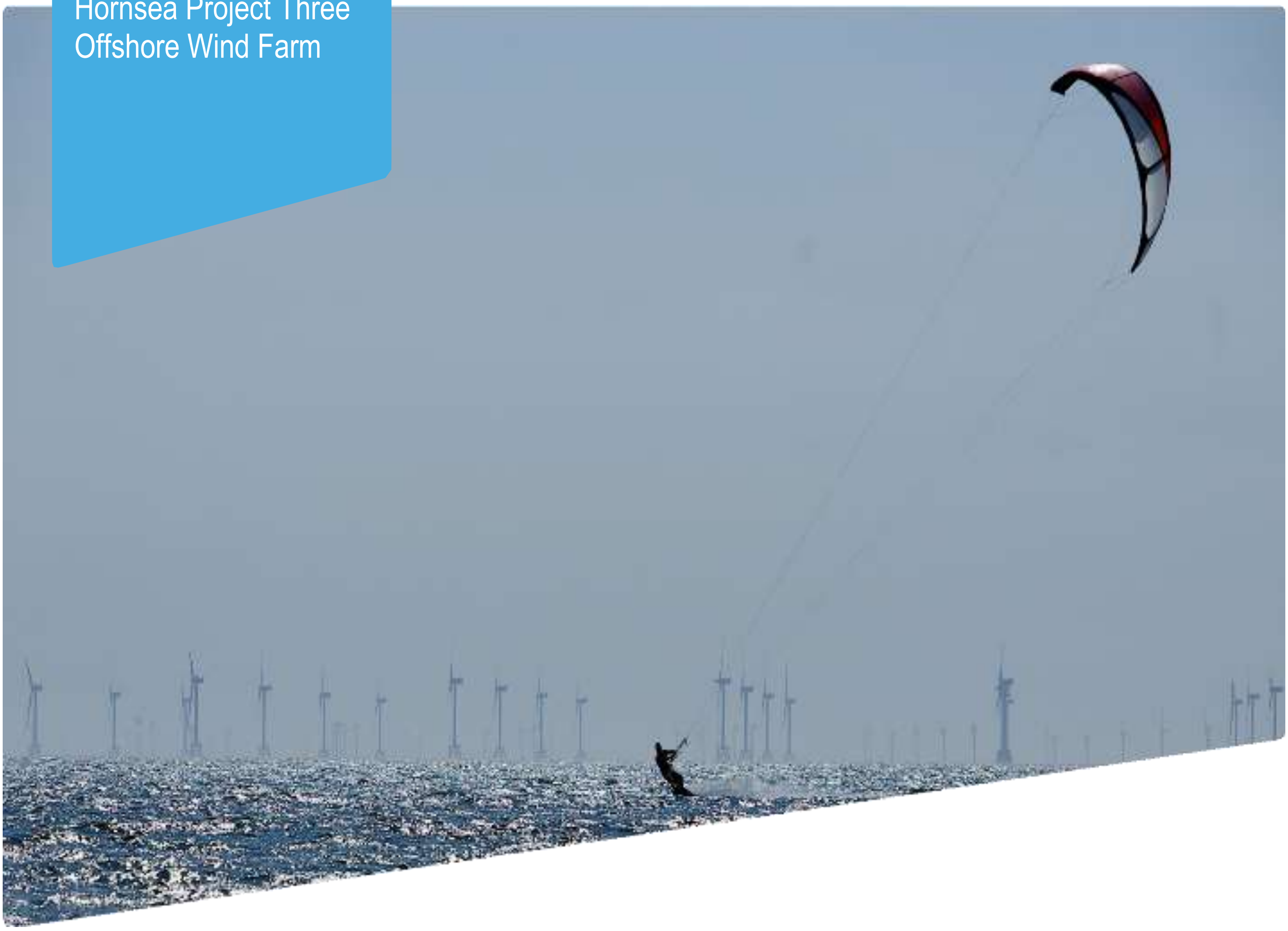
Hornsea Project Three
Offshore Wind Farm



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Appendix 11 to Deadline 2 submission – SAR Technical Note

Date: 21st November 2018

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Ørsted

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Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2018.

