APPENDIX 1

AI BRIDGES RESPONSE TO AIRNAV IRELAND’S SUBMISSION

Response Statement

Response to the AirNav Ireland Observation on the Strategic Infrastructure Development Application

Case Reference PA03.03.318782 Oatfield Wind Farm within townlands of Co. Clare

1. AirNav Ireland

1.1 Observation Overview

1.1.1 This Response Statement relates to an observation received from AirNav Ireland regarding the proposed development at Oatfield Wind Farm. The observation was dated 24th January 2024 and was received by online submission and entitled "Observation on the Strategic Infrastructure Development Application submitted by AirNav Ireland (Re: Reference PA03.318782 Oatfield Wind Farm within townlands of Co. Clare)".

1.1.2 The online submission has been prepared by the Airspace and Navigation Management Team at AirNav Ireland.

1.1.3 AirNav Ireland state that the "Oatfield Wind Farm Aviation Review Statement" (hereafter called Aviation Review Statement) compiled by Ai Bridges Limited in December 2023, on behalf of the developer, has been reviewed.

1.1.4 AirNav Ireland states that the Oatfield Wind Farm Aviation Review Statement identifies two areas of concern that requires further analysis.

1.1.5 The areas of Instrument Flight Procedures and Radar Surveillance Systems Safeguarding are identified by AirNav Ireland as specific areas of concern.

1.1.6 In their concern regarding **Instrument Flight Procedures**, AirNav Ireland highlight the following from the Executive Summary contained within the Aviation Review Statement:

> *"A preliminary assessment of the Instrument Flight Procedures (IFP) for Shannon Airport indicates that two of the IFPs are potentially impacted. In addition, the ATC SMAC[1] surface is penetrated by some of the proposed turbines."*

AirNav Ireland also refers to the following statement from Table 12 within the Summary Section of the Oatfield Wind Farm Aviation Review Statement:

> *"To confirm the possible impact on the IFPs and ATCSMAC an IAA[2] approved Aviation Design Specialist would be engaged, to undertake a detailed IFP Assessment Mitigation measures to offset any potential concerns raised by the IAA in relation to the proposed turbines are outlined in Section 3 of this report."*

In their observation, AirNav Ireland comment that

> *"A certified Instrument Flight Procedures Designer will confirm these findings and may recommend mitigations. However, if these mitigations require*

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[1] Air Traffic Controller Surveillance Minimum Altitude Chart

[2] Irish Aviation Authority

significant amendments to the identified items above, these may not be acceptable to AirNav Ireland"

1.1.7 In their concern regarding **Radar Surveillance Systems Safeguarding**, AirNav Ireland refers to the following statement from Table 12 within the Summary Section of the Oatfield Wind Farm Aviation Review Statement

"Radar Surveillance Systems Safeguarding: "According to EUROCONTROL Guidelines, the MSSR at Shannon Airport will not be impacted. The MSSR at Woodcock Hill may need a confirmatory study to assess if potential impacts occur. The PSR at Shannon Airport is outside the 17km assessment range but within the instrumented range of the radar and in partial line of sight. A confirmatory assessment may be required by the IAA.

It should be noted that the radar systems (Thales RSM970 (MSSR) and Thales STAR 2000 (PSR)) used by the IAA at Woodcock Hill and Shannon Airport have sophisticated capabilities to process and handle impacts from wind turbines offering the best mitigation measure path."

1.1.8 In their observation, AirNav Ireland comment that

*''A deeper assessment of impacts is required and has **previously been completed for another developer**, on this site. This said, AirNav are not satisfied with previous reports received.*

*While the Ai Bridges Report references **other facilities that have applied mitigations**, these are not in our opinion Enroute (High-Level) Radar facilities, which in this case Woodcock Hill MSSR is. Significant impacts would be expected on high-level traffic, in the altitude range 10,000 feet to 35,000 feet, which would not be acceptable to AirNav Ireland''.*

1.1.9 AirNav Ireland conclude their observation by stating:

''On this basis and in view of the fact that this is the third occasion that this development has been proposed, AirNav objects to this development proceeding. Furthermore, on the two previous occasions we interacted with other developers on this site, this was also our position.

1.1.10 AirNav state that on the basis that this is the third occasion that a development has been proposed for this location, they object to the development proceeding.

1.1.11 The final comment by AirNav Ireland concludes that their position has not changed in relation to wind farm development at this site since their previous interactions with other developers.

1.2 Response

1.2.1 A consultation occurred in September 2023 between the Environmental and Planning Consultants, acting on behalf on the applicant, and the Airspace & Navigation Team at AirNav Ireland. This consultation record is included in the Oatfield Wind Farm Aviation Review Statement, submitted as part of the original planning application (see page 56 of **Appendix 11.2 of the EIAR**).

1.2.2 The areas of Instrument Flight Procedures and Radar Surveillance Systems Safeguarding are identified by AirNav Ireland as specific areas of concern. A response to both concerns is provided below. The concern in relation to Instrument Flight Procedures is dealt with in sections 1.2.3 to 1.2.11 below and the concern in relation to Radar Surveillance Systems Safeguarding is dealt with in sections 1.2.12 to 1.2.23.

1.2.3 As well as the specific concerns relating to Instrument Flight Procedures and Radar Surveillance Systems Safeguarding, AirNav have also referred to previous developments by other developers on the same site and that they are not satisfied with the previous technical assessments. AirNav also state that, that in their opinion, that the references (within the Aviation Review Statement prepared by Ai Bridges, **Appendix 11.2 of the EIAR**) to wind farm impact mitigation strategies implemented by Airport Authorities in the UK are not relevant. A response to each of these additional points in also included below under the additional headings:

- Instrument Flight Procedures (Impacts & Mitigation Options)
- Radar Surveillance Safeguarding Systems (Impacts & Mitigation Options)
- Previous Developments
- State Performance Based Navigation (PBN) Implementation Plan
- Other Facilities that have Applied Mitigations (UK Radar Facility Reference Sites)
- UK Aviation Plan – Wind Turbines and Aviation Radar (Mitigation Issues)

Instrument Flight Procedures:

(Impacts & Mitigation Options)

1.2.4 During the consultation in September 2023 and observation in January 2023 AirNav Ireland stated that all of the proposed 11 wind turbines would impact the Instrument Flight Procedures at Shannon Airport. They also stated that a detailed IFP Assessment from a certified IFP designer would be required to establish the impacts and to suggest possible mitigations.

1.2.5 In December 2023 Ai Bridges was commissioned by the Environmental and Planning Consultant to carry out a screening assessment of all of the aeronautical surfaces, ground based navigational aids, aviation facilities, surveillance equipment and communications infrastructure that could be possibly impacted by the proposed development.

1.2.6 Ai Bridges state in their Aviation Review Statement (see **Appendix 11.2 in EIAR Chapter 11,** submitted as part of the original planning application) that there was a total of 11 aeronautical surface\infrastructure areas that could potentially be impacted by the proposed development. The screening assessment carried out by Ai Bridges within the Aviation Review Statement showed that only 2 of the 11 aviation surfaces\areas would be potentially impacted - the Instrument Flight Procedures and the Radar Surveillance Equipment. The screening assessment of the Instrument Flight Procedures showed that there would not be an impact to all the procedures as stated by AirNav Ireland in their observation. It was also shown that not all of the proposed turbines would cause impacts to the procedures. The Aviation Review Statement includes a recommended mitigation path.

1.2.7 Following the screening assessment, Ai Bridges provided mitigation options and presented these in Section 3.2 of the Aviation Review Statement.

1.2.8 As part of the mitigation proposed, Ai Bridges recommended that a more detailed Technical Assessment be undertaken by Cyrrus Limited who are an IAA\AirNav certified IFP Designer. Ai Bridges then commissioned Cyrrus Limited to conduct a detailed IFP Safeguarding Assessment Report which is attached in Appendix 1.

1.2.9 The findings presented by Cyrrus (see Appendix 1 below) identifies that the Wind Farm will have an impact on some of the instrument flight procedures and the Air Traffic Control Surveillance Minimum Altitude Chart (ATCSMAC) for Shannon Airport. Cyrrus presented viable mitigation measures to remove the impact of the proposed development on the instrument flight procedures.

1.2.10 The mitigation options are presented in Section 3 of the Cyrrus IFP Safeguarding Assessment Report (Appendix 1 below). Cyrrus present a series of mitigation options for Shannon Airport to consider:

> *"Raise the applicable MOCA or PDG of the affected procedures, this option will be for the airport to consider.*
>
> *a. SIDS (TOMTO3A, DIGAN3A, ABAGU3A) RWY06, increase the obstacle clearance PDG from 3.3% to 3.9%*
>
> *b. ILS OR LOC RWY 06, impact to the ILS CAT I MACG, increase in Obstacle Clearance Altitude/Height (OCA/H) required, or redesign of ILS procedure to include OCA/H for a 2.5% MACG and 3.0% MACG.*
>
> *c. VOR RWY 24, Final Approach, increase MOCA from 1270ft to 1530ft, an additional Step- down fix (SDF) may be required to prevent an increase to the final approach gradient.*
>
> *d. ATCSMAC increase Sector 1 Minimum Vectoring Altitude (MVA) from 2300ft to 2600ft or redesign the ATCSMAC to reduce the size of Sector 1 but keep the remaining Sector 1 area at the existing 2300ft MVA."*

1.2.11 Based on previous correspondences in 2022 with the IAA for proposed wind farm developments that were considered for this same site, it was identified that there were mitigation options for the impacts to the currently published IFPs. The IAA stated that the proposed mitigation in relation to PDG increase of the affected procedures was consistent with non-SID departure instruction increased PDG:

> *"Increasing of PDG from 3.5% to 4.0% for affected SIDs: Agreed in principle and can be incorporated in updated IFP designs planned for late 2022. This is also consistent with non-SID departure instructions increased PDG" .*

1.2.12 Based on previous correspondences in 2022 with the IAA for proposed wind farm developments that were considered for this same site it was identified that there were mitigation options to solve the impacts for VOR Runway 24 Instrument Approach Procedure. The IAA stated that should the development have proceeded at that time that they would recommend the withdrawal of the VOR approach on the basis that it would be in line with the State PBN plan and that Required Navigation Performance (RNP) IAP's were planned for 2022.

> *"VOR RWY 24 IAP: Impact noted, and mitigations understood. These are not however consistent with our requirements for SDF etc. If the development goes ahead, I would recommend withdrawal of the VOR IAP on the basis that this would be in line with the State PBN plan and that RNP IAPs are planned for Shannon during 2022".*

1.2.13 The mitigation options identified by Cyrrus for the proposed Oatfield development are viable and implementable based on the consultations with IAA dating back to 2022.

1.2.14 Cyrrus also identified that there was an impact to the ATCSMAC for Shannon Airport. Ai Bridges then commissioned Cyrrus to produce a series of concept design options to mitigate the impact to the ATCSMAC against the proposed Oatfield development. Cyrrus produced a Concept Designs ATCSMAC Report (Appendix 10). Cyrrus present the following mitigation options that would limit the impacts to the ATCSMAC at Shannon Airport:

> *"Option A – Raise the Sector 1 Minimum Vectoring Altitude (MVA).*
> *Option B – Extend Sector 2 area to cater for the Wind Farms.*
> *Option C – Create a new Sector to address the Wind Farms.*
> *Option D – Create a new Sector and redesign with focus on ATC utility."*

1.2.15 The above mitigation options are available to mitigate the impacts to the ATCSMAC at Shannon. While Cyrrus state that the list of options is not exhaustive, the Minimum Vector Altitudes in each of the options would not change and any proposed design optimization would be to the Surveillance Minimum Altitude Area sector shape and size. Any further discussion around the selection of the optimum Design Option for the ATCSMAC for Shannon Airport will likely require engagement between Cyrrus with AirNav Ireland, The Irish Aviation Authority and Shannon Airport.

1.2.16 Comprehensive interaction with the Public Authorities would ensure that all concerns are addressed, that clear Guidance is provided, that proposed mitigation is acceptable and would further confirm that the detailed mitigation in the form of these Redesign Concepts would allow for safe and effective vectoring of aircraft at Shannon Airport.

The applicant would welcome the opportunity for a meeting to engage with AirNav Ireland, IAA and Shannon Airport as appropriate to provide a presentation on the Airspace Redesign Concepts and Mitigation Options and agree the Optimum mitigation to ensure safe and effective vectoring of aircraft at Shannon Airport.

Radar Surveillance Systems Safeguarding:

(Impacts & Mitigation Options)

1.2.17 AirNav Ireland stated during the September 2023 consultations that in their opinion, the proposed development would affect the operation of the Monopulse Secondary Surveillance Radar (MSSR) at Woodcock Hill. They have requested a detailed examination.

1.2.18 AirNav Ireland have noted one concern in their observation in relation to the potential impacts on En-route Surveillance Radar facility at Woodcock Hill. The role of this En-route Radar at Woodcock Hill is for surveillance and monitoring of transatlantic air traffic as it passes over Irish Airspace in the altitude range 10,000ft to 35,000ft.

1.2.19 In December 2023 Ai Bridges was commissioned by the Environmental and Planning Consultant to carry out a Radar Surveillance screening assessment for all of the radar equipment and sensors located in the vicinity of Shannon Airport and Woodcock Hill. Ai Bridges conducted a review of the effects of the proposed wind farm on the Radar Surveillance equipment. It was assessed against EUROCONTROL GUIDELINES. It was reported that there were no impacts on the Monopulse Secondary Surveillance Radar (MSSR) at Shannon Airport. The Primary Radar at Shannon Airport was assessed, and it was deemed to be outside the Radar Assessment Range as per the EUROCONTROL GUIDELINES. However, it was noted that the Primary Radar was still within instrumented range of the proposed wind turbines. Refer to the relevant Appendix in the EIAR (See Appendix 11.2 in Chapter 11 of the EIAR).

1.2.20 Ai Bridges carried out a desk-top assessment and identified that the proposed development was within the instrumented range of the Woodcock Hill Secondary Radar.

1.2.21 Based on the desktop assessment findings described above in Section 1.2.21 (and as presented in the Aviation Review Statement), Ai Bridges recommended that the Communications, Navigation & Surveillance Consultants at Cyrrus Limited carry out a detailed Mitigation Options Study of the possible impacts to the Primary Radar at Shannon Airport and the Secondary Radar at Woodcock Hill.

1.2.22 AirNav have highlighted a single specific concern relating to the potential impacts En-route Radar Facility at Woodcock Hill for the surveillance of transatlantic flights. This was addressed by Cyrrus in the Mitigation Options Study. This was also informed by the recent concerns highlighted by AirNav relating to other wind farm developments that are currently in the public planning process, and also in the vicinity of the proposed Oatfield development.

1.2.23 Cyrrus completed a detailed Mitigation Options Study as part of *the "deeper impact assessment"* requested by AirNav Ireland. This study considers all of the common issues relating to wind farm impacts on radars and includes a series of mitigation options. The Mitigations Options Study (Appendix 2) considered the Primary Radar facility at Shannon Airport. The Secondary Radar facilities at Shannon Airport and Woodcock Hill were also considered.

1.2.24 In this Mitigations Options Study, Cyrrus Limited have conducted a detailed technical assessment with detailed calculations and analysis. This has been carried out according to EUROCONTROL GUIDELINES and shows that there would be no radar shadowing effect caused by the proposed wind farm on the Woodcock Hill Monopulse Secondary Surveillance Radar and this causes no impacts to En-route facilities as stated by AirNav Ireland. These calculations can be found in Section 4.3 of the Mitigations Options Study.

1.2.25 This analysis shows that there will be no impact to Woodcock Hill Radar Surveillance of En-route aircraft at heights of 10,000 to 35,000ft as the shadow regions beyond the proposed turbines are considered sufficiently small to be operationally tolerable. Cyrrus draw reference to further field trials that have taken place in the UK to support this.

1.2.26 This point addressing the minimal shadow region impacts on En-route Radar facilities is supported by reference to the UK Civil Aviation Authority (CAA) CAP670 Air Traffic Services Safety Requirements documentation. This area has been addressed in Appendix 3 to SUR 13: Guidance on Wind Farm Mitigation Techniques (extract shown in Appendix 3). More specifically the section *"Part 3: Impact of Wind Turbine Interference Effects on Surveillance Performance Parameters"* addresses the shadowing and low-level coverage impacts caused by the physical obstruction of wind turbines

> *SUR13A.68 Trials have indicated that wind turbines also create a shadow beyond the wind farm so that low flying aircraft flying within this shadow go undetected. The magnified shadows of the turbine blades and the moving rotors are visible on the radar screens of weather and ATC radars. However recent trial measurements have indicated that the shadow region behind the wind turbines would last only a few hundred meters and would hide only very small objects.*

> *SUR13A.85 Existence of a shadow region means the radar's ability to detect targets directly behind the wind turbines can be affected. Since a shadow region is thought to exist only a few kilometers behind a wind farm and the size is believed to be defined by a straightforward geometric relationship between the radar and the wind turbine farm, only the low-level coverage is affected.*

1.2.27 Cyrrus Limited have also carried out a deeper impact assessment on the potential wind farm impacts on Primary Radar Surveillance equipment at Shannon Airport. This assessment has been informed by recent concerns raised by AirNav Ireland in relation to other wind farm developments that are currently in the planning process and also in the vicinity of the proposed Oatfield development. These concerns have been addressed in Section 5 of the Mitigations Options Study.

1.2.28 A series of Mitigation Options have been presented in Sections 7 and 8 of the Mitigations Study Report. Though not requested by AirNav Ireland, a due-diligence assessment of the Shannon Airport Primary Radar shows that a wind farm impact mitigation strategy can be provided, that includes a suite of optimization and upgrade packages.

1.2.29 Cyrrus conclude by stating that a conditions survey of the Primary Radar at Shannon Airport and the Secondary Radar at Woodcock Hill could be carried out by the manufacturer (Thales) to assess what type of mitigation upgrade and software updates, if any, are required. It is also stated that the Woodcock Hill Radar has the inbuilt capabilities to filter out and reduce wind turbine impacts should they be required.

1.2.30 The applicant would welcome the opportunity for a meeting to engage with AirNav Ireland to facilitate a discussion and exploration of the Woodcock Hill Radar mitigation measures resented in the Mitigations Option Study**.**

Previous Developments:

<u>Brookfield Renewable (Brookfield) – Oatfield Wind Farm:</u>

1.2.31 AirNav states that a deeper assessment of impacts was previously completed by another developer, on this site.

1.2.32 This is a reference to a proposed development on the same site by Brookfield Renewable (Brookfield) for 26 turbines which went through a pre-planning cycle.

1.2.33 The initial consultation with the IAA for this previous development was in 2008 regarding a meteorological mast. At that time the IAA stated that an objection would be raised against any future wind farm planned for the site.

1.2.34 Brookfield engaged with the IAA from 2016 – 2018 and a number of detailed technical assessments were carried out at the request of the IAA. Brookfield contracted Ospreys Consulting Services and Pager Power Limited to conduct specialist Instrument Flight Procedures and Radar Assessments respectively. In 2018 Brookfield also contracted the National Air Traffic Services (NATS) to conduct a Technical Safeguarding Summary against the Osprey and Pager Power Reports (NATS is UK's principal air navigation services provider which provides air traffic management services to aircraft within UK airspace). On the matter of the Woodcock Hill Radar assessment, NATS noted that the Radar Assessment, derived from EUROCONTROL GUIDELINES, carried out by Pager Power was very similar to the process that NATS themselves use to safeguard their own Secondary Radars across the UK. NATS also noted that they were unable to comment on the conclusion by Pager Power that *"aircraft would be unlikely to fly within the shadow"* without input from the IAA or Shannon Airport Authority but that the conclusion does not seem unrealistic given the low altitudes of shadow regions indicated in the report.

1.2.35 The IAA reviewed these reports.

1.2.36 There were extensive pre-planning engagements and consultations during this time period and the minutes of a meeting, held in February 2020, between IAA and Brookfield are included in Appendix 4. Item No. 3 of this meeting addressed the Woodcock Hill Radar. It was noted that the Woodcock Hill Radar was due for replacement in 2026. In item No.7 it was noted as a meeting summary point that the Radar Impacts are potentially mitigatable at a cost to the developer.

1.2.37 There were also meeting minutes relating to the IAA's concern of Instrument Landing Systems (ILS) and collision risk i.e. a key aspect for airport approach and air navigation that has been in place since the 1940's. It is the main form of approach technology and is based on ground-based infrastructure and on-board equipment. However there has been "new" technology, in use since the early 1990's for Instrument Flight Rules, which is based on Global Navigation Satellite Systems, and which provides the required reliability for a European wide air navigation system. This form of navigation is called Performance Based Navigation (PBN).

1.2.38 In item 5 of the meeting minutes (Appendix 4) from the meeting in February 2020 there is a reference to the different Required Navigation Performance (RNP) approaches which are applicable to aerodromes with different collision risks. RNP is a PBN navigational method in which aircraft can fly accurate approaches as required.

1.2.39 At the meeting the IAA raised one of their key concerns in relation to a wind farm development at Oatfield which is Safety. In item 5 of the minutes of the meeting IAA state their concern that the proposed development may present an unacceptable flight risk.

1.2.40 For guidance of this safety concern around collision risk with wind turbines a review of the **Irish State Plan for Aviation Safety 2023-2025** was carried out.

1.2.41 There is no reference within this State Plan for Aviation Safety 2023 – 2025 to safety issues concerning collision risks presented by wind turbines. There is a Safety Issue identified that has been addressed in section 2.2 Controlled Flight into Terrain (CFIT), as shown in Appendix 9. There is no reference to wind turbine obstacle collision.

1.2.42 The Status Highlights within section 2.2 of this State Plan for Aviation Safety states that PBN Transition Plan has been developed which suggest a key part of risk mitigation for CFIT accidents is to implement PBN approach procedures with vertical guidance (RNP APCH) that conforms to the requirements of the RNP approach specification at instrument runway ends which are not served by precision approach procedures. This was the same approach that was adopted within the State Plan for Aviation Safety 2021 – 2024.

<u>Violet Hill 2020-2022 Pre-planning Consultation:</u>

1.2.43 AirNav refers to a "third occasion" that this development has been proposed.

1.2.44 This is a reference to an engagement between and the IAA in relation to a pre-planning consultation in relation to a site located at Violet Hill. There was a series of engagements between the IAA and Coillte in 2020-2022.

1.2.45 This Violet Hill site was adjacent to the Brookfield Renewable Oatfield Site. Violet Hill considered an 18-turbine site layout. The Violet Hill site did not proceed through the planning process.

1.2.46 During the pre-planning consultation stage Coillte commissioned Ai Bridges to engage with Cyrrus Limited to conduct a number of detailed technical assessments at the request of the IAA. Cyrrus completed a specialist Instrument Flight Procedures Assessment for Shannon Airport. Cyrrus also completed a Radar Assessment against the Radars at Shannon Airport and Woodcock Hill.

1.2.47 The IAA reviewed these reports.

1.2.48 Following extensive engagements and consultations during this period the IAA documented an email response in February 2022. In relation to the Radar Assessment the IAA state that *"Methodology of this assessment has been accepted in principle".*

1.2.49 In relation to the Instrument Flight Procedure completed by Cyrrus the IAA state:

> *"Increasing of PDG from 3.5% to 4.0% for affected SIDs: Agreed in principle and can be incorporated in updated IFP designs planned for late 2022. This is also consistent with non-SID departure instructions increased PDG"*
>
> *"VOR RWY 24 IAP: Impact noted and mitigations understood. These are not however consistent with our requirements for SDF etc. If the development goes ahead, I would recommend withdrawal of the VOR IAP on the basis that this would be in line with the State PBN plan and that RNP IAPs are planned for Shannon during 2022".*

1.2.50 The above response from IAA in February 2022 would appear to address the same impacts to approach and departure procedures as the current proposed Oatfield development. However, the response would indicate that both impacts can be mitigated in line with Required Navigation Performance (RNP) approaches which have been implemented in 2022. The IAA also refers to the State PBN Plan which is addressed in the following section.

State Performance Based Navigation (PBN) Implementation Plan for Ireland:

1.2.51 The International Civil Aviation Organization (ICAO) published their Global Air Navigation Plan 2013 – 2018 which sets out the introduction of Performance Based Navigation in order to achieve a transition to a more modern navigation system from the traditional navigation infrastructure.

1.2.36 The IAA published their PBN Implementation Plan for Ireland in March 2021. The EU Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 lays down airspace usage requirements concerning Performance Based Navigation (PBN IR). The IAA has developed the PBN Transition plan applicable to all airspace users as required under EU regulations. This is to ensure a transition and rationalization of the ground-based navigation infrastructure so that there is a smooth and safe transition to the provision of the Air Traffic Management and Air Navigation services using performance-based navigation and the eventual rationalization of the ground-based navigation infrastructure.

1.2.52 The traditional navigation infrastructure that has been in use is simple and easy to use for pilots and air traffic controllers where there have been two types of aircraft approaches i.e. precision approaches (ILS) or non-precision approaches (VOR). As part of the State PBN implementation plan mixed mode approaches will be phased out and navigation infrastructure rationalized by 06 June 2030.

1.2.53 The IFP Safeguarding Assessment for the Oatfield Wind Farm (Attached as Appendix 1) completed by Cyrrus in May 2024 highlights that some of the Instrument Flight Procedures for approach onto Runway 24 will be impacted. Cyrrus state:

- *The VOR Runway 24 Instrument Approach Procedure. This procedure would be in line for removal according to the aforementioned State PBN Plan and Required Navigational Approach (RNP) Instrument Approach Procedures have been planned for Shannon during 2022 and this would have to be confirmed with the IAA\AirNav Ireland.*
- *Also, the impact to the Air Traffic Control Surveillance Minimum Altitude Chart could be re-designed on the basis of an Airspace Redesign Concept RNP Instrument Approach Procedure (IAP) on a shortened ILS as a possible mitigation. This would have to be reviewed and discussed with AirNav Ireland also.*

1.2.54 The VOR Runway 24 Instrument Approach Procedure would be in line for removal according to the aforementioned State PBN Plan and RNP Instrument Approach Procedures have been scheduled for Shannon during 2022.

1.2.55 As noted above in Section 1.2.53, the Cyrrus report states that the impact to the ATC SMAC could be re-designed on the basis of an Airspace Redesign Concept RNP IAP on a shortened ILS as a possible mitigation, which would have to be reviewed and discussed with AirNav Ireland.

1.2.56 The Concept Designs ATC SMAC Report for the Oatfield Wind Farm (Appendix 10 below) completed by Cyrrus in June 2024 concludes:

> *"As the number of Area Navigation (RNAV)-equipped aircraft continues to expand, alternative methods for aligning aircraft with the ILS final approach path could involve leveraging RNP to ILS procedures or utilizing Required Navigation Performance (RNP) procedures with vertical guidance, such as Lateral navigation (LNAV) / Vertical navigation (VNAV) or Localizer Performance with Vertical Guidance (LPV). By doing so, the reliance on ATC vectoring to intercept the ILS could be minimized. While vectoring could still serve as a fallback to the RNP procedures, this approach would mitigate any potential impact on efficiency and flexibility "*

1.2.57 This draws reference to the requirements for Required Navigation Performance (RNP) procedures as part of the long-term implementation plan with a target date for completion by June 2023:

> *"Long Term. Mixed mode operations will be phased out and navigation infrastructure rationalized by 06 June 2023, (phase3)*

1.2.58 The State PBN Implementation Plan (attached in Appendix 5) allows for the implementation of Performance Based Navigation in Ireland's controlled airspace. In section 30.2 of this State PBN Plan it is stated that Ireland's methodology for the transition to PBN would include:

- *Development of RNP APCH (to include LPV') for all runways as well as RNAV SID's and STAR's*
- *Removal by 06 60 2030 (phase 3) of conventional instrument flight procedures and mixed mode traffic*
- *Removal of ground based navigational aids by 06 June 2023 (phase 3)*

1.2.59 The State PBN Implementation Plan allows for the implementation of Performance Based Navigation in Ireland's controlled airspace what would phase out conventional instrument flight procedures while also removing the reliance on ground based navigational aids and offers a mitigation path for the Instrument Fight Procedure concerns ATCSMAC concerns that IAA\AirNav have raised in relation to the Oatfield Wind Farm.

Other Facilities that have Applied Mitigations (UK Radar Facility Reference Sites)

1.2.60 AirNav state, in their opinion, that the Aviation Review Statement completed by Ai Bridges in December 2023 references *"other facilities"* that have applied mitigations which are not Enroute Radar facilities which is the case for the Radar.

1.2.61 This is a reference to *"Section 3.3 Radar Surveillance Sensors – Mitigation Measures"* within the Chapter 11, Appendix 11.2 Aviation Review Statement where Ai Bridges refer to the Newcastle Airport Radar Upgrades and the Marshall Project which consists of over forty Military of Defence (MOD) Radar installations.

1.2.62 The first reference site of Newcastle Airport has a Thales STAR2000 with a co-mounted Thales RSM970 Secondary Radar, the same model that is used at Woodcock Hill.

1.2.63 The Cyrrus Mitigation Options Study Report, carried out in May 2024, refers to the Wind Farm Mitigation Scheme in operational use at Newcastle Airport (see Appendix 7 Newcastle Airport Reference of the Cyrrus Report Appendix 1). In Section 6 of this study, Cyrrus have demonstrated by reference to the published Aeronautical Informational Procedure (AIP) for Newcastle Airport, that there are several wind farms located within the radar's operating volume. There are wind turbines with an AMSL of 203m which are located near Cramlington and are within 8km of the MSSR Radar at Newcastle Airport. The radar is operational and is used to control aircraft within the control airspace. Some of the wind farms are closer to Newcastle Airport than the proposed Oatfield development is to Woodcock Hill.

1.2.64 The reference to the Project Marshall Radar Upgrade in the UK is a reference to the UK Wind Industry FOI Request in relation to the MOD Radar Upgrade Program for Air Traffic Control. The UK Military of Defence (MOD) deployment is an upgrade program that incorporated Windfarm Mitigation Filters to their existing radars some of which were the same model and age as the existing Woodcock Hill Radar. The upgrade list is provided in Appendix 8 of the Cyrrus Report in Appendix 1. This list shows that of the 25 radars upgraded eight were the Thales RSM970S which is the same model as the Woodcock Hill Secondary Radar.

1.2.65 These references demonstrate that the Woodcock Hill Secondary Radar can be upgraded, subject to a conditions survey. Cyrrus state in Section 9 of their Mitigations Options Study (Appendix 1) that:

> *"Thales (the manufacturer) will be able to assess the type of mitigation package required (if any). They will confirm costs and timescales based on their scope of work. The main advantage of this would be an improved surveillance picture from a controller's perspective and the ability of the radar to provide mitigation for the other windfarm developments".*

UK Aviation Plan – Wind Turbines and Aviation Radar:

1.2.66 From 2005 until 2011 Newcastle airport received over 250 consultations for on and off-shore wind farm developments from across the UK North-East region, all aiming to meet government-set targets for renewable energy. Many of the developments had the potential to affect the daily operations of Newcastle Airport's Air Traffic Control since wind turbines in operation can appear on the airport radar with similar markings to a moving aircraft.

1.2.67 In the past, in the absence of a solution, Newcastle Airport had no alternative but to object to proposed wind farm developments where an unacceptable impact was predicted. However, a technological solution was found in the form of Radar Blanking software, which updated the airport's radar system. The software places a 'patch' to cover the potential wind farm sites, thereby preventing turbines appearing, so they cannot be mistaken for moving aircraft.

1.2.68 The Newcastle Airport reference site, discussed above, uses the same model Radar as is used at Woodcock Hill and the successfully upgrading and implementation of its Radar software clearly demonstrate that mitigation of potential effects from wind farms is an achievable solution and can be applied to Woodcock Hill.

1.2.69 The Project Marshall is a further example of a project that included an upgrade deployment to the Thales RSM970S radars, the same model of the Radar used at Woodcock Hill, which provided the required mitigation.

1.2.70 The potential effects of wind energy development on Radar Infrastructure and operation have been carefully considered in the UK. There, Renewable UK has been working with the Ministry of Defence, Department for Transport, Department for Business, Energy and Industrial Strategy (BEIS), the Scottish Government, the Civil

Aviation Authority, NATS, the Airport Operators Association, the General Aviation Awareness Council, and The Crown Estate (responsible for leasing areas for wind energy development), for many years to identify and implement suitable mitigation.

1.2.71 In 2008 in the UK, the DECC, the Dept for Transport, Ministry of Deference, Renewable UK, Civil Aviation Authority and National Air Traffic Services signed a Memo of Understanding which committed them to work together to identify mitigation solutions and drive forward progress on projects as part of an "Aviation Plan". This Plan was endorsed by representatives from the relevant stakeholders within the Aviation Sector.

1.2.72 The MoD participated in this UK Aviation Plan. The reference in Appendix 9 shows a list of Installation of new and upgraded radars at MOD sites as part of Project Marshall. This project was undertaken by MoD where MSSR Radars, similar to the MSSR Radar at Woodcock Hill (model RSM970), was upgraded to STAR NG which has the functionality to mitigate wind farm impacts.

1.2.73 Citing these references above, which are relevant to the proposed Oatfield wind farm development, provides a pathway for further engagement between the applicant and AirNav Ireland to achieve an acceptable aviation mitigation solution.

Summary and Conclusion:

1.2.74 As part of their observations, AirNav and Shannon Airport state that the areas of concern identified required more analysis in relation to Instrument Flight Procedures. AirNav \ Shannon Airport also state that a deeper assessment of impacts is required in relation to Radar Surveillance Systems Safeguarding.

1.2.75 The IFP Safeguarding Assessment completed for Oatfield Wind Farm by Cyrrus demonstrates that there are viable mitigation measures to the issues raised by Air Nav and which can be implemented.

1.2.76 This is supported by the detailed and documented consultations that have previously taken place, prepared by third party aviation specialists, during the pre-planning stages from 2016-2022 for previous developments within this general area. In these consultations, reference is made to viable mitigation measures and also to the State PBN Plan (attached in Appendix 5) which provides for phasing out of the legacy flight approaches or to their replacement by more modern navigation methods.

