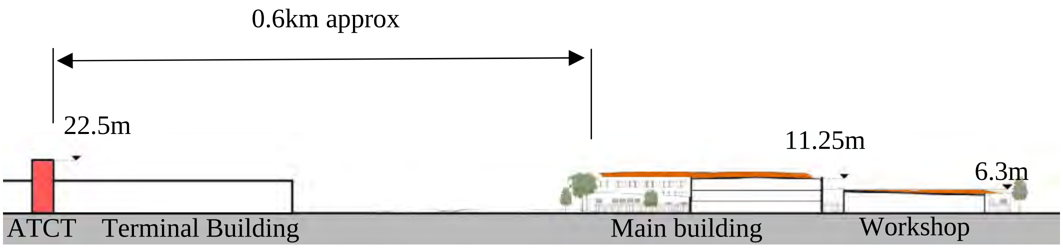


Figure 6 Section of the Advanced Technology Centre and airport buildings with relative heights

Figure 7 example SPV array installations

1.5 Guidance

At present, the Civil Aviation Authority (CAA) does not issue specific criteria against which SPV installations can be accessed. However, in 2010 the CAA published 'Interim CAA Guidance - Solar Photovoltaic Systems' which acknowledges the potential safety issues which could be caused by SPV installations in close proximity to airports:

> *'Airport interest in solar energy is growing rapidly as a way to reduce operating costs and to demonstrate a commitment to renewable energy and sustainable development. In response, the CAA is seeking to develop its policy on the installation of Solar Photovoltaic (SPV) Systems and their impact on aviation. In doing so, it is reviewing the results of research having been carried out in the United States by the Federal Aviation Administration (FAA) culminating in the publication of Technical Guidance for Evaluating Solar Technologies on Airports and also reviewing guidance issued by other National Aviation Safety Administrations and Authorities on this subject.'*
>
> *'At present the key safety issue is perceived to be the potential for reflection from SPV to cause glare, dazzling pilots or leading them to confuse reflections with aeronautical lights. Whilst permission is not required from the CAA for any individual or group to shine or reflect a light or lights into the sky, SPV developers should be aware of the requirements to comply with the Air Navigation Order (ANO) 2009. In particular, developers and Local Planning Authorities (LPA) should be cognisant of the following articles of the ANO with respect to any SPV development regardless of location:*
>
> *• Article 137 – Endangering safety of an aircraft.*
>
> *• Article 221 – Lights liable to endanger.*
>
> *• Article 222 – Lights which dazzle or distract.'*

The CAA guidance recommends 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. The CAA guidance references guidance on safeguarding procedures at CAA licenced aerodromes within CAP 738 Safeguarding of Aerodromes.

The Airport Operators Association 'Safeguarding of Aerodromes Advice Note 5 – Renewable Energy and Impact on Aviation', which was published (2016) in collaboration with the CAA, outlines:

> *'Solar energy provision has the potential to produce reflectivity (glint and glare). Reflectivity Assessments may be needed to measure the potential of glare and/or flash blindness. The CAA endorses the Federal Aviation Authority (FAA) interim policy titled 'FAA for Solar Energy System Projects'. For assessment it is recommended to use the 'Sandia Solar Glare Hazard Analysis Tool or carry out an equivalent assessment.'*

The Solar Glare Hazard Analysis Tool (SGHAT) summarises the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276 as:

- No "yellow" glare (potential for after-image) for any flight path from threshold to 2 miles.

- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.

In May 2021, the FAA published a final policy titled ‘Review of Solar Energy System Projects on Federally-Obligated Airports’ which replaced the Interim Policy published in 2013. The FAA has concluded that for Pilots on final approach the glint and glare experienced for SP is similar to that routinely experienced from other reflecting bodies (water, glass façade buildings etc). as a result the policy now focuses on potential glint and glare to ATCTs only. They now only ask an airport to confirm that there is no potential for ocular impact to the ATCT. The FAA also removed the requirement for use of a Solar Glare Hazzard Analysis Tool (SGHAT) which was previously mandated. Whilst the FAA are not discouraging the use of a SGHAT, simply that, as it is no longer freely available to all users and there is no longer a need to consider final approach, it is not mandated for use.

1.6 Concerns

Although the FAA guidance and Solar Glare Hazard Analysis Tool (SGHAT) focuses on final approach flight paths (from threshold to 2 miles) and ATCTs, Airfield Operations at Cardiff airport have identified several questions and/or scenarios of concern. These questions/scenarios are considered those mostly likely to require assurance that any solar panel installation would not interfere with operations, or could be managed through policy and procedures:

- Risk of glint/glare/reflections to ATCT.
- Risk of glint/glare/reflections to final approaches to RWY12 and RWY30.
- Visual circuit pattern to the north and south of the airport.

It is acknowledged that the period from short finals (within 2 miles) of the runway, until the aircraft has landed and slowed to taxiing speed, is considered to be the most crucial phase of flight.

1.7 Glint and Glare

Glint is defined as a momentary flash of bright light often caused by a reflection off a moving source, for example a moving car.

Glare is defined as a continuous source of bright light and is generally associated with stationary objects, which, due to the slow relative movement of the sun, reflect sunlight for a longer duration.

The difference between glint and glare is **duration**. Industry-standard glare analysis tools evaluate the occurrence of glare on a minute-by-minute basis; accordingly, they generally refer to solar hazards as 'glare'.

1.8 Process

The analysis of reflected sunlight from the proposed SPV array has been broken down into two stages with stage 2 undertaken based on the findings and results of stage 1:

- Stage 1 - Geometric modelling - Modelling of reflected sunlight and intersection with flight paths and ground viewing positions to establish when and where reflected sunlight from the SPV panels has the potential to enter the cockpit of an aircraft or intersect with a ground viewing position. Geometric modelling does not quantify the risk of glint and and/or glare.
- Stage 2 - SGHAT analysis tool - Quantification of risk level of glint and/or glare for final approaches and air traffic control towers using the solar glare hazard analysis.

Stage 2 is only undertaken if the stage 1 geometric assessment identifies a potential risk.

2. Geometric Modelling

2.1 Methodology

Geometric modelling has been undertaken in four steps:

- Modelling of the sun movements for the site location.
- Modelling of the reflected sunlight from the proposed SPV array.
- Modelling of flight paths and observation points.
- Intersection of reflected sun light modelling and flight paths/observation points.
- Interpretation of intersections and identification of situations where reflected sunlight has the potential to enter the cockpit or impact the observation points.

2.1.1 Establishing Areas of Potential Glare

Only reflected sunlight entering the cockpit will have the potential to affect the safety critical vision of the aircrew. Essentially, if the aircrew cannot see the SPV array from typical seating positions, there will be no risk of glare.

Detailed analysis of the intersection between flight path models and the reflected sunlight cone was undertaken.

The analysis considers the following elements to identify if, where and when reflected sunlight has the potential to enter the cockpit:

- Position and direction of travel of the aircraft.
- Visibility of SPV array from the flight deck; determined by the Cockpit Cut-off Angle.

Aircrew have vision limited by the cockpit and aircraft construction, this is described as an angle, known as the cockpit cut-off angle. The cockpit cut-off angle is defined as the angle between the longitudinal axis of the aircraft fuselage and an inclined plane below, up to the limit at which the pilot can view.

The cut off angles assumed in the interpretation of the geometric modelling are as follows and as illustrated in Figure 8:

- The azimuthal viewing angle is taken to be 50° to the left and right field-of-view of the pilot during approach. A view angle of 180° implies the pilot can see glare emanating from behind the plane. A view angle of 50° implies the pilot has a field-of-view of 50° to their left and right during approach, i.e. a total FOV of 100°.
- The vertical viewing angle of 30° is applied. The vertical field-of-view of the pilot, measured positive downward from the XY plane (i.e. horizontal). A value of 30° assumes glare appearing beyond that FOV is not visible to the pilot. A value of 90° assumes the pilot can see glare appearing directly underneath the aircraft.

These values are based on FAA research.

