CARBON TRUST

OFFSHORE RENEWABLES JOINT INDUSTRY PROGRAMME (ORJIP) FOR OFFSHORE WIND

Best practice guidance for the installation of monitoring equipment to support post-construction seabird collision monitoring at offshore wind farms

Prevalence of Seabird Species and Collision Events in Offshore Wind (PrediCtOr) project

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Offshore Wind Evidence + Change Programme
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Project information

The PrediCtOr project was initiated and set up within the Offshore Renewables Joint Industry Programme (ORJIP) for Offshore Wind. The project is jointly delivered by the Carbon Trust, British Trust for Ornithology (BTO), and Waardenburg Ecology.

PrediCtOr project partners include: Equinor Energy AS; Ørsted Wind Power A/S; Rijskwaterstaat Water; Verkeer en Leefomgeving; RWE Offshore Wind GmbH; Shell Global Solutions International B.V.; The Scottish Ministers; TotalEnergies OneTech; and ScottishPower Renewables (UK) Limited.

The project forms part of the Offshore Wind Evidence and Change Programme (OWEC), led by The Crown Estate, in partnership with the Department for Energy Security and Net Zero and the Department for Environment, Food and Rural Affairs. The Offshore Wind Evidence and Change programme is an ambitious strategic research and data-led programme. Its aim is to facilitate the sustainable and coordinated expansion of offshore wind to help meet the UK’s commitments to low carbon energy transition whilst supporting clean, healthy, productive and biologically diverse seas.

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We would like to thank the following organisations for their advice and support of the project via participation in the Project Advisory Group: Natural England, Joint Nature Conservation Committee (JNCC), NatureScot, Natural Resources Wales (NRW), Royal Society for the Protection of Birds (RSPB), The Crown Estate, Federal Maritime and Hydrographic Agency of Germany (BSH), Scottish Government's Marine Directorate, Department for Environment, Food & Rural Affairs (Defra).

We would also like to thank the bird monitoring equipment suppliers and consultants who shared their insights on monitoring equipment installation during project delivery.

Who we are

Our mission is to accelerate the move to a decarbonised future. We are your expert guide to turn your climate ambition into impact.

We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions to drive positive climate action. To date, our 400 experts globally have helped set 200+ science-based targets and guided 3,000+ organisations and cities across five continents on their route to Net Zero.

Executive summary

The ORJIP PrediCtOr project seeks to reduce uncertainty surrounding seabird collision risk in offshore wind farms. As offshore wind expands to meet Net Zero targets, effective monitoring designs are essential to help quantify this risk. This guidance document provides best practice recommendations for the design and installation of seabird collision monitoring equipment, aiming to support developers, turbine manufacturers, and monitoring specialists in successfully deploying collision monitoring systems offshore.

Motivation and approach

The creation of this guidance is motivated by the complexity encountered in designing previous monitoring system deployments and the clear need to share lessons for more efficient design of monitoring campaigns going forward. Additional challenges have arisen from differing requirements among developer teams, highlighting the need for coordinated guidance. The content is informed by extensive stakeholder engagement, technical reviews, and engineering case studies. Inputs were primarily gathered from offshore wind developers and monitoring equipment suppliers through questionnaires and interviews, complemented by a review of existing monitoring technologies and installation concepts, as well as detailed design assessments for selected case studies, ensuring that the recommendations reflect both practical experience and technical feasibility.

Monitoring technologies and practices

Collision monitoring in offshore wind farms primarily relies on cameras and radar systems. Cameras, including daylight, thermal, and stereo configurations, are widely used for species identification and flight height estimation, with recent advances enabling improved tracking and automated detection. Radar systems complement cameras by providing large-scale coverage and flight height data; their placement must be carefully planned to minimise blind spots caused by turbine structures. Other technologies, such as acoustic sensors and bio-logging, are generally used as supplementary tools, offering additional insights into nocturnal flight calls or individual bird behaviour, but they are not considered core methods for collision monitoring.

The document provides a review of current installation practices and explores practical solutions for mounting monitoring equipment on offshore wind structures. It considers options such as attaching cameras to guardrails, installing radars within laydown areas, and using additional platforms or offshore substations for larger systems. These approaches are reviewed in terms of structural integrity, space availability, and their impact on operations and maintenance activities. The guidance also sets out key requirements for successful installation, including planning for power and data connectivity, ensuring equipment protection against harsh marine conditions, and incorporating maintenance access into design. Health and safety requirements and logistical constraints are highlighted as critical factors influencing both initial installation and long-term reliability. Early integration of these elements into design is strongly recommended to reduce complexity and minimise risks during offshore work.

Retrofitting vs. integrated designs

The guidance includes an overview of considerations for both retrofitting campaigns and integrated designs, covering key recommendations and risks for each approach. While retrofitting into operational wind farms is possible, it is generally more complex, costly, and risk-prone due to space constraints, offshore logistics, and potential turbine downtime. Integrated designs are strongly preferred because they allow monitoring requirements to be incorporated during early design stages, enabling standardisation, reducing offshore work, and improving long-term reliability and safety.

In practice, misalignment between permitting and engineering timelines can limit opportunities for full integration of monitoring systems, with late changes to requirements, installation feasibility issues, and prolonged approval times leading to redesign, additional cost, and programme delays. To mitigate these risks, the guidance promotes early, principle-level engagement with consenting bodies, close coordination between engineering and consenting teams, and preserving flexibility in early designs where possible, through reserved space, interfaces, and contingency when final monitoring system requirements cannot be confirmed early.

Case studies and recommendations

The guidance presents specific case studies that illustrate practical design solutions for mounting monitoring equipment. These examples focus on two selected concepts: a guardrail-mounted camera support and a radar baseplate positioned within the platform area. Detailed design drawings and load analyses were produced to illustrate these concepts, considering factors such as environmental loading, material selection, and ease of installation.

Overall, the guidance emphasises the importance of early planning and collaboration to ensure successful implementation of monitoring systems. Incorporating monitoring requirements into turbine and foundation design at an early stage allows for standardisation, reduces offshore work, and improves reliability. Clear allocation of space for the equipment and early planning for power and data connections are critical to avoid retrofit complications and ensure safe, efficient installation. Applying the practices outlined in the guidance will support effective monitoring, minimise installation risks, and contribute to meeting environmental and regulatory commitments as offshore wind continues to expand.

How to use this document

This document provides best practice guidance for the design and installation of seabird collision monitoring equipment in offshore wind farms. It is intended to sit alongside project-specific monitoring plans, OEM documentation, and site-specific design requirements, providing a common reference for developers, manufacturers, and monitoring specialists.

The guidance is structured to support planning and delivery across the project lifecycle, from early design and procurement through to installation, operation, and maintenance. It presents practical, experience-based recommendations rather than step-by-step instructions, and is intended to be adapted to different project contexts, foundation types, and regulatory frameworks.

Sections on retrofitting campaigns and integrated designs support selection of an appropriate installation approach by outlining typical challenges, risks, and trade-offs. The installation design case studies illustrate how selected concepts can be translated into workable engineering solutions. These examples are representative rather than prescriptive, demonstrating application of design principles while recognising that site conditions, equipment specifications, and OEM requirements will vary between projects.

The key recommendations section consolidates the main messages as concise, actionable points mapped to common stages of collision monitoring campaigns. It can be used as a checklist to support early design discussions, review proposed installation concepts, and confirm that key technical, logistical, and safety considerations have been addressed prior to deployment.

Abbreviations

AIS	Automatic identification system
AOWFL	Aberdeen Offshore Wind Farm
BMS	Bird monitoring system
BSH	Federal Maritime and Hydrographic Agency of Germany
BTO	British Trust for Ornithology
CRM	Collision risk modelling
CTV	Crew transfer vessel
Defra	Department for Environment, Food & Rural Affairs
ECMWF	European Centre for Medium-Range Weather Forecasts
EIA	Environmental Impact Assessment
EOWDC	European Offshore Wind Deployment Centre
GPS	Global Positioning System
HSE	Health, safety, and environment
IP	Ingress protection
JNCC	Joint Nature Conservation Committee
JV	Joint venture
LV	Low voltage
NRW	Natural Resources Wales
O&M	Operations and maintenance
OEM	Original equipment manufacturer
OFCS	Offshore converter station
ORJIP	Offshore Renewables Joint Industry Programme for Offshore Wind
OSS	Offshore substation
OSW	Offshore wind
OWF	Offshore wind farm
PAG	Project Advisory Group
PCM	Post-construction monitoring

PrediCtOr	Prevalence of Seabird Species and Collision Events in Offshore Wind project
RPM	Revolutions per minute
RSPB	Royal Society for the Protection of Birds
RSZ	Rotor-swept zone
RWS	Rijkswaterstaat
SCADA	Supervisory Control and Data Acquisition
SNCB	Statutory Nature Conservation Body
SOV	Service operation vessel
TP	Transition piece
UHF	Ultra-high frequency
WP	Work package
WTG	Wind turbine generator

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1. Introduction

The installation of seabird collision monitoring equipment in offshore wind farms presents a unique set of technical, logistical, and stakeholder challenges. As part of Work Package 5 (WP5) of the Prevalence of Seabird Species and Collision Events in Offshore Wind Farms (PrediCtOr) project, this guidance document aims to support developers, manufacturers, and monitoring specialists in designing and implementing effective post-construction monitoring systems.

The installation of bird collision monitoring equipment offshore presents a range of practical challenges, driven by space constraints for equipment installation, health and safety requirements, offshore logistics, and interference with turbine operation and maintenance activities. These challenges are often compounded by the late confirmation of monitoring requirements through consenting procedures, increasing the complexity, cost, and risk of installation where monitoring systems have not been considered early in design.

The guidance draws on a combination of stakeholder engagement, technical review, and case study analysis to identify practical recommendations and promote alignment across the industry.

This guidance document has the following objectives:

- Identify and mitigate potential challenges and conflicts around installation of bird monitoring equipment in offshore wind farms;
- Investigate requirements for early-stage integration of monitoring systems
- Explore retrofitting requirements and challenges
- Communicate developers' needs to manufacturers (and vice versa) and identify opportunities for improved coordination

In order to achieve these objectives, we:

- Stakeholder engagement with developers and monitoring equipment suppliers through questionnaires and interviews:
    - Input from four developers (including foundations teams);
    - Input from seven monitoring equipment suppliers;
    - Input from one wind turbine OEM;
    - Two workshops with the PrediCtOr partners and PAG to seek input on case study selection and feedback on guidance content;
- Review of the "Review of seabird monitoring technologies for offshore wind farms (SBMon)" report and supplementary desk research;
- Analysis of existing monitoring studies, with a focus on installation design;
- Engineering design office review of existing installation concepts and design drawings;
- Case studies of installation designs based on equipment and scenarios agreed with PrediCtOr partners.

The expected outcomes of this guidance document are:

- Improved understanding of the impacts, opportunities, risks, and mitigations associated with the installation of monitoring equipment;
- Greater alignment between developers and manufacturers on recommended retrofitting and integration approaches;
- Reduced time and effort for developers when designing and implementing monitoring campaigns.

It is important to note that this design best practice guidance and the PrediCtOr project as a whole are primarily focused on seabirds and daytime monitoring. While it is acknowledged that migratory land birds can also be susceptible to collisions with offshore wind farms, migratory species can be difficult to monitor as migration occurs predominantly at night and broad front corridors are used in assessment (although it is known that birds will pass through footprints in discrete time windows, depending on the weather conditions). Although in some jurisdictions migratory birds are the primary focus of bird collision monitoring (e.g. Germany), conducting detailed research and developing best practice guidance that would also include migratory land birds is not feasible within the scope of the PrediCtOr project.

Considering that the project focus is on seabirds, daytime focus is more feasible. Due to factors such as limited use of camera equipment, lower visibility, less vessel activity, collecting night-time data would make any study considerably more complicated, requiring different monitoring specifications and equipment. However, some considerations for migratory birds and night-time monitoring have been included where available and relevant.[1]

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[1] In current practice, this is typically considered using nocturnal activity adjustments to collision risk estimates, as discussed in:

- Cook, A.S.C.P, Thaxter, C.B., Davies, J., Green, R.M.W., Wischnewski, S. and Boersch-Supan. P., 2023. Understanding seabird behaviour at sea part 2: improved estimates of collision risk model parameters. Report to Scottish Government. Accessed at link.
- Garthe, S. and Hüppop, O., 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology, 41,724–734, 2004. Accessed at link.

2. Overview of typical monitoring equipment

This section outlines the primary technologies used for seabird collision monitoring in offshore wind farms. It focuses on equipment capable of detecting, recording, or supporting the identification of collision events, and highlights key developments and future directions relevant to offshore deployment.

To date, a range of different collision monitoring systems have been used at offshore wind farms and surrounding areas. Combinations of different systems and monitoring sensors have been used which allows a powerful tool to assess different aspects of bird movement and behaviour over a range of different spatial scales (RPS 2022, SBMon). These have mainly included use of camera technologies, radar monitoring, combined with further visual observations. However, some other systems such as acoustic methods, LiDAR and bird-borne telemetry have been used as supporting survey technology platforms alongside this.

Further, blade-sensors such as acoustic or vibration sensors have been used at onshore wind farm sites – use of these has been trialled or proposed in future monitoring plans for some sites, but their use in the offshore environment has to date been more limited. In general, the evolution of these systems is tied to developments in the system components, both in terms of sensors (e.g. higher resolution and/or higher frame rate cameras, more cost effective thermal imaging systems, or the recent rapid development of tracking radars for small targets) and processing infrastructure (in particular the rapid development of machine learning approaches for image and other signal processing).

In general, the number of equipment suppliers remains fairly limited, particularly for systems specifically designed for offshore use. However, supplier numbers are increasing, especially for camera-based systems, with several systems recently being marketed or adapted for offshore deployment.

System development is largely driven by market demand, with some suppliers continuing to focus on onshore applications while others are increasingly targeting offshore wind. Additional drivers include involvement from research institutes and wind farm developers, for example through funded deployments or collaborative projects that encourage coordination across stakeholders. Increasing coordination and shared learning has been identified as important for system acceptance in the onshore sector (Gottlieb et al., 2025) and is likely to play a similar role offshore, alongside trials, independent validation, and transparent sharing of results.

2.1. Cameras

Camera systems often involve multiple cameras of varying designs. These typically involve high resolution cameras used in daylight and low-light or thermal infra-red imagery for nocturnal detection and 24-hour monitoring (Tjørnløv et al. 2023), with further use of cost-effective daylight CCTV systems also used (Equinor & Spoor 2024). Species identification is possible when targets are imaged in favourable lighting conditions and at sufficient resolution. Minimum image quality requirements are species- and context dependent, but for many species groups good identification can be achieved at c. 2 cm/px (Weiß et al., 2016). In general, species identification is typically more limiting in terms of effective range rather than object detection, i.e. birds are detected at far greater ranges than they can be identified (Brighton et al., 2025). There is a general trade-off between detection range and the size of the field of view, with wide-angle cameras having much shorter detection ranges than zoom-lenses for a given resolution. Pan-tilt-zoom cameras can provide a compromise between range and field-of-view for the purposes of species identification, in particular if deployed concurrently with sensors that provide target tracking in a larger field-of-view (e.g. wide-angle cameras or radars).

Camera systems also include capabilities for tracking targets using artificial intelligence, improving species detection and recognition. Stereo system camera set ups have also now been installed at some sites (such as in the ATOM system) providing more precise information on 3D activity of birds (Wilmott et al., 2023), including flight height and speed, more so than mono camera setups but produce larger data volumes and require more complex data processing (Boersch-Supan et al., 2024, Brighton et al., 2025). Data volumes scale with image resolution and frame rate, and data streams can easily exceed real-time transmission capabilities of OWF data networks, thus requiring in-situ imagery processing and/or storage.Depending on the system and aim, cameras can be attached on the turbine tower or on the railing of the walkway platform. Currently, one system on the market is placed on the nacelle. Cameras should be stable and vibrations should be kept to an absolute minimum, to avoid reducing the quality of the data collected.

Camera systems are controlled from a central module that is often housed within the turbine and can weigh up to 45 kg. Cameras themselves weigh much less – normally under 15 kg (not including the frame and/or housing).

2.2. Radars

Radars can be used alone or in combination with cameras (although radar alone is unlikely to be suitable specifically for monitoring bird collisions, as it cannot reliably achieve species identification; in addition, radar will also be influenced by backscatter from the rotor blades, limiting detections of actual collisions). When used as a standalone tool, radar is therefore best suited to describing patterns of bird activity and movement, particularly over larger areas and at night, and can be used to estimate macro- and meso-avoidance – albeit without species information and may be limited due to shadowing and clutter within wind farms. Radars are not suitable for providing direct estimates of species-level collision risk, and typically requires supporting data (e.g. cameras or visual surveys) to ensure appropriate ecological interpretation. When used in combination, this allows targets discovered by radar to be tracked by cameras. Radar systems typically use horizontal (S) and vertical (X) band radars (e.g. Robin Radar, Merlin) together providing a three-dimensional perspective of bird activity and flight height of targets over wide spatial scales covering many kilometres (e.g. Krijgsveld et al., 2011). Specialist software is often linked with specific radar systems to classify tracks into general classes such as large or small birds, bats or insects. Radars with smaller bundles, often scanning vertically, are typically able to classify more specifically than radars scanning over larger areas. The choice of radar will depend on whether information on flight heights or larger spatial flight patterns is needed.

Radars can be placed on stand-alone (stable or stabilised) floating buoys/structures, turbine transition piece, or turbine tower. Depending on the structure these are usually positioned between several and several tens of metres above the water's surface. The main types of radar include horizontal, vertical (sometimes used in combination) and 3D radar. The actual type can vary with rotating antenna, solid state (FMCW) and scanning pulse radars (most common). Radar systems vary considerably in size, mass, and configuration, ranging from compact enclosed or radome-type units with characteristic dimensions of approximately 0.5-1.5 m, to larger open-array rotating or panel-based systems with antenna lengths of ~2-6 m and installed weights of several hundred kilograms or more, with direct implications for mounting location, structural integration, and installation design. Additional hardware such as computing and servers could typically be expected to be housed within the turbine and measure 1x1x0.5 m, although sizes could vary depending on the system and site requirements.

Radars can suffer from clutter and shadowing effects if placed too close to solid structures such as wind turbines; clutter from sea surface and precipitation can also present issues. The level of clutter from the sea surface varies depending on radar settings as well as the size and direction of waves, with clutter filtering criteria often needing to be assessed regularly throughout the day as conditions change. For higher flying birds (particularly at rotor height) it may be possible to filter out the lowest few metres of radar data to avoid these wave clutter issues. Radar range and detection may be limited if installed too close to turbines; some manufacturers recommend that vertical radar systems be installed no closer than twice the turbine's total height from a wind turbine. Horizontal and 3D radars will also suffer from shadowing that ultimate results in blind areas behind turbines. The distance of the radar to the turbine will influence the angle and size of this blind spot. Radars need to be fairly stable, and some systems may need to be deactivated during strong winds to reduce the risk of damage to motors.

2.3. Acoustic sensors

The use of acoustic sensors has been more limited in the offshore environment and less so as a main method for collision monitoring, acting as more of a supporting technology. However, there are some cases worth noting. Automated microphone recordings (Hill et al., 2022) have been used to inform species occurrence based on nocturnal flight calls. These are species-specific calls produced by many nocturnally migrating birds during flight, and are of particular relevance in jurisdictions that have regulations and/or monitoring requirements around collision risks of nocturnally migrating birds. Flight calls are typically recorded by Autonomous Recording Units and detected and classified by machine learning algorithms, which may involve human input and/or quality control (Osterhaus et al., 2025). Monitoring outputs are species lists, and in some cases proxies for abundance can be derived based on assumptions of calling and passage rates. However, exact localisation of calling birds is generally not available, no quantitative information can be obtained on the number of birds, and not all relevant species are calling.

Acoustic and vibration sensors within turbine blades have also been trialled onshore and thus could potentially be used for direct monitoring of collisions, providing information such as turbine-variations in collision impacts and improvements in numbers of turbines monitored. However, it is generally appreciated that such methods can be difficult to apply to attain a desired level of standard. Installation, monitoring and maintenance are part of this discussion, given the critical role of turbine blades for the function of wind turbine generators, the wear and tear they experience, and the difficulty of maintenance and/or retrofitting work on blades post-construction. In addition, placing vibration sensors inside the blades could potentially void turbine warranties in some cases.

2.4. Bio-logging (animal tracking)

Among other methods, biologging, i.e. the use of animal-borne telemetry devices to track animal movements, has been used alongside the main methods outlined above in some studies. The predominant biologging technology in seabird applications is Global Positioning System (GPS) positioning, which has provided important insights about seabird movements around offshore wind infrastructure, particularly at the macro- and meso scale (e.g. Bogdanova et al., 2020; Johnston et al. 2022; Pollock et al. 2024). GPS tracking generally does not rely on the installation of monitoring equipment at OWF sites, as birds are generally fitted with telemetry devices at their nesting sites and tag data is retrieved via recapture, ultra-high frequency (UHF) download or cellular data links. GPS tags are comparably expensive and often have limited battery life (days to weeks), making it costly to scale up tagging campaigns and generate large sample sizes of birds interacting with OWF infrastructure. A complementary approach to tracking is to use simpler and cheaper radio-frequency transponders such as those of the MOTUS tracking system which has been deployed along the US Atlantic Coast (Robinson Willmott, 2023) and at the Gemini Wind Farm off the coast of the Netherlands, or the ATLAS tracking system, which has been deployed in the Dutch Waddensea, albeit not directly in an OWF monitoring context (Beardsworth et al. 2022). Both systems rely on base station networks to receive transmissions from the animal-borne tags and potentially triangulate animal positions, and therefore require the installation of base stations within OWF or in their close vicinity to be of use for collision monitoring.

In general, biologging campaigns are often part of wider programme of research depending on study aims and is often not sufficient on its own to provide the necessary wider post-construction collision monitoring, both because the positional accuracy and/or temporal resolution of the obtained tracks is often too coarse to make robust inferences at the micro-scale and because large sample sizes of tagged birds interacting with OWFs are difficult to achieve . The use of bird-borne telemetry can however give valuable perspectives on behaviour of individual animals in and around wind farms and footprints, providing information on spatial and temporal usage or areas, flight height, speed, avoidance, behaviours engaged in (e.g. foraging, commuting resting), and contextual importance of areas used by specific populations through links back ('connectivity') to breeding colonies or wider biologically-defined geographic areas outside of breeding periods.

3. Review of existing installation designs

This section provides an overview of how bird monitoring equipment has been installed at offshore wind farms to date. It examines typical mounting locations and connection methods, highlights common challenges encountered during installation, and outlines the types of platforms and support structures used for cameras and radar systems. The aim is to inform future installations by identifying practical solutions and lessons learned from existing deployments.

3.1. Equipment placement

The placement of monitoring equipment can influence data quality, system performance, and operational feasibility. It depends on the specific aims of the study, the type of monitoring equipment used, and the physical and operational characteristics of the wind farm. Practical considerations such as available space, safety requirements, and ease of maintenance also play a role. Strategic placement, for example locating systems at both the centre and edges of the wind farm, can help capture spatial variation in bird activity and collision risk.