1.2.77 The Concept Designs ATCSMAC Report completed for Oatfield Wind Farm by Cyrrus demonstrates that there are viable mitigation measures which can be implementable with further engagement with AirNav and Shannon Airport. Cyrrus conclude by stating:

> *"The stability of approaches by landing aircraft is coming evermore to the forefront of Airline Safety Departments and National Authorities safety agenda's and less and less operators are accepting of aircrew conducting 'shortened' ILS approaches. However, this does not mean that flexibility of ATC vectoring operations should no longer be considered important. Busy sequences of traffic sometimes require aircraft that are able to accept maneuvering that, although obviously still safe, does not necessarily meet other Operators SOPs and are*

placed into the 'approach plan' to create an overall efficient flow of air traffic – a core element of ATC."

The operational feasibility of concept design options provided within the Concept Designs ATCSMAC Report can only be decided upon by Shannon Air Traffic Control. Cyrrus go on to state:

> *"Any option deemed to have merit would need to be fully assessed and, possibly, refined so as to meet Shannon ATC expectations and provide them with the confidence of a solution that is safe and, on balance, expedient to the majority of users."*

Cyrrus also, in their final concluding statement, highlight the alternative methods for aligning aircraft with the ILS final approach path could involve leveraging RNP to ILS procedures or utilizing RNP Procedures with vertical guidance.

The IAA themselves have already developed the PBN transition plan applicable to all airspace users as required under EU regulations under the State PBN Implementation Plan for Ireland. A key part of risk mitigation for Controlled Flight into Terrain incidents is to implement PBN approach procedures with vertical guidance that conforms to the requirements of the RNP Approach specification (RNP APCH) at instrument runway ends which are not served by precision approach procedures. The part of the State PBN Implementation Plan for Ireland was completed in 2020.

1.2.78 The State PBN Implementation Plan allows for the implementation of Performance Based Navigation in Ireland's controlled airspace. In section 30.2 of this State PBN Plan it is stated that Ireland's methodology for the transition to PBN would include:

- *Development of RNP APCH (to include LPV') for all runways as well as RNAV SID's and STAR's*
- *Removal by 06 60 2030 (phase 3) of conventional instrument flight procedures and mixed mode traffic*
- *Removal of ground based navigational aids by 06 June 2023 (phase 3)*

1.2.79 The above points 1.2.7.8 to 1.2.79 shows that the implementation of the State PBN Plan by 06 June 2030 offers a pathway for further discussion with AirNav on ways to mitigate out the aviation concerns relating to the IFP's and ATCSMAC as raised by AirNav and Shannon Airport.

1.2.80 The Radar Assessment completed for Oatfield by Cyrrus, identified that there would be no impacts to the Monopulse Secondary Surveillance Radar at Shannon Airport. The Primary Radar at Shannon Airport was also assessed and subject to available upgrades by the manufacturer, wind farm impacts can be filtered out which would result in the 11-turbine wind farm at Oatfield having no operational effect. The Mitigation Options Study produced by Cyrrus (Appendix 1) also addressed the concerns raised by the IAA that there would be an impact on the Enroute Radar facility at Woodcock Hill. The detailed assessment showed no impacts to this radar by the proposed Oatfield wind farm.

1.2.81 The IAA state that the Reference Sites ("other facilities that have applied mitigations that are not Enroute") provided are not relevant to Oatfield Wind farm. The reference sites in the UK referred to (namely Newcastle Airport and the Project Marshall Radar Upgrade by the UK Military of Defence (MoD)) are relevant, as the Thales Radar sensors at Shannon Airport are also Thales RSM970S radar sensors. Hence, they offer a valid upgrade precedent clearly demonstrating that such mitigation has been effectively implemented and that software upgrades are available to mitigate potential wind farm effects.

1.2.82 The Newcastle Airport precedent has been a key reference that shows co-existence of wind farms in close proximity to Aviation Radar and how Mitigation Measures can be deployed and implemented. The Project Marshall reference represents a countrywide upgrade in the UK that was completed for the same Radar that is at Woodcock Hill.

1.2.83 The "UK Aviation Plan" has been referenced as it has been conceived on the basis of the work completed by key stakeholders in the Aviation Sector and the Renewable Sectors in the UK. it offers a basis as to how this could also work in an Irish context through further stakeholder engagement.

1.2.84 With regard to the Instrument Flight Procedures, mitigation options are presented in Section 3 of the Cyrrus IFP Safeguarding Assessment Report (Appendix 1). These clearly indicate that potential impacts in Instrument Flight Procedures can be mitigated out. More detailed Re-design Concepts that propose a series of airspace design options to mitigate out the impacts on the Instrument Flight Procedures and also to mitigate the impacts to the Air Traffic Control Surveillance Minimum Altitude Chart are also being developed. There are a number of design options available, and the selection of the Optimum Design Option for Shannon Airport will likely require engagement between Cyrrus with AirNav Ireland, The Irish Aviation Authority and Shannon Airport.

1.2.85 With regard to Radar Surveillance System Safeguarding, Cyrrus (Mitigations Options Study), conducted a detailed technical assessment with detailed calculations and analysis in accordance with EUROCONTROL GUIDELINES and showed that there would be no radar shadowing effect caused by the proposed wind farm on the Woodcock Hill Monopulse Secondary Surveillance Radar. No impacts as stated by AirNav Ireland to En-route facilities will therefore occur.

1.2.86 The applicant would welcome the opportunity for a meeting to engage with AirNav Ireland, IAA and Shannon Airport as appropriate to provide a presentation on the Airspace Redesign Concepts and Mitigation Options and agree the Optimum mitigation to ensure safe and effective vectoring of aircraft at Shannon Airport.

Appendix 1

IFP Safeguarding Oatfield Windfarm

IFP Safeguarding

Oatfield Windfarm

Shannon Airport

20 May 2024

CL-6049-RPT-003 V1.1

www.cyrrus.co.uk

info@cyrrus.co.uk

Document Information	
Document title	Oatfield Windfarm
Author	Shaun Gouvea
Reviewed by	Ferlicia Matloha
Produced by	Cyrrus Limited Cyrrus House Concept Business Court Allendale Road Thirsk North Yorkshire YO7 3NY T: +44 (0) 1845 522 585 F: +44 (0) 8707 622 325 E: info@cyrrus.co.uk W: www.cyrrus.co.uk
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V1.0	Initial Issue	01 May 2024	Issue
V1.1	Amendments to proposed mitigation options	20 May 2024	Second Issue

Executive Summary

The assessment has been carried out against the proposed Oatfield windfarm development approximately 8.96 Nautical Miles (NM) northeast of Shannon Airports Aerodrome Reference Point (ARP).

The purpose of this assessment is to assess if the proposed windfarm development penetrates the protection areas/surfaces of the Instrument Flight Procedures serving the Airport. These protection areas and surfaces (sloping or level) are established based upon the runway (RWY) and thresholds (THR), Aerodrome Reference Point (ARP), clearways, ground navigation equipment, and established waypoints.

The assessment has determined that the proposed windfarm does impact the currently published IFPs for Shannon Airport.

The Wind Farm has an impact to the following procedures:

- SID RWY 06 DIGAN 3A (EINN AD 2.25-5.1)
- SID RWY 06 TOMTO 3A (EINN AD 2.25-5.1)
- SID RWY 06 ABAGU 3A (EINN AD 2.25-5.1)
- Instrument Approach ILS OR LOC RWY 06 (EINN AD 2.24-10.1)
- Instrument Approach VOR RWY 24 (EINN AD 2.24-14.1)
- ATC Surveillance Minimum Altitude Chart (EINN AD 2.24-16.1)

Possible mitigation options to remove impact to the Instrument Flight Procedures are listed in the conclusion.

Abbreviations

AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
ARP	Aerodrome Reference Point
ATC	Air Traffic Control
ATCSMAC	Air Traffic Control Surveillance Minimum Altitude Chart
ATM	Air Traffic Management
CAT	Category
DME	Distance Measuring Equipment
IAA	Irish Aviation Authority
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organisation
IFP	Instrument Flight Procedure
ILS	Instrument Landing System
LOC	Localiser
m	Metres
MACG	Missed Approach Climb Gradient
MOC	Minimum Obstacle Clearance
MOCA	Minimum Obstacle Clearance Altitude
MSA	Minimum Sector Altitudes
MVA	Minimum Vectoring Altitude
NM	Nautical Mile
OPS	Operations
PANS	Procedures for Air Navigation Services
PDG	Procedure Design Gradient
RWY	Runway
SID	Standard Instrument Departure
SMAA	Surveillance Minimum Altitude Area
THR	Threshold
UTM	Universal Transverse Mercator
VOR	Very High Frequency Omnirange
WGS-84	World Geodetic System 1984
WTG	Wind Turbine Generator

References

[1] ICAO DOC 8168 - Procedures for Air Navigation Services, Aircraft Operations, Vol III, 7th Ed, Amendment 9, Corrigendum 2, dated 21 March 2022.

[2] ICAO Annex 4 – Aeronautical Charts, 11th Ed, Corrigendum (12/10/17), Amendment 61 dated 4 November 2021.

[3] ICAO DOC 4444 – Procedures for Air Navigation Services, Air Traffic Management , Sixteenth Edition, 2016.

[4] ASAM 017 – Guidance Material on Instrument Flight Procedure Design, dated 24 January 2022.

[5] ICAO DOC 8168 - Procedures for Air Navigation Services, Aircraft Operations, Vol III, First Edition, dated 8 November 2018.

Contents

List of figures

List of tables

1. General

1.1. Geodesic Datum

Name	Ireland-WGS84[1]-UTM29[2]
Reference Latitude	00°00'00.00"N
Reference Longitude	009°00'00.00"W
Reference X	500000.0000
Reference Y	0.0000
Semi Major Axis [a]	6378137 m
Eccentricity [e]	0.0818191908426215
Scaling Factor	0.9996
Projection	Transverse Mercator
Reference Latitude	00°00'00.00"N

Table 1: Geodesic Datum Parameters

1.2. Notes

Table below indicates the criteria used for this assessment.

Criteria	Comments
Height	In metres (m)
Bearings	True bearings
Speed	Knots
Temperature	IAS+15 used for all speed conversions from Indicated Air Speed (IAS) to True Air Speed (TAS)
Aircraft categories	As Defined
Mountainous terrain	No
Buffer for trees and unknown structures not defined in CAP232/1732 surveyed areas (see Section 1.6)	N/A
Cold Temperature Adjustments	ICAO DOC 8168 volume III

Table 2: Criteria

[1] World Geodetic System 1984
[2] Universal Transverse Mercator

1.3. Runway Information

Runway	Bearing (°T)	Latitude	Longitude	Elevation (ft)
06	052.22°	524135.42N	0085636.67W	46
24	232.25°	524236.03N	0085427.87W	15

Table 3: Runway Information

2. IFP Safeguarding

2.1. Overview

The assessment has been carried out in relation to 11 Wind Turbine Generator (WTG) positions approximately 8.96 Nautical Miles (NM) northeast from Shannon Airports Aerodrome Reference Point (ARP).

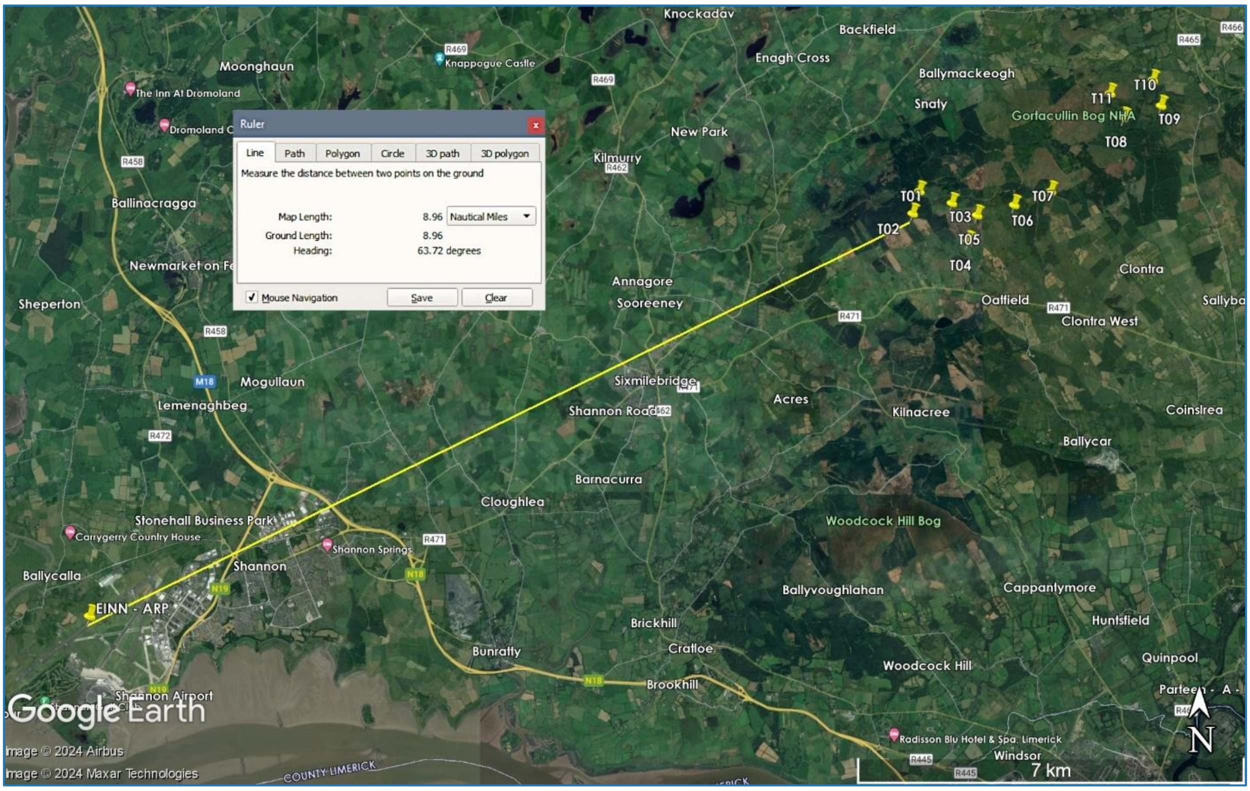

Figure 1: WTG layout Relative to ARP

2.2. IFP's Assessed

The following IFPs, as published in the Irish Aviation Authority (IAA) Aeronautical Information Publication (AIP), Aeronautical Information Regulation and Control (AIRAC) effective 21 March 2024 were assessed.

- RNAV Standard Instrument Departure RWY 06
- RNAV Standard Instrument Departure RWY 24
- RNAV Standard Arrival RWY 06
- RNAV Standard Arrival RWY 24
- Instrument Approach ILS or LOC RWY 06
- Instrument Approach VOR RWY 06
- Instrument Approach ILS CAT I & II or LOC 24
- Instrument Approach VOR RWY 24
- ATC Surveillance Minimum Altitude Chart

2.3. Data

The following data received from the client was used for the purpose of this assessment:

- Turbine Coordinates and Elevations - Oatfield Wind Farm Turbine Coordinates.xlsx
- Turbine Model – Vestas V150

The resulting data used is indicated in Table 4 below.

Name	Latitude (DMS WGS84)	Longitude (DMS WGS84)	Ground Height (m AGL)	Tip Elevation (m AMSL)	Radius (m)
T01	52° 46' 16.592"N	8° 42' 08.311"W	258.05	438.05	73.7
T02	52° 46' 03.546"N	8° 42' 14.823"W	249.65	429.65	73.7
T03	52° 46' 09.627"N	8° 41' 36.883"W	242.20	422.20	73.7
T04	52° 45' 47.425"N	8° 41' 21.062"W	181.05	361.05	73.7
T05	52° 46' 02.553"N	8° 41' 12.552"W	218.65	398.65	73.7
T06	52° 46' 08.518"N	8° 40' 36.636"W	209.80	389.80	73.7
T07	52° 46' 16.582"N	8° 40' 01.176"W	233.80	413.80	73.7
T08	52° 46' 59.651"N	8° 38' 50.592"W	193.55	373.55	73.7
T09	52° 47' 06.609"N	8° 38' 14.565"W	193.65	373.65	73.7
T10	52° 47' 21.580"N	8° 38' 22.417"W	189.25	369.25	73.7
T11	52° 47' 13.685"N	8° 39' 03.983"W	222.90	402.90	73.7

Table 4: Wind Turbine Assessment Data

2.4. Discrepancies and Assumptions

The radius used for the assessment was sourced from the Vestas website[3].

2.5. IFP Safeguarding Assessment

An IFP Safeguarding assessment was completed against the applicable procedures for Runway 06 / 24, at Shannon Airport.

For each departure and approach the Pans-Ops obstacle protection areas were constructed. These areas were then checked to determine if the proposed development was inside or outside of the obstacle protection areas. A further in-depth assessment would only be required if the proposed structure was inside these areas and the Obstacle Clearance Altitude (OCA) required by the obstacle was above the published OCA value.

Due to the technical nature of the information, this report is a distillation of the IFP modelling and subsequent assessment of the obstacles, the full data set is available if required[4]. The purpose of this report is to identify what procedures were assessed and whether there is an impact, in the event of an impact, potential mitigation is provided[5]. Where an impact was identified, only the assessment of the respective segment for said procedure, is provided.

The IFPs were assessed using PHX V23.0.4.17017.

2.6. Assessment Summary

Table 5 provides an impact summary of all the Instrument Approach Procedures (IAPs) that were assessed.

Assessed Procedure	RWY	Impact	Comments
MSA	Both	No	Nil.
ILS or LOC	06	Yes	T1 and T2, penetrate the Missed Approach which results in a Missed Approach Climb Gradient (MOCG) greater than 2.5%
VOR	06	No	Nil.
RNAV STARs	06	No	Outside Protection Areas
RNAV SIDs	06	Yes	T1, T2 and T3, penetrate the turn area for SIDs DIGAN 3A, TOMTO 3A and ABAGU 3A which results in a higher Procedure Design Gradient (PDG) than the standard obstacle clearance PDG of 3.3%.
ILS CAT I & II or LOC	24	No	Nil.

[3] https://www.vestas.com/en/products/4-mw-platform/V150-4-2-MW

[4] Please note that the full data set can run into an excess of 20 pages per procedure and can only be decoded by those familiar with the output generation from the IFP Software and trained IFP Designers.

[5] Mitigation for the IFPs is for the Airport (Sponsor) to decide upon as these may have a direct impact on their operations. It is recommended that further discussion and guidance is obtained from the IAA.

VOR		Yes	T1, T2 and T3 impact the Final Approach and raise the published minima by 260ft from 1270ft to **1530ft.**
RNAV STARs		No	Outside Protection Areas
RNAV SIDs		No	Outside Protection Areas
ATCSMAC	Both	Yes	All Turbines impact Sector 1 and raise the published minima by 300ft from 2300ft to **2600ft.**

Table 5: IFP Assessment Impact Summary

2.7. IFP's not assessed

The following IFPs, although considered, were not assessed as the turbines lie outside the protection areas of the following procedures.

- RNAV STARs RWY 06
- RNAV STARs RWY 24
- RNAV SIDs RWY 24

2.8. Assessment Details

2.8.1. Minimum Sector Altitude (MSA)

The turbines fall into sector 1 (056°M to 146°M 3400ft) and sector 2 (146°M to 056°M 3000ft), of the MSA.

Homing Facility Position	
ID	DVOR SHA
Latitude	52°43'15.60"N
Longitude	008°53'06.80"W
Parameters	
Magnetic Variation	4.0000°W
Outer Radius	25 NM
MOC	300 m
Sector 1	
From	056° M
To	146° M
Calculated Minimum	2500 ft
Number of Checked Obstacles	11
Sector 2	
From	146° M
To	056° M
Calculated Minimum	2500 ft
Number of Checked Obstacles	11

Table 6: Minimum Sector Altitudes (MSA) - General

Name	Latitude	Longitude	Alt. (m)	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	300.0	2369.5

T07	52°46'16.58"N	008°40'01.18"W	413.8	300.0	2341.9
T11	52°47'13.69"N	008°39'03.98"W	402.9	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	300.0	2168.8

Table 7: Minimum Sector Altitudes (MSA) - Checked Obstacles - 056° M - 146° M

Name	Latitude	Longitude	Alt. (m)	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	300.0	2369.5
T07	52°46'16.58"N	008°40'01.18"W	413.8	300.0	2341.9
T11	52°47'13.69"N	008°39'03.98"W	402.9	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	300.0	2168.8

Table 8: Minimum Sector Altitudes (MSA) - Checked Obstacles - 146° M - 056° M

As indicated in Table 7 and Table 8 there is no impact to the MSA.

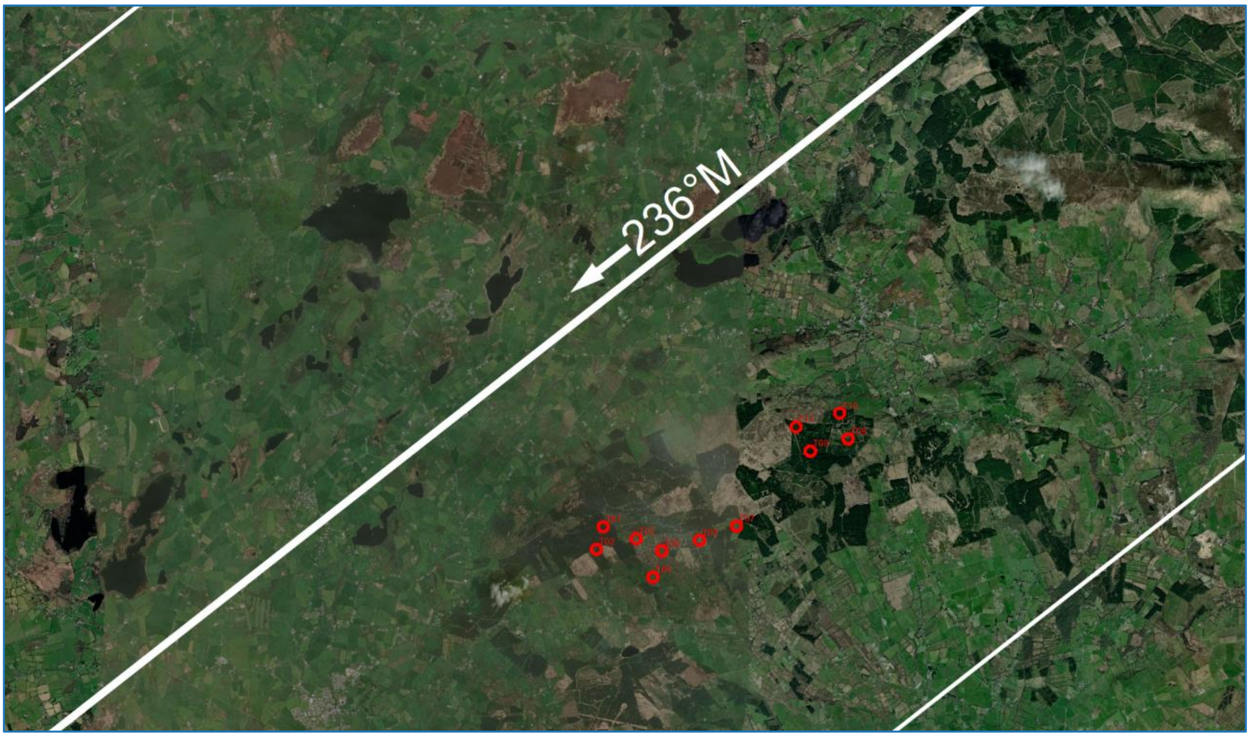

Figure 2: MSA VOR/DME SHA - Wind farm Location

2.8.2. DERAG HOLD (Conv)

The turbines fall into the buffer areas (1-2NM and 2-3NM) of the Hold, which has a Lowest Holding Altitude (LHA) of 3000ft.

VOR/DME Position	
ID	DVOR SHA
Latitude	52°43'15.60"N
Longitude	008°53'06.80"W
Altitude	60.96 m (200 ft)
Parameters	
Used For	Holding
Type	Towards the Station
IAS	220 kts
TAS	280.6 kts
Altitude	14000 ft
ISA	15 °C
Wind	74.6 kts (ICAO)
Holding DME	14 NM
Limiting DME	20 NM
MOC	300 m
Reciprocal Entry Radial	038.3 °
Entry Areas	
Sector 1	Yes
Sector 2	Yes
Reciprocal Entry	Yes
Orientation	
In-bound Track	232.25 °
Turns	Right
Obstacles	
Number of Checked Obstacles	11

Table 9: VOR/DME Holding DERAG – General

Name	Latitude	Longitude	Alt. (m)	Surface	MOC applied (m)	OCA (ft)	Controlling
T01	52°46'16.59"N	008°42'08.31"W	438.1	Buffer (2 nm - 3 nm)	120.0	1830.9	No
T11	52°47'13.69"N	008°39'03.98"W	402.9	Buffer (1 nm - 2 nm)	150.0	1814.0	No
T02	52°46'03.55"N	008°42'14.82"W	429.7	Buffer (2 nm - 3 nm)	120.0	1803.4	No
T03	52°46'09.63"N	008°41'36.88"W	422.2	Buffer (2 nm - 3 nm)	120.0	1778.9	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Buffer (2 nm - 3 nm)	120.0	1751.4	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Buffer (1 nm - 2 nm)	150.0	1718.1	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Buffer (1 nm - 2 nm)	150.0	1717.7	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	Buffer (1 nm - 2 nm)	150.0	1703.6	No
T05	52°46'02.55"N	008°41'12.55"W	398.7	Buffer (2 nm - 3 nm)	120.0	1701.7	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Buffer (2 nm - 3 nm)	120.0	1672.6	No

Table 10: VOR/DME Holding DERAG - Checked Obstacles – All

Name	Latitude	Longitude	Alt. (m)	MOC applied (m)	OCA (ft)	Controlling
T11	52°47'13.69"N	008°39'03.98"W	402.9	150.0	1814.0	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	150.0	1718.1	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	150.0	1717.7	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	150.0	1703.6	No

Table 11: VOR/DME Holding DERAG - Checked Obstacles - Buffer (1 NM - 2 NM)

Name	Latitude	Longitude	Alt. (m)	MOC applied (m)	OCA (ft)	Controlling
T01	52°46'16.59"N	008°42'08.31"W	438.1	120.0	1830.9	No
T02	52°46'03.55"N	008°42'14.82"W	429.7	120.0	1803.4	No
T03	52°46'09.63"N	008°41'36.88"W	422.2	120.0	1778.9	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	120.0	1751.4	No
T05	52°46'02.55"N	008°41'12.55"W	398.7	120.0	1701.7	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	120.0	1672.6	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	120.0	1578.3	No

Table 12: VOR/DME Holding DERAG - Checked Obstacles - Buffer (2 NM - 3 NM)

As indicated in Table 10, no turbines impact the Hold.

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Figure 3: DERAG Conventional HOLD - Wind farm Location

2.8.3. DERAG HOLD (RNAV)

The turbines fall withing the primary area of the Hold, which has a LHA of 3000ft.

Waypoint	
ID	DERAG
Latitude	52°51'46.60"N
Longitude	008°34'49.40"W
ATT	0.8 NM
XTT	1 NM
Parameters	
Holding Functionality Required	No
Out-bound Leg Limitation	Time
IAS	220 kts
TAS	280.6 kts
Altitude	14000 ft
ISA	15 °C
Time	1 min
Wind	74.6 kts (ICAO)
MOC	300 m
Cat. H (linear MOC reduction up to 2 NM)	No
Entry Areas	
70° Intercept	Yes
Sectors 1 & 2	Yes
Orientation	
In-bound Track	232.6 °
Turns	Right
Obstacles	
Number of Checked Obstacles	11

Table 13: DERAG HOLD (RNAV)

Name	Latitude	Longitude	Alt. (m)	Surface	MOC applied (m)	OCA (ft)	Controlling
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary Area	300.0	2421.5	No
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary Area	300.0	2393.9	No
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary Area	300.0	2369.5	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary Area	300.0	2341.9	No
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary Area	300.0	2306.2	No
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary Area	300.0	2292.2	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary Area	300.0	2263.2	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary Area	300.0	2210.2	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary Area	300.0	2209.9	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary Area	300.0	2195.8	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary Area	300.0	2168.8	No

Table 14: RNAV Holding DERAG - Checked Obstacles - All

As indicated in Table 14, no turbines impact the HOLD.

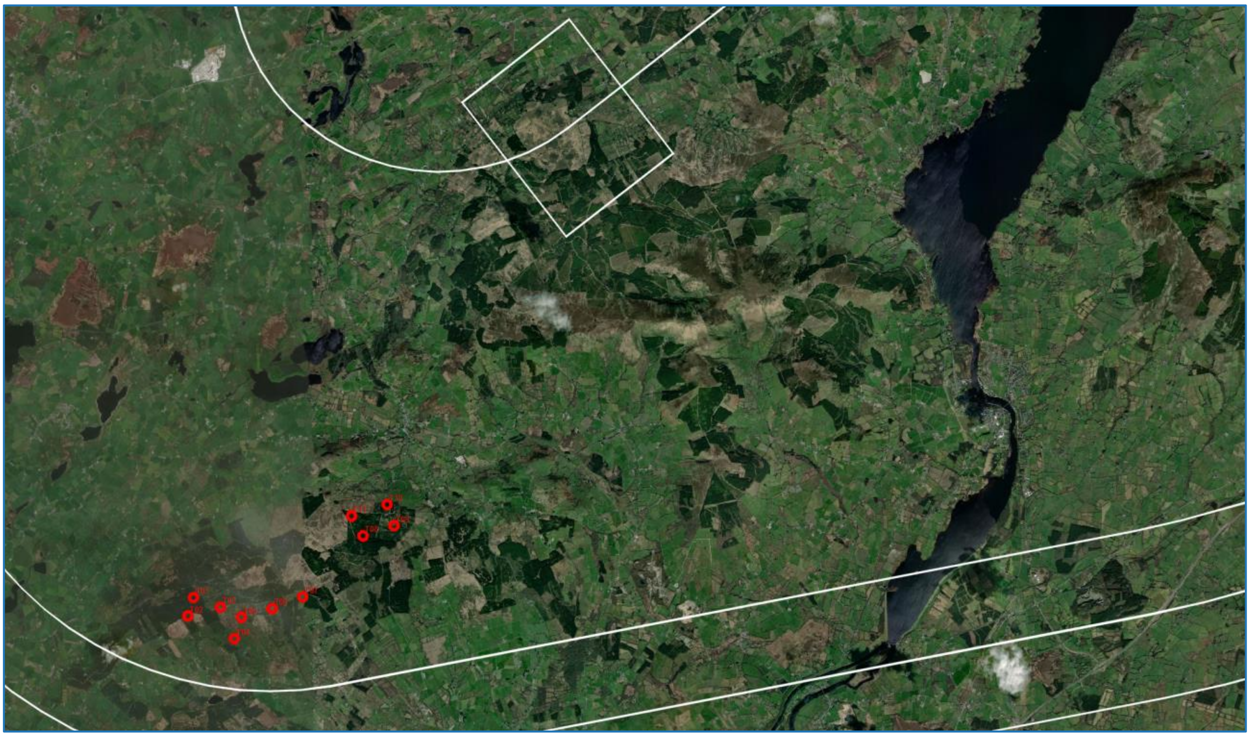

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Figure 4: DERAG HOLD (RNAV) - Wind farm Location

2.8.4. IAP – ILS Runway 06

The Turbines fall into the Intermediate and Final Missed Approach segment for the procedure.

Parameters	
SOC Position	
ID	SOC
Latitude	52°41'51.51"N
Longitude	008°56'02.51"W
Altitude	18.67 m (61.24 ft)
Track	052.17 °
MOC [int./fin.]	30 m / 50 m
MACG	2.5 %
Portion #2 (Turning Straight)	
Earliest Turning Point[ETP]	
Latitude	52°48'47.78"N
Longitude	008°41'14.15"W
Dist. DER -> ETP	21042.84 m
Nominal Track	052.17°
Obstacles	
Number of Checked Obstacles	11

Table 15: ILS RWY 06 Missed Approach OA – General

Name	Latitude	Longitude	Alt. (m)	Area	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)	Controlling
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	16956.7	30.0	1452.0	1508.0	2.7	Yes
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	17299.3	30.0	1480.1	1535.6	2.6	Yes
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	17634.8	30.0	1507.7	1483.6	2.5	No
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	17862.8	30.0	1526.4	1406.3	2.3	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	19187.3	30.0	1635.0	1456.0	2.3	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	18508.7	30.0	1579.3	1377.3	2.2	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	17451.3	30.0	1492.6	1283.0	2.2	No

Table 16: ILS RWY06 Missed Approach OA - Intermediate Phase - Checked Obstacles

Name	Latitude	Longitude	Alt. (m)	Area	Dz (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)	Controlling
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	21042.8	69.6	50.0	1792.9	1485.9	2.1	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	21042.8	4.2	50.0	1787.5	1389.6	2.0	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	21042.8	670.3	50.0	1842.2	1389.9	1.9	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	21042.8	835.6	50.0	1855.7	1375.5	1.9	No

Table 17: ILS RWY06 Missed Approach OA - Final Phase - Checked Obstacles

As indicated in Table 16, Turbines 01 and 02, impact the 2.5% MACG.