Figure 8 Aircraft field-of-view defined by azimuthal and vertical *viewing angle* parameters

2.2 Modelling of Reflected Sunlight Cone

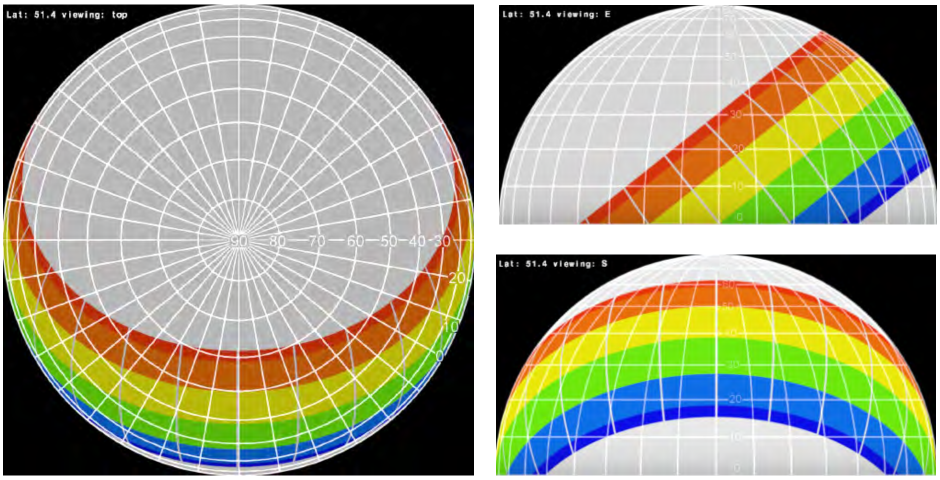


Figure 9 Stereographic projection of sunpath for the Advanced Technology Centre location

The movement of the sun through summer, winter solstices along with mid-season equinox has been modelled within the 3D software. These represent the extremes of sun azimuth and altitude and provide the bounding criteria for the annual sun position, i.e. the position of the sun for all other times of the year will fall within the two solstice sunpath lines.

- Low angle winter sun (winter solstice 21st December) – Blue.
- High angle summer sun (summer solstice 21st June) – Orange.

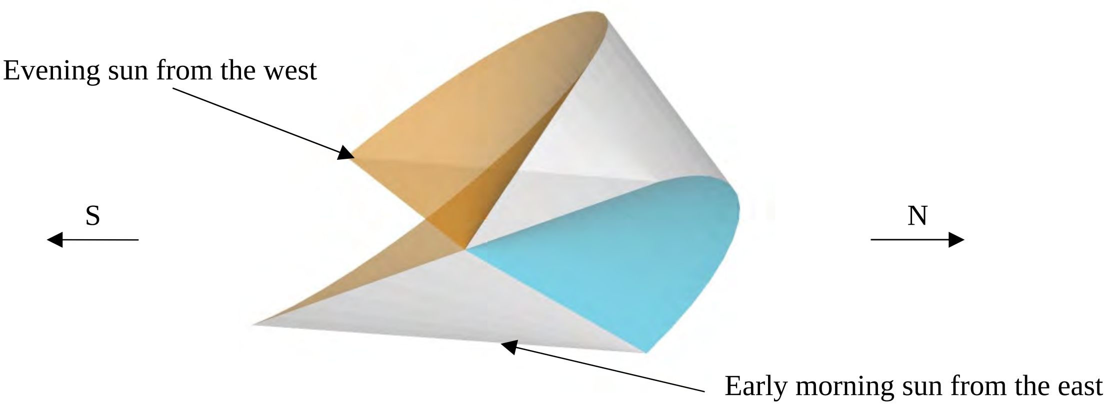


Figure 10 Sunlight falling onto SPV panels

Sun rays have been traced from the solstice sun positions to the SPV panel, establishing the extent and depth of reflection from the proposed SPV panel. The reflected rays were modelled to create a bounded cone, a volume representing the path of all reflected sunlight from the SPV array. Separate reflected sunlight volumes have been created for each of the three SPV parts (as identified in section 1.4) to reflect the relative tilt and orientation angles.

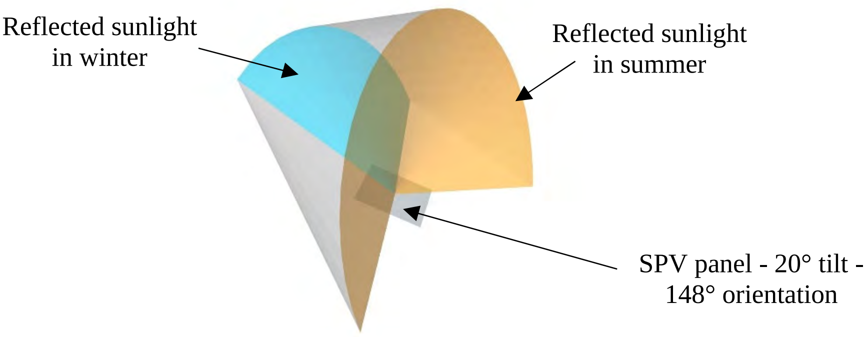


Figure 11 Area of reflected sunlight from individual Part 1 SPV panels with a tilt of 20° above horizontal and an orientation of 148° anticlockwise from due south.

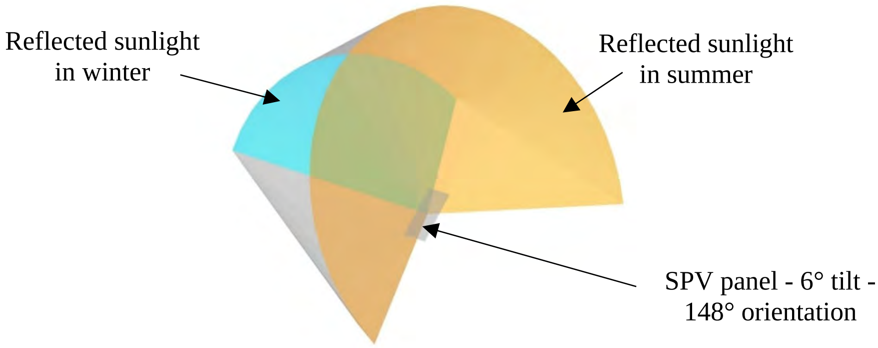


Figure 12 Area of reflected sunlight from individual Part 2 SPV panels with a tilt of 6° above horizontal and an orientation of 148° anticlockwise from due south.

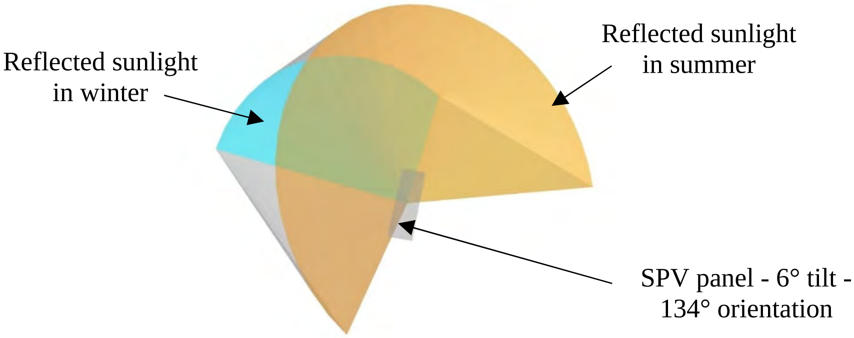


Figure 13 Area of reflected sunlight from individual Part 3 SPV panels with a tilt of 6° above horizontal and an orientation of 134° anticlockwise from due south.

Reflected sunlight models have been positioned at each corner of the proposed SPV arrays (Part 1, Part 2, Part 3) to provide a bounding area within which all reflections could occur.

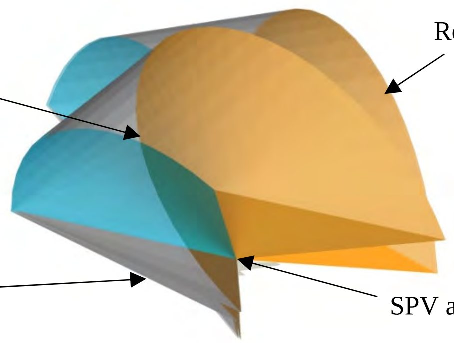


Figure 14 Area of reflected sunlight from SPV arrays

2.3 Intersection with Flight Paths & ATCT

Geometric representations of the following scenarios have been modelled:

- Air Traffic Control Tower (ATCT).
- RWY 12 final approach flight path.
- RWY 30 final approach flight path.
- Visual circuit to north and south of airport.

These models have been overlaid with the reflected sunlight cone to understand where reflected sunlight and air traffic may coincide.

Intersections between the cone and the flight paths represent where aircraft could potentially coincide with reflected sunlight at some point within a yearly solar cycle. The intersection of the flight path and the reflected sunlight cone does not necessarily represent a risk of potential glare.

2.4 Input Data and Assumptions

2.4.1 General

Input data	Originator & Date
Topographical model lidar scan data	Emapsite – 28/11/2023
Development site landscape plan	Ares Landscape Architects – 17/11/2023
Advanced Technology Centre architectural model.	Sheppard Robson Architects – 03/11/2023
ATCT location and height	As advised by Cardiff Airport Airfield Operations – 27/11/2023
Aircraft movements associated with the airport	NATS website and as advised by Cardiff Airport Airfield Operations – 27/11/2023 – Refer to Appendix A for data.

Table 1 Assessment input data

2.4.2 Surrounding Context

The surrounding context presents a low density area. To the west there are 1-2 storey airport buildings and a car park, while to the south, east, and west there are open fields.

All the surrounding buildings have been included in the modelling.

