# BVLOS Use Case and Market Analysis Report

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GENERIC REPORT

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OLTER NZTTP Programme

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## DOCUMENT HISTORY

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# NOMENCLATURE

| | |
|---|---|
| AUV | Autonomous Underwater Vehicle |
| BVLOS | Beyond Visual Line of Sight |
| CAA | Civil Aviation Authority |
| CAPEX | Capital Expenditure |
| CTV | Crew Transfer Vessel |
| FOW | Floating Offshore Wind |
| HSE | Health and Safety Executive |
| LOLER | Lifting Operations and Lifting Equipment Regulations |
| LCOE | Levelised Cost of Energy |
| MMO | Marine Management Organisation |
| ORE | Offshore Renewable Energy |
| O&G | Oil and Gas |
| O&M | Operations and Maintenance |
| OLTER | Offshore Low Touch Energy Robotics and Autonomous Systems |
| OPEX | Operational Expenditure |
| OSW | Offshore Wind |
| RAS | Robotic and Autonomous Systems |
| ROC | Remote Operation Centre |
| ROV | Remotely Operated Vehicle |
| SCADA | Supervisory Control and Acquisition |
| SOV | Service Operation Vessel |

| | |
|---|---|
| TRL | Technology Readiness Level |
| UAV | Uncrewed/Unmanned Surface Vessel |
| USV | Uncrewed/Unmanned Surface Vessel |
| UKCS | UK Continental Shelf |
| VLOS | Visual Line of Sight |

# EXECUTIVE SUMMARY

The OLTER project has conducted a study into the commercial viability of BVLOS operations for offshore energy assets. Potential use cases were determined through interviews with multiple operators across the Offshore Wind (OSW) and Oil & Gas (O&G) industries. Cost analyses are presented for the primary use cases at offshore wind farms, namely delivery of parts (both planned and unplanned) and inspection of assets.

Cost reductions were determined for both scheduled and unscheduled deliveries over the lifetime of the wind farm. Scheduled deliveries offer a greater certainty of usage owing to incomplete recording of unplanned needs for parts, but the displacement of vessel/helicopter activity is not as pronounced, as visits would still be conducted for transportation of technicians and for other O&M tasks.

Further use cases considered were wind turbine blade inspections and navigation/aviation light inspections. For turbine blade inspections, a non-significant cost reduction was determined over the lifetime of each of the windfarm scenarios compared with the standard VLOS approach. Greater cost benefits may be experienced if more frequent inspection averted the need for a major blade repair or replacement. The limited contribution of navigation/aviation light inspections to the overall O&M costs means that the use case adds little value in isolation but should be an obvious inclusion if a variety of inspection tasks are collated.

The recommended use case to be prioritised is the delivery of parts (considering planned and unplanned deliveries together) due to the potential for both CAPEX and OPEX reductions through the elimination of davit cranes at offshore wind farms and reduction in crewed transport passages.

# 1 INTRODUCTION

## 1.1 Project Background

This study has been undertaken by the Offshore Low Touch Energy Robotics and Autonomous Systems (OLTER) project. OLTER is a three-year Scottish Government funded project focussing on high Technology Readiness Level (TRL) robotic technologies for use in the offshore energy sector. The National Robotarium, Net Zero Technology Centre and Offshore Renewable Energy Catapult are working in collaboration to deliver the project.

The programme proposes to be accountable for the adoption of UK offshore industrial Robotics and Autonomous Systems (RAS) and provide a forum where the offshore industry, supply chain, academia, developers, and other stakeholders can connect and collaborate in the deployment of RAS for the UK Continental Shelf (UKCS). The aims of the project are to:

- Consolidate RAS data and knowledge in the UK;
- Showcase how digitalized offshore energy assets use robotic systems to reduce emissions and human exposure; and
- Offer options to increase productivity and resilience, and to improve next generation net zero design.

## 1.2 Purpose of the Study

Whilst technology developers are continuing to work on solutions for using Unmanned Aerial Systems (UAS) both on and offshore, there is a dearth of client-driven use cases for BVLOS operations on energy assets. The lack of a credible business case for Beyond Visual Line of Sight (BVLOS) operations on offshore energy assets makes it more challenging for technology developers to invest in technologies and to demonstrate the technology need to funding bodies. In addition, the lack of use cases can be difficult for technology developers in making the commercial justification to industry. The costed use cases presented here will be made available to developers to demonstrate value to their potential customers.

BVLOS operations are defined by the UK Civil Aviation Authority (CAA) as the “operation of an unmanned aircraft beyond a distance where the remote pilot is able to respond to or avoid other airspace users by direct visual means” [1]. Currently BVLOS operations are only permitted in segregated airspace. However, the CAA plans to understand how BVLOS operations can safely take place in non-segregated airspace [2]. Further discussion concerning BVLOS regulations is outside the scope of this report. For the purpose of this report, it has been assumed regulations will catch up to the needs of the industry and as such will not impede future possible use cases. The use of swarm robotics has not been included in the scope of consideration.

## 1.3 BVLOS Demonstrations

Opportunities for BVLOS operations have been discussed across the offshore industries in various forms. Individual demonstrations have showcased different unmanned aerial vehicle (UAV) BVLOS opportunities as described below:

- Ørsted Denmark partnered with DSV to trial long distance spare parts transport by drone to the Anholt Offshore Wind Farm, a distance of 25km. The drone had a payload capacity of 2.5kg [3].
- Equinor used a drone to fly a 3D printed lifeboat system part from the Mongstad base to the Troll A oil & gas platform in the North Sea, a distance of 80km. The drone used was 4m long with a payload capacity of 50kg [4].
- Flylogix has performed multiple methane detection surveys around O&G assets for BP, Total, Shell, and other operators [5].
- Skyports performed offshore flight trials as part of the OLTER project to showcase the maritime capability of their operational team and their technology, and to illustrate the current state-of-the-art in technical aspects of BVLOS operations [6].

# 2 APPROACH AND METHODOLOGY

## User Engagement

Invitations were sent to 16 operators across the Offshore Wind (OSW) and Oil & Gas (O&G)
2.1 industries to participate in a BVLOS focussed engagement session. Six respondents were invited to a
1-hour online interview with members of the ORE Catapult OLTER team. The proportion of interviewee companies across the OSW and O&G industries is shown in Figure 2-1. Where interviewee companies operated in both the OSW and O&G industries, separate interviews were held. A total of seven interviews were conducted amongst the six companies, five concerning OSW and two focused on O&G.

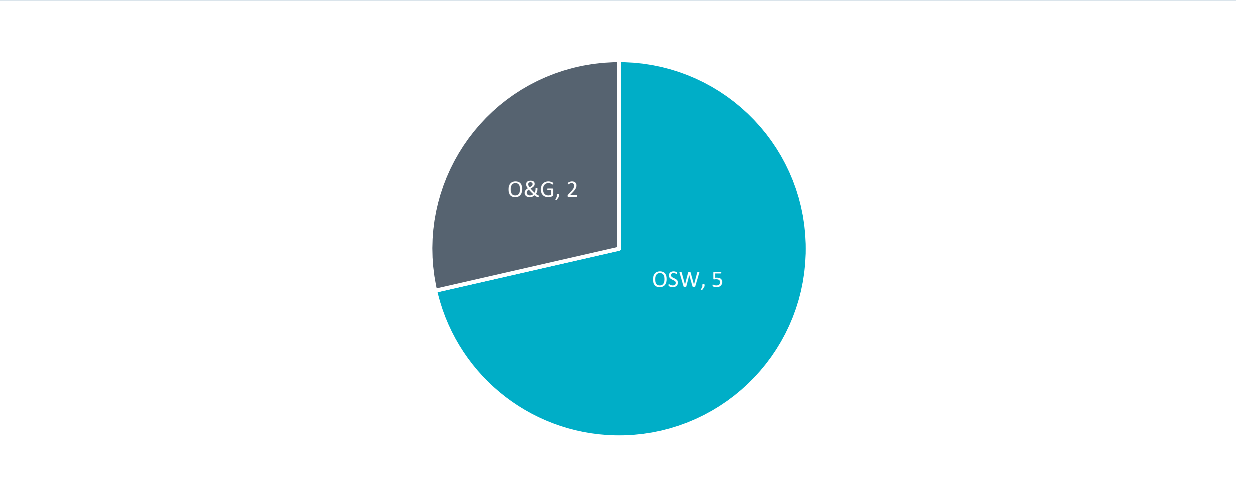


Figure 2-1 Pie chart showing split of operators interviewed across the OSW ad O&G industries.