Placement decisions can also influence which collision-relevant flight heights, behaviours, and movement pathways are most readily detected. Monitoring locations define the vertical and horizontal sampling window used to assess collision risk, which may not fully align with the range of bird flight behaviour around turbines. As a result, systems may preferentially detect birds flying at rotor-swept height, along approach trajectories, or within particular sectors, while higher, lower, or evasive flight paths may be under-represented. Birds exhibiting avoidance responses, such as late diversion or changes in flight height, may therefore be less likely to be detected depending on sensor placement. Consequently, observed patterns may reflect what is detectable within the monitoring configuration, rather than the full range of collision-relevant responses occurring around turbines.

3.1.1. Camera

The location and number of cameras are typically determined by the specific camera system in use. Many systems are designed to be mounted on the turbine tower or platform, facing upward to monitor the RSZ or the area just in front of it. To achieve full 360-degree coverage, multiple cameras are often installed around the tower. Mounting solutions commonly use straps and magnets to avoid drilling into the structure, although penetration is usually required to route the cable from the camera to the computer system housed inside the turbine. Stauff clamps are commonly used for handrail attachments. Equipment used in fixed-bottom wind farms may require adaptation for floating platforms, including adjustments to camera coverage and mounting stability.

Cameras are most frequently mounted on the wind turbine generator (WTG) tower or on the platform handrails. In some cases, cameras have been installed on the nacelle (e.g. on nacelle guardrails or helicopter-hoist) to detect birds entering the RSZ; nacelle placement can provide direct, close-range coverage of the RSZ, and improved detection accuracy, particularly regarding distance detection for small passerines. However, installation on the nacelle can be challenging due to limited space and the fixed nature of these components, and there may be resistance from turbine OEMs and additional costs implications for modifications in these areas. In addition, cameras on the nacelle could pose challenges for installation and maintenance, create additional complications due to different power and cabling requirements, and could lead to HSE implications. These challenges are not insurmountable, but need to be considered and addressed if installation on the nacelle is being considered.

Platform-mounted cameras can be oriented toward adjacent turbines, which typically requires long lenses and high-resolution sensors to capture usable footage for tracking and species identification. Alternatively, they can be directed upward to monitor the rotor of the turbine they are mounted on.

Image quality and system performance should be evaluated carefully. Some systems may not provide sufficient resolution for species-level identification, which can limit the effectiveness of monitoring. Equipment used in fixed-bottom wind farms may require adaptation for floating platforms, including adjustments to camera coverage and mounting stability.

Recommendations:

- If considering nacelle-mounted cameras, carefully weigh the benefits of improved detection against practical constraints, including limited space, OEM approval requirements, installation and maintenance complexity, power and cabling arrangements, HSE implications, and potential cost impacts.
- Ensure camera mounts are stable to minimise vibration and jitter; consider stiffening/damping if needed.

3.1.2. Radar

Radars installed in offshore wind farms have typically been mounted on meteorological masts or turbine platforms. These are typically mounted on custom-built brackets connected to the handrails or walkway structures. To avoid obstructing moving parts, rotating radar antennas are commonly mounted outside the handrails. Some systems use swing-arm designs that allow the radar to be extended away from the structure during operation and swung back over the walkway for maintenance or during extended periods of deactivation.

Computers and servers supporting the radar system are usually housed inside the structure. Since radars are often deactivated when personnel are present for safety reasons, it is beneficial to avoid placing them in areas that require frequent access.

While radars are most commonly installed on WTG platforms, other potential locations include the nacelle, helipad, offshore substation (OSS), or a separate structure such as a buoy. This type of structure, commonly referred to as floating radar, is being developed and could be expected to be more common in the coming years. An advantage of floating radar is that it can be deployed before the construction of the wind farm and can also be moved to multiple locations without being limited to locations of existing structures. Floating radars also have fewer issues with shadowing as the radar is positioned at the highest point on the structure, giving 360-degree coverage. Although they can be custom built to house multiple sensors, floating radar deployments may be more expensive than deployments on existing structures and still need to be developed beyond their current stage.

Due to the compact design of WTG platforms, larger radars may require additional structural supports, such as balcony-style extensions. For larger high-performance radar systems, the OSS is often the preferred location, offering both optimal coverage and minimal interference with turbine structures.

Radar placement significantly affects coverage. For example, radars mounted on WTG platforms will have blind spots caused by the turbine tower. Additionally, turbine structures within the wind farm can create further shadowing effects, limiting coverage. Installing radar with a focus on the peripheral turbines of the wind farm and pointing outwards can help minimise interference of the turbines with the radar signal.

Multiple radars may be required to achieve sufficient spatial coverage, with placement carefully planned to minimise blind areas[2]. The detection ranges of radar for large to medium birds is often stated to be 6 km, but reliable detection at 3-4 km is more realistic.

Most radars cover the airspace at the height of the radar upwards. This means a lower placement is preferable to record birds close to the water's surface. Radars placed higher than several tens of metres above the water may have limited coverage close the water.

Recommendations:

- Avoid placing radars in areas with frequent personnel access to minimise downtime due to safety shutdowns.
- Use swing-arm or mounting configurations that position the radar away from the main structure to reduce interference with radar operation and facilitate maintenance access.
- Consider placing high-performance radars on the OSS to maximise coverage and reduce structural impacts on WTGs.
- Plan radar placement to minimise blind spots caused by turbine structures and consider multiple units for full spatial coverage. Installing radar with a focus on the peripheral turbines of the wind farm and pointing outwards can help minimise interference of the turbines.

3.1.3. Acoustic sensors

Acoustic sensors are typically installed on the WTG platform floor, tower, or handrails, where they are shielded from rotor-induced vibrations and accessible for maintenance. Mounting methods vary depending on the sensor type; microphones may be housed in weatherproof casings and bolted to structural elements. Careful placement is essential to minimise interference from turbine noise and environmental conditions.

Cabling and power supply considerations are similar to those for cameras and radars, and must be planned to avoid structural interference and ensure long-term durability. Power is typically drawn from turbine systems, though standalone units may use battery or solar power. To ensure reliable operation in harsh offshore environments, sensors should be installed in sheltered locations or include other protection measures.

3.1.4. Additional equipment

Developers and monitoring equipment suppliers highlighted challenges in allocating physical space for additional equipment such as server racks and control units. A key issue is the lack of pre-planned space within turbine or offshore substation structures, which complicates retrofitting and limits

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[2] For monitoring of migratory birds, it is recommended to either install two radar systems (peripheral facing the respective main migration route) or, alternatively, switch the radar location depending on the spring and autumn migration seasons.

accessibility. While some space may be available in the basement of the transition piece (TP), it often competes with other control systems. Certain foundation areas are inaccessible due to health and safety constraints, particularly where high-voltage cables are present.

One developer described the installation of a server rack cabinet which houses multiple components including the system PC, radar processor, and power control unit. This rack can be installed internally (within the WTG or offshore converter station (OFCS)) or externally in a custom micro-shelter on the TP/OFCS deck. A bespoke quad pod frame was engineered to secure camera systems to the TP. This involved bolting through the grating into underlying beams using extended bolts. However, this solution was described as a substantial engineering effort and not easily adaptable for retrofit scenarios. Similar solutions normally require structural assessments and OEM approval.

Recommendation:

- Allocate dedicated, accessible space for additional monitoring equipment (e.g. server racks, control units) during early design stages to avoid retrofit complications, ensure safe access, and support long-term system integration.

3.2. Installation concepts

This section summarises the different BMS secondary steel and support structure design decisions and assessments undertaken. The purpose is to provide an overview of how different systems have been installed, the key considerations behind these designs, and how the learnings can inform future installations. The design options presented were selected based on designs available to Ramboll from previous projects, those shared by the PrediCtOr partners, and commonly referenced approaches and considerations identified during stakeholder engagement with offshore wind developers and monitoring equipment suppliers. The subsections below cover each design option considered and its application, grouped into four main types:

1. System on additional platform,
2. System attached to guardrails,
3. System within laydown area, and
4. System outside of guardrails.

It is important to note that projects will have different constraints that need to be considered that will impact the most appropriate design solution, including factors such as available space, safety requirements, operation and maintenance procedures, and environmental conditions. For example, for some sites and foundation types, there may be constraints in the lay-down area due to space availability, evacuation requirements or crane operations, which could make this area unsuitable for the placement of systems. For each individual project, the different options for location of systems should be assessed with these aspects in mind, to identify constraints and opportunities for placement.

3.2.1. Additional platform

An additional platform is required for a 3D BMS Panel radar system. The radar antenna is around 6m long, and weighs approximately 400kg, and sits atop a shelter. The total weight of the additional equipment is

1800kg and the whole platform can be over 4000kg. See Figure 1 for additional platform layout on a jacket foundation.

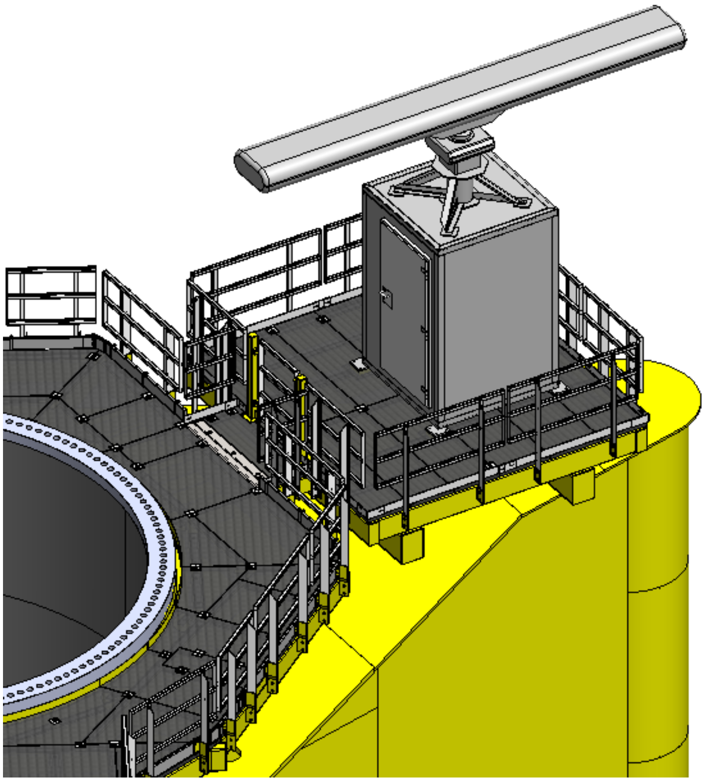

Figure 1: Additional platform for BMS system.

The design requirements include the weight of the system (approx. 1800kg including shelter, antenna and drive), platform weight, walkway area loading, point loads, railing and grating loads, wind loading and anchorage points.

For a jacket, the platform could sit atop one of the jacket legs, which reduces the impact on attachment points to the primary steel/TP or need for additional vertical supports. A monopile design is more complicated as it would not be vertically supported by the leg below like a jacket structure. The platform would then have to be supported by new attachments to the TP or monopile foundation which affects the primary steel design and increases the secondary steel weight. A monopile would need significantly more integration into the primary structure/TP, and if the structure were TP-less, the design would need to be integrated at an early stage for the primary structure to incorporate the additional support points. Nonetheless, separate radar platforms for monopiles have been designed previously.

As it is a separate support structure it would reduce standardisation across the wind farm, particularly in fabrication. The low voltage electrical (LV) design would also not be standard, and O&M across the OWF will differ, as an additional platform will require alternative layouts for guardrails and cable routing that will cause divergence from the typical foundation design within the wind farm. The difference will require operatives to carry out different inspection and maintenance procedures, that may require unique access arrangements. Standardisation across the assets helps improve health and safety and reduces errors both during fabrication and offshore. Thus, particular attention should be put into the design, manufacturing and installation stages to identify and manage any risks specific to the separate support structure.

Due to the significant mass of an additional platform and associated equipment, a transportation analysis is required to assess loads and accelerations during transportation from the fabrication or assembly yard to the offshore installation site (including load-out, sea transport, lifting, and set-down operations If this analysis identifies excessive loads or constraints that exceed allowable limits for pre-installed equipment, the bird monitoring system may need to be installed, tested, and commissioned offshore rather than onshore. This would increase installation cost and risk due to additional vessel time and offshore activities. As such, it is best practice to maximise onshore installation and testing wherever feasible, and designers should make reasonable efforts to accommodate onshore assembly within transport and lifting constraints.

There may also be a risk if some of the equipment for the BMS is being provided by onshore suppliers with little offshore experience. These risks can include, but are not limited to, more challenging and restricting installation conditions, corrosion due to the marine environment, and vibrations and additional transportation loads. These risks can be mitigated by ensuring products meet stringent offshore requirements, with additional testing, mock up, etc, if required. The responsibility to mitigate these risks falls to the equipment supplier, with input from the developer procuring the equipment. Solutions may vary from unique design and analysis, to marine-grade material and coating.

3.2.2. System attached to guardrails

A camera attached to the guardrails, including camera and equipment for O&M of the BMS. No additional structure is required. The system is shown in Figure 2. Note that radar systems would not typically be suitable for mounting on guardrails, due to their size and weight. The example shown here is for a monopile, but this type of system can just as easily be implemented on a jacket structure.

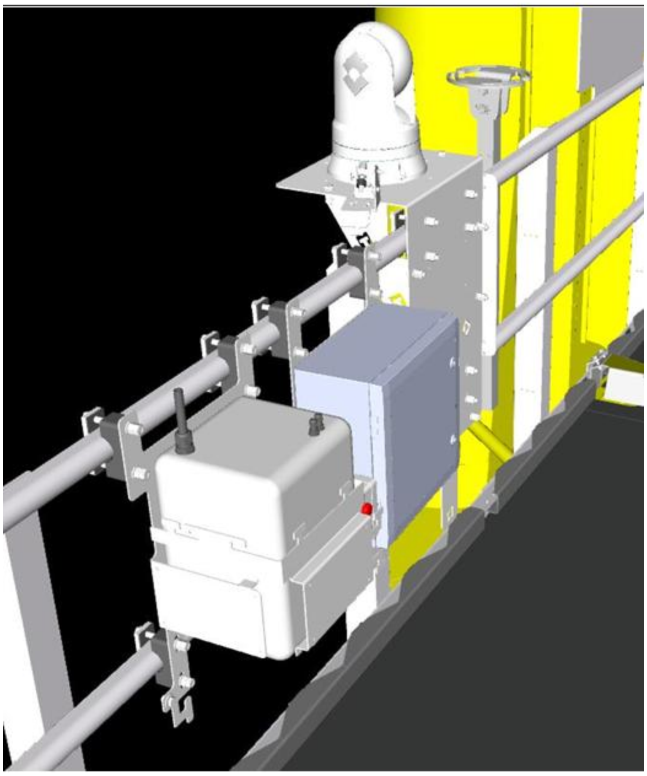

Figure 2: System attached to guardrails.

If the BMS was larger or heavier than assumed for other equipment on the guardrail, then the guardrail may need to be strengthened.

The walkway width around the tower is usually designed to the limit of what is required by WTG supplier for safe access, rescue and evacuation, and cannot always accommodate any large obstructions or attachments to the guardrails that would reduce the walkway width. Therefore, if a large item such as radar equipment is attached in this location, additional width may be required for the walkway.

If heavy equipment will be bolted on the guardrails and would be present during transportation, then further analysis would need to be undertaken to ensure the guardrails aren't damaged.

3.2.3. System within laydown area

A BMS system (radar) can be placed within the guardrails and within the laydown area – the designated flat space on offshore wind turbine structures (such as the transition piece of a wind turbine generator, or an offshore substation) that is generally used for placing or installing equipment, carrying out maintenance tasks, etc. (see Figure 3). The system can have a 3m long arm (to swing the radar towards the edge of the platform), is approximately 3m tall and weighs 600kg. In the example in Figure 4, a support plate was designed for the radar to be attached to. The plate was roughly 600mm by 600mm. This design is shown for a monopile but could be used within a jacket laydown area as well.

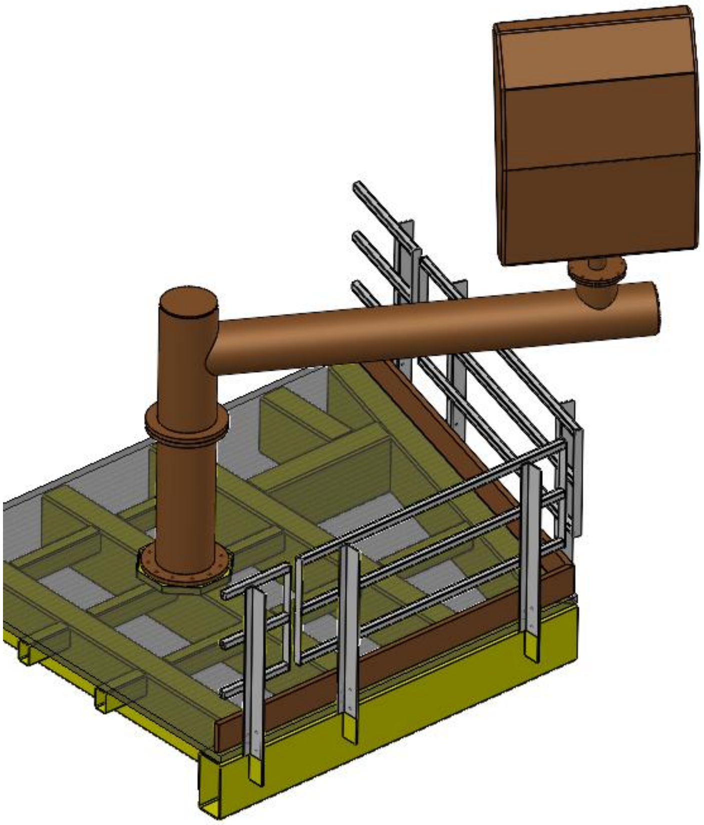

Figure 3: System within laydown area.

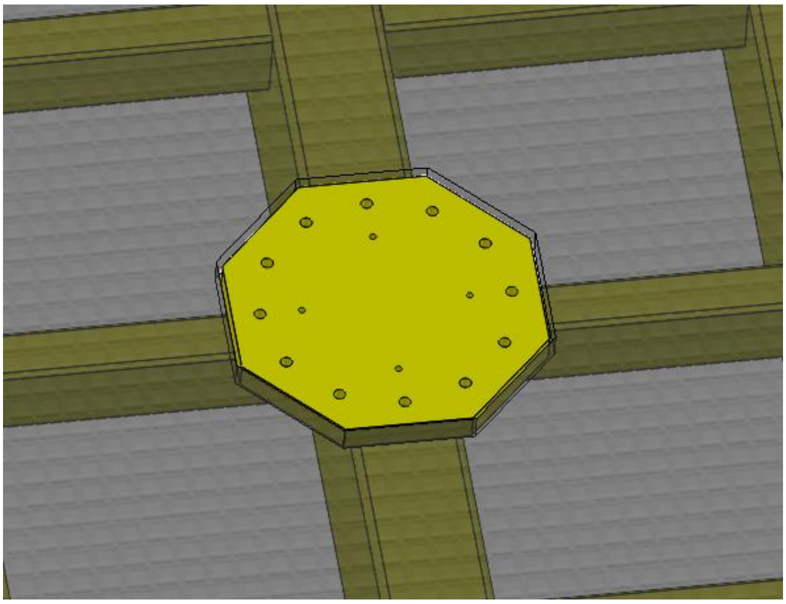

Figure 4: Laydown area support plate.

The attachment plate used required the BMS to be bolted onto the platform – see Figure 4. Bolts will require regular inspection to ensure they are appropriately secure. This BMS sits within the laydown area, which would have to be approved with the O&M team and turbine supplier as it would reduce the available laydown area when the BMS is in place. It is likely that the BMS is required to be assembled and disassembled if the whole laydown area is needed for operations (e.g. switchgear replacement). This additional work offshore could present additional challenge or risk. A mitigation for this risk, would be to consider the BMS in the platform design at an early stage, so sufficient space around the BMS and laydown area could be included to reduce offshore work.

If the BMS must sit at the location shown and infringes on the original laydown area, then the turbine supplier may require the platform size to increase to accommodate the full laydown area needed, which would reduce standardisation. Conversely, if a standard platform is used across the wind farm this could result in some positions without BMS having platforms that are larger and heavier than required, likely increasing the cost.

A BMS can also be installed on other areas of the external working platform if small enough. Figure 5 is an example of this. It shows a Radome BMS on the walkway of the external platform. As this is a relatively small system, it doesn't impinge on the walkway required for the operatives or require any further reinforcement. A support plate has been designed for it to be attached to.

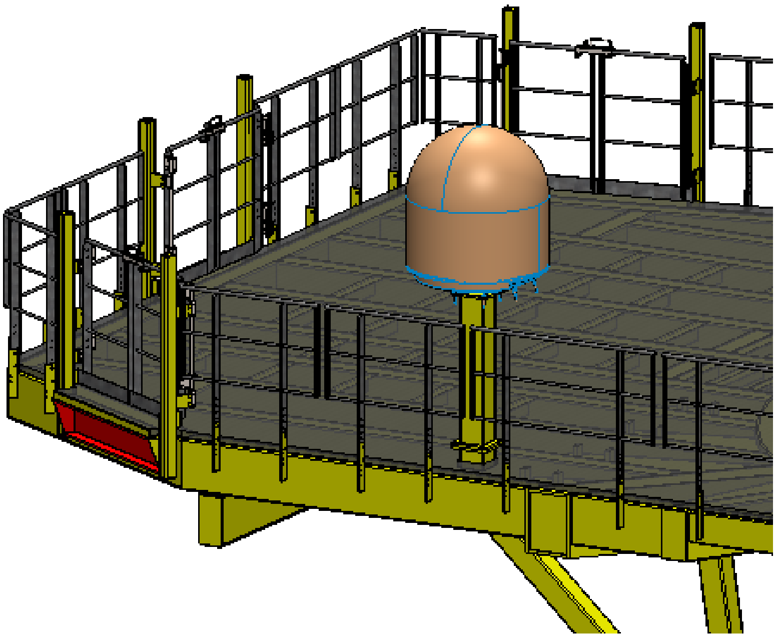

Figure 5: Radome radar on external platform.

3.2.4. System outside of guardrails

A BMS system can be designed outside of the guardrails to support a bird monitoring camera, with its own support point as shown in Figure 6. The support is loaded by self-weight and wind loading only. The additional support is easy to design for but can accommodate small systems only. The support plate in this example is 200mm by 250mm and supported 350mm from the edge of the external platform.

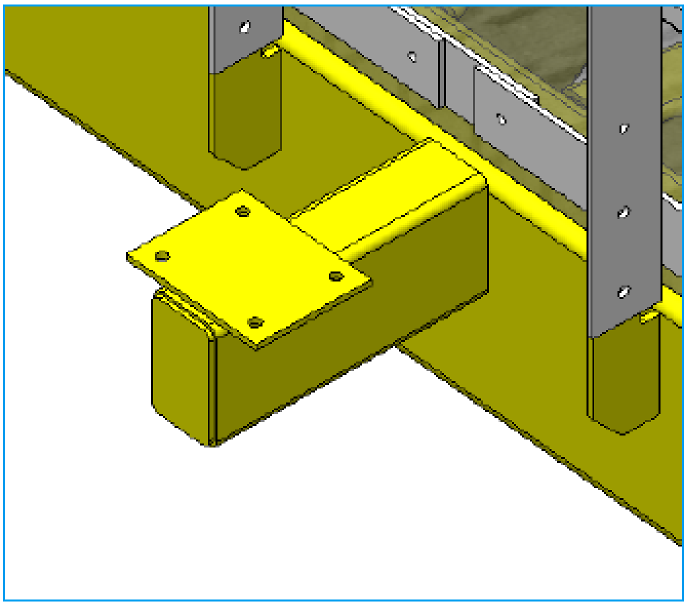

Figure 6: Support system for outside guardrails.