2.4.3 Reflected Sunlight Cone

Obstructions adjacent to the SPV location may create cut off angles below which direct or reflected sunlight will be obscured. However due to the relatively low nature of the existing boundary vegetation and elevated position of the SPV array it is deemed they will have negligible impact on the reflection path. For the purpose of this assessment, shading from vegetation has not been included within the assessment.

A simplified form of the reflected sunlight from the SPV array as a whole has been created by positioning a ‘area of reflection model’ in each corner and combining these areas together.

While the SPV array comprises numerous individual panels, their size and close spacing, driven by the scale and goal of maximising their density, will minimise the gaps' visibility from an aerial perspective.

2.4.4 ATCT and Flight Paths

The ATCT properties, flight paths for RWY 12 and RWY 30 and visual circuits have been modelled based information provided by CWL and as available from National Air Traffic Services (NATS as noted in Table 1 and consolidated in Appendix A).

2.5 Interpretation of Geometric Visual Model

2.5.1 ATCT

The geometric modelling indicates there is no intersection between reflected sunlight from all parts (1, 2 and 3) of the proposed SPV installation and the ATCT as shown in Figure 15. This indicates there would be no risk of glint or glare at this location from the proposed installation.

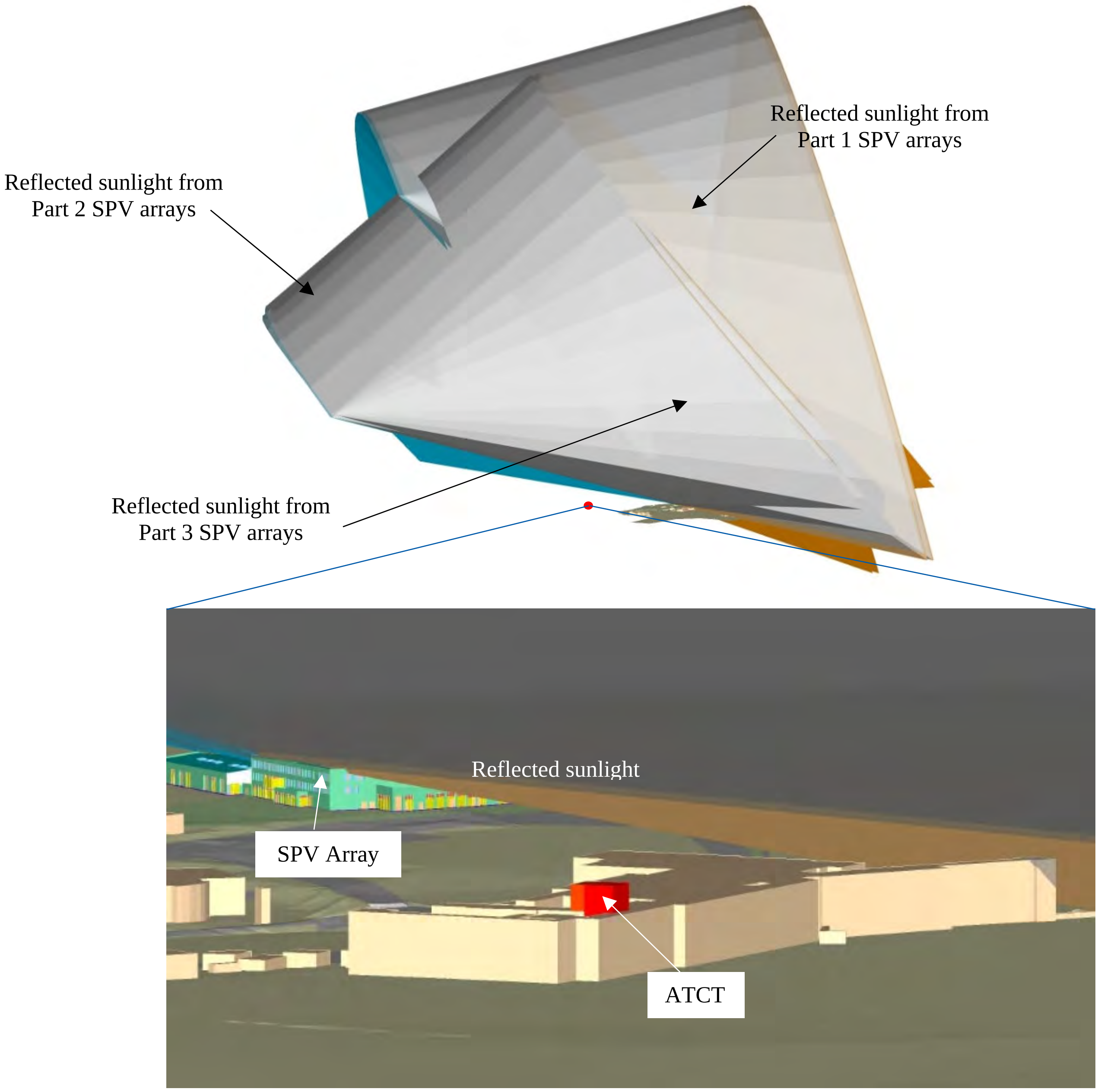


Figure 15 No intersection of reflected sunlight from proposed SPV installation with ATCT

2.5.2 Runway 12 Final Approach

The geometric analysis indicates that there is no intersection between reflected sunlight from all parts (1, 2 and 3) of the proposed SPV installation and the final approach to runway 12 as shown in Figure 16. This indicates there would be no risk of glint or glare to aircraft on final approach to runway 12.

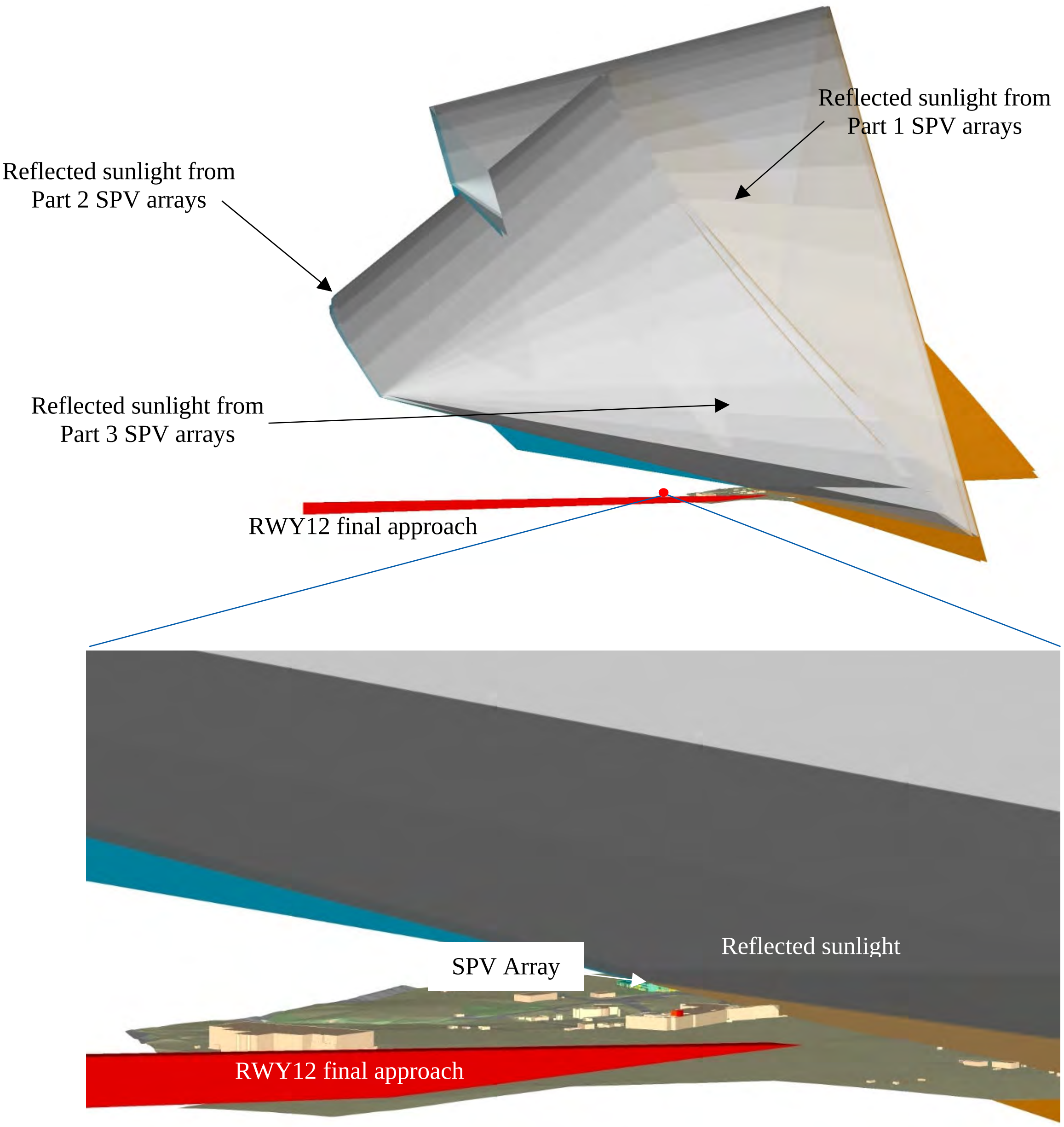


Figure 16 No intersection of reflected sunlight from proposed SPV installation with RWY12 final approach

2.5.3 Runway 30 Final Approach

The geometric analysis indicates that there is intersection between the runway 30 final approach and reflected sunlight from Part 1 installations as shown in Figure 17.