The companies interviewed were represented by a broad range of individuals involved in differing specific roles, such as O&M managers, innovation experts and robotics specialists. These provided different views on the use of UAVs for the Operations and Maintenance (O&M) of their assets. This
2.2 resulted in a wide variety of opinions and thoughts, giving a spectrum of requirements for analysis.
During the interviews, potential use cases in O&G and OSW were identified and explored further. From the information gathered, two primary use cases and five additional use cases were selected for further discussion in this report.

## Market Analysis (Analysis of Total Costs and Sensitivity Analysis)

The cost reduction potential of BVLOS for the main identified use cases compares the costs of business-as-usual practice against the cost of utilising BVLOS. Wind farm operators provided real-life costs of current practices and drone operators estimated costs for utilising BVLOS for these particular use cases. ORE Catapult’s in-house cost model has also been used to model different use case scenarios and sensitivities.

# 3 PRIMARY USE CASE - DELIVERY OF PARTS

## 3.1 Overview

The delivery of parts using BVLOS is a key use case, with both scheduled and unscheduled operations considered. Flight times for one way and return trips are calculated from the distance to shore, shown in Table 3-1 for assets in both OSW and O&G (based on the distance to the nearest mainland, in contrast to the journeys to the designated operations and maintenance (O&M) port that are used for the cost analysis later in the chapter). The North Sea Transition Authority Offshore Oil and Gas Activity[1] map was used to analyse the distances to O&G assets. Data from 4C offshore[1] was used to analyse the distances to OSW assets. This included wind farms under construction, partially commissioned and fully commissioned, consisting of 3 or more turbines. It should be noted that future wind farms are expected to be further from shore and therefore the maximum and average distances are likely to increase. In most cases the nearest mainland was in the UK, although for some O&G assets the nearest mainland is Norway.

Table 3-1 Distance from mainland to OSW assets and O&G assets

| Distance (km) | Offshore Wind Assets | Oil & Gas Assets |
|---|---|---|
| **Minimum Distance** | 2 | 21 |
| **Maximum Distance** | 148 | 276 |
| **Average Distance** | 29 | 124 |

## 3.2 Unscheduled Delivery of Parts

An unscheduled delivery may be required if:

- A scheduled activity requires unexpected parts;
- A scheduled activity does not have the expected parts; or
- An unexpected issue is identified during the scheduled works and additional parts are needed.

The frequency of unscheduled deliveries is not well defined. The number of times a part was required and which parts these were, is either not typically recorded or not able to be shared. For the purpose of this analysis a frequency of 10 deliveries per site (i.e. per rig for O&G assets and per wind farm for OSW assets) per year requiring a payload up to 20kg has been used as an envisaged example scenario.

### 3.2.1 Business as Usual

Current practice is to plan to either transport all required parts and tools (hereafter referred to as parts) with the technicians or hold sufficient spares on the asset (O&G only). In the event an additional part is required a decision must be undertaken whether to transport the part to the

[1] Accessed June 2023.

operational location or delay the operation to another day when the part is available. Depending on the industry and site location, different solutions may be available to make an unscheduled delivery.

**Near-Shore Wind Farm**

Near-shore wind farms are typically accessed by technicians using a crew transfer vessel (CTV), similar to that shown in Figure 3-1. Where a wind farm is close enough to shore (less than 1hr30min one way transfer [7]) and/or there are other CTVs in the vicinity for safety reasons, the CTV may leave the technicians at the turbine and return to shore to collect the required part.

For wind farms further from shore but still accessible by CTV it is likely a decision will be made not to undertake the work that day, but instead to return on another day with the correct parts.

Figure 3-1 CTV at a turbine (Source: energyfacts)

**Far-Shore Wind Farm**

Far-shore wind farms often have technicians stationed at the wind farm site on a service operation vessel (SOV). An SOV will typically remain at the wind farm for 2-4 weeks before returning to shore to change technician teams and restock. When at the wind farm technicians transfer from the SOV to turbines using a walk-to-work system (see Figure 3-2) or transit from the SOV using a daughter craft (similar to a small CTV).

Figure 3-2 SOV with walk-to-work system at a turbine (source: Royal IHC)

Where a part is needed, if this is stored on the SOV, the SOV may return to the wind turbine (or offshore substation) and deliver the part through the walk-to-work system. Alternatively, the daughter craft may be used to transfer the part from the SOV.

If a required part is onshore there are currently three available options, all involving delaying the work to another day:

- Wait for the SOV to return to port and load the part on the SOV during the planned technician changeover and restock, resulting in up to a 2 week delay;
- Charter a CTV to take the part to the SOV. This would likely take 1-2 days to implement;
- Charter a helicopter to take the part to the SOV. This could be implemented within 24 hours but has an extremely high associated cost. This is very rare and likely to occur only in high loss situations.

**O&G Assets**

O&G assets are typically accessed by helicopter, with most major parts stored on the asset itself. Helicopter transfers may take place daily or 2-3 times per week depending on the asset and weather conditions. Where an unexpected part is needed this is most likely either onshore or on a nearby asset and therefore must be transported to the asset. The transport can be completed by helicopter or vessel depending on the asset location, urgency of need and part size. It may be possible to add the part to a planned helicopter trip or redirect a helicopter from another platform. However, a simpler solution is to charter a vessel for the part if time permits.

### 3.2.2 BVLOS UAV Use Case

The UAV would be kept at or near the O&M port. In the event a part was needed unexpectedly the O&M supply chain system would identify the part and prepare for transport. A trained member of the team would secure the part to the UAV and prepare it for flight. Once ready the remote operation control centre (ROC) sets the flight path and launches the UAV. The UAV would fly on its planned route to the asset or vessel requiring the part. When it reaches the correct location, the UAV can autonomously land for the part to be removed by a technician or member of the vessel team. The UAV can return to the O&M port after charging if needed, or return with the technician team or by air/sea transfer depending on the size and payload.

### 3.2.3 Operational Requirements for BVLOS Use Case

Although not intended as an exhaustive list, the following operational requirements are specific examples considered for this use case:

- Route between retrieval and drop-off
- UAV endurance
- Delivery payload characteristics (i.e. weight and geometry)
- Landing on a vessel or other non-stable platform
- Weather conditions (i.e. fog, rain, heavy winds)
- Fragile parts (e.g. electrical)
- COSHH samples (particularly in O&G)
- Delivery mechanism and secure attachment of delivery payload
- O&M supply system integration
- Night flying

### 3.2.4 Cost Analysis

ORE Catapult has used its in-house cost model, in addition to engagement with various operators, to assess the potential use of BVLOS to reduce the cost of unscheduled deliveries for both the Oil & Gas and Offshore Wind industries.

The cost reduction impact is assessed by comparing, for an example offshore wind farm, the estimated cost of using BVLOS with the estimated cost of unplanned delivery using current solutions. In this case, chartering a CTV and a helicopter have been modelled as scenarios which might currently be used in the case where an unplanned delivery is required.

**Model Site Parameters**

An example fixed-bottom offshore wind farm has been modelled (as outlined in Table 3-2) to carry out the cost comparison analysis. This wind farm is assumed to be both operational and far-shore to enable comparison with multiple solutions for delivering the part to the wind farm. For the purpose of the cost analysis, it has been assumed that the delivery is critical. This means that turbine downtime occurs for the duration of the time taken to complete the delivery.

Table 3-2 Model site parameters for unscheduled delivery of parts

| Parameters | Units | Wind Farm |
|---|---|---|
| **Turbine Rating** | MW | 8 |
| **Turbine Numbers** | # | 165 |
| **Site Capacity** | MW | 1,320 |
| **Distance to Port** | km | 90 |
| **Project Life** | years | 30 |
| **Net Capacity Factor** | % | 48.0 |
| **Revenue per MWh**[2] | £/MWh | 80 |

**CTV Charter Comparison**

In the case of an unscheduled delivery relying on chartering a CTV, the CTV will take the part offshore to the SOV. It is assumed that this will take 1-2 days to implement. Therefore, the comparison is between two days with the use of a CTV against half a working day using a BVLOS UAV, which will already be stationed at the O&M port.

Operators advise that, where a BVLOS UAV has been purchased by the wind farm operator, an onshore technician would be used to operate the UAV. The BVLOS UAV will have pre-programmed routes and waypoints which will allow for a relatively autonomous flight. The technician will be trained to a sufficient level to request the UAV to perform parts delivery, monitor the flight remotely and be able to override the UAV flight path to a safe location, if required. It has therefore been assumed that an onshore technician at £500 per day, and an offshore technician at £500 to unload the UAV will be employed for this task. The cost of the CTV crew has been included in the charter day rate.