The attachment plate used required the BMS to be bolted to the plate – see Figure 6. Bolted assemblies are to be visually inspected as part of the regular annual inspection to ensure fasteners are not coming loose, as is standard for offshore wind farms. More detailed visual inspections can be performed if desired. If bolted assemblies are pre-loaded, further inspection must be agreed with the maintenance contractor. A mitigation of this would be to weld the BMS into place but this would make the system more difficult to replace.

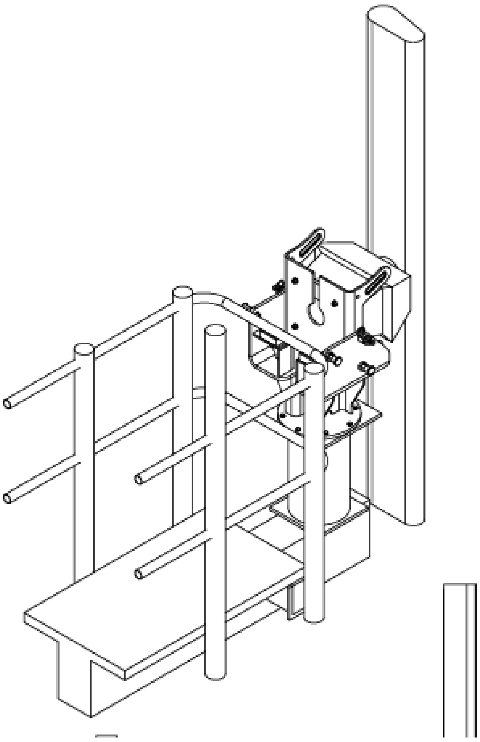

Figure 7: Support system for outside of guardrails – other example.[3]

Figure 7 shows an example of another system attached outside of the guardrails which is welded. If welding a structure above the platform level is not feasible, then the bolted connection should be detailed in a way that makes access and inspection of the connection as easy and safe as possible. Figure 8 shows another example.

This system would need installation, maintenance and inspections (particularly of the bolted connection) outside of the guardrails. This is an HSE risk that would need to be considered and managed by the wind farm operator. There is also a dropped object risk of working outside the handrails with bolts or other loose items. This can be mitigated through tethering of work tools or using netting to catch small objects, for example [27].

These systems can be designed for both a monopile or a jacket structure.

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[3] The image showcases a design shared by a project partner, presented here in confidence for illustrative purposes.

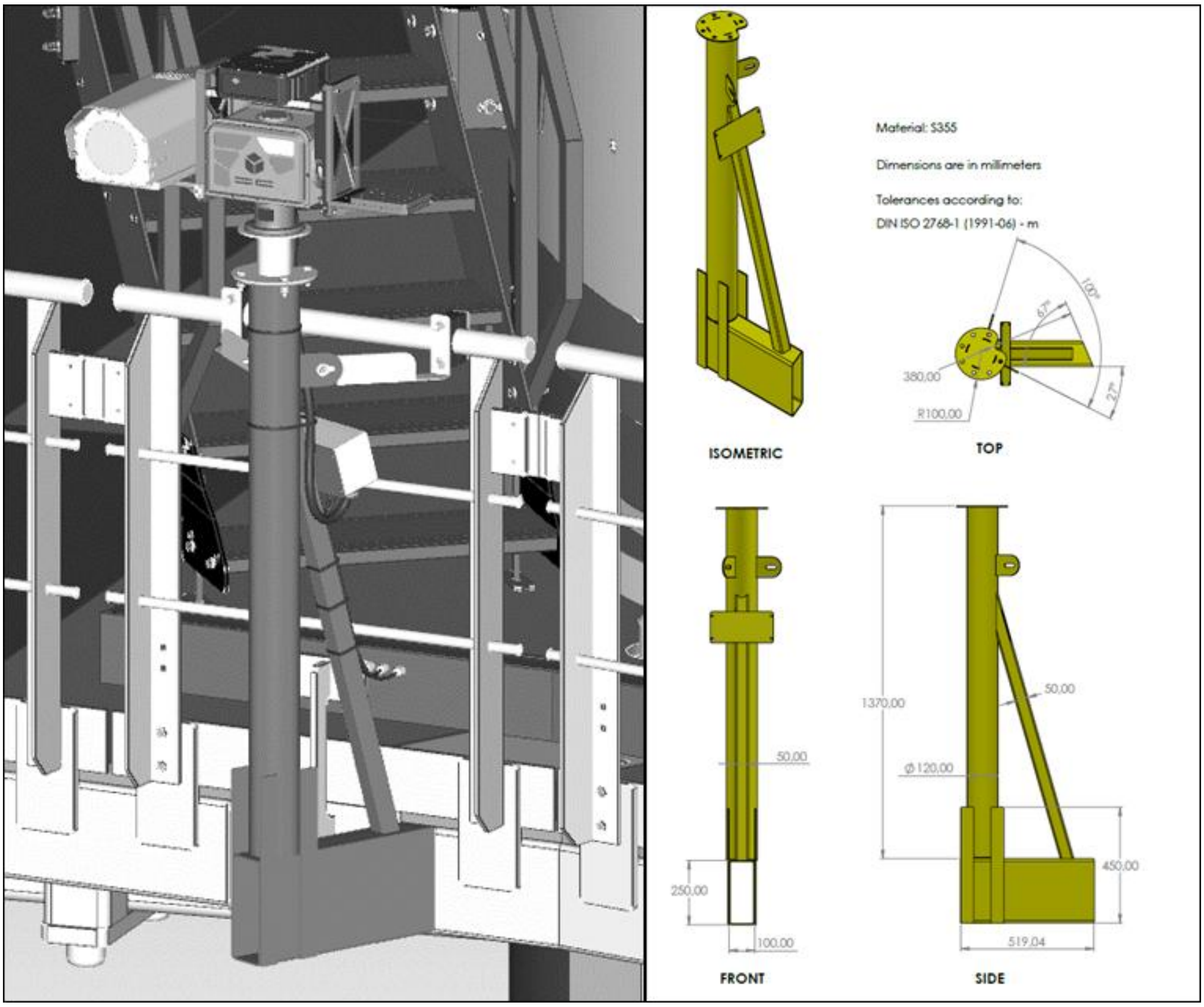

Figure 8. Support system for outside of guardrails – other example.

3.3. System on offshore substation (OSS)

WTG platforms – internal and external – are typically compact and optimised for essential operations, leaving limited space for mounting equipment in ad hoc positions. This depends on the turbine supplier and the developer, and the amount of equipment already required at each location (e.g., navigation aids, other radar equipment). Developers aim to avoid structural modifications to turbine foundations and prefer solutions that do not interfere with the main production process. Therefore, offshore substations can be the preferred location for installing larger bird monitoring system components, particularly radar units.

Systems on the OSS are usually installed on the top deck or on the handrails. The laydown area on an OSS is in more constant use than on the WTG foundation and a BMS on the laydown area would get in the way of O&M activities. Specific safety considerations on the OSS include ensuring there is a safe walkway distance around the radar. Including the BMS on the top deck of the OSS where there is already other equipment would need to be carefully considered to ensure safe walkways are present for operatives. A solution for the location of the BMS could be on the antenna/meteorological mast where the radar/camera would have uninterrupted views of the wind farm and would be out of operatives' way to avoid safety concerns. The drawback of this would be that maintenance of equipment would be more difficult.

It is also important to consider that locating the radar on the OSS top deck or met mast can mean that it is at a high altitude relative to sea level and to the lowest sweep height of the WTG rotors. This can limit the coverage of these lower altitude air volumes by the radar, potentially compromising the quality of the obtained data.

3.4. Selection of installation design

When selecting an installation design for BMS, aspects such as placement, design effort, impact on O&M requirements, associated risk and LV design must be considered. The design requirements for the BMS are not always clear from the kick-off of the project, which can prevent the design from being integrated from an early stage. Changes to design later in the design process are typically more difficult and costly to implement.

A high-level comparison matrix covering just the four main types of support structures and their application for both radars and cameras is presented in Table 1. Note solutions such as magnets have not been included within this matrix as the focus here is around the integration and installation of structural designs. This is also just applied to the placement of BMS in the WTG foundation; placement in the OSS or specific design solutions have not been considered.

For the purposes of this work, and in line with the project scope, the focus was placed on installation on TPs and jacket foundations. Given the wide variation between offshore wind farms in terms of turbine design, foundation type, monitoring system specifications, environmental conditions, and project-specific constraints, it was recognised that fully standardised designs are not achievable. Instead, through discussion with the PrediCtOr project partners, it was agreed to carry forward two representative case studies for detailed design development and load analysis: a camera attached to the guardrail, and a radar located on the external working platform or within the laydown area. The resulting designs and analyses are presented in Section 7.

Table 1: Installation design comparison matrix (for placement of BMS in the WTG foundation).

Installation Design Options	**Integrated Design**		**Retrofit Campaign**	
	Radar	**Camera**	**Radar**	**Camera**
Additional Platform	🟩 **OK in principle, if accepting the added complexity and individualisation** of design, manufacturing and installation. Considerations: Radar often requires sufficient space for operation and systems are getting larger as wind farms and turbines are also increasing in size.	🟥 **Disproportionate and undesirable** for what is typically a small system. Considerations: Alternative options that are more space efficient.	🟥 **Undesirable** to retrofit such platform to an operating WTG offshore, complex operation. Considerations: There may be space on the OSS, or a smaller radar could be considered within the platform area.	🟥 **Disproportionate and undesirable** for what is typically a small system. Considerations: Alternative options that are more space efficient.
Attachment to Guardrails	🟥 Not possible for large system. Considerations: More space required, or alternative options such as an additional platform or area on the platform.	🟩 **OK in principle**, with suitable installation set-up. Considerations: Vibrations on handrails for quality of footage.	🟥 **Not possible** for what is typically a large system. Considerations: More space required, or alternative options such as an additional platform or area on the platform.	🟨 **Possible but with added complexity of installation** Considerations: Vibration on handrails for quality of footage, or whether usage of mounts and new weight for retrofit may require new handrails.
Within Laydown or Platform Area	🟩 **OK in principle, subject to radar size and performance** in this location. Considerations: Impact on operations and maintenance.	🟩 **OK in principle**, with suitable installation set-up. Considerations: Impact on operations and maintenance.	🟥 **Unlikely due to radar size and performance** in this location. Considerations: Space requirements on platform post installation will be tight and may be difficult to find enough room for all required equipment, needs to be placed close enough to tower for power supply.	🟨 **Possible but with added complexity of installation** Considerations: Space requirements on platform post-installation will be tight and it may be difficult to find enough room for all required equipment, needs to be placed close enough to tower for power supply.
Outside Guardrails	🟨 **Unsuitable in principle** for what is typically a large system. Considerations: If installation and maintenance can be carried out.	🟨 **Possible but with added complexity of installation and maintenance** and subject to camera weight. Considerations: If installation and maintenance can be carried out, or the use of a swing arm to pull the BMS within the platform area for O&M.	🟥 **Unsuitable in principle** for what is typically a large system. Considerations: Risk assessment for bolting or welding outside of guardrails.	🟥 **Undesirable with added complexity of installation and maintenance** and subject to camera weight. Considerations: Difficult to implement post installation as offshore operations outside of handrails will be difficult.

Legend		
🟩 Feasible Solutions	🟨 Challenging Solutions	🟥 Undesirable Solutions

4. Installation specifications and requirements

This section sets out the key technical and operational requirements for installing seabird collision monitoring equipment at offshore wind farms. It covers essential considerations for power supply and low voltage (LV) integration, equipment protection against harsh marine conditions, maintenance planning, health and safety (HSE) compliance, and logistical and personnel requirements. These specifications aim to ensure safe, reliable, and efficient installation, whether during early-stage design or retrofit scenarios.

4.1. Power supply requirements and cabling

Reliable and appropriately rated power supply is essential for seabird monitoring systems. Sourcing power directly from the WTG and OSS is preferred, as this reduces the need for frequent servicing compared to battery-powered systems.

Monitoring systems typically require a 230V/16A connection, though connector availability can be limited. In some cases, compromises have been made to accommodate lower capacity supplies (e.g. 10A). Solar power and generators can be viable alternatives for remote or constrained installations, including buoy-mounted systems.

LV considerations for OSS installations are similar to WTGs, though OSS typically hosts third-party equipment and may already have a separate network in place.

From a design perspective, additional cable routing capacity and space for networking equipment must be planned early. Here, ‘network’ refers to data connectivity for monitoring systems (e.g. Ethernet or fibre links). Power and network equipment should be physically separated from high-voltage areas to allow safe access without requiring turbine shutdowns. Signal and network cables should also be routed separately from power cables to reduce interference and improve safety.

Recommendations:

- Integrate power supply access into turbine and/or OSS design early, with sufficient capacity and clear routing.
- Plan for additional cable routing and space for networking equipment during early design stages to avoid retrofit complications.
- Physically separate power and signal/network cables to minimize interference and improve safety.
- Locate power and network equipment away from high-voltage areas to allow safe access without turbine shutdowns.

4.2. Equipment protection

Prior to installation, monitoring equipment may require certain storage conditions (e.g. temperature, humidity) to prevent damage to equipment performance while awaiting installation. Equipment may also have packaging requirements (e.g. padding of fragile areas, watertight packing of certain component parts) to prevent damage during transportation and storage.

Particularly when equipment is being stored at fabrication yards, there is a risk of damage due to the frequent movement of vehicles, and large OWF components, in addition to the potential for equipment to be lost. If the equipment will be stored for long periods of time prior to installation, the warranty period should also be considered. The equipment supplier will be able to confirm the packaging and storage requirements for the specific equipment provided. These requirements must be communicated to all teams handling or storing equipment prior to installation.

Installed equipment must be protected against harsh offshore conditions. This can include:

- Protective housings for cameras and radar radomes.
- Automated cleaning systems (e.g. wipers) to remove sea spray and bird excrement.
- Materials and components rated for marine environments:
    - Carbon steel should meet minimum coating specifications.
    - Stainless steel on external platforms should ideally be Duplex 1.4462 to prevent corrosion.
    - Cables should be fire-retardant and certified for offshore use.
- Equipment must withstand vibrations and accelerations during transport and operation. Systems installed prior to transport should tolerate up to 1g acceleration and not be sensitive to frequencies below 5-6 Hz.
- Select equipment with appropriate ingress protection (IP) rating for offshore conditions.

Recommendations:

- Confirm and communicate storage and packaging requirements to all relevant teams before installation. Consider warranty implications for long-term storage and verify compliance with supplier specifications.
- Use protective housings and automated cleaning systems to maintain equipment functionality in marine environments.
- Select materials suitable for offshore conditions (e.g. Duplex stainless steel, fire-retardant cables).
- Ensure equipment meets vibration tolerance standards and has an appropriate IP rating.

4.3. HSE requirements

The installation, operation, maintenance, and decommissioning of seabird monitoring equipment on offshore wind farm structures must be planned and executed in accordance with robust HSE standards. These requirements should be integrated into project planning from the outset and aligned with site-specific safety rules and regulatory expectations.

Based on input from developers and monitoring equipment suppliers, personnel involved in offshore monitoring equipment activities should typically hold the following minimum certifications:

- Global Wind Organisation (GWO) Basic Safety Training, including:

- Sea Survival
  - Working at Heights
  - Manual Handling
  - First Aid
  - Fire Awareness
  - Safe travel and transfer
  - Hazards in a wind turbine generator
- OGUK Medical Certification, including Chester Step assessment
- Confined Space Training, where access to enclosed areas (e.g. turbine basements or blades) is required
- HUET (Helicopter Underwater Escape Training) for sites located further offshore
- Advanced Rescue and Enhanced First Aid, which may be required depending on national regulations or site-specific protocols (e.g. in Germany, a minimum of two out of three personnel may need these qualifications)

Before any installation or maintenance activity takes place, Risk Assessments and Method Statements (RAMS) should be prepared and formally approved. This includes a site-specific induction. Personal protective equipment (PPE), such as harness', must be inspected and serviced at least once every 12 months to ensure compliance and safety.

Additional considerations include:

- Use of tool tethers and similar measures when working near handrails or elevated platforms to prevent dropped objects.
- Electrical tasks must be carried out by personnel certified as electrically competent.
- Equipment specifications should be cross-checked against manual lifting weight limits during installation planning. Cameras, radars and server cabinets often exceed manual handling thresholds and require mechanical lifting. Lifting plans should be developed in advance, and equipment should include secure attachment points for crane lifting.
- Certain areas of offshore foundations may be inaccessible due to health and safety risks (e.g. proximity to high-voltage cables). These constraints should be considered during equipment design and placement.
- Any equipment placed inside the turbine tower may need to pass through narrow doorways and/or hatches. This needs to be accounted for when selecting server racks and other hardware.
- Infrared illuminators may pose eye safety risks; safe working distances must comply with relevant regulations and be confirmed with the supplier.
- Radar systems should be powered off before personnel work nearby; safe working guidelines should be checked with the supplier or operator licence.

Monitoring contractors must comply with the HSE standards of the wind farm operator and the specific site where equipment is deployed. This includes meeting or exceeding minimum safety requirements and ensuring all personnel are appropriately trained and certified.

Recommendations:

- Integrate HSE requirements into project planning and align with site-specific safety rules. Embed compliance with operator HSE standards into all contractor activities.
- Ensure all personnel hold required certifications (GWO modules, OGUK medical, HUET, confined space, advanced rescue where applicable).
- Prepare and approve RAMS before any activity; conduct site-specific inductions and maintain PPE inspections annually.
- Develop lifting plans for heavy equipment and ensure secure attachment points for crane operations.
- Consider space constraints and proximity to high-voltage areas during design; confirm safety protocols for infrared cameras and radar systems with suppliers.

4.4. Logistics requirements

Logistical planning is a key consideration for the installation, maintenance, replacement, and decommissioning of seabird monitoring equipment on offshore wind farms. These activities should be coordinated with existing operational schedules wherever possible to optimise access and reduce disruption.

Weather windows are an important consideration during installation of equipment and maintenance visits. Installation should ideally be planned during times of year where there is a higher chance of appropriate weather windows (e.g. summer), to minimise delays if installation cannot be completed on the original installation date due to poor weather. Contingency time for installation should be built into plans to accommodate uncertainty around weather windows.

Transport logistics should be planned well in advance. Seats or rooms on Crew Transfer Vessels (CTVs) and Service Operation Vessels (SOVs) can be booked, but availability may be limited during busy periods such as summer maintenance campaigns. Early booking is recommended to secure access.

Planned maintenance can often be aligned with turbine service schedules, allowing for more efficient use of vessel space and personnel. However, unplanned maintenance and troubleshooting may be more challenging to accommodate, particularly during peak servicing periods when turbine operations take priority.

Responsibility for logistics is typically shared: monitoring contractors transport equipment to onshore facilities, while offshore transport and lifting operations are managed by the wind farm operator. Lift plans and safe attachment points should be confirmed during design. Smaller units may be transported via CTVs, while larger systems may require additional planning and resources.

Strong magnets may be required for installing equipment on floating offshore wind farms; this needs to be carefully planned and monitored to reduce risk of personnel injury or damage to equipment (e.g. turbine structure, monitoring equipment, other electrical equipment), taking the size of magnetic fields into account. The location for storing the magnets prior to installation also needs to be carefully considered and communicated. It is also noted that once magnets are attached, they can't be moved without specialist equipment, which could cause delays and increased costs. A robust installation plan and appropriately trained/ experienced staff are important to increase the likelihood of the magnet to be installed correctly on the first attempt.

Recommendations:

- Align installation and maintenance with wind farm schedules; plan for weather windows and include contingency time.
- Book vessel capacity (CTVs, SOVs) early to secure access during peak periods.
- Confirm lifting plans and ensure equipment includes secure attachment points for crane operations.
- Define logistics responsibilities clearly between contractors and operators.

4.5. Equipment maintenance

Effective maintenance planning is essential to ensure the continued performance of seabird monitoring systems at offshore wind farms. Maintenance activities should, where possible, be aligned with regular wind farm O&M schedules to minimise disruption and optimise access logistics.

Maintenance responsibilities should be clearly defined early in the project lifecycle. This includes distinguishing between supplier-led servicing and tasks that can be undertaken by the developer's O&M teams. Light maintenance activities such as camera lens cleaning or fluid top-ups can often be integrated into routine turbine visits, provided appropriate training is in place. More complex interventions may require specialist personnel or additional site access planning. For more specialised or complex maintenance activities such as repositioning equipment or resolving technical faults, remote supervision by supplier technicians may be beneficial.

O&M teams may be reluctant to undertake more substantial interventions, particularly those that fall outside their standard scope of work. Clear guidance, training, and delineation of responsibilities should be established early in the project to ensure maintenance tasks are carried out safely and effectively.

Maintenance intervals vary depending on site conditions, national regulations, and equipment type. For example, offshore installations may require more frequent attention due to harsher environmental exposure. Some indicative guidelines might include:

- Preventive maintenance once or twice per year, depending on location and equipment resilience.
- Camera lens cleaning every six months, with some systems incorporating automated cleaning features.
- Hardware checks once or twice per year to ensure mounts are secure, components are intact, and rotating parts are functioning properly.
- Radar servicing approximately every six months, though this may vary by model.

In addition, for monitoring migratory birds, maintenance of all systems should be undertaken shortly before the beginning of the main migration seasons in spring and autumn to ensure that all systems are working as required during these critical periods.

Remote access capabilities can significantly reduce the need for physical interventions, allowing for software updates and system checks (e.g. image quality) to be performed off-site. Where equipment is installed on normally unmanned structures, service visits should be coordinated with turbine maintenance schedules and accompanied by wind farm personnel as required. It is noted that regular turbine maintenance visits are often time constrained and maintenance of monitoring equipment can be lower priority for the maintenance team than that of the offshore wind farm components. It is recommended that maintenance of monitoring equipment is imbedded into wider maintenance plans well in advance and that maintenance teams are aware of the importance of carrying out these checks.

Training O&M teams to carry out basic maintenance tasks can improve responsiveness and reduce reliance on external contractors. Equipment selection should also consider robustness and ease of servicing, with some suppliers offering systems designed to withstand offshore conditions and minimise maintenance demands.

Recommendations:

- Align monitoring equipment maintenance with wind farm O&M schedules to optimise logistics and minimise downtime. Plan vessel capacity and site access for maintenance well in advance to avoid delays.
- Define maintenance responsibilities early, distinguishing between basic tasks for O&M teams and specialised interventions requiring supplier support.
- Train O&M teams to perform basic maintenance (e.g. lens cleaning, fluid top-ups) safely and effectively.
- Consider equipment robustness and ease of servicing when selecting monitoring equipment to minimise maintenance demands.

5. Requirements and specifications for 'retrofitting campaigns'

Retrofitting seabird monitoring equipment into operational offshore wind farms presents a distinct set of challenges compared to installations during the construction phase. These challenges span technical, logistical, operational, and safety domains, and require careful planning and coordination to ensure successful deployment with minimal disruption to wind farm operations.

