Aeronautical Study: Ocean Spa Plaza

P1077/R1/Issue 2

Report prepared on behalf of Ocean Village

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Eddowes Aviation Safety Ltd
Specialist Aviation Assessments

Authorisation Sheet

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Summary

Ocean Village is proposing a new development in Gibraltar, the Ocean Spa Plaza. The proposed development is a single building, comprising two distinct elements. The lower seven levels occupy the full footprint of the site and comprise mostly car parking. The height of this element of the building is up to approximately 25 m above ground floor level. The upper element of the development is an elliptical tower, occupying the central part of the site, and comprising ten residential floors and a Spa Level at the top of the building. The roof top reaches to a maximum of 52.99 m above ground floor level, this maximum height corresponding with the central stair core. Ground floor level is understood to be 2 m above Alicante Datum.

The development site lies in the vicinity of flight paths to and from Gibraltar Airport in an area subject to aerodrome safeguarding, the process by which airspace required for safe and efficient take-off and landing at airports is maintained free of new development and by which other potential hazards to aviation from new developments are minimised. In support of the development an Aeronautical Study has been undertaken to ensure that it will not adversely affect the safety of aircraft operations to and from Gibraltar Airport and that the appropriate safeguarding requirements will be met. In particular, the following issues have been considered:

- Physical safeguarding requirements according to the specifications of the Obstacle Limitation Surfaces.
- Wind and Turbulence effects.
- Potential problems of reflective glare towards aircraft or ATC from surfaces or windows on the exterior of the building.
- Potential for birds to roost on the building.
- Foreign Object Debris suppression.
- Use of cranes during construction.

The findings of the assessment of the development in respect of each of those issues are as follows.

Physical safeguarding requirements

The physical safeguarding assessment has determined that the development lies predominantly within an area covered by the Inner Horizontal Surface, a level surface at a height of 45 m above aerodrome reference elevation. The taller elliptical element of the building is found to be a penetration of this surface, by an estimated 6.76 m. The more northerly part of the development where the maximum height of the building is about 25 m above ground floor level lies within the area covered by the Transitional Surface. This part of the proposed development is not a penetration of the Transitional Surface.

The relevant international standards identify circumstances in which penetrations of the Inner Horizontal Surface may be considered acceptable. Specifically, the standards state that new objects or additions to existing objects should not extend above an inner horizontal surface, except when the object would be shielded by an existing immovable object or it is determined by aeronautical study that the object would not adversely affect the safety or significantly affect the regularity of aircraft operations. The proposed development may therefore be considered acceptable, provided that these criteria are met.

As regards operational implications, the presence of the Rock already limits the nature of operations, in particular the approach procedures in use at Gibraltar Airport. The proposed development would not add to those restrictions and would therefore have no impact on the regularity of operations. Operational safety considerations, having regard to the visual nature of operations in the area of the runway and its immediate surroundings, indicate that aircraft will be able to maintain a safe lateral margin with respect to the development and hence that it would not adversely affect the safety of operations. There is a clear case on the basis of aeronautical study, based on an assessment of local circumstances and published operational procedures, that the penetration of Inner Horizontal Surface by the development may be considered acceptable, without any consideration of shielding.

Moving next to consider shielding, it is noted that there are several existing buildings in the immediate vicinity of the Ocean Spa Plaza site that exceed the height of the Inner Horizontal Surface. The Tradewinds 3 and Royal Ocean Plaza buildings are located immediately to the West of the Ocean Spa Plaza site, on the West side of the road that runs along the western boundary of the site, around 10 to 12 m from it. Constitution House, located about 20 m to the East of the Ocean Spa Plaza site, has a height of 54.58 m above the identified ground floor level. Referendum House, the two elements of which are at heights of 53.6 m and 54.18 m above the identified ground floor level, is located about 150 m to the East of the Ocean Spa Plaza site. All these existing developments are taller than the Ocean Spa Plaza. Elements of these buildings that are taller than the proposed Ocean Spa Plaza are also found to lie closer to the runway than the proposed development. When viewed from both the West and the East along a line parallel with the runway, the Ocean Spa Plaza building will be shielded along the whole of its northern edge by these existing buildings.

The physical safeguarding assessment therefore indicates that penetration of the Inner Horizontal Surface by the proposed development may be considered acceptable, on the grounds of shielding by existing buildings and may, on the basis of the lack of any adverse impacts on operations, be considered acceptable even if it were not to be shielded.

Wind and turbulence effects

The development site is over a kilometre from the Runway 27 threshold and can therefore be expected not to have any material impact on turbulence on the Runway 27 approach. It is closer to the Runway 09 threshold and touchdown zone but still some distance away, for example about 450 m to the South-east of the touchdown zone. Based on previous experience of the assessment of other schemes, significant additional turbulence impacts on the Runway 09 approach path and touchdown zone are not expected at these sorts of distances for buildings of the height of the Ocean Spa Plaza. Impacts associated with the existing tall buildings in the area are expected to be minimal and the new development is expected to have no additional material impact on turbulence in areas where aircraft operate.

Reflective glare

There are no scenarios for reflections from the lower part of the building to any of the three aeronautical targets, due to a combination of sun azimuth-related constraints and shadowing by other buildings and terrain.

Reflections from the taller, elliptical element of the building are less restricted by sun azimuth-related constraints, due its multifaceted nature which increases the options for the required geometrical alignments for reflections to the aeronautical targets being met. Reflections from this part of the building will still be significantly constrained due to shadowing by other buildings and terrain. However, four cases of potential reflection from this part of the building are identified as follows:

- ***Runway 09 approach at sunrise.*** There is a possibility of reflection of light from the rising sun to the Runway 09 approach from north-facing elements of the elliptical tower. Due to a combination of constraints, in particular shadowing by Referendum House and Constitution House, these reflections will be limited to sun azimuth angles of less than 79°. This sun azimuth range constraint restricts reflections to the Runway 09 approach path at aircraft height at and slightly after the Runway 09 threshold between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice and to panels towards the top of the building, due to shadowing of lines of sight by the Tradewinds 1 and Tradewinds 2 buildings.
- ***Runway 27 approach at sunset.*** There is a possibility of reflection of light from the setting sun to the Runway 27 approach from north-facing elements of the elliptical tower. Due to elevation angle-related constraints, these potential reflections cannot arise until a distance of around 400 m before threshold. After that point, reflections to the approach path at aircraft height from the top part of the building from sunlight across the azimuth range of 290° to 300° is identified as a possibility. For the identified sun azimuth range, the time periods over which this possibility will exist is estimated to be from about mid-May to the end of July. Reflections will be limited to sunset, at about 20:55 on those dates and 21:30 at the summer solstice.
- ***ATC Tower at sunrise.*** Reflection of light from the rising sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 09 approach at sunrise. Reflections are identified as a possibility between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice.
- ***ATC Tower at sunset.*** Reflection of light from the setting sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 27 approach at sunset. Reflections are identified as a possibility between about mid-May to the end of July. Reflections will be limited to sunset, at about 20:55 on those dates and 21:30 at the summer solstice.

A number of factors can immediately be identified that will limit the amount of light that can be reflected in the cases where potential glare impacts may occur. For reflections to the ATC Tower the following attenuation factors are estimated to apply:

- The glass surface reflectance for this scenario is estimated to be around 10%, giving an attenuation of intensity of the reflected light compared with that of the incident light of around a factor of 10.
- The multi-faceted nature of the building means that there is a limited surface area only for reflection in any direction. It is estimated that sufficient surface area will be available to reflect no more than about 8.5% or less of the effective surface area of the sun in any direction at any one time. An estimated attenuation factor of about 12 will therefore apply in respect of the limited glazed surface area available.
- Impacts will occur at sunset only when atmospheric path length effects will provide attenuation by an estimated factor of around 100 to 1,000 compared with the intensity of the midday sun.

Taking each of these factors together, the overall attenuation of the reflected light intensity compared with that of the mid-day sun is estimated to be in the region of 12,000 or more. On that basis, it is concluded that any reflections to the ATC Tower will be below the intensity at which they would cause any significant reflective glare impacts that may adversely affect the safety of airport operations.

For reflections to the Runway 09 and Runway 27 approaches, no attenuation associated with the glass reflectance has been assumed, due to the higher angle of incidence in these cases. An overall attenuation factor of 1,200 or more is estimated. For these scenarios, any impacts will be minimised by their transient nature, as aircraft move into and out of areas of alignment and the angle of view to the Ocean Spa Plaza building which will be well to the side of the main focus of view along the runway axis. On that basis, it is concluded that there will be no significant adverse reflective glare impacts on approach operations.

Bird hazard management

It is expected that established approaches to the management of bird attraction during the construction phase of the project and during the on-going life of the development will be able to satisfactorily address bird hazards by avoiding the availability of food sources and fresh water.

Foreign Object Debris suppression

Foreign Object Debris (FOD) arising from construction activities is of potential concern to airport operations. Given the proximity of the site to the runway at Gibraltar loose, wind-blown material might potentially affect operations. The adoption of appropriate management practices for Foreign Object Debris suppression during construction is therefore recommended.

Use of cranes during construction

Since the proposal is for development above the height of the Inner Horizontal Surface, the use of cranes to supply materials to the upper levels of the development during construction will inevitably require penetration of that surface. No specific crane plan has been identified at this stage of the development proposal but some general comments on the use of cranes during construction may be made.

The operational considerations presented earlier in relation to the development itself will apply in respect of the use of cranes: operations are constrained by the presence of the Rock at a substantially greater height than cranes of the height required. As a result, no increases in the identified obstacle clearance altitudes would be required to accommodate construction cranes. Given the distance of the site from the runway, there can generally be expected to be an adequate lateral margin with respect to tall obstacles at it to ensure aircraft safety. Where a saddle jib crane is oriented with the jib facing North towards the runway, the lateral margins may be eroded to some extent. Taking account of the margins available and having regard to the operational considerations presented earlier in the safeguarding assessment of the building itself, this erosion in margins is expected not to have a material impact on the safety of operations at Gibraltar Airport. Pragmatic qualitative arguments supported by previous detailed quantitative risk analysis indicate that the risks of collision associated with the proposed cranes are likely to be negligible. However, as a precaution, it may be prudent to avoid jib orientations that erode the lateral clearance margins at times when runway operations are taking place. It is understood that these operational practices have been adopted previously and it is recommended that Ocean Village liaise with RAF Gibraltar in order to establish requirements for crane management, as appropriate.

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Appendices

1 Introduction

Ocean Village is proposing a new development in Gibraltar, the Ocean Spa Plaza. The development site lies in the vicinity of flight paths to and from Gibraltar Airport in an area subject to aerodrome safeguarding, the process by which airspace required for safe and efficient take-off and landing at airports is maintained free of new development and by which other potential hazards to aviation from new developments are minimised. In support of the development an Aeronautical Study has been undertaken to ensure that it will not adversely affect the safety of aircraft operations to and from Gibraltar Airport and that the appropriate safeguarding requirements will be met.

In particular, the following issues have been identified as requiring consideration, due to the location of the site:

- Physical safeguarding requirements according to the specifications of the Obstacle Limitation Surfaces.
- Wind and Turbulence effects.
- Potential problems of reflective glare towards aircraft or ATC from surfaces or windows on the exterior of the building.
- Potential for birds to roost on the building.
- Foreign Object Debris suppression.
- Use of cranes during construction.

The more general requirements for aerodrome safeguarding apply, as set out in Civil Aviation Publication (CAP) 738 on Safeguarding of Aerodromes and CAP 168 on the Licensing of Aerodromes, published by the UK CAA, and in the Manual of Aerodrome Design & Safeguarding issued by the Military Aviation Authority.