Table 3-3 highlights the costs involved in unscheduled deliveries to the wind farm for both solutions. Capital costs for the drone and docking station have been provided through engagement and fed into the cost model. Table 3-4 shows the potential cost savings of the BVLOS solution, compared with a CTV charter.

The capital cost of buying the BVLOS UAV has been incorporated into the cost model which has resulted in a very small impact on LCOE.

[2] Seasonal variations in revenue not considered.

Table 3-3 BVLOS vs. CTV charter cost comparison for unscheduled delivery of parts

| Element | Units | CTV charter | BVLOS |
|---|---|---|---|
| **CTV Day Rate** | £/day | 3,000 | - |
| **Personnel Cost** | £/day | - | 500 |
| **Downtime per Turbine** | Hours | 48 | 6 |
| **Downtime Cost per Delivery** | £ | 14,937 | 1,867 |
| **Annual Unscheduled Delivery Cost** | £ | 180,400 | 23,800 |

Unscheduled deliveries using BVLOS results in significant cost savings compared to chartering a CTV, specifically saving 87% of current unscheduled delivery costs. This cost saving has resulted from eliminating the need for a vessel and by carrying out the delivery in a much quicker time. Some deliveries may take more time to arrange than others. A conservative task duration of ½ a day of personnel time has been modelled that would likely be the upper limit before delivery the following day is considered.

Table 3-4 BVLOS cost saving vs. CTV charter (critical delivery) for unscheduled delivery of parts

| Element | Units | Critical Delivery – Cost Saving BVLOS vs CTV Charter |
|---|---|---|
| **Annual Cost Saving** | £ | 156,600 |
| **Cost Saving per MW** | £/MW | 119 |
| **Cost Saving %** | % | 87% |
| **Lifetime Cost Saving** | £m | 4.7 |

**BVLOS UAV Charged per Delivery**

A sensitivity analysis was conducted looking at a scenario where the wind farm operator would not own the BVLOS UAV and instead would charter it in a similar way to a vessel which would incur daily fees. In this case, it has been assumed that turbine downtime would be 30 hours. This assumes it takes one full day to source the BVLOS and again 6 hours to mobilise the UAV and deliver the part to the necessary location. Engagement with a drone operator has provided a figure of £420 per delivery, and it has been assumed that the drone operator would provide a pilot at a day rate of £700 to operate the UAV.

This scenario has resulted in cost savings compared to CTV charter, as shown in Table 3-5, albeit significantly lower than where the wind farm operator owns the BVLOS and can deliver the package in a much quicker time.

Table 3-5 BVLOS cost savings vs. CTV charter (critical delivery with BVLOS charged per delivery) for unscheduled delivery of parts

| Element | Units | Critical Delivery – Cost Saving BVLOS (charged per delivery) vs CTV Charter |
|---|---|---|
| **Annual Cost Saving** | £ | 75,700 |
| **Cost Saving per MW** | £/MW | 57 |
| **Cost Saving %** | % | 42% |
| **Lifetime Cost Saving** | £m | 2.3 |

**Non-critical deliveries**

For non-critical deliveries, that would not result in turbine downtime, the use of BVLOS still results in a cost saving, as detailed in Table 3-6, albeit not as significant as for critical deliveries. The only difference in this scenario is that the turbine can remain operational while awaiting the unscheduled delivery.

Table 3-6 BVLOS cost saving vs. CTV charter (non-critical delivery) for unscheduled delivery of parts

| Element | Units | Non-Critical Delivery – Cost Saving BVLOS vs CTV Charter |
|---|---|---|
| **Annual Cost Saving** | £ | 25,900 |
| **Cost Saving per MW** | £/MW | 20 |
| **Cost Saving %** | % | 83% |
| **Lifetime Cost Saving** | £m | 0.8 |

The non-critical delivery sensitivity results in no impact on LCOE. This brings into question the viability of using BVLOS in this context. Additionally, the uncertainty around frequency of unscheduled deliveries also raises questions regarding the suitability of BVLOS for this purpose. For instance, a wind farm might require fewer than 10 unscheduled deliveries per year meaning that the cost savings would be less and there would be the same negligible impact on LCOE.

The main advantage of utilising BVLOS in this context is the ability to deliver the parts more quickly to the wind farm than the CTV which results in significantly reduced turbine downtime. Another consideration in this case is whether the BVLOS aircraft can operate in an increased operational envelope compared with traditional methods. A dedicated delivery UAV would be expected to fly in wind speeds greater than that of inspection-class drones. However, it would be speculative to suggest that they would be flown in harsher weather than a CTV would sail out in, and should be proven in the offshore environment. The scenario of technicians already being present at the wind farm during such unsuitable conditions for transit to the port, would be limited to those with an SOV strategy.

**Helicopter Charter**

In specific circumstances, a helicopter might be chartered to deliver the part in a shorter timeframe than a CTV. Operators confirmed during interviews that delivering parts via helicopter is rare and, as to be expected, incurs high costs.

For this scenario, the same model site was used. It is also based on an operational wind farm that currently employs helicopters during the operations phase.

For the purposes of the cost analysis, it has been assumed that a helicopter is only used in urgent situations that will incur high loss without the necessary part, and has therefore been modelled as incurring downtime in a turbine while awaiting the delivery. As previously mentioned, chartering a helicopter can be implemented in 24 hours, so the cost analysis has assumed the helicopter will be chartered for one working day over 12 hours.

Table 3-7 outlines the cost comparison for critical unscheduled deliveries for both solutions. In this case, the utilisation of BVLOS results in significant cost savings compared to chartering a helicopter. In this scenario, the use of a BVLOS UAV would provide an annual saving of 96% compared to the current cost of chartering a helicopter for unscheduled deliveries, as detailed in Table 3-8.

Table 3-7 BVLOS vs. helicopter charter cost comparison for unscheduled delivery of parts

| Element | Units | Helicopter charter | BVLOS |
|---|---|---|---|
| **Helicopter Day Rate** | £/day | 48,000 | - |
| **Personnel Cost** | £/day | 2,000 | 500 |
| **Downtime per Turbine** | Hours | 12 | 6 |
| **Downtime Cost per Delivery** | £ | 3,734 | 1,867 |
| **Annual Unscheduled Delivery Cost** | £ | 547,300 | 23,800 |

Table 3-8 BVLOS cost saving vs. helicopter charter for unscheduled delivery of parts

| Element | Units | Critical Delivery – BVLOS vs helicopter charter |
|---|---|---|
| **Annual Cost Saving** | £ | 523,500 |
| **Cost Saving per MW** | £/MW | 397 |
| **Cost Saving %** | % | 96% |
| **Lifetime Cost Saving** | £m | 13.1 |

### 3.2.5 Assessment of Use Case

Utilising BVLOS for unscheduled deliveries can provide significant cost savings, as outlined in this report section. This is a result of BVLOS being able to deliver the parts to the offshore asset more quickly than current solutions, therefore reducing associated turbine downtime in the case of critical deliveries. Although not explicitly accounted for in the analysis, additional time savings may be experienced if the part can be delivered to the wind turbine nacelle (if there is a safe and viable way to do so). Avoiding the two stages of craning (CTV to working platform, working platform to nacelle) could be valuable in such a time-sensitive scenario. In the case where the delivery is considered non-critical, utilising BVLOS will still provide both cost and emission savings through eliminating the use of either crewed vessel trips, or in rare occurrences helicopters, both of which have high associated day rates.

The main limitation of this use case, in isolation, is the uncertainty around the frequency of unscheduled deliveries. As an area that is not well defined, either because it is not currently documented or the data widely shared by operators, it makes it difficult to assess whether there are enough occurrences of unscheduled deliveries that would make the utilisation of a BVLOS UAV worthwhile. A solution to this would be if a wind farm or O&G asset operator bought a BVLOS UAV for general use. In this case it could be used frequently for scheduled deliveries and other maintenance purposes, in addition to unscheduled deliveries, if and when they may occur.

## 3.3 Scheduled Delivery of Parts

A planned delivery may be required to deliver equipment and parts to an asset or vessel as part of standard operations. Unlike unplanned deliveries, these are expected to be frequent, possibly daily, during the peak O&M times. This is particularly prevalent in the OSW industry but may also play a part within the O&G industry. Parts required for scheduled maintenance are expected to be up to 200kg, whereas parts required for service intervals are expected to be 600-1000kg. These weights are within the lifting and cargo capacities of davit cranes and CTVs, although other supply vessels may be used.

### 3.3.1 Business as Usual

**OSW industry**

Technicians may only transport with them a LOLER (Lifting Operations and Lifting Equipment Regulations) certified bag up to 5kg during transfer from the vessel to turbine. Where tasks require parts in excess of 5kg, it is best practice for the davit crane to be used to transfer the parts from the vessel to the transition piece (TP). The parts are then transferred to the nacelle either using the turbine lift or nacelle crane. The turbine layout and relative locations are shown in Figure 3-3. Once works are completed the process is completed in reverse. These processes could take 1-2 hours depending on the number and complexity of lifts required.