The reflection occurs approximately 790m after the threshold point and originate from behind the aircraft direction of travel as shown in Figure 18. As such it is concluded that reflections would not be within the pilot’s direction of view.

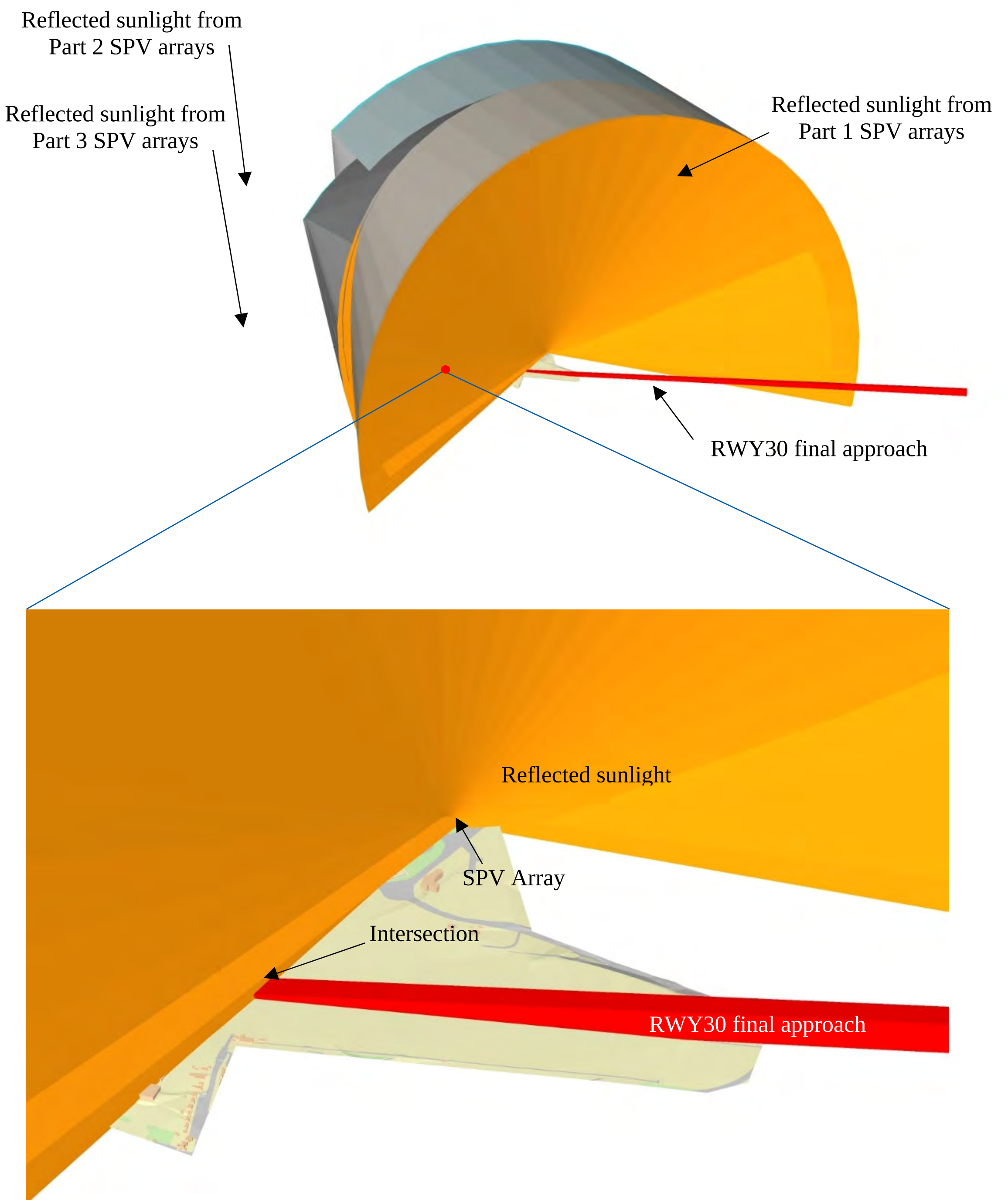


Figure 17 Intersection of reflected sunlight from proposed SPV installation with RWY30 final approach

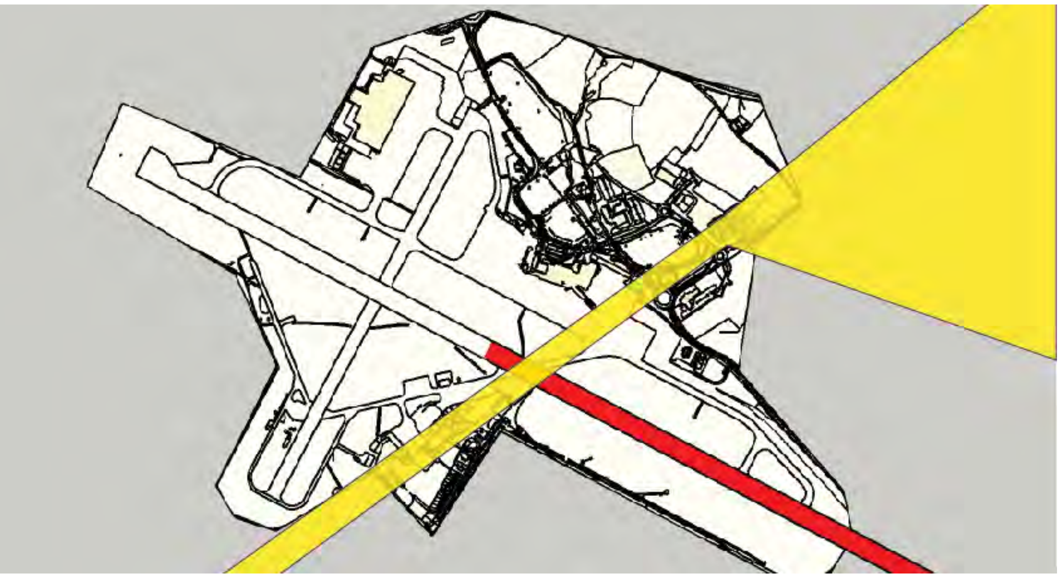


Figure 18 Intersection of reflected sunlight from proposed SPV installation with RWY30 final approach

2.5.4 Visual Circuit to North and South of the Airport

Visual approaches have been modelled as flat volumes at 1200ft AFL/1500 flAMSL as advised by Cardiff Airport Airfield Operations. Both travel directions (For Runway 12 and Runway 30) are included in this assessment.

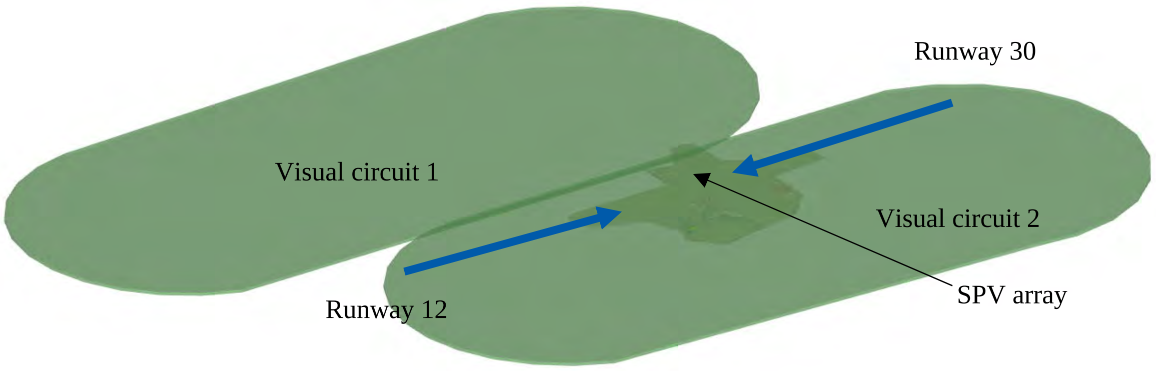


Figure 19 Altitudes and directions for visual circuits

These volumes have then been overlaid with the reflected sunlight models for SPV installations to identify potential intersections between aircraft and reflected sunlight.