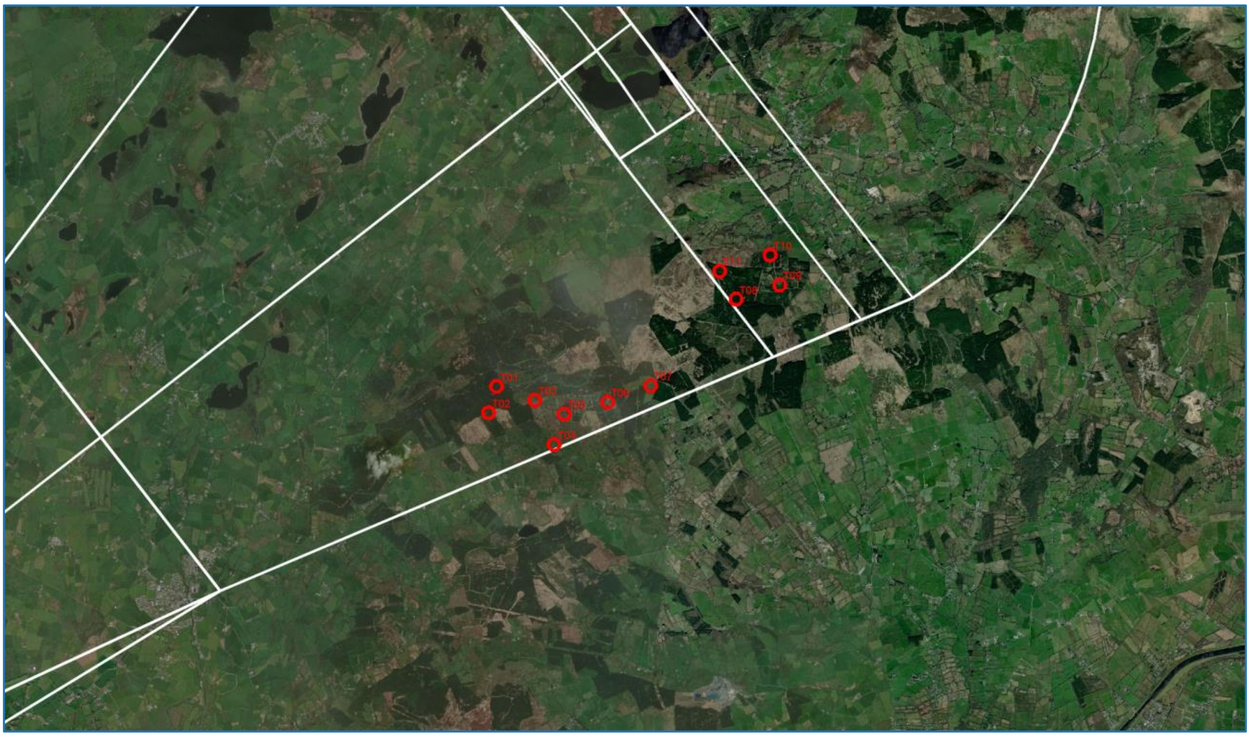

Figure 5: ILS RWY 06 –Missed Approach – Windfarm Location

2.8.5. IAP – LOC Runway 06

The Turbines fall into the Intermediate and Final Missed Approach segment for the procedure.

Parameters	
SOC Position	
ID	SOC (350ft)
Latitude	52°41'45.32"N
Longitude	008°56'15.66"W
Altitude	106.68 m (350 ft)
Track	052.17 °
MOC [int./fin.]	30 m / 50 m
MACG	2.5 %
Portion #2 (Turning Straight)	
Earliest Turning Point[ETP]	
Latitude	52°51'04.98"N
Longitude	008°44'09.14"W
Dist. DER -> ETP	21354.93 m
Nominal Track	052.17°
Obstacles	
Number of Checked Obstacles	11

Table 18: LOC RWY 06 Missed Approach OA – General

Name	Latitude	Longitude	Alt. (m)	Area	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)	Controlling
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	17611.7	30.0	1794.5	1535.6	2.1	No
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	17269.0	30.0	1766.4	1508.0	2.1	No

T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	17947.1	30.0	1822.0	1483.6	2.0	No
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	18175.1	30.0	1840.7	1406.3	1.8	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	19499.7	30.0	1949.4	1456.0	1.8	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	18821.0	30.0	1893.7	1377.3	1.7	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	17763.6	30.0	1807.0	1283.0	1.7	No

Table 19: LOC RWY06 Missed Approach OA - Intermediate Phase - Checked Obstacles

Name	Latitude	Longitude	Alt. (m)	Area	Dz (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)	Controlling
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	21354.9	77.4	50.0	2107.9	1485.9	1.7	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	21354.9	11.9	50.0	2102.5	1389.6	1.5	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	21354.9	678.1	50.0	2157.2	1389.9	1.5	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	21354.9	843.4	50.0	2170.7	1375.5	1.5	No

Table 20: LOC RWY06 Missed Approach OA - Final Phase - Checked Obstacles

As indicated in Table 19 and Table 20, the LOC procedure is not impacted.

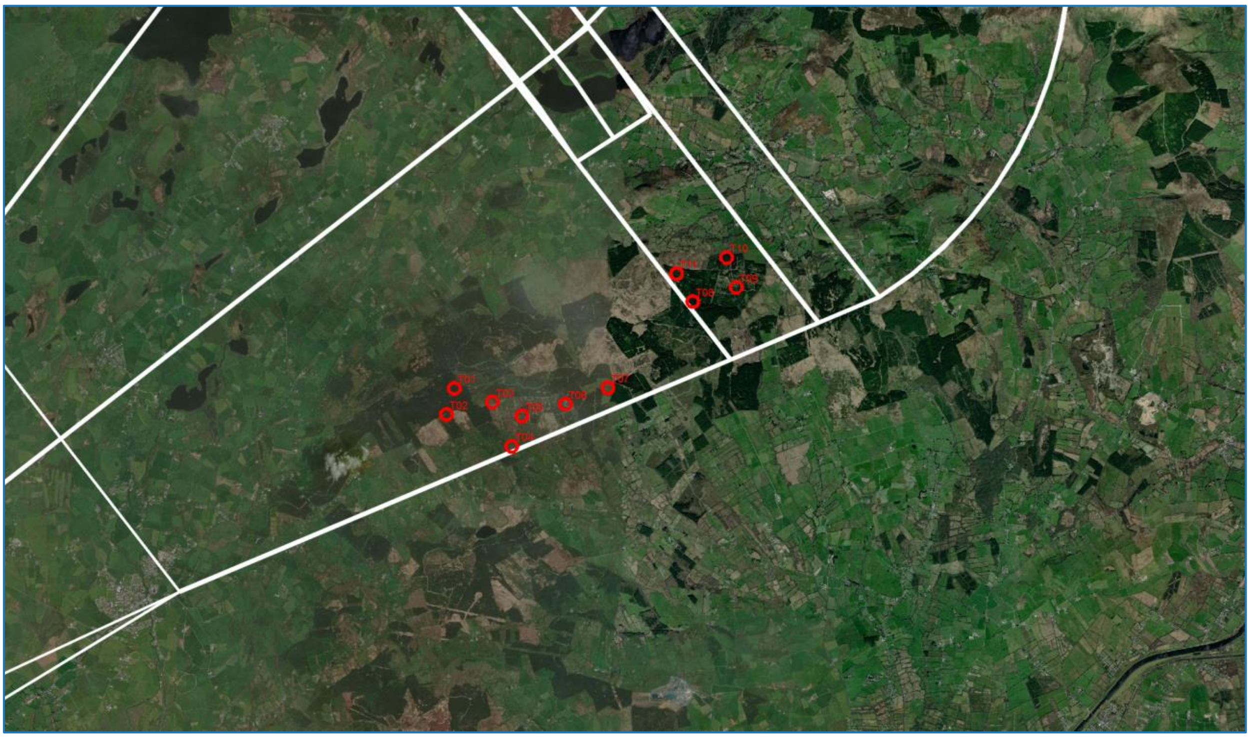

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Figure 6: LOC RWY 06 - Missed Approach – Windfarm Location

2.8.6. IAP – VOR Runway 06

The turbines fall in the Missed Approach Intermediate and Final segment of the procedure.

Parameters	
SOC Position	
ID	SOC (360ft)
Latitude	52°41'47.65"N
Longitude	008°56'13.21"W
Altitude	109.73 m (360 ft)

Track	052.02 °
MOC [int./fin.]	30 m / 50 m
MACG	2.5 %
Portion #1 (Turning Straight)	
Earliest Turning Point[ETP]	
Latitude	52°48'49.78"N
Longitude	008°41'16.72"W
Dist. DER -> ETP	21274.31 m
Nominal Track	052.02°
Obstacles	
Number of Checked Obstacles	5

Table 21: VOR RWY 06 - CAT A-D - Missed Approach

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Secondary	1217.5	17523.0	10.0	1797.3	1470.1	2.0
T02	52°46'03.55"N	008°42'14.82"W	429.7	Secondary	1485.4	17179.8	5.3	1769.1	1427.1	1.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	Secondary	1724.8	17857.1	2.1	1824.7	1391.9	1.8

Table 22: VOR RWY 06 - CAT A-D – Intermediate Missed Approach Phase - Checked Obstacles

Name	Latitude	Longitude	Alt. (m)	Area	Dz (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	MACG (%)
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	21274.3	60.0	50.0	2109.9	1485.9	1.7
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	21274.3	825.3	50.0	2172.6	1375.5	1.5

Table 23: VOR RWY 06 - CAT A-D – Final Missed Approach Phase - Checked Obstacles

As indicated in Table 22 and Table 23, there is no impact to the procedure.

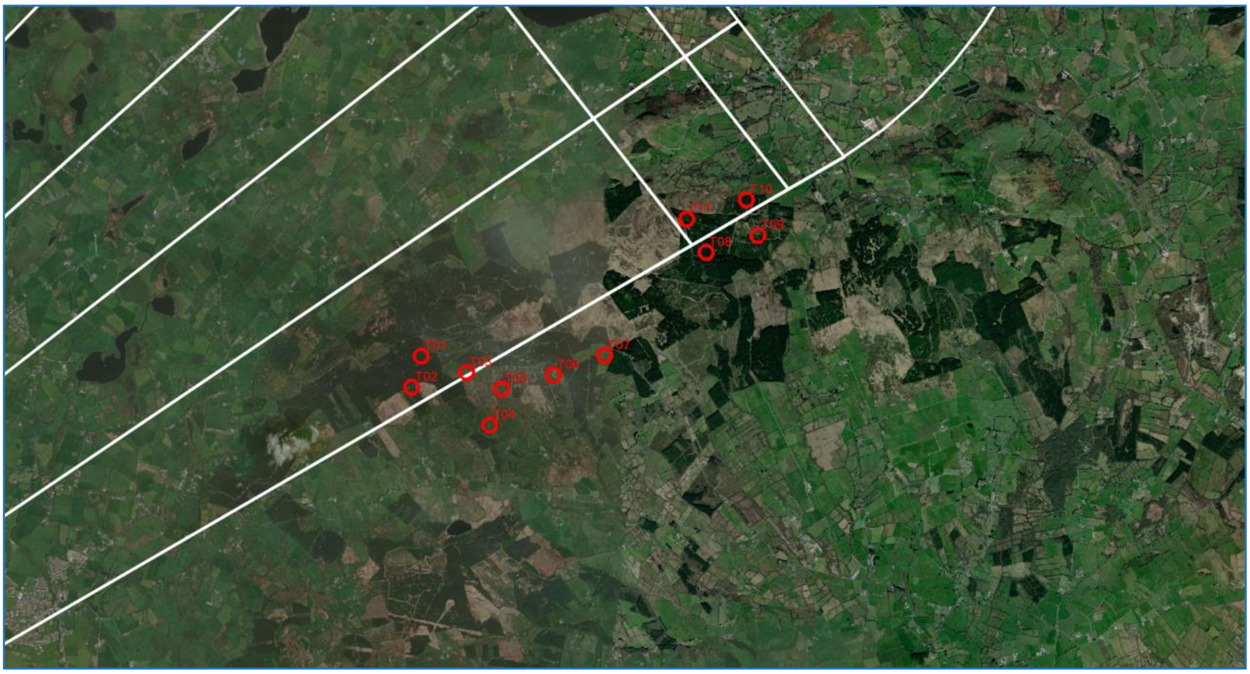

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Figure 7: VOR RWY 06 – Missed Approach – Windfarm Location

2.8.7. RNAV SID (DIGAN 3A) RWY 06

DER	
Latitude	52°42'37.24"N
Longitude	008°54'25.30"W
Altitude	4.57 m (14.99 ft)
Parameters	
Track	052.13 °
MOC	0.8 %
Minimum MOC	75 m
PDG	3.3 %
Turning Altitude	600 ft
Distance DER->TP [Dr]	5251.82 m

Table 24: SID - RWY 06 - DIGAN3A - Turn Area - Obstacle Assessment

11 obstacles and terrain points were checked. The 10 most controlling obstacles are listed in the following table.

Name	Latitude	Longitude	Alt. (m)	Area	Dr (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	PDG (%)	Controlling
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	5251.8	9559.9	118.5	1635.0	1798.4	3.9	Yes
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	5251.8	9856.4	120.9	1667.1	1833.7	3.9	Yes
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	5251.8	10279.9	124.3	1713.0	1792.8	3.6	Yes
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	5251.8	10600.2	126.8	1747.7	1724.0	3.3	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	5251.8	11999.4	138.0	1899.2	1810.4	3.1	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	5251.8	11290.6	132.3	1822.4	1713.1	3.1	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	5251.8	10270.6	124.2	1712.0	1592.0	3.0	No
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	5251.8	13733.3	151.9	2086.9	1820.1	2.8	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	5251.8	13758.1	152.1	2089.6	1724.5	2.5	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	5251.8	14459.1	157.7	2165.5	1743.2	2.5	No

Table 25: SID - SID - RWY 06 - DIGAN3A - Turn Area - Obstacle Assessment - Checked Obstacles

As indicated in Table 25, the turbines have an impact on the procedure, which results in a higher PDG than the standard obstacle clearance PDG of 3.3%.

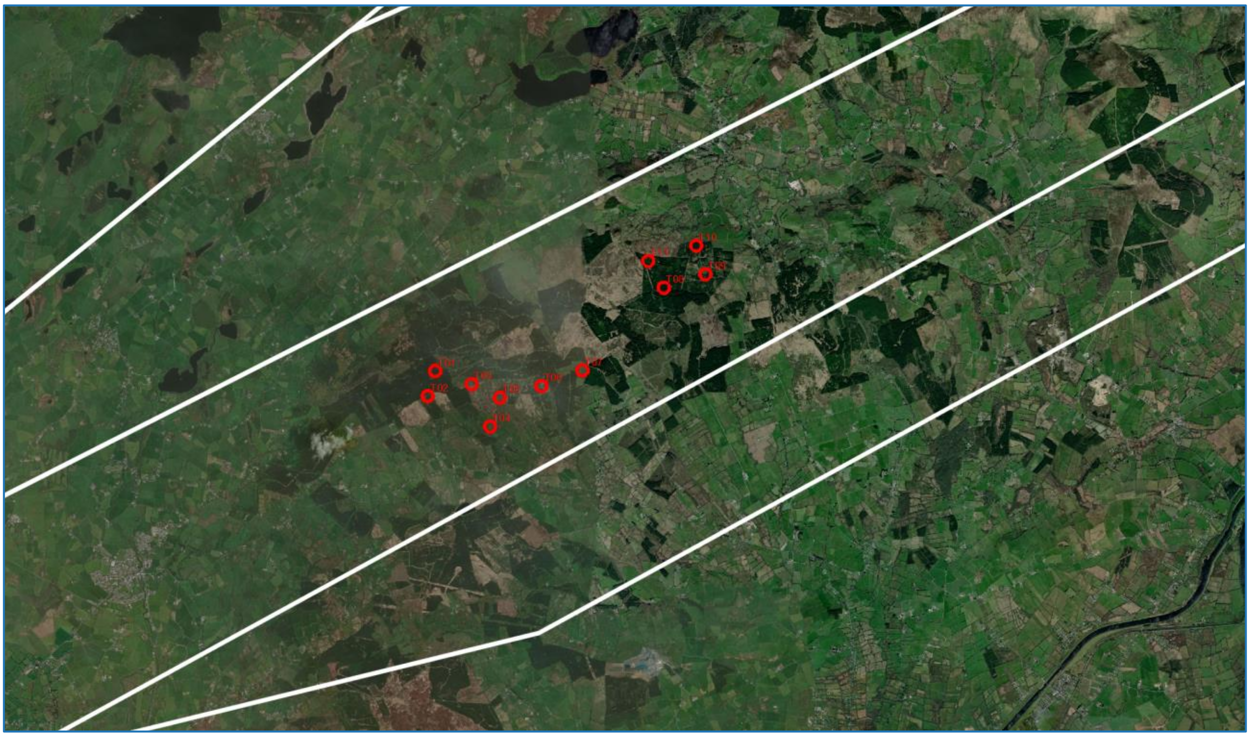

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Figure 8: SID - DIGAN3A – Windfarm Location

2.8.8. RNAV SID (TOMTO 3A) RWY 06

Parameters	
DER Position	
ID	DER
Latitude	52°42'37.24"N
Longitude	008°54'25.30"W
Altitude	4.57 m (14.99 ft)
Track	052.2 °
MOC	greater of 0.8 % or 75 m
PDG	3.3 %
Portion #1 (Turn at an Altitude)	
Turning Altitude	600 ft
Obstacles	
Number of Checked Obstacles	11

Table 26: SID - RWY 06 - TOMTO3A - Turn Area - Obstacle Assessment

11 obstacles and terrain points were checked. The 11 most controlling obstacles are listed in the following table.

Name	**Latitude**	**Longitude**	**Alt. (m)**	**Area**	**Dr (m)**	**Do (m)**	**MOC req. (m)**	**Ac. alt. (ft)**	**Alt. req. (ft)**	**PDG (%)**	**CTRL?**
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	5253.8	9559.8	118.5	1635.0	1798.4	3.9	Yes
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	5253.8	9856.3	120.9	1667.1	1833.8	3.9	Yes
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	5253.8	10279.8	124.3	1713.0	1792.9	3.6	Yes
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	5253.8	10600.2	126.8	1747.7	1724.0	3.3	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	5253.8	11999.4	138.0	1899.1	1810.5	3.1	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	5253.8	11290.5	132.4	1822.4	1713.1	3.1	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	5253.8	10270.6	124.2	1712.0	1592.0	3.0	No
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	5253.8	13733.3	151.9	2086.9	1820.2	2.8	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	5253.8	13758.1	152.1	2089.6	1724.6	2.5	No
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	5253.8	14459.0	157.7	2165.4	1743.3	2.5	No
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	5253.8	14535.5	158.3	2173.7	1730.9	2.4	No

Table 27: SID - RWY 06 - TOMTO3A - Turn Area - Obstacle Assessment - Checked Obstacles

As indicated in Table 27, the turbines have an impact on the procedure, which results in a higher PDG than the standard obstacle clearance PDG of 3.3%.

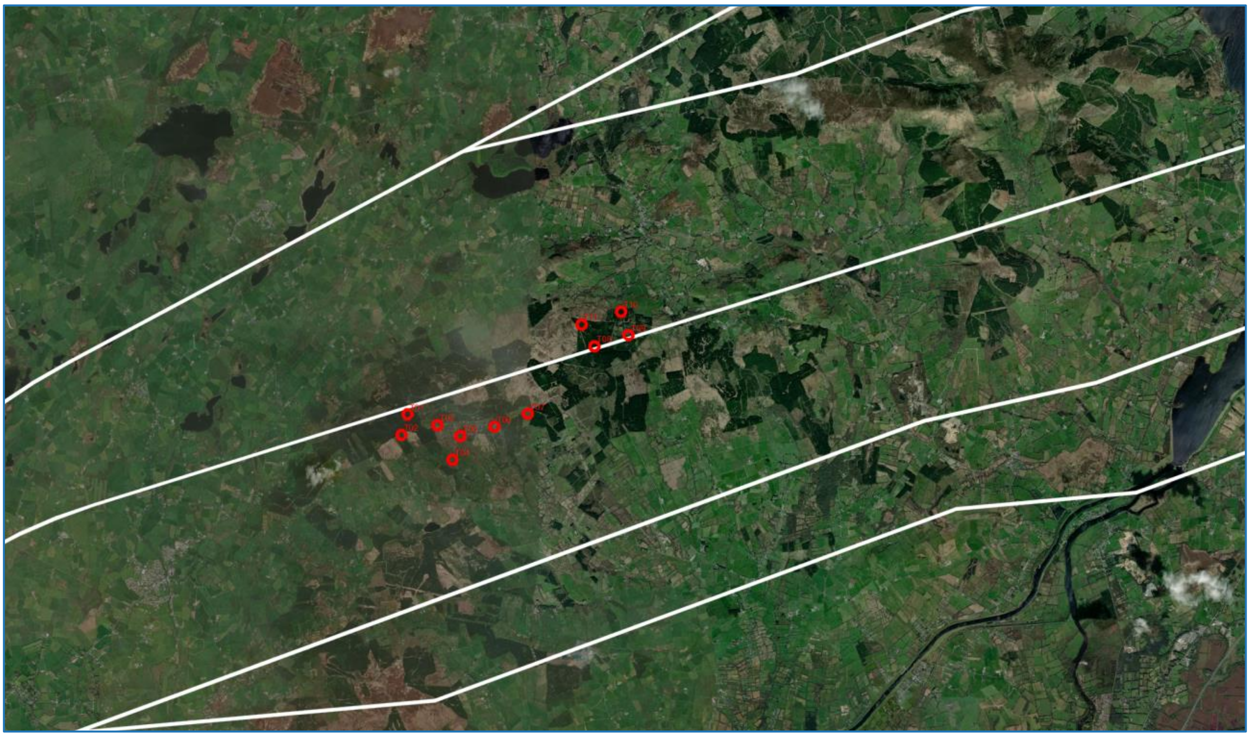

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Figure 9: SID - TOMTO3A – Windfarm Location

2.8.9. RNAV SID (ABAGU 3A) RWY 06

DER	
Latitude	52°42'37.24"N
Longitude	008°54'25.30"W
Altitude	4.57 m (14.99 ft)
Parameters	
Track	052.13 °
MOC	0.8 %
Minimum MOC	75 m
PDG	3.3 %
Turning Altitude	600 ft
Distance DER->TP [Dr]	5251.82 m

Table 28: SID – RWY 06 ABAG3A - Turn Area - Obstacle Assessment

8 obstacles and terrain points were checked. The 8 most controlling obstacles are listed in the following table.

Name	Latitude	Longitude	Alt. (m)	Area	Dr (m)	Do (m)	MOC req. (m)	Ac. alt. (ft)	Alt. req. (ft)	PDG (%)	Controlling
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	5251.8	9559.9	118.5	1635.0	1798.4	3.9	Yes
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	5251.8	9856.4	120.9	1667.1	1833.7	3.9	Yes
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	5251.8	10279.9	124.3	1713.0	1792.8	3.6	Yes
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	5251.8	10600.2	126.8	1747.7	1724.0	3.3	No
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	5251.8	11999.4	138.0	1899.2	1810.4	3.1	No
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	5251.8	11290.6	132.3	1822.4	1713.1	3.1	No
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	5251.8	10270.6	124.2	1712.0	1592.0	3.0	No
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	5251.8	13758.1	152.1	2089.6	1724.5	2.5	No

Table 29: SID - RWY 06 - ABAGU3A - Turn Area - Checked Obstacles

As indicated in Table 29, the turbines have an impact on the procedure, which results in a higher PDG than the standard obstacle clearance PDG of 3.3%.

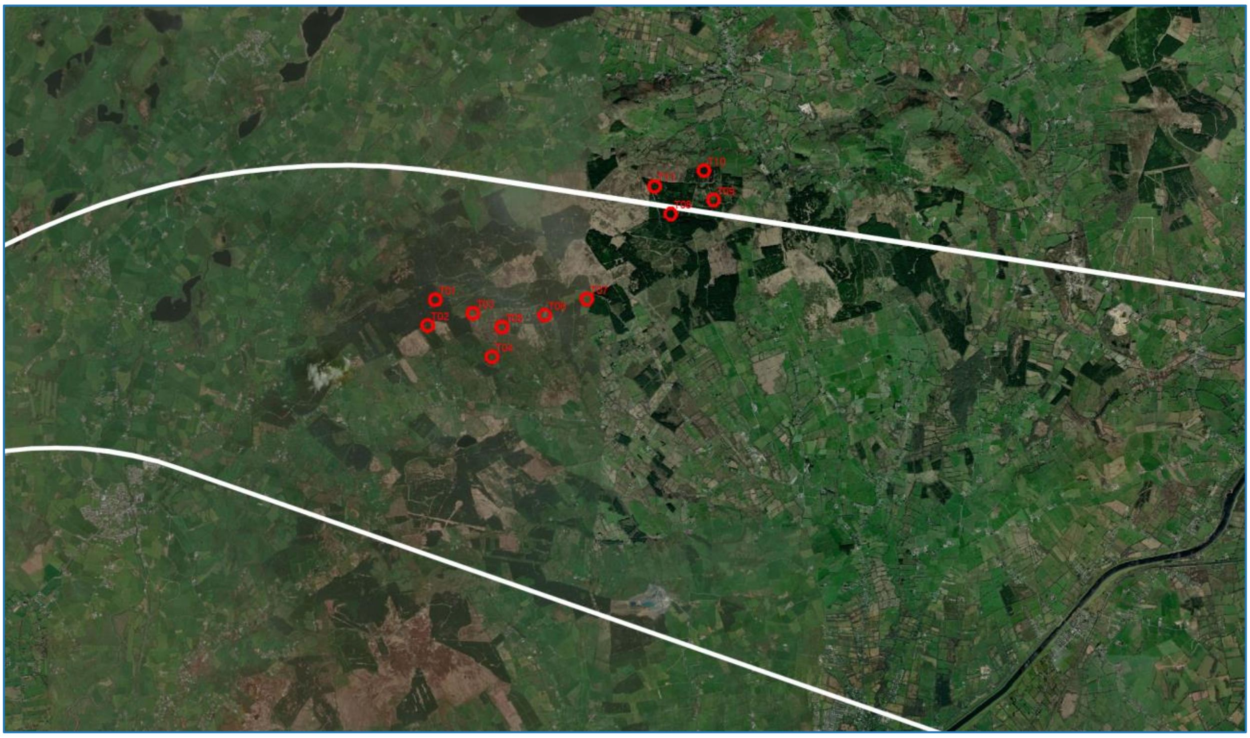

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Figure 10: SID - ABAGU3A – Windfarm Location

2.8.10. IAP – ILS Runway 24

The turbines fall within the Initial approach Base turns, which have a lowest altitude of 3000ft and the Intermediate approach which has a Missed Approach Climb Gradient (MACG) of 2500ft.

General	
Primary MOC	300 m
Obstacles	
Number of Checked Obstacles	11

Table 30: ILS CAT I & II RWY 24 - Base Turn CAT A/B

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	N/A	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	N/A	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	N/A	300.0	2369.5
T07	52°46'16.58"N	008°40'01.18"W	413.8	Secondary	68.7	295.5	2327.3
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	N/A	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	N/A	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	N/A	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	N/A	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	N/A	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	N/A	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	Secondary	141.4	290.8	2138.8

Table 31: ILS CAT I & II RWY 24 - Base Turn CAT A/B - Checked Obstacles

As indicated in Table 31, the turbines do not impact the procedure.

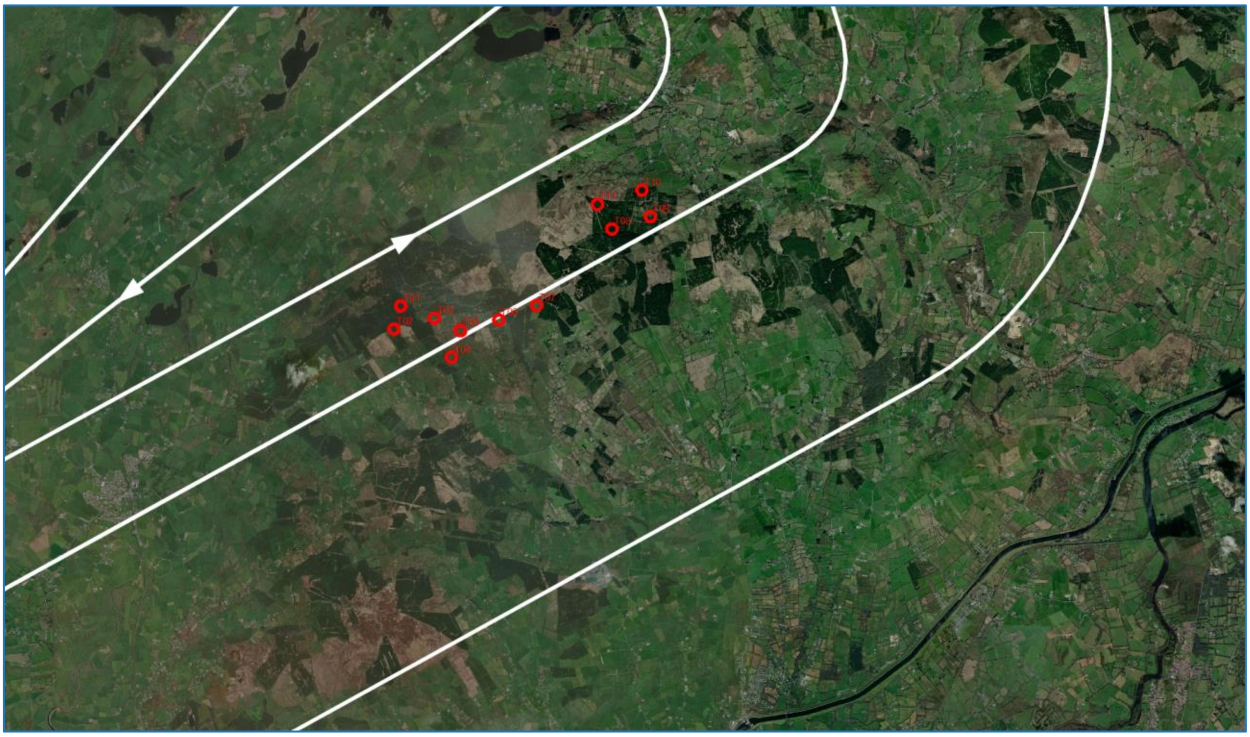

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Figure 11: ILS/LOC RWY 24 - Base Turn CAT AB – Windfarm Location

General	
Primary MOC	300 m
Obstacles	
Number of Checked Obstacles	11

Table 32: ILS CAT I & II RWY 24 - Base Turn CAT CD

Name	Latitude	Longitude	Alt. (m)	Area	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	300.0	2369.5
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	300.0	2341.9
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	300.0	2168.8

Table 33: ILS CAT I & II RWY 24 - Base Turn CAT CD - Checked Obstacles

In indicated in Table 33, the turbines do not impact the procedure.

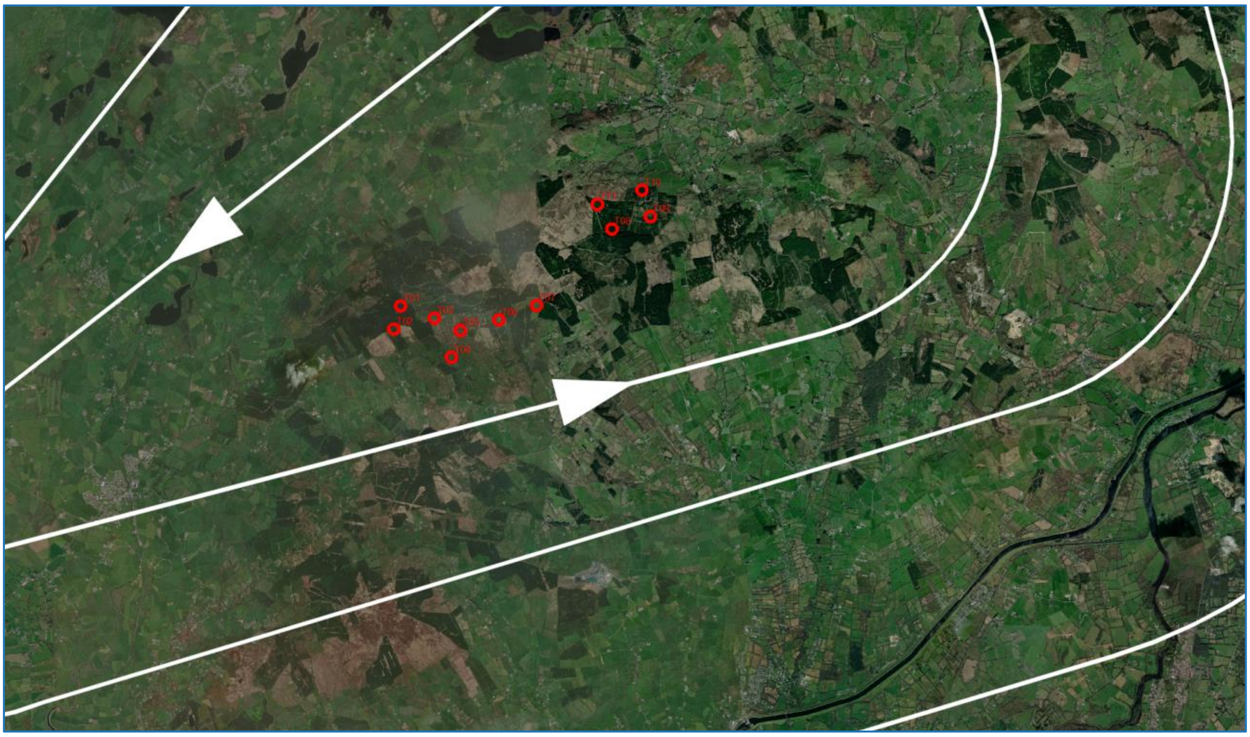

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Figure 12: ILS/LOC RWY 24 - Base Turn CAT CD – Windfarm Location

General	
Primary MOC	150 m
Obstacles	
Number of Checked Obstacles	2

Table 34: ILS RWY 24_Intermediate Approach - General

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	MOC applied (m)	OCA (ft)
T11	52°47'13.69"N	008°39'03.98"W	402.9	Secondary	856.3	14.3	1368.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	Secondary	978.3	31.7	1315.7

Table 35: ILS RWY 24_Intermediate Approach - Checked Obstacles

As indicated in Table 35, the turbines do not impact the procedure.