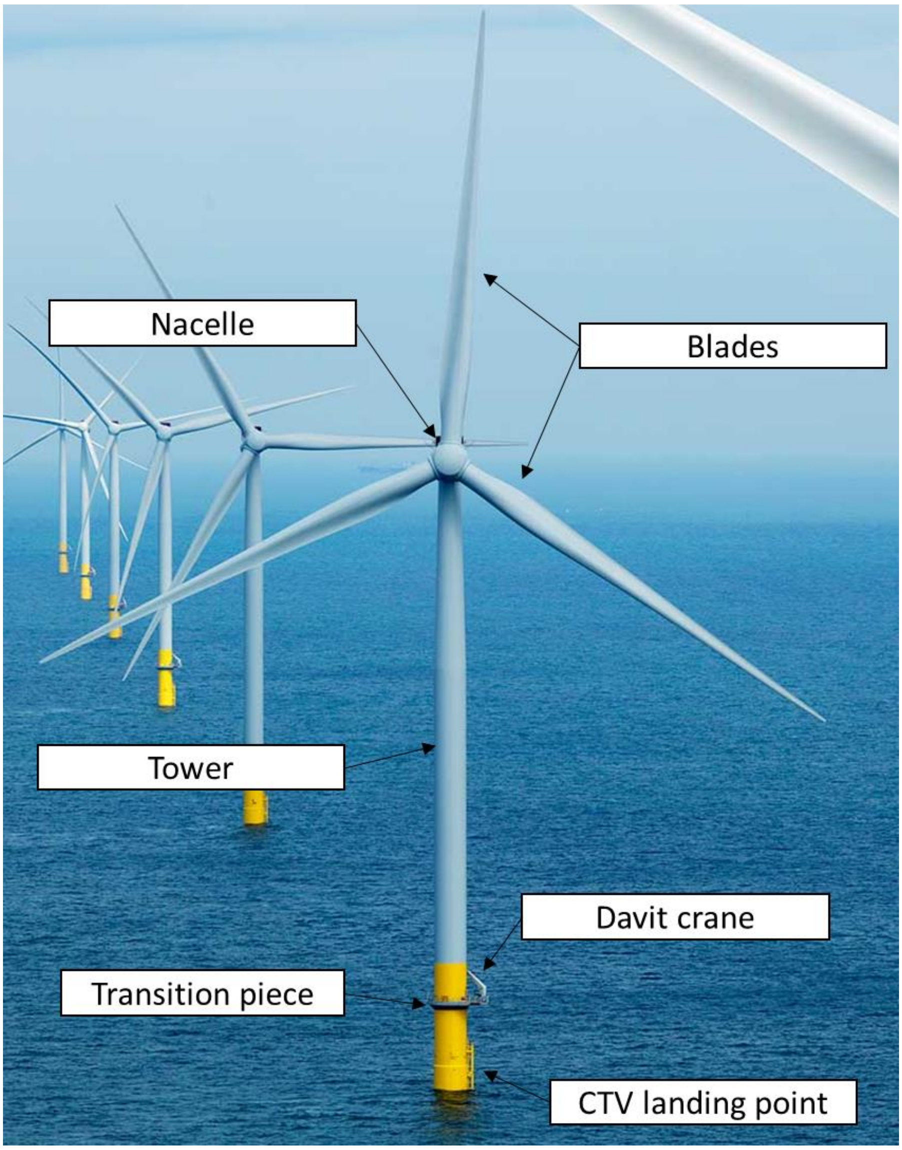


Figure 3-3 Turbine key elements (Adapted from source: Orsted)

**O&G industry**

Currently many parts are stored on offshore assets, as delivery vessels can be slow to respond to requirements. One operator stated an excess of £3 billion worth of spare parts were stored on assets, taking eight years to circulate their inventory, with some parts becoming obsolete in storage.

An example of a regular scheduled delivery is the transport of samples from the platform to an onshore advanced testing laboratory. Current practice uses scheduled vessels to transport samples to shore. This can take 24 hours or longer depending on the next available scheduled vessel.

### 3.3.2 BVLOS UAV Use Case

**OSW industry**

The UAV would be kept at or near the O&M port. When scheduled activities are required the UAV would be loaded with the designated parts, being signed off by a trained member of staff. Once ready the ROC launches the UAV on a pre-determined flight path to the asset.

For a near-shore wind farm, it is expected scheduled deliveries will take place from the port to asset, with the aim of arriving and delivering the parts at a suitable time for when the technician team arrive. This enables the technician team to transfer without any need to perform a lift. Potentially, this could be performed ahead of time, but the safe storage of the parts would need to be considered, especially if there is a risk. A more complex method of delivery would be required, potentially requiring additional infrastructure and cost. It would likely be more sensible to schedule the delivery to arrive once technicians are ready to receive them.

For far-shore wind farms, it is expected scheduled deliveries will take place from the SOV to the asset. These parts would still likely be delivered before the technician team arrives. The flight would still be managed from the ROC.

**O&G Industry**

For the O&G application, a change in ethos to keeping parts onshore or at offshore hubs between multiple assets would be needed. Here a UAV would be loaded up with parts and then launched on the pre-agreed flight path by the ROC. A stock of parts onshore or at the offshore hub would still be required, but this would be a significantly smaller number than those currently kept offshore.

A UAV could also be used to transport samples from the platform to the onshore advanced testing laboratory. Trained personnel would load the sample onto the UAV in a suitable container before the ROC launched the UAV and it followed a pre-determined flight pattern to the laboratory.

### 3.3.3 Operational Requirements for BVLOS Use Case

The following operational requirements are additional considerations for the delivery of scheduled versus unscheduled parts:

- Heavy lift capabilities of UAV
- Pre-planned scheduling of deliveries

### 3.3.4 Cost Analysis

ORE Catapult has used its in-house cost model, in addition to engagement with various operators to assess the cost implications of use of BVLOS for scheduled deliveries to offshore wind farms and oil & gas platforms.

The cost impact is assessed by comparing, for an example offshore wind farm, the estimated cost of using BVLOS with the estimated cost of using a vessel to transport equipment and parts with payloads both under and over 5kg. In the case where the delivery will be in excess of 5kg, the use of a davit crane has been modelled to highlight additional incurred costs.

**Model Site Parameters**

The example offshore wind farm outlined in Table 3-2 has been used again in this cost comparison. It has been assumed that a CTV will transport the package from shore to the SOV stationed at the wind farm.

**Over 5kg delivery**

In the case of a delivery to the wind farm where the payload is greater than 5kg, a davit crane will be used to transfer the package from the CTV to the transition piece. If the SOV is used for transfer to the turbine, the part can be transported across on the walk-to-work gangway. Previous project work has provided the estimated capital cost of a davit crane, which has been incorporated into the cost model. In the case of using a BVLOS UAV for scheduled deliveries at a far-shore wind farm, the UAV would be kept on the SOV therefore eliminating the use of a CTV. The package would then be delivered directly to the asset from the SOV. Assuming a delivery containing a package weighing greater than 5kg occurs 300 days per year, the cost comparison between the current business as usual and delivery using BVLOS is shown in Table 3-9.

Table 3-9 BVLOS vs. CTV charter cost comparison for scheduled delivery of parts

| Element | Units | CTV | BVLOS |
|---|---|---|---|
| **CTV Day Rate** | £/day | 3000 | - |
| **Personnel Cost** | £/day | - | 1,000 |
| **Annual Scheduled Delivery Cost** | £ | 996,300 | 305,400 |

The use of BVLOS in this context results in significant cost savings per year, as shown in Table 3-10. This is a result of the frequency of deliveries modelled in the analysis which have contributed to a proportion of overall operational expenditure (OPEX), in addition to eliminating the use of both a CTV and davit crane. A sensitivity analysis was conducted modelling a scenario where scheduled deliveries in excess of 5kg only occurred 100 days per year instead. This resulted in lower but still significant cost savings per year of £273,600.