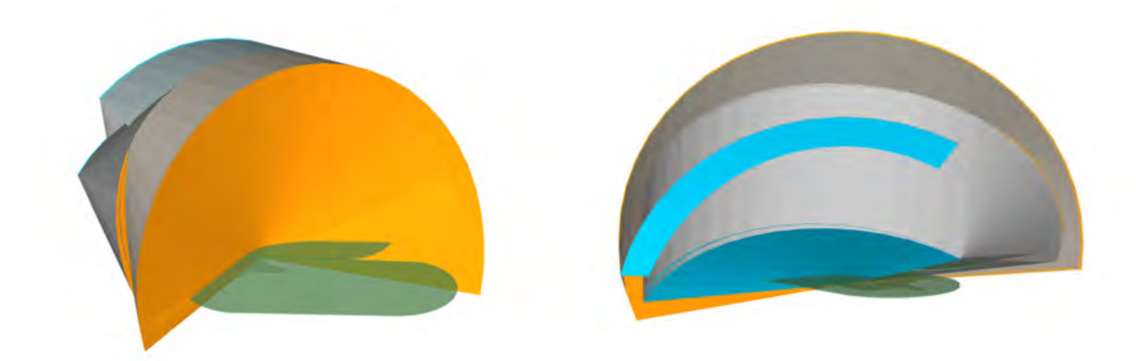


Figure 20 Visual circuits overlaid with reflected sunpath models (left: south-east view, right: north-west view)

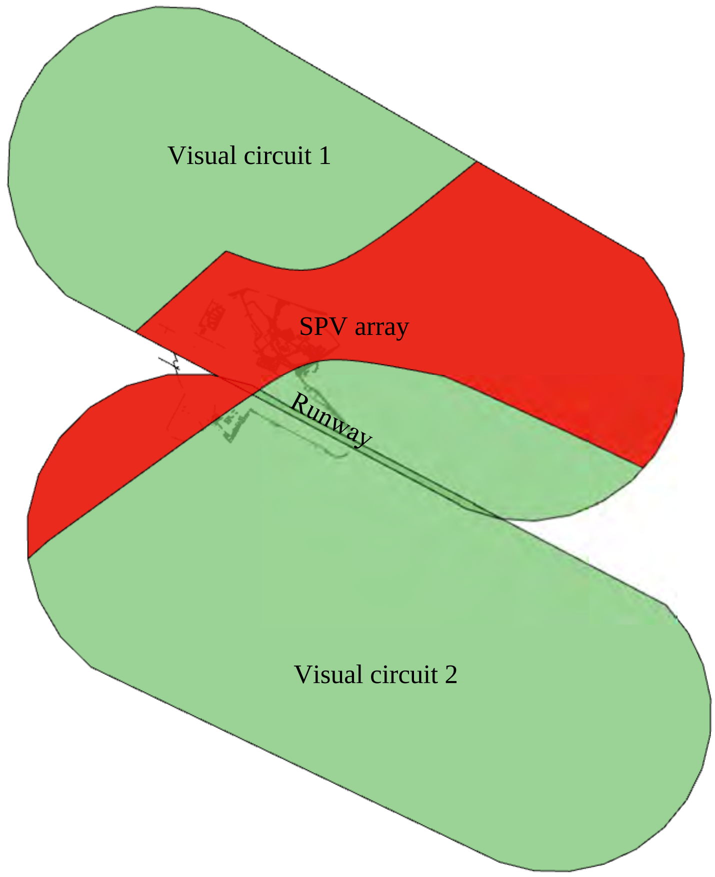


Figure 21 Reflected sunlight intersection with both visual circuits

For both visual circuits, once the aircraft has passed over the SPV array, any potential reflections would occur from behind the aircraft and would not enter the cockpit and therefore would not be of concern.

Reflections at the altitudes which subtend an angle of greater than 30° below the horizontal are deemed to be outside of an aircraft pilots vertical viewing angle (as defined in section 2.1.1) and therefore not visible to the pilot.

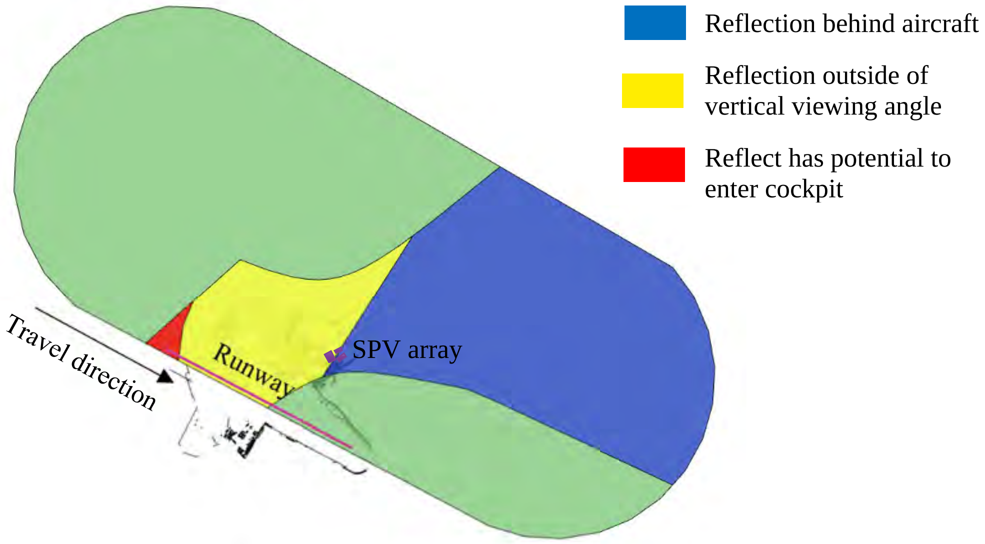


Figure 22 Reflected sunlight intersection with visual circuit 1 traveling south-east

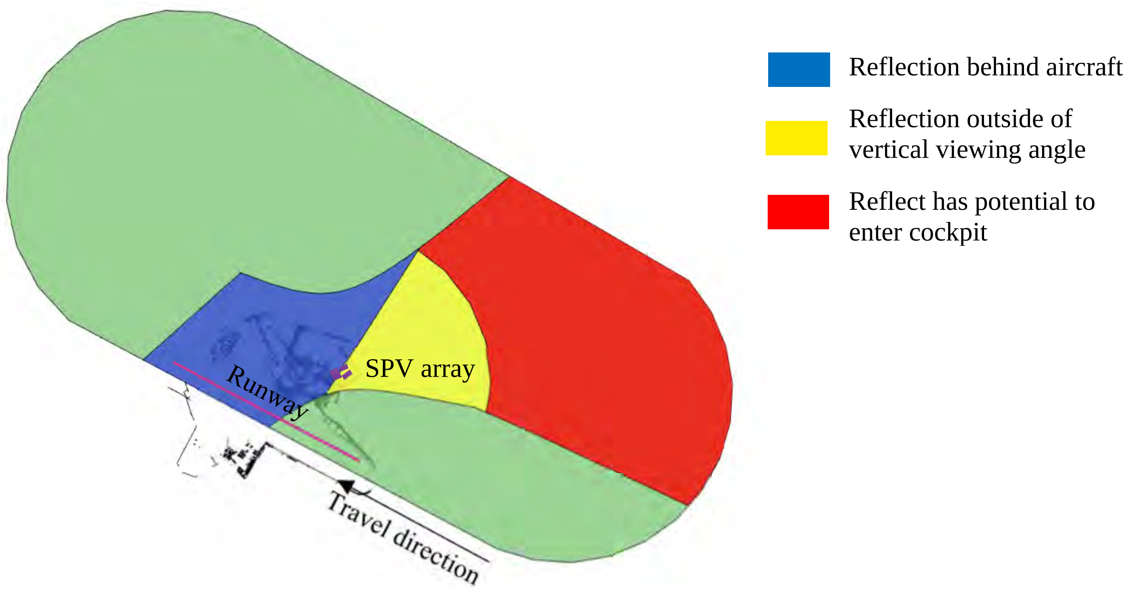


Figure 23 Reflected sunlight intersection with visual circuit 1 traveling north-west