5.1. Planning and lead times

Retrofitting campaigns should be planned well in advance, with lead times of at least 7–12 months depending on equipment type and procurement processes. Early engagement with suppliers is essential to allow for the exchange of technical documentation, integration planning, and alignment with operational schedules.

Where possible, onshore preparation such as equipment assembly, pre-termination and pre-routing of cables within equipment or support structures, and system configuration should be completed prior to offshore deployment to reduce time spent on site and mitigate weather-related delays. Additionally, it is recommended to organise a visit out to the WTG(s) where the equipment will be placed to investigate equipment locations, cable routes, power supplies, lines of sight, etc., as this can help with installation planning, preparing RAMS, and other aspects of study planning and implementation.

Due to the timing of retrofitting campaigns, there is also a need for caution when interpreting retrofit-based collision datasets. In cases when monitoring is conducted well after wind farm construction, early operational years, which may include behavioural adjustment periods for birds, are not captured, and this can affect estimates of collision risk over the lifetime of the wind farm.

5.2. Operational and infrastructure constraints

Retrofitting can impact turbine operations, particularly when equipment is installed in sensitive areas such as blades or high-voltage zones. In some cases, considerable turbine downtime may be required and turbine warranties may be affected, which could require approval from joint venture (JV) partners. Installations that require confined space entry or work at height introduce additional health and safety risks and must be carefully managed.

Space constraints are a recurring issue. Finding suitable locations for cameras, radar units, server racks, and cabling can be difficult, especially on platforms where safety paths must remain clear. Cable routing may be restricted by structural limitations, such as concrete barriers or inaccessible compartments.

The structural integrity of existing infrastructure must be preserved. Any new equipment mounted on turbines or substations should be assessed for potential fatigue risks and mechanical interference. Interfaces between monitoring systems and wind farm infrastructure may be less robust than those designed during initial construction, potentially increasing maintenance demands. These aspects can restrict the identification of feasible installation design solutions to retrofit monitoring equipment.

5.3. Approvals and certification

Retrofitting activities require approval from the wind farm operator and, in some cases, external authorities. RAMS must be prepared and accepted before offshore works commence. Additional certifications may be required depending on the jurisdiction and equipment type.

Internal approvals, including those from JV partners, are often necessary, particularly where turbine downtime or infrastructure modifications are involved. Clear documentation and communication with all stakeholders are essential to avoid delays. It is recommended that an approval plan is put in place and communicated to all involved, setting out who needs to approve and by when, as well as delegated authorities if the planned approvers aren't available at the required time.

5.4. Technical and cybersecurity considerations

Monitoring systems must be compatible with existing infrastructure, including power and data networks. In operational wind farms, remote data access is often preferred over physical cabling, which can introduce cybersecurity and data protection concerns. These should be addressed early in the planning process, with input from IT and compliance teams.

Data storage capacity and system commissioning requirements should also be considered, particularly for offshore deployments where bandwidth and access may be limited. Limited bandwidth or restricted access can lead to delays in data transfer, reduced resolution, or gaps in monitoring data. Alternatives include local data storage with scheduled uploads, data compression, or using dedicated communication links such as fibre or satellite for critical transfers.[4]

5.5. Installation and maintenance logistics

Installation offshore is time-intensive and weather-dependent. Technicians from the developer are typically required to accompany supplier personnel during installation. Weather windows must be planned carefully, and vessel access coordinated with other operational activities.

Smaller equipment, such as compact cameras, may be easier to retrofit and install during regular O&M visits. Larger systems, including radar units, may require dedicated vessels and crane operations, significantly increasing cost and complexity.

Maintenance access should be considered during installation design. Equipment should be positioned to allow safe and efficient servicing, with minimal disruption to turbine operations.

5.6. Retrofitting summary – key recommendations and risks

Good practice recommendations

- Plan retrofitting with at least 7–12 months lead time.
- Coordinate installation and maintenance with regular O&M schedules.

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[4] Data considerations are discussed in more detail in PrediCtOr WP4.

- Share technical documentation early, especially if supplier involvement begins late.
- Organise a visit out to the WTG(s) where the equipment will be placed for on-site investigations and more efficient planning.
- Prepare and approve RAMS before offshore works.
- Choose compact equipment and design for safe, accessible installation.
- Consider cybersecurity and remote data access needs.
- Engage O&M teams early and ensure technician availability.
- Simulate equipment coverage, especially for floating wind farms.

Potential risks

- Turbine downtime may affect warranties and require JV approval.
- Limited space and safety path constraints can complicate installation.
- Structural fatigue or mechanical interference from added equipment.
- Increased HSE exposure due to offshore conditions and confined spaces.
- Cybersecurity and data protection vulnerabilities with remote access.
- Higher maintenance needs due to less robust integration with existing infrastructure.
- Offshore retrofitting can be costly and weather dependent.

6. Requirements and specifications for 'integrated designs'

Integrating seabird monitoring systems into offshore wind farm infrastructure during the design and construction phases offers significant advantages compared to retrofitting. Early planning enables smoother installation, reduces operational disruption, and improves long-term system performance.

6.1. Timing and coordination

Integration should be considered as early as possible, ideally during the development or pre-construction phase. It is most effective when addressed at the point design contracts are placed for turbines, foundations, and offshore substations. Developers typically aim to define additional systems and structures three to four years before installation. Early engagement allows for preparatory works such as allocating power and network ports, installing cable trays, and reinforcing mounting points.

Coordination with turbine suppliers and foundation fabricators is essential. Monitoring system requirements should be incorporated into turbine supply agreements and foundation design packages to avoid costly changes later. Where measurement sub-suppliers are involved, their scope and access to fabrication yards should be clearly defined.

It is important to note, however, that in practice, opportunities for fully integrated monitoring designs can be constrained by the timing of consenting and permitting processes. In some jurisdictions, final avian monitoring requirements are not confirmed until late in the development or permitting phase, following detailed engagement with regulatory and environmental authorities. By this stage, key engineering decisions may already be largely fixed. This can limit the extent to which monitoring equipment can be fully integrated and may necessitate partial integration or retrofit solutions, even where early integration would otherwise be preferred.

This misalignment between permitting and engineering timelines can create several challenges, including:

- Late changes to monitoring requirements after engineering activities have commenced, resulting in redesign, additional cost, and programme delays.
- Approved monitoring designs proving impractical during offshore installation, necessitating further design changes and additional approvals.
- Extended or unpredictable review periods from consenting bodies, which can delay monitoring campaigns and increase the risk of missing critical or seasonal survey windows.

While these constraints cannot always be avoided, their impacts can be reduced through early and proactive coordination, including:

- Early engagement with consenting bodies, such as involving them in at least one preliminary review of monitoring design principles, to reduce the likelihood of significant late-stage changes.
- Maintaining ongoing communication between engineering and consenting teams to ensure alignment as requirements evolve.

- Clear sequencing of engineering activities, prioritising elements that are either less likely to change, or are more flexible or easier to modify. Where possible, adopting a flexible design approach where final requirements are uncertain, by reserving space, load capacity, power supply, and data interfaces capable of accommodating a range of potential monitoring systems.
- Including contingency and flexibility within contracts to enable adaptation to evolving requirements while minimising cost, safety, and programme impacts.

6.2. Design integration and standardisation

Integrated designs benefit from semi-standardised setups and future-proofing. Establishing baseline requirements for equipment dimensions, mounting brackets, data formats, and installation procedures can streamline coordination across projects and suppliers. Standard railing designs, for example, have enabled suppliers to develop off-the-shelf mounting solutions.

Monitoring equipment such as cameras, radar units, and server cabinets can be integrated more easily when space and interfaces are planned in advance. This includes ensuring adequate room for internal components and routing for cables and power supply. While cables are often more difficult to plan than the equipment itself, early design consideration can help mitigate these challenges.

Designs should also account for the increasing number of equipment suppliers and the variability in equipment specifications. Flexibility in mounting options and infrastructure interfaces can help accommodate different technologies without compromising safety or performance.

6.3. Site-specific and technical considerations

Effective integration requires consideration of site-specific factors, including turbine specifications, environmental conditions, and target species. Key variables include rotor diameter, blade length, turbine height, and shutdown speed, as well as avian flight patterns, nesting behaviour, and regulatory protection requirements.

Suppliers recommend planning for dedicated fibre connections to support environmental monitoring data, including other systems such as acoustic or marine mammal monitoring. Fibre connections have fewer restrictions than SCADA networks in terms of accessing the data. It is critical that the required bandwidth for the monitoring equipment data transmission is established early so that it can be accommodated in the OWF design. If sufficient bandwidth isn't available, the quality of transmitted data may have to be reduced or there may be gaps in the data, which could compromise the success of the monitoring study. The monitoring equipment supplier can confirm the expected file size of the data and the minimum resolution required to be able to analyse the data. Networks/ IT teams should be included in discussions during the design phase to ensure the data transfer capabilities are appropriate for the monitoring equipment. It is also recommended to have a contingency plan in place for data transfer if sufficient bandwidth isn't available on the fibre network for limited periods of time.

Access to 3D models of transition pieces and substations can support optimal equipment placement and coverage analysis, by helping to identify space requirements and exact mounting locations, confirm structural compatibility, check for any potential interference with existing components, and help determine cable routing paths. Models can also help to assess any equipment sightlines, ensuring that cameras and radars have optimal coverage without interference from turbine/OSS components or other infrastructure.

System scope should be defined early, whether focused on general bird monitoring or collision detection with curtailment, since this affects equipment type, coverage area, and data requirements.

6.4. Installation and commissioning

Where possible, installation should be carried out onshore or in fabrication yards to reduce offshore work and associated risks. Pre-installing components such as external cables and mounting brackets can streamline commissioning and reduce weather-related delays.

Close collaboration between developers, suppliers, and fabricators is essential to ensure delivery schedules, access requirements, and interface responsibilities are clearly understood and documented.

6.5. Integrated designs summary – key recommendations and risks

Good practice recommendations

- Begin integration planning during development or pre-construction phases.
- Include monitoring system requirements in turbine and foundation design contracts.
- Engage suppliers early and share technical documentation such as 3D models.
- Standardise mounting interfaces and bracket designs where possible.
- Allocate space, infrastructure and bandwidth for power, data, and cable routing.
- Define system scope early to guide equipment selection and placement.
- Pre-install components onshore to reduce offshore installation time.
- Coordinate with all relevant parties, including turbine OEMs and substation fabricators.

Potential risks

- Late-stage design changes may increase costs and delay fabrication.
- Lack of standardisation can complicate supplier coordination and equipment compatibility.
- Insufficient space or infrastructure may limit integration options.
- Poorly defined scopes can lead to mismatched equipment or inadequate coverage.
- Offshore installation requirements may increase health and safety exposure and logistical complexity.
- Inadequate planning for data access and cybersecurity may affect system performance.

7. Installation design case studies

Through discussion with the PrediCtOr project partners, two installation design case studies were chosen for creating design drawings and carrying out load analysis:

- Camera attached to the guardrail, and
- Radar sat on the external working platform or within the laydown area.

These locations were selected in consultation with the PrediCtOr partners, considering the installation design comparison matrix in Table 1. Monitoring equipment for these designs were chosen to be representative of current equipment and with publicly available specifications. The concepts were developed with a standardised design in mind as far as possible and similar designs have been produced for operational wind farms; however, given that numerous factors and parameters will differ between projects, these should not be regarded as universally applicable designs.

In this section, we provide an overview of the key considerations for designing these solutions. Detailed design drawings with supporting information can be found in Appendix 1:.

7.1. Guardrail camera support

The first design selected is an attachment to the guardrail for a camera for both an integrated and retrofitted design. The selected camera for the purpose of dimensioning and carrying out the analysis is the FLIR M400 camera, weighing 12.7kg and with dimensions of: 10.8” (273mm) x 15.7” (398mm).

A single support structure has been designed. It is composed of standard circular hollow section (CHS) lengths and flat plates and is attached to the guardrails with modified Stauff clamps. Aspects such as bonding, cable routing, and adaptability have been considered and discussed in Sections 7.1.1.4 and 7.1.3. The design is shown in Figure 9 and in the drawings, ref. [23], [24], [25] and [26].

As part of this work only the support structure has been assessed, not the guardrail. Stauff clamps can be chosen to appropriately fit the guardrail present.

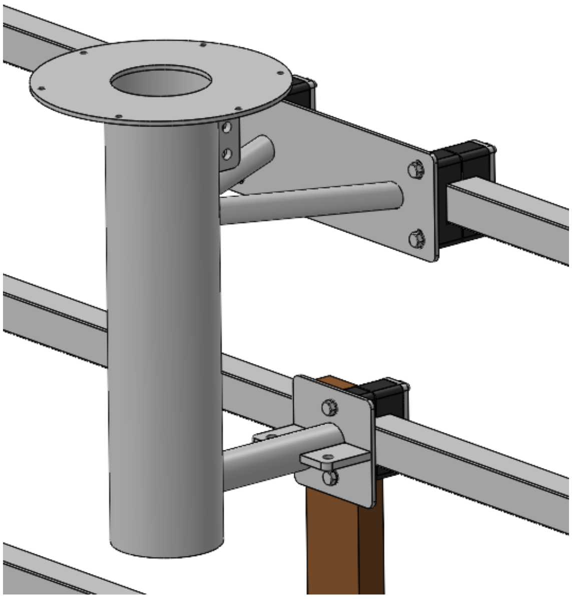

Figure 9: CAD model of camera support.

7.1.1. Design assumptions

7.1.1.1. Scope

Guardrail design will vary across projects. The primary impact of the camera support and camera on the guardrail is the additional weight and wind load.

The clamp component is to be decided on a project-by-project basis. The general design supplied uses a modified Stauff block clamp. The bolt pattern on the plates can be adjusted to match various clamp options. The attachment of the support to the guardrail is with a third-party supplied Stauff clamp, ref. [22]. These can be bought or modified to fit different guardrail sizes and shapes, each with a different capacity. The capacity of the clamps and clamp bolts should be verified with the supplier.

7.1.1.2. Environmental

Environmental conditions are assumed for the analysis of the camera support. Based on experience from previous projects and typical wind conditions, a maximum wind speed of 55 m/s at the external platform is assumed. Air density is assumed to be 1.22 kg/m^3. Higher wind speed or density will result in larger loads on the structure. This may require larger welds and thicker plates/sections. It may also impact the guardrail design. If the camera were placed within the wave loading area, then wave loading/slamming would need to be considered.

If the farm location is in a site where seismic events are regular, such as Japan, seismic analysis of the structure may be required. This can create additional accelerations and loads on the structure that require further analysis. This is beyond the scope of this study.

7.1.1.3. Material

The camera support is designed to be made of Aluminium EN-AW 6082-T6. Other material options, such as coated carbon steel or stainless steel, are acceptable given that they comply with required codes and project specifications. The higher density of these materials will result in larger loading and impacts on the guardrails. Material choice will also determine where isolation, as discussed in Section 7.1.1.4, is required. Corrosion in the marine environment also needs to be considered in material selection.

The bolts assumed to be D6-70 stainless steel bolts. Other options, such as A4-70 bolts may be acceptable provided that additional risks and inspections are accepted on the specific project. Materials must comply with EN1090-2, ref. [16].

7.1.1.4. Bonding and isolation

Isolation requirements are defined on the drawing. Materials with different electric potential must be protected against corrosion. Direct contact between dissimilar metals shall be prevented to limit bimetallic corrosion, where material is chemically eroded away. This can be performed via isolation pads, usually made of an insulating material such as neoprene, between plates or sleeves in bolt holes. An example of a typical bolt isolation is shown in Figure 10.

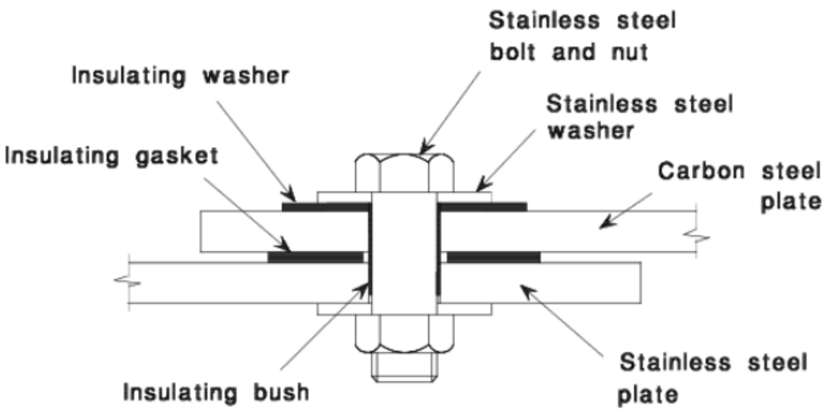

Figure 10: Example of electrical insulation, ref. [14].

Bonding has also been considered in the design. A plate has been included near the camera interface with a pair of holes. One is to allow for an exterior bonding cable to be attached to the camera casing should it be required. The other is a hook-on point for a tether line during maintenance or replacement. Additional bonding plates at the bottom guardrail attachment point allow for connection to the nearest guardrail, or directly to the platform, depending on project requirements. The supporting guardrail will need to be bonded to the external platform as is standard.

7.1.2. Design validation

The guardrail camera design was checked with RFEM, a piece of Finite-Element Analysis (FEA) software. The structure was modelled as a set of surfaces supported at the locations of the bolts for the guardrail clamps. The analysis satisfies the checks required under Eurocode 3 – Part 1-1, ref. [1].

7.1.2.1. Model setup

The model is built out of a series of surfaces of various thicknesses. These are meshed to create the overall model. Translational boundary conditions are applied at the bolt locations. The surfaces are set to be 6082-T6 Aluminium. The model is shown in Figure 11.

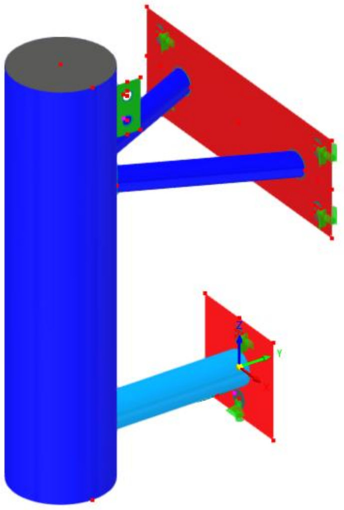

Figure 11: RFEM model of camera support.

7.1.2.2. Loading

The mass of the FLIR M400 camera is 12.7kg, which conservatively results in a 0.127kN force applied at the centre of the camera interface. The weight and sizing are sourced from the supplier's documentation, refs. [19] and [20]. The wind load is calculated to apply a 2.95kN/m^2 distributed load over the surface. The wind load on the camera itself is applied as a point load at the interface.

7.1.2.3. Analysis results

The results are shown in Figure 12. The maximum stress calculated in the support is 160MPa. This allows room for increased loading from additional environmental conditions or larger camera systems.

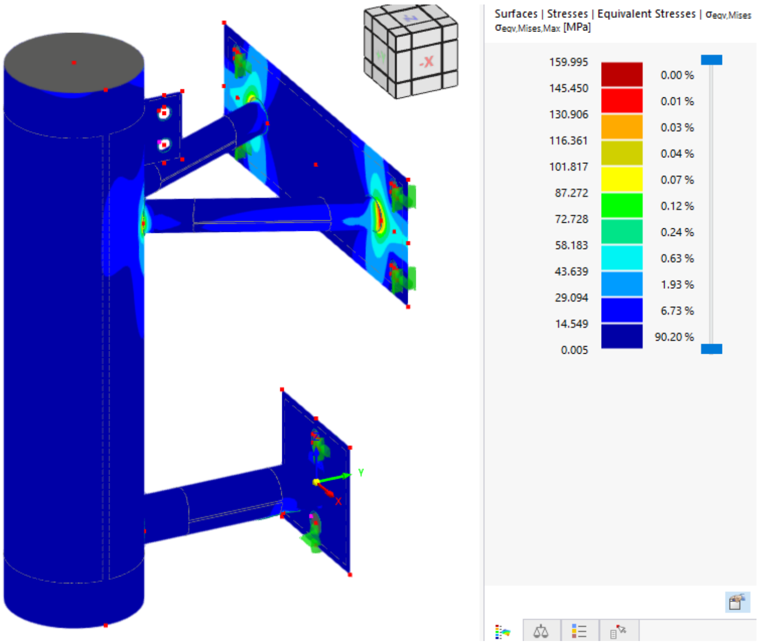

Figure 12: RFEM results of camera support analysis.

7.1.3. Design application

As discussed above, the dimensions and loading of the FLIR M400 camera have been used. If a different camera is chosen, the size, thickness, and hole pattern of the interface plate may require altering. The connections and welds in that area will require verification. The weight and size of the selected camera must be checked against the design. While there is capacity for a heavier camera, additional wind load attracted by a larger camera will impact the design. Bespoke guardrails may require designing to pass checks with the increased load.

The camera support is also shown centred horizontally on the guardrail. If it is desired, the support can be shifted towards one end of the guardrail, pending a check of the effect on the guardrail.

The models show the support clamped to the top and middle rails. However, it can also be attached to the middle and bottom rails assuming the spacing is consistent.

The proposed design results in components extending vertically above the top of the guardrail. Some stakeholders provide guidance that this should be avoided where possible to allow for safe lifting of equipment over the guardrails. The design and location of the camera should be agreed with all stakeholders.

7.1.3.1. Vibration considerations

There is the potential for vibration in the guardrail. This can be caused by seismic activity or certain wind-induced vortex behaviour. This may cause vibration and jitter in the output data of the camera. The impact of this on the final data should be confirmed with the camera supplier.

Both the camera and support structure could be stiffened to reduce the vibration effects. This may require additional material or bracing. Additionally, damping can be added into the support structure or into the camera. The amount of vibration reduction will depend on the damping method and size of the damper, as well as the frequencies being avoided. This will vary project-to-project.

7.1.3.2. Floating wind considerations

This design may be used on a floating wind turbine, assuming that the guardrail requirements are the same as for a fixed-bottom turbine. However, the camera support has not been designed for fatigue conditions and would need verification.

7.2. Baseplate radar support

As discussed in Section 3.4, the second design chosen is a radar that sits within the laydown/platform area. This design just considers an integrated design. If the support plate is not utilised a cover plate can be used to leave a flush working area.

A connection from the baseplate to the radar has not been designed here, as this would be designed by a third party to accommodate specific OEM requirements to cover operational, maintenance and secure positions. A post could be designed to have the radar straight above the baseplate, or the radar could be mounted to a swing arm, offset from the centre of the baseplate.

An adaptable baseplate has been designed to support the radar, which is assumed to be the MAX 3D 360° Avian Detection, Robin Radar system. A set of M24 bolts is used to mount the extended radar support and has additional M12 holes for attaching a protective cover plate during periods of disuse. The plate is welded down to the beams or plates of an external platform. The baseplate is shown in Figure 13.