Table 3-10 BVLOS vs. CTV charter cost savings for scheduled delivery of parts

| Element | Units | BVLOS vs. CTV charter |
|---|---|---|
| **Annual Cost Saving** | £ | 690,900 |
| **Cost Saving per MW** | £/MW | 523 |
| **Cost saving %** | % | 69% |
| **Lifetime cost saving** | £m | 20.7 |

In reality, it is expected that a CTV will typically be employed to carry out other O&M activities per visit meaning that the vessel and crew would already be working. In this case, there wouldn't be significant cost savings from eliminating the use of a CTV and crew. A sensitivity analysis has therefore been modelled adopting the same assumption as above where deliveries occur 300 days per year. However, it has been assumed that a CTV and crew would be utilised solely to perform deliveries on 100 of these days only. The resultant cost comparison and cost savings are shown in Table 3-11 and Table 3-12, respectively. In reality, the number of isolated incidents where the vessel and crew are used solely for deliveries in a day is likely to be much less than the frequency modelled in the analysis, and therefore may result in less significant cost savings.

Table 3-11 BVLOS vs. CTV charter cost comparison for scheduled deliveries of parts (reduced vessel utilisation rate)

| Element | Units | CTV | BVLOS |
|---|---|---|---|
| **CTV Day Rate** | £/day | 3,000 | - |
| **Personnel Cost** | £/day | - | 1,000 |
| **Annual Scheduled Delivery Cost** | £ | 375,400 | 305,400 |

Table 3-12 BVLOS vs. CTV charter cost savings for scheduled delivery of parts (reduced vessel utilisation rate)

| Element | Units | Reduced vessel utilisation rate – BVLOS vs. CTV charter |
|---|---|---|
| **Annual Cost Saving** | £ | 70,000 |
| **Cost Saving per MW** | £/MW | 53 |
| **Cost saving %** | % | 18% |
| **Lifetime cost saving** | £m | 2.1 |

The cost savings resulting from lower utilisation of a CTV and crew solely for deliveries results in much lower cost savings per year. In reality, this saving could be higher or lower dependent on how often an offshore wind farm might require deliveries and how often a vessel will be used solely to perform these deliveries. Although lower than initially shown, the cost savings from the use of a BVLOS UAV are still significant, particularly over the lifetime of the wind farm with an estimated saving of around £2.1m. This will mostly result from the elimination of a davit crane which will not be required for transporting the heavier deliveries from the vessel onto the turbine. It is important to note that this only applies to a new wind farm where the davit crane would not be included in the design and would therefore eliminate the capital cost involved.

In the case of already operational wind farms, the saving would result from the davit crane no longer in use and therefore not requiring annual maintenance. Figures from ORE Catapult's in-house cost model provided an estimated davit crane inspection cost of £500,000 per annum for a 1.3GW wind farm assuming every turbine is fitted with a davit crane. This would result in significant savings from overall annual O&M costs.

It should be noted that further investigation is required to evaluate the feasibility of completely eliminating a davit crane from offshore wind O&M activities. While current BVLOS capabilities may enable reduced use of the davit cranes, full elimination of this equipment would require technical readiness of BVLOS to address any and all lifting needs. Aspects such as lifting capacity and operational model of BVLOS system (e.g. the requirement for multiple drones to service a wind farm) need to be further developed. However, the potential benefits of eliminating/minimising davit crane use were highlighted by several of the operators interviewed, including not only the cost reduction highlighted here, but also reduction in safety risk and operational time of the lifting activities. This therefore remains an area of interest for future BVLOS development.

A sensitivity analysis has been carried out which considers the case where use of BVLOS is used alongside davit cranes. This scenario results in significantly smaller cost savings with an overall lifetime saving of £151,000.

#### 3.3.5 Assessment of Use Case

In reality, a scheduled delivery of parts system is likely to make the most use of BVLOS UAV out of all identified use cases. The frequency of equipment and parts deliveries to an offshore wind farm or O&G asset, in some cases daily occurrences, is likely to prove the most cost-effective use of BVLOS UAV in the long term. The main potential contributor to the cost savings is elimination of the davit crane for transporting the deliveries, and potentially a CTV and crew on occasion if being utilised solely for deliveries. Additional time could be saved from the use of the davit crane and, depending on the task undertaken, the nacelle crane to transport it to the top of the turbine.

In addition, the capability of the BVLOS UAV to also undertake unscheduled delivery of parts is likely to incur additional cost savings through eliminating the use of either a CTV or helicopter during high-risk urgent situations. Therefore, the most cost effective use of a BVLOS UAV for an offshore asset is going to result from the UAV being used in tandem to perform a variety of offshore activities, including both scheduled and unscheduled deliveries.

An expenditure that has not been accounted for in this, and other use cases, is the initial set up and administration cost in allowing for BVLOS operations. Particularly for this example, investment would be required to ensure wind farm processes and procedures are adapted for BVLOS, and that the onshore systems (including links to warehouses) are appropriately configured to have this capability. It is difficult to ascertain the level of cost associated with this and has not been included in the modelling.

For BVLOS drones to become the primary method of transportation, the quantity of payload and number of trips would need to be analysed in more detail. Multiple drone systems, including use of cooperative drones that work on a specific task together, are outside the scope of this study. However, it may be advantageous to have more than one delivery UAV for certain tasks or certain wind farms to improve efficiency or feasibility of O&M tasks. This therefore remains an area of interest in BVLOS development.

# 4 PRIMARY USE CASE - INSPECTIONS OF ASSETS

## 4.1 Overview

A variety of inspections are required during the operation of OSW and O&G assets. A selection of these is listed in Table 4-1 below.

Table 4-1 List of typical inspections for OSW and O&G assets relevant for aerial inspection

| Offshore Wind Assets | Oil & Gas Assets |
|---|---|
| • Turbine blades<br>• Transition pieces<br>• Concrete platforms<br>• Below platform inspections<br>• Towers<br>• Jacket foundations (above water)<br>• Navigation and aviation lights | • Flare tips<br>• Underdeck inspection<br>• Platform<br>• Drilling tower |

Most inspections are completed yearly, although some are required every six months. Some inspections would be carried out more frequently, but the current methodologies are too complex, and as such they are often left until a problem is identified and action required. For the purpose of this report two inspection types with the best understood cost profiles are included:

- Wind turbine blade inspections; and
- Navigation and aviation light inspections.

## 4.2 Wind Turbine Blade Inspections

### 4.2.1 Business as Usual

Historically, blade inspections have been completed using rope access technicians. This process does still occur where further assessment of possible defects and repairs are needed. However, it is common to use pilot operated UAVs flying within the visual line of sight (VLOS) of the operator. This requires the UAV operator and UAV to be transported to the site by vessel. This vessel would typically be the dedicated wind farm CTV, although a separate charter may be required. The vessel must remain within VLOS of the UAV throughout the operation. Here the working window can be limited by the requirement for the CTV to drop off other wind farm technicians at turbines before the inspection can take place and needing to collect them again before the end of a shift. For example, a 12-hour shift with a 2-hour transit time at each end and 1-hour transfer time to drop off or collect two teams of technicians would result in six hours or less of inspection time.

### 4.2.2 BVLOS UAV Use Case

Depending on the wind farm location the UAV will either take off from, and return to, the O&M base or have docking stations within the wind farm. The UAV operation will be planned and launched by the ROC. Depending on the wind farm location the UAV may be able to complete surveys of multiple turbines before returning to shore to recharge and download data, or travel to the docking station within the wind farm to undertake these tasks.

#### 4.2.3 Operational Requirements for BVLOS Use Case

Although not intended as an exhaustive list, the following operational requirements are specific examples considered for this use case:

- UAV endurance and docking station
- UAV operational envelope
- Inspection payload (i.e. visual camera, thermal)
- UAV manoeuvrability and stability for image quality
- Upload and assessment of inspection data
- Weather conditions (i.e. fog, rain, heavy winds)

#### 4.2.4 Cost Analysis

ORE Catapult has used its in-house cost model, in addition to engagement with BVLOS operators, to provide an assessment of the potential use of BVLOS to reduce the cost of blade inspection operations on offshore wind farms.

The cost impact is assessed by comparing, for an example offshore wind farm, the estimated cost of using a BVLOS UAV with carrying out blade inspections using current solutions. In this case, both rope access and UAVs (VLOS) have been used in the comparison.

**Model Site Parameters**

To model the cost comparison between current business-as-usual practice and inspection using BVLOS, different example sites have been modelled.

- Wind Farm A is based on a small site located 20 km from shore. It employs a CTV-based maintenance strategy.
- Wind Farm B is an example 1 GW offshore wind farm taken from ORE Catapult's in-house cost model. It is located 60 km from shore, so will still utilise a CTV for O&M purposes.
- Wind Farm C is the same site as Wind Farm B, but has been modelled further from shore an example large site, taken from ORE Catapult's in-house cost model. It is located 100km from shore, and will therefore utilise an SOV-based maintenance strategy with the SOV stationed at the wind farm. A CTV will be employed to transit from the SOV to the wind turbines and back. The distance from SOV to wind turbines is assumed to be 10 km.