This report presents the findings of the aeronautical study, undertaken to ensure adequate safeguarding of the airport. The report starts with a description of the development and relevant features of the airport which is followed by an account of the assessment of each of the above issues in turn.

2 Site Description

2.1 PROPOSED DEVELOPMENT

The Ocean Spa Plaza site is located to the North-west of the Rock, towards the north end of Gibraltar, slightly to the South-west of the Marina. The site lies between approximately 380 m and 460 m from the Gibraltar Airport runway centreline and its location relative to the airport runway is shown in Figure 2.1.

Figure 2.1: Ocean Spa Plaza Site Location relative to Gibraltar Airport

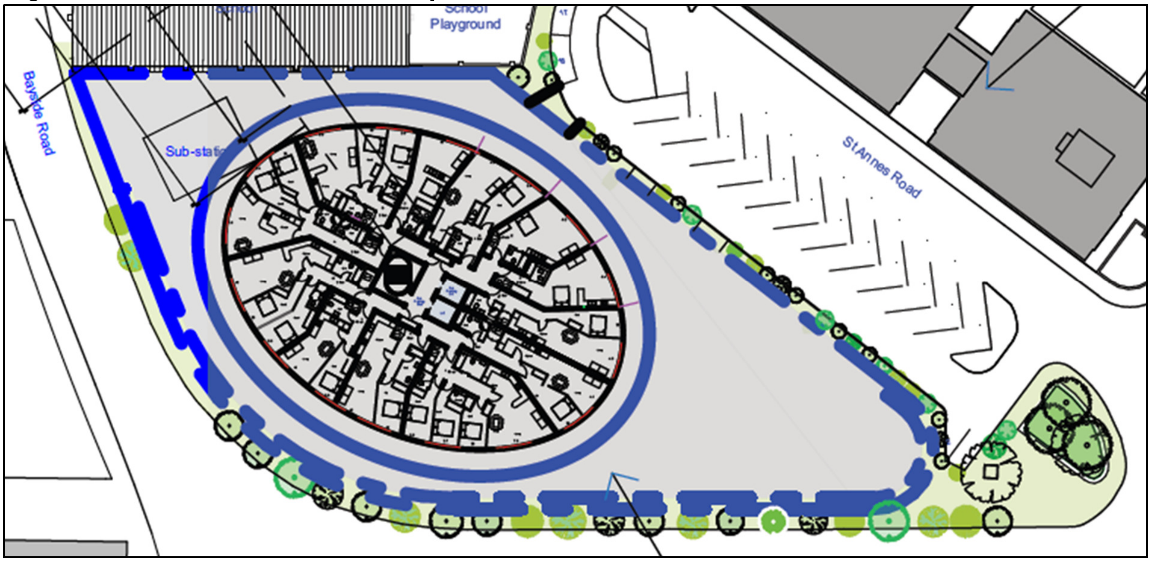
The proposed Ocean Spa Plaza is a single building, comprising two distinct elements. The lower seven levels occupy the full footprint of the site, as shown in Figure 2.1 and comprise mostly car parking. The height of this element of the building is up to approximately 25 m above ground floor level. The upper element of the development is an elliptical tower, occupying the central part of the site, and comprising ten residential floors and a Spa Level at the top of the building. The roof top reaches to a maximum of 52.99 m above ground floor level, this maximum height corresponding with the central stair core. Ground floor level is understood to be 2 m above Alicante Datum. This basic layout is illustrated by the plan view shown in Figure 2.2.

Coordinates for the site have been determined by reference to Google Earth satellite images, as shown in Table 2.1. For the purposes of the assessment, it is generally convenient to work in terms of runway-aligned coordinates which are also shown in Table 2.1.

Table 2.1: Ocean Spa Plaza Site Coordinates

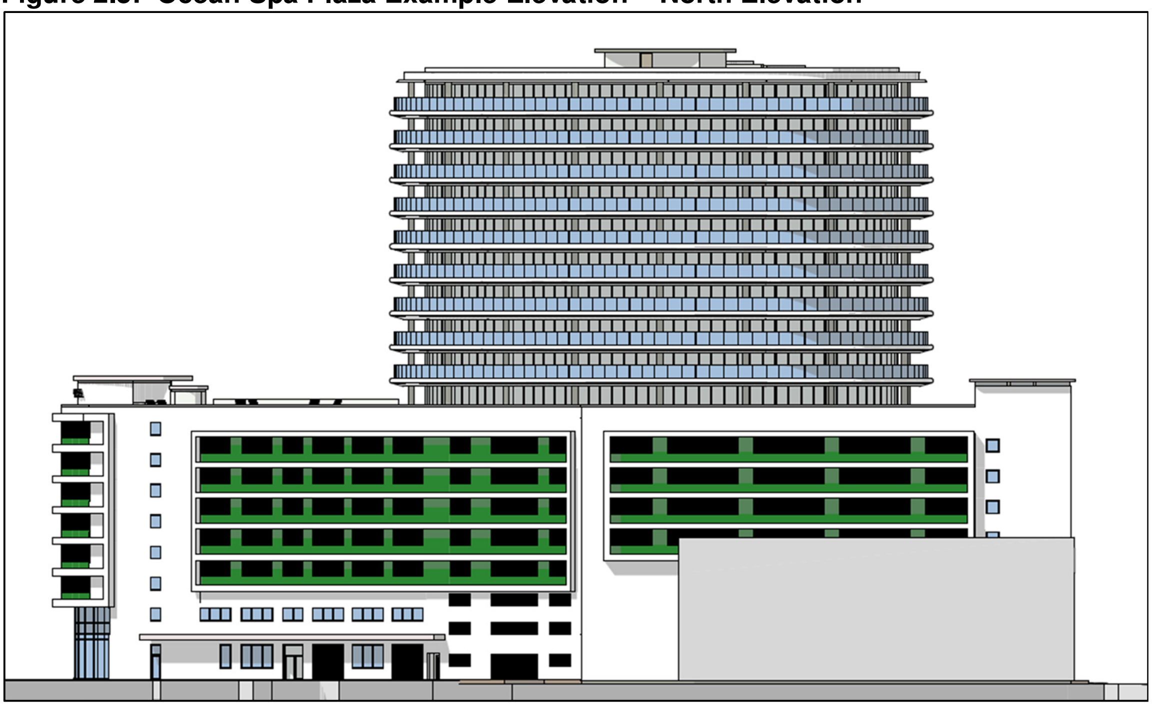
Location	Latitude	Longitude	UTM Coordinates		Runway-aligned	
			Easting	Northing	X (m)	Y (m)
NE corner	36 08 50.75 N	5 21 07.22 W	288396.41	4002864.61	-531.92	406.46
SE corner	36 08 48.96 N	5 21 06.99 W	288400.84	4002809.32	-535.31	461.81
Start of curve - SW	36 08 49.77 N	5 21 08.52 W	288363.19	4002835.25	-498.15	435.19
End of curve - NW	36 08 50.68 N	5 21 08.89 W	288354.40	4002861.63	-489.86	408.65
NW corner	36 08 51.50 N	5 21 08.64 W	288361.31	4002888.53	-497.27	381.88

Figure 2.2: Plan View of Ocean Spa Plaza



The North elevation of the building is shown in Figure 2.3 and is representative of the general nature of the development.

Figure 2.3: Ocean Spa Plaza Example Elevation – North Elevation



A specification for the variation of building height with distance from the runway has been provided by Morgan Carn. The most northerly part of the elliptical tower element of the building has a height of 48.96 m above ground floor level at a distance of 398.158 m from the runway centreline, corresponding with the balcony on the residential 10th floor. The height steps up to 51.085 m above ground floor level at a distance of 400.598 m from the runway centreline, corresponding with the roof level parapet. Further detail concerning the profile is provided in Appendix 1.

2.2 RUNWAY SPECIFICATION

The available Aeronautical Information Publication (AIP) for Gibraltar Airport gives the runway threshold locations shown in Table 2.2. The threshold elevations given in the table are those identified in the AIP. The threshold elevations given in the AIP are 10.6 ft and 12.3 ft for Runway 09[1] and Runway 27 and compare with values in feet identified on the 2011 Type A chart of 10.72 ft and 12.3 ft.

Table 2.2: Runway Threshold Locations and Elevations

	Runway 09 Threshold	Runway 27 Threshold	Aerodrome reference point
Latitude	36 09 03·18 N	36 09 05·30 N	36 09 04.20 N
Longitude	005 21 29·17 W	005 20 28·21 W	005 20 58.80 W
UTM Easting	287857.01	289382.23	288616.84
UTM Northing	4003261.08	4003289.52	4003274.10
Elevation*	10.6 ft / 3.27 m	12.3 ft / 3.75 m	12 ft / 3.658 m
Heading / degrees**	87.58	267.58	-

* The 2011 Type A chart at some points refers to heights "AOD", implying "above Ordnance Datum" and at others identifies the elevation datum as "Alicante". The normal convention in aeronautical information is to use sea level as the reference level.
** Value derived from the Google Earth satellite image which does not correspond exactly with the value given on the 2011 Type A chart.

The available Gibraltar Town Plan gives spot heights along the runway centreline to the nearest 0.1 m and the height shown that corresponds must closely to the Runway 09 threshold is at 2.8 m above Alicante Datum. This spot height is apparently marginally to the West of the threshold where the runway appears to be increasing in height slightly to a spot height of 3.0 m at a distance of 225 m to the East. On that basis, it appears that the threshold location is slightly above 2.8 m vs Alicante Datum. For the purposes of this assessment the threshold elevations are assumed to be referenced against Alicante Datum which is the more conservative of the two primary options.

As noted in Section 2.1, it is convenient to work in terms of runway-aligned coordinates referenced against the Runway 09 threshold: i.e. the Runway 09 threshold centre is at x = 0, y = 0. By reference to the UTM coordinates for the thresholds, the Runway 27 threshold is determined to be at x = -1,631 m.

2.3 ATC TOWER SPECIFICATION

The Air Traffic Control facility is located approximately 150 m to the North of the runway centreline and slightly to the East of the runway mid-point. It is octagonal and estimated to be approximately 6.7 m in diameter. Its centre location, estimated by reference to Google earth satellite images, is as shown in Table 2.3. The height of an observer's eye in the ATC facility has previously been estimated to be approximately 17.6 m AMSL.

[1] The runways are designated according to their direction with respect to North, rounded to the nearest 5 degrees. For example, Runway 09 for operations towards the East is aligned at 87.58°: i.e. at an angle of approximately 90° when rounded to the nearest 5°. Runway 27 for operations towards the West is at an angle of 180° to Runway 09 and at approximately 270° vs North.

Table 2.3: ATC Tower Location and Elevation

Latitude	36.152554°
Longitude	-5.348108°
UTM Easting	288760.81
UTM Northing	4003424.62
Runway-aligned X	-906.70
Runway-aligned Y	-146.67
Elevation / m AMSL	17.6

2.4 GIBRALTAR ELEVATION REFERENCE DATUMS

Four different elevation reference datums are of potential relevance to the current study and are, in order of increasing height, as follows:

- Chart Datum (2001): the datum typically employed on nautical charts.
- Ordnance Datum Gibraltar: the local datum that was previously used as the standard elevation datum for mapping in Gibraltar.
- Alicante Datum: the elevation datum adopted more widely in that Geographical region.
- Mean Sea Level: the elevation datum normally employed in aeronautical information, based on the WGS84 coordinate system.

The following relative heights for these datums have been provided[2]:

- Chart Datum (2001): 0.09 m below Ordnance Datum and 0.52 m below Mean Sea Level.
- Alicante Datum: 0.138 m above Ordnance Datum.
- Mean Sea Level: 0.39 m above Ordnance Datum.