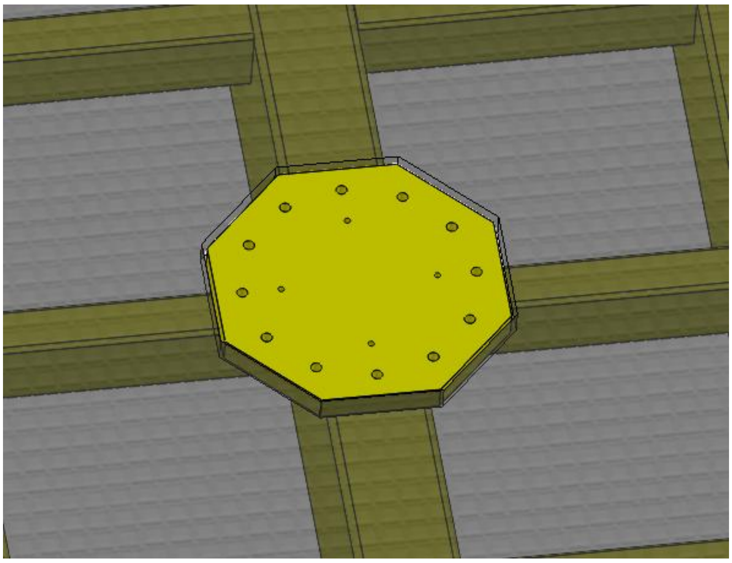

Figure 13: Radar baseplate.

7.2.1. Design assumptions

The drawing and calculations are performed assuming a steel beam structure for a traditional monopile foundation. The same design can be applied to a jacket structure - provided that the welds to the steel plate on the jacket structure are no smaller than those shown, the baseplate design does not need adapting.

7.2.1.1. Radar location

The radar has been placed at a position where the interface is 2500mm horizontally offset and 1800mm vertically offset from the centre of the baseplate, as shown in Figure 14. This placement is used as a maximum distance to create a load envelope. Factors such as access and radar clear space and range may impact the final location, which should be confirmed with all stakeholders. It is understood that operators would prefer the radar to sit towards the guardrail while in operation to get ideal coverage. There may be a project requirement that the support should be able to move the radar into the platform working area for maintenance.

The connection of the baseplate with the radar interface is beyond the scope of this design. An indicative arm is shown as an example connection. A rotational element within the radar arm may need designing if multiple positions for the radar are required. Section sizing and connection design have not been considered in the indicative arm. The support solution should be designed on a project-by-project basis, to accommodate the specific requirements and layout of the project.

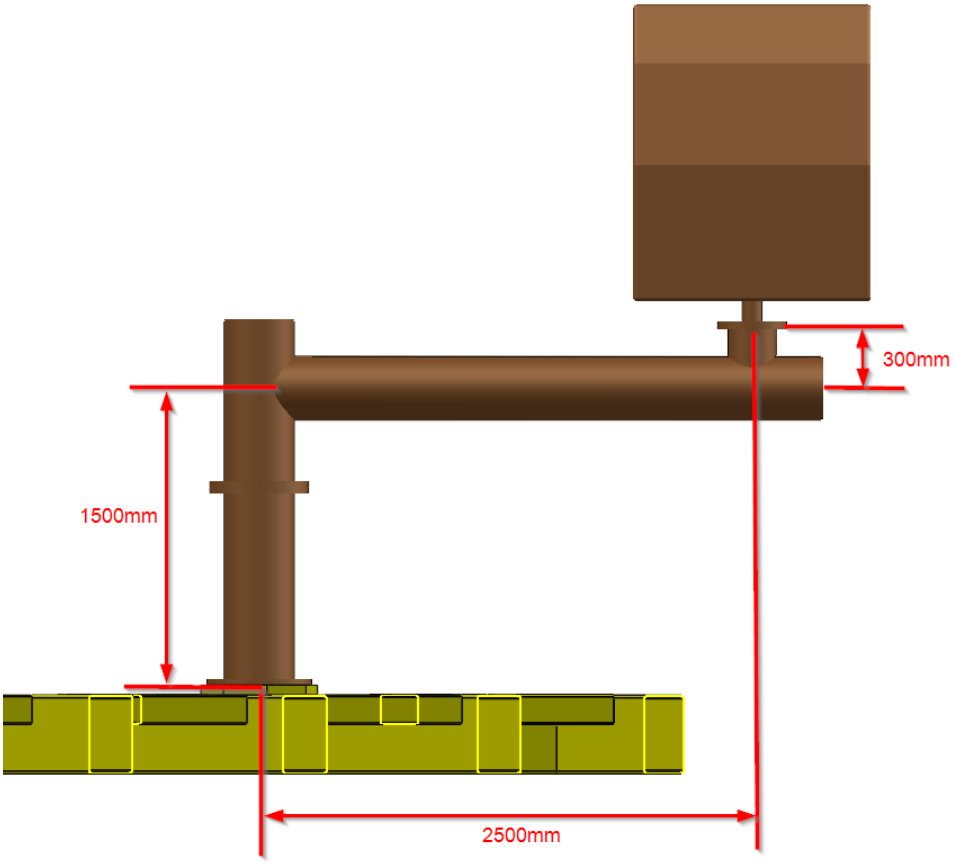

Figure 14: Radar location dimensions.

7.2.1.2. Environmental

The baseplate is checked in scenarios that consider a 55m/s wind and 80mm of icing on all arm and radar components. Air density is assumed to be 1.22 kg/m^3. Higher wind speed or density will result in larger loads on the structure. If the radar were placed within the wave loading area, then wave loading/slamming would need to be considered.

Seismic events have not been considered. The accelerations caused by the seismic activity would need to be applied to the radar and arm structure to calculate the resulting loading on the baseplate. This has not been considered.

7.2.1.3. Material assumptions

The plate is defined as EN 1.4462 grade Stainless Steel. This is to avoid the potential for corrosion in the bolt holes. If another material is desired, coatings for corrosion and scratching should be considered. The bolts are defined as D6-70 Stainless Steel bolts.

7.2.1.4. Isolation

Materials with different electric potentials must be protected against corrosion by avoiding direct contact. An isolation layer may be required at the baseplate interface. This thickness should be considered in the thickness of the cover plate to keep it flush with the grating when installed.

7.2.2. Design validation

The analysis of the radar support baseplate is performed using hand calculations in a MathCAD sheet. These calculations are based on checks from Eurocode 3, EN1993-1-8, ref. [15], for bolt and weld verification.

7.2.2.1. Loading

The mass of the MAX 3D 360° Avian Detection system from Robin Radar Systems is 325kg, ref. [21]. The load on the baseplate from the mass is calculated based on the location defined above.

The total wind load on the radar is calculated as 6.1kN. That load is applied as a point load at the radar interface.

The icing is applied as a point load caused by the ice layering on all faces of the radar. The icing thickness is a typical value for latitudes including the North Sea, taken from NORSOK 3, ref. [18].

7.2.2.2. Analysis results

The resulting forces from the RFEM model are used as inputs into the MathCAD check sheet. The maximum utilisations of the bolts and welds can be found in Table 2, as defined in Eurocode 3 – Part 1-8, ref. [15]. Utilisation of less than 1 is acceptable. It is conservatively assumed that only two bolts are taking the loads at any given time. Similarly, only a pair of 82mm long sections are used to calculate the weld capacity.

Table 2: Maximum bolt and weld utilisation of baseplate support.

Component	Maximum utilisation
Bolt	0.88
Weld	0.86

7.2.2.3. Design application

As discussed above, the placement of the radar analysed is conservative. Provided that the radar is the same weight and size and that the environmental conditions are the same or less severe, the radar may be placed anywhere within the cylindrical area defined by the dimensions defined in Section 7.2.1.1. Variations of the size and weight of the radar may limit the distance that the radar can be from the plate.

It is worth reiterating that the analyses checking the bolt and weld connections of the plate use conservative assumptions about the number of bearing bolts and the size of the welds. There is a small amount of buffer in the utilisations which allow for a larger radar. However, if these assumptions are refined to meet project-specific requirements, or the design is strengthened via more bolts or bigger welds, the design can take increased loading.

7.2.2.4. Floating wind turbine consideration

As with the camera support, this design may be able to be used on a floating wind turbine. However, the welds nor bolts have been analysed for this design situation. In particular, the accelerations caused by the wave motion may impact the required number and size of bolts in the interface plate and the location of the radar.

7.2.2.5. Concrete platform considerations

The radar placement within the external working area for a concrete platform is feasible using a bolted baseplate. A standard solution for a concrete platform has not been considered. To optimise such a design, the layout, dimensions of the platform, and concrete specification would need to be defined, which are very project specific.

A concrete external platform would consist of concrete strengthened with an embedded steel rebar structure. The complexity and amount of rebar strengthening will depend on the overall loading. The local punching check of the radar baseplate through the platform will need the anchoring design and strengthening layout to be analysed. These details are highly integrated with the overall the platform design and require inputs such as platform thickness, rebar layout, overall weight, and radar position. As a result, a baseplate detail for concrete platforms has not been included as this may not be suitable for a generic external platform layout.

7.3. Design summary

Designs have been created for a guardrail-mounted bird camera support and an integrated platform radar baseplate. These designs passed all relevant local checks. The bird camera support can be implemented as an initial design or as a retrofit solution. The radar baseplate is only an integrated solution. Both solutions can be seen in-situ in Figure 15.

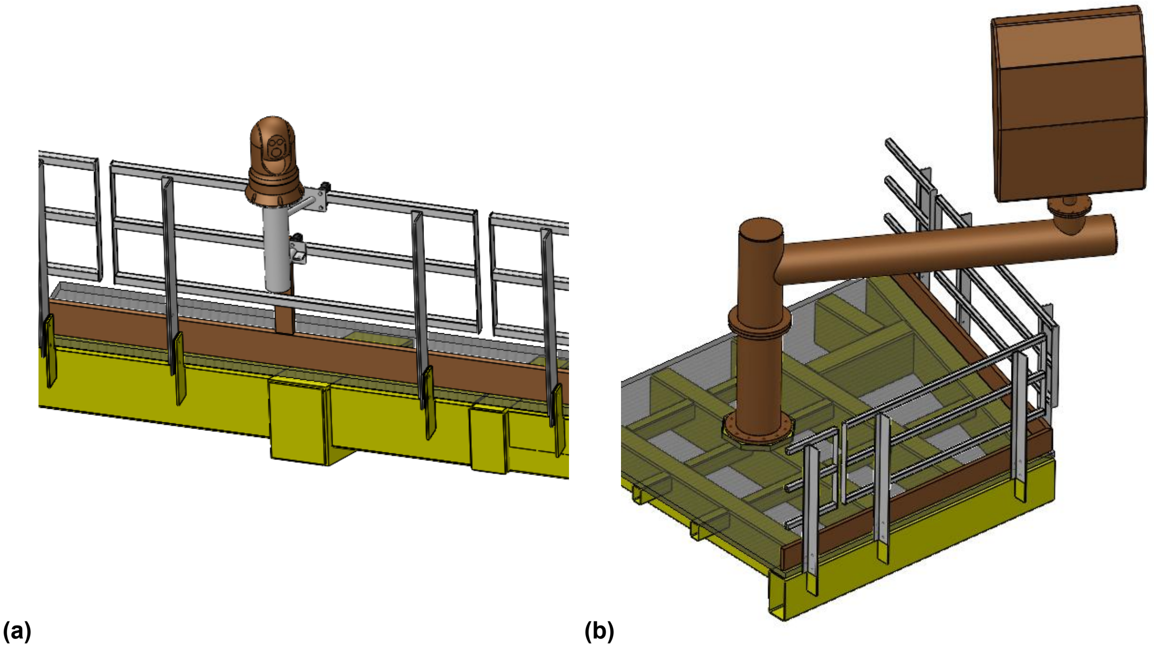

Figure 15: In-situ views of (a) camera support and (b) radar baseplate.

The camera solution assesses the support but does not assess the guardrail. The Stauff clamps (attachment from the support to the guardrail) needs to be chosen to suit the project specific guardrails. The support has been designed for the specific baseplate for the FLIR M400 camera this will need to be reassessed for different cameras.

The radar solution is shown on an indicative swing arm, only the baseplate attaching the swing arm to the platform has been assessed. OEM requirements will dictate how the radar is attached to the platform either through a similar swing arm solution or a straight post.

A summary of the two designs and important considerations for each are shown in Table 3.

Table 3: Case studies summary table.

	Guardrail Camera	Radar Baseplate
Structure material	- Aluminium	- Stainless steel
Environmental conditions	- 55 m/s wind speed - 1.22 kg/m^3 air density	- 55 m/s wind speed - 1.22 kg/m^3 air density - 80mm icing
Analysis method	- RFEM FEA model	- Hand calculations
Analysis results	- Passes all checks with capacity for increased loading with reanalysis	- Passes all checks with capacity for increased loading with reanalysis
Future design options and areas of analysis	- Vibration effects - Seismic events	- Vibration effects - Seismic events

		• Concrete platform
Key inputs	• Metocean/environmental data • Camera selection • Guardrail design	• Metocean/environmental data • Radar selection • Platform type
Key interfaces	• Interface with turbine supplier • Interface with camera supplier • Input data collection (metocean) • Interface with operations and maintenance contractor	• Interface with turbine supplier • Interface with radar supplier • Input data collection (metocean) • Interface with operations and maintenance contractor
Required checks	• Local section checks • Weld verification • Bolt/clamp check • LV design (cable routing) • Bonding & Isolation • Guardrail design	• Radar placement • Arm/pedestal design • Load generation at plate • Bolt/weld verification at plate • LV design (cable routing) • Isolation design

7.4. Case study limitations

The completion of the case studies demonstrates some key considerations in the design process for mounting of monitoring equipment. While certain aspects of designs and concepts can be generated and compared, the unique conditions of each offshore wind farm and specifications of different monitoring equipment can result in different optimal solutions.

Turbine suppliers, developers, contractors, BMS suppliers and other stakeholders will have different priorities and requirements that create certain conditions for the design. These interfaces, and effective communication between these stakeholders, are critical to studies going forward.

If the BMS requirements are known early in the foundation design process, this will reduce the complexity of integration. This is particularly important if large radars are required that need additional platforms or enlarged external platforms.

8. Key recommendations

This section summarises the key recommendations for the design and installation of seabird collision monitoring equipment in offshore wind farms. The recommendations are grouped into categories to support planning, integration, and operational efficiency. They reflect best practices identified through stakeholder engagement, technical review, and case study analysis.

While broad representation of relevant stakeholder groups was sought, direct OEM input was limited: one turbine OEM provided input, and attempts to engage TP and jacket OEMs did not yield substantive responses. Consequently, the guidance may not reflect the full range of OEM design philosophies or manufacturing constraints across the market.

In addition, the guidance reflects the best available evidence and expert judgement at the time of writing. As technologies and industry standards continue to evolve, users should revisit assumptions and confirm applicability for their project context.

The recommendations presented here are intended as guidance rather than strict requirements, as practical constraints such as cost, technical feasibility, and project-specific or jurisdictional differences may limit full implementation. OSW developers and monitoring equipment suppliers should aim to adopt the recommendations wherever practically possible, acknowledging these constraints.

Table 4: Key recommendations.

Category	Recommendations
Equipment placement & design	➢ If considering nacelle-mounted cameras, carefully weigh the benefits of improved detection against practical constraints, including limited space, OEM approval requirements, installation and maintenance complexity, power and cabling arrangements, HSE implications, and potential cost impacts. ➢ Ensure camera mounts are stable to minimise vibration and jitter; consider stiffening/damping if needed. ➢ Avoid placing radars in areas with frequent personnel access (to reduce safety shutdowns). Use swing-arm or offset mounting to position radars clear of structures for better performance and easier maintenance. ➢ Consider OSS for larger radar systems to maximise coverage and reduce turbine impacts. ➢ Plan radar siting to minimise blind spots and structural shadowing; multiple units may be required. Account for height effects (e.g. lower placement improves near-water detection) and follow OEM siting guidance to avoid clutter/shadowing. Installing radar on the peripheral turbines of the wind farm and pointing outwards can help minimise interference of the turbines. ➢ Ensure mounting solutions do not obstruct walkways or O&M activities, as much as practically possible.
Power & data integration	➢ Integrate power access early in turbine/OSS design with sufficient capacity and clear routing; prioritise turbine/OSS power over batteries where feasible.

	➢ Plan cable routing and space for networking equipment during design (not retroactively). Separate power and signal/data cables and locate power/data equipment away from high-voltage areas to improve safety and access. ➢ Plan for fibre connectivity and bandwidth appropriate to monitoring data; engage IT early and confirm data transfer requirements and contingencies.
Material & equipment protection	➢ Confirm and communicate storage/packaging requirements to all handling teams; consider warranty implications for long storage. ➢ Use protective housings and automated cleaning systems (e.g. for sea spray and bird excrement). ➢ Select corrosion-resistant materials and certified cables for offshore use. ➢ Ensure equipment withstands transport and operational vibrations and has appropriate IP ratings for marine conditions.
HSE	➢ Integrate HSE requirements into project planning and align with site-specific rules; ensure contractors comply with operator standards. ➢ Ensure personnel hold required certifications (e.g. GWO modules, OGUK medical, HUET, confined space, advanced rescue where applicable). ➢ Prepare/approve RAMS before activities; conduct site-specific inductions; inspect PPE annually. ➢ Develop equipment lifting plans and provide secure lifting points; respect manual handling limits and use mechanical lifting where needed. ➢ Confirm supplier safety protocols for infrared cameras and ensure radars are powered down before personnel work nearby (as specified by the supplier).
Logistics & access	➢ Align installation and maintenance with wind farm schedules; plan for suitable weather windows and include contingency time. ➢ Book service vessel capacity early during peak periods; define logistics responsibilities between contractors and operators. ➢ Confirm lifting plans and integrate secure attachment points into design. Where possible, pre-install and test components onshore to minimise offshore work.
Maintenance & operations	➢ Align monitoring equipment maintenance with wind farm O&M schedules; plan vessel capacity and site access well in advance. ➢ Define maintenance responsibilities early (supplier-led vs developer-led). ➢ Train O&M teams for routine tasks (lens cleaning, fluid top-ups, visual inspections) and integrate these into regular turbine visits where practical. Embed monitoring tasks in

	wider maintenance plans and communicate their importance to all teams. ➢ Use remote access for diagnostics/updates to reduce offshore interventions. Facilitate remote supervision by suppliers (e.g. video support) for more complex tasks.
Retrofit campaigns[5]	➢ Plan retrofits with sufficient lead times (8-12 months) ahead and coordinate with O&M schedules. Share technical documentation early (especially if supplier involvement is late in project development timeline). ➢ Organise a visit out to the WTG(s) where the equipment will be placed for on-site investigations and more efficient planning. ➢ Prepare/approve RAMS before offshore works. Engage O&M teams early and ensure technician availability. ➢ Choose compact equipment and design for safe, accessible installation. ➢ Address cybersecurity and remote data access requirements with IT/compliance. Simulate coverage (especially for floating wind) and, where possible, complete onshore preparation (assembly, cable routing, configuration) to reduce offshore time. ➢ Design retrofits with maintenance access in mind (both for monitoring equipment and for turbine components).
Integrated designs[5]	➢ Begin integration in development/pre-construction and include monitoring equipment installation requirements in turbine/foundation/OSS contracts. ➢ Engage suppliers early; share technical documentation (including 3D models) to support optimal placement and coverage. ➢ Standardise mounting interfaces and cable routing solutions across assets where feasible. ➢ Allocate space/infrastructure/bandwidth for monitoring systems in design, and pre-install brackets/cable trays onshore to reduce offshore work. ➢ Coordinate across OEMs, fabricators, and developers on delivery schedules, access and responsibilities.

This PrediCtOr design best practice guidance is intended to support more consistent and effective deployment of seabird collision monitoring equipment across offshore wind projects. Applying these recommendations can help reduce complexity, improve data quality, and streamline installation and maintenance of monitoring equipment. Ongoing collaboration and alignment between developers, suppliers, and regulators will be essential to address these and other challenges in collision monitoring and ensure that monitoring practices keep pace with the evolving needs of the sector.

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[5] Note that recommendations for retrofitted and integrated designs may have cross-relevance; the recommendations highlighted here are deemed particularly important for the respective equipment installation approaches.

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[14] EN1993-1-4 – Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels (2007)

[15] EN1993-1-1 – Eurocode 3: Design of steel structures – Part 1-8: Design of joints

[16] EN1090-2: 2018 +A1:2024: Execution of steel structures and aluminium

[17] DNV-ST-0126: Support structures for wind turbines

[18] NORSOK N-003: 2017 – Actions and action effects

[19] Installation Guide M400, FLIR

[20] M400 ICD, FLIR

[21] Product sheet, MAX 3D 360° Avian Detection, Robin Radar Systems

[22] Catalogue STAUFF Clamps, STAUFF

[23] REN2024N01435-CD-MPWTG-SS-05-001, CAMERA SUPPORT BRACKET – SECTIONS AND DETAILS Drawing

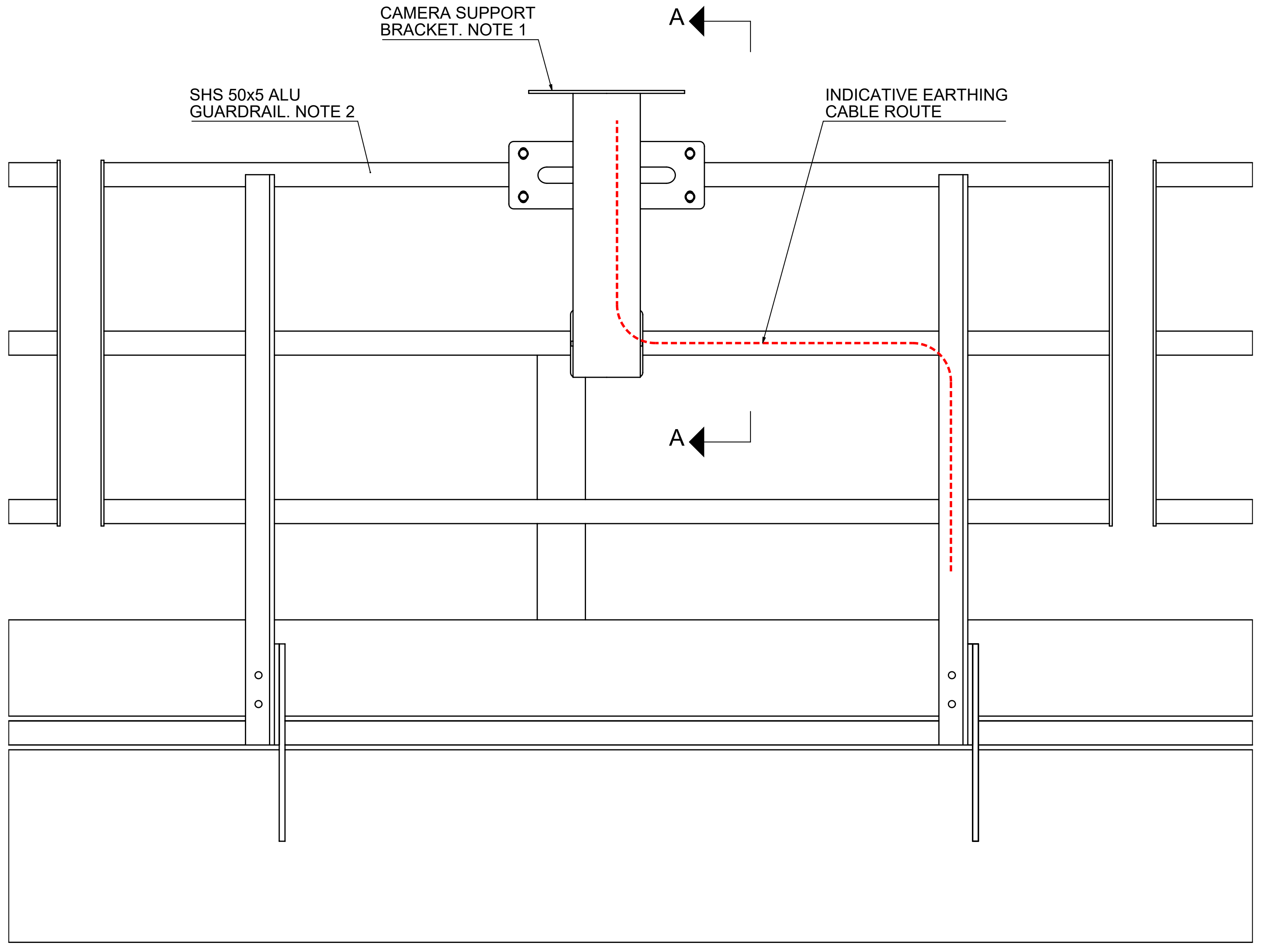
[24] REN2024N01435-CD-MPWTG-SS-05-002, CAMERA SUPPORT BRACKET – GENERAL NOTES Drawing