Table 4-2 Model site parameters for wind turbine blade inspections

| Parameters | Units | Wind Farm A | Wind Farm B | Wind Farm C |
|---|---|---|---|---|
| **Turbine Rating** | MW | 6 | 10 | 10 |
| **Turbine Numbers** | # | 50 | 100 | 100 |
| **Site Capacity** | MW | 300 | 1,000 | 1,000 |
| **Distance to Port** | km | 20 | 60 | 100 |
| **Project Life** | Years | 25 | 25 | 25 |
| **Net Capacity Factor** | % | 44.4 | 47.5 | 47.5 |
| **Maintenance Vessel Strategy** | Text | CTV | CTV | SOV/CTV |
| **BVLOS UAV Recharge Location** | Text | O&M base | Docking station | Docking station |

**Inspection Frequency**

It is assumed that for rope access led inspections the turbines will be inspected once every two years and for both UAV (VLOS) and BVLOS solutions once every year or once every two years for larger sites. Specifically, for the following analysis, it has been assumed that the UAV (VLOS) and BVLOS UAV will inspect turbines once every year at Wind Farm A, and once every two years at Wind Farms B and C.

It is assumed that the BVLOS allows for a greater number of turbine blades to be inspected per day compared to the UAV (VLOS). The BVLOS UAV can move directly from one turbine to the next before being restricted by battery endurance, unlike the UAV (VLOS) which is vessel-based meaning it will have to travel to and from a vessel in between inspections to stay in visual line of sight and for any battery swaps that are needed.

For the cost analysis, the time taken to return the BVLOS UAV to perform a battery swap has also been incorporated into the model. The battery life of current BVLOS UAVs will be a limiting factor to operation, but maximum flight times are expected to continually improve as technology develops. The BVLOS will recharge either at the O&M base or at docking stations located at the wind farm. The location of recharging will depend on the distance of the wind farm from shore. As highlighted in Table 4-2, the BVLOS UAV will be recharged at the O&M base for Wind Farm A, and at docking stations for Wind Farm B and C. It has been assumed that it will take longer for recharge at the O&M base than the docking station, taking into account transit time. The capital expenditure (CAPEX) for the drone and docking station have been provided through engagement and fed into the cost model.

Engagement with a drone operator has provided estimated durations for BVLOS inspection. For the smaller 6MW turbines at Wind Farm A, each turbine inspection will take 25 minutes. Inspections at Wind Farms B and C will take 30 minutes for the larger 10MW turbines. For Wind Farm B located 60km from shore, and accounting for recharge time, the BVLOS UAV will be able to inspect around 12 turbines per day. For the purposes of this study, it is assumed that one BVLOS UAV will carry out the blade inspection operation.

The number of turbines inspected per day will be dependent upon the distance of the wind farm from shore. For instance, for wind farm B located 60km from shore, the CTV, travelling at an average speed of 37km/h (20 knots) will take just over three hours to get there and back each day. From a 12-

hour working day this leaves an inspection time of nine hours per day for the UAV (VLOS) case. Engagement with a drone operator provided a slightly longer estimated inspection time for a VLOS UAV compared to BVLOS, as a result of the increased level of automation for BVLOS operations. This inspection time would allow for around ten inspections per day for a VLOS UAV, taking into account transit time between turbines. It is assumed that rope access led inspections will inspect one turbine per day regardless of wind farm distance from shore.

Table 4-3 Wind turbine blade inspections per day

| Methodology | Unit | Wind Farm A | Wind Farm B | Wind Farm C |
|---|---|---|---|---|
| **Rope Access** | # | 1 | 1 | 1 |
| **UAV (VLOS)** | # | 14 | 10 | 15 |
| **BVLOS** | # | 15 | 12 | 15 |

Table 4-3 highlights the expected inspection frequency for each solution at each model wind farm that has been used for the cost comparison analysis. These frequencies have been based on estimated inspection times provided through engagement, and have considered factors such as transit time, recharge time and weather downtime. It is assumed that the turbine is switched off for the whole working day of 12 hours for rope access led inspections, and 30 minutes for both UAV (VLOS) and BVLOS. The analysis has not accounted for any potential turbine shutdown required following the inspection.

Wind Farm C uses an SOV for maintenance purposes meaning the vessel will be stationed out by the wind farm. In this case a CTV would be employed to transit from the SOV to the wind turbine and back, resulting in a transit distance of 10km. With the SOV stationed at the wind farm, the lengthy transit time is mitigated. While the journey for the BVLOS UAV to the SOV is notably shorter than to shore, it will still have to continually return there after a certain threshold of flight time. The VLOS UAV, on the other hand, will won’t have to return to the SOV until the end of the day, instead returning to the CTV that is in close proximity. Overall, this will result in a similar number of inspections at Wind Farm C for both VLOS and BVLOS UAVs.

The BVLOS UAV will carry out the same number of blade inspections at Wind Farms A and C. Although the UAV will have to return to journey back and forth between Wind Farm A and the O&M port to replenish battery levels, the shorter duration for inspection for the smaller turbines will offset this difference.

Table 4-4 outlines the annual blade inspection costs for the different methods at each model site and potential cost savings described in Table 4-5. Inspections using BVLOS result in significant cost savings across all sites, compared to both rope access and UAV (VLOS) led inspections. These cost savings have resulted from eliminating the need for a CTV during inspections. The percentage and lifetime savings are much greater for Wind Farms B and C than Wind Farm A, which is to be expected with Wind Farms B and C having double the number of turbines of Wind Farm A. The greater the number of turbines to be inspected, the more cost-effective the use of BVLOS becomes, as more and more CTV trips are saved.

Table 4-4 Wind turbine blade inspection cost comparison

| Element | Units | Wind Farm A | Wind Farm B | Wind Farm C |
|---|---|---|---|---|
| **Wind Farm OPEX** | £/year | 27,900,000 | 75,000,000 | 78,000,000 |
| **Rope Access** | £/year | 103,800 | 236,500 | 243,200 |
| **Blade Inspection % of Annual OPEX** | % | 0.37% | 0.30% | 0.30% |
| **VLOS Cost** | £/year | 22,100 | 28,700 | 25,800 |
| **BVLOS Cost** | £/year | 8,900 | 12,200 | 11,800 |

Table 4-5 BVLOS cost savings for wind turbine blade inspection

| Element | Units | Wind Farm A | | Wind Farm B | | Wind Farm C | |
|---|---|---|---|---|---|---|---|
| | | Vs. Rope Access | Vs. VLOS | Vs. Rope Access | Vs. VLOS | Vs. Rope Access | Vs. VLOS |
| **Annual Cost Saving** | £ | 94,900 | 13,200 | 224,300 | 16,500 | 231,400 | 14,000 |
| **Cost Saving per MW** | £/MW | 316.4 | 44.1 | 224.3 | 16.6 | 231.4 | 14.0 |
| **Cost Saving for Relevant Operations** | % | 92% | 60% | 95% | 58% | 95% | 54% |
| **Lifetime Cost Saving** | £m | 2.4 | 0.3 | 5.6 | 0.4 | 5.8 | 0.4 |

The LCOE for each inspection method at each wind farm has been calculated using the cost model. The use of BVLOS to carry out blade inspections results in LCOE reduction across all wind farms albeit relatively small reductions because blade inspections account for a small proportion of overall OPEX spend, as highlighted in Table 4-4.

The main advantage of utilising BVLOS for blade inspection will come from the ability to perform more inspections per day resulting in an overall greater frequency. This will allow for earlier identification of any issues that might lead to major faults and costly downtime for repair or replacement.

Another area of benefit of BVLOS for blade inspection is around health and safety. Although inspections are typically being conducted more autonomously using UAVs (VLOS), the increase in automation through the use of BVLOS results in fewer people required offshore.

### 4.2.5 Assessment of Use Case

Utilising BVLOS for offshore wind farm blade inspections provide significant cost savings through allowing for more frequent and efficient blade inspections. However, in the context of LCOE, the impact is relatively small. The main value that BVLOS is likely to bring is with regard to preventive maintenance over a longer timeframe. Through allowing more frequent inspections compared to the current convention, it is expected that the BVLOS UAV will be able to detect any faults at a much earlier stage. The potential cost savings that might result from earlier stage fault detection is significant as the cost to perform major repair or replace turbine blades offshore is extremely high.

## 4.3 Navigation and aviation light inspections

### 4.3.1 Business as Usual

Navigation and aviation light inspections are undertaken twice yearly, with each survey taking approx. 4 hours (depending on wind farm size) plus 3 hours for reporting. Inspections are completed by the vessel master and crew whilst waiting for technicians to complete their tasks. A marine coordinator is employed to report on the findings from the survey. During the inspection flash patterns are checked at a distance, although these can be challenging to see during daylight hours.