Mean Sea Level is therefore determined to be 0.252 m above Alicante Datum and would be estimated to be 0.48 m above Chart Datum (2001), using the above relative heights of Chart Datum and Mean Sea Level with respect to Ordnance Datum, compared with the value of 0.52 m given in the available reference.

[2] www.euref.eu/symposia/book2001/nr_15.PDF

3 Safeguarding Assessment

3.1 PHYSICAL SAFEGUARDING

The development site is determined to lie predominantly under the Inner Horizontal Surface. Standards prescribed by the International Civil Aviation Organisation (ICAO) identify the Inner Horizontal Surface to be a level surface at a height of 45 m above the appropriate aerodrome reference and extending from an origin at the edge of the Transitional Surface, in this case at a distance of 390 m from the centre-line of the runway. UK practice is typically to reference the height of the Inner Horizontal Surface against the lowest runway threshold at an airport, in this case the height of 3.27 m identified for the Runway 09 threshold. The ICAO standards for these surfaces, set out in ICAO Annex 14 on aerodrome design and operations, are adopted by the UK CAA, as identified in Civil Aviation Publication (CAP) 168 and by the UK Military Aviation Authority in its Manual of Aerodrome Design & Safeguarding (MADS).

As described earlier, a specification for the variation of building height with distance from the runway has been provided by Morgan Carn and is summarised in Appendix 1. The most northerly part of the elliptical tower element of the building has a height of 48.96 m above ground floor level at a distance of 398.158 m from the runway centreline, corresponding with the balcony on the residential 10th floor. The height steps up to 51.085 m at a distance of 400.598 m above ground floor level from the runway centreline, corresponding with the roof level parapet. The stair core, at a height of 52.99 m above ground floor level, is located at a distance of 415.106 m from the runway centreline. Ground floor level is understood to be 2 m above Alicante Datum. This tallest part of the proposed development is found to lie entirely under the Inner Horizontal Surface.

Based on the above specifications, the highest part of the development is estimated to penetrate the Inner Horizontal Surface by 6.76 m.

The more northerly part of the proposed development, towards the NW corner of the site and the point closest to the runway, is identified as being 383.2 m from the runway centreline. It is therefore determined to lie under the Transitional Surface. Standards prescribed by the International Civil Aviation Organisation (ICAO) identify the Transitional Surface to be a sloping surface extending from an origin at the elevation of the nearest point on the centre-line of the runway and at a defined distance from the runway centre-line, according to the category of the runway. The specification of the Transitional Surface at Gibraltar is for the origin to be located at 75 m from the runway centre-line. The Transitional Surface has a slope of 1 in 7 and rises to a height of 45 m above aerodrome reference level where it meets the Inner Horizontal Surface. It extends to 390 m from the runway centreline[3]. At the northernmost part of the proposed development, at 383.2 m from the runway centreline, the Transitional Surface is estimated to be 0.97 m below the height of the Inner Horizontal Surface: i.e. 44.3 m above aerodrome reference level. The part of the development at this distance from the centreline is 25 m above ground floor level and is therefore found to be below the Transitional Surface.

[3] The surface rises with a slope of 1 in 7 from the edge of the runway strip at the height of the runway centreline at that point. Due to possible undulations in the runway, that starting elevation is not necessarily the same as the reference elevation for the Inner Horizontal Surface. The value of 390 m given is that which would apply if these two elevations were the same. In practice due to changes in runway height along its length, the Transitional Surface may extend to a slightly different distance.

The standards identified for civil operations, as set out in ICAO Annex 14 and CAP 168, identify circumstances in which penetrations of the Inner Horizontal Surface may be considered acceptable. Specifically, the standards state that new objects or additions to existing objects should not extend above an inner horizontal surface, except when the object would be shielded by an existing immovable object or it is determined by aeronautical study that the object would not adversely affect the safety or significantly affect the regularity of aircraft operations. The proposed development may therefore be considered acceptable, provided that these criteria are met.

The purpose of the Inner Horizontal Surface is clearly identified in the Airport Services Manual Part 6 on the control of obstacles (ICAO Doc 9137 – AN.898/2) which states the following

> *1.2.3.1 The purpose of the inner horizontal surface is to protect airspace for visual circling prior to landing, possibly after a descent through cloud aligned with a runway other than that is use for landing.*
>
> *1.2.3.2 In some instances, certain sectors of the visual circling areas will not be essential to aircraft operations and, provided procedures are established to ensure that aircraft do not fly in these sectors, the protection afforded by the inner horizontal surface need not extend into those sectors. Similar discretion can be exercised by the appropriate authorities when procedures have been established and navigational guidance provided to ensure that the defined approach and missed-approach paths will be followed.*

Visual circling in the area of the proposed development is already precluded by the presence of the Rock and maintaining the Inner Horizontal Surface in that area will therefore not serve the identified purpose of the surface. Procedures are in place to ensure that the defined approach and missed-approach paths will be followed. In the case of the missed-approach, this will be initiated when aircraft are at the Visual Descent Point identified in the published approach procedures, at an elevation of 920 ft, equivalent to 280 m. The proposed development is evidently considerably below the height of aircraft flying a missed-approach and will represent no threat to the safety of aircraft following that procedure.

Aircraft will drop below the VDP only when visual reference to the runway has been gained. Under visual conditions, aircraft will be able to see the runway and obstacles to the side of it. They can therefore be expected to be able to follow an appropriate approach path that will avoid the development site by a safe lateral margin. Overall, the circumstances are such that the conditions outlined in the Airport Services Manual Part 6 on the control of obstacles under which a penetration of the inner horizontal surface may be permitted are met. There is a clear case on the basis of aeronautical study, based on an assessment of local circumstances and published operational procedures, that the penetration of inner horizontal surface by the development may be considered acceptable, without any consideration of shielding.

Moving next to consider shielding, it is noted that there are several existing buildings in the immediate vicinity of the Ocean Spa Plaza site that exceed the height of the Inner Horizontal Surface. The Tradewinds 3 and Royal Ocean Plaza buildings are located immediately to the West of the Ocean Spa Plaza site, on the West side of the road that runs along the western boundary of the site, around 10 to 12 m from it.

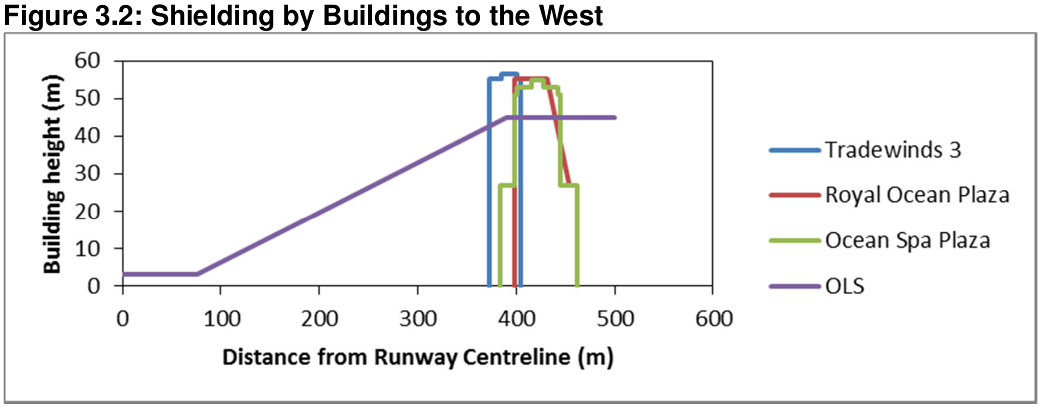
The Royal Ocean Plaza, which is located under the Inner Horizontal Surface with its closest corner 397.8 m from the runway centreline, has a maximum height of 55.08 m. The Tradewinds 3 building, the northerly part of which is located under the southern edge of the Transitional Surface with its closest corner estimated to be 373 m from the runway centre line, has a main roof height of 53.20 m above the identified ground floor level. The stairs of the Tradewinds 3 building, located slightly further from the runway centreline at a minimum distance estimated to be 385 m, reaches a height of 54.48 m above the identified ground floor level.

In addition, there are two existing buildings to the East of the Ocean Spa Plaza that exceed its proposed maximum height of 52.99 m above ground floor level. Constitution House, located about 20 m to the East of the Ocean Spa Plaza site, has a height of 54.58 m above the identified ground floor level. Referendum House, the two elements of which are at heights of 53.6 m and 54.18 m above the identified ground floor level, is located about 150 m to the East of the Ocean Spa Plaza site. The locations of these four buildings are shown in red in Figure 3.1.

Figure 3.1: Location of Existing Taller Buildings in relation to the Ocean Spa Plaza

When viewed from the West along a line parallel with the runway, the Ocean Spa Plaza building will be shielded along the whole of its northern edge by the existing Tradewinds 3 and Royal Ocean Plaza buildings. These profiles are shown schematically in Figure 3.2.

Figure 3.2: Shielding by Buildings to the West

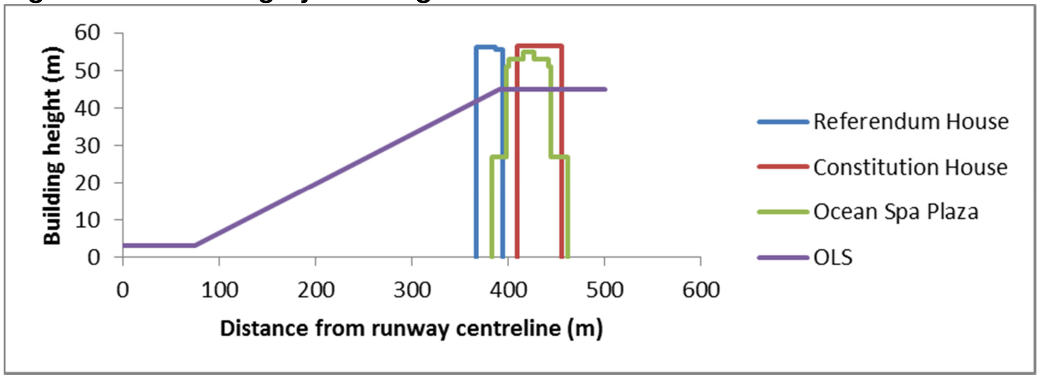


Similarly, when viewed from the East along a line parallel with the runway, the Ocean Spa Plaza building will be shielded along the whole of its northern edge by the existing

Referendum House and Constitution House buildings. These profiles are shown schematically in Figure 3.3.

The building profiles upon which these figures are based are summarised in Appendix 1.

Figure 3.3: Shielding by Buildings to the East



ICAO provides guidance on the principle of shielding in Doc 9137 but ICAO standards do not prescribe any specific geometrical interpretation that must be always adopted. This guidance points to potential geometrical prescriptions and one is provided by the UK CAA in CAP 168. However, referring to international practices, ICAO guidance provides a more general interpretation of the principle of shielding, for example as follows:

> *"An object should not be considered an obstacle if its location with respect to obstacles of a permanent character is such that there results no material increase in the aeronautical hazard. In the determination of whether an object is shielded, each obstacle of a permanent character, located in the runway approach-departure area, is regarded as casting a shadow plane outward away from the runway end. Thus, an obstacle shielded by the shadow plane of a governing obstacle will not be considered as an obstacle."*

ICAO does not provide any specification for the shadow plane. The CAP 168 geometrical specification for the areas in which it will be accepted that shielding with respect to an existing obstacle applies, is defined in terms of the shadows cast with respect to vertical and horizontal reference planes at the obstacle, as illustrated in Figure 3.4. These geometrical prescriptions apply specifically to shielding in the areas of the Take-off Climb Surface and the Approach Surface. The UK CAA has identified no specific prescriptions for the geometrical interpretation of shielding in the area covered by the Inner Horizontal Surface.