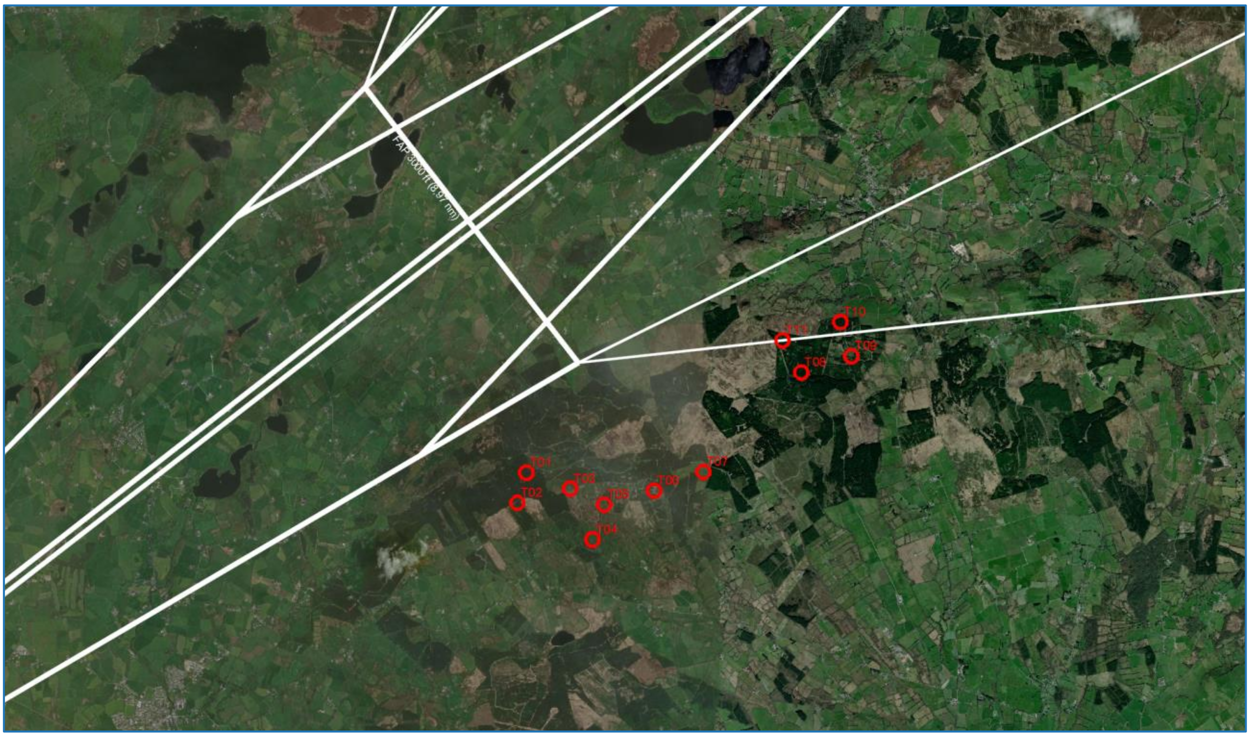

Figure 13: ILS/LOC RWY 24 – Intermediate Approach – Windfarm Location

2.8.11. IAP – LOC Runway 24

The turbines fall within the Initial approach for the procedure. The Initial approach via base turn is common to the ILS RWY 24 procedure and is reported on in section 2.8.10 above.

2.8.12. IAP – VOR Runway 24

The Turbines fall within the Initial approach (base turn) for CAT A/B and C/D, which have a lowest altitude of 3000ft, the initial approach segment, and the final approach segment for the procedure.

General	
Primary MOC	300 m
Obstacles	
Number of Checked Obstacles	11

Table 36: VOR RWY 24 - Base Turn CAT AB

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	N/A	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	N/A	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	N/A	300.0	2369.5
T07	52°46'16.58"N	008°40'01.18"W	413.8	Secondary	68.7	295.5	2327.3
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	N/A	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	N/A	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	N/A	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	N/A	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	N/A	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	N/A	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	Secondary	141.4	290.8	2138.8

Table 37: VOR RWY 24 - Base Turn CAT AB - Checked Obstacles

As indicated in Table 37, the turbines do not impact the procedure.

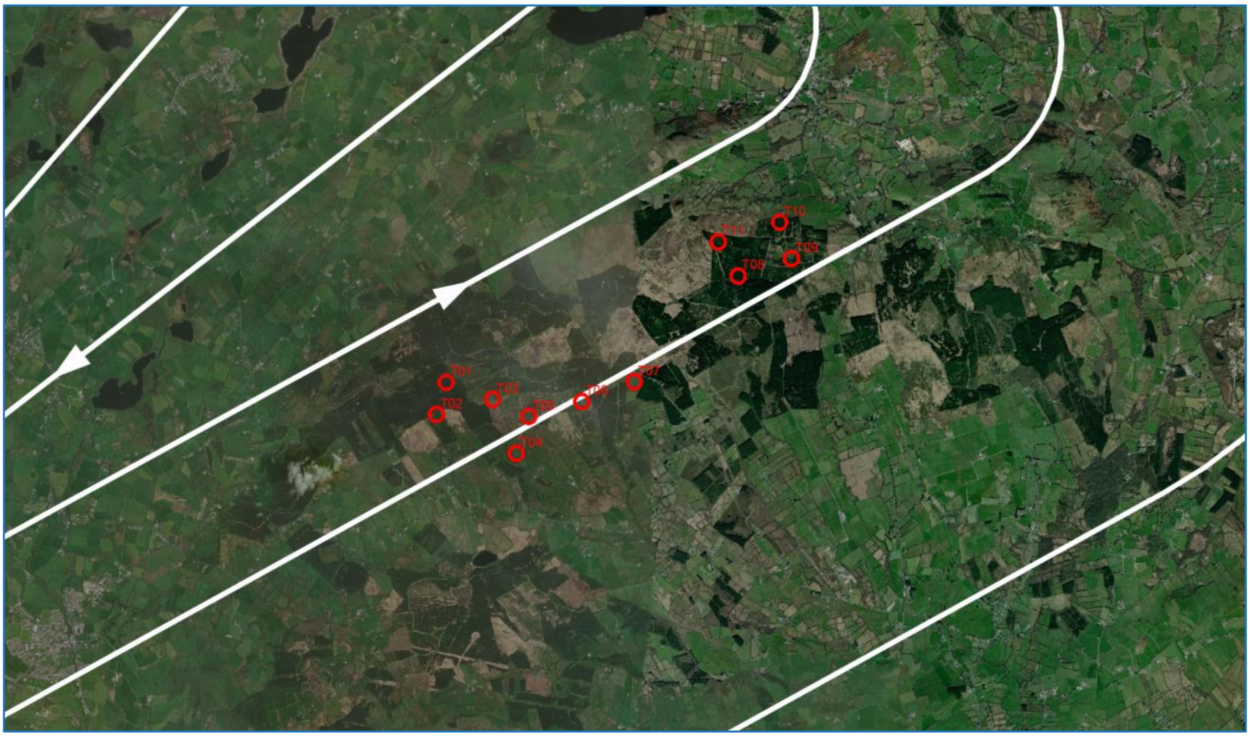

Figure 14: VOR RWY 24 - Base Turn CAT AB – Windfarm Location

General	
Primary MOC	300 m
Obstacles	
Number of Checked Obstacles	11

Table 38: VOR RWY 24 - Base Turn CAT CD - General

Name	Latitude	Longitude	Alt. (m)	Area	MOC applied (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Primary	300.0	2421.5
T02	52°46'03.55"N	008°42'14.82"W	429.7	Primary	300.0	2393.9
T03	52°46'09.63"N	008°41'36.88"W	422.2	Primary	300.0	2369.5
T07	52°46'16.58"N	008°40'01.18"W	413.8	Primary	300.0	2341.9
T11	52°47'13.69"N	008°39'03.98"W	402.9	Primary	300.0	2306.2
T05	52°46'02.55"N	008°41'12.55"W	398.7	Primary	300.0	2292.2
T06	52°46'08.52"N	008°40'36.64"W	389.8	Primary	300.0	2263.2
T09	52°47'06.61"N	008°38'14.57"W	373.7	Primary	300.0	2210.2
T08	52°46'59.65"N	008°38'50.59"W	373.6	Primary	300.0	2209.9
T10	52°47'21.58"N	008°38'22.42"W	369.3	Primary	300.0	2195.8
T04	52°45'47.43"N	008°41'21.06"W	361.1	Primary	300.0	2168.8

Table 39: VOR RWY 24 - Base Turn CAT CD - Checked Obstacles

As indicated in Table 39, the turbines do not impact the procedure.

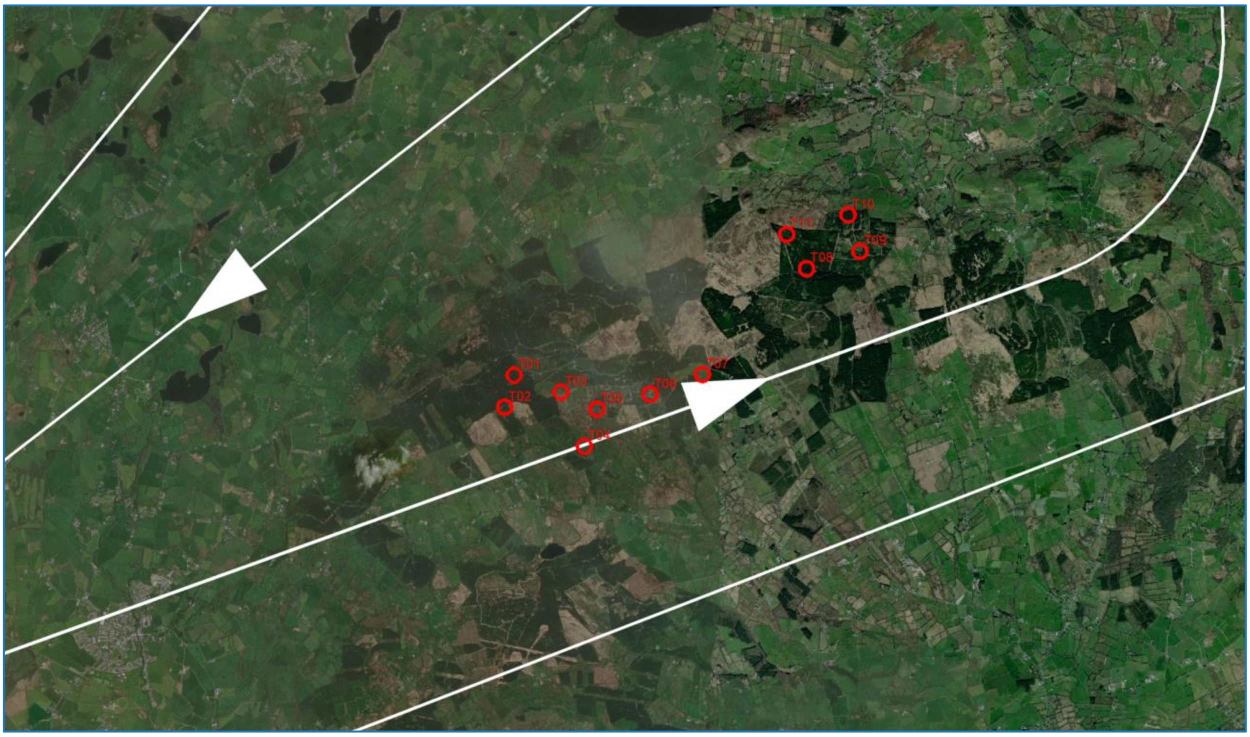

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Figure 15: VOR RWY 24 - Base Turn CAT CD – Windfarm Location

General	
Primary MOC	150 m
Obstacles	
Number of Checked Obstacles	4

Table 40: VOR RWY 24 – Intermediate Approach

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	MOC (m)	MOCA (ft)
T11	52°47'13.69"N	008°39'03.98"W	402.9	Secondary	1352.4	59.4	1516.6
T10	52°47'21.58"N	008°38'22.42"W	369.3	Secondary	1465.7	58.3	1402.6
T09	52°47'06.61"N	008°38'14.57"W	373.7	Secondary	1946.7	27.5	1316.1
T08	52°46'59.65"N	008°38'50.59"W	373.6	Secondary	1851.7	26.3	1312.0

Table 41: VOR RWY 24 - Intermediate Approach - Checked Obstacles

As indicated in Table 41, the turbines do not impact the procedure.

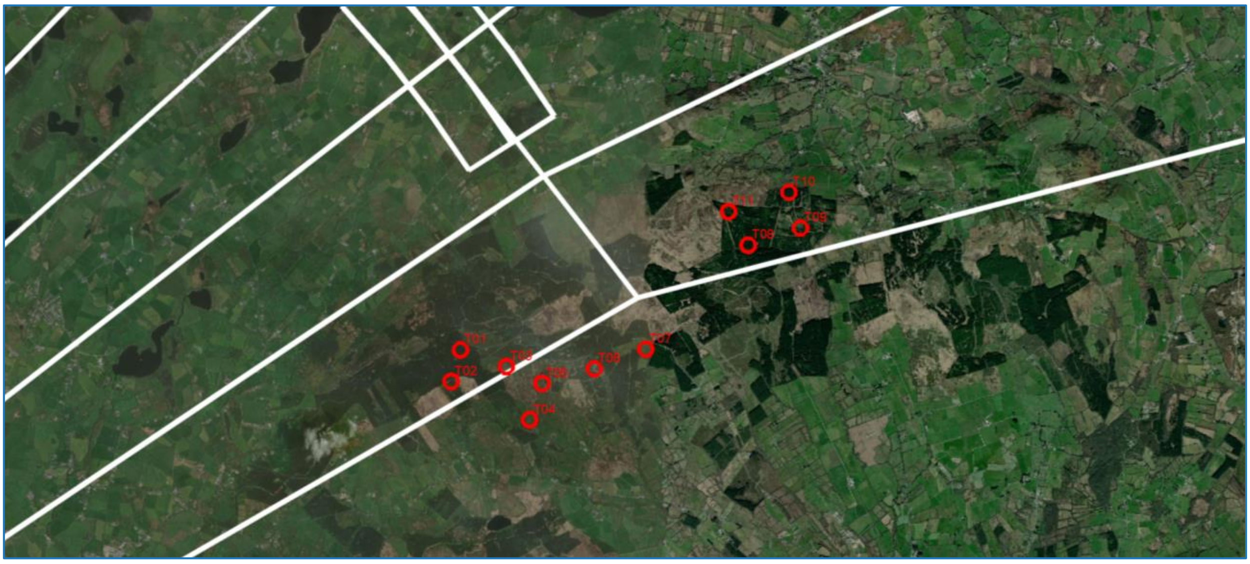

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Figure 16: VOR RWY 24 – Intermediate Approach – Windfarm Location

General	
Primary MOC	75 m
Obstacles	
Number of Checked Obstacles	3

Table 42: VOR RWY 24 - Final Approach

Name	Latitude	Longitude	Alt. (m)	Area	Dist. in (m)	MOC (m)	OCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Secondary	1174.7	26.7	1524.7
T02	52°46'03.55"N	008°42'14.82"W	429.7	Secondary	1443.0	14.9	1458.6
T03	52°46'09.63"N	008°41'36.88"W	422.2	Secondary	1679.8	6.8	1407.6

Table 43: VOR RWY 24 - Final Approach - Checked Obstacles

As indicated in Table 43, the turbines have an impact on the procedure and raises the currently published MOCA by 260ft from 1270ft to **1530ft**.

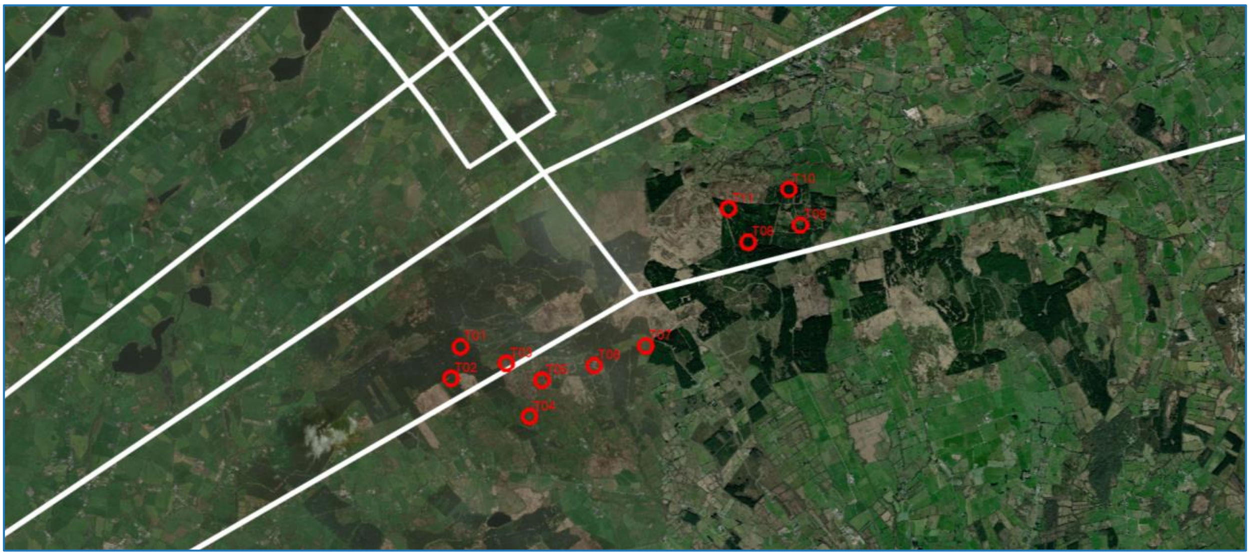

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Figure 17: VOR RWY 24 - Final Approach – Windfarm Location

2.8.13. ATC Surveillance Minimum Altitude Chart

The ATC Surveillance Minimum Chart consists of four sectors. The turbines fall within Sector 1 **(2300ft)** and Sector 2 **(3000ft)** areas of the ATCSMAC. A 3 NM buffer has been incorporated to account for turbines located within 3 NM of the area boundary.

A temperature correction factor has been used to determine the Minimum Obstacle Clearance[6].

- The cold temperature AIP EINN AD 2.24-16 (0°C)
- Aerodrome elevations as published in the AIP EINN AD 2.2.3 (46 ft AMSL)
- Height Above the Altimeter Setting Source, published MOCA used.

Parameters	
Aerodrome Minimum Temperature	0 °C
Aerodrome Elevation	46 ft
Altimeter Setting Source Elevation	46 ft
Height Above the Altimeter Setting Source	2300 ft
Results	
Approximate Correction	40.97 m / 134.42 ft
Linear Standard Correction	40.97 m / 134.42 ft
Off-standard Accurate Correction	35.84 m / 117.57 ft

Table 44: Temperature Correction Calculation - 2300 ft

Parameters	
Aerodrome Minimum Temperature	0 °C
Aerodrome Elevation	46 ft
Altimeter Setting Source Elevation	46 ft
Height Above the Altimeter Setting Source	3000 ft
Results	
Approximate Correction	53.69 m / 176.16 ft
Linear Standard Correction	49.7 m / 163.04 ft
Off-standard Accurate Correction	47.08 m / 154.46 ft

Table 45: Temperature Correction Calculation- 3000 ft

General	
Primary MOC	335.84 m
Obstacles	
Number of Checked Obstacles	11

Table 46: ATCSMAC Sector 1

Name	Latitude	Longitude	Alt. (m)	Area	MOC applied (m)	MOCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	Sector 1	335.8	2539.1
T02	52°46'03.55"N	008°42'14.82"W	429.7	3NM Buffer	335.8	2511.5
T03	52°46'09.63"N	008°41'36.88"W	422.2	Sector 1	335.8	2487.1

[6] Cyrrus is aware that Ireland applies an adjustment for temperature correction. Assessments based on the cold temperature correction are for the airport and regulatory authority to inspect with reference to the information available to us at the time of issuing this report.

T07	52°46'16.58"N	008°40'01.18"W	413.8	Sector 1	335.8	2459.5
T11	52°47'13.69"N	008°39'03.98"W	402.9	3NM Buffer	335.8	2423.7
T05	52°46'02.55"N	008°41'12.55"W	398.7	Sector 1	335.8	2409.8
T06	52°46'08.52"N	008°40'36.64"W	389.8	Sector 1	335.8	2380.8
T09	52°47'06.61"N	008°38'14.57"W	373.7	3NM Buffer	335.8	2327.8
T08	52°46'59.65"N	008°38'50.59"W	373.6	3NM Buffer	335.8	2327.4
T10	52°47'21.58"N	008°38'22.42"W	369.3	3NM Buffer	335.8	2313.3
T04	52°45'47.43"N	008°41'21.06"W	361.1	Sector 1	335.8	2286.4

Table 47: ATCSMAC Sector 1 - Checked Obstacles

As indicated in Table 47, the MOCA is 2539.1 ft rounded to 2600 ft. The currently published MOCA is 2300 ft therefore the turbines have an impact on the procedure and raises the published minima for Sector 1 by 300ft from 2300ft to **2600ft.**

General	
Primary MOC	347.08 m
Obstacles	
Number of Checked Obstacles	11

Table 48: ATCSMAC Sector 2

Name	Latitude	Longitude	Alt. (m)	Area	MOC applied (m)	MOCA (ft)
T01	52°46'16.59"N	008°42'08.31"W	438.1	3NM Buffer	347.1	2575.9
T02	52°46'03.55"N	008°42'14.82"W	429.7	3NM Buffer	347.1	2548.4
T03	52°46'09.63"N	008°41'36.88"W	422.2	3NM Buffer	347.1	2523.9
T07	52°46'16.58"N	008°40'01.18"W	413.8	3NM Buffer	347.1	2496.4
T11	52°47'13.69"N	008°39'03.98"W	402.9	Sector 2	347.1	2460.6
T05	52°46'02.55"N	008°41'12.55"W	398.7	3NM Buffer	347.1	2446.7
T06	52°46'08.52"N	008°40'36.64"W	389.8	3NM Buffer	347.1	2417.6
T09	52°47'06.61"N	008°38'14.57"W	373.7	Sector 2	347.1	2364.6
T08	52°46'59.65"N	008°38'50.59"W	373.6	Sector 2	347.1	2364.3
T10	52°47'21.58"N	008°38'22.42"W	369.3	Sector 2	347.1	2350.2
T04	52°45'47.43"N	008°41'21.06"W	361.1	3NM Buffer	347.1	2323.3

Table 49: ATCSMAC Sector 2 - Checked Obstacles

As indicated in Table 49, the MOCA is 2575.9 ft rounded to 2600 ft. The currently published minima is 3000 ft therefore the turbines have no impact on the procedure.

Figure 18: ATC Surveillance Minimum Altitude Chart - Windfarm Location

3. Conclusion

The assessment has been carried out against the proposed windfarm development approximately 8.96 NM northeast from Shannon ARP.

The assessment has determined that the proposed windfarm does impact the currently published IFPs for Shannon Airport.

Mitigation Options

The mitigation options listed below are for the Airport to consider, this will be subject to their Safety Management System (SMS) requirements and the commercial benefit of accepting the mitigation.

1. Raise the applicable MOCA or PDG of the affected procedures, this option will be for the airport to consider.

    a. SIDS (TOMTO3A, DIGAN3A, ABAGU3A) RWY06, increase the obstacle clearance PDG from 3.3% to 3.9%

    b. ILS OR LOC RWY 06, impact to the ILS CAT I MACG, increase in Obstacle Clearance Altitude / Height (OCA/H) required, or redesign of ILS procedure to include OCA/H for a 2.5% MACG and 3.0% MACG.

    c. VOR RWY 24, Final Approach, increase MOCA from 1270ft to 1530ft, an additional Step-down fix (SDF) may be required to prevent an increase to the final approach gradient.

    d. ATCSMAC increase Sector 1 Minimum Vectoring Altitude (MVA) from 2300ft to 2600ft, or redesign the ATCSMAC to reduce the size of Sector 1 but keep the remaining Sector 1 area at the existing 2300ft MVA.

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Appendix 2

Mitigation Options Study Oatfield Windfarm

Mitigation Options Study

Oatfield Windfarm

AI Bridges Ltd

[Date] 24 May 2024

CL-6049-RPT-002v 1.1

www.cyrrus.co.uk

info@cyrrus.co.uk

British Assessment Bureau UKAS MANAGEMENT SYSTEMS 8289 ISO 9001 QUALITY MANAGEMENT

British Assessment Bureau UKAS MANAGEMENT SYSTEMS 8289 ISO 14001 ENVIRONMENTAL MANAGEMENT

Document Information

Document title	Mitigation Options Study
Author	Kevin Sissons
Reviewed by	Project Manager Name
Produced by	Cyrrus Limited Cyrrus House Concept Business Court Allendale Road Thirsk North Yorkshire YO7 3NY T: +44 (0) 1845 522 585 F: +44 (0) 8707 622 325 E: info@cyrrus.co.uk W: www.cyrrus.co.uk
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1.0	Initial Issue	23 May 2024	Initial Issue
1.1	Minor correction	24 May 2024	Amendment 1

Executive Summary

Cyrrus have been requested by AI Bridges to provide a Radar Assessment of the Shannon PSR and MSSR also for the Woodcock Hill MSSR for the Oatfield Windfarm proposal. Radar Line of Sight assessments have been carried out which confirm both the Shannon Airport Primary Surveillance Radar and Woodcock Hill Monopulse Secondary Surveillance Radar have Radar Line of Sight with the proposed Windfarm. More recently, the IAA have raised the issue of radar performance degradation in the area beyond the Windfarm.

The IAA have made a request for a detailed technical Impact Assessment. Previously they had raised a number of concerns in relation to other proposed wind farm developments in the area which are in the planning process.

- A deeper assessment of impacts is required and has previously been completed for another developer, on this site. This said, AirNav are not satisfied with previous reports received.
- While the Ai Bridges Report references other facilities that have applied mitigations, these are not in our opinion Enroute (High-Level) Radar facilities, which in this case Woodcock Hill MSSR is. Significant impacts would be expected on high-level traffic, in the altitude range 10,000 feet to 35,000 feet, which would not be acceptable to AirNav Ireland.

This report aims to address the issues of Beam deflection, reflections, shadowing and enroute radar performance degradation. Currently NATS in their enroute radars and most international Airport radar systems include mitigation to prevent these issues affecting operational use.

Primary Surveillance Radar (PSR)

The Shannon Airport radar is a Thales STAR2000 Primary Radar with co-mounted Thales RSM970 Monopulse Secondary Radar. Primary Radars (also known as non-cooperative sensors) work by transmitting a series of pulses which are reflected back and received by the Radar. Within the Radar the Surveillance Data Processor uses the timing between the pulse being transmitted and received to calculate the distance to the target. Also within the Radars processing are algorithms which calculate the time between target returns and use this to eliminate stationary objects. This is a very simplistic explanation as every manufacturer's Surveillance Data Processing system will vary with a multitude of possible parameters.

Wind turbines can cause Primary Radars problems as the processing algorithms used can see the turbine blades as moving targets and display them as clutter. Modern Surveillance Data Processing systems can use advanced techniques to prevent the clutter from the Wind turbines from being displayed. Thales have developed a suite of upgrades for the STAR2000 radar, as sited at Shannon Airport, which if required could be implemented to enhance its surveillance capabilities in areas with a high number of wind turbines.

Monopulse Secondary Surveillance Radar (MSSR)

MSSR (also known as cooperative sensors) work by transmitting a series of pulses to the Aircraft. The Aircraft will receive these pulses using a transponder. The transponder will then decode this series of pulses and transmit a response on a separate frequency. The Radar will receive this response and use the information in the Surveillance Data Processor to display the aircraft position, height etc for the Air Traffic Controller to use. As MSSR system require two frequencies to operate, they are not as vulnerable to problems from the wind turbines.

IAA Concerns

The IAA have a legitimate concern that reflections caused by the turbines will degrade the radars ability to accurately plot aircraft in the area above and behind the windfarm. It is agreed turbines can cause reflections to be received by the Woodcock Hill MSSR. The radar is a Thales RSM970 MSSR which utilises two stage reflection processing to eliminate this problem. The Thales technical description provided confirms this and that the radar can operate safely in areas with a high number of reflections.

Another concern that IAA have recently raised in relation to wind farms in the area is that Beam deflection can take place on the Woodcock Hill MSSR. Having investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated in Time (FRUIT). The SDP within the Woodcock Hill MSSR will use a De-FRUITER to remove these false targets. This technique is used in most MSSR systems including the Thales RSM970 radar used at Woodcock Hill.

A third concern documented by the IAA is that of shadowing. Having investigated shadowing with respect to windfarms, CAP670 SUR13A.68 references trials where aircraft were flown behind a windfarm to determine the effect. They concluded that the shadowed area would be minimal (usually <200m) and only affect very low-level cover, this should be operationally tolerable in most cases.

Recently the IAA have raised a specific concern relating to the Enroute (HighLevel) radar coverage from the Woodcock Hill MSSR. This degradation to the enroute radar performance may be caused by the windfarm has also been addressed.

There are some common problems which can occur when wind turbines are sited near to radars. Table 1 below uses a traffic light system to highlight the mitigation available for the Shannon Airport and Woodcock Hill radars which should allow them to operate alongside the proposed Oatfield windfarm.

Issue	Mitigation	Operationally Acceptable
	Shannon Airport MSSR	Y / N
Reflections	The Thales RSM970 MSSR Sited at Shannon Airport is 17.34 km from the nearest wind turbine. Eurocontrol recommend that MSSR systems should be assessed if turbines are within 16 km of the radar. The fact Shannon Airports MSSR is outside the assessment zone, along with the evidence that the Thales system has inbuilt adaptive reflection processing, referenced in The Thales RSM970 MSSR Technical Description Document[2] , gives assurance the radar	Y

	can work alongside the wind turbines. The radar utilises a two-stage system to remove both temporary (Dynamic) and permanent (Static) reflections from the system.	
Deflections	Although no assessment is necessary, The Thales RSM970 MSSR uses a well-established processing system to remove any False Replies Unsynchronised In Time (FRUIT). This process removes the issue of deflections from the system.	Y
Shadowing	The Shannon Airport radar is beyond the Eurocontrol wind turbine assessment zone. Any Shadowing from the Turbines would be minimal and have no Operational effect.	Y
Woodcock Hill MSSR		
Reflections	The Thales RSM970 MSSR Sited at Woodcock Hill is 4.85 km from the nearest wind turbine. The Thales radar utilises a two-stage system to prevent both temporary (Dynamic) and permanent (Static) reflections being displayed. It also has inbuilt adaptive reflection processing. This is referenced in The Thales RSM970 MSSR Technical Description Document[2]. To prevent possible reflection issues, some minor optimisation may be required. This is usually carried out as part of the scheduled maintenance of the equipment.	Y
Deflections	The Thales RSM970 MSSR uses a well-established processing system to remove any False Replies Unsynchronised In Time (FRUIT). This process removes the issue of deflections from the system. No additional optimisation is required as a DEFRUITER is part of the standard MSSR processing on the Thales system.	Y
Shadowing	Due to the close proximity of the Turbines to the Woodcock Hill radar, some shadowing will occur. Trials have shown any shadowing behind the windfarm would be minimal and be operationally tolerable.	Y
Enroute Degradation	As the area affected is immediately behind the windfarm and only at very low levels, there will be no degradation to the enroute performance of the radar.	Y
Shannon Airport PSR		
Clutter caused by turbine blades	The Shannon Airport Thales STAR2000 radar was designed to operate in areas with wind turbines. Over the last 10-years, several improvements have been made to the processing systems used to prevent unacceptable clutter being caused by wind turbines. Some optimisation of the current radar may be required. This should be assessed by Thales	Y

	and, if required, they can provide a series of staged upgrades to address this issue.	
Desensitisation of radar	As above, Thales could assess if optimisation or upgrades would be required to address any desensitisation issues.	Y

Since 2021, Cyrrus have worked on several projects involving Thales STAR2000 Primary Surveillance Radars. The STAR2000 as used at Shannon Airport is a solid-state S-band radar designed to be windfarm tolerant. Thales has completed several dedicated impact studies of STAR2000 systems working successfully in areas with multiple wind turbines.

Cyrrus recommend that a condition survey be carried out on the Shannon Airport STAR2000 radar system to confirm its suitability to provide an operationally acceptable radar picture once the turbines are built. The survey would provide an opportunity to clarify and formally define the ATC User Requirements for the associated Airspace.

The radar mitigation solution may not require an upgrade. Thales may determine the existing radars capability includes sufficient wind turbine filtering. If required system optimisation or upgrades are available to maximise the radars ability to comply with the ATC User Requirement. Thales has a suite of upgrade packages ranging from simple software updates to full system refresh's depending on the systems current configuration.

Due to the radar's modular system architecture, if upgrades are required on the Shannon Airport Primary Surveillance Radar, it is likely any downtime would be minimal. Thales have confirmed they have completed many projects of this type using tried and tested transition plans to allow the systems to remain operational throughout.

The erection of 11-wind turbines at the proposed Oatfield windfarm would have no operational impact on the Shannon Airport and Woodcock Hill MSSR systems. If upgrades are required to the Shannon Airport Primary Surveillance Radar, these should be completed before the windfarm is built. Any effect from the windfarm on the operational picture should have minimal effect. Should the Woodcock Hill radar require optimisation, this would be completed one channel at a time and allow the system to remain operational throughout.

In Summary, both the Shannon Airport and Woodcock Hill radars could Mitigate against adverse effects caused by the proposed Oatfield 11-turbine windfarm.

Sections have been included within the report outlining in-use Operational Mitigation Systems at other facilities. This information has been provided so an informed decision can be made on whether the proposed upgrades can be applied to the Radar Surveillance sensors to mitigate out the impacts Oatfield Wind Farm development.