### 4.3.2 BVLOS UAV Use Case

The UAV would be sent from the O&M port by the ROC on a planned flight path with a camera to take images and videos of the light patterns. The UAV would be sent later or earlier in the day, such as dusk, when the lights can be more easily seen. The UAV can also travel closer to the lights for further inspection if a potential issue is identified.

### 4.3.3 Operational Requirements for BVLOS Use Case

See Section 4.2.3.

### 4.3.4 Cost Analysis

ORE Catapult has used its in-house cost model, in addition to engagement with offshore wind operators, to provide an assessment of the potential use of BVLOS to reduce the cost of navigation and aviation light inspections for offshore wind farms.

The cost impact is assessed by comparing, for an example offshore wind farm, the estimated cost of using BVLOS for undertaking inspections against the current solution which requires a vessel and crew to carry this out.

**Model Site Parameters**

In order to carry out the cost comparison analysis, an example offshore wind farm has been modelled, as outlined in Table 4-6. This site is based on a currently operational wind farm and has been chosen as a result of engagement which has provided parameters and costs specific to this site. For maintenance purposes, the wind farm employs a CTV as it is a near shore site. For a site located as close to shore, it is assumed that the BVLOS will take off from the O&M base and will transit to and from the wind farm.

Table 4-6 Model site parameters for navigation and aviation light inspections

| Parameters | Units | Wind Farm |
|---|---|---|
| **Turbine Rating** | MW | 3.6 |
| **Turbine Numbers** | # | 175 |
| **Site Capacity** | MW | 630 |
| **Distance to Port** | km | 20 |
| **Project Life** | years | 25 |
| **Net Capacity Factor** | % | 46.5 |

**Cost Comparison**

It is assumed that the inspection takes place around the perimeter of the wind farm only where Significant Peripheral Structures (SPSs), such as a corner structure or significant point on the boundary of the wind farm are required to be marked with lights visible from all directions [8].

The costs shown in Table 4-7 for the base case current solution were provided from engagement with an operator. In reality, it is likely that the vessel and crew would not be employed solely for inspection purposes and would already be out at site carrying out other tasks that day. Therefore, the potential cost savings would not be as significant than shown in the analysis. Direct input from an operator for this analysis has allowed for the costs used to be representative of the duration of the task and not on a daily basis, in an attempt to avoid artificially inflating costs. For instance, a CTV costs £3,000 per day to charter, where a working day is assumed to be 12 hours. Based on an annual survey time of eight hours (for two four-hour surveys per year), the cost of the CTV will be £2,000 solely for navigation and aviation light inspections. Based on an average speed of 37 km/h (20 knots), the CTV will take just over an hour to travel to and from the wind farm, resulting in a survey time of just under 3 hours.

Table 4-7 Base case navigation and aviation light inspection cost

| Element | Unit | Cost |
|---|---|---|
| **CTV Charter Rate** | £/year | 2,000 |
| **Fuel Cost** | £/Litre | 1.33 |
| **Fuel Consumption** | Litres/year | 3,333 |
| **Fuel cost per year** | £/year | 4,433 |
| **Marine Coordinator Cost** | £/year | 250 |
| **Annual Cost of Inspection** | £ | 6,683 |

It is assumed that BVLOS will complete the survey more quickly than the current solution using a vessel and crew. However, the BVLOS will require recharging during the operation where it will have to return to the O&M base and therefore add additional time to the inspection. Based on an average speed of 72 km/h and a surveying speed of 32 km/h, the total inspection time, including mobilisation and demobilisation, getting to and from site, and recharging will be just over 3.5 hours. This duration also considers additional time that may be required for closer inspection. Based on engagement with a drone operator, it is assumed that both a pilot and operator will be required onshore to mobilise and then fly the BVLOS. The operator cost has been excluded from the cost analysis as it is expected that a sufficiently trained onshore technician can mobilise the BVLOS UAV. The costs presented in the table are also based on the duration of the inspection only.

Table 4-8 BVLOS navigation and aviation light inspection cost

| BVLOS | | |
|---|---|---|
| **Element** | **Unit** | **Cost** |
| **BVLOS Cost per Mile of Inspection** | £/mile | 17 |
| **BVLOS Cost of Inspection** | £/year | 1,033 |
| **BVLOS Pilot Cost** | £/year | 422 |
| **Marine Coordinator Cost** | £/year | 250 |
| **Annual Cost of Inspection** | £ | 1,705 |

Table 4-8 describes the annual costs for both the current inspection solution and inspection using BVLOS. The use of BVLOS for navigation and aviation light inspection provides significant annual and lifetime cost savings for the wind farm, with BVLOS led inspections saving around 74% annually compared to current inspection costs. The pilot makes up the majority of the overall BVLOS spend due to the skilled nature of the job.

The largest cost savings, as shown in Table 4-9, are a result of eliminating the need for a vessel and the resultant fuel consumption. In addition to cost savings, another advantage that the utilisation of BVLOS to conduct these surveys provides is the ability to carry out the inspections during darkness, when the performance of the lights is more apparent than when viewed from a vessel during the day.

Table 4-9 Navigation and aviation light inspection cost comparison

| BVLOS cost saving vs. base case | | |
|---|---|---|
| **Annual Cost Saving** | £ | 4,978 |
| **Annual Saving %** | % | 74% |
| **Lifetime Cost Saving** | £m | 0.1 |

Currently, navigation and aviation light inspection are relatively cheap to carry out by conventional means. The use of BVLOS still provides a significant cost saving if a dedicated charter is required. There will also be a positive impact by reducing emissions associated with CTV use. The impact of the cost savings on LCOE is negligible as the navigation and aviation light inspection operation is a very small percentage of the overall OPEX spend for the wind farm.

### 4.3.5 Assessment of Use Case

Section 4.3.4 has outlined the cost benefit of using a BVLOS UAV for navigation and aviation light inspections. BVLOS can provide an annual saving of 73% compared to approaches that use a dedicated vessel and crew. However, as with other use cases, it is common practice to combine inspections with other operations. This means that the crew and vessel would already be out at site and would not be mobilised solely for this purpose, significantly impacting any potential savings. Another limitation with this use case is the already cheap cost and infrequency of carrying out these inspections, which makes the commercial proposition not evident on its own. In order to make using BVLOS worthwhile for navigation and aviation light inspections, the UAV should be used for a range of different inspection and maintenance purposes.

# 5 ADDITIONAL USE CASES

During the interviews additional possible use cases were identified by certain operators. As there was limited discussion on these a cost analysis was not completed, and they are included below for awareness.

## 5.1 Monitoring Discharge of Oil to the Sea (O&G Focussed)

Within the O&G industry there are scenarios where a discharge of oil to the sea may become apparent. This could be from the O&G asset itself or a vessel. When an oil discharge is noticed all asset operations cease until the source of the oil can be identified, with monitoring of the discharge also put in place. A Petroleum Operations Notice 1 (PON1) is the notice used to report all releases to sea of oil and offshore chemicals that occur during offshore oil and gas activities. Offshore hydrocarbon release data is reported by the HSE[3]; classified as 'Minor', 'Significant', or 'Major' on the basis of their severity. For the period 2012-2020, 32 major incidents were recorded.

### 5.1.1 Business as Usual

Current practice is to use emergency response vessels and supply vessels to assess the spread of the oil spill and take samples. Search and rescue helicopters with a thermal camera fitted may also be used to assess the spread of oil. If an emergency person overboard scenario was to occur, then the rescue operation would be prioritised over the environmental monitoring. Larger oil spills may also use satellite imagery to assess the boundary and how it changes over time.

Oil spill samples will be transported to the offshore asset laboratory to assess if the oil is directly from the asset or not. If results are inconclusive the samples may need to be transported to the onshore advanced laboratory (see section 3.3.1). Once the outcome is determined, operations at the asset will either be restarted or remain suspended.

Following an oil spill, containment measures must be put in place. Maritime Rescue Co-ordination Centres act as co-ordinators during incidents in the UK and circulate all pollution or situation reports to the Marine Management Organisation (MMO) for English waters. Marine Scotland, Natural Resources Wales and the Northern Ireland Environment Agency are responsible for their waters[4]. Dispersants are applied to increase the rate of dispersal and breakdown of the oil. During this process aircraft and satellites must continually assess the oil spill spread until the emergency is deemed to be over.