As has been noted earlier and is illustrated in Figures 3.2 and 3.3, the identified existing buildings would provide complete shielding of the proposed Ocean Spa Plaza development when viewed along a line parallel to the runway. Shielding according to the 10% slope and splays of 12.5% and 15% applicable to the take-off climb and approach surfaces, respectively, as identified in CAP 168, will not be provided. However, these specifications can be seen to be somewhat cautious, taking account of realistic runway-aligned flight paths that can normally be expected to be followed during take-off and landing. The level of shielding that is provided can be considered to effectively preclude all safe use of airspace in the vicinity of the development site. The safety of any aircraft approaching that area can be expected to be compromised by the existing developments, before reaching a point at which a collision with the Ocean Spa Plaza would become a possibility.

Overall, the key requirements for considering a new object to be shielded by an existing obstacle are, first and foremost, that the new object will not have any significant adverse impacts on operations and that it will not result in any material increase in the aeronautical hazard. Conformance with any specific geometrical prescription is not a formal requirement. It will be matter of interpretation on a case-by-case basis as to whether the shielding principle applies in any particular circumstances.

Figure 3.4: Extract from CAP 168 on Shielding

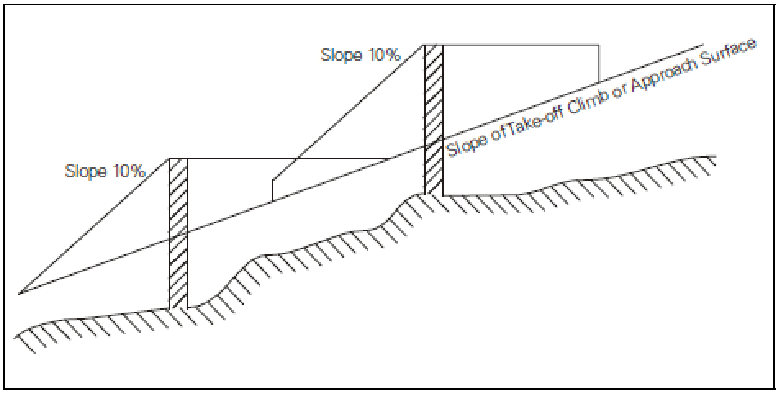


Figure 4.14

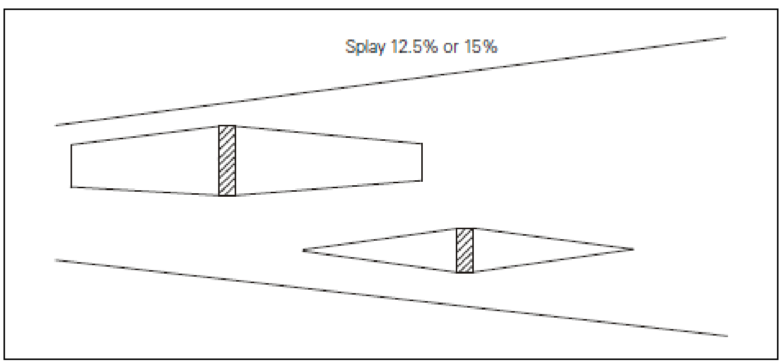


Figure 4.15

As has already been noted, there are no operational implications associated with the proposed development. The obstacle clearance altitudes identified for operational procedures are dominated by the Rock which is very substantially higher. No increases in the identified obstacle clearance altitudes would be required to accommodate the development.

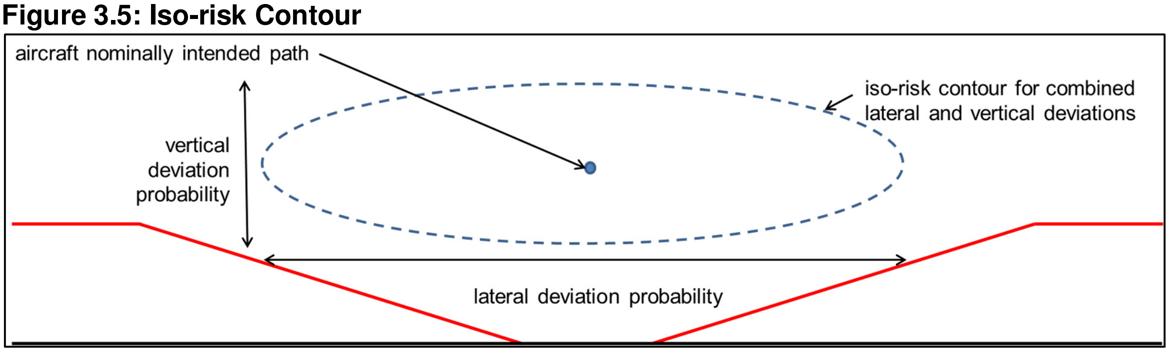
Together with the Transitional Surface those parts of the Inner Horizontal Surface closest to the runway may serve a role in the protection of aircraft executing a go-around. Aircraft executing an approach leading to successful touch down on the runway can be expected to be confined much more closely to the runway axis and this scenario is therefore of no concern. When performing a go-around, aircraft following the identified procedures will have visual reference and can normally be expected to be able to maintain a flight path that is effectively aligned with the runway axis and hence be able to maintain a lateral margin of around 350 m with respect to the Ocean Spa Plaza site, based on the distance of 380 m from the centreline and making an allowance for the aircraft wingspan and some drift from the centreline.

For normal operations the available lateral margin can be expected to provide for an entirely adequate level of safety. Some consideration of the potential hazard presented by the proposed development during non-standard and emergency situations will be appropriate. It is difficult to envisage lateral deviation to the extent that there were to be a realistic possibility of collision with the proposed development except in the most extreme circumstances and unusual circumstances where control of the aircraft has been lost. The most common, reasonably foreseeable non-standard operation identified is the late go-around where aircraft discontinue an approach relatively close to the ground at a height at which there will be no vertical clearance margin with respect to the proposed building and an appropriate lateral margin will be required to ensure aircraft safety. Studies of aircraft deviation using aircraft positioning information derived from flight data monitoring of real approach operations indicate that deviation beyond the edge of the Transitional Surface will be extremely improbable. Studies using flight simulators that have been undertaken previously to assess the likely threat to emergency situations involving more severe fault conditions of obstacles located to the side of the runway support that general conclusion.

It has previously been suggested that an extension of the 1 in 7 slope of the Transitional Surface into the area of the Inner Horizontal Surface may be safely adopted when considering relaxation of height restrictions at these sorts of distance from the runway centreline where there is no requirement to safeguard circling operations and the primary objective is to protect runway operations in the event of deviation from the runway-aligned flight path. Whilst this may be considered a reasonable first step in relaxation of height controls, consideration of flight path distributions indicates that this approach will be unnecessarily restrictive and that a greater relaxation, above the height of the extrapolated 1 in 7, will provide an adequate level of safety.

The position of aircraft on approach and during the go-around and the safety implications of normal deviations about the flight path can be described in terms of an “iso-risk contour”, dependent upon the lateral and vertical deviation probabilities which together determine the probability of aircraft deviation to any given point from the nominally intended path. This iso-risk contour is shown schematically in Figure 3.5. At distances further from the runway centreline, there will be a reduced benefit in restricting development to the level of the 1 in 7 slope of the Transitional Surface and obstacles significantly above that height will have no material impact on the safety of aircraft at sufficient distances from the runway centreline.

Figure 3.5: Iso-risk Contour



In any event, the shielding analysis indicates that if an aircraft were to deviate laterally from the nominally intended path to the extent that a collision with the proposed development were a possibility, a collision with one of the existing taller buildings would be expected. Overall, it may be concluded that there will be no material increase in the aeronautical hazard associated with the built environment in the vicinity of the runway if the proposed Ocean Spa Plaza development were to be constructed.

As regards the potential impact on take-off operations, it is noted that the Inner Horizontal and Transitional Surfaces are not a requirement at runways intended for take-off according to the relevant ICAO standards. Obstacle restriction alongside the runway is required up to the edge of the runway strip, at a distance of 75 m from the centreline but not beyond. On that basis, it is concluded that the proposed development will not present any hazard to aircraft during take-off.

3.2 WIND AND TURBULENCE

Wind and turbulence effects are of specific concern at Gibraltar Airport and arise in some conditions, due in particular to the close proximity of the Rock. As identified in the AIP, strong winds from the South East create turbulence on the North West side of the Rock, in the area of the final approach to Runway 09, whereas strong winds from the South West create turbulence on the North East side of the Rock, in the area of the final approach to Runway 27. Stronger winds from the South are identified as making the whole runway subject to turbulence. Turbulence in the final approach path shortly before landing is of particular concern because it may lead to displacement of the aircraft from its intended path at a point when there may be limited time available to correct for the effect of the turbulence before reaching the runway. Turbulence is less of a concern for take-off operations since there is not the same requirement for accurate positioning of the aircraft in that case.

The development site is over a kilometre from the Runway 27 threshold and can therefore be expected not to have any material impact on turbulence on the Runway 27 approach. It is closer to the Runway 09 threshold and touchdown zone but still some distance away, for example about 450 m to the South-east of the touchdown zone. Based on previous experience of the assessment of other schemes, significant additional turbulence impacts on the Runway 09 approach path and touchdown zone are not expected at these sorts of distances for buildings of the height of the Ocean Spa Plaza. Impacts associated with the existing tall buildings in the area are expected to be minimal and the new development is expected to have no additional material impact on turbulence in areas where aircraft operate.

3.3 REFLECTIVE GLARE

Large glass structures that might allow strong reflections of sun light, and that are located close to the approach path to a runway, are of potential concern due to the possible impairment of visual reference that they might cause, in particular at a more critical time during landing. A sustained glare during the final approach phase of flight might affect a pilot's ability to maintain adequate visual reference to the runway and a short burst of intense light may affect visual function for some time after the event. Where vision is not impaired, reflections might still cause some level of distraction. Temporary impairment of sight of ATC personnel due to this type of effect may also present a potential threat to safe airport operations.

Whether or not a potentially harmful reflection affecting pilots or ATC staff could occur in practice is dependent upon the geometry of the system, taking account of the approach path of the aircraft or the ATC Tower, the location and elevation of reflective surfaces of the structure and the angles of incidence of sun light on them, according to the position of the sun. Where reflection is found to be geometrically possible, a number of factors may lead to attenuation of the intensity of reflected light such that it need not lead to significant glare impacts that might potentially endanger airport operations. Three primary attenuation factors have been considered, as follows:

- The reflectance of the glass surface, taking account of its dependence on the angle of incidence of sunlight;

- The effective area of the reflective surface, as compared with that of the source (the sun);
- Attenuation due to the atmospheric path length, in particular at sunrise and sunset which is the period over which potential impacts are expected to occur.

The assessment approach adopted here is first to determine whether or not any reflective glare impacts on aeronautical targets may occur at all, based on the identified geometrical constraints on the possible pathways for sunlight. In the event that potential pathways from the sun to aeronautical targets are identified consideration is next given to possible shadowing effects that may block the identified potential reflection pathways. Where pathways are found to remain, further consideration is given to the likely scale and intensity of the associated glare impacts, having regard to factors that will attenuate the light.

Three aeronautical targets at potential risk from reflective glare are identified, as follows:

- The Air Traffic Control facility;
- Aircraft on approach to Runway 09;
- Aircraft on approach to Runway 27.

Whilst the lower element of the building has 4 primary elevations, facing predominantly to the North, East, South and West, the elliptical tower is multi-faceted with glazed surfaces facing across a wide range of intermediate directions. This multi-faceted nature leads to the sun azimuth constraints on reflections being somewhat relaxed compared with those normally encountered when dealing with more conventional building shapes. In essence, there will be far more options for achieving the required geometrical alignments than would be the case for a building with four sides. Occurrences of reflections to the aeronautical targets will therefore be more likely. However, this increased rate of occurrence will be offset by the relatively small glazed area associated with each of them which will limit the amount of light and hence limit the severity of any glare impacts. In practice, shadowing by existing buildings and terrain is found to place significant constraints on the potential for reflective glare impacts.