Abbreviations

MSSR	Monopulse Secondary Surveillance Radar
NM	Nautical Miles
PSR	Primary Surveillance Radar
RDP	Radar Data Processor
RLoS	Radar Line of Sight

References

[1] CL-5715-RPT-002 V1.0 Oatfield Wind Farm Aviation Technical Assessment

[2] CAP670 Air Traffic Services Safety Requirements

[3] EUROCONTROL Specification for ATM Surveillance System Performance (Volume 1)

[4] Thales STAR2000 datasheet – 1/1/2014

Contents

List of figures

List of tables

1. Introduction

1.1. Overview

1.1.1. AI Bridges requested a Radar Assessment and Mitigations Options for Shannon Airport PSR and MSSR and Woodcock Hill MSSR, for the Oatfield Windfarm proposal. To ensure the report is robust, Radar Line of Sight checks have been completed against the turbine positions to both the Shannon Airport Thales STAR2000 PSR and Woodcock Hill Thales RSM970 MSSR radars. These are Provided in section 3.

1.2. Aim

1.2.1. This report aims to provide evidence that mitigation options are available which would allow the safe operation of the Shannon Airport and Woodcock Hill radars should the proposed Oatfield Windfarm to be developed.

1.2.2. The following sections provide evidence to address each of the concerns raised by the IAA and demonstrate that suitable Mitigation for the Oatfield Windfarm should be possible.

2. Overview

2.1. Oatfield Windfarm

2.1.1. Table 2 details the turbine positions for the Oatfield windfarm. Figure 1 shows the positions.

Turbine	Co-ordinates (WGS84)		Turbine Tip Height (AGL) (m)	Turbine Base m AOD (m)	Tip Height (AMSL)	
	Lat	Long			(m)	(ft)
T01	52° 46' 16.592"N	8° 42' 8.311"W	180	258.05	438.05	1437.17
T02	52° 46' 3.546"N	8° 42' 14.823"W	180	249.65	429.65	1409.61
T03	52° 46' 9.627"N	8° 41' 36.883"W	180	242.2	422.2	1385.17
T04	52° 45' 47.425"N	8° 41' 21.062"W	180	181.05	361.05	1184.55
T05	52° 46' 2.553"N	8° 41' 12.552"W	180	218.65	398.65	1307.91
T06	52° 46' 8.518"N	8° 40' 36.636"W	180	209.8	389.8	1278.87
T07	52° 46' 16.582"N	8° 40' 1.176"W	180	233.8	413.8	1357.61
T08	52° 46' 59.651"N	8° 38' 50.592"W	180	193.55	373.55	1225.56
T09	52° 47' 6.609"N	8° 38' 14.565"W	180	193.65	373.65	1225.89
T10	52° 47' 21.580"N	8° 38' 22.417"W	180	189.25	369.25	1211.45
T11	52° 47' 13.685"N	8° 39' 3.983"W	180	222.9	402.9	1321.85

Figure 1: Oatfield Turbine Positions

2.1.2. The windfarm is 17.75 km from the Shannon Airport Thales STAR2000 PSR with co-mounted Thales RSM970 Monopulse Secondary Surveillance Radar. Section 2.2 covers common issues which can occur when wind turbines are sited in close proximity to radars.

2.2. Common Issues

2.2.1. All radar systems can suffer from problems when working alongside windfarms. Table 3 below details the most common issues, and how they can be mitigated using the current systems.

Issue	Mitigation	Operationally Acceptable
	Shannon Airport MSSR	Y / N
Reflections	The Thales RSM970 MSSR Sited at Shannon Airport is 17.34 km from the nearest wind turbine. Eurocontrol dictate that MSSR systems should be assessed if turbines are closer than 16 km. This, along with the fact the Thales system has inbuilt adaptive reflection processing. This is referenced in The Thales RSM970 MSSR Technical Description Document[2] The radar utilises a two stage system to prevent both temporary (Dynamic) and permanent (Static) reflections being displayed.	Y
Deflections	Although no assessment is necessary, The Thales RSM970 MSSR uses a well established processing system to remove any False Replies Unsynchronised In Time (FRUIT). This process removes the issue of deflections from the system.	Y
Shadowing	The Shannon Airport radar is beyond the Eurocontrol wind turbine assessment zone. Any	Y

	Shadowing from the Turbines would be minimal and have no Operational effect.	
Woodcock Hill MSSR		
Reflections	The Thales RSM970 MSSR Sited at Woodcock Hill is 4.85 km from the nearest wind turbine. The Thales radar utilises a two-stage system to prevent both temporary (Dynamic) and permanent (Static) reflections being displayed. It also has inbuilt adaptive reflection processing. This is referenced in The Thales RSM970 MSSR Technical Description Document[2]. To prevent possible reflection issues, some minor optimisation may be required. This is usually carried out as part of the scheduled maintenance of the equipment.	Y
Deflections	The Thales RSM970 MSSR uses a well established processing system to remove any False Replies Unsynchronised In Time (FRUIT). This process removes the issue of deflections from the system. No additional optimisation is required as a DEFRUITER is part of the standard MSSR processing on the Thales system.	Y
Shadowing	Due to the close proximity of the Turbines to the Woodcock Hill radar, some shadowing will occur. A detailed assessment was completed by Cyrrus. It was considered any shadowing would be minimal and be operationally tolerable.	Y
Shannon Airport PSR		
Clutter caused by turbine blades	The Shannon Airport Thales STAR2000 radar was designed to operate in areas with wind turbines. Over the last 10-years, several improvements have been made to the processing systems used to prevent unacceptable clutter being caused by wind turbines. Some optimisations of the current radar may be required. This should be assessed by Thales and If required, they can provide a series of staged upgrades to address this issue.	Y
Desensitisation of radar	As above, Thales could assess if optimisations or upgrades would be required to address any desensitisation issues.	Y

Table 1: Radar Issues and Mitigation solutions

3. PSR

3.1. Radar LoS Shannon PSR

3.2. Shannon Airport

Figure 2: Shannon Airport PSR with co-mounted MSSR

3.2.1. Figure 3 shows the location of the Shannon Airport radar in relation to the Windfarm. The distance between the radar and the nearest turbine is 17.34 km. Therefore the Shannon Airport MSSR is beyond the 16 km assessment zone recommended by Eurocontrol [2], no assessment is required.

Figure 3: Shannon Airport t Oatfield Windfarm

3.2.2. Figure 3 shows the between the proposed Oatfield Windfarm and the Shannon Airport Thales STAR2000 PSR.

3.2.3. The magenta shading in Figure 4 illustrates the RLoS coverage from the Shannon Airport PSR with co-mounted MSSR to the turbines Tip heights of 180m AGL.

3.2.4. Although this will need to be considered, the Thales STAR2000 has the capability to operate in areas with windfarms this should be operationally tolerable.

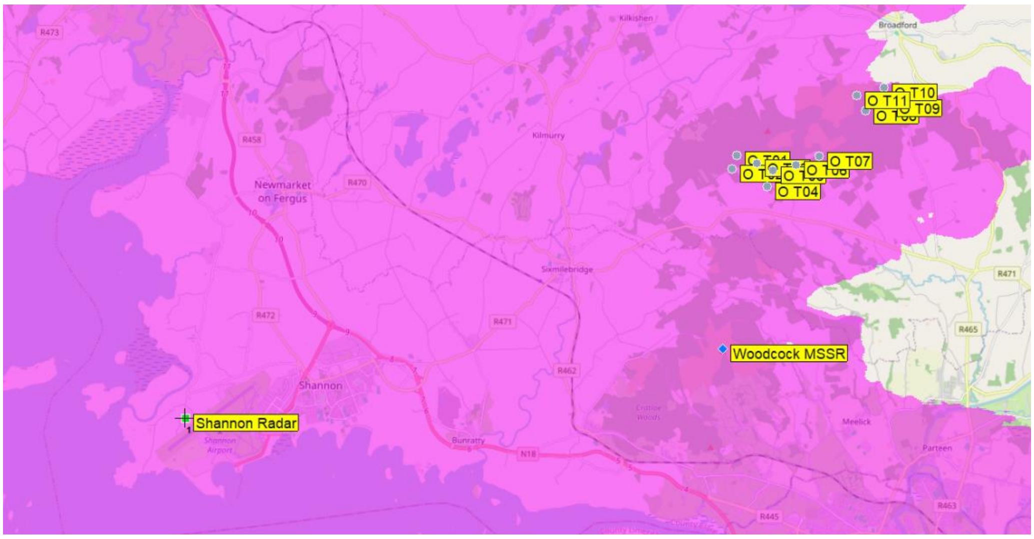

Figure 4: RLoS Map Shannon PSR / MSSR

4. MSSR

4.1. Radar LoS Woodcock Hill MSSR

4.2. Woodcock Hill MSSR

Figure 5: Woodcock Hill MSSR

4.2.1. Figure 6 shows the relation between Woodcock Hill MSSR and Oatfield Windfarm.

Figure 6: Woodcock Hill MSSR to Oatfield Windfarm

4.2.2. Figure 7 shows the RLoS between the proposed Oatfield Windfarm and the Woodcock Hill Radar.

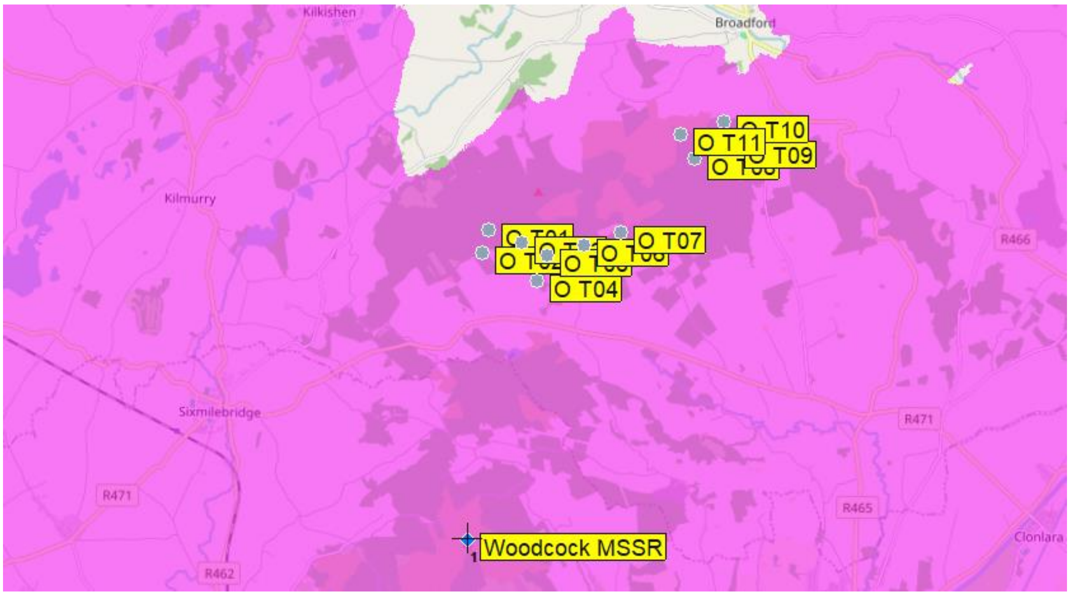

Figure 7: RLoS Map Woodcock Hill MSSR

4.2.3. The magenta shading illustrates the RLoS coverage from the Woodcock Hill MSSR to the turbines tip height of 180m AGL.

4.2.4. Although this will need to be considered, as the Thales RSM970 has the capability to operate in areas with windfarms this should be operationally tolerable.

4.3. Path Loss

4.3.1. Figures 8 – 11 below contain the path Loss results for the Woodcock Hill MSSR to the proposed Oatfield turbines.

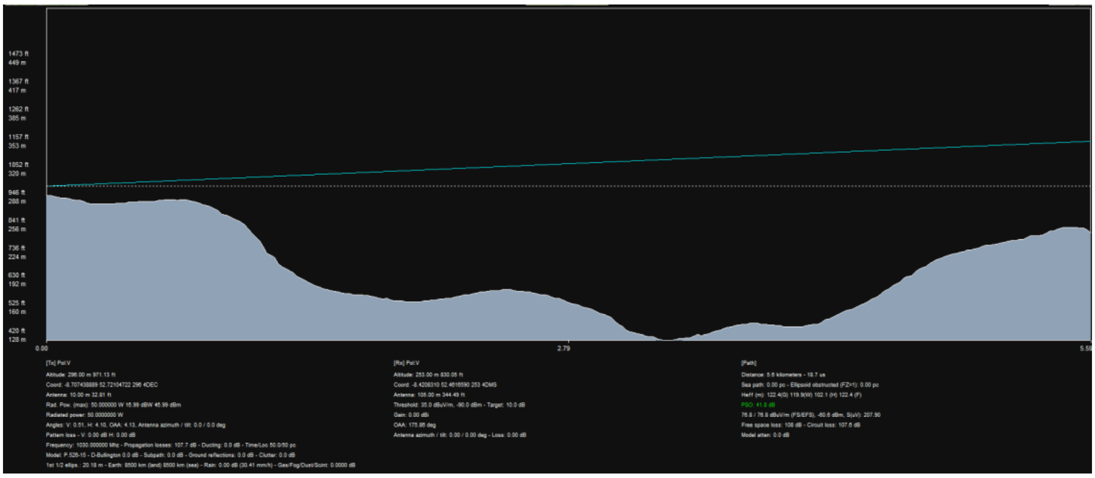

Figure 8: Pathloss Turbine 1

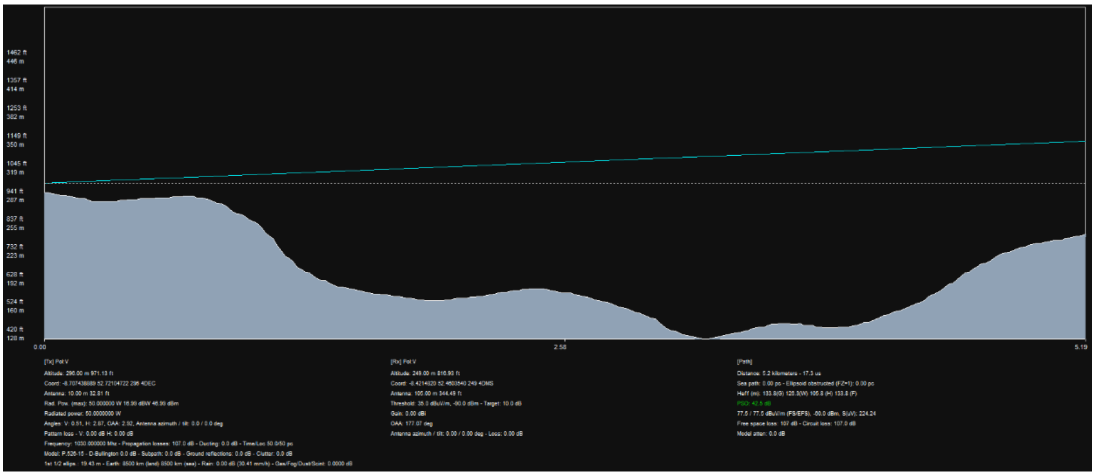

Figure 9:Pathloss Turbine 2

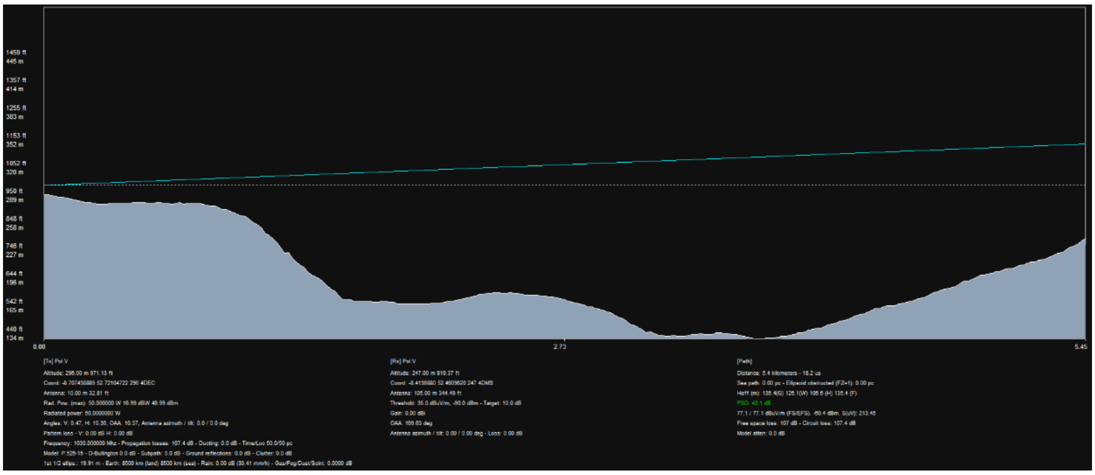

Figure 10: Pathloss Turbine 3

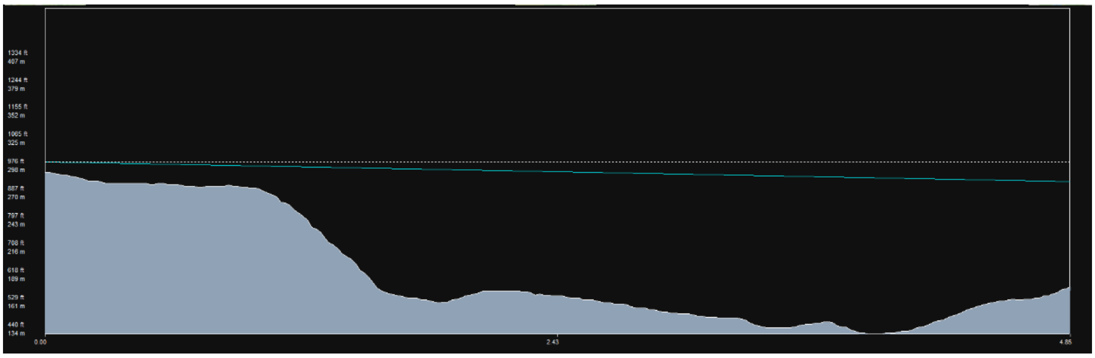

Figure 11: Pathloss Turbine 4

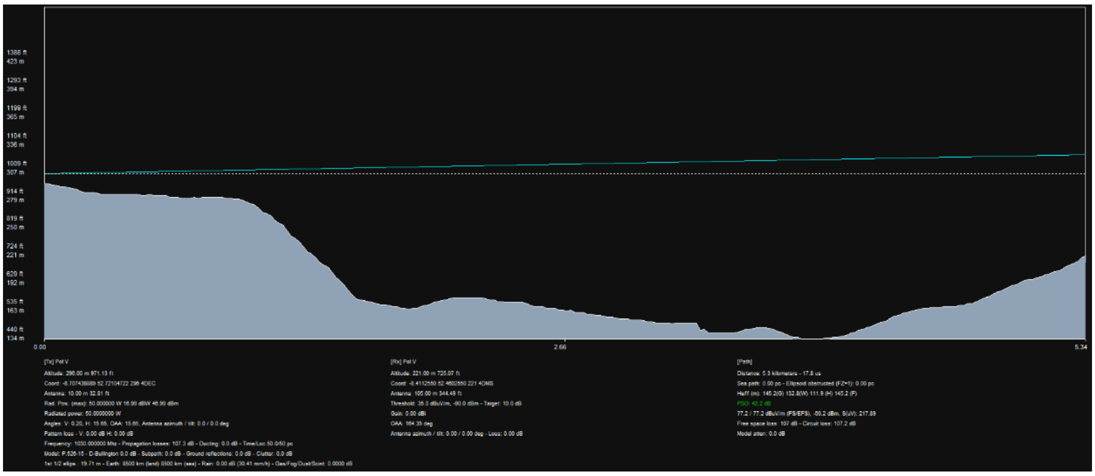

Figure 12: Pathloss Turbine 5

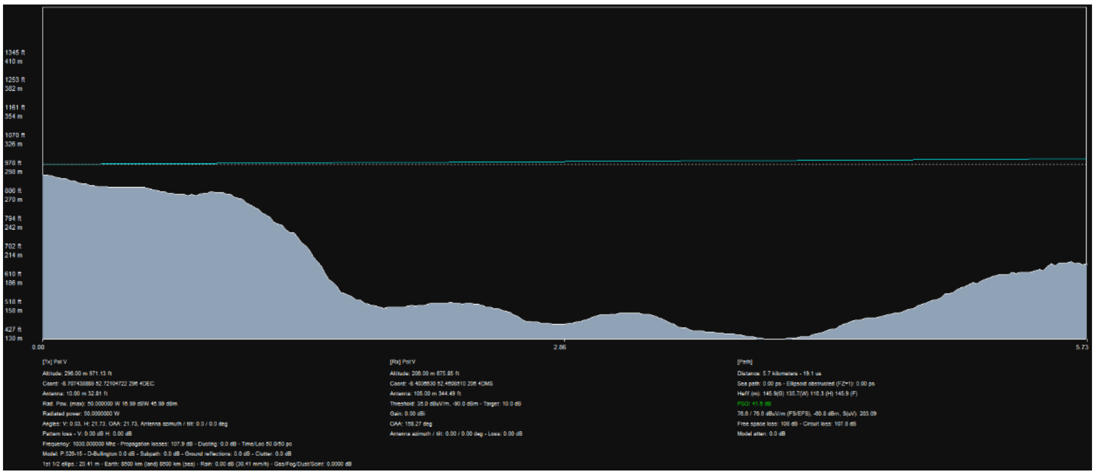

Figure 13: Pathloss Turbine 6

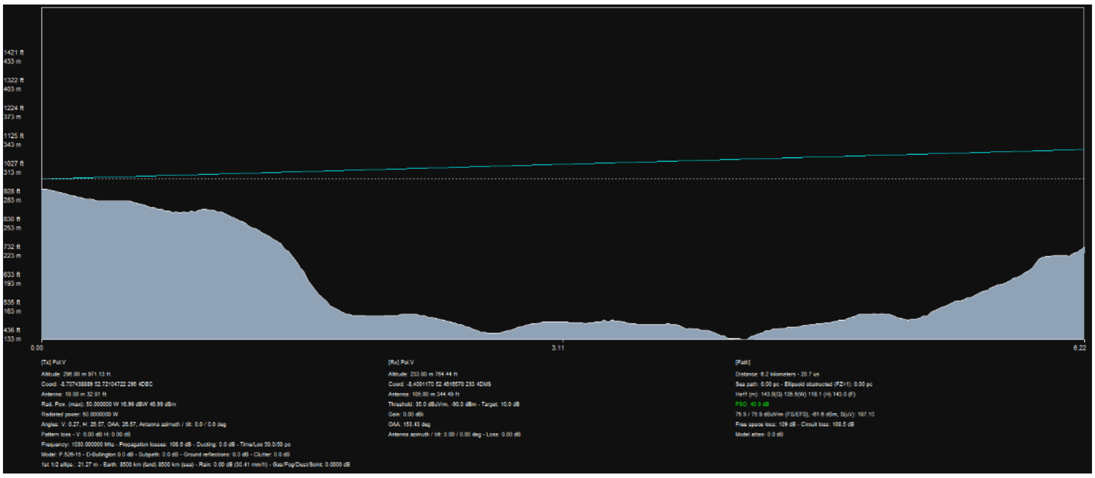

Figure 14: Pathloss Turbine 7

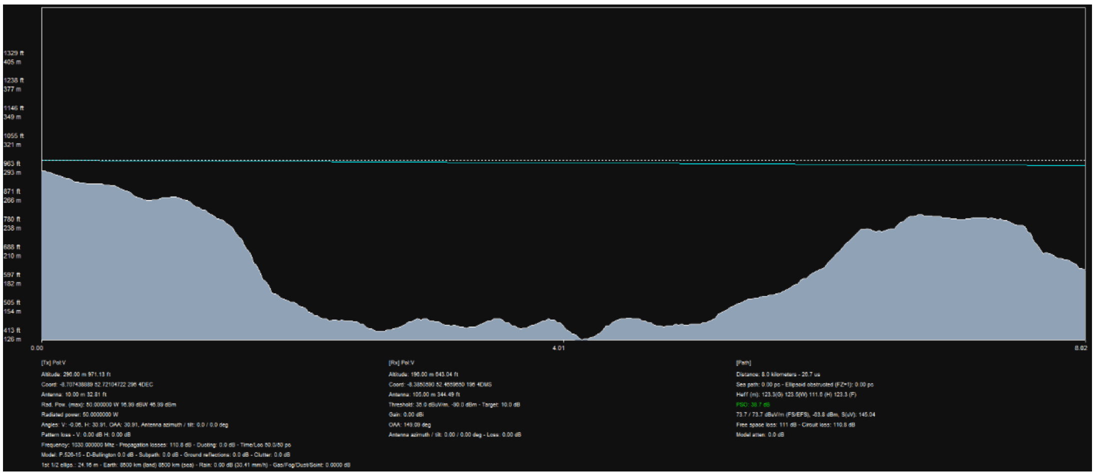

Figure 15: Pathloss Turbine 8

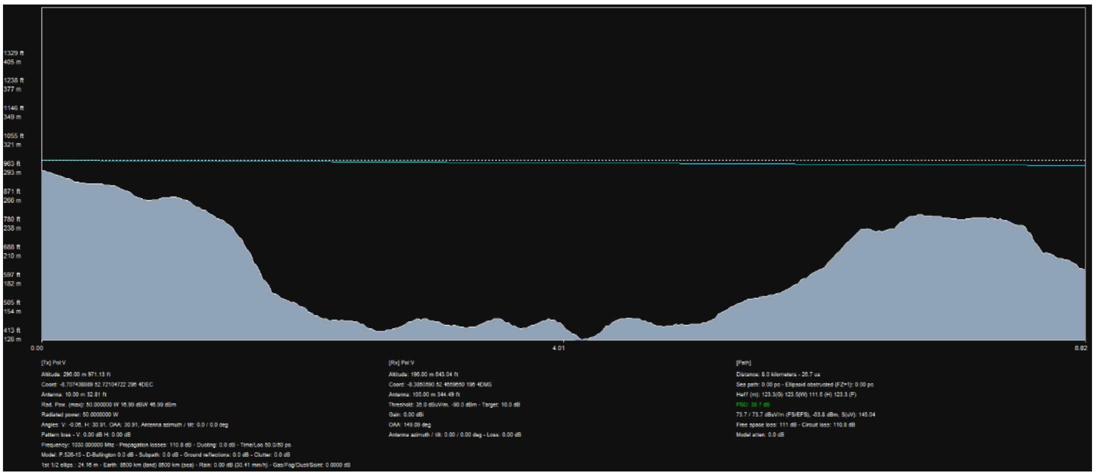

Figure 16: Pathloss Turbine 9

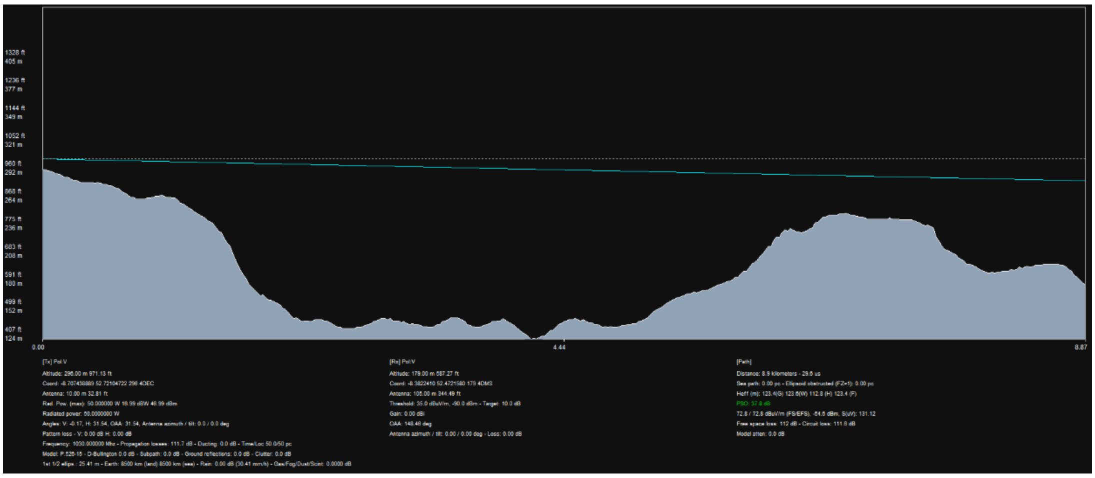

Figure 17: Pathloss Turbine 10

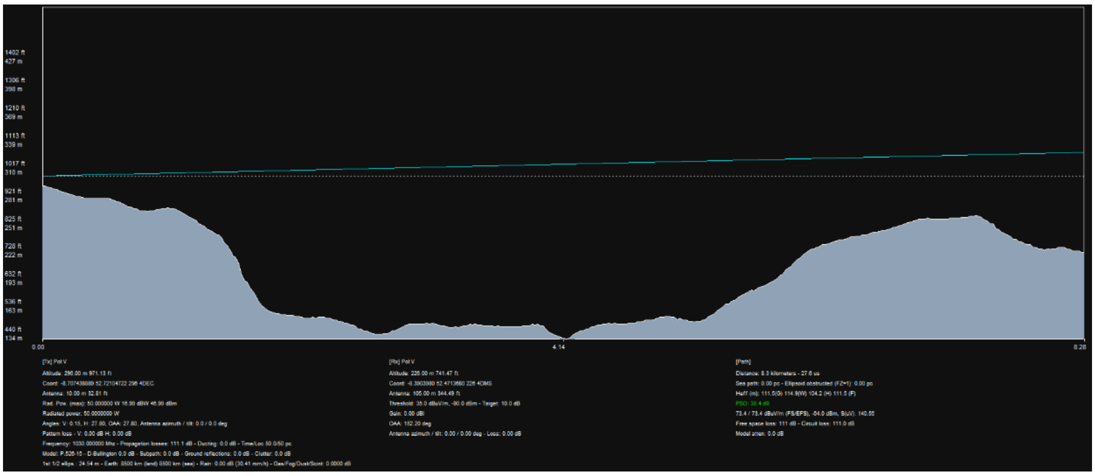

Figure 18: Pathloss Turbine 11

4.3.2. The path profiles between Woodcock Hill MSSR and the Oatfield Turbines are shown above.

4.3.3. Multipath, or bistatic, reflections from turbine towers can potentially cause ‘ghost’ targets on MSSR. This occurs when an aircraft replies to a signal reflected from an obstruction; the radar attributes the response to the original signal and outputs a false target in the direction of the obstruction, which can lead to Air Traffic Control Officer (ATCO) deconflicting real traffic from targets that do not physically exist.

4.3.4. The likelihood of bistatic reflections can be determined by knowing the MSSR transmitter power, antenna gain, path loss to the turbine tower, Radar Cross Section (RCS) gain and aircraft receiver sensitivity.

4.3.5. The amount of signal reflected by a turbine tower is a function of the tower’s RCS. A typical RCS value for a 100m steel tower of 8m diameter is 3,000,000m^2. However, a 0.5° taper of the tower can reduce this figure from millions to hundreds of square metres.

4.3.6. EUROCONTROL Guidelines [3] recommend an RCS value of $10^{3.5}$m^2 or 35dBm^2 for a turbine tower which equates to an RCS gain of 57dB at the MSSR uplink frequency of 1030MHz.

4.3.7. The following calculation can be used to determine the power of a radar signal reflected by a wind turbine tower:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB
=	Reflected Power	dBm

4.3.8. Free Space Path Loss can be used to calculate the maximum distance from the reflecting obstacle an aircraft can be in order for the reflected signal to trigger a response from the aircraft transponder.

4.3.9. The maximum range at which a reflection can trigger a response is proportional to the reflected power of the signal. From the above calculation it can be seen that reflected power is greatest when the path loss between the MSSR and a turbine is the least.

4.3.10. Using the radar propagation model the actual path loss between the MSSR and the tops of the Oatfield Turbine Towers can be determined.

4.3.11. The path loss results between Woodcock Hill MSSR and the Turbine Towers are shown in Table 2.

Turbine	Path Loss dB
T01	108.6
T02	107.0
T03	107.4
T04	107.3
T05	107.4
T06	107.8
T07	108.5
T08	110.8
T09	111.3

Turbine	Path Loss dB
T10	111.6
T11	111.0

Table 2 - Woodcock Hill MSSR Path Loss

4.3.12. From Table 2 it can be seen that the worst-case or smallest path loss is 111.6dB at Turbine 10.

4.3.13. The Tx Power for a Thales RSM 970 S MSSR is 60.35 dBm at the antenna input. The MSSR antenna gain varies with elevation angle, with peak gain of 27dB at an elevation of between 8° and 9° above the horizontal, as shown in Figure 16.

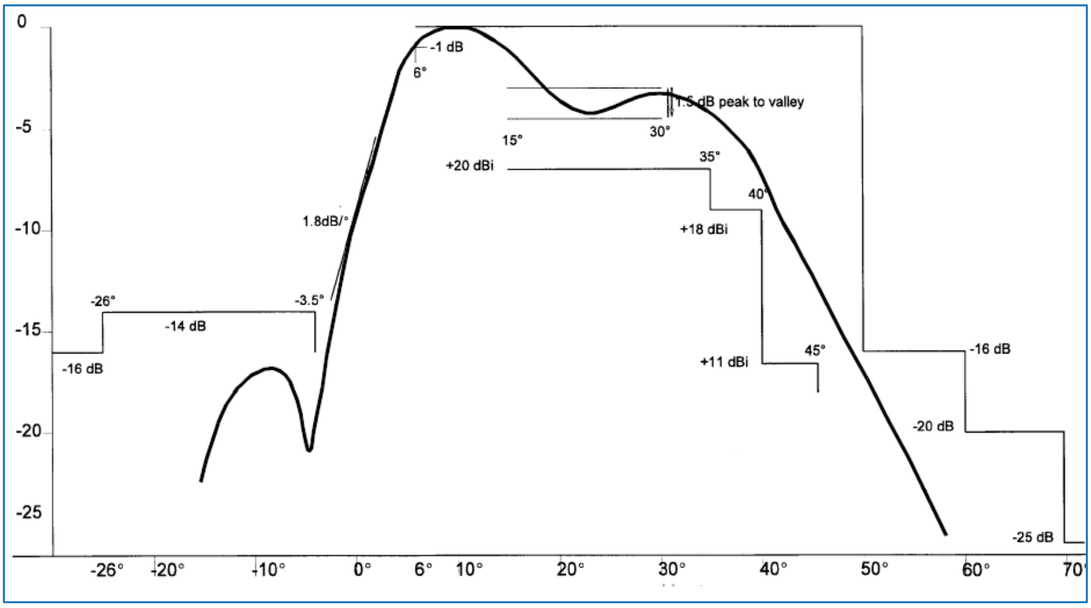

Figure 19: Thales RSM 970 S VPD

4.3.14. The vertical angle from the MSSR to the hub of Turbine 07 is 0.06°. If a mechanical tilt of 0° is assumed, this means a reduction in gain of -9dB at this elevation.