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1. Glossary of Terms

Abbreviation	Term
AIS	Automatic Identification System
CGOC	Coastguard Operations Centre
CSV	Comma-Separated Values
EASA	European Aviation Safety Agency
EGPWS	Enhanced Ground Proximity Warning System
FDM	Flight Data Monitoring
FLIR	Forward Looking InfraRed
FMS	Flight Management System
ft	Foot
IMC	Instrument Meteorological Conditions
IR	InfraRed
Km	Kilometre
kt	Knot
lb	Pound
m	Metre
MCA	Maritime and Coastguard Agency
MHz	Megahertz
NVG	Night Vision Goggles
PBN	Performance based Navigation
PPE	Personal Protective Equipment
PinS	Point in Space Approach
Radar	Radio Detection and Ranging
SAR	Search and Rescue
SAROPS	Search and Rescue Operations
SART	Search and Rescue Transponder
SERA	Standardised European Rules of the Air
SOP	Standard Operating Procedure
TAS	Temperate Airspeed
WGS84	World Geodetic System 1984

2. Introduction

2.1 This note has been prepared for Hornsea Three by Mark Prior, SAR Helicopter Specialist, specifically in relation to the matters raised by the Maritime and Coastguard Agency (MCA) in relation to Search and Rescue (SAR) helicopter operations associated with the proposed Hornsea Project Three offshore wind farm.

2.2 Following a meeting on the 15th August 2018 at the Ørsted office at Victoria, London, between Hornsea Three and the MCA, the following specific actions were identified:

- Provide a technical summary of the radius of turn calculations;
- Provide comments on the MCA/Bristow turning trial;
- Provide a technical summary of the ability to search a 300 metre (m) Development Lane; and
- Provide a technical summary on the requirement for a Helicopter Refuge Area.

3. Background

3.1 No current experience exists with SAR operations in Round 3 wind farms. That is to say, that there is no experience of conducting a search in an array where the turbines are spaced at least 1 kilometre (km) apart and current Standard Operating Procedures (SOPs) are based on more tightly packed arrays, which may not be valid for Hornsea Three.

3.2 In some ways a parallel can be drawn to searching in hilly terrain where the helicopter can be constrained to valleys when the hill tops are covered in cloud. Unlike hilly terrain, all obstacles in a turbine array will be controlled, accurately mapped and information provided to the crew on paper maps and electronically in map projection World Geodetic System 1984 (WGS84) format for inclusion in the EuroNav 7* situational awareness and mission management system software and possibly the aircraft's Enhanced Ground Proximity Warning System (EGPWS) obstacle databases. The MCA, and their helicopter contractor, could modify their search profiles and procedures to take account of the obstacle environment in Round 3 turbine arrays.

4. Manoeuvring Within the Array

4.1 The MCA provided data to Ørsted from a trial conducted by their SAR helicopter contractor, Bristow Helicopters, over Loch Ness in Scotland during the summer of 2018. Conducting such trials is challenging and can require the use of specialist tracking equipment in order to produce accurate and repeatable results. The single image presented in Figure 4.1 (as provided by MCA) appears to show turns at an inconsistent angle of bank as the orbits are not round, despite it being stated that the turns were flown in zero wind. Furthermore, it does not appear to show the diameter being measured accurately.

Figure 4.1 MCA Turning Trial Data (provided courtesy of the MCA).

4.2 A suggested way to measure the turn would be to use the Flight Data Monitoring (FDM) system fitted to the Bristow aircraft. This will record an accurate position, angle of bank, heading and airspeed. These data can be exported from the system in comma-separated values (CSV) format for analysis in Excel and other tools. Using the position data, the actual size of a turn can be plotted and measured. Using the change in heading and airspeed, the rate of turn for a given airspeed can be calculated. The data for this trial may still be held on the Bristow system; if not this methodology can be used to measure the turning performance on any future flight without any additional equipment fitted. As part of the follow-up discussion the following information was provided:

4.3 **Email from Peter Lowson (MCA) to Mark Prior 28/08/2018 09:36**

4.4 "*The 80 knot turn is as fast as we would be going Night/DVE and would probably execute it at 20 to 30 degrees thus remaining inside the 1 nm diameter turn. At 50 knots we would probably stop to the hover and reposition*".