In the absence of a detailed specification for the multi-faceted elliptical tower, in terms of the precise locations of the various sections facing in different directions, it has not been feasible to provide a detailed geometrical analysis of all reflection scenarios, defining all incident and reflected azimuth angles. Instead, recognising that the multiple directions in which different windows will face will inevitably lead to the required azimuth conditions being met in some instances, it has simply been assumed in most cases that geometrical constraints associated with the azimuth angle cannot be relied upon to prevent reflections. The geometrical analysis has therefore focused more on other factors limiting the impacts, in particular shadowing by existing buildings and terrain.

The details of the assessment are presented in Appendix 2 and its main findings are summarised here.

There are no scenarios for reflections from the lower part of the building to any of the three aeronautical targets, due to a combination of sun azimuth-related constraints and shadowing by other buildings and terrain.

Reflections from the taller, elliptical element of the building are also significantly constrained due to shadowing by other buildings and terrain. However, four cases of potential reflection from this part of the building are identified as follows:

- ***Runway 09 approach at sunrise.*** There is a possibility of reflection of light from the rising sun to the Runway 09 approach from north-facing elements of the elliptical tower.

Due to a combination of constraints, in particular shadowing by Referendum House and Constitution House, these reflections will be limited to sun azimuth angles of less than 79°. This sun azimuth range constraint restricts reflections to the Runway 09 approach path at aircraft height at and slightly after the Runway 09 threshold between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice and to panels towards the top of the building, due to shadowing of lines of sight by the Tradewinds 1 and Tradewinds 2 buildings.

- ***Runway 27 approach at sunset.*** There is a possibility of reflection of light from the setting sun to the Runway 27 approach from north-facing elements of the elliptical tower. Due to elevation angle-related constraints, these potential reflections cannot arise until a distance of around 400 m before threshold. After that point, reflections to the approach path at aircraft height from the top part of the building from sunlight across the azimuth range of 290° to 300° is identified as a possibility. For the identified sun azimuth range, the time periods over which this possibility will exist is estimated to be from about mid-May to the end of July. Reflections will be limited to sunset, at 20:55 on those dates and 21:30 at the summer solstice.
- ***ATC Tower at sunrise.*** Reflection of light from the rising sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 09 approach at sunrise. Reflections are identified as a possibility between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice.
- ***ATC Tower at sunset.*** Reflection of light from the setting sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 27 approach at sunset. Reflections are identified as a possibility between about mid-May to the end of July. Reflections will be limited to sunset, at 20:55 on those dates and 21:30 at the summer solstice.

A number of factors can immediately be identified that will limit the amount of light that can be reflected in the cases where potential glare impacts may occur. For reflections to the ATC Tower the following attenuation factors are estimated to apply:

- The glass surface reflectance for this scenario is estimated to be around 10%, giving an attenuation compared with that of the incident light of around a factor of 10.
- An estimated attenuation factor of about 12 will apply in respect of the limited glazed surface area available.
- Impacts will occur at sunrise and sunset only when atmospheric path length effects will provide attenuation by an estimated factor of around 100 to 1,000 compared with the intensity of the midday sun.

Taking each of these factors together, the overall attenuation of the reflected light intensity compared with that of the mid-day sun is estimated to be in the region of 12,000 or more.

To put those attenuation factors into perspective it may be noted that the sun has luminance of about 1.6 x 10^9 cd/m^2 at noon whereas the sky has luminance of up to 30,000 cd/m^2. The first figure may be considered to be a very high brightness that is likely to cause adverse reflective glare impacts whereas the second figure may be considered a low brightness that would not cause adverse impacts. The mid-point between the two is 6.9 x 10^6 cd/m^2, a factor of 230 lower than the brightness of the sun and a factor of 230 greater than the brightness of the sky. For this scenario, the reflected intensity is estimated to be between around 10 times greater than the above value for the luminance of the sky. The brightness of the reflected light will therefore be very much closer to the lower reference than the higher one.

Another potentially useful reference point is the observation that a factor of 1,000 attenuation is considered to be sufficient to allow safe continuous observation of the sun. The estimated attenuation factor of around 12,000 exceeds this identified minimum requirement.

On that basis, it is concluded that any reflections to the ATC Tower will be below the intensity at which they would cause any significant glare impacts.

For reflections to the Runway 09 and Runway 27 approaches, no attenuation associated with the glass reflectance has been assumed, given the relatively high angle of incidence that applies. In these cases attenuation by a factor of 1,200 or more is estimated. For these scenarios, any impacts will be minimised by their transient nature, as aircraft come into and out of any area of geometrical alignment, and the angle of view to the Ocean Spa Plaza building which will be well to the side of the main focus of view along the runway axis.

3.4 BIRD HAZARD MANAGEMENT

Bird strike has the potential to cause damage to aircraft and can sometimes lead to a threat to aircraft safety. Design and certification requirements for civil aircraft seek to maximise the tolerance of aircraft to bird strike with the objective of minimising the likelihood of catastrophic consequences in the event of a strike.

Civil aircraft design and certification requirements specify the necessary tolerance of aircraft to defined bird strike events. Key elements of these standards include the ability of an engine to withstand ingestion of birds without catching fire, suffering uncontained failure or becoming impossible to shut down and whilst retaining some partial thrust for a specified period after the strike. Essentially, these standards should ensure that any multi-engine civil aircraft will be able to withstand engine ingestion of a single “large” bird without endangering the aircraft, even if the engine is destroyed beyond economic repair, and similarly to withstand ingestion of a certain number of “small” and “medium” sized birds without endangering the aircraft.

In addition there are airframe certification requirements that an aeroplane must be capable of continued safe flight and landing after hitting a 4 lb bird when travelling at cruise speed and that windshield integrity must be maintained in the event of a single impact of a large (4 lb / 1.8 kg) bird at cruise speed.

Recent operating experience indicates that these certification standards are effective at essentially eliminating the risk of loss of a civil aircraft in the event of impact with a single “large” bird. In the UK, the most recent bird strike-related loss of a civilian type aircraft involved a Nimrod at Kinloss on take-off in 1980 which encountered a dense flock of Canada Geese flying in arrowhead formation between overnight roosting and daily feeding grounds. This aircraft suffered numerous bird-strikes and multiple engine failures. The more recent Hudson River bird strike event is understood also to have involved a flock of Canada Geese flying in dense formation. The relatively large size of the Canada Goose (4.6 kg) as well as the number and the close proximity of birds involved is expected to have been a significant factor in these accidents.

Reporting of bird strikes has been mandatory in the UK since 2004 and the UK Civil Aviation Authority publishes comprehensive monthly bird strike statistics, including data on the top ten species. Typically, there are of the order of 1,500 strikes per annum in the UK. Throughout the year, gulls make a significant contribution to the total and are typical responsible for the order of 10 to 30 strikes per month. In the summer months, some smaller species make significant contribution, including around 50 or more swift strikes between May to August and around 200 strikes involving swallows and martins, more particularly in the late summer and associated with juvenile birds. These latter species are aerial rather than ground feeders which may be a factor influencing the strike frequency. The majority of bird strikes result in little or no damage to aircraft but around 3% of reported bird strikes in the UK are classified as “serious”. Such events can generally be expected either to involve relatively large birds or large flocks that lead to multiple strikes. The historical incident data enable the bird strike threat that may arise from the proposed development to be placed in perspective.

The bird hazard encountered at any given aerodrome will be dependent upon the specific local characteristics of the site and its surroundings and the behaviour of local birds. As noted above, transiting flocks of large birds can be a particularly significant threat. Developments near airports that might attract large numbers of larger species, either by providing roosting or feeding opportunities, and lead to bird flight lines across aircraft flight paths, would be of particular concern. Local movements of smaller birds in the immediate vicinity of a development some distance from an aerodrome need not necessarily present a significant problem.

The primary bird strike risk at Gibraltar Airport can be expected to arise from gulls, since these are present in relatively large numbers in the area and are of sufficient size to present a more significant threat to an aircraft in the event of a strike. At certain times of year, relatively large numbers of migratory birds pass through Gibraltar and might also represent a bird strike hazard. In general, bird strike hazard can be minimised by reducing the extent to which birds that are present in the general area are attracted more specifically to the aerodrome.

Given its proximity to the airfield, attraction of birds to the development site could represent a potential threat to the safety of aircraft operations. Bird attraction during the construction phase of the project and during the on-going life of the development following completion is of potential concern and needs to be formally addressed. Primary attractants that need to be avoided are food sources and fresh water, and include also potential nesting and roosting sites. Attraction of larger birds will be of more particular concern.

Site activities, for example excavation and demolition, may provide areas in which fresh water can accumulate and, as a general rule, such accumulations should be avoided wherever practicable. Disturbance of the ground may, at some sites at least, expose soil invertebrates that serve as suitable food for some species. This is certainly the case in the UK during ploughing of farmland, for example. Whereas, given the recent land uses at the site, it may seem unlikely that ground disturbance would uncover significant quantities of suitable food it cannot necessarily be concluded that ground disturbance would not attract birds. Birds may, due to their more general experience, associate human activity that disturbs the ground with the possible availability of food, regardless of what is to be found at any particular site and hence be attracted by such activity, at least initially, to investigate. A further potential source of food at the site is waste left by construction workers which will also require management. Attractants for birds during construction may include grass seeding of any grassed areas though this may be managed by means of bird netting enclosures if necessary.

Although the above factors may be identified as potential bird attractants that will require attention during construction, all potential attractants cannot necessarily be identified readily. There may therefore be some benefit in those responsible for construction monitoring the site to check for congregations of birds and, if necessary, taking steps to manage them.

In order to address these sorts of issues, a programme for management of bird attraction during construction is recommended, including the following:

1. Site demolition and excavation activities to be managed to avoid accumulation of standing water (e.g. pooling in the event of rain or due to the use of water on site).
2. Where water accumulation is unavoidable, use of alternative measures to prevent congregation of birds (e.g. use of netting).
3. Attention to be paid to the management of any wastes that might provide food and hence attract birds, for example by identification of a disposal route for potential food sources that is not open to birds, regular disposal from site of accumulations of waste and netting of any temporary waste accumulations to prevent direct access by birds.
4. Monitoring of the site to determine whether any activities lead to the congregation of birds and, if appropriate, liaison with bird control staff at the airport to advise of any potential problems.
5. Management of any activities during construction that may provide food for birds (e.g. netting during seeding of any grassed areas).

It should be noted that the airport operators undertake bird strike hazard management activities as a matter of routine and liaison with those at the airport responsible for bird hazard management should form a part of any future construction phase bird hazard management programme that might be adopted. It should be emphasised, however, that the developer should be solely responsible for bird hazard management at the site.

It is generally recommended that the design of buildings near airports should avoid features that would be expected to attract birds, for example water features. Attention should be made to slopes and drainage of open surfaces that might otherwise lead to water accumulation. During the life of the development, an appropriate level of attention should be given to waste management in order to avoid food attraction.

In accordance with CAA guidance, it has been noted that wherever possible buildings in close proximity to the aerodrome should incorporate the following measures to minimise their attractiveness to birds:

- Prevention of access to the building, including the roof space.
- Self-closing doors to prevent access by birds or openings should have plastic strip curtains fitted.
- Waste disposal containers should be self-closing to prevent access for birds.
- Food outlets and cafes should not have open litter bins or any areas where waste food is available for birds.
- Steeply pitched roofs to deter breeding gulls.
- Roof overhangs kept to a minimum.
- Ledges beneath overhangs and external protrusions should be avoided."