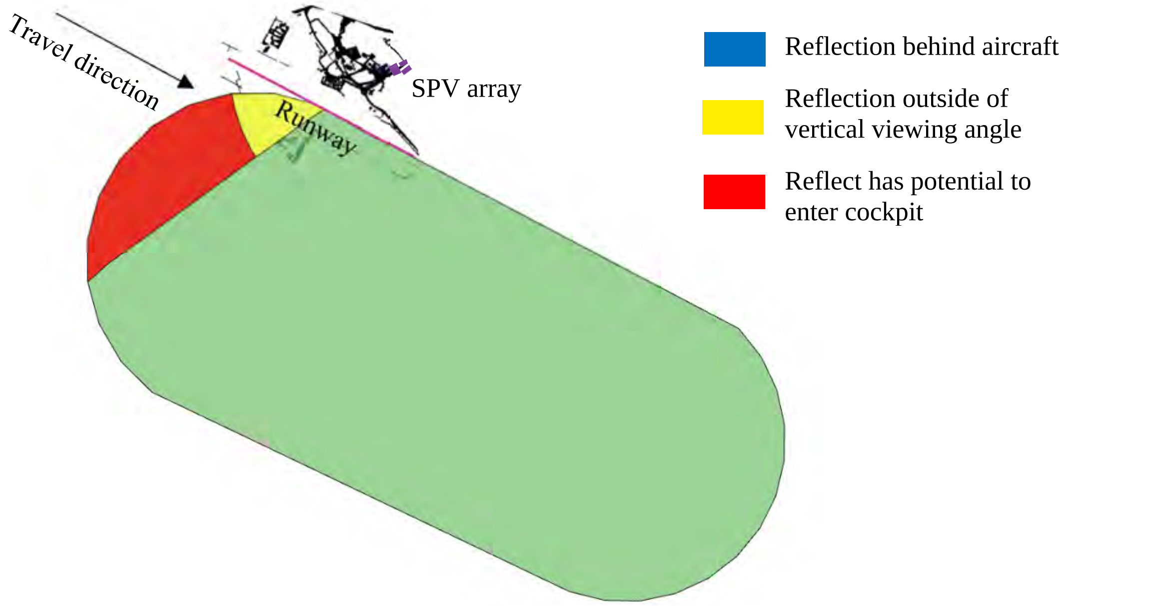


Figure 24 Reflected sunlight intersection with visual circuit 2 traveling south-east

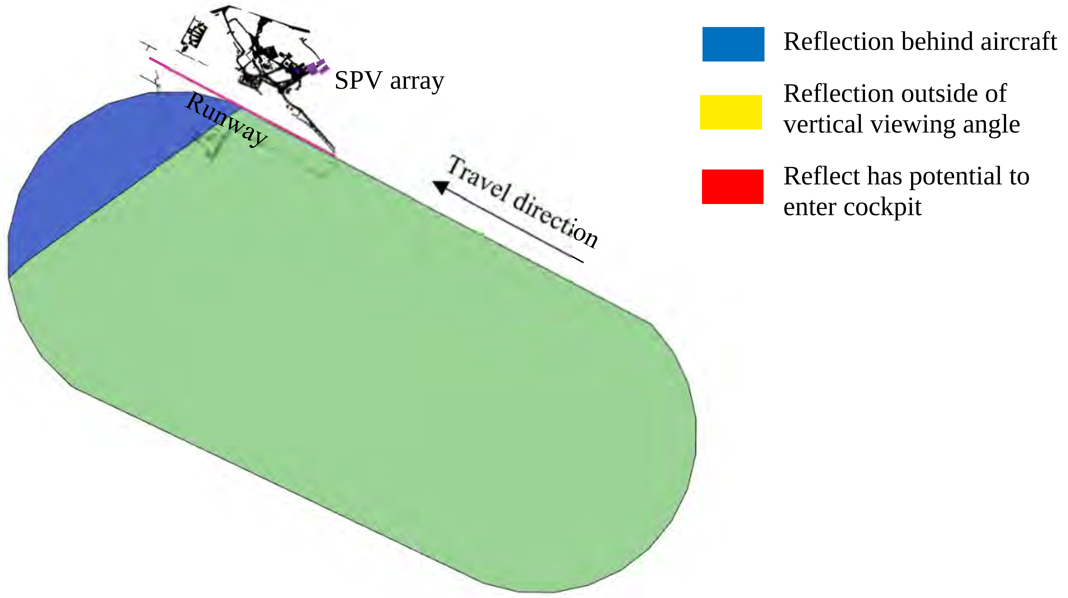


Figure 25 Reflected sunlight intersection with visual circuit 2 traveling north-west

The above images show the geometric modelling illustrating potential areas of intersection throughout the year. The total area of intersection is dependent on the angle of incident of the reflection.

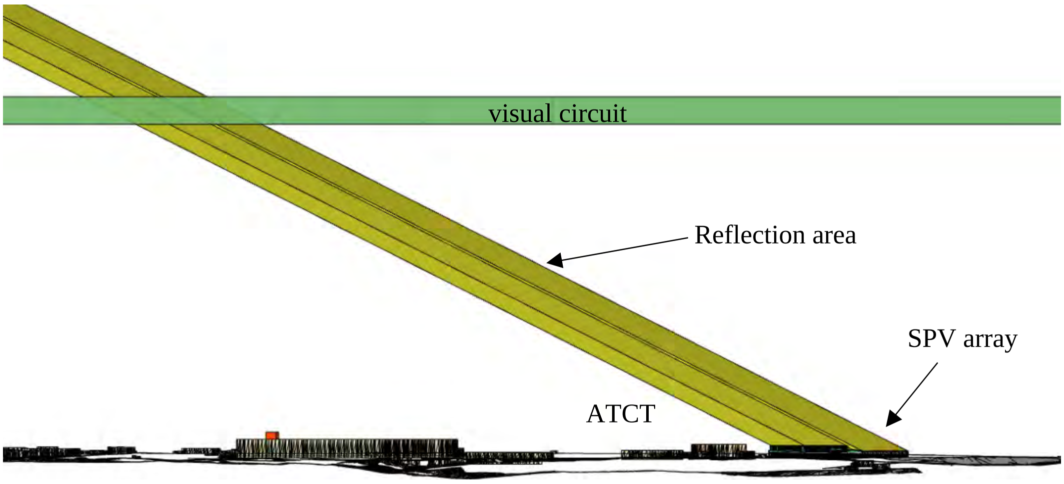


Figure 26 Cross section of reflections through typical altitude

The longest distance an aircraft will fly through a reflection is approximately 91m.

Depending on the ground speed of the aircraft, the approximate duration of potential reflections is presented in the table below.

Aircraft Ground Speed (knots)	Aircraft Speed (m/s)	Reflection- 91m area (seconds)
160	82.3	1.11
140	72.0	1.26
120	61.7	1.47
100	51.4	1.77
80	41.1	2.21

Table 2 Approximated duration of flection for typical ground speeds

Due to the short duration, distance between the aircraft and the SPV panel and likelihood of an aircraft being in the area of reflection at the specific time of occurrence, the potential impact in **not** considered to be significant. In addition, in accordance with the current FAA guidance, any impact is considered to be similar to glint and glare pilots routinely experience from other reflective bodies such as water bodies, glass façade buildings and car parks.

3. Observations, Considerations and Mitigation

3.1 Other Reflecting Bodies

While the results of the analysis indicate that reflected sunlight from the proposed SPV array has the potential to enter aircraft cockpits on the visual circuits, the potential impact should be considered in the context of other natural and manmade reflective surfaces in and around the airfield such as:

- Inclined and horizontal glazing to the terminal building.
- Large areas of vehicle parking.
- Roof glazing.
- Domestic SPV installations.
- Bodies of water or water build up following heavy rainfall.

3.2 Impact of Weather

Assessments are untaken assuming a clear cloudless sky. The potential for glint and/or glare from reflected sunlight will not exist where cloud, rain or other weather event obscures the sun from the panels.

- Direct irradiance is the part of the solar irradiance that directly reaches a surface;
- Diffuse irradiance is the part that is scattered by the atmosphere;
- Global irradiance is the sum of both diffuse and direct components reaching the same surface.

The data presented in Figure 27 shows the direct irradiance though out the year. Review of this direct irradiance monthly average data reveals there are points of the year, when the proportion/probability of direct sunlight is much higher.

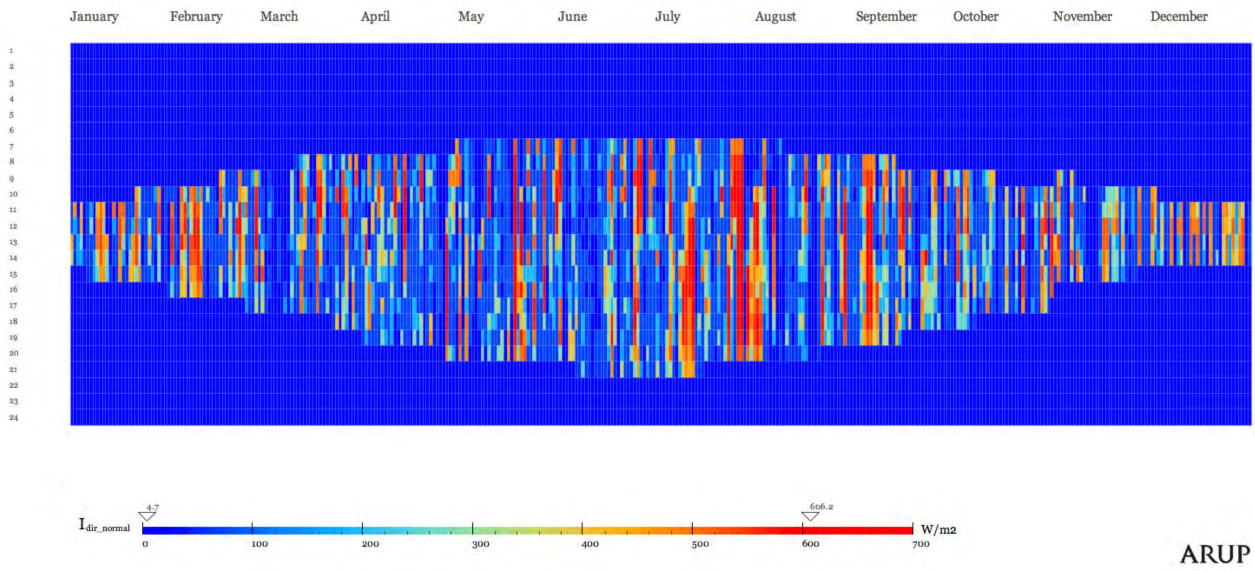


Figure 27 Daily Direct Irradiance (Weather data for Cardiff)