4.5 At 80 knots (kt) and 20° angle of bank, a 360° turn could be made within a diameter of 1,000 m and with a 30° angle of bank the turn would be even tighter. Based on the information provided by the MCA and the Applicant's specialist, the Applicant suggests that the SAR contractor does not require 1 nm for turning, particularly if account is taken of the advisory speeds shown in Table 4.1.

Calculation of the Distance Required for Turning

4.6 The European Aviation Safety Agency (EASA) Part Standardised European Rules of the Air (SERA) is used for guidance as to the speeds flown against visibility. Although an advisory airspeed is provided, this is really the ground speed, as that determines the closure rate with obstacles.

Table 4.1 EASA Part SERA Recommended Speeds

Visibility (m)	Advisory speed (kt)	Time to cover "visible distance" at "advisory speed" (sec)
800	50	31
1,500	100	29
2,000	120	32

4.7 With visibility in excess of 1,000 m, the turbine ahead, and laterally, will be visible and so a turn can be made without risk of colliding with the turbine. With visibility below 1,000 m, the airspeed will be reduced towards 50 kt, reducing the turning distance further.

Calculating Radius of Turn

4.8 Providing the turn is not power limited, which will be the case for MCA helicopters in temperate climates, classic aerodynamic theory shows that:

$$r = \frac{v^2}{g} \tan \emptyset$$

4.9 Where:

$r = radius\ of\ turn\ (m)$
$g = 9.81\, m/s^2$
$v = true\ airspeed\ (kt)$
$\emptyset = angle\ of\ bank\ (°)$

4.10 It is noted that for helicopters operating at low level in temperate climates the temperate airspeed (TAS) is equivalent to the indicated airspeed.

4.11 In the Bristow trial it is noted that the crew used an angle of bank for a Rate 1 turn (rate of turn of 3°/sec) based on an approximation of 15% (i.e. TAS/10+5) of the helicopter's true airspeed. This is a fixed wing approximation which is less accurate at low airspeed and takes no account of the inherent sideslip and asymmetry present in a single rotor helicopter. A commonly used approximation for bank angle to achieve a Rate 1 turn in a helicopter is TAS/10+7, (i.e. 17%). In order to avoid confusion, both values for angle of bank are shown below, with the 17% figures in **bold black** (80 kt 15°, 50 kt 12°) and the 15% values in **blue** (80 kt 12°, 50 kt 7°). If turns were measured using FDM then it could be confirmed that the correct rate of turn was being applied. As the email above stated that a higher angle of bank would be used operationally, the values for 20° and 30° angle of bank at 80 kt are highlighted in **green** (see section 5.4 for application of radius of turn).

4.12 The information presented in Table 4.2 indicated that turns can be made in degraded visual condition within a radius that is less than the spacing in the SAR lanes.

Table 4.2 Radius of Turn in m and nm for Various Bank Angles and Airspeeds

Airspeed (kt)	Angle of Bank (°)	Radius (m)	Radius (nm)	Diameter (nm)
80	**30**	**298**	**0.16**	**0.32**
80	**20**	**473**	**0.25**	**0.50**
80	**15**	**643**	**0.34**	**0.68**
80	**12**	**811**	**0.43**	**0.86**
70	40	157	0.08	0.16
70	30	228	0.12	0.24
70	20	362	0.19	0.38
70	14	529	0.28	0.56
60	40	115	0.06	0.12
60	30	167	0.09	0.18
60	20	266	0.14	0.28
60	13	420	0.22	0.44
50	20	185	0.09	0.18
50	**12**	**316**	**0.17**	**0.34**
50	**7**	**548**	**0.29**	**0.58**