[25] REN2024N01435-CD-MPWTG-SS-05-003, BIRD RADAR BASEPLATE – SECTIONS AND DETAILS Drawing

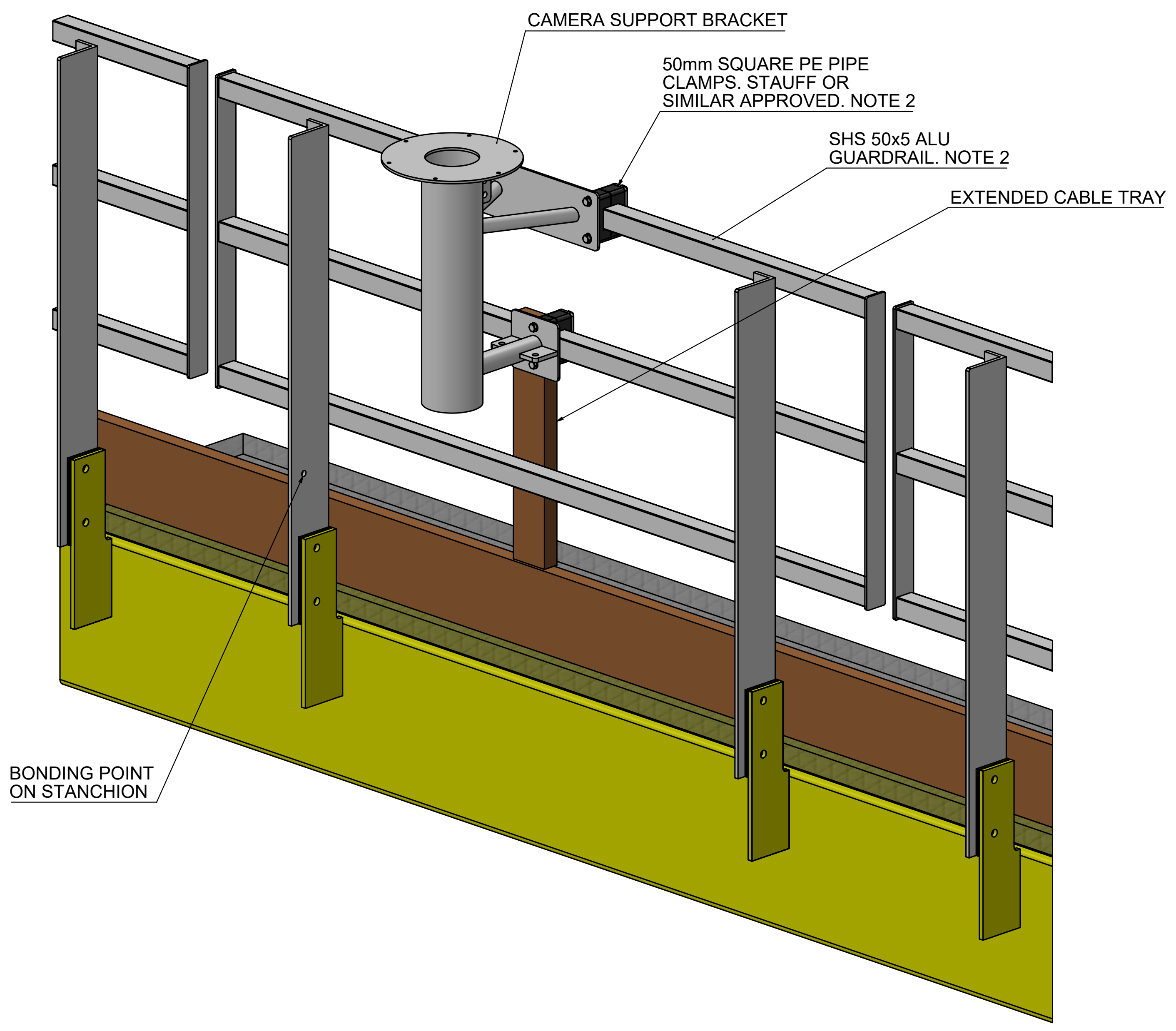
[26] REN2024N01435-CD-MPWTG-SS-05-004, BIRD RADAR BASEPLATE – GENERAL NOTES Drawing

[27] G+/DROPS Reliable Securing Booklet for Offshore Wind – June 2019

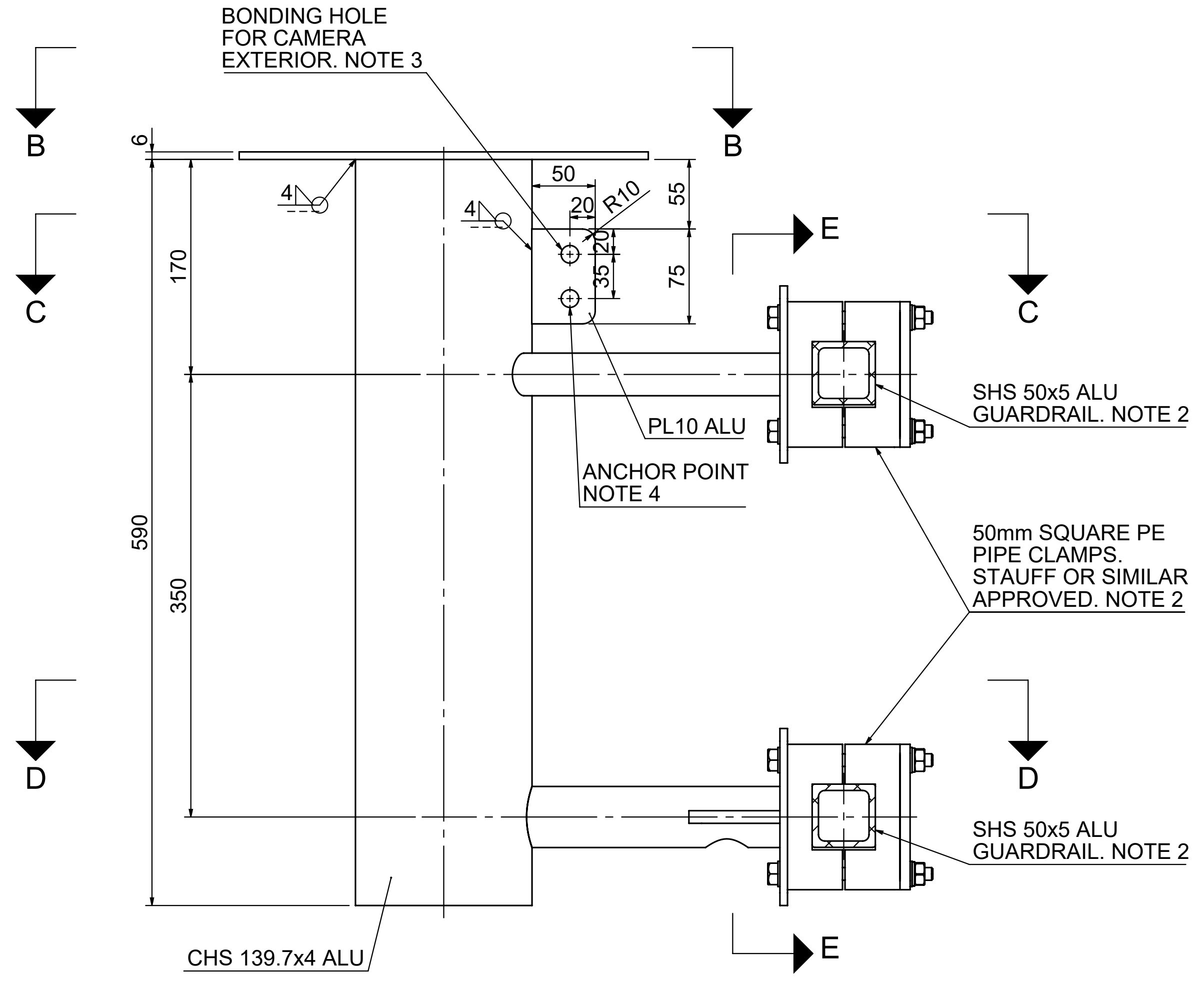
Appendix 1: Case study design drawings



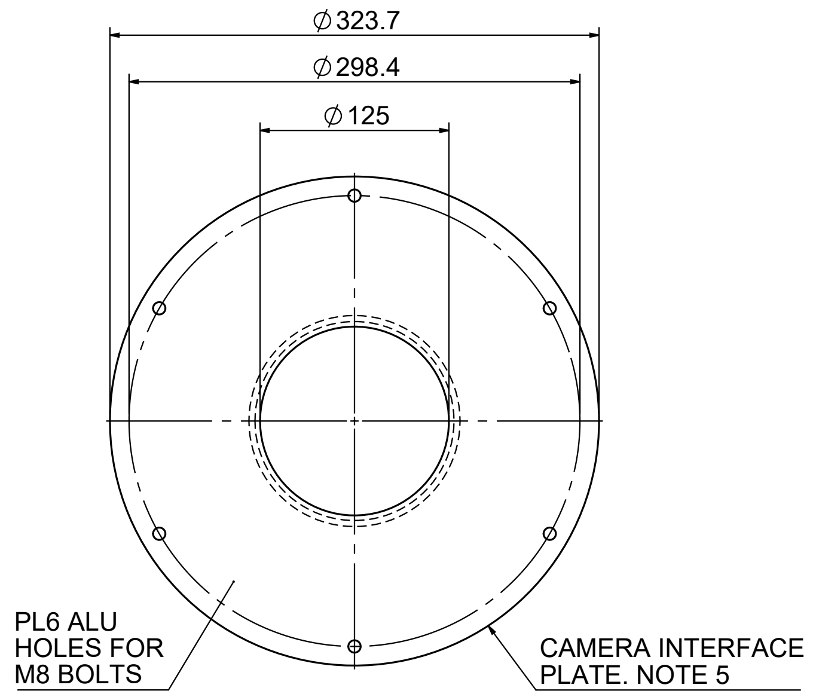
SIDE VIEW
1 : 10
CAMERA SUPPORT BRACKET



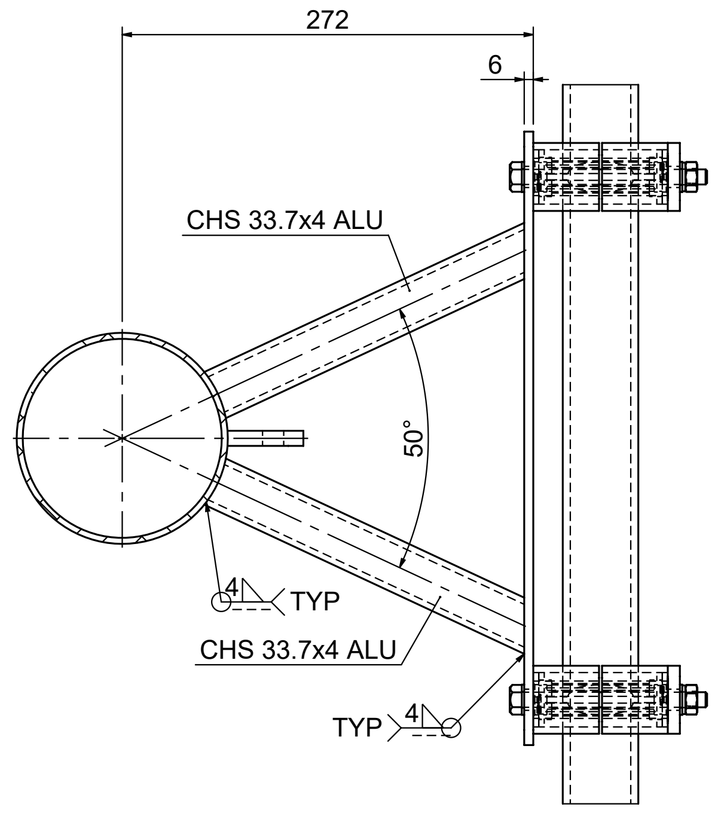
3D VIEW
CAMERA SUPPORT BRACKET



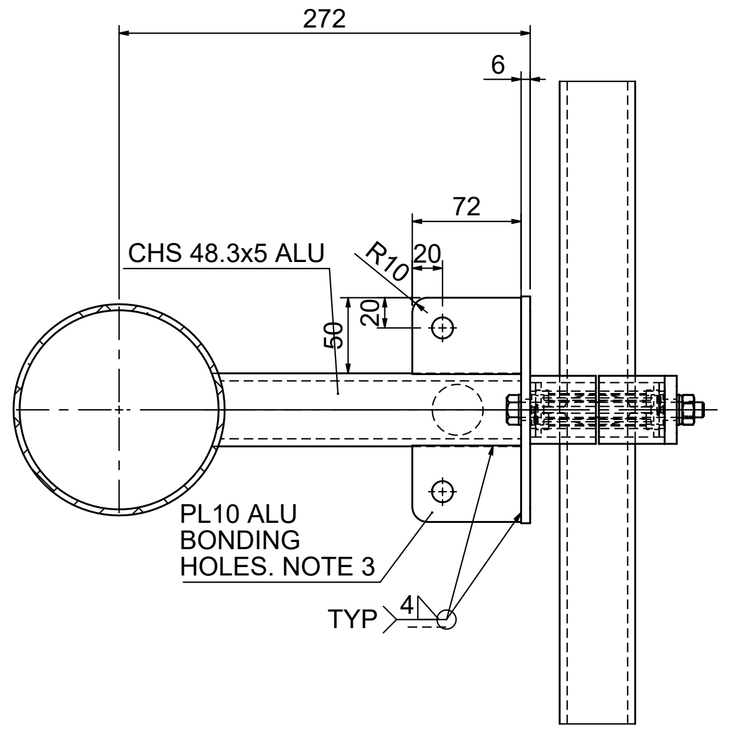
SECTION A-A
1 : 5



SECTION B-B
1 : 5



SECTION C-C
1 : 5



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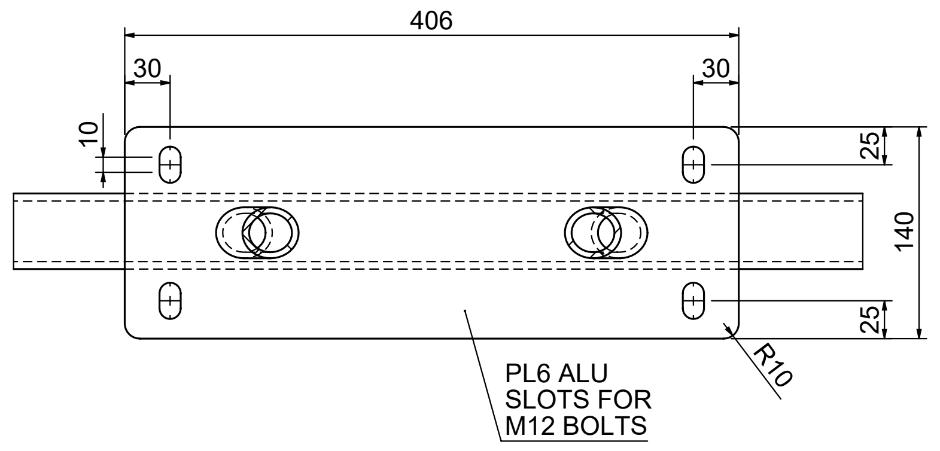
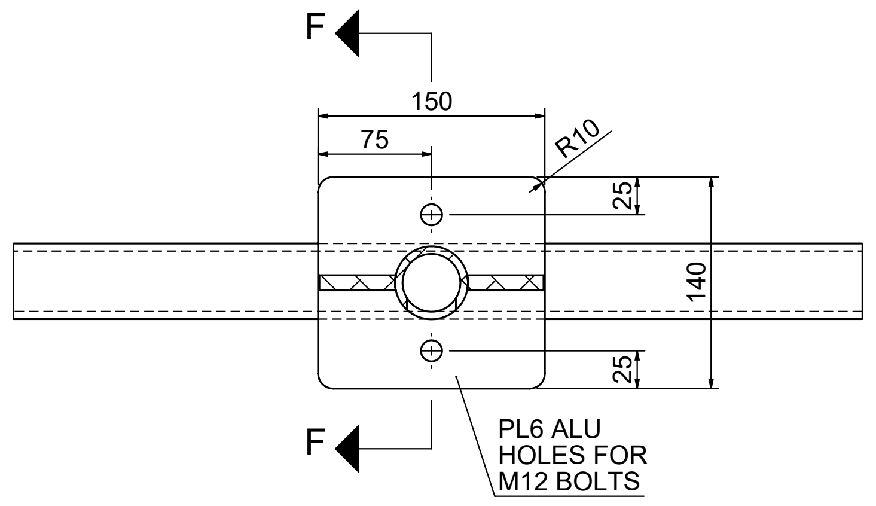
1 : 5





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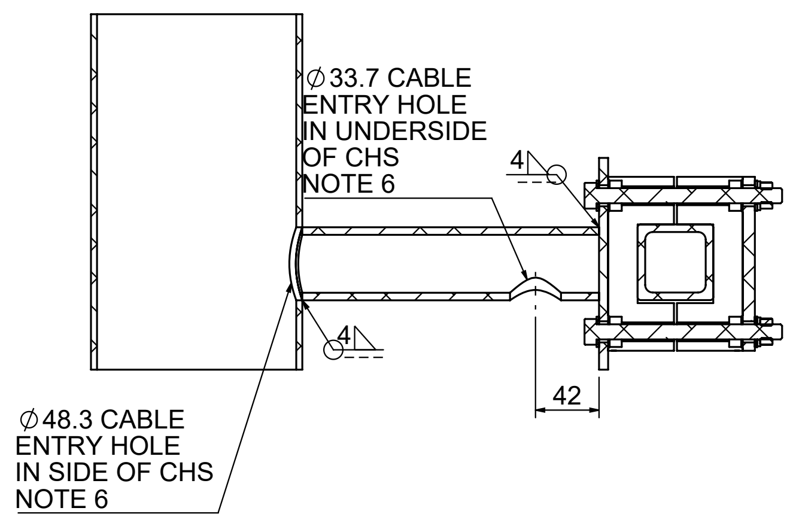
1 : 5

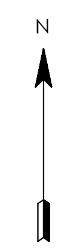


SECTION F-F
1 : 5

NOTES

1. STANDARD DESIGN INCLUDES ELEMENTS EXTENDED BEYOND THE TOP OF THE GUARDRAIL. THIS SHOULD BE AGREED WITH ALL STAKEHOLDERS.
2. GUARDRAIL RAILING SIZING MAY VARY. CLAMP SHOULD BE SELECTED ON A PROJECT-BY-PROJECT BASIS. A MODIFIED STAUFF BLOCK CLAMP IS USED INDICATIVELY.
3. BONDING POINTS ARE PROVIDED FOR CAMERA TO THE SUPPORT AND FOR THE SUPPORT TO THE EXTERNAL PLATFORM. GUARDRAILS ARE TO BE BONDED TO EXTERNAL PLATFORM AS STANDARDS REQUIRE. SIZING SHOULD BE CONFIRMED BY THE DESIGNER.
4. AN ANCHOR POINT IS PROVIDED FOR RESTRAINT DURING INSTALLATION, MAINTENANCE, OR REMOVAL.
5. CAMERA INTERFACE PLATE IS INDICATIVE. THIS WILL BE SPECIFIC TO CAMERA SUPPLIER.
6. REQUIRED CABLES AND CABLE PROPERTIES FOR CAMERA SHOULD BE VERIFIED WITH CAMERA SUPPLIER. BENDING RADII AND ROUTING SHOULD BE CHECKED ON A PROJECT-BY-PROJECT BASIS. EDGES THAT INTERACT WITH CABLES MUST BE ROUNDED OR PROTECTED TO PREVENT CABLE DAMAGE.