3.5 FOD

Foreign Object Debris (FOD) arising from construction activities is of potential concern to airport operations, given the proximity of the site to the airport runway. Given the location of the development site in relation to the runway and the anticipated nature of site activities, loose material at the site that might be wind-blown or otherwise dispersed from the site on to the runway would appear to be of more potential concern.

These issues have not been considered in any specific detail as part of the aeronautical study but it is recommended that methods of work that are subsequently adopted during construction include measures to control FOD. Measures by which this hazard might be minimised would include on-site house-keeping activities to keep potential sources of FOD to a minimum and fencing to limit the mobility of any loose material on site that cannot be avoided. This requirement is considered further below in Appendix 3.

3.6 USE OF CRANES DURING CONSTRUCTION

Since the proposal is for development above the height of the Inner Horizontal Surface, the use of cranes to supply materials to the upper levels of the development during construction will inevitably require penetration of that surface. No specific crane plan has been identified at this stage of the development proposal but some general comments on the use of cranes during construction may be made.

Where saddle jib tower cranes are employed, experience from previous projects indicates that crane heights can generally be limited to about 10 m above finished building level. Where multiple cranes are in use, the requirement for independent operation may lead to greater heights above finished building level being required. In general, it is often possible to operate with lower crane heights during the earlier stages of construction and work at the maximum height for a limited period only during the final stages of construction. The operational considerations presented earlier in relation to the development itself will apply in respect of the use of cranes: operations are constrained by the presence of the Rock at a substantially greater height than cranes of the height required. No increases in the identified obstacle clearance altitudes would be required to accommodate construction cranes.

Given the distance of the site from the runway, there can generally be expected to be an adequate lateral margin with respect to tall obstacles at it to ensure aircraft safety. Where a saddle jib crane is oriented with the jib facing North towards the runway, the lateral margins may be eroded to some extent. Taking account of the margins available and having regard to the operational considerations presented earlier in the safeguarding assessment of the building itself, this erosion in margins is expected not to have a material impact on the safety of operations at Gibraltar Airport. However, as a precaution, it may be prudent to avoid jib orientations that erode the lateral clearance margins at times when runway operations are taking place. It is understood that these operational practices have been adopted previously and it is recommended that Ocean Village liaise with RAF Gibraltar in order to establish requirements for crane management, as appropriate. Ocean Village is referred to written guidance[4,5,6] that is available to construction companies in relation to the management of cranes near airports.

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[4] CAP 1096 Guidance to crane operators on aviation lighting and notification, UK Civil Aviation Authority, August 2013
http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=5705

[5] Technical Information Note (TIN) 039 Operating Tower Cranes in the Vicinity of Aerodromes, Notification and En-route Obstacle Lighting, Construction Plant-hire Association, January 2014

http://www.cpa.uk.net/assets/js/tinymce/plugins/moxiemanager/data/files/Downloads/TCIG%20-%20Publications/TCIG%20TINS/CPA-TCIG-TIN-039-Issue-C-140108.PDF

[6] Advice Note 4: Cranes and Other Construction Issues, UK Civil Aviation Authority, Airport Operators Association and General Aviation Awareness Council, January 2013
http://www.gaac.org.uk/news/caa-aoa-gaac-advice%20note%204-jan03.PDF

Appendices

Appendix 1 Building Height Profiles

Table A1.1: Ocean Spa Plaza building profile

Building Element	Distance from centreline (m)	Height[3] (m above Alicante Datum)
Car parking levels[1]	383.20	27
Residential 10th floor balcony[1]	398.16	50.96
Roof level parapet[1]	400.60	53.085
Roof level stair core[1]	415.11	54.99
Roof level stair core – South[2]	427.25	54.99
Roof level parapet – South[2]	441.76	53.085
Residential 10th floor balcony – South[2]	444.20	50.96
Car parking levels[2]	461.81	27

1 Distance data provided by Morgan Carn
2 Distance data estimated on the basis of scaled measurements from the available plans and by reference to Google Earth
3 Height data provided by Morgan Carn

Table A1.2: Buildings to the East of Ocean Spa Plaza

Building Element	Distance from centreline (m)	Height[3] (m above Alicante Datum)
Referendum House East - north side[2]	366.38	56.18
Referendum House East - south side[2]	386.56	56.18
Referendum House West - north side[2]	373.61	55.6
Referendum House West - south side[2]	393.68	55.6
Constitution House - north corner[1]	409.80	56.58
Constitution House - south corner[2]	454.94	56.58

1 Distance data provided by Morgan Carn
2 Distance data estimated by reference to Google Earth
3 Height data provided by Morgan Carn

Table A1.3: Buildings to the West of Ocean Spa Plaza

Building Element	Distance from centreline (m)	Height[3] (m above Alicante Datum)
Trade winds – north side[1]	366.38	55.2
Trade winds – south side[2]	386.56	55.2
Trade winds stair – north side[1]	373.61	56.48
Trade winds stair – south side[2]	393.68	56.48
Royal Ocean Plaza – north side[1]	409.80	57.08
Royal Ocean Plaza south side of top level[2]	454.94	57.08
Royal Ocean Plaza – lower step down[2]		29.54

1 Distance data provided by Morgan Carn
2 Distance data estimated by reference to Google Earth
3 Height data provided by Morgan Carn except for lower step down levels of Royal Ocean Plaza

Appendix 2 Reflective Glare Assessment

A1.1: Outline Assessment Approach

Whilst reflective glare arising from sunlight reflection from building surfaces is a potential hazard to aircraft operations, the extent of any practical impacts may be limited by a number of factors, according to the details of individual circumstances. In the first instance, reflections will generally be subject to a number of geometrical constraints in respect of the alignment of the sun, the reflective surface and the areas potentially sensitive to the reflective glare hazard, together with possible additional constraints arising from shadowing by terrain or existing buildings. Second, the reflected light will generally be subject to some degree of attenuation compared with the source, due to a number of different factors, for example including the relative fractions of light transmitted and reflected from a surface, the limited size of the reflective surfaces concerned, as compared with the source, and light scattering on passage through the atmosphere when the sun is relatively low in the sky which, due to geometrical constraints, are the only times when the required geometries for glare impacts to arise will occur. The location of the potential glare source within the primary field of view is a further relevant consideration, with sources located to the side of an observer's target of interest being of lesser concern. As a result, according to the details of individual cases, real impacts on airport operations may not arise at all and if they do occur they may be relatively minor.

The assessment approach adopted here is first to determine whether or not any reflective glare impacts on aeronautical targets may occur at all, based on the identified geometrical constraints on the possible pathways for sunlight. In the event that potential pathways from the sun to aeronautical targets are identified, consideration is next given to possible shadowing effects that may block the identified potential reflection pathways. Where pathways are found to remain, further consideration is given to the likely scale and intensity of the associated glare impacts, having regard to attenuating factors.

Three primary aeronautical targets at potential risk from reflective glare are identified, as follows:

- The Air Traffic Control facility;
- Aircraft on approach to Runway 09;
- Aircraft on approach to Runway 27.

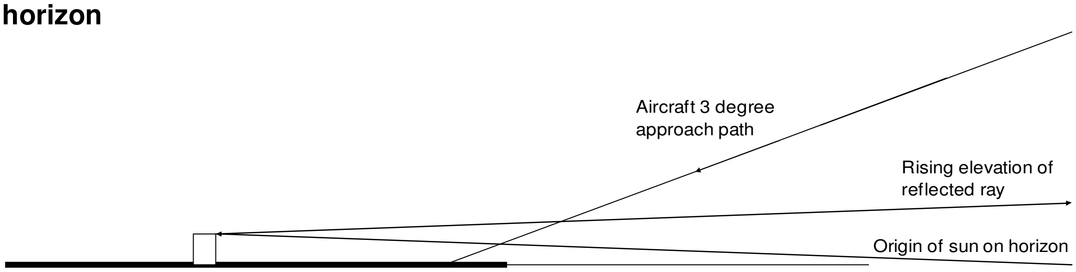
Consideration of the materials to be employed in the buildings indicates that the only surfaces that may give rise to potentially significant reflections are the glass windows that form a part of the building elevations. It is understood that walls and roofs will not be formed with smooth surfaces that would reflect incident light in any single direction but will absorb some light and scatter what light is reflected across a range of angles, thereby avoiding glare in any specific direction. Other surfaces identified as part of the review of drawings are the barriers at the perimeter of the balconies. Whilst it is not expected that these would necessarily add significantly to reflective glare impacts if they were to be made of reflective materials, it is recommended that this should be avoided if possible.

The assessment starts with an analysis of the geometrical constraints on reflection paths of sunlight. In the first instance, consideration is given to the constraints associated with the azimuth of the sun (the position of the sun relative to true North) and the range of azimuth angles between sunrise and sunset across the limits that occur between mid-winter and mid-summer. In some cases, it is possible to demonstrate that there were no pathways of reflected light from building elevations to the identified aeronautical targets for any azimuth angles of the sun that occur at any time of year.

Where reflections could not be excluded by means of consideration of azimuth constraints alone, constraints associated with the elevation of the sun, the height of the reflective building surface and the aeronautical targets were next considered. There are a number of constraints associated with the limited height of the building elevations and the height of the aeronautical targets that generally mean that potential reflective glare impacts on runway operations and the ATC facility can occur only when the sun is relatively low in the sky. Many potential impacts associated with some elevations that could not be excluded on the basis of azimuth constraints alone can be shown on the basis of the combined constraints associated with the azimuth and the elevation of the incident sunlight not to give rise to any potential reflective glare impacts.

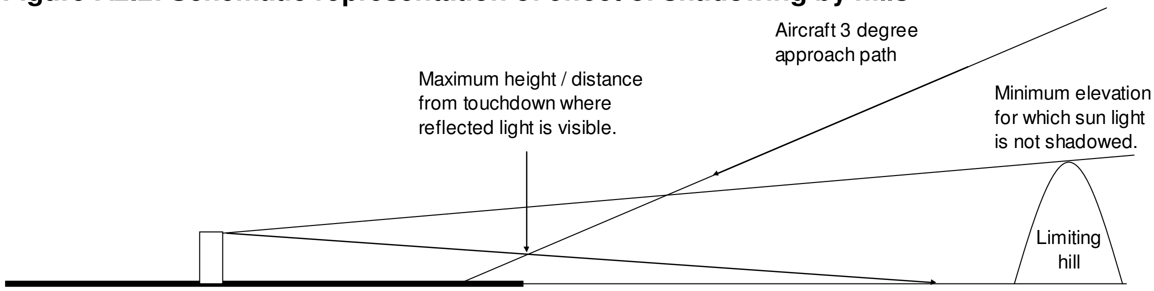
For reflection from a vertical surface, the elevation of the reflected light at any distance from the building is limited by the height of the building, according to the elevation angle of the sun. The maximum elevation angle of the beam rising towards the aeronautical target will occur with the sun at its lowest point on the horizon, as shown schematically in Figure A2.1. An aircraft on a 3° approach path will initially be above the region potentially affected by the reflected ray and descend into that area. By reference to the radius of the earth, *r*, the angle of elevation, θ, of the line of sight to the horizon as viewed from the top of a building of height, *h*, is given by the following expression: $\theta = \mathrm{acos}\,\{ r / (h + r) \}$. For a building that is 54.99 m AMSL, the value of θ is determined to be 0.238°. This limiting angle would apply over an obstacle free surface at sea level but, in practice, the presence of existing buildings in the vicinity of the development site is likely to impede light along this limiting pathway.