5. Helicopter Refuge Areas

MCA MGN 543

5.1 Annex 5 of the MCA's MGN 543[1] includes the following text:

5.2 (Paragraph 9.24.2) "*Where wind farms are proposed to become very large e.g. more than c.10 nm in any direction, a requirement may be imposed for helicopter refuge areas to be built in to the design within the wind farm area. This requirement will have to be assessed during discussion with the MCA on layout design. The minimum helicopter refuge distance required will be evaluated on a case by case basis and will depend on the context of the development, but distances less than 1 nm are unlikely to be considered acceptable.*"

5.3 (Paragraph 9.24.4) "*Helicopter refuge areas are to allow SAR helicopters access to a defined area of safe airspace to: manoeuvre in preparation to enter or when exiting wind farms, to safely turn within a windfarm or, in the event of an emergency requiring the helicopter to escape from the wind farm*".

Manoeuvring

5.4 Table 4.2 identifies turning performance at various speeds and angles of bank. When the visibility is good the helicopter can route between the turbines, which will be a minimum of 1,000 m apart. If the visibility is poor, then the helicopter's airspeed will be reduced for safety reasons and so the radius of turn is reduced. The MCA's proposal to fly at less than 80 kt and use 20°+ angle of bank would result in a diameter of turn of less than 0.5 nm. Therefore, since the existing minimum separation distance is considered adequate for manoeuvring purposes it is difficult to see the added value of a single Helicopter Refuge lane.

Orientation

5.5 At the 15th August 2018 meeting MCA stated that the Helicopter Refuge Area would assist in orientating the crew, as a previous evaluation in a Round 2 array with closer spaced turbines led to the conclusion that orientation and situational awareness within an array might be an issue. The Hornsea Three array turbines will be spaced at least 1 km apart, in poor visibility fewer turbines would be seen and so a large Helicopter Refuge Area would only exacerbate the orientation issue as even less would be seen to orientate the crew. What would be more useful for the SAR crew would be marking areas to turn between turbines from one SAR Lane into the next using vessel Automated Identification System (AIS). For example, midway down the SAR Lanes a perpendicular series of gaps through to the next SAR Lane would be marked with AIS. This would give crews the confidence to route between turbines into the next SAR lane in extremely poor weather and provide confirmation using an independent transmitter that the map display was valid and Radio Detection and Ranging (Radar) returns accurate. As AIS is displayed to both the pilots and crewmen on their display, it would help in orientation in poor visibility and would allow turns between SAR Lanes to be planned several miles in advance.

[1] Text is taken from the draft update of MGN 543 Annex 5 which has not yet been approved and published.