KEY-PLAN



Rev.	Date	Prepared	Checked	Approved	Description
1	2025-10-17	ABATS	CBORO / APAGE	ETINS	ISSUED FOR REVIEW

Client
CARBON TRUST

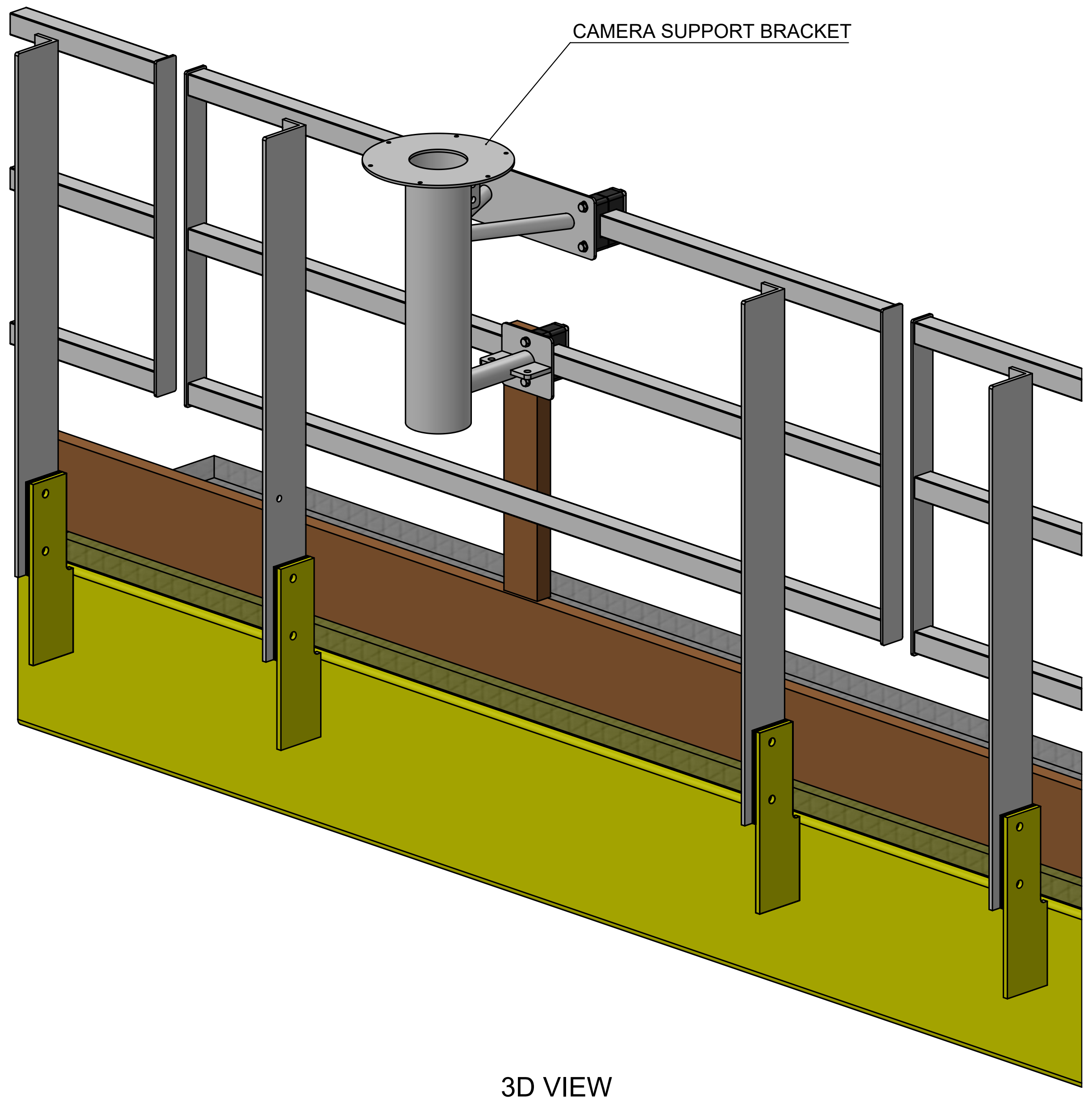
RAMBOLL

Project Number 1620017521
Project ID. REN2024N01435

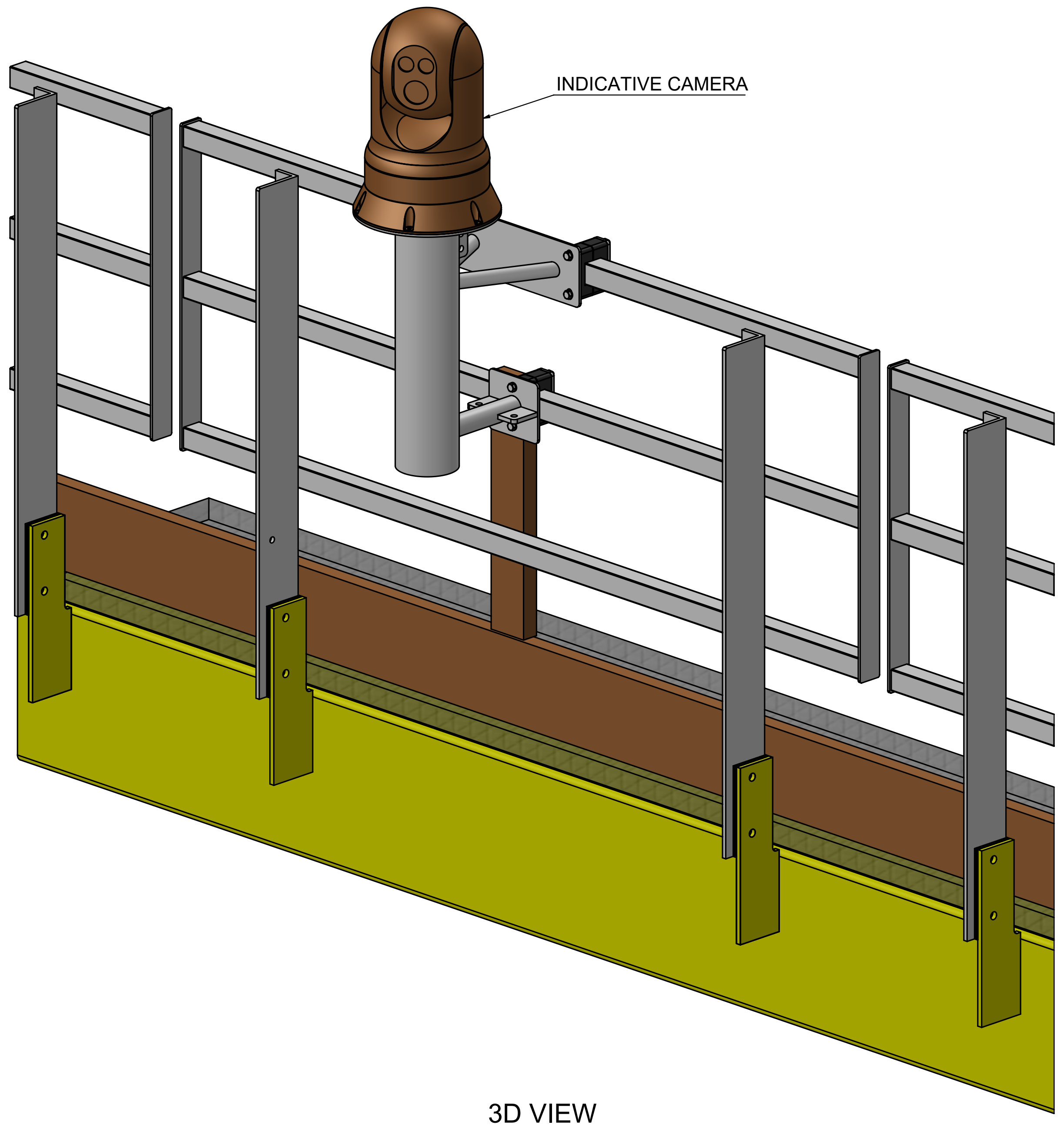
Project Name
CARBON TRUST - INSTALLATION DESIGN FOR BIRD MONITORING SYSTEMS

Title
EXTERNAL PLATFORM
CAMERA SUPPORT BRACKET
SECTIONS AND DETAILS

Scale	Size	Drawing No.	Rev.
NOTED	A1	REN2024N01435-CD-MPWTG-SS-05-001	1



3D VIEW
CAMERA SUPPORT BRACKET



3D VIEW
INDICATIVE CAMERA

RECOMMENDED BIRD CAMERA SUPPORT DESIGN FOR PUBLIC RELEASE

- THE ASSESSMENT COMPLETED FOR THIS PROJECT AND THE CONCLUSIONS MADE ARE FOR A FLIR M400/M400XR PTZ CAMERA. THIS CAMERA HAS BEEN CHOSEN BY THE CARBON TRUST AND PARTNERS. THE SPECIFICATIONS USED FOR THE CAMERA ARE WHAT IS IN THE PUBLIC DOMAIN. THE DESIGN WAS COMPLETED ON A NUMBER OF ASSUMPTIONS TO ENABLE DESIGN INPUT PARAMETERS TO BE DEFINED. FOR A SPECIFIC PROJECT, THESE ASSUMPTIONS SHOULD BE CHECKED AND VALIDATED AGAINST AVAILABLE DATA TO ENSURE THEY ARE APPROPRIATE. THESE DRAWINGS ARE FOR GENERIC DESIGN CASES AND NOT DESIGNED TO REPLACE A DETAILED BIRD CAMERA SUPPORT DESIGN AND REVIEW PROCESS.

DESIGN ASSUMPTIONS

- THE GUARDRAIL SUPPORT FOR THE BIRD CAMERA IS DESIGNED TO BE BOTH AN INTEGRATED AND A RETROFIT DESIGN.
- GUARDRAIL-SUPPORT BIRD CAMERA IS DESIGNED TO BE RETROFITTABLE ONTO TYPICAL GUARDRAIL DETAILS.
- SUPPORT DESIGN IS PERFORMED WITH INTERFACE AND LOADING DETAILS ASSUMING THE USE OF A FLIR M400 CAMERA. FURTHER ASSESSMENT SHOULD BE PERFORMED FOR PROJECT-SPECIFIC EQUIPMENT.
- CLAMP DETAILS ARE INDICATIVE AND SHOULD BE UPDATED FOR PROJECT-SPECIFIC SUPPLIERS. VERIFICATION OF LOADING ON CLAMPS SHOULD ALSO BE PERFORMED BY CLAMP SUPPLIER. THE SUPPORT CAN BE ATTACHED TO RHS OR CHS RAILS OF VARIOUS SIZING.

MATERIALS

- CAMERA SUPPORT IS DESIGNED ASSUMING THE USE OF ALUMINIUM EN-AW 6082-T6.
- BOLTS ARE DEFINED AS D6-70 STAINLESS STEEL BOLTS. A4-70 BOLTS MAY BE USED, PROVIDED THAT ANY ADDITIONAL INSPECTION AND MAINTENANCE REQUIRED DUE TO INCREASED RISK OF CORROSION IS ACCEPTED ON THE SPECIFIC PROJECT.

ISOLATION

- MATERIALS WITH DIFFERENT ELECTRIC POTENTIALS MUST BE PROTECTED AGAINST CORROSION. DIRECT CONTACT BETWEEN METALS, SUCH AS ALUMINIUM AND STAINLESS STEEL, SHALL BE PREVENTED.
- AN ISOLATION LAYER MAY BE REQUIRED AT THE INTERFACE PLATE. THIS SHOULD BE VERIFIED BASED ON CAMERA SUPPLIER. ISOLATION IN THE RELEVANT BOLT HOLES MAY ALSO BE REQUIRED.
- ISOLATION SLEEVE/SHOULDER WASHERS MUST BE USED AT CLAMP LOCATIONS. FABRICATOR MUST ENSURE LARGE WASHERS ARE USED TO AVOID DEFORMATION TO ISOLATION COMPONENTS UNDER BOLT TIGHTENING. ISOLATION COMPONENTS MUST BE VISUALLY INSPECTED AFTER TIGHTENING.

OPERATIONAL CONDITIONS AND LOADING

- ULS CONDITIONS ARE CHECKED USING A MAXIMUM WIND LOAD OF 55M/S.
- GUARDRAILS HAVE NOT BEEN ASSESSED. THE WEIGHT OF THE ASSUMED CAMERA IS 12.7KG. DETAILED EQUIPMENT EFFECTS ON THE GUARDRAIL SHOULD BE VERIFIED FOR ULS AND SLS CONDITIONS ON A CASE-BY-CASE BASIS.

BONDING

- BONDING CONNECTIONS ARE INCLUDED IN SUPPORT DESIGN. FURTHER CONNECTION POINTS MAY BE REQUIRED ON THE GUARDRAILS OR EXTERNAL PLATFORM.
- BONDING CABLES MUST BE LONG ENOUGH TO ALLOW FOR TERMINATION WITH NO STRESS ON CONNECTIONS WHILE MINIMIZING EXCESS SLACK.
- BONDING CONNECTIONS SHALL BE SEALED BY APPLYING NON-CONDUCTIVE WATER RESISTANT GREASE ON TOP OF CONNECTION.

FABRICATION NOTES

- PUNCHING OF SLOTTED HOLES IS NOT ACCEPTABLE. SLOTS MUST BE DRILLED AND MACHINED.
- PRELOADING OF BOLTS SHOULD BE VERIFIED WITH CAMERA SUPPLIER AND CLAMP SUPPLIER FOR RESPECTIVE CONNECTIONS. PRELOADING LEVEL WILL DETERMINE USE OF OVERSIZED OR PLATE WASHERS PER EN1090-2.
- BOLT SELECTION FOR OFF-THE-SHELF COMPONENTS (CLAMPS, CAMERA) SHOULD BE AGREED WITH SUPPLIERS. A BOLT LOCKING SYSTEM SHOULD BE IMPLEMENTED.

REFERENCES

1. EN1993-1-1 - EUROCODE 3: DESIGN OF STEEL STRUCTURES - PART 1-1: GENERAL RULES AND RULES FOR BUILDINGS
2. EN1993-1-8 - EURODCODE 3: DESIGN OF STEEL STRUCTURES - PART 1-8: DESIGN OF JOINTS
3. EN 1090-2:2018+A1:2024: EXECUTION OF STEEL STRUCTURES AND ALUMINIUM STRUCTURE - PART 2: TECHNICAL REQUIREMENTS FOR STEEL STRUCTURES
4. DNV-ST-0126: SUPPORT STRUCTURES FOR WIND TURBINES
5. INSTALLATION GUIDE M400, FLIR
6. M400 ICD, FLIR

NOTES

KEY-PLAN

N

Rev.	Date	Prepared	Checked	Approved	Description
1	2025-10-17	ABATS	CBORO / APAGE	ETINS	ISSUED FOR REVIEW

Client

CARBON TRUST

RAMBOLL

Project Number 1620017521
Project ID. REN2024N01435

Project Name
CARBON TRUST - INSTALLATION DESIGN FOR BIRD MONITORING SYSTEMS

Title
EXTERNAL PLATFORM
CAMERA SUPPORT BRACKET
GENERAL NOTES

Scale	Size	Drawing No.	Rev.
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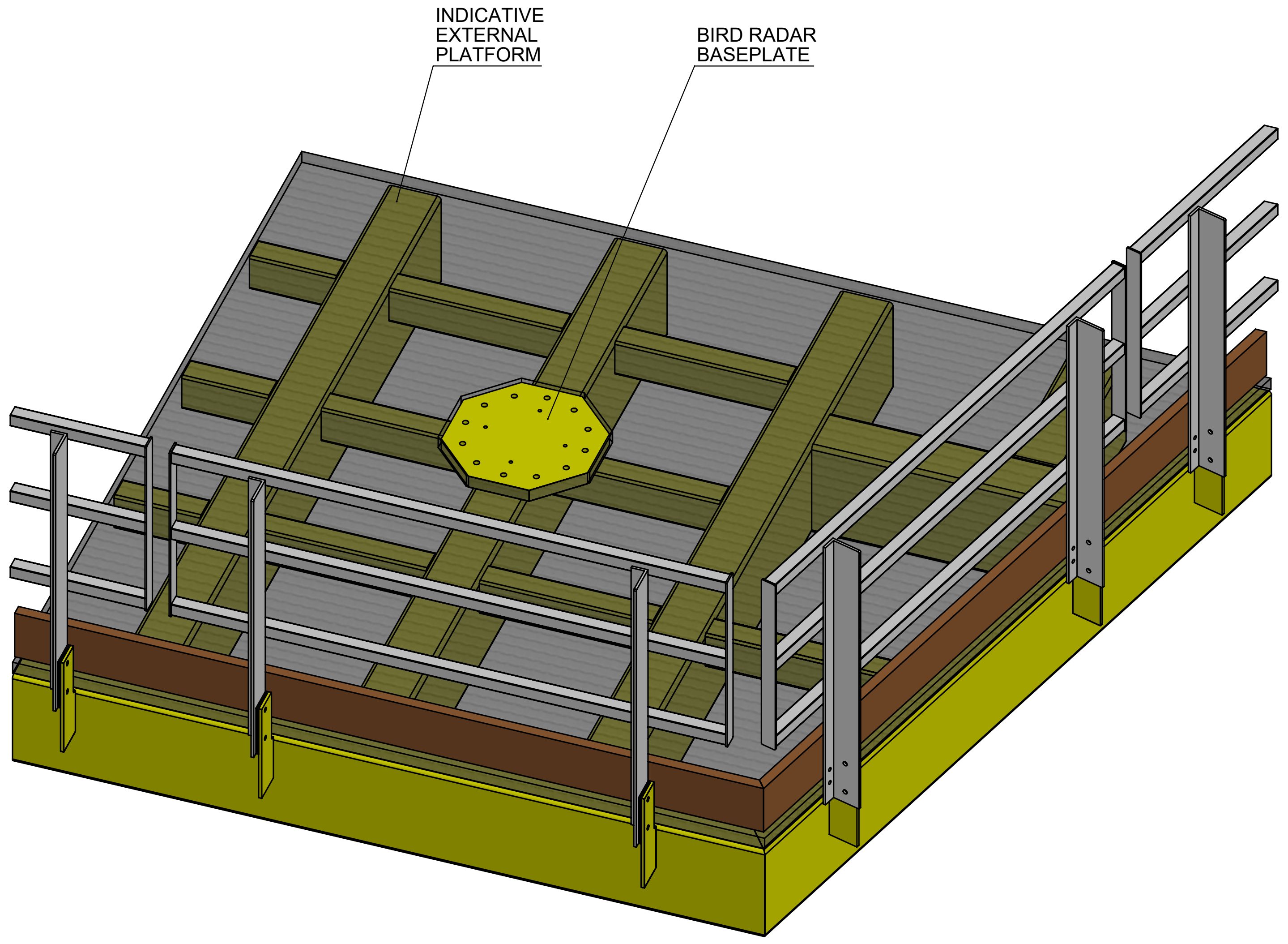
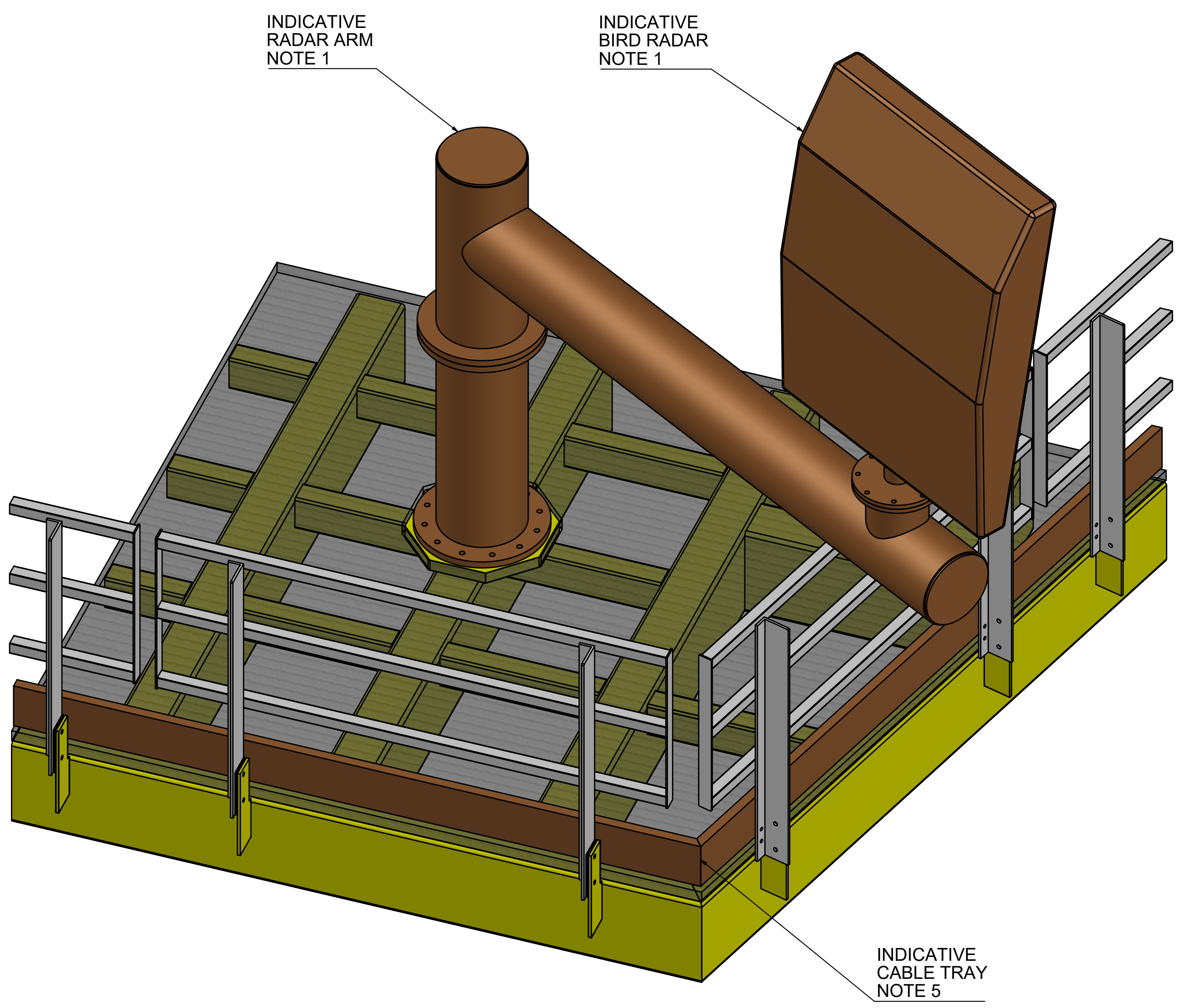
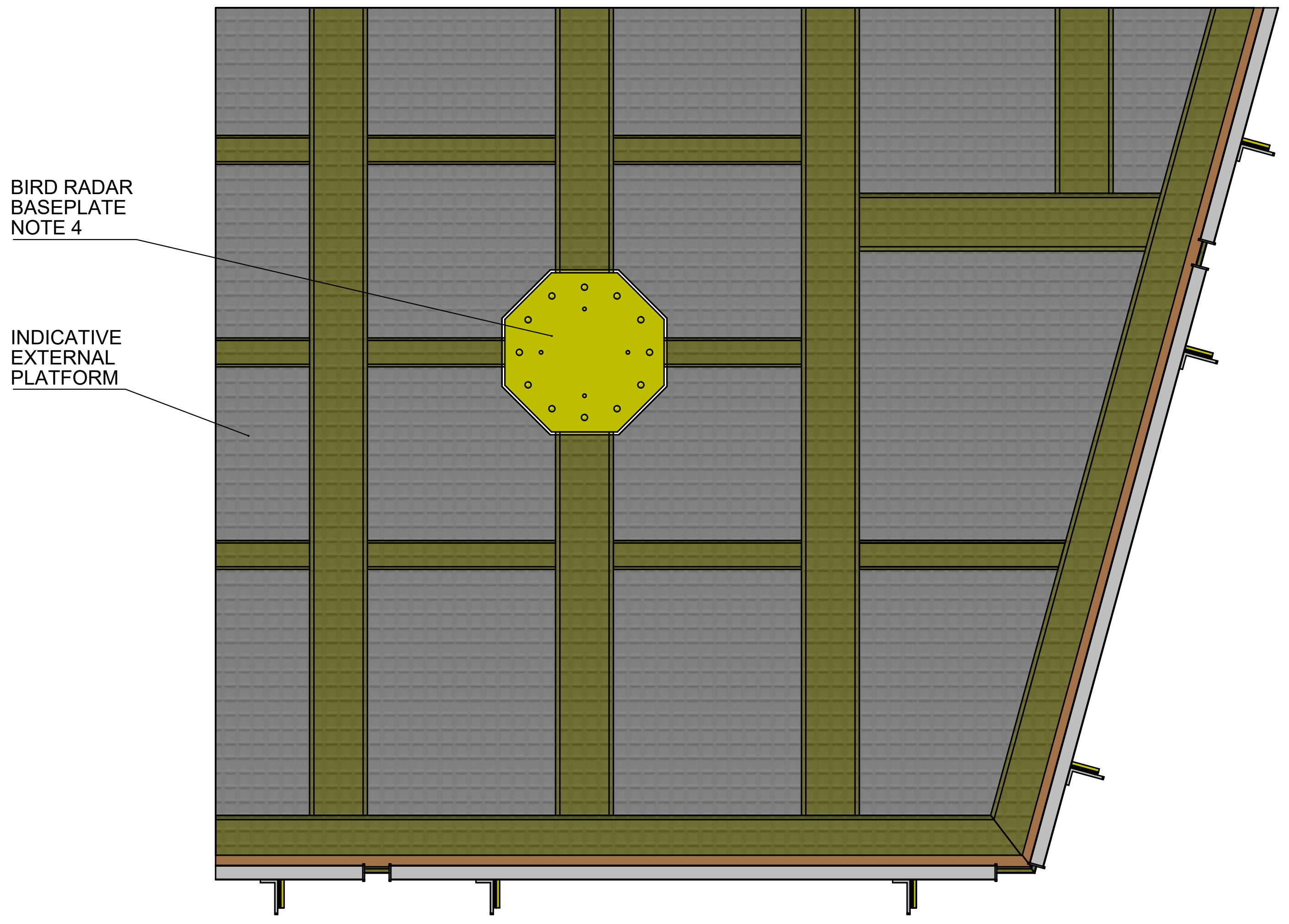