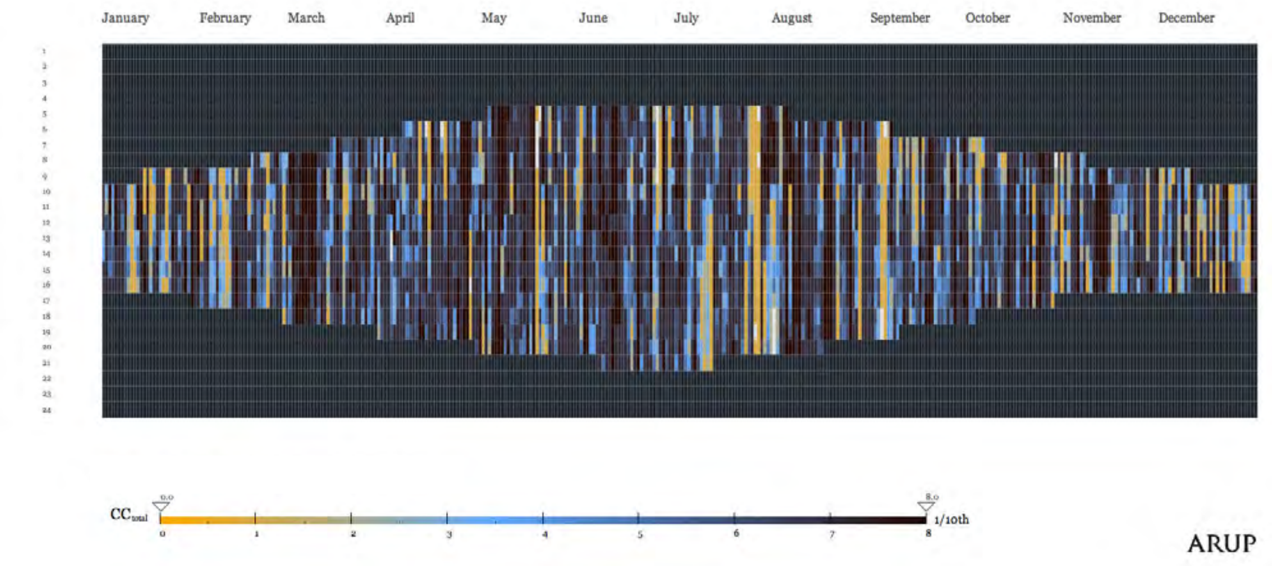


Figure 28 Daily Cloud Cover (Weather data for Cardiff)

Cloud cover is illustrated in Figure 28 and is measured in Oktas. This provides a quantitative scale of how much cloud cover is visible at a point in time. It does not take into consideration the density or how dark the clouds are but will influence the exposure due to the amount of direct/diffuse light there is in the sky.

If a cloud cover has a value of 6-8 Oktas (3/4 to full cloud cover) it could be considered likely to provide an approximation of an overcast sky. While this is likely to be the sky condition for part of the year, it cannot be considered to be the predominant condition.

3.3 Coating

Different coatings on the SPV array will have a significant impact on the resulting reflections. Where a smooth glass with anti-reflective coating (ARC) may cause a small amount of glint and glare, a deeply textured glass coating is able to spread it out over a wider area and make the effect less intense. However, as deeply textured increases the scattering of reflected sunlight, the potential for glare is also spread over a wider area.

4. Overview of Analysis Findings

4.1 Geometric Modelling

The geometric analysis indicates the following:

- No potential for reflections from the proposed SPV arrays to impact the Air Traffic Control Tower (ATCT).
- No potential for reflected sunlight to enter the cockpit of aircraft on final approach to RWY12.
- No potential for reflected sunlight to enter the cockpit of aircraft on final approach to RWY30.
- Potential for reflected sunlight to enter the cockpit of aircraft on visual approach circuits to both runways. Depending on the ground speed of the aircraft these reflections are expected to be experienced for no more than approximately 2.5 seconds. The potential impact is not considered significant due to duration, proximity and likelihood of occurrence.

4.2 SGHAT Analysis

The Solar Glare Hazzard Analysis Tool (SGHAT) is primarily designed to assess and quantify the potential impact of glint and glare to the ATCT and final approach paths. As the geometric modelling demonstrates that there is no potential for reflections from the proposed SPV arrays to impact the ATCT or entre the cockpit of aircraft on final approach to either runway, it is concluded that SGHAT assessments are not required.

This conclusion aligns with the latest FAA guidance.

5. Conclusion

Arup have undertaken a Glint and Glare assessment in line with current CAA/FAA guidance to assess any potential impact of the proposed solar photovoltaic (SPV) installation associated with the Cardiff and Vale College, Advanced Technology Centre development located to the north-east of Cardiff Airport (CWL).

A geometric assessment has been undertaken to establish when and where reflected sunlight from the SPV panels has the potential to enter the cockpit of an aircraft or intersect with a ground viewing position. Geometric modelling does not quantify the risk of glint and and/or glare.

The assessment has assumed the SPV array will cover the whole of identified roof areas and makes no allowance for gaps and spaces for other rooftop mounted services therefore representing a worst case scenario.

The geometric modelling indicates that reflected sunlight from the proposed SPV installations is unlikely to impact the ATCT or enter the aircraft on final approach to RWY12 and RWY30.

Whilst the geometric modelling indicates there is potential for reflected sunlight to enter the cockpit of aircraft on visual approach circuits to both runways, the potential impact is not considered significant due to duration, proximity and likelihood of occurrence.

Based on the findings of the geometric assessment, limitations of the SGHAT and current recommendations from the FAA, a Solar Gare Hazard Analysis Tool assessment is not considered nessesary.

It must be noted that this assessment has been taken based on the Arup designed performance specification for the SPV array which will be developed by a specialist contractor. Should there be any deviations from the specification in the final design, the design will need to be assessed to confirm the validity of the results.

Based on the findings of the assessment no mitigation is deemed nessesary.

Appendix A

A.1 Aircraft Movement associated with CWL

GUND (Geoid Undulation) = The height of the Geoid (MSL) above the Reference Elipsoid (WGS 84) at the stated position.