4.3.15. Using these values results in a reflected power of 21.75dBm from Turbine 10.

4.3.16. If an aircraft receiver sensitivity of -77dBm is assumed, the reflected signal will not trigger a response if the Free Space Path Loss from the turbine to the aircraft is more than 77 + 21.75 = 98.75 dBm.

4.3.17. The Free Space Path Length for an MSSR frequency of 1030MHz and path loss of is 1194.3m. This means that aircraft beyond this distance from the turbine will not detect a reflected signal. Reflected signals from other Oatfield Turbines will only be detected at ranges less than 1194.3m.

4.3.18. Annex D of the EUROCONTROL GuidelinesError! Reference source not found. states that an airborne t ransponder will be insensitive for 35µs following reception of a radar interrogation. Thus, an aircraft closer than 5250m (half the distance corresponding to 35µs) to the source of a reflected interrogation will not reply to reflected interrogations because the path length between the direct and reflected signals will always be smaller than 35µs.

4.3.19. Aircraft will not respond to reflected MSSR interrogations as they will only be detected when the aircraft is within 5250m of the turbines.

4.3.20. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTOL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = dtw \;/\; [\lambda \frac{Dtw}{S^2}\left(1-\sqrt{PL}\right)^2 - 1]$$

- Dwr = depth of shadow region
- Dtw = distance of turbines (4.85km – 8.87km)
- Λ = wavelength (0.29)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

4.3.21. The depth of the shadow region beyond each of the Oatfield Turbines will vary between 498.25m and 515.25m.

4.3.22. The EUROCONTROL Guidelines [3] also provide equations for calculating the width and height of the shadow regions. For Woodcock Hill MSSR the shadow regions will vary between 27m and 32m wide and will vary in height between 587ft (179m) and 830ft (253.05m) Above Mean Sea Level (AMSL).

4.3.23. The volumes of the Woodcock Hill MSSR shadow regions beyond the proposed turbines are considered sufficiently small to be operationally tolerable.

4.4. Shannon Airport MSSR

4.4.1. As the Shannon Airport MSSR is beyond the 16 km assessment distance required by Eurocontrol further assessment for the proposed Oatfield windfarm is not required.

5. Concerns

5.1. IAA Concerns

5.1.1. The IAA stated that a deeper assessment of impacts is required and has previously been completed for another developer, on this site. This said, AirNav Ireland have stated they are not satisfied with previous reports received from other proposed developers.

5.1.2. **Reflections**

The IAA have recently raised a number of concerns in relation to other proposed wind farm developments in the area.

The following concern regarding reflections:

"Reflections generate dual aircraft tracks which set off IAA automation system (COOPANS) safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist. Each Safety Net Alarm initiates a safety occurrence report. Reflections occur when an aircraft replies to both a radar interrogation directly and to an interrogation reflected by the Turbine tower or rotor blade; the radar generates both a real aircraft track and a false reflected track in the direction of the turbine. It is possible to reduce the probability of reflections through mitigation. This is normally done at the commissioning phase, where reflection mitigations for existing structures are implemented and tested prior to the operational use of the radar. Mitigating for multiple changing reflections during the construction and operation of wind Turbines within 4km of the woodcock radar, may require the radar to be taken out of service for the duration of the construction phase to implement and test the reflection mitigations. Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace. Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes."

5.1.3. Modern MSSR systems including the Thales RSM970 sited at Woodcock Hill are fitted with advanced processing algorithms to negate the effects of reflections. These systems may require some minor optimisation once the windfarm is built but it is likely the effects will be minor.

5.1.4. **Deflections**

The IAA have stated the following regarding deflections:

"Deflections also generate dual aircraft tracks which set off COOPANS safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist.Each Safety Net Alarm initiates a safety occurrence report. Deflections occur when a Radar interrogation signal is deflected by the Wind Turbine introducing an error in the measured bearing of the Aircraft. This bearing error increases

with range of the aircraft from the radar, becoming significant at ranges beyond 100Nautical miles. The radar bearing errors become an issue when the deflected Radar tracks are fused with the track data from other radars which calculate a different position for the aircraft track, and the deflected track is not associated with the true track position and a new Duplicate track is generated. We have mitigated for deflections from individual masts by implementing non-initialisation-areas in our Tracking systems (ARTAS). However, this non-initialisation-area mitigation must be kept to a minimum to avoid introducing holes in radar coverage. Due to the proximity of the proposed Oatfield wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Oatfield generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements."

5.1.5. The IAA states that Beam deflection can take place on the Woodcock Hill MSSR. Cyrrus investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated In Time (FRUIT). The SDP within the Woodcock Hill MSSR will use a De-FRUITER to remove these false targets. This technique is used in most MSSR systems.

5.1.6. Further investigation has shown that rather than deflection the combination of standard deviation errors in azimuth for systems working at ranges >200NM can be measurable.

5.1.7. Figure 20 Shows the respective coverage areas of the Woodcock Hill enroute MSSR and Dublin Airport enroute MSSR. These are shown to demonstrate the potential area were the two radars have crossover coverage fed into the AirNav Ireland Multi Radar Tracker (MRT)

Figure 20: Woodcock Hill and Dublin Airport enroute MSSR coverage

5.1.8. All radars suffer from some standard deviation error (SDE) which affects azimuth accuracy. Eurocontrol accept that an SDE of +/- 0.068 can provide an azimuth accuracy deviation of up to 300m at 80NM. AT 200NM it can be calculated that the SDE can be up to 800m. Figure 21 shows an expanded view of the detection area for the two radars at this distance.

Figure 21: Crossover Area

5.1.9. If the Woodcock Hill radar was to detect an aircraft while lagging by 0.068 degrees at the same time the Dublin Airport radar detected the aircraft leading by 0.068 degrees, there is the possibility that the multi radar tracker would try to plot the same aircraft twice in two separate positions. If this was to occur, the system would report a Short Term Conflict Alert as reported by AirNav Ireland.

5.1.10. **<u>Shadowing</u>**

5.1.11. The IAA have stated the following with respect to shadowing:

"Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines. This may result in the Woodcock hill radar not meeting its mandated Surveillance performance requirements."

Cyrrus recognise that shadowing will exist behind the turbines for the Woodcock Hill radar. As was stated in the previous Cyrrus report[1] The effect from this shadowing will be minimal and of no consequence to Air Traffic Control.

6. Current Mitigation schemes

6.1.1. In order to assess the most suitable mitigation scheme for Oatfield Windfarm, Cyrrus considered current mitigation schemes in operational use. Schemes which provide mitigation for onshore windfarms and multiple windfarms within close proximity of a radar site were investigated and the manufacturers approached for evidence that their solutions work. This chapter first considers each mitigation option and the evidence of its operational use.

6.1.2. The radar in operational use at Newcastle Airport is a Thales STAR2000 with a co-mounted Thales RSM970 MSSR of the same type used at Woodcock Hill. The AIP for Newcastle Airport in Figure 1 shows there are several windfarms located within the radars operating volume.

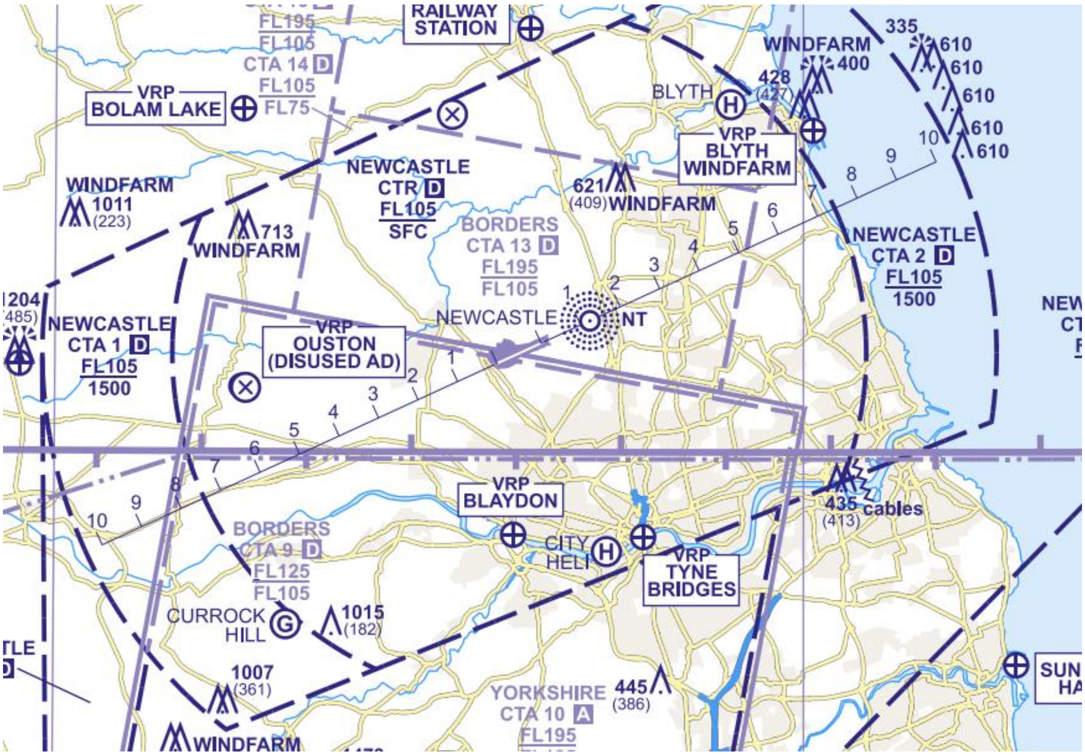

Figure 22: Newcastle Airport AIP

The radar is operational and used to provide control within the airspace. No additional MSSR mitigation is used and no operational impact on the radar performance has been reported by ATC.

7. PSR Mitigation

7.1. Windfarm Tolerant Radars

7.1.1. Several of the current generation of Surveillance radars have the capability to tolerate Wind turbines without causing clutter or degradation of the surveillance picture. PSR Systems from Thales, and others are available. Each of these systems works differently, but all are currently in Operational use at the following Airports:

- Newcastle Airport – A Thales Star Radar, fitted with a wind turbine filter is used along with an older Terma PSR which was originally fitted as an Infill radar.
- Cardiff Airport – The Thales Star Radar at Cardiff Airport has been upgraded to increase it's tolerance to wind turbines.

7.2. Shannon Airport PSR

7.2.1. The Shannon Airport PSR is a Thales STAR 2000 PSR installed in 2011 / 12. The system was designed to work in coverage volumes containing wind turbines. The Thales STAR2000 data sheet[4] explains how wind turbine filtering is achieved. For a relatively small windfarm within the radar's coverage volume, the turbines should have a minimal impact on performance.

7.2.2. Thales has a suite of optimisation and upgrade packages available for the STAR2000. If required, these could further enhance the STAR 2000 capability to filter the turbines at proposed Oatfield windfarm and elsewhere.

4.2.3. Thales state that they have a mature transition framework which allows system upgrades and optimisation to be implemented without the requirement for long periods of operational downtime. Cyrrus has experience of working with Airports and ANSPs to produce Transition Plans that minimise downtime, risk and comply with Safety Management Systems as required by regulators.

8. MSSR Mitigation

8.1. MSSR Radars

8.1.1. It is widely accepted that the effects of wind turbines on MSSR systems is much less than the effects on PSR systems.

8.2. Option 1

8.2.1. **Shannon Airport PSR with Co-mounted MSSR.**

Cyrrus understand that the Thales Star radar in use at Shannon Airport is suitable for an upgrade. The main advantage of this option would be the improved surveillance picture from a controllers view and the ability of the radar to provide mitigation for other windfarm developments.

8.2.2. **Woodcock Hill MSSR**

This may also require assessing to ensure any upgrades required can be implemented before the windfarm is built. Once the windfarm becomes operational, the radar may require some minor optimisation work.

If Option 1 was undertaken, Cyrrus believe the Oatfield Windfarm would not cause adverse effects on the Shannon Airport or Woodcock Hill Radars. Also depending on the cost of the upgrade and the increase in the Operational life of the system, a shared cost option between affected developers and the Airport may be possible.

9. Conclusion

9.1. Recommendations

9.1.1. An asset condition survey on the Shannon Airport and Woodcock Hill radar systems should be undertaken by Thales. This will include the current build state.

9.1.2. As the manufacturer and Design Authority of both radar systems, Thales will be able to assess the type of mitigation package required (if any). They will confirm costs and timescales based on their scope of work.

9.1.3. The main advantage of this would be an improved surveillance picture from a controllers view and the ability of the radar to provide mitigation for other windfarm developments.

9.2. Summary

9.2.1. The performance of the MSSR systems at both Shannon Airport and Woodcock Hill will not be unacceptably impacted by the proposed 11-turbines at Oatfield. Both systems have the inbuilt capabilities to filter wind turbine impacts.

9.2.2. The PSR at Shannon Airport may already be capable of filtering the wind turbines. Furthermore, Thales can provide various upgrades to further reduce the impact. These mitigations would result in the proposed 11-turbine windfarm at Oatfield having no operational effect.

9.2.3. If upgrades and optimisation are required to the systems, transitional arrangements can be managed to ensure minimal operational disruption occurs.

9.2.4. If Option 1 was undertaken, Cyrrus believe the Oatfield Windfarm would not cause adverse effects on the Shannon Airport or Woodcock Hill Radars.

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Appendix 3

CAP670 Air Traffic Services Safety Requirement

acknowledged that the likelihood of wind turbine generated receiver saturation is low; however, any possibility of receiver saturation should be taken into consideration.

Receiver De-sensitisation causing Loss of Targets with Small RCS

SUR13A.65 Trials have shown that the large RCS of wind turbines and the blade flash effect have lead to a decrease in radar sensitivity. Reduced receiver sensitivity increases the minimum detectable signal by a radar receiver, therefore loss of small targets and the maximum range at which the smallest targets can be detected can be reduced as a result. Radar’s clutter suppression circuitry uses noise thresholds which increases as the average noise levels increase leading to lack of receiver sensitivity.

SUR13A.66 Since wind turbines can have relatively high RCS they can obscure other targets in the same resolution cell, and so when an aircraft flies over a densely packed wind farm, the turbines’ RCS will tend to be higher than that of the aircraft as it passes through the same resolution cell seen by the radar and so the aircraft is obscured.

Loss of Targets due to Adaptive Moving Target Indication (AMTI) Techniques

SUR13A.67 The AMTI processing assesses the background Doppler returns being received in each of its range cells and sets a velocity for which returns are ‘notched out’. As the tip speed of the turbines can reach speeds similar to aircraft, it is possible that aircraft detected in the same AMTI range cell as a rotating turbine may fall into the AMTI Doppler notch and be discarded. It is, therefore, possible for some aircraft returns to be lost due to the presence of an AMTI Doppler notch in radars having such capability.

Shadowing behind the Turbines caused by Physical Obstruction

SUR13A.68 Trials have indicated that wind turbines also create a shadow beyond the wind farm so that low flying aircraft flying within this shadow go undetected. The magnified shadows of the turbine blades and the moving rotors are visible on the radar screens of weather and ATC radars [Reference 3]. However recent trial measurements have indicated that the shadow region behind the wind turbines would last only a few hundred meters and would hide only very small objects.

SUR13A.69 The wind turbine’s tower and nacelle components present a large physical obstruction in the radar coverage areas in the same way as any other structure, such as a large building. The presence of a physical obstruction with a large RCS in the path of the radar beam creates a region behind the turbine farm within which aircraft would not be detected. The shadow region behind a wind turbine farm within which primary radar contact is lost by interference with the propagation of the radar beam is believed to be defined by a straightforward where an additional (false) track is initiated and seduced away from the true track, leading to confusion as to which the true target is.

SUR13A.73 The tracking algorithms in a radar associates the plots confirmed as targets, in to individual tracks it believes to be from the same target. The false declarations of targets caused by wind turbines can confuse the tracking algorithms and the plot association function in a plot extracted radar, causing the effects described above.

Degradation of Target Processing Capability

SUR13A.74 Most modern ATC primary radars are fitted with a plot extractor. The plot extractor takes the output of the signal processor, i.e. the hits generated across the beam width, and declares a plot position which may also include course and radial speed information. Plot extraction ranges from a simple position declaration to advanced hit processing, which takes the output of an MTI filter bank and generates plots taking account of amplitude information and Doppler information. There is normally a maximum number of targets the radars processing systems can handle at any one time. Therefore, if a radar experiences a large number of clutter and false plots returned by wind turbines, its processing capacity may be reached and the processing capability can be affected as a result. This may lead to errors and processing delays.

Effects on SSR

Physical blanking and diffraction effects

SUR13A.75 Wind turbine effects on SSR can be caused due to the physical blanking and diffracting effects of the turbine towers depending on the size of the turbines and the wind farm. These effects are only a consideration when the turbines are located very close to the SSR, i.e less than 10 km.

Reflections causing false targets

SUR13A.76 SSR energy may be reflected off the structures in both the uplink and downlink directions. This can result in aircraft, which are in a different direction to the way the radar is looking, replying through the reflector and tricking the radar into outputting a false target in the direction where the radar is pointing, or at the obstruction.

Introducing range and azimuth errors

SUR13A.77 Monopulse secondary radar performance is also affected by the presence of wind turbines (Theil & van Ewijk, 2007). The azimuth estimate obtained with the monopulse principle can be biased when the interrogated target emits its response when partially obscured by an large obstacle such as a wind turbine.

Appendix 4

Meeting Minutes – Brookfield & IAA Feb. 2020

	OATFIELD: SUMMARY NOTE **MTG BETWEEN IAA AND BROOKFIELD HELD 11th FEBRUARY 2020**
	Date of Issue: 28th February 2020
	Attendees: Brookfield: Gemma Hamilton, Head of Development (GH) and Edwina White, Project Developer (EW). PagerPower: Mike Watson (MW) IAA: Cathal MacCriostail (CMC), Charlie O'Loughlin (COL), Jonathan Byrne (JB), Fergal Doyle (FD).
Item No.	**Notes**
1	CMC lead introduction of attendees and set out the three primary categories under which the IAA's initial key concerns about a wind farm development at Oatfield fall under. These are: a) Radar b) Instrument Landing System (ILS) c) Safety
2	GH set out an overview of: a) Brookfield as an organisation b) Motivating factors for progressing a wind farm development at Oatfield c) Summary of reports prepared relating to aviation impacts for Oatfield between March 2017 and August 2019
3	On 1 a), CO'L and MW lead a discussion focussed on the Woodcock Hill Monopulse Secondary Surveillance Radar (MSSR) with the following points noted: i. The MSSR at Woodcock Hill is scheduled for replacement by approx. 2026. ii. Though radar is considered exempted development under planning legislation, the ancillary infrastructure (for e.g. access tracks, security, welfare facilities) is not and can potentially pose a planning risk. iii. If an alternate location had to be selected for the MSSR at Woodcock Hill, a suitable site might have been Slieve Callan / Mount Callan prior to the existing Brookfield wind farm having been constructed there. iv. IAA set out that concern relates to wind farm's potential impact on Woodcock Hill MSSR at limit of its range to the west, where incoming transatlantic traffic is first detected.
4	On 1 b), FD and MW lead a discussion on the ILS with the following points noted: i. There is a regulatory requirement to retain the ILS at Shannon Airport ii. Testing the glide slope: A wind farm development at Oatfield could pose an issue for testing the glide slope. ICAO Annex 10 (Aeronautical Telecommunications – Volume 1 – Radio Navigational Aids) requires testing of ILS glide slope using an 8° slice approach. MC to review Annex 10 as well as DOC8168. iii. Testing the localiser: A wind farm development at Oatfield would not pose an issue for testing the localiser. iv. Electrical signal: Potential impacts due to a wind farm development at Oatfield on electrical signal have not yet been examined by IAA.
5	On 2 c), JB and MW lead a discussion on collision safety with the following points noted: i. A wind farm at Oatfield would increase collision risk for aircraft approaching Shannon Airport Runway 24. It is recognised that developments of all sizes and at all locations increase aviation collision risk marginally. There is a national and international process for establishing whether particular proposed developments are deemed obstacles and present an unacceptable collision risk. Initial analysis commissioned by Brookfield shows that the proposed development is not an obstacle and therefore that the collision risk presented by the proposed turbines is sufficiently low. Nevertheless, IAA is concerned that the proposed development may present an unacceptable collision risk.
5 cnt'd	ii. Different Required Navigation Performance (RNP) approaches (with different specifications for crew and aircraft) are applicable to aerodromes with differing collision risks.

6	CMC and JB set out that IAA is due to split out from circa July 2020 into the Regulator (IAA) and the Air Navigation Services (IANS or similar). From this point, separate consultation will be required with IAA and IANS.
7	In summary, the following conclusions were arrived at for the three primary categories under which the IAA's initial key concerns about a wind farm development at Oatfield fall under: a) Radar: Impacts are potentially mitigatable at a cost to the developer b) ILS: Further investigation is required on the testing of the glide slope (MC) and on electrical signal (FD) c) Safety: Need to produce clear and concise evidence that proposed development does not present an unacceptable collision risk

Appendix 5

PBN Implementation Plan for Ireland

PBN IMPLEMENTATION PLAN FOR IRELAND

<u>COMMENTS AND OBSERVATIONS TO:</u>

airspace@iaa.ie

Version 11.0 Mar 2021

Table of Contents

1. Document Change Control Sheet

Date	Version	Author	Revision Description
29/01/2010	1.0	SRD	Document Created
22/06/2012	2.0	SRD	Detailed implementation tables updated
16/01/2015	3.0	SRD	EASA NPA & detailed implementation tables updated & removal of Galway
01/04/2017	4.0	SRD	SES Navigation Strategy
17/08/2018	5.0	SRD	Implementation dates update;
27/04/2020	6.0	SRD	Review and update
05/06/2020	7.0	SRD	Incorporation of consultation responses
17/06/2020	8.0	SRD	Note regarding EICK Rwy 25
23/11/2020	9.0	SRD	Removal of EIME & EIWT from para 27, 28 & 29; Update of EISG runway designators.
28/01/2021	10.0	SRD	EISG implementation dates update
25/03/2021	11.0	SRD	Implementation date updates & insertions of runway classifications.

2. Acronyms

The following is a list of acronyms used in this document:

ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
ANSP	Air Navigation Service Provider
APCH	Approach
APV	Approach Procedures with Vertical Guidance
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
ANS	Air Navigation Services
AWS	Automated Weather Station
Baro-VNAV	Barometric Vertical Navigation
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CFIT	Controlled Flight into Terrain
CNS/ATM	Communication Navigation Surveillance/Air Traffic Management
CPDLC	Controller Pilot Data Link Communications
CTA	Controlled Airspace
DTTAS	Department of Transport, Tourism and Sport
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EGNOS	European Geostationary Navigation Overlay Service
ETS	Emissions Trading Scheme
FANS	Future Air Navigation System
FMS	Flight Management System
Galileo	Is a global navigation satellite system (GNSS) currently being built by the European Union (EU) and European Space Agency (ESA)
GPS	US Military Global Positioning System
GHG	Greenhouse Gas
GLONASS	GLObal NAvigation Satellite System
GNSS	Global Navigation Satellite System
IAA	Irish Aviation Authority
IAC	Irish Air Corps
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules

ILS	Instrument Landing System
INS	Inertial Navigation System
IRU	Inertial Reference Unit
LPV	Localiser Performance with Vertical guidance
MEL	Minimum Equipment Lists
MSSR	Mono-pulse Secondary Surveillance Radar
NDB	NonDirectional Beacon
OCA	Oceanic Control Area
PBN	Performance Based Navigation
PSR	Primary Surveillance Radar
RAIM	Receiver Autonomous Integrity Monitoring
RCP	Required Communication Performance
RSP	Required Surveillance Performance
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance Authorisation Required
SBAS	Satellite Based Augmentation System
SID	Standard Instrument Departure
SJU	Single European Sky ATM Research Joint Undertaking
SRD	Safety Regulation Division
STAR	Standard Instrument Arrival
TMA	Terminal CTA
VOR	VHF Omni-directional Radio-range
WAM	Wide Area Multilateration

3. Executive Summary

3.1. ICAO's Global Air Navigation Plan (GANP) 2013-2028 sets out the introduction of Performance Based Navigation (PBN) as its highest priority. Whilst ICAO has generally sought to remain flexible in its approach, the ICAO Assembly Resolution A37-11 took a more top-down approach and, reflecting the importance of PBN, called for implementation of PBN required navigation performance (RNP) approaches with vertical guidance (APV) using either satellite-based augmentation system (SBAS) or barometric vertical navigation (Baro-VNAV) by 2016, with the following intermediate milestones: 30% by 2010 and 70% by 2014. Where vertical guidance is not feasible due to lack of availability of local altimeter setting or APV-equipped aircraft, lateral guidance, to most instrument flight rules (IFR) runway ends, was prescribed by 2016.

3.2. Evidently Ireland's/Europe's implementation of PBN approach operations remains well below the ICAO GANP target, despite EGNOS (the EU SBAS) being available (i.e. certified for use in aviation) since March 2011 and the wide availability of BARO-VNAV for decades.

3.3. ICAO's GANP also sets out a roadmap for the reversionary technologies to be used in case of widespread GNSS failure. Whilst the robustness of GNSS is expected to be improved through the use of multi-frequency and multi-constellation technologies, a reversionary mode based on purely non-GNSS technologies is still considered necessary. This back-up is intended to be realised in the form of ILS for approaches and for en-route a combination of DME/DME and radar vectoring.

3.4. In order to achieve a transition to a more modern navigation system and most of all to reap the economic, capacity and environmental benefits from it, there is a need for a navigation roadmap that outlines the various steps and the desired end-state. Although for the time being there is no pressing operational need to transfer to a new navigation system, there are several aspects that support the need for a navigation strategy:

- Technological innovation has enabled an increasing variety of navigation applications with a continuous expansion of an air navigation "toolbox". Substantial benefit may be gained by selecting a set of solutions in order to clarify the main thrust forward for Ireland, thus facilitating investment decisions, speeding development and avoiding operational complexity for air traffic controllers and flight crews;

- Globally, the indication that PBN is the future, is clear, and this needs to be structured in an Irish context together with an intelligent rationalisation plan for the navigation infrastructure in order to control maintenance and replacement costs. Lack of clarity will perpetuate the current first mover disadvantage that demotivates both airspace users and ANSPs from investing in new technology;

- Finally, whilst the EASA opinion on PBN rule is well founded, it needs to be set in the broader context of what the end-state and timing for the EU navigation system should be at least in the next 20-30 years.

3.5. Use of area navigational concept while providing some operational benefits, is not sufficient in itself to produce the required overall benefits with respect to both operational and economic improvements. Much of the economic benefit comes from a rationalisation of the ground infrastructure, incentivising ground as well as on board equipment and decommissioning the outdated legacy navigation infrastructure. Furthermore, PBN also contributes to increased accessibility of less equipped airfields and supports improved traffic flow.

3.6. The PBN concept differs from classic navigational concepts by relying on defining the required navigational performance rather than the precise equipment to be used. In practise the most convenient means for position determination today is using GNSS together with an on-board RNAV system. GNSS use in the EU is based on EGNOS, but soon to be joined by Galileo – satellite constellation(s), thus introducing a potential single point of failure whether because of environmental or deliberate interference, technological issues etc. Furthermore, the nature of GNSS services exposes them to new kinds of security threats (intentional spoofing etc.). Therefore, in deciding about PBN, we also need to focus carefully on the possible failure modes and the reversionary (back-up through radar vectoring or DME/DME) modes of operation that are required to maintain a minimum level of service with an acceptable level of safety.

4. Stakeholders Roles

4.1. IAA SRD / DTTAS

- Ensure that the relevant Safety Cases, IAA processes, Irish Aviation Notices and guidance material enable a safe and efficient PBN environment that aligns with both ICAO Standards and European Regulation.

- Ensure that the national infrastructure (CNS/ ATM capability) will support the airspace concepts and the performance specifications associated with each phase of PBN implementation.

4.2. Air Navigation Service Providers

- Affirming responsibility to seek continual improvements to the safety, access, capacity, efficiency and environmental sustainability of the air transport system. Recognising that PBN provides a catalyst for these improvements to air traffic operations, while enabling a seamless and cost-effective solution throughout the entire flight.

4.3. Aircraft Operators

- Ensure that investment in aircraft fleet capability is aligned with both the performance specifications outlined in this plan and the timeframe associated with each phase.

4.4. Aerodrome Operators

- Ensure the supporting aerodrome infrastructure for PBN operations is coordinated with aircraft operators and IAA SRD.

4.5. All Stakeholders ensure that sufficient trained and qualified personnel are available to support the implementation of PBN.

5. **SESAR**

5.1. Whilst the Pilot Common Projects AF1 provided the first SES-related implementation decision of PBN, a wider implementation plan is also underway. The European ATM Master Plan and related more detailed SJU studies have largely followed the ICAO approach for the short term (until 03 December 2020, phase 1), though there are some important differences for the longer term. Generally speaking, the current SJU documentation is mainly focused on charting out the technological options while final strategy decisions still remain to be made. A general update of the ATM Master Plan is also underway and scheduled to complete the update in 2018. It will link navigation aspects more firmly to communication and surveillance issues, both as regards involved timing and technology. It will also include specific provisions for drones and cybersecurity that may influence the future CNS environment.

5.2. In the short term PBN is seen as the major enabler, though – whilst not contradicting GANP -with more stress on a co-existence of SBAS and GBAS than in ICAO GANP, whereby GBAS is expected to see increased use as a method for precision approaches.

5.3. As regards the important decision on reversionary technologies, SJU foresees a two-staged approach where short term solutions may later on be replaced by a selection of alternative technologies providing reversionary capability. As Europe's DME network is already very dense, DME/DME has been a natural choice for primary back-up technology. However SJU documentation notes that if the intention is to achieve identical operational capability as the GNSS-based PBN system provides, the current system will need some upgrades both for its ground and airborne components, so that its use in the planned (SESAR) functionality as an alternative means to operate PBN, would still involve considerable investments.

5.4. For aircraft without DME/DME capability, the reversionary technology will be a reduced VOR-network. For approaches ILS should continue to serve as the main back-up to GBAS operations.

5.5. Where SESAR differs from ICAO is the longer-term reversionary solution. Whereas ICAO GANP is more inclined towards a single-stage reversionary technology decision, SJU considers a multitude of new technologies that could be introduced in the longer term as additional reversionary positioning and navigation means to enhance or even replace DME and VOR. Options for these long-term solutions include Enhanced DME, Mosaic/DME, LDACS-NAV (based on cellular network), e-LORAN, Wide-Area Multilateration/TIS-B, pseudolite (pseudo-satellite) network, Mode-N or inertial systems.

6. Fundamental assumptions for the future system in the EU

6.1. Drawing on the ICAO and SESAR plans as well as discussions with various aviation stakeholders, the future system is to be based on two basic technologies:

- The "new" technology (in civilian IFR use since circa 1993) is PBN realised primarily via GNSS. Whilst area navigation techniques have existed since the 1950's, only its realisation though GNSS navigation has really brought it into the limelight as the all-round solution. Nominally PBN is written to be independent of technology, but currently GNSS positioning – where necessary augmented by SBAS, ABAS and/or GBAS - is the foundation for PBN approaches. From the viewpoint of space infrastructure, the ultimate goal will be to establish a multi-frequency, multi-constellation GNSS system that also complies with the safety regulatory requirements for certification of navigation service providers (N.B. not necessarily systems themselves) in order to provide the required reliability for the EU air navigation system. However, with right mitigation measures, PBN implementation can – and has - already started with todays' GNSS constellations.

- The main CATII/III precision approach technology is and will remain ILS except where supplemented in the longer term by GBAS or a combination of GNSS and on-board systems, such as EVS or SVS to allow operations below CAT I minima. ILS has been in approved use since circa 1941 and operated with autoland systems since the 1960's so there is abundant data on its reliability and failure modes. It is also currently the only widespread technology able to support CATIII approaches.

6.2. After this basic framework is agreed, the next question is related to the type and extent of the reversionary system to be maintained. Maximal economic benefits could be achieved by aiming for a (long-term) introduction of purely PBN-based navigation system, without ground-based reversionary options. However, we should also consider the different failure modes that need to be tackled and consequently decide what level of service should be maintained in each case. Generally, a failure could be:

- Airframe (receiver) specific failure, affecting only one aircraft at time.

- Local or regional (such as in case of intentional or accidental satellite signal jamming) GNSS provision failure leading to a loss of PBN capability on a restricted amount of routes and runway-ends.

- Total GNSS failure, wiping out GNSS availability in all, or most, of European airspace.

6.3. Depending on the type of failure, different reversionary solutions may be employed. These solutions need to consider also the fact that GNSS is used in many other applications (e.g. ADS-B, datalink etc.) so whilst surveillance and communication systems form an important part of the back-up systems, they must be able to provide for operations independent from these also affected systems e.g.

through the use of SSR rather than ADS-B. Future roadmaps on surveillance and communications must thus be aligned with the navigation roadmap to ensure they support each other fully. It is also important to determine what level of service we wish to provide in the case of GNSS failure, as that has a direct impact on the cost of the reversionary system to airspace users and ANSP's.