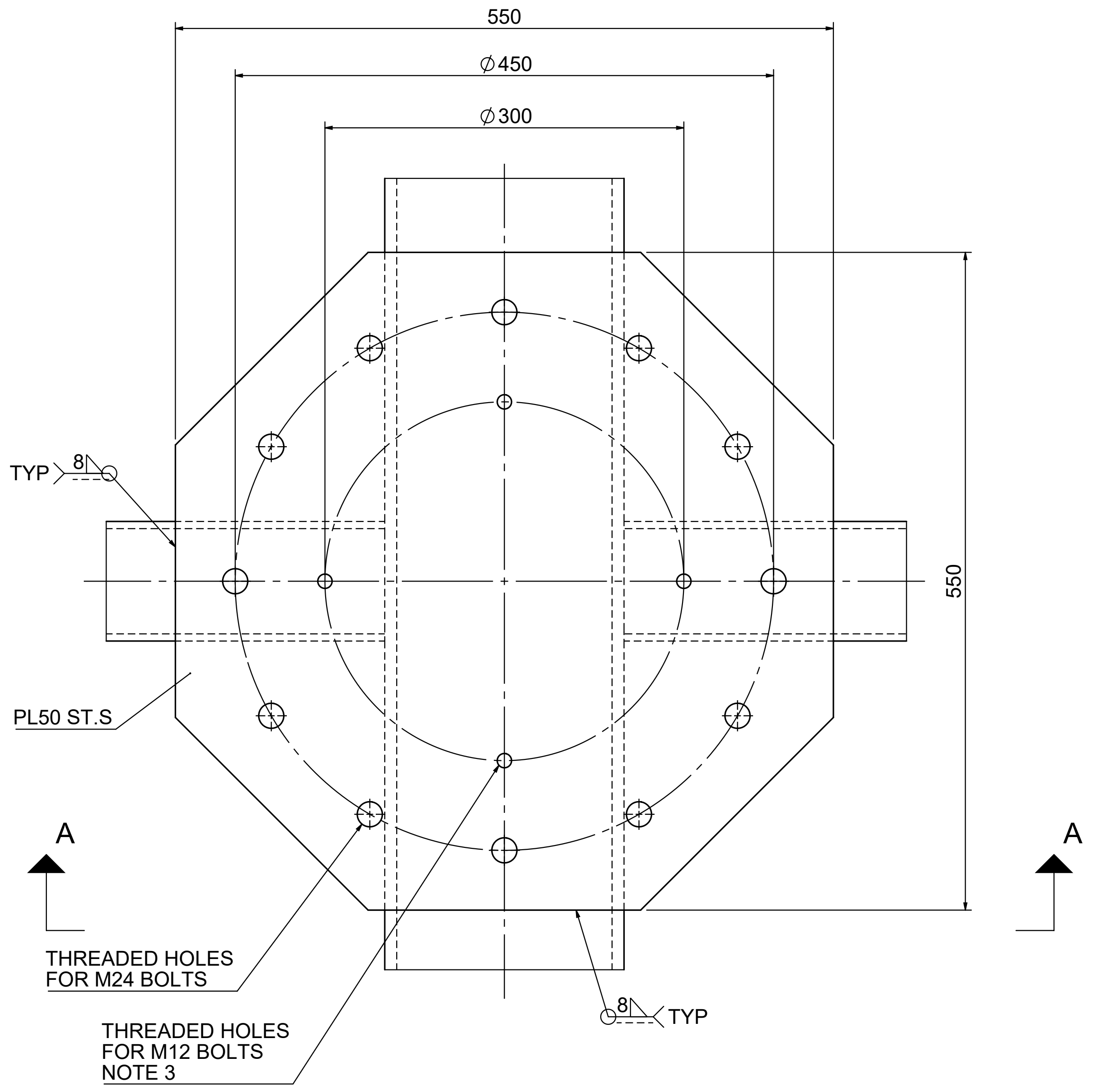
3D VIEW
BIRD RADAR BASEPLATE



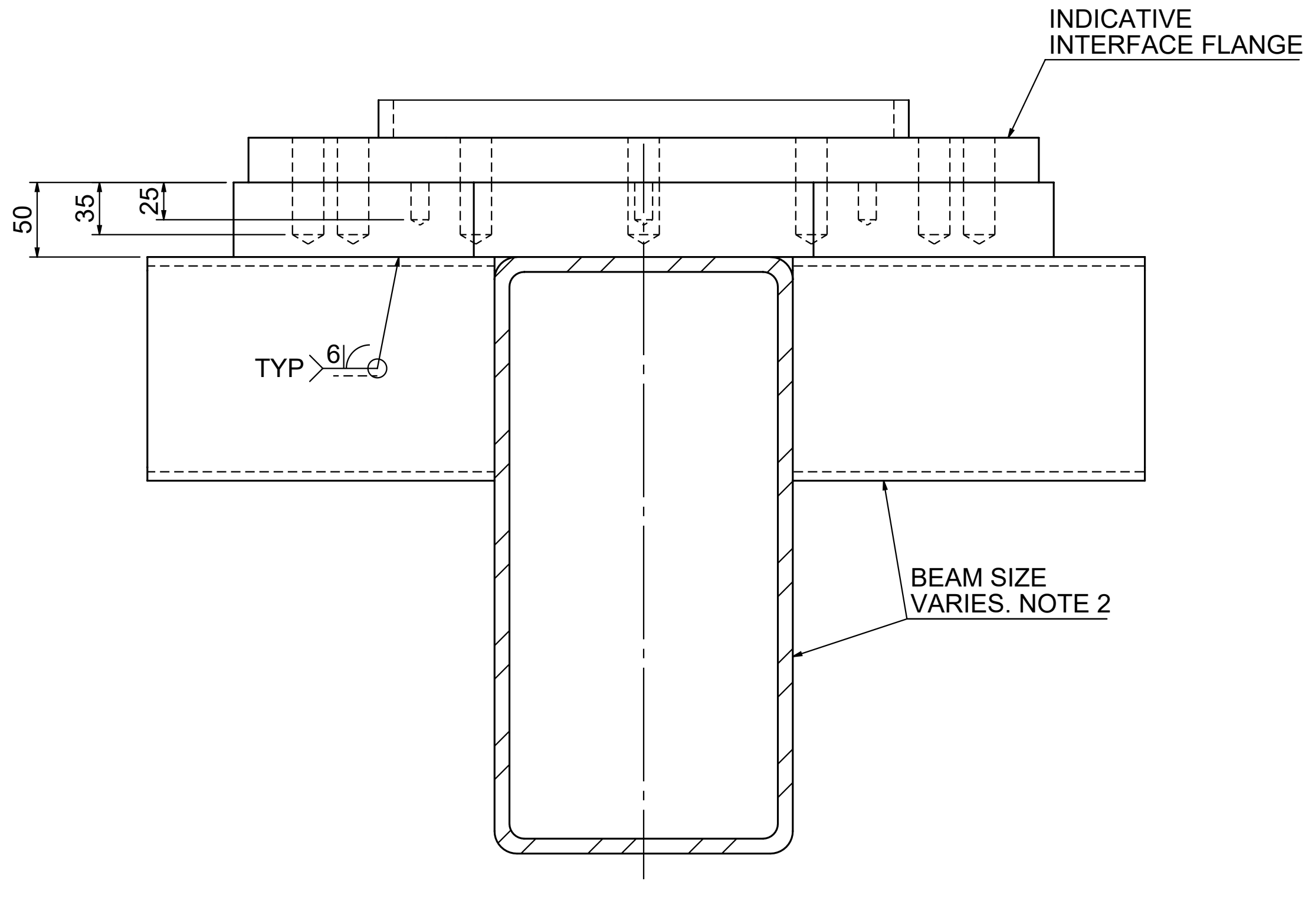
3D VIEW
INDICATIVE BIRD RADAR



TOP VIEW
1 : 20
BIRD RADAR BASEPLATE



TOP VIEW
1 : 5
BIRD RADAR BASEPLATE

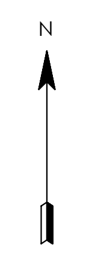


SECTION A-A
1 : 5

NOTES

1. PEDESTAL IS INDICATIVE AND SHOULD BE DESIGNED AS PART OF DETAILED PLATFORM DESIGN. REQUIREMENTS MAY INCLUDE THE ABILITY TO ROTATE THE RADAR TO MULTIPLE POSITIONS ALONG THE GUARDRAIL.
2. BEAM SIZE MAY VARY FOR SUPPORT OF PLATE. THE TOP FLANGE OF THE MAIN SUPPORTING BEAM HAS BEEN DESIGNED FOR A MINIMUM WIDTH OF 82mm.
3. A 10mm THICK ANTI-SLIP COVER PLATE SHOULD BE INSTALLED TO BRING THE SURFACE LEVEL WITH THE GRATING IF RADAR IS NOT USED. COVER IS TO BE ATTACHED WITH FOUR M12 COUNTERSUNK BOLTS TO LIE FLUSH OR BELOW GRATING LEVEL.
4. PLACEMENT OF BASEPLATE IS INDICATIVE. PLACEMENT SHOULD BE ALIGNED WITH THE RADAR SUPPLIER AND SHOULD FACTOR IN ACCESS TO BOLTS AND TO GUARDRAILS.
5. CABLES ARE TO TRANSIT FROM RADAR BASE TO PLATFORM CABLE TRAYS AT OR BELOW GRATING LEVEL.

KEY-PLAN



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Project Number 1620017521
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Project Name
CARBON TRUST - INSTALLATION DESIGN FOR BIRD MONITORING SYSTEMS

Title
EXTERNAL PLATFORM
BIRD RADAR BASEPLATE
SECTIONS AND DETAILS

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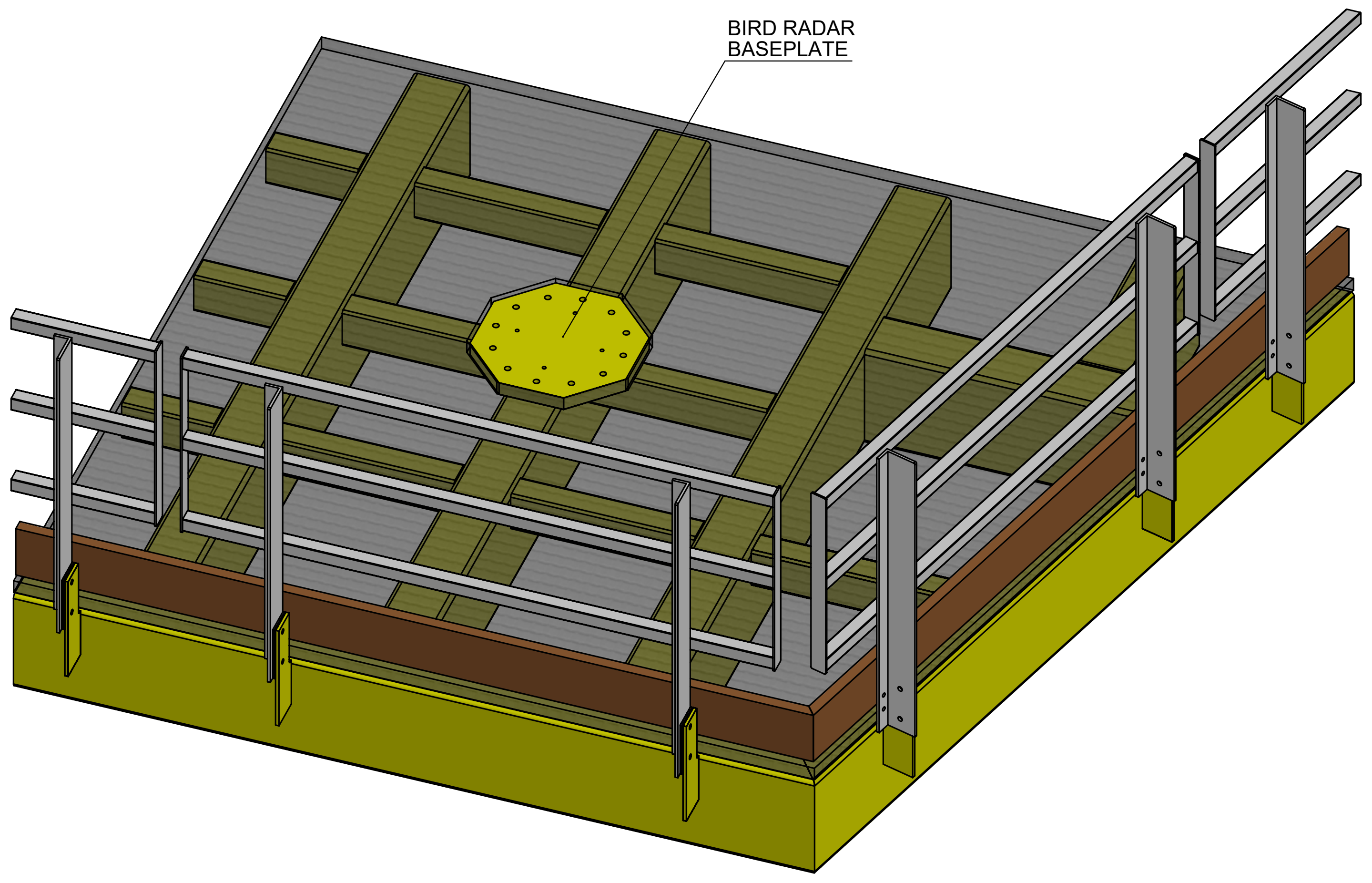
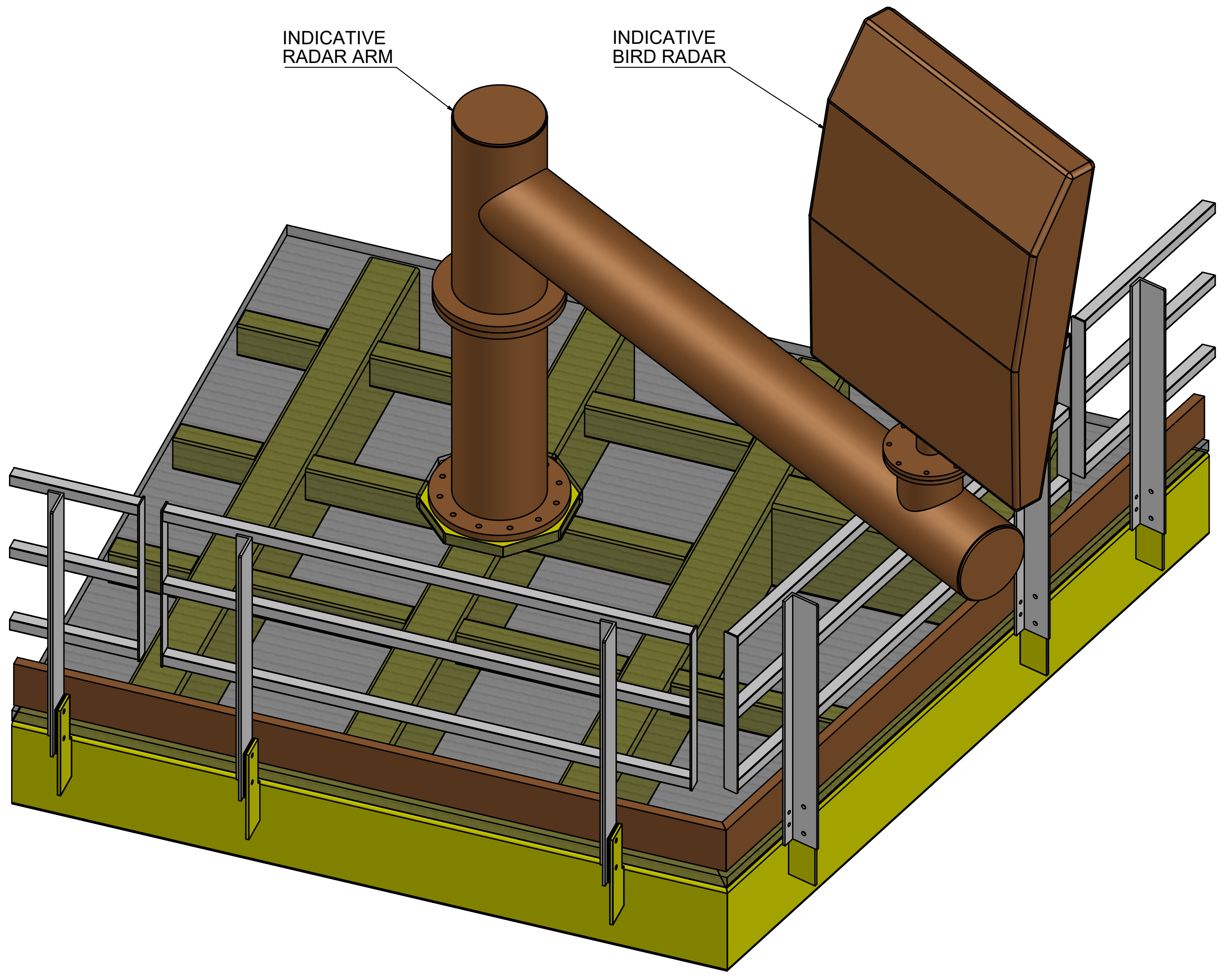


3D VIEW
BIRD RADAR BASEPLATE



3D VIEW
INDICATIVE BIRD RADAR

RECOMMENDED BIRD RADAR SUPPORT DESIGN FOR PUBLIC RELEASE

- THE ASSESSMENT COMPLETED FOR THIS PROJECT AND THE CONCLUSIONS MADE ARE FOR A ROBIN RADAR MAX 3D AVIAN RADAR. THE RADAR HAS BEEN CHOSEN BY THE CARBON TRUST AND PARTNERS. THE SPECIFICATIONS USED FOR THE RADAR ARE IN THE PUBLIC DOMAIN. THE DESIGN WAS COMPLETED ON A NUMBER OF ASSUMPTIONS TO ENABLE DESIGN INPUT PARAMETERS TO BE DEFINED. FOR A SPECIFIC PROJECT, THESE ASSUMPTIONS SHOULD BE CHECKED AND VALIDATED AGAINST AVAILABLE DATA TO ENSURE THEY ARE APPROPRIATE. THESE DRAWINGS ARE FOR GENERIC DESIGN CASES AND NOT DESIGNED TO REPLACE A DETAILED BIRD RADAR SUPPORT DESIGN AND REVIEW PROCESS.

DESIGN ASSUMPTIONS

- BASEPLATE IS DESIGNED TO BE FABRICATED AS PART OF THE PLATFORM. A COVER PLATE IS RECOMMENDED TO BE INCLUDED TO ALLOW FOR REMOVAL OF THE RADAR ON SITE
- SUPPORT DESIGN IS PERFORMED WITH THE SIZING AND LOADING OF THE MAX 3D AVIAN ROBIN RADAR. THE 325kg ROBIN RADAR MASS HAS BEEN PLACED AT A LOCATION 2500mm HORIZONTALLY AND 1800mm VERTICALLY OFFSET FROM THE CENTRE OF THE BASEPLATE.
- DESIGN IS SHOWN INSTALLED ON A MONOPILE EXTERNAL PLATFORM. THE DESIGN CAN ALSO BE WELDED DIRECTLY TO THE DECK OF A TRADITIONAL JACKET STRUCTURE.
- BOLT SIZE MAY VARY BASED ON ARM/RADAR SUPPLIER AND SHOULD BE VERIFIED ON A PROJECT-BY-PROJECT BASIS.

MATERIALS

- PLATE IS DEFINED AS 1.4462 STAINLESS STEEL.
- BOLTS ARE DEFINED AS D6-70 STAINLESS STEEL BOLTS.

RADAR PLACEMENT

- BASEPLATE LOCATION ON THE DRAWING IS INDICATIVE. CONSIDER ACCESS AROUND THE RADAR, LOADING, ETC. WHEN DETERMINING PLACEMENT.
- LOCATION OF RADAR SHOULD BE ALIGNED WITH RADAR SUPPLIER. DESIGN OF SUPPORT PLATE ASSUMES RADAR PLACEMENT ABOVE THE GUARDRAIL.
- SUPPORT BETWEEN THE RADAR AND THE PLATFORM IS BEYOND THE SCOPE OF THIS STUDY. AN INDICATIVE SWING ARM IS SHOWN IN THIS DESIGN TO SUPPORT THE RADAR FROM THE BASEPLATE.

OPERATIONAL CONDITIONS AND LOADING

- ULS CONDITIONS ARE CHECKED USING A MAXIMUM WIND LOAD OF 55m/s.
- 80mm OF ICING IS INCLUDED IN THE ANALYSIS.

ISOLATION

- MATERIALS WITH DIFFERENT ELECTRIC POTENTIALS MUST BE PROTECTED AGAINST CORROSION. DIRECT CONTACT BETWEEN METALS SHALL BE PREVENTED.
- AN ISOLATION LAYER MAY BE REQUIRED AT THE BASE PLATE INTERFACE. THIS SHOULD BE VERIFIED BASED ON ARM/RADAR SUPPLIER. ISOLATION IN THE RELEVANT BOLT HOLES MAY ALSO BE REQUIRED.

FABRICATION NOTES

- PRELOADING OF BOLTS SHOULD BE VERIFIED WITH ARM/RADAR SUPPLIER.
- DRAWING CONSIDERS MINIMUM LENGTH OF THREAD ENGAGEMENT OF BOLTS, AND CAREFUL ALLOWANCE SHOULD BE MADE FOR TOLERANCES OF ALL COMPONENTS IN THE BOLTED ASSEMBLY AND FOR THE DRILL AND TAP CHOSEN TO FORM THE HOLES.
- A BOLT LOCKING SYSTEM, SUCH AS A LOCTITE THREAD-LOCKING SYSTEM, SHOULD BE APPLIED TO BOLTS IN THREADED HOLES. PRODUCTS SHOULD BE AGREED WITH RELEVANT STAKEHOLDERS.

REFERENCES

1. EN1993-1-1 - EUROCODE 3: DESIGN OF STEEL STRUCTURES - PART 1-1: GENERAL RULES AND RULES FOR BUILDINGS
2. EN1993-1-8 - EURODCODE 3: DESIGN OF STEEL STRUCTURES - PART 1-8: DESIGN OF JOINTS
3. DNV-ST-0126: SUPPORT STRUCTURES FOR WIND TURBINES
4. NORSOK N-003: 2017 - ACTIONS AND ACTION EFFECTS
5. PRODUCT SHEET, MAX 3D 360° AVIAN DETECTION, ROBIN RADAR SYSTEMS

NOTES

KEY-PLAN

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Rev.	Date	Prepared	Checked	Approved	Description
1	2025-10-17	ABATS	CBORO / APAGE	ETINS	ISSUED FOR REVIEW

Client

CARBON TRUST

RAMBØLL

Project Number 1620017521
Project ID. REN2024N01435

Project Name
CARBON TRUST - INSTALLATION DESIGN FOR BIRD MONITORING SYSTEMS

Title
EXTERNAL PLATFORM
BIRD RADAR BASEPLATE
GENERAL NOTES

Scale	Size	Drawing No.	Rev.
NOTED	A1	REN2024N01435-CD-MPWTG-SS-05-004	1

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