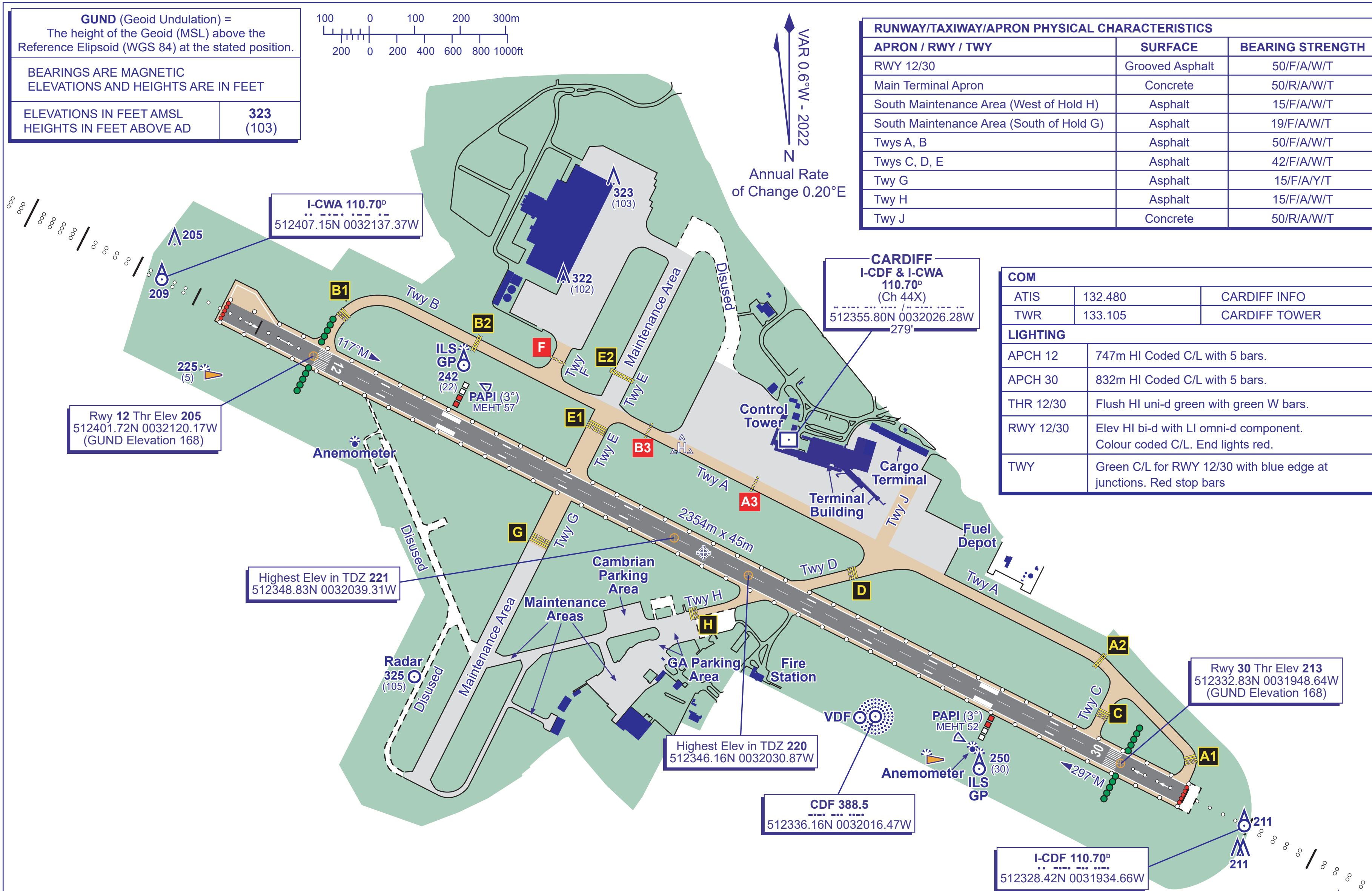
BEARINGS ARE MAGNETIC
ELEVATIONS AND HEIGHTS ARE IN FEET

ELEVATIONS IN FEET AMSL	**323**
HEIGHTS IN FEET ABOVE AD	(103)

RUNWAY/TAXIWAY/APRON PHYSICAL CHARACTERISTICS		
APRON / RWY / TWY	**SURFACE**	**BEARING STRENGTH**
RWY 12/30	Grooved Asphalt	50/F/A/W/T
Main Terminal Apron	Concrete	50/R/A/W/T
South Maintenance Area (West of Hold H)	Asphalt	15/F/A/W/T
South Maintenance Area (South of Hold G)	Asphalt	19/F/A/W/T
Twys A, B	Asphalt	50/F/A/W/T
Twys C, D, E	Asphalt	42/F/A/W/T
Twy G	Asphalt	15/F/A/Y/T
Twy H	Asphalt	15/F/A/W/T
Twy J	Concrete	50/R/A/W/T

COM		
ATIS	132.480	CARDIFF INFO
TWR	133.105	CARDIFF TOWER

LIGHTING	
APCH 12	747m HI Coded C/L with 5 bars.
APCH 30	832m HI Coded C/L with 5 bars.
THR 12/30	Flush HI uni-d green with green W bars.
RWY 12/30	Elev HI bi-d with LI omni-d component. Colour coded C/L. End lights red.
TWY	Green C/L for RWY 12/30 with blue edge at junctions. Red stop bars



CHANGE (7/23): ILS DME COORD & ELEV. RWY MARKING & APCH LIGHTING EDITORIAL. OBSTACLES. BUILDINGS. CARDIFF FIRE COMMS REMOVED. TWY G & H PCN.

COM		
ATIS	132.480	CARDIFF INFO
TWR	133.105	CARDIFF TOWER

RUNWAY/TAXIWAY/APRON PHYSICAL CHARACTERISTICS

APRON / RWY / TWY	SURFACE	BEARING STRENGTH
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Twy H	Asphalt	15/F/A/W/T
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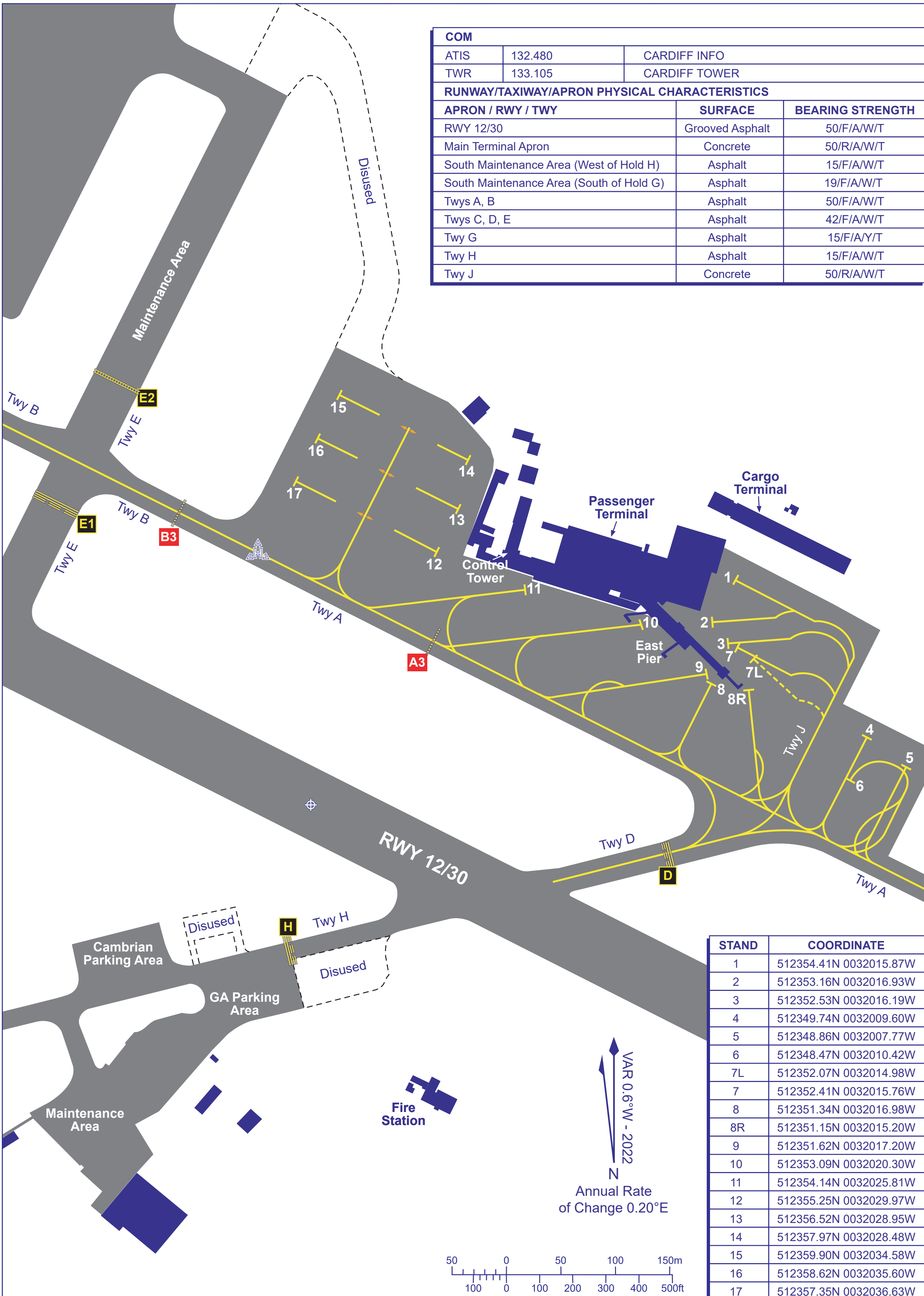

STAND	COORDINATE
1	512354.41N 0032015.87W
2	512353.16N 0032016.93W
3	512352.53N 0032016.19W
4	512349.74N 0032009.60W
5	512348.86N 0032007.77W
6	512348.47N 0032010.42W
7L	512352.07N 0032014.98W
7	512352.41N 0032015.76W
8	512351.34N 0032016.98W
8R	512351.15N 0032015.20W
9	512351.62N 0032017.20W
10	512353.09N 0032020.30W
11	512354.14N 0032025.81W
12	512355.25N 0032029.97W
13	512356.52N 0032028.95W
14	512357.97N 0032028.48W
15	512359.90N 0032034.58W
16	512358.62N 0032035.60W
17	512357.35N 0032036.63W

CHANGE (7/23): STAND CENTRELINES. BUILDINGS. STAND 8, 9 & 15 COORDS. CARDIFF FIRE COMM REMOVED. TWY G & H PCN.