6.4. Finally; whilst the liability regimes of GNSS constellations used are beyond the scope of this paper, further work should be undertaken to determine the Member States and ANSP's liabilities when using third country GNSS constellations. As regards EU's regulatory framework, the use of GNSS constellations for the provision of air navigation services fall under existing legal provisions and as their oversight will thus be regularised, and liability responsibility for them will be taken by the service provider and competent authority as applicable. Future equipment mandates could also take into account the related level of safety assurance for the various systems.

7. Proposed layout of the future system

7.1. The traditional navigation infrastructure has been relatively simple and easy to comprehend for pilots and controllers. Apart from en-route navigation, there were essentially two kinds of approaches; precision approaches with ILS or non-precision approaches with VOR or NDB. The current system includes the legacy options (until 06 June 2030, phase 3), but has also introduced a wide variety of PBN solutions – many of which are overlapping but, may require slightly different equipment or crew qualifications. Also, the terminology, charting, training and phraseology for these operations is unnecessarily different. Whilst this may have been an inevitable result of historical development when the technology was evolving, the future system should be able to provide the desired performance improvements whilst also returning the general understand ability and interoperability of the system so as to facilitate the maximum number of aircraft with the minimum number of technical variations.

7.2. In essence, the navigation system should be laid out so that all current navigation systems are progressively replaced by roughly the following framework:

8. **En-route**

8.1. In the en-route phase navigation is conducted under PBN – primarily realised through GNSS positioning. In this phase of flight, the PBN specification should be such to ensure that aircraft can navigate from point to point in a structured manner.

8.2. **Oceanic – Retain RNP 10 (RNAV 10) and RNP 4** with existing communications and surveillance requirements (CPDLC and ADS-C where necessary to support application of 30/30 separation standards).

8.3. As at December 2019, approximately 85% of current Ireland oceanic airspace users are FANS 1A capable and therefore able to benefit from the 30/30 separation standard, traffic forecasts do not indicate capacity will be constrained with current standards.

8.4. **Domestic – Specify RNAV 5** for all promulgated routes in domestic CTA.

8.5. Plan to develop Direct/Free route airspace throughput the Shannon FIR/UIR

8.6. Surveillance will be provided by the existing Mode–S capable MSSR network. This will be supplemented by the existing PSR systems at Dublin, Cork and Shannon.

8.7. Communications provided by VHF network.

8.8. The IAA's ATM system capability has been updated with the introduction of the COOPANS system at the Shannon and Dublin ATCCs since 2011.

9. **TMA Procedures**

9.1. Arrival and departure routes from all aerodromes with instrument procedures, are also provided as PBN routes to RNAV 1 or where required by operational considerations to RNP 1 specification, so as to allow aircraft to operate PBN from take-off to landing. For helicopters PinS specifications will apply.

9.2. **Specify RNAV 1** for all terminal routes with surveillance services and **RNP 1** for routes without surveillance services. Where a surveillance service is available, it will be provided by the existing PSR/Mode–S capable MSSR network.

9.3. Communications provided by VHF network.

9.4. The IAA's ATM system capability has been updated with the introduction of the COOPANS system at the Shannon and Dublin ATCCs since 2011.

10. Non-Precision Runways. Approaches will be offered at all non-precision instrument runway ends using PBN. Minima shall be laid out so as to provide for not only LNAV & LNAV/VNAV but also LPV minima using SBAS (taking due account of the given geographical and meteorological environment including the aerodrome infrastructure and required utilisation). Due to the additional safety benefit of SBAS when compared e.g. to BARO-VNAV, and although legacy aircraft will be accommodated by the provision of different minima lines, the overall target is RNP APCH to the lowest feasible LPV minima. On runway ends that currently have only non-precision approaches, or that currently do not have instrument approaches, but intend to implement them, PBN approaches shall be established by 03 December 2020 (phase 1).

11. Precision Instrument Runways

11.1. CAT II/III precision approaches to major hubs or other airports that require better operational capability are provided with a combination of PBN arrival and departure routes and ILS-based final approaches.

11.2. Additionally RNP approaches (LNAV & LNAV/VNAV & LPV Minima) will also be provided at all instrument runway ends on these airports in the same manner as to other airports, in order to add flexibility and as a back-up, as well as to facilitate those aircraft that only have PBN navigation capability.

11.3. Eventually, some precision approaches may be converted to GBAS, but for reasons of redundancy ILS approaches will still be needed at least at some runway ends so GBAS cannot be the only solution. The case for GBAS should be made considering both the benefit of e.g. curved approaches and the additional burden on aircraft equipage.

11.4. On runway ends that currently have precision approaches, RNP approaches (LNAV & LNAV/VNAV & LPV Minima) shall be established at the same time as the PCP airports, by 25 January 2024 (phase 2).

12. Mixed mode operations. Mixed mode operations will be phased out and navigation infrastructure rationalised by 06 June 2030 (phase 3).

13. Back-up solutions. PBN specifications require infrastructure support from either GNSS or DME/DME or radar vectoring capability. The capability of the existing DME network to support DME/DME updating needs to be verified to ensure it will be adequate for planned future use in both en-route and terminal airspace throughout the entire state or ensure that radar vectoring can meet the backup needs for all aerodromes (State as well as regional) in the event of a GNSS failure.

14. **Non-GNSS ANS failure**. Autonomous navigation in case of ANS failure (i.e. loss of communications, surveillance, ATC unit etc.) is provided by PBN. It will allow aircraft to fly out of the area of ANS failure and if required also to land without ANS support.

15. **Failure of primary navigation infrastructure**. Total long-term failure of GNSS would provide major issues for ATM Operations. Airspace capacity will be limited to most essential flights only, so very few new flights will take off and many of these will be State aircraft capable of operating independently. For shorter term outages or as a means of reducing airspace capacity in a controlled manner by limiting airborne flights, the following back-ups will be maintained for the foreseeable future:

- For aircraft with DME/DME capability (i.e. larger modern airlines) DME/DME provides PBN capability, combined with access to ILS-equipped airports. Considering the past reliability of GNSS, it seems unlikely that a DME-system upgrade to achieve RNP-specification capabilities would actually bring sufficient benefits to warrant the required investment. Some minor adjustment of the DME-network may be required to ensure sufficient coverage, but generally SJU and Eurocontrol studies have indicated that the existing framework is sufficient both in numbers and location.

- For those flights without DME/DME capability (mostly regional aircraft, military and general aviation) the alternative navigation means is to leave a minimum operational network (MON) of VOR's so that an aircraft will never be more than e.g. 100-150 nm away from a functioning VOR. However, this network will be truly minimal and not enable sustained operations in case of total GNSS failure. The VOR MON infrastructure will eventually be fully replaced (06 June 2030, phase 3) by only DME and ATC vectoring within Ireland.

- Finally vectoring by ATC using non-GNSS based surveillance technology, to an airport with an ILS approach, RNP Approaches (LNAV & LNAV/VNAV & LPV Minima) or visual conditions, will provide the final recourse to navigating especially our regional airports.

- In case of local failure of ILS, aircraft will land either using RNP Approaches (LNAV & LNAV/VNAV & LPV Minima) or visual conditions at the destination or alternate airport or divert to an airport with functioning ILS.

- Transition and rationalisation of the ground-based navigation infrastructure

16. **Transition and rationalisation of the ground-based navigation infrastructure**. IAA SRD is liaising with the providers of ATM/ANS in accordance with EU Regulation 2018/1048, to ensure a smooth and safe transition to the provision of their services using performance-based navigation and the eventual rationalisation of the ground-based navigation infrastructure.

17. **Aircraft equipage**

17.1. In a performance-based environment, aircraft equipage is not dictated in detailed regulations, but it is determined by the required navigation (or communications or surveillance etc.) performance. In the past IFR-approved aircraft were required to equip with the full array of navigation equipment from ADF to ILS, regardless of whether all of them were ever actually needed. In the performance-based approach, it is for the aircraft operator to determine which routes they wish to operate and then equip the aircraft so as to provide for required navigation capability on that route. This principle is already enshrined in the Standardised European Rules of the Air (SERA) and in particular, the Air-OPS Regulation for EU operators and Regulation (EU) No 452/2014 for third country operators.

17.2. Such an approach helps rationalise equipage, but also ensures that aircraft are able to operate in the environment they fly in without causing hindrances to other stakeholders. Whilst the exact equipage solutions are open to the aircraft operators, it is expected that airlines will typically use a combination of DME/DME, GNSS (augmented as desired by ABAS, SBAS and/or GBAS) and ILS for positioning, whilst in the other end of spectrum General Aviation aircraft will probably rely increasingly on a combination of GNSS (augmented as per operator needs), ILS and VOR, with ADF being quickly phased-out and in the longer term probably also VOR seeing less and less use (06 June 2030, phase 3).

18. **Safety – Risks Associated with Major System Change**. During the transition to a mature PBN environment the government and industry will face significant challenges. The government challenges will include support of Irish Aviation Rule changes and associated preparatory work. The industry challenges will involve resourcing and managing a diverse range of navigation systems with equally diverse requirements. Some of the key identified challenges are:

- Adoption of supporting Irish Aviation Rules
- PBN capability register and aircraft minimum equipment lists (MEL)
- Integration of PBN capability into the ATM system (Flight Plan data fields)
- Mixed fleet/system operations
- Safety monitoring of ATM system
- Approach naming and charting conventions
- Navigation database integrity and control
- GNSS system performance and prediction of availability service
- Continued involvement in CNS/ATM and PBN development
- Resources of the IAA SRD to implement PBN
- Education and training of personnel employed by the IAA, ANSP's and aircraft operators.

19. **Environment**

19.1. Environmental challenges include minimising the impact of noise and emissions on both the communities in the proximity of aerodromes and the global environment. PBN may support the achievement of these goals while preserving aviation safety and efficiencies in the ATM system, but a collaborative approach will be essential to deliver all these objectives. The introduction of Ireland's emission trading scheme (ETS) provides aircraft operators flying domestic routes with a commercial incentive to upgrade their fleet, including PBN capability. With the introduction of regional or global emissions trading schemes for aviation, this commercial incentive could significantly increase and extend to international aircraft operators flying to and from Ireland.

19.2. Environmental challenges therefore include:

- Political developments/considerations
  - Increased ATM system capacity due to PBN efficiency gains
  - Emission control/management, including demonstrated efficiencies associated with PBN operations
  - Noise control/management
- Technological developments
  - Tension between noise outcomes and emissions reduction outcomes.

20. **Infrastructure Development**. Design and implementation of GNSS Instrument Flight Procedures is well advanced. Approved Procedure Design organisations have a significant workload in turning the design work into published documents. The following issues need to be addressed by the IAA SRD and the aviation industry:

- Terrestrial Navaids
  - Transition to GNSS based system
  - Decommissioning of existing aids (NDB's & VOR's)
- GNSS/RAIM prediction requirements including
  - Overall GNSS status monitoring, reporting and recording
  - Prediction of availability for a particular operation and aircraft
- Automatic Weather Station (AWS) for APV Baro-VNAV
  - Implementation will require coordination between the IAA, Met Eireann, ANSP's and aerodrome operators
  - Responsibilities for funding of these initiatives will need to be determined
- RNP Approach design
- Runway infrastructure
  - Aerodrome obstacle survey
  - Aerodrome lighting (approach and surface)
- Use of GNSS
  - Use of GNSS within Irish airspace is subject to the compliance with applicable international requirements and standards (for example ICAO Annex 10).
  - Formal safety assurance evidence will need to be provided to determine whether the performance of GNSS within Irish airspace is adequate to support the planned increase in reliance on this technology by the aviation industry. Such safety evidence will have to consider risks such as the susceptibility of GNSS signals to external sources of interference.
  - Co-operative agreements between NSAs may be required to address the regulatory oversight of GNSS providers and services (e.g. oversight of the EGNOS safety of life service).

21. Operational Efficiency Benefits

- Efficiency gains enabled through PBN include:
    - Reduced separation standards for air traffic routes in oceanic and some portions of domestic en-route airspace
    - Greater flexibility of airspace design in terminal area airspace
    - Reduced track distance, noise and fuel consumption through PBN enabled ATS routes and approach procedures
    - Reduced environmental impact.
- The synchronised integration of PBN and non-PBN air routes, airspace and aircraft will be vital if these efficiency gains are to be fully realised.

22. Helicopter Operations. The development of Point in Space (PinS) procedures & ATS routes is currently under discussion / development with operators.

23. **Implementation**

23.1. **Short Term**. On runway ends that currently have only non-precision approaches, or that currently do not have instrument approaches, but intend to implement them, (except at those airports listed in point 1.2.1 of the Annex to the PCP Regulation 716/2014). PBN approaches shall be established by 03 December 2020 (phase 1).

23.2. **Medium term**. On runway ends that currently have precision approaches, PBN approaches shall be established at the same time as the PCP airports, by 25 January 2024 (phase 2).

23.3. **Long Term**. Mixed mode operations will be phased out and navigation infrastructure rationalised by 06 June 2030, (phase 3).

24. Tables' Legend

Not Implemented, no plan.
Not Implemented, planned dates.
Implemented.

25. Runway Classifications

Aerodrome	Designator	RWY	Classification
Cork	EICK	34	Precision Approach Cat I
		16	Precision Approach Cat II
		25	Non-Precision Approach
		07	Non-Precision Approach
Donegal	EIDL	20	Non-Precision Approach
		02	Non-Precision Approach
Dublin	EIDW	28L	Precision Approach Cat IIIB
		10R	Precision Approach Cat IIIB
		16	Precision Approach Cat I
		34	Non-Precision Approach
Ireland West	EIKN	26	Precision Approach Cat II
		08	Non-Precision Approach
Kerry	EIKY	26	Precision Approach Cat I
		08	Non-Precision Approach
Shannon	EINN	24	Precision Approach Cat II
		06	Precision Approach Cat I
Sligo	EISG	28	Non-Precision Approach
		10	Non-Precision Approach
Waterford	EIWF	21	Precision Approach Cat I
		03	Non-Precision Approach

26. **Routes**.

RNAV 5 is fully implemented in all ATS routes above FL150

27. GNSS Departures and Arrivals

Aerodrome	Designator	RWY	Current Procedures	Proposed Procedures	Sensor
Cork	EICK	34 Q1/2017	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		16 Q1/2017	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		25 Q1/2017	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		07 Q1/2017	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
Donegal	EIDL	20 Q3/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup
		02 Q3/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup
Dublin	EIDW	28L Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		10R Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		16 Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		34 Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
Ireland West	EIKN	26 Q3/2016	SID & STAR (RNAV 1)		GNSS With radar backup
		08 Q3/2016	SID & STAR (RNAV 1)		GNSS With radar backup
Kerry	EIKY	26 Q3/2016	SID (RNAV 1)		GNSS With radar backup
		08 Q3/2016	SID (RNAV 1)		GNSS With radar backup
Shannon	EINN	24 Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
		06 Q4/2018	SID & STAR (RNAV 1)		DME/DME or GNSS With radar backup
Sligo	EISG	28 Q3/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup
		10 Q3/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup
Waterford	EIWF	21 Q4/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup
		03 Q4/2021	Nil	SID & STAR (RNAV 1)	GNSS With radar backup

28. **Approach Procedures (Phase 1)**. Facilitate a mix of ground-based approaches; RNP APCH (RNAV GNSS) including Baro-VNAV enabled Approach with Vertical Guidance and Localizer performance with vertical guidance (LPV), where possible. Where a surveillance service is available, it will be provided by existing PSR/Mode–S capable MSSR network or ADS-B and Wide Area Multilateration systems when these are commissioned, integrated with ATM system and certified for use. Communications provided by VHF network.

Aerodrome	Designator	RWY	Current Procedures	Proposed Procedures	Sensor
Cork	EICK	34 (NP) Q1/2017	ILS Cat II LOC VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
		16 Q1/2017	ILS Cat I LOC VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
		25 Q1/2017	VOR LNAV **Note**: Descent gradient of 3.7° for CAT AB is greater than max. allowable (3.5°) for an approach with vertical guidance.		DME/DME or GNSS With radar backup
		07 Q1/2017	VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
Donegal	EIDL	20 Q3/2021	NDB	LNAV/VNAV LNAV LPV	GNSS With radar backup
		02 Q3/2021	NDB	LNAV/VNAV LNAV LPV	GNSS With radar backup
Dublin High density TMA; PCP IR Annex - 1.2.1	EIDW	28L Q4/2018	ILS Cat I & II LOC VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
		10R Q4/2018	ILS Cat II LOC VOR LNAV/VNAV		DME/DME or GNSS With radar backup

			LNAV LPV		
		16 Q4/2018	ILS Cat II LOC VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
		34 Q4/2018	VOR LNAV/VNAV LNAV LPV		DME/DME or GNSS With radar backup
Ireland West	EIKN	26 Q1/2021	ILS Cat I & II LOC VOR NDB LNAV/VNAV LNAV LPV		GNSS With radar backup
		08 Q1/2021	VOR NDB LNAV/VNAV LNAV LPV		GNSS With radar backup
Kerry	EIKY	26 Q1/2021	ILS Cat I LOC NDB LNAV/VNAV LNAV LPV		GNSS With radar backup
		08 Q1/2021	NDB LNAV/VNAV LNAV LPV		GNSS With radar backup
Shannon	EINN	24 Q4/2021	ILS Cat I & II LOC VOR	LNAV/VNAV LNAV LPV	DME/DME or GNSS With radar backup
		06 Q4/2021	ILS Cat I & II LOC VOR	LNAV/VNAV LNAV LPV	DME/DME or GNSS With radar backup
Sligo	EISG	28 Q1/2021	LNAV/VNAV LNAV LPV NDB		GNSS With radar backup
		10 Q1/2021	LNAV/VNAV LNAV LPV NDB		GNSS With radar backup
Waterford	EIWF	21 Q3/2021	ILS Cat I LOC	LNAV/VNAV LNAV	GNSS With radar backup

			NDB	LPV	
		03 Q3/2021	NDB	LNAV/VNAV LNAV LPV	GNSS With radar backup

29. **Point in Space (PinS) Approach Procedures (Phase 2)**. Facilitate PinS approach procedures for the following:

Aerodrome	Designator	RWY	Current Procedure	Proposed Procedure	Sensor
Sligo	EISG	28 Q3/2021	Nil	PinS	GNSS With radar backup
		10 Q3/2021	Nil	PinS	GNSS With radar backup
Waterford	EIWF	21 Q4/2021	Nil	PinS	GNSS With radar backup
		03 Q4/2021	Nil	PinS	GNSS With radar backup
Castletownbere	Nil	Helipad Q1/2022	Nil	PinS	GNSS With radar backup
Blacksod	Nil	Helipad Q1/2022	Nil	PinS	GNSS With radar backup
Custume Bcks Athlone	EIAC	Helipad Q1/2022	Nil	PinS	GNSS With radar backup
Kerry University Hospital	Nil	Helipad Q1/2022	Nil	PinS	GNSS With radar backup
Galway University Hospital	Nil	Helipad Q1/2022	Nil	PinS	GNSS With radar backup
Letterkenny University Hospital	Nil	Helipad Q1/2022	Nil	PinS	GNSS With radar backup

30. **Conclusion**. The implementation of PBN in Ireland's controlled airspace will require the allocation of significant resources by each of the key industry stakeholders and the Irish Aviation Authority (IAA). This investment is considered essential to securing the benefits for Ireland at the earliest opportunity.

30.1. Benefits:

- Safety improvements through greater adherence to a safe flight trajectory (e.g. use of Continuous Descent Operations (CDO)/Continuous Climb Operations (CCO) which is a key component of the ICAO strategy to address Controlled Flight into Terrain (CFIT) accidents).

- Efficiency improvements through changes to air route and approach procedure designs that minimise the air miles flown and enhance schedule reliability, provide greater conformance to the flight plan and reduce enroute traffic delays, which will collectively reduce total operating costs and improve on-time performance.

- Improved environmental performance through greater use of uninterrupted climb and descent trajectories which ensure that both Green House Gas (GHG) emissions and the noise footprint for aviation are minimised.

30.2. Ireland's methodology for the transition to PBN is:

- Maintenance of the present area navigation capability
- Transition to the SES Navigation Strategy
- Introduction of APV capability through barometric vertical navigation
- Development of RNP APCH (to include LPV's) for all runways as well as RNAV SID's & STAR's
- Non-Precision runways by 03 December 2020 (phase 1) and precision runways by 25 January 2024 (phase 2).
- Utilise the European GNSS as the enabling technology for the implementation of PBN
- Utilise radar vectoring (the backup system) for all aerodromes.
- Removing by 06 June 2030 (phase 3) of conventional instrument flight procedures and mixed mode traffic
- Removal of ground based navigational aids by 06 June 2030 (phase 3)
- Installation of GBAS for Dublin

31. Consultation.

31.1. **Process**. Written consultation was carried out with the key stakeholders as listed below. A period of one month was given for responses.

31.2. The key stakeholders are:

- Air Navigation Service Providers & Aerodrome Operators
  - ATM Operations & Strategy, IAA (EICK, EINN, EIDW)
  - daa (EICK, EIDW)
  - EIDL
  - EIKN
  - EIKY
  - EIME (Irish Air Corps)
  - EISG
  - EIWF
  - EIWT
  - saa
- Aircraft Operators
- IAA SRD / DTTAS
- Network Manager, EuroControl
- Network Manager, ATM Operations & Strategy, IAA
- Airspace users and representative organisations
- Providers of ATM/ANS that provide their services in adjacent airspace blocks (CAA, UK).

Appendix 6

UK Aviation Plan – Wind Turbines and Aviation Radar

MEMORANDUM OF UNDERSTANDING – 2010 UPDATE

WIND TURBINES AND AVIATION RADAR (MITIGATION ISSUES)

1. The Climate Change Act 2008 sets a legally binding target of at least an 80% cut in UK greenhouse gas emissions by 2050. In the shorter term it sets a target rate of a reduction in emissions of at least 34% by 2020. As part of EU-wide action to increase the use of renewable energy, the UK also has a legally-binding commitment to source 15% of its energy from renewable sources by 2020. This represents an increase in the share of renewables by a factor of at least 5 between 2010 and 2020.

2. The long-term target requires the UK to decarbonise our electricity supply during the 2030s, which will be achieved by a major expansion of renewable and nuclear energy, and the introduction of carbon capture and storage. This expansion will also be essential in order to ensure the security of our electricity supplies.

3. Deployment of about 28GW of wind energy by 2020 - onshore and offshore - is expected to be needed to deliver the targets, compared with current deployment of 5GW. The Government also intends to realise the economic development benefits from wind deployment, including many thousands of new green jobs.

4. Wind turbines can have significant effects on radar, which in turn is a major barrier to deployment. Aviation radar objections to wind farms arise from three distinct groups of aviation stakeholders: the MoD (for air defence and military air traffic control); NATS En Route in respect of its regulated en route air traffic control service; and terminal civilian air navigation service providers, namely airports.

5. This conflict illustrates the constraint on aviation's ability to meet its commitment to Government policies, international obligations and licence conditions. It is noted that the licence conditions of certain air navigation service providers prevent them from investing in technologies that do not directly benefit their aviation customers. Solutions will need to be found which compromise neither the safe operation nor the significant benefits delivered by the aviation industry to the UK economy.

6. In recent years, planning law and policy throughout the UK has come to focus more on early pro-active pre-planning consultation to identify key issues for the decision maker, particularly when considering large offshore wind farm

projects where the developer is expected to have identified aviation mitigation solutions before submission of the planning application.

7. These changes highlight the need for early assessment of potential aviation issues and, where appropriate, consideration of potential and proportionate mitigation solutions. Aviation stakeholders recognise that they will need to provide resources and expertise to help the wind industry identify the most pragmatic solutions for mitigating sites, whilst not compromising on their licence obligations to provide safe and efficient aviation services.

8. In the UK, it is estimated that over 10GW of onshore wind energy and 15-20 GW of offshore wind energy could be held up by aviation objections over the next decade.

9. In 2010, radar issues accounted for over 6.5GW worth of objections in the planning system. It is estimated that a further 5GW of projects that are likely to be held up by aviations constraints are in development pre-planning, while approximately 1.3GW of projects are consented but with aviation issues outstanding that require solutions before construction can begin.

10. DECC (formerly BERR), DfT, MoD, RenewableUK (formerly BWEA), CAA and NATS/NERL signed an MOU in 2008 which committed them to work together to identify mitigation solutions, and drive forward progress on projects corralled under an 'Aviation Plan'. The Aviation Plan was endorsed by representatives of the relevant aviation stakeholders and focused on those workstreams most likely to succeed in bringing forward workable solutions.

11. The Aviation Plan is an evolving document. To own it and take responsibility for monitoring progress and driving delivery, three bodies were set up: the senior-level Aviation Management Board (AMB); the technical Aviation Advisory Panel (AAP); and the Fund Management Board (FMB). The projects under the Aviation Plan and the membership of these groups have evolved as progress has been made. With the Scottish Government, the Crown Estate and AOA joining the MOU, representatives from each of these organizations will join the AMB as well as continuing to be engaged with the AAP. Beyond this, we do not expect any further changes in governance as a result of this MOU.

12. The Aviation Plan has seen considerable achievements so far, with contracts being let to further research and development on En-Route and Air Defence radar and integration software to eliminate the problems of interference; and new defence radar being jointly purchased and installed.

13. The Plan is now entering a new phase where it needs to continue supporting relevant resource, research and development projects, while at the same time ensuring that software and hardware solutions are implemented. In addition, it is an opportunity to address other aspects beyond radar to deliver a cohesive and coordinated way forward related to all aviation issues, including navigation and communications.

14. Delivering the Aviation Plan will also require that all signatories commit to best efforts to delivering their part of the work on time, and to working together to scope a workplan to roll out effective mitigations and identify the means to fund and deliver the plan, subject to resources. As this is a highly innovative and complex field it is critical that credible technical advice and expertise is also made available by the signatories to this MOU to support the development and deployment of the Aviation Plan.

15. The wind industry recognises that it is the responsibility of the wind farm developer to achieve an acceptable aviation mitigation solution when required in cooperation with the aviation industry. The aviation industry recognises that it is the responsibility of the aviation stakeholder to engage with the developer in a manner that will allow for reasonable, consistent and timely advice on the identification of mitigation solutions. The wind industry also recognises that the current budgetary constraints within Government and through the FMB will continue to support, so far as possible, the investment into research and development projects.

16. For their part Government Departments will continue to explore financial, regulatory and legislative levers to push forward the delivery of mitigation solutions where a national approach is necessary, within the legal and financial constraints that signatories to this MOU and others (airlines and other ANSPs) are required to operate in, or where a change in the regulatory paradigm to facilitate the deployment of sub-national / regional mitigations would be of assistance. It is further recognised that only the Government authorities can effect change to the regulatory frameworks under which aviation stakeholders and wind farm developers operate.

We, the signatories to this Memorandum of Understanding (MOU), commit to working together to implement the Aviation Plan and to ensuring the timely and effective delivery of solutions to mitigate the effects of wind turbines on aviation in order to promote the deployment of wind energy generation, whilst taking all necessary steps to protect air safety and air defence requirements.

We accept that the development and deployment of radar and wind-turbines which can more effectively co-exist, together with new ways of working, will be increasingly necessary if the Government's ambitions for wind energy deployment are to be met.

Signed:

CAA	
DECC	DfT
MoD	NATS/NERL
AOA	RenewableUK
Scottish Executive	The Crown Estate

Appendix 7

Newcastle Airport Reference

Newcastle Airport embraces wind power, allaying fears about radar interference

Tuesday, 25 January 2011

Newcastle International Airport in north-eastern England has launched a unique, groundbreaking Radar Blanking Strategy which will allow for a number of potential wind farm schemes in the North East to go ahead without disruption air traffic control.

Since 2005, the airport has received over 250 consultations for on and off-shore wind farm developments from across the region, all aiming to meet government-set targets for renewable energy. Many of the schemes have the potential to affect the daily operations of Newcastle Airport's Air Traffic Control since wind turbines in operation can appear on the airport radar with similar markings to a moving aircraft.

In the absence of a solution, in the past, the airport has had no alternative but to object to schemes where an unacceptable impact was predicted. However, a technological solution has been found in the form of Radar Blanking software, which updates the airport's radar system. In effect, the new software places a 'patch' to cover the potential wind farm sites, thereby preventing turbines appearing, so they cannot be mistaken for moving aircraft.

"RenewableUK welcomes the proactive work that Newcastle Airport has undertaken in developing a radar mitigation strategy. This is a great example of where the aviation industry is working with wind farm developers to allow wind energy and aviation interests to co-exist," Nicola Vaughan, head of aviation at RenewableUK (formally the British Wind Energy Association, BWEA).

Over the past two years, the airport has worked closely with the aviation industry, the renewables sector and regional partners to facilitate this mitigation. "For several years One North East has hosted meetings between airport and industry representatives, including RenewableUK, to help find a solution to these issues and we therefore welcome Newcastle International Airport's work in preparing this new strategy and hope it will benefit both the airport and the renewables sector," commented Ian Williams, Director of Business and Industry at the One North East regional development agency.

“We recognise the importance of the renewables agenda, not just to the region, but on a national and even global level. We were very keen to explore ways in which we could work to facilitate wind turbine developments. This strategy allows certain developments to proceed whilst growing the region’s largest airport, which annually contributes £400 million to the regional economy,” explains Graeme Mason, planning and corporate affairs director at Newcastle Airport.

It is expected that there will be a limit to the number of Radar Blanking Areas that are possible. Given its finite nature, the Radar Blanking Strategy is therefore seen as short-term mitigation. The Civil Aviation Authroity and others throughout the industry have made, and continue to make, a concerted effort to explore a long-term solution to this issue, yet none of the emerging technologies have been proven at this time.

“Newcastle Airport, alongside other stakeholders, is open and committed to exploring all alternatives which might emerge to find lasting solutions which will allow for further development of wind farm schemes in the North East,” said the airport in a statement.

Appendix 8

Project Marshall - Installation of New and Upgraded Thales RSM970S Radars at MOD Sites in the UK

Project Marshall - Installation of new and upgraded radars at MOD sites

Site	Planned start date for transition work (correct at June 2019 but subject to change in accordance with the Marshall contract)	Planned date of commission or to complete the upgrade and/or replacement. (correct at June 2019 but subject to change in accordance with the Marshall contract).	Type & Model of Radar
RAF Akrotiri	Quarter (Q) 2 2020	Quarter (0)1 2022	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Aberporth	Q1 2020	042020	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Benson	Q1 2020	Q1 2021	Thales Star NG PSR
RAF Brize Norton	01 2020	Q1 2021	Thales Star NG PSR
RAF Coningsby	Q4 2019	Q4 2020	Thales Star NG PSR
RAF Cranwell	Q2 2019	02 2020	Thales Star NG PSR
RNAS Culdrose	Q3 2019	Q3 2020	SSR (Thales RSM970S)
	042020	Q3 2021	BAE Watchman PSR
Gibraltar	042020	Q4 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Leuchars	Under review	Under review	Under review
RAF Linton-on-Ouse	Q1 2021	Q1 2022	Thales Star NG PSR
RAF Lossiemouth	Q4 2019	Q3 2021	Thales Star NG PSR
RAF Marham	Q1 2019	02 2020	Thales Star NG PSR
RAF Odiham	Q1 2020	Q1 2021	lhales Star NG PSR
RAF Mount Pleasant	Q1 2021	04 2021	Thales Star NG PSR
RNAS Portland	Q3 2020	Q2 2021	.SSR (Thales RSM970S),
	Q1 2021	Q4 2021	BAE Watchman PSR .
Porton Down	Under review	Under review	Thales Star NG PSR
RAF Shawbury	01 2019	Q4 2019	Thales Star NG PSR

Site	**Planned start date for transition work** (correct at June 2019 but subject to change in accordance with the Marshall contract)	**Planned date of commission or to complete the upgrade and/or replacement.** (correct at June 2019 but subject to change in accordance with the Marshall contract).	**Type & Model of Radar**
RAF Spadeadam (Dead Water Fell)	02 2019	Q4 2021	Upgrade existing radar to Thales STAR NG PSR
RAF Spadeadam (Berry Hill)	03 2019	01 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF St !<ilda	02 2020	Q1 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Valley	03 2019	032020	Thales Star NG PSR
RAF Wattisham	02 2019	02 2020	Thales Star NG PSR
RAFWembury	03 2019	032020	SSR (Thales RSM970S),
	04 2020	03 2021	BAE Watchman PSR
RAF West Freugh	03 2020	02 2021	Thales Star NG PSR
RAF Wittering	Under review	Under review	Under review

Appendix 9

Irish State Plan for Aviation Safety 2023 –2025 Vol. II

2.2 Controlled Flight into Terrain

2.1.5 Actions

ACTIONS		TARGET DATE
a)	The IAA will focus on the management of the risk of LOC-I occurrences with Irish regulated organisations, as appropriate to their operations, as part of safety oversight and performance monitoring activities **EPAS References MST.028.**	Ongoing

2.1.6 Status Highlights

- Focus on management of risks associated with LOC-I during oversight of SMS
- Review of organisational safety objectives and SPIs to ensure they are appropriate and that they consider State level safety objectives (ref SPAS Volume I, Chapter 5)
- Monitoring of LOC-I related events and precursors
- Updating sector risk register to include new risks in this area
- Safety promotion of key risks in this area, such as entry of incorrect performance data

The actions in this chapter support the GASR 2023-2025 Operational SEI Mitigate contributing factors to LOC-I accidents and incidents

2.2 Controlled Flight into Terrain

2.2.1 Safety Issue

Controlled Flight Into Terrain describes an event where the aircraft is flown into terrain whilst under control of the flight crew, and is usually associated with loss of situational awareness in poor visibility conditions, or navigation errors. Controlled Flight Into Terrain (CFIT) is identified as one of the main contributory causes to fatal and non-fatal accidents across all sectors of civil aviation.

2.2.2 Safety Objective

To continuously improve safety by assessing and mitigating the risks of controlled flight into terrain involving Irish commercial aeroplane operators or operators flying in Irish controlled airspace.