Figure A2.1: Schematic representation of maximum elevation of rays from sun on the horizon



The maximum elevation of the sunlight illustrated in Figure A2.1 will occur where the sun rises or sets over the sea. This will apply for sunrise in the case of the assessment of Gibraltar Airport. In practice, the angles of elevation of sunlight may be further constrained in the case of sunset at Gibraltar by shadowing by the hills West of Algeciras, as shown schematically in Figure A2.2. Shadowing elevation angles determined on the basis of available topographical data are summarised in Table A2.1.

Figure A2.2: Schematic representation of effect of shadowing by hills



Whilst Figures A2.1 and A2.2 are drawn so as to illustrate the height constraints that apply in respect of aircraft on approach, similar principles apply in respect of the ATC Tower which is of relatively limited height. The angle of elevation of the incident light will determine how far the reflected light travels after being reflected at the building surface, whether or not it will travel as far as the ATC Tower and, if it does, if it will impinge on the tower at a height where it will be visible to an observer.

The position of the sun at any time of day throughout the year at Gibraltar was determined by reference to the solar calculator tool[7] available from the U.S. Department of Commerce National Oceanic & Atmospheric Administration. In the first instance, the geometrical constraints assessment considered the limiting azimuths of sunrise and sunset in mid-winter of between 119° and 241° and in mid-summer of between 60° and 300° to determine whether reflections could be excluded on the basis that there were no periods in the year when the correct azimuth for a potential alignment could occur, irrespective of the additional constraints associated with the angle of elevation and the associated height of the reflected beam.

[7] http://www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html

Table A2.1: Angles of Elevation Constrained by the Hills West of Algeciras

Azimuth	Height[1] (m)	Distance (m)	Corrected[1] height (m)	Zenith	Azimuth	Height (m)	Distance (m)	Corrected height (m)	Zenith
241	384	16,772	361.9	1.236	271	510	16,520	488.6	1.694
242	486	16,821	463.8	1.579	272	502	16,541	480.5	1.664
243	610	16,958	587.4	1.984	273	521	17,753	496.3	1.601
244	650	16,726	628.0	2.150	274	509	19,269	479.9	1.427
245	670	16,542	648.5	2.245	275	592	23,212	549.7	1.357
246	705	16,411	683.9	2.386	276	651	23,017	609.4	1.517
247	750	16,431	728.8	2.540	277	655	22,802	614.2	1.543
248	750	16,451	728.8	2.536	278	735	23,119	693.1	1.717
249	722	16,539	700.5	2.425	279	654	22,844	613.0	1.537
250	712	16,736	690.0	2.361	280	553	21,885	515.4	1.349
251	711	16,830	688.8	2.344	281	537	24,029	491.7	1.172
252	718	17,008	695.3	2.341	282	481	21,312	445.4	1.197
253	729	17,148	705.9	2.357	283	481	22,141	442.5	1.145
254	784	17,894	758.9	2.428	284	455	21,898	417.4	1.092
255	743	17,443	719.1	2.361	285	423	28,153	360.8	0.734
256	745	17,603	720.7	2.344	286	487	25,362	436.5	0.986
257	764	17,727	739.3	2.388	287	489	25,250	439.0	0.996
258	758	17,762	733.2	2.364	288	410	24,602	362.5	0.844
259	699	18,039	673.5	2.138	289	394	23,988	348.8	0.833
260	640	18,407	613.4	1.909	290	343	23,471	299.8	0.732
261	557	18,563	530.0	1.635	291	424	29,773	354.4	0.682
262	485	16,791	462.9	1.579	292	545	29,555	476.4	0.924
263	481	16,767	458.9	1.568	293	554	29,422	486.1	0.946
264	509	16,545	487.5	1.688	294	617	29,179	550.2	1.080
265	495	16,825	472.8	1.610	295	548	29,698	478.8	0.924
266	508	17,092	485.1	1.626	296	587	29,566	518.4	1.004
267	524	17,223	500.7	1.665	297	556	29,800	486.3	0.935
268	535	17,505	511.0	1.672	298	464	28,577	399.9	0.802
269	555	16,804	532.8	1.816	299	363	27,294	304.5	0.639
270	517	16,581	495.4	1.711	300	335	26,880	278.3	0.593

Note 1: the height is that at the location concerned whilst the corrected height takes account of the curvature of the Earth.

A2.2: Geometrical Analysis

For the elliptical tower, presenting a multi-faceted structure with surfaces facing in a wide range of directions, consideration needs to be given to possible reflections from the rising sun in the East and the setting sun in the West to each of the identified aeronautical targets. For the lower part of the building, the elevations of potential interest will be dependent upon the aeronautical target concerned. Potential reflection pathways to the three aeronautical targets are considered in turn.

In the absence of a detailed specification for the multi-faceted elliptical tower, in terms of the precise locations of the various sections facing in different directions, it has not been feasible to provide a detailed geometrical analysis of all reflection scenarios, defining all incident and reflected azimuth angles. Instead, recognising that the multiple directions in which different windows will face will inevitably lead to the required azimuth conditions being met in some instances, it has simply been assumed in most cases that geometrical constraints associated with the azimuth angle cannot be relied upon to prevent reflections. The geometrical analysis has therefore focused more on other factors limiting the impacts, in particular shadowing by existing buildings and terrain.

A2.2.1: Runway 09 Approach Path

Direct lines of sight from the Runway 09 approach path to the Ocean Spa Plaza building will be largely shadowed by the taller Tradewinds 3 and Royal Ocean Plaza buildings, located slightly to the West and this shadowing, together with the elevation constraints illustrated in Figures A2.1 and A2.2, will be the primary limitations on reflective glare impacts on the Runway 09 approach. Consideration is given in turn to reflections of light from the rising sun and light from the setting sun.

Sunrise reflections

In the earlier stages of the approach, an aircraft at the VDP and undertaking the subsequent turn along a 3° glide path will be at a sufficient height for the top of the elliptical tower to be visible above the Tradewinds 3 and Royal Ocean Plaza buildings. However, the constraints on the reflected beam illustrated in Figure A2.1 will apply in respect of reflections of light from the rising sun in the East and no reflections across the approach path at aircraft height will be possible.

For the maximum angle of elevation of the sun on the horizon over the sea reflected from the top of the 54.99 m building, the maximum distance from threshold at which the beam will coincide with an aircraft on a 3° glide path is determined to be about 800 m, according to the precise location of the window on the elliptical building concerned. At this point along the flight path, direct lines of sight from the Runway 09 approach path will be completely blocked by the taller Tradewinds 3 and Royal Ocean Plaza buildings and no reflections to aircraft on approach will be possible.

Direct lines of sight to the Ocean Spa Plaza building will continue to be blocked along the flight path by the taller Tradewinds 3 and Royal Ocean Plaza buildings until aircraft reach the threshold, at which point the northern facing part of the Ocean Spa Plaza building would potentially start to become visible to the left of the Tradewinds 3 and Royal Ocean Plaza buildings.

By the time aircraft have reached the threshold they will have dropped below the height of the Tradewinds 1 and Tradewinds 2 buildings and direct lines of sight to much of the Ocean Spa Plaza northern elevation will be blocked by these buildings. Taking account of the relative heights and locations of these buildings it appears that reflection to aircraft at threshold from the top of the elliptical tower, above these lower buildings, may be possible.

There will be shadowing of incident light from the rising sun in the East by Referendum House and Constitution House and this will prevent reflections at larger sun azimuth angles. Taking account of this shadowing, the maximum sun azimuth for which light from the rising sun will be able to impinge on the north-easterly facing panels of the Ocean Spa Plaza is estimated to be slightly less than 79°. The identified sun azimuth limits indicate that there may be reflections to the approach path at aircraft height at and slightly after the Runway 09 threshold between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice and to panels towards the top of the building, due to shadowing of lines of sight by the Tradewinds 1 and Tradewinds 2 buildings.

It may be noted that direct lines of sight from the Runway 09 approach path to the lower section of the building, at a maximum height of 25 m above ground floor level, will be shadowed throughout by the taller Tradewinds 1, Tradewinds 2, Tradewinds 3 and Royal Ocean Plaza buildings. Accordingly, there can be no reflections from this part of the building to the Runway 09 approach.

Sunset reflections

Similar basic constraints related to the elevation angle of the reflected beam and shadowing of lines of sight by the taller Tradewinds 3 and Royal Ocean Plaza buildings to those identified for reflections at sunrise considered earlier will apply in this case. Direct lines of sight will become available as aircraft reach the threshold. However, these direct lines of sight will be limited to parts of the building that are facing in a predominantly northerly direction. For reflection of the sun in the West back towards an aircraft approaching from the West, the reflective surfaces need to be facing in a predominantly westerly direction. The more westerly facing elements of the building will still be shadowed by the taller Tradewinds 3 and Royal Ocean Plaza buildings when aircraft are at the Runway 09 threshold. Under these circumstances, there can be no reflections of light from the setting sun to aircraft at the threshold.

As in the case of reflections at sunrise, direct lines of sight from the Runway 09 approach path to the lower section of the building, at a maximum height of 25 m above ground floor level, will be shadowed throughout by the taller Tradewinds 1, Tradewinds 2, Tradewinds 3 and Royal Ocean Plaza buildings. Accordingly, there can be no reflections from this part of the building to the Runway 09 approach at sunset.

A2.2.2: Runway 27 Approach Path

Direct lines of sight from the Runway 27 approach path to the Ocean Spa Plaza building will be largely shadowed by the taller Referendum House and Constitution House, located slightly to the East. As in the case of the Runway 09 approach path analysis, this shadowing, together with the elevation constraints illustrated in Figures A2.1 and A2.2, will be the primary limitations on reflective glare impacts on the Runway 27 approach. Consideration is given in turn to reflections of light from the rising sun and light from the setting sun.

Sunrise reflections

In the earlier stages of the approach, the constraints on the reflected beam illustrated in Figure A2.1 will apply and no reflections across the approach path at aircraft height will be possible. This constraint will continue to apply until aircraft are approximately 850 m from threshold.

Whilst there will be some shadowing of direct lines of sight to the Ocean Spa Plaza by the taller Referendum House and Constitution House, by that point, an increasing fraction of the Ocean Spa Plaza building will become visible from an aircraft on a runway-aligned approach path to the North of these buildings, to the right as viewed from the aircraft. At the point where the elevation constraint identified above no longer applies, the available direct lines of sight from the Runway 27 approach path will be to parts of the building that are facing in a predominantly northerly direction only. For reflection of the sun in the East back towards an aircraft approaching from the East, the reflective surfaces need to be facing in a predominantly easterly direction. No reflective glare impacts are possible under these circumstances. As aircraft approach the threshold, more easterly facing parts of the building will start to be visible from the approach path. However, reflections across the approach path along these lines to the North of these two existing buildings will be significantly constrained by shadowing of incident light by the Rock and by those buildings. That is to say, sunlight with the azimuth required for reflection to the approach path will be not be able to impinge on the more easterly facing parts of the building, due to interruption of the required pathway by the Rock and Referendum House and Constitution House.

Overall, it can therefore be concluded that there will be no reflective glare impacts on the Runway 27 approach associated with reflection of light from the rising sun in the East.

For the lower part of the building, at a maximum height of 25 m above ground floor level, there would be the potential for reflections to the Runway 27 approach path at sunrise from the Eastern elevations. However, for the sun azimuth angles required for reflection to the approach path, the pathway of incident light to the East elevation will be blocked by the Rock and Referendum and Constitution House.

Sunset reflections

This scenario involves potential reflection from parts of the building facing in a predominantly northerly direction. Shadowing by the taller Tradewinds 3 building located to the North-west of the Ocean Spa Plaza will prevent light from the setting sun impinging on the building for sun azimuth angles of less than about 290°. Reflections of light from the setting sun towards the Runway 27 approach path will be possible at greater sun azimuth angles only, up to the maximum azimuth angle of the setting sun in mid-summer of 300°.