### 5.1.2 BVLOS UAV Use Case

A UAV could be deployed from the shore, or the asset, with a thermal camera equipped to assess the spread of the oil spill and live assessment of images. The ROC would still launch the UAV on a pre-planned flight path to assess the oil spill, but take over manual piloting or change the flight path as necessary. The UAV could be used in the emergent stage to reduce the demand on the search and rescue helicopter, and also throughout the dispersant phase during planned operations.

[3] https://www.hse.gov.uk/offshore/statistics/index.htm

[4] How we respond to marine pollution incidents - GOV.UK (www.gov.uk)

As discussed in section 3.3.2 the UAV could also be used to transport oil spill samples to the onshore advanced laboratory.

## 5.2 Bathymetric Surveys (OSW Focussed)

Bathymetric surveys measure and map the depth of the sea floor and are one of the geophysical surveys undertaken during the development and consenting stage of an offshore wind farm.

### 5.2.1 Business as usual

Current practice uses a survey vessel with single beam or multibeam echo sounder to undertake the survey. The vessel travels across the survey area at approximately 100m intervals. Typically, the bathymetric survey is completed alongside side scan sonar sea floor mapping, acoustic seismic profiling, and magnetometer assessment for potential unexploded ordinances (UXOs). The vessel operates for 24 hours a day, usually spending a month at sea at a time. Some developers are looking at how uncrewed surface vessels (USVs) or autonomous underwater vessels (AUVs) could be used to undertake these processes instead.

Figure 5-1 Drone-Based Echosounder for Bathymetry (source: SPH Engineering)

### 5.2.2 BVLOS UAV Use Case

A payload for sea floor mapping would be required and the UAV would fly a pre-planned route, defined by the ROC, across the survey area. The UAV is likely to be launched from shore to undertake the survey, but may also be able to dock and recharge on a vessel, USV or alternative solution in the area. Typical survey vessels have the capability to complete surveys at night and in adverse weather conditions. A UAV application would need to consider how to compete against this methodology. This implementation would also have to collect survey data of similar accuracy and have sufficient vehicle endurance to be a viable use case.

## 5.3 Wind Resource Analysis (OSW Focussed)

Measuring the wind resource at wind farm sites is the principal factor in determining the potential energy yield of an offshore wind turbine. Determining the wind speed and direction at the turbine, as well as the wake effects of the turbine are crucial in maintaining a high level of efficiency. Wake effects are the effects of a turbine on the wind downstream of it, and subsequently the wind resource neighbouring turbines receive. Understanding the wind profile is also key for assessing the loads on the turbine and weather windows for wind farm operations.

Figure 5-2 Aerial picture of the Horns Rev II wind farm, in which the wind turbine wakes are visualised by low hanging fog that is mixed into the wake region (source: Bel Air Aviation Denmark-Helicopter Services)

### 5.3.1 Business as Usual

Current practice is to use the turbines' turbine mounted anemometers, accessed through the supervisory control and data acquisition (SCADA) system, to determine the wind resource available at each turbine. There are historical concerns over the accuracy of these anemometers for estimating the wind and understanding the wake effects on downstream turbines.

### 5.3.2 BVLOS UAV Use Case

5.4 A UAV with a payload suitable for measuring wind speed and direction could be used to undertake a planned route around the wind farm. This, combined with the SCADA data, would provide a more accurate picture of the turbine wake effects, and enable different scenarios to be monitored.

## Monitoring Person Overboard Scenarios (Both O&G and OSW)

Throughout discussions it was felt that search and rescue, or person overboard, scenarios were not as pertinent a BVLOS UAV use case in OSW, as for most scenarios a vessel is in very close proximity to the person. Therefore, the vessel is likely to be on hand for rescue. However, within O&G the scenario is different. A person overboard situation is most likely to be from an asset with no vessel immediately in the vicinity. It is this scenario that is considered here.

### 5.4.1 Business as Usual

Current protocol when there is a person overboard situation is to:

- Sount the alarm on the asset;
- Deploy the person overboard rescue boat within 15 minutes (8 minutes in colder environments);
- Set up a spotter on the asset to keep visual sight of the person in the water;

- A helicopter may be used in some scenarios, but with a 15-minute mobilisation time and approximately 20-minute flight time, plus time to plan the rescue on arrival, these are less common.

Person overboard scenarios are not common with limited annual instances across the offshore industries. When they do happen the risk to life is very high, with two separate fatalities occurring in the UK within 6 months of each other in 2020[5].

### 5.4.2 BVLOS UAV Use Case

A BVLOS UAV could assist by keeping visual sight of the person. This could improve the outcome of using a fall guy, where they can lose sight of the person. A video of the person and sea state, along with accurate GPS location could be provided for the vessel and helicopter. In addition, the live video feed would assist the helicopter rescue team, enabling them to plan the rescue on route and saving time on arrival.

An asset-based UAV with camera payload, flown by the ROC, would be the most appropriate solution for this. The asset would need personnel available to ready the UAV for operation.

This use case could be linked in with scheduled deliveries. However, the UAV would need to cope with the most severe weather conditions, such as fog and high winds.

## 5.5 Internal Monopile Inspections (OSW Focussed)

Although not strictly BVLOS as defined by the CAA, this use case was mentioned in interviews more than once and therefore has been recorded in this report. For OSW inspections must be completed inside monopile foundations. This inspection includes activities such as:

- Visually inspecting welds and known defects;
- Measuring the plates to grouted joints;
- Checking wall thickness measurements;
- Taking LPS measurements.

### 5.5.1 Business as Usual

Current practice is to use technicians to access the confined space. This can require the monopile to be pumped out if there is water inside and forced ventilation to ensure the atmosphere is safe for entry. This process requires a minimum of 3 technicians for a period of time and has inherent risks associated with the application.

### 5.5.2 BVLOS UAV Use Case

If a UAV could be used to fly into the confined space and undertake many of these measurements the need for technicians to enter the area could be significantly reduced or removed completely. The UAV operator could be positioned outside the confined space at a safe distance to monitor the UAV. The UAV size and payload would need to be considered. New systems would need to be developed and trialled to undertake many of these tasks, but there is a potential use case here.

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[5] https://toolbox.energyinst.org/c/presentations/man-overboard!-workers-drowned-when-not-wearing-a-personal-flotation-device

# 6 CONCLUSION

This study shows that there are definitive use cases for BVLOS identified by end users within the Offshore Wind and Oil & Gas industry that could be commercially viable and warrant further exploration.

Delivery of parts by UAV has been highlighted as a notable application of interest for the two sectors, considering unscheduled and scheduled circumstances. For unscheduled deliveries at offshore wind farms, cost modelling showed a reduced overall expenditure compared with utilising either a CTV or helicopter. The lack of documented instances means that the frequency of these events is ambiguous and would be difficult to recommend in isolation. Scheduled deliveries would be expected to be more frequent. However, the displacement in vessel/helicopter usage would not be as evident, as offshore asset operators already combine visits to the asset for scheduled deliveries with other O&M duties. A greater cost reduction would be found at wind farms if the implementation of BVLOS for this use case could also eliminate the need for a davit crane, although this would be more applicable for future wind farm developments.

Visual inspection by UAV is a use case that is common practice for both industries, and the benefits for this against traditional rope access inspection are already clear for offshore assets. The reduction in cost is not as pronounced for adapting VLOS operations to BVLOS as, like scheduled deliveries, the mitigation of vessel usage is not as certain. More frequent inspection could be more feasible to implement with BVLOS and could theoretically result in a reduction in major repairs/replacement if damage is determined at a suitably earlier stage. There would need to be definitive evidence that the current inspection model is not sufficient to adopt additional campaigns.

Other identified use cases are difficult to envisage in isolation due to specific requirements or infrequent occurrences. These could be additional responsibilities to an existing primary use case if the capabilities of the UAV are not too dissimilar but should not be the priority of focus.

Overall, the primary use cases of delivery of parts and inspection of assets show commercial promise but are not clear cut as individual applications, especially where the use of traditional transport cannot be eliminated entirely. The reduced need to coordinate multiple O&M operations and organisations on the same vessel would ease the logistical burden for operators. Conversely, a robust BLVOS use case would require effective integration into existing O&M and would put additional responsibility on the wind farm to manage and monitor this. To be responsive and sustainable, this may mean the operator taking ownership of the BVLOS UAVs and related infrastructure, rather than contracting out the service. Undoubtedly, this would require initial expenditure to ensure integration into everyday operations, not accounted for in the analysis.

There is potentially an opportunity to collate these discrete primary use cases to make the business case more attractive, but their operational requirements may be quite different and not effective to combine into a single UAV proposition. This report would recommend prioritising the combined unscheduled/scheduled delivery of parts for a future wind farm application, with an aim to remove the need for the davit crane in terms of commercial viability. However, the inspection of assets using BVLOS would likely be easier to initially trial.

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