2.2.3 Safety Performance Indicators (Ref SPAS Volume I, Chapter 5 for details)

Accident, Serious Incident and Incident rates and trends related to CFIT category occurrences involving Irish commercial aeroplane operators.

2.2.4 Stakeholders/Roles

Irish Aviation Authority – analysis of CFIT occurrences rates and trends and identification of sector-based safety issues

Industry (Air Operators) – managing CFIT related safety risks and reporting pre-cursor events that could result in a CFIT occurrence

Industry (ANSP's, airports) – developing approach procedures to minimise the risk of CFIT

2.2.5 Actions

ACTIONS		TARGET DATE
a)	The IAA will focus on the management of the risk of CFIT occurrences with Irish regulated organisations, as appropriate to their operations, as part of safety oversight and performance monitoring activities **EPAS References MST.028.**	Ongoing

2.2.6 Status Highlights

- Focus on management of risks associated with CFIT during oversight of SMS
- Review of organisational safety objectives and SPIs to ensure they are appropriate and that they consider State level safety objectives (ref SPAS Volume I, Chapter 5)
- Monitoring of CFIT related events and precursors
- Updating sector risk register to include new risks in this area
- Safety promotion on new regulations affecting this risk area, such as new EASA AWO regulations
- PBN transition plan developed and the latest version is found at https://www.iaa.ie/docs/default-source/default-document-library/airspace/pbn-transition-plan-for-ireland-v11-0.pdf?sfvrsn=390818f3_2

The actions in this chapter support the GASR 2023-2025 Operational SEI Mitigate contributing factors to CFIT accidents and incidents

Appendix 10

Concept Designs ATCSMAC

Concept Designs

ATCSMAC

Shannon Airport

04 June 2024

CL-6049-RPT-006 V1.0

www.cyrrus.co.uk

info@cyrrus.co.uk

Document Information

Document title	Concept Designs
Author	Shaun Gouvea
Reviewed by	Ferlicia Matloha
Produced by	Cyrrus Limited Cyrrus House Concept Business Court Allendale Road Thirsk North Yorkshire YO7 3NY T: +44 (0) 1845 522 585 F: +44 (0) 8707 622 325 E: info@cyrrus.co.uk W: www.cyrrus.co.uk
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Issue	Change Reference	Date	Details
V1.0	Initial Issue	04 June 2024	First Issue

Executive Summary

Ai Bridges Limited (hereafter referred to as 'the Client'), has requested Cyrrus to produce a series of concept design options to mitigate the impact to the Air Traffic Control Surveillance Minimum Altitude Chart (ATCSMAC) for Shannon Airport (hereafter referred to as 'the Airport'), against the proposed Oatfield Windfarm. The proposed Wind Farm comprises 11 turbines. Cyrrus delivered an Instrument Flight Procedure (IFP) Safeguarding Assessment which highlighted impact to the IFPs currently published at Shannon Airport.

To limit impact to the ATCSMAC the following options have been identified:

- Option A – Raise the Sector 1 Minimum Vectoring Altitude (MVA).
- Option B – Extend Sector 2 area to cater for the Wind Farms.
- Option C – Create a new Sector to address the Wind Farms.
- Option D – Create a new Sector and redesign with focus on ATC utility.

Whilst the list of options determined is not exhaustive, the Minimum Vectoring altitudes (MVA) determined in each option are not likely to change and any further design optimisation would be to the Surveillance Minimum Altitude Areas (SMAA) Sector shape and size.

Abbreviations

ATC	Air Traffic Control
ATCSMAC	ATC Surveillance Minimum Altitude Chart
ATM	Air Traffic Management
ATS - Authority	Air Traffic Services
DME	Distance Measuring Equipment
EGPWS	Enhanced Ground Proximity Warning System
GP	Glide Path
IAA	Irish Aviation Authority
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organisation
IFP	Instrument Flight Procedure
ILS	Instrument Landing System
km	Kilometre
LOC	Localiser
LNAV/VNAV	Lateral navigation / Vertical navigation
LPV	Localizer Performance with Vertical Guidance
MVA	Minimum Vectoring Altitude
nm	Nautical Mile
OPS	Operations
PANS	Procedures for Air Navigation Services
RNAV	Area Navigation
RNP	Required Navigation Performance
RWY	Runway
SMAA	Surveillance Minimum Altitude Area
THR	Threshold
VHF	Very High Frequency
VOR	VHF omnidirectional range

References

[1] ICAO Doc 4444, Procedures for Air Navigation Services — Air Traffic Management Sixteenth Edition 10 November 2016

[2] ICAO DOC 8168 - Procedures for Air Navigation Services, Aircraft Operations, Vol II, 7th Ed, Amendment 9, dated 05 November 2020.

Contents

List of figures

1. Air Traffic Control Surveillance Minimum Altitude Chart (ATCSMAC)

1.1. Criteria

1.1.1. There is no prescribed limit on the size, shape, or orientation of the ATCSMAC; however, in all cases the boundary of the ATCSMAC subdivisions must be located at a distance not less than 5.6 km (3 nm) from an obstacle which is to be avoided.

1.1.2. Criteria for the determination of minimum altitudes applicable to procedures based on radar vectoring are contained in Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS, Doc 8168). A minimum of 300 m (1 000 ft) vertical separation shall be applied.

1.1.3. Whenever possible, Minimum Vectoring Altitudes (MVA) should be sufficiently high to minimize activation of aircraft enhanced ground proximity warning systems (EGPWS). Activation of such systems may induce aircraft to pull up immediately and climb steeply to avoid hazardous terrain and obstacles, possibly compromising separation between aircraft.

1.1.4. The ATCSMAC shall enable the aircraft to be established on the final approach course or track, in level flight for at least 2.0 nm prior to intercepting the Glide Path (GP) or vertical path for the selected Instrument Approach Procedure (IAP).

1.2. Purpose

1.2.1. It is the responsibility of the Air Traffic Service (ATS) authority to provide the controller with minimum altitudes corrected for temperature effect.

1.2.2. Used by ATC to vector aircraft in the airspace, it provides obstacle clearance until the aircraft reaches the point where the pilot will resume own navigation.

1.2.3. The ATCSMAC is commonly split into several Surveillance Minimum Altitude Areas (SMAA) which provide relief from obstacles which would only affect vectoring on one runway circuit direction.

1.2.4. The minimum altitudes available within the SMAA sector should be adequate to permit vectoring of an aircraft to the final approach of a published IAP.

Shannon Airport ATCSMAC

1.2.5. Shannon Airports ATCSMAC is configured into four SMAA sectors.

- Sector 1: 2300 ft
- Sector 2: 3000 ft
- Sector 3: 4000 ft
- Sector 4: 4400 ft

1.2.6. Figure 1, depicts the ATSCSMAC sectors and a red line to represent the extended runway centreline. Also depicted is the location of the windfarm within the sectors of the ATCSMAC.

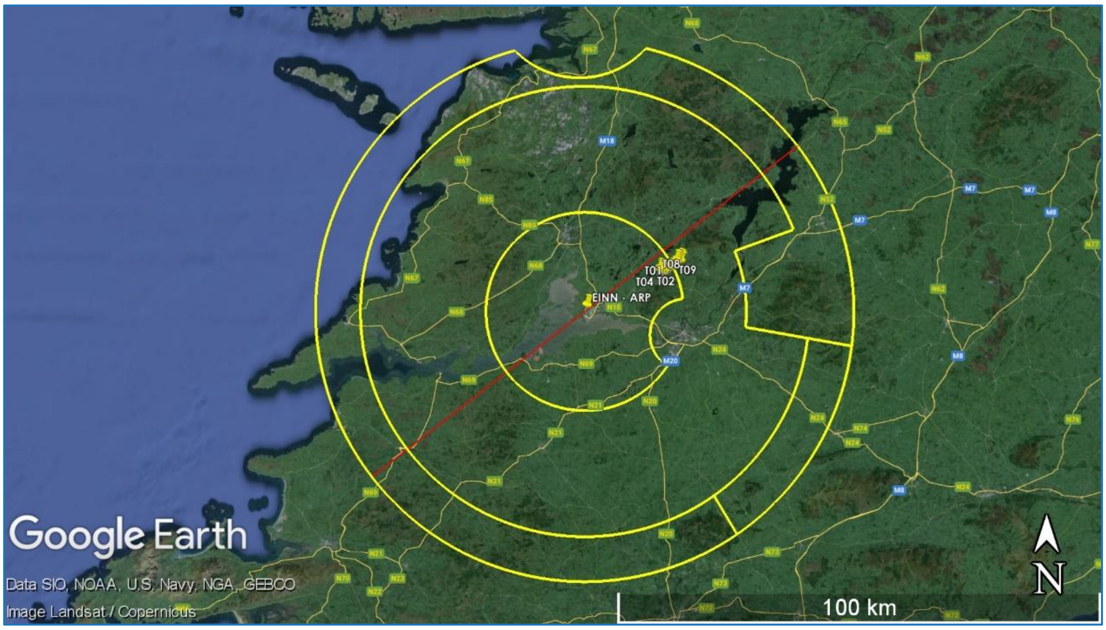

Figure 1: Wind Farm Location in ATCSMAC

2. Design Options

2.1. Overview

2.1.1. Four design options are proposed, whilst this is not a definitive list of potential options, they enable the evaluation of the potential ways to reduce the impact to the ATCSMAC.

2.1.2. The concept design options would need to be evaluated by the Airport, Air Navigation Service Provider (ANSP) and The Irish Aviation Authority (IAA) to determine if the proposed options reduce the impacts to a level where safe and effective vectoring can continue.

2.1.3. If a design option looks to have potential, a full design would be required to further optimise the concept and consider all obstacles.

2.1.4. The design options consider a Surveillance RADAR lateral separation certified at 3 nm.

2.2. Design Option A

2.2.1. Option A provides the simplest solution to implement, with minimal modification to the ATCSMAC as currently published.

2.2.2. The proposed solution is to increase the MVA associated with the SMAA sector 1 from 2300 ft to 2600 ft as depicted in Figure 2, this would provide sufficient Minimum Obstacle Clearance (MOC) above the wind turbines.

2.2.3. Aircraft crossing into sector 1 SMAA would be at a nominal altitude at or above 3000 ft. The Instrument Landing System (ILS) Glide Path (GP) intercept is at 3000 ft which occurs around 9.3 nm from the applicable Threshold (THR).

2.2.4. SMAA Sector 3 is approximately 2.5 nm from the nominal 2600 ft altitude position. Air Traffic Control (ATC) may still have the capability to vector an Aircraft onto the ILS Localiser (LOC) for GP intercept and to other Instrument Approach Procedures (IAPs). However, this reduction on capability could potentially hinder ATC when sequencing inbound traffic during busy periods.

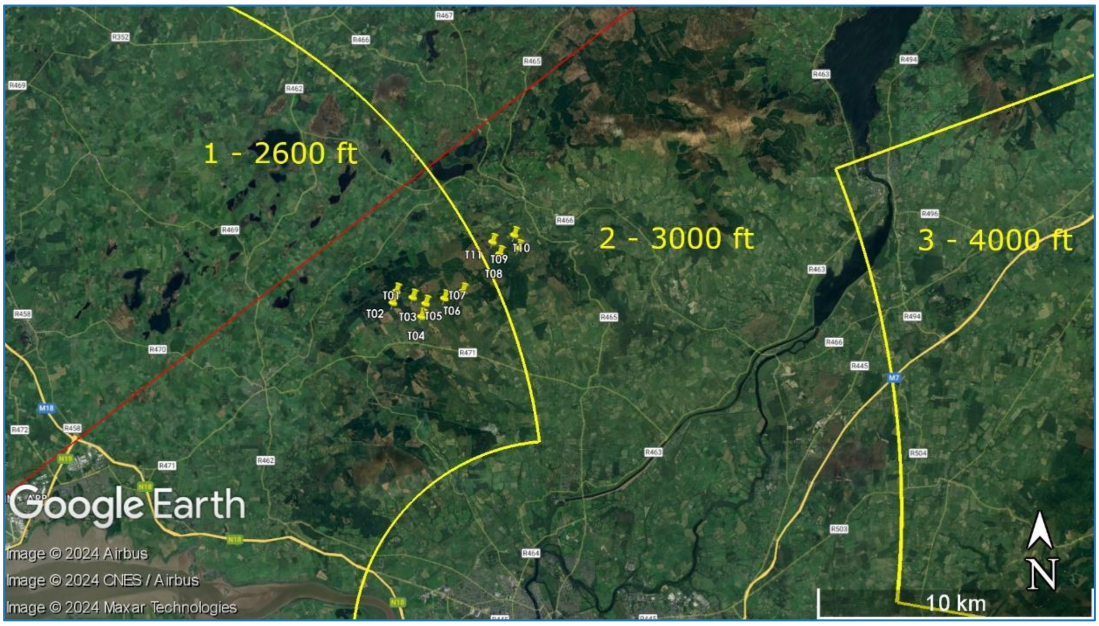

Figure 2: ATCSMAC Design Option A

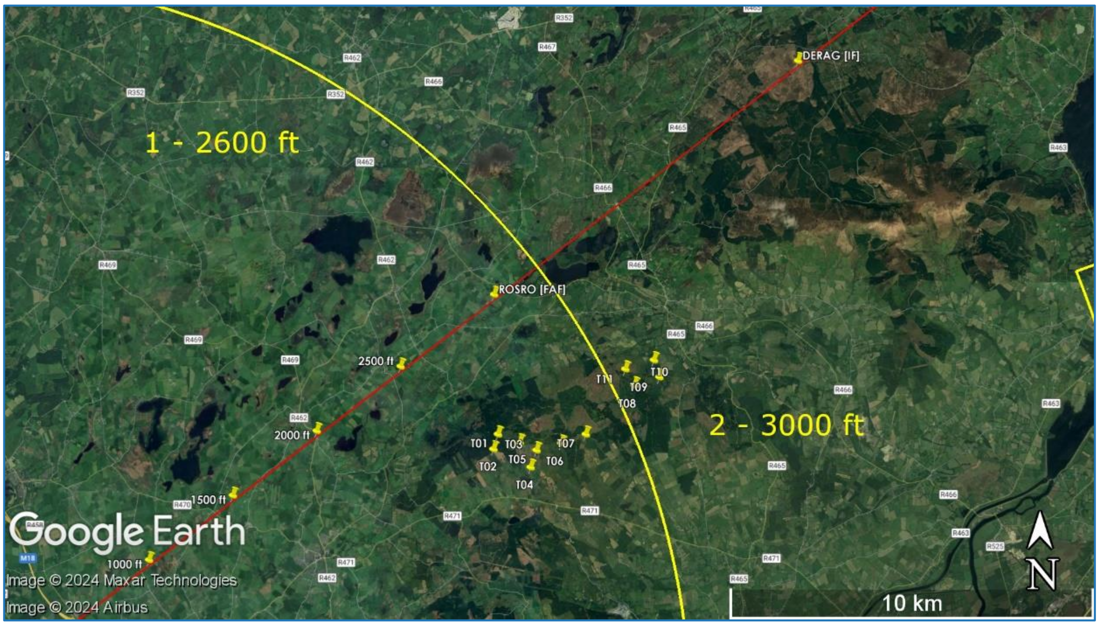

Figure 3: ATCSMAC Design Option A – Nominal Approach Altitudes

2.3. Design Option B

2.3.1. Design option B considers the adaptation of SMAA Sector 2 to incorporate the Wind Farm.

2.3.2. Each Turbine is considered with a 3 nm radius (plus the rotor radius) to determine the area which is required to be excluded. The area is combined with the existing SMAA Sector 2.

2.3.3. Aircraft crossing into the Option B SMAA sector 1 would be at a nominal altitude of around 2000 ft, as indicated in Figure 5. At this point aircraft would have to be fully established on the ILS, ATC would only be able to vector aircraft onto the ILS within sector 2, at a distance of around 9 nm or greater from THR RWY 26.

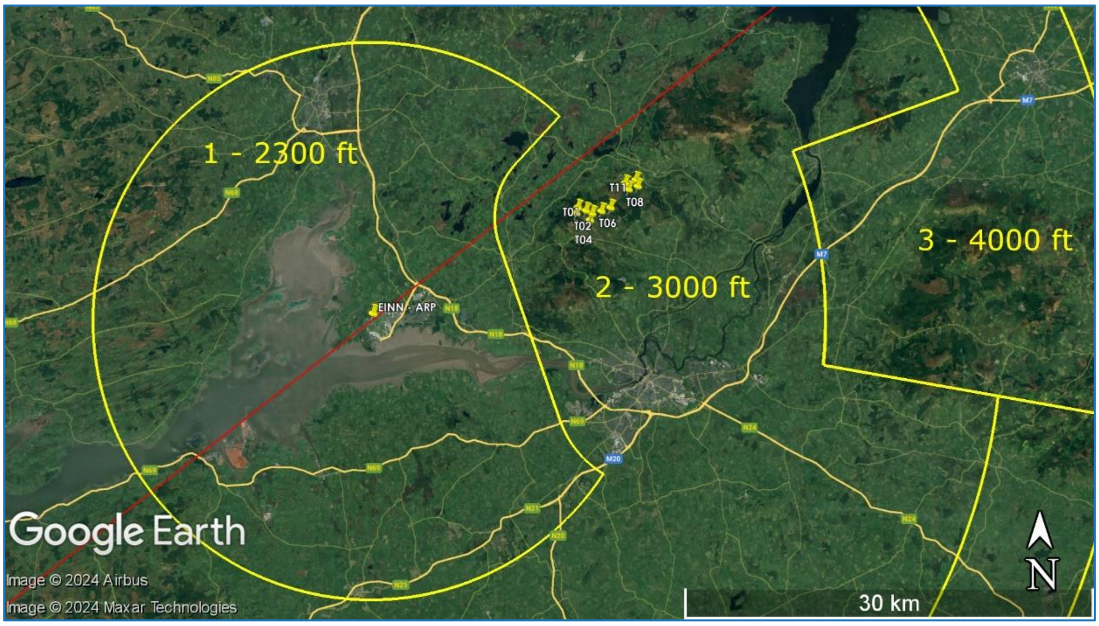

Figure 4: ATCSMAC Design Option B

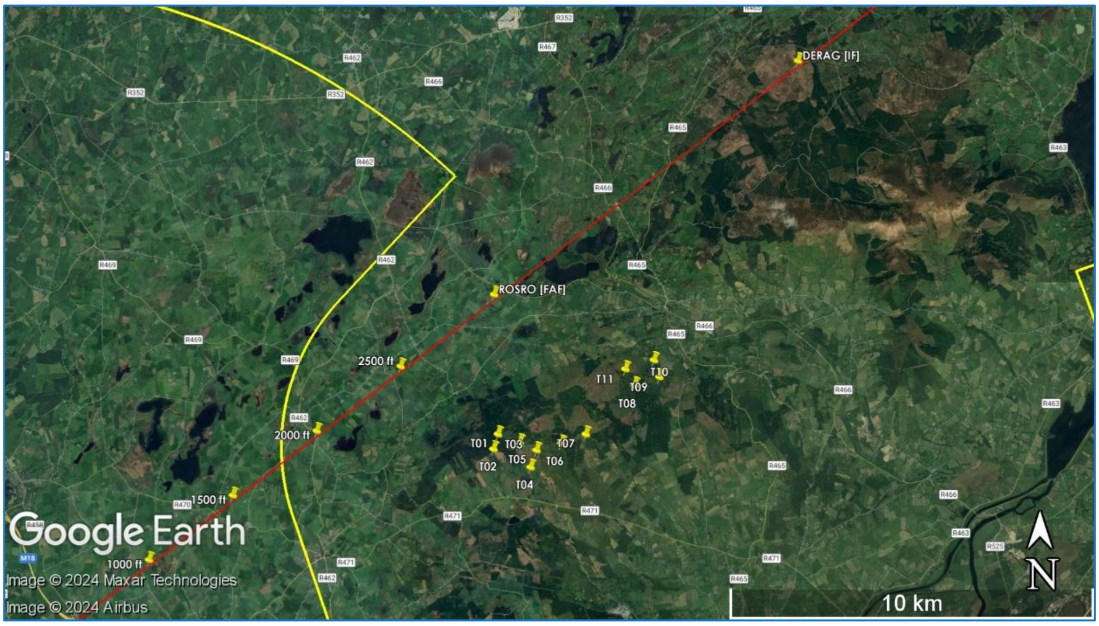

Figure 5: ATCSMAC Design Option B - Nominal Approach Altitudes

2.4. Design Option C

2.4.1. Design Option C considers the introduction of a new SMAA sector.

2.4.2. The SMAA sector consider each Turbine with a 3 nm radius (plus the rotor radius) to determine the new sector. The area is simplified using tangential radials from the Shannon VHF Omnidirectional Range (VOR) with distance-measuring equipment (DME) titled SHA and defined using a single radius of 3.2 nm.

2.4.3. The proposed SMAA sector would have a MVA of 2600 ft, the area is indicated as SMAA sector 5 below in Figure 6.

2.4.4. Aircraft on the nominal glide path would enter the proposed SMAA from SMAA sector 3 at or above 3000 ft and leave the proposed SMAA sector 5 to enter SMAA sector 1 at around 2000 ft. This should allow for ATC to vector aircraft down to 2600 ft to intercept the GP at around 8 nm from THR RWY 26.

2.4.5. The nominal altitude of 2300 ft is achieved around 7 nm from THR RWY 26.

2.4.6. Whilst this configuration would allow the Wind Farm to be built, there would still be a potential reduction in efficiency and flexibility for ATC.

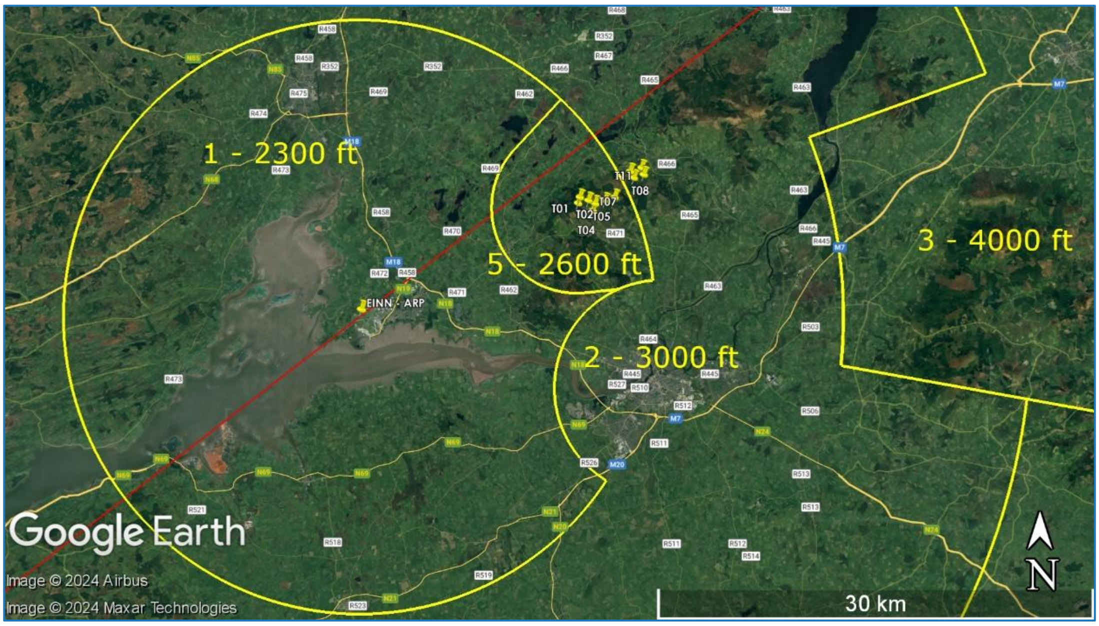

Figure 6: ATCSMAC Design Option C

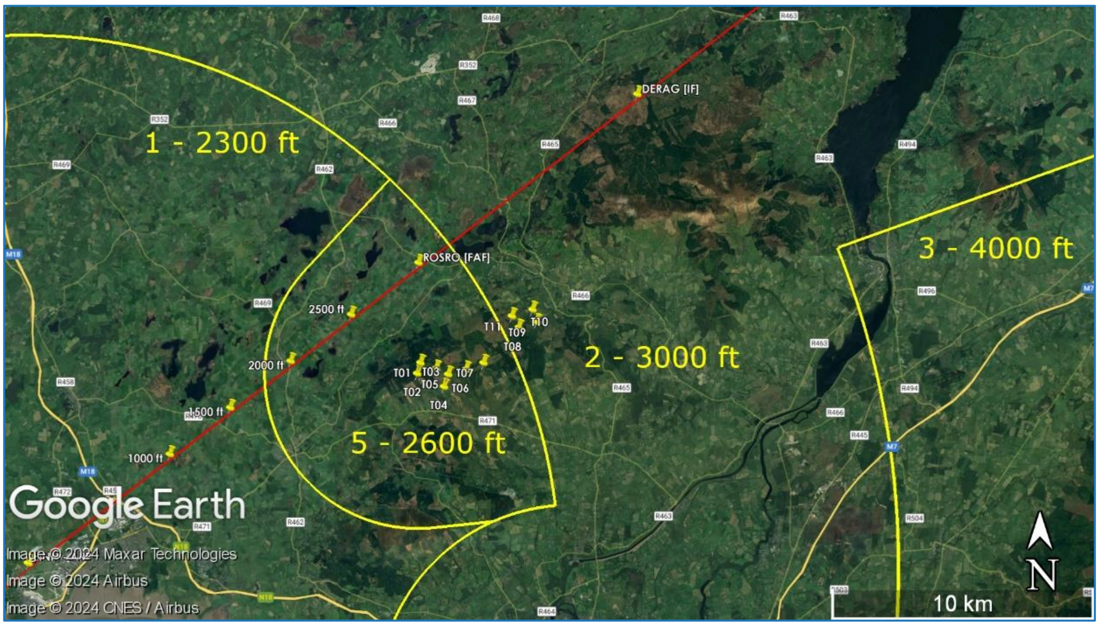

Figure 7: ATCSMAC Design Option C - Nominal Approach Altitudes

2.5. Design Option D

2.5.1. Design Option D, considers the introduction of a new SMAA sector whilst redefining the existing SMAA areas to provide an ATCSMAC which may be more operationally suited.

2.5.2. SMAA sector 2 has been redefined using radials and distances from the ARP, this would eliminate small areas between SMAA sectors where vectoring is not practical.

2.5.3. The proposed SMAA sector 5 is positioned next to the reconfigured SMAA sector 2, with a MVA of 2600 ft.

2.5.4. Aircraft on the nominal path would enter the proposed SMAA from SMAA sector 3 at or above 3000 ft and leave the proposed SMAA sector to enter SMAA sector 1 at around 1900 ft. This should allow for ATC to vector aircraft down to 2600 ft to intercept the GP at around 8 nm from THR RWY 26.

2.5.5. Whilst this configuration would allow the Wind Farm to be built, there could still be a potential reduction in efficiency and flexibility for ATC.

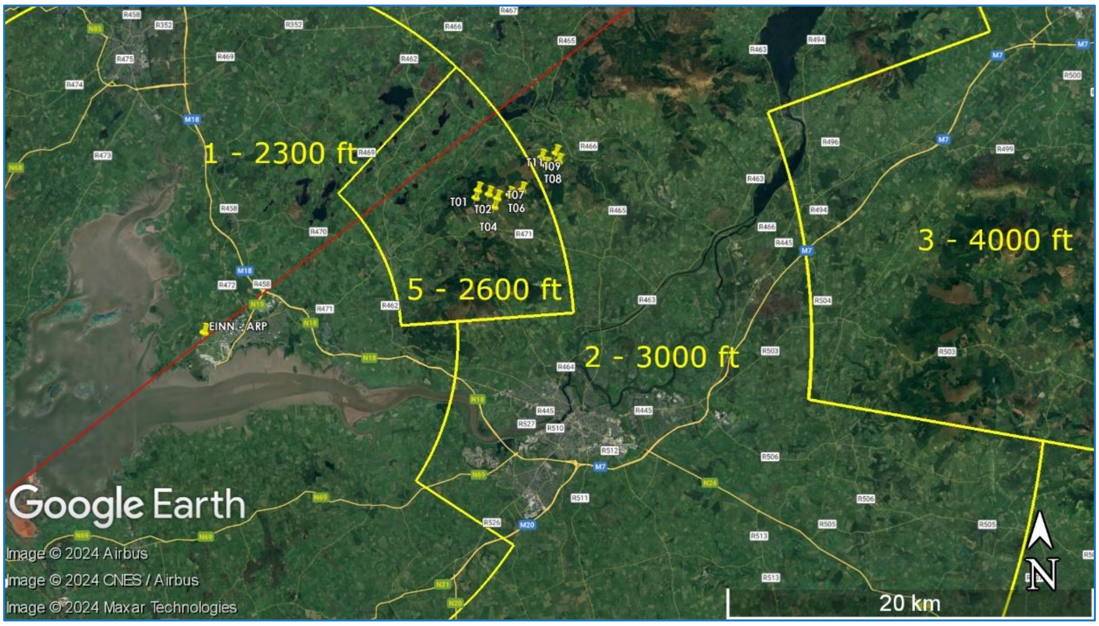

Figure 8: ATCSMAC Design Option D

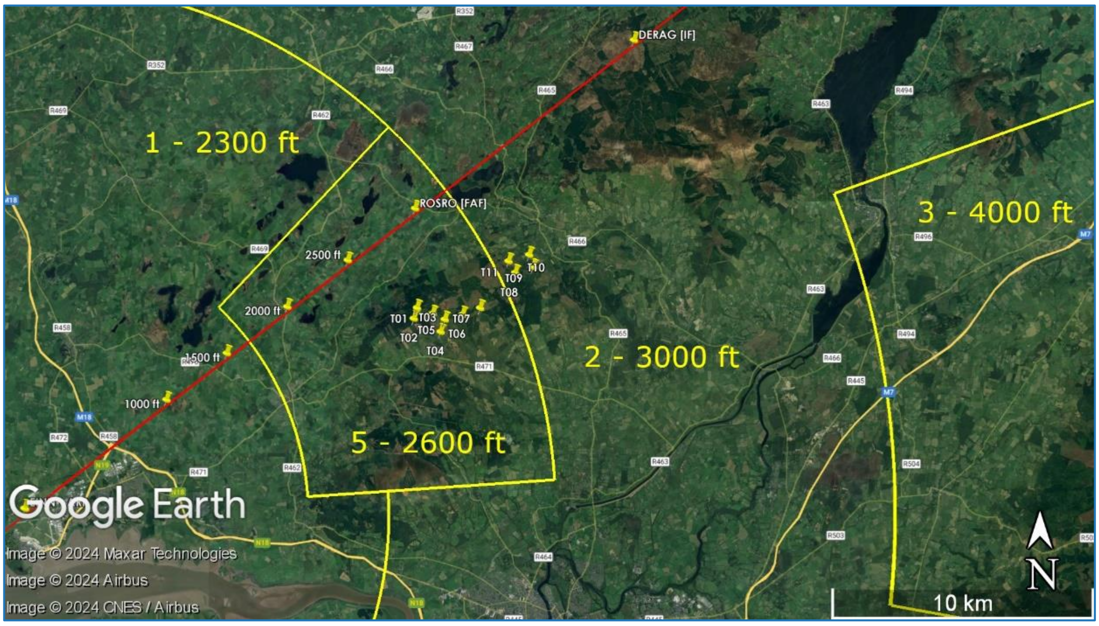

Figure 9: ATCSMAC Design Option D - Nominal Approach Altitudes

3. Conclusion

3.1. The Wind Farm will still have an impact to the ATCSMAC. Whilst all the identified options could allow for safe vectoring onto the IAPs, the Airport, ANSP, and the IAA would have to determine if the proposed options would still allow for effective vectoring operations. If it is deemed that the Wind Farm can be mitigated by a redesign, the full design process will need to be conducted.

3.2. Design option A will still allow for aircraft to be vectored onto an Instrument Approach Procedure for RWY 24. Aircraft would be required to be established on the IAP at 8 nm from THR RWY 24 to descend below the MVA.

3.3. Design option B would allow for the current SMAA sector 1 to remain at 2300 ft, however SMAA sector 2 would be expanded to encompasses the Wind Farm. ATC would be unable to vector aircraft onto the RWY 24 IAPs within SMAA sector 1.

3.4. Design options C and D would allow for the current SMAA sector 1 to remain at 2300 ft, although its area would reduce. A new SMAA is proposed as part of this option which will give ATC the ability to vector aircraft to intercept the IAPs at 2600 ft for RWY 24 whilst keeping a 2300 ft MVA for RWY 06.

3.5. The stability of approaches by landing aircraft is coming evermore to the forefront of Airline Safety Departments and National Authorities safety agenda's and less and less operators are accepting of aircrew conducting 'shortened' ILS approaches. However, this does not mean that flexibility of ATC vectoring operations should no longer be considered important. Busy sequences of traffic sometimes require aircraft that are able to accept manoeuvring that, although obviously still safe, does not necessarily meet other Operators SOPs and are placed into the 'approach plan' to create an overall efficient flow of air traffic – a core element of ATC.

3.6. This, of course, needs to be balanced (obviously with safety as the foundation) with the Country's Green Energy aspirations. Ultimately, only Shannon Airport ATC can decide whether the options presented in this report are operationally feasible. As the report has stated, any option deemed to have merit would need to be fully assessed and, possibly, refined so as to meet Shannon ATC expectations and provide them with the confidence of a solution that is safe and, on balance, expedient to the majority of users.

3.7. As the number of Area Navigation (RNAV)-equipped aircraft continues to expand, alternative methods for aligning aircraft with the ILS final approach path could involve leveraging RNP to ILS procedures or utilizing Required Navigation Performance (RNP) procedures with vertical guidance, such as Lateral navigation (LNAV) / Vertical navigation (VNAV) or Localizer Performance with Vertical Guidance (LPV). By doing so, the reliance on ATC vectoring to intercept the ILS could be minimised. While vectoring could still serve as a fallback to the RNP procedures, this approach would mitigate any potential impact on efficiency and flexibility.

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