In accordance with the data presented in Table A2.1, the angle of elevation of light from the setting sun across that azimuth range will be constrained to a value of around 0.593° or more, due to terrain to the North and West of Algeciras. For that angle, the constraint illustrated in Figure A2.2 is found to prevent any reflections at aircraft height until a distance of around 400 m before threshold. After that point, reflections to the approach path at aircraft height from the top part of the building from sunlight across the azimuth range of 290° to 300° is identified as a possibility. The possibility of reflections reaching aircraft prior to touchdown will be limited to relatively shallow elevations angles, of around 4° or less. For the identified sun azimuth range, the time periods over which this possibility will exist is estimated to be from about mid-May to the end of July. Reflections will be limited to sunset, at about 20:55 on those dates and 21:30 at the summer solstice.

For the lower part of the building, at a maximum height of 25 m above ground floor level, there would be the potential for reflections to the Runway 27 approach path at sunset from the North elevation. However, for the sun azimuth angles required for reflection to the approach path, the pathway of incident light to the North elevation will be blocked by the Tradewinds buildings and the Royal Ocean Plaza.

A2.2.3: Air Traffic Control Tower

Sunrise reflections

The primary constraint on reflections to the ATC Tower will be the sun azimuth constraint associated with shadowing by Referendum House and Constitution House identified earlier in respect of Runway 09 approach. As identified earlier, the maximum sun azimuth for which light from the rising sun will be able to impinge on the north-easterly facing panels of the Ocean Spa Plaza is estimated to be slightly less than 79°. The identified sun azimuth limits indicate that there may be reflections to the ATC Tower between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice.

There are potential direct lines of sight from the ATC Tower to the North and East elevations of the lower part of the building. However, for the East elevation, the required azimuth is in the south-east quadrant for which incident light at the required elevation angle would be blocked by the Rock. For the North elevation, the required azimuth angle is below the minimum azimuth angle of the sun in summer. It may therefore be concluded that there is no possibility of reflection of light from the rising sun to the ATC Tower.

Sunset reflections

The primary constraint on reflections to the ATC Tower will be the sun azimuth constraint associated with shadowing by Tradewinds 3 and Royal Ocean Plaza buildings identified earlier in respect of Runway 27 approach. As identified earlier, the minimum sun azimuth for which light from the rising sun will be able to impinge on the north-easterly facing panels of the Ocean Spa Plaza is estimated to be about 290°. The identified sun azimuth limits indicate that there may be reflections to the ATC Tower between mid-May and end of July. Reflections will be limited to sunset, at about 20:55 on those dates and 21:00 at the summer solstice.

For the lower part of the building, at a maximum height of 25 m above ground floor level, there is no potential for reflections to the ATC Tower at sunset. There are direct lines of sight from the ATC Tower to the North and East elevations. Light from the setting sun cannot impinge on the East elevation which faces in the opposite direction. For the North elevation, the required azimuth angle is above the maximum azimuth angle of the sun in summer. In any event, the pathway of incident light to the North elevation at this height will be blocked by the Tradewinds buildings and the Royal Ocean Plaza. It may therefore be concluded that there is no possibility of reflection of light from the rising sun to the ATC Tower.

A2.2.4: Summary of Geometrical Analysis Findings

There are no scenarios for reflections from the lower part of the building to any of the three aeronautical targets, due to a combination of sun azimuth-related constraints and shadowing by other buildings and terrain. Reflections from the taller, elliptical element of the building are also constrained due to shadowing by other buildings and terrain. However, four cases of potential reflection from this part of the building are identified as follows:

- ***Runway 09 approach at sunrise.*** There is a possibility of reflection of light from the rising sun to the Runway 09 approach from north-facing elements of the elliptical tower. Due to a combination of constraints, in particular shadowing by Referendum House and Constitution House, these reflections will be limited to sun azimuth angles of less than 79°. This sun azimuth range constraint restricts reflections to the Runway 09 approach path at aircraft height at and slightly after the Runway 09 threshold between 12 April and 31 August. Reflections will be limited to sunrise, at about 07:55 on those dates and 07:05 at the summer solstice and to panels towards the top of the building, due to shadowing of lines of sight by the Tradewinds 1 and Tradewinds 2 buildings.
- ***Runway 27 approach at sunset.*** There is a possibility of reflection of light from the setting sun to the Runway 27 approach from north-facing elements of the elliptical tower. Due to elevation angle-related constraints, these potential reflections cannot arise until a distance of around 400 m before threshold. After that point, reflections to the approach path at aircraft height from the top part of the building from sunlight across the azimuth range of 290° to 300° is identified as a possibility. For the identified sun azimuth range, the time periods over which this possibility will exist is estimated to be from about mid-May to the end of July. Reflections will be limited to sunset, at 20:55 on those dates and 21:30 at the summer solstice.

- ***ATC Tower at sunrise.*** Reflection of light from the rising sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 09 approach at sunrise. Reflections are identified as a possibility between 12 April and 31 August. Reflections will be limited to sunrise, at 07:54 on those dates and 07:05 at the summer solstice.
- ***ATC Tower at sunset.*** Reflection of light from the setting sun to the ATC Tower from north-facing elements of the elliptical tower is identified as a possibility. These reflections will be subject to the same shadowing constraints identified earlier for reflection to the Runway 27 approach at sunset. Reflections are identified as a possibility between about mid-May to the end of July. Reflections will be limited to sunset, at 20:55 on those dates and 21:30 at the summer solstice.

A number of factors can immediately be identified that will limit the amount of light that can be reflected in the cases where potential glare impacts may occur. The factors providing attenuation of the reflected light are considered in further detail in Section A1.3.

A2.3: Light Attenuation Analysis

A2.3.1: Reflective Surface Area

Due to the elliptical shape of the building, the surface area available for reflection in any given direction at any given time will be quite limited. The width of an individual panel is estimated to be 1.1 m, based on scaled measurements made from the available elevation drawings. The height of the visible element of each window is estimated to be 1.33 m in a total height of 2.81 m for a residential floor, with most of the remainder being the balcony. Windows therefore represent about 47% of the area of the residential floors of the elliptical tower.

When assessing the scale of the glazed areas of the building, it is instructive to reference them in common terms with respect to the sun. The diameter of the sun is 1,392,000 km and its distance from the Earth is 149,578,870 km. As viewed from Earth the angular distance from one side of the sun to the other is determined on that basis to be 0.533 degrees. The area covered by the sun from the perspective of an observer on Earth can be expressed in terms of its angular dimension and is found to be 6.8×10^{-5} radians^2 (steradians).

The size of glazed areas of the elevations of the Ocean Spa Plaza development can be expressed in similar terms and will vary according to the distance of the observer. The obliqueness of any angle of view to the elevation is also a relevant consideration determining the angular width.

For an observer in the ATC Tower, at a distance of about 670 m from the Ocean Spa Plaza building, the window width of 1.1 m is equivalent to about 0.095°, about 18% of the angular width of the sun. Given that 47% of the area is window, the amount of reflected light is attenuated to 8.5% of the incident light from the whole surface area of the sun, equivalent to attenuation by a factor of 12. Similar considerations apply in respect of approach operations for which the distances will typically be greater and the effective areas smaller.

A2.3.2: Glass Reflectance

At lower angles of incidence, reflectance from a glass surface is low and transmittance is high. For a standard glass surface and angles of incidence less than 30° the reflectance is typically about 6%, taking account of the reflection that occurs at both the inner and outer glass surfaces. Above 30° the reflectance starts to increase gradually and subsequently increases progressively to reach 1 as the angle of incidence approaches 90°. It may be noted that the above values apply to a single glazing panel and that slightly higher values of reflectance may apply to double glazed panels, according to their transmittance and thickness. Based on theoretical considerations and the specifications identified during previous similar assessments, a minimum reflectance at lower angles of incidence of 10% has been assumed. This value is expected to apply in the case of reflections to the ATC Tower.

For reflections to the Runway 09 approach and Runway 27 approach, light will be incident at a shallow angle with respect to the glass surface: i.e. at a high angle of incidence. At these angles of incidence, a significant fraction of the incident light can be expected to be reflected. No attenuation has been assumed in these cases.

A2.3.3: Atmospheric Path Length Effects

For lower angles of elevation of the sun, the pathway of light through the atmosphere is greater than at higher elevation angles. The length of this pathway determines the extent to which the intensity of light reaching the surface of the Earth is attenuated, primarily through light scattering. The level of attenuation may be estimated for any location using the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) model. For the lower elevation angles of a few degrees only that are of relevance to the geometrical assessment, attenuation by more than a factor of 100 compared with mid-day intensity is estimated using the ASHRAE model.

A2.4: Overall Glare Impacts Assessment

For reflections to the ATC Tower a number of attenuation factors will apply as follows:

- The glass surface reflectance for this scenario is estimated to be around 10%, giving an attenuation compared with that of the incident light of around a factor of 10.
- An estimated attenuation factor of about 12 will apply in respect of the limited glazed surface area available.
- Impacts will occur at sunset only when atmospheric path length effects will provide attenuation by an estimated factor of around 100 to 1,000 compared with the intensity of the midday sun.

Taking each of these factors together, the overall attenuation of the reflected light intensity compared with that of the mid-day sun is estimated to be in the region of 12,000 or more.

To put those attenuation factors into perspective it may be noted that the sun has luminance of about 1.6×10^9 cd/m^2 at noon whereas the sky has luminance of up to 30,000 cd/m^2. The first figure may be considered to be a very high brightness that is likely to cause adverse reflective glare impacts whereas the second figure may be considered a low brightness that would not cause adverse impacts. The mid-point between the two is 6.9×10^6 cd/m^2, a factor of 230 lower than the brightness of the sun and a factor of 230 greater than the brightness of the sky. For this scenario, the reflected intensity is estimated to be between around 10 times greater than the above value for the luminance of the sky. The brightness of the reflected light will therefore be very much closer to the lower reference than the higher one.

Another potentially useful reference point is the observation that a factor of 1,000 attenuation is considered to be sufficient to allow safe continuous observation of the sun. The estimated attenuation factor of around 12,000 exceeds this identified minimum requirement.

On that basis, it is concluded that any reflections to the ATC Tower will be below the intensity at which they would cause any significant glare impacts.

For reflections to the Runway 09 and Runway 27 approaches, no attenuation associated with the glass reflectance has been assumed. In this case attenuation by a factor of 1,200 or more is estimated. For these scenarios, any impacts will be minimised by their transient nature and the angle of view to the Ocean Spa Plaza building which will be well to the side of the main focus of view along the runway axis.

Appendix 3 Recommendations for the management of Foreign Object Debris (FOD)

Management practices for use during construction activities

1. Use of covered skips, or other types of material containers, to prevent wastes or other loose materials being blown off site.
2. Site fencing design to minimise likelihood of FOD being blown off site.
3. Use of covered vehicles for the transportation of loose materials, for example, fill or sand, where there is any possibility of spillage or of such material being blown onto the aircraft movement area.
4. Vehicle management, including for example routing of disposal activities to minimize risk of runway contamination, cleaning of potential contaminants from vehicle wheels on departure from site.
5. Inspection and cleaning of contaminants transported from site to Winston Churchill Avenue to limit transfer to runway.
6. Development of contingency measures to address spillages and other sources of runway contamination.
7. Scheduling of transport activities, if practicable, to allow runway cleaning if required without undue disruption to airport activities, taking account of the schedule for use of runway for take-off and landing.

Building design features and on-going management practices

1. On-going attention to the management of wastes to prevent FOD being blown off site.
2. General attention to site cleanliness and good housekeeping.