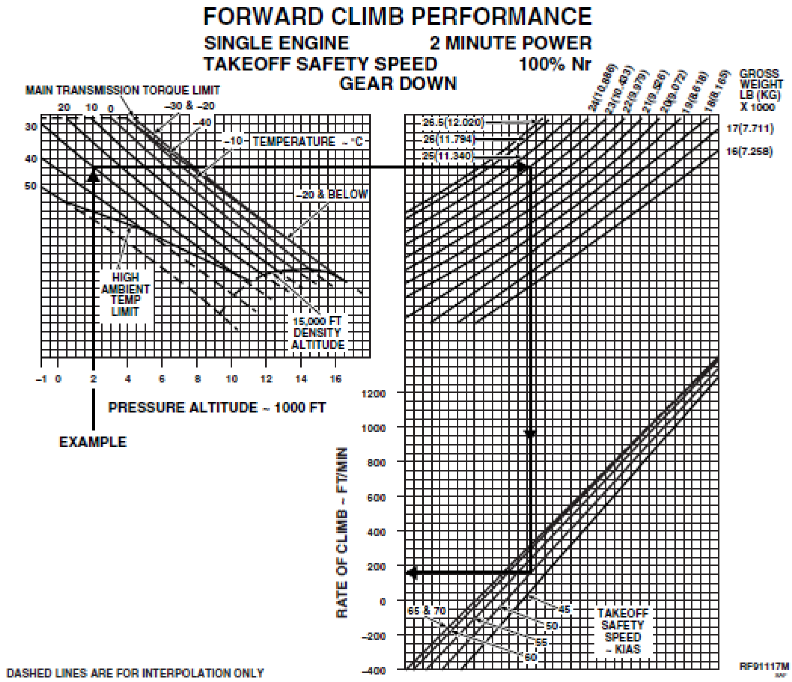
Entry and Exit

5.6 Paragraph 9.24.4 of Annex 5 of MGN 543 implies that the refuge is for entry and exit from the wind farm. In Hornsea Three the SAR Lanes are the main means of entering and exiting the array in low visibility weather. With better visibility the array can be entered from any point as the turbines are widely spaced and can be stopped during SAROPS to minimise turbulence. If a series of AIS transmitters are mounted to indicate a lane across the SAR Lanes, then this could also be used as a route to enter and exit the array in reduced visibility. The MCA SAR helicopters are equipped with advanced SAR autopilot modes which facilitate transition to and from the hover in zero visibility. It is assumed that the auto-transition modes would only be used outside the array, unless Point in Space (PinS) approaches were developed for the Hornsea Three array.

Emergencies

5.7 In an emergency the SAR crew may choose to stay at low level and exit the array. Emergencies of this sort could be those resulting in a degraded autopilot or major electrical problem. In this case, the factors set out above regarding turn radius and the ability to manoeuvre remain valid, especially as emergencies usually require a reduced airspeed. If the cloud base is sufficiently high, then the crew may choose to climb out of the array. The closest MCA base to Hornsea Three is at Humberside Airport and uses the S92 helicopter. The S92 Flight Manual Part 1 Section IV includes the rate of climb graph presented in Figure 5.1. This shows that at sea level with temperatures below 20°C then at maximum all up mass of 26,500 pounds (lb) (which could only exist if the aircraft had picked up >7 survivors during a rescue and had departed Humberside at maximum mass, which is unusual) it would have a rate of climb on one engine of 400 feet (ft) per minute. Assuming still air and the helicopter starting at 50 ft, then it would take just over 2.5 nm to climb above the array at 70 kt. Any headwind would reduce this distance. Due to the minimum spacing of the turbines of ≥1 km then a safe climb heading with minimal track changes should be available at all times. To be useful in an emergency, a Helicopter Refuge Area would have to be close to where the emergency occurred and be aligned with the ambient wind direction, a combination of which is improbable.

SA S92A-RFM-006 | S-92 | Part 1, Section IV
PERFORMANCE INFORMATION



REDUCE RATE OF CLIMB DETERMINED FROM CHART BY AMOUNT SHOWN IN TABLE

Gross Weight - LBS	Reduction Anti-Ice On	Reduction Air Conditioner On
16,000	100	105
18,000	95	95
20,000	95	90
22,000	90	85
24,000	90	85
26,000	90	85
26,500	90	85

Figure 4-12. OEI Forward Climb Performance, Takeoff Safety Speed

FAA APPROVED: NOVEMBER 8, 2005
Revised: March 16, 2007

4-19

Figure 5.1 Rate of Climb Graph for S92 Helicopter

6. 300 m Development Lanes

6.1 The MCA's Relevant Representation (APP-060)[2] stated that a 300 m Development Lane (± 150 m of the centreline) would result in 23% of the array not being searchable. This value is considered to be unrealistic and does not account for the infrastructure being spaced at least 1 km apart. The SAR helicopter has the following equipment available to allow a close approach and search of the area between the widely spaced turbines.

Star SAFIRE HD

6.2 The MCA SAR helicopters use an electro-optical system made by Forward Looking InfraRed (FLIR) Systems, the Star SAFIRE HD. This combines high definition visual imagery with a Near InfraRed (IR) (3-5μ) sensor, both with ×120 magnification. Thermal and visual imagery has a field of view of 30° for a general search down to 0.25° when zoomed in on a target. Due to its location on the nose of the helicopter it can scan through 360° in azimuth. Unlike previous systems, this product can combine visual and IR imagery onto a single screen which optimises the search in difficult conditions. This would permit a search of the Development Lanes from the SAR Lanes in all but the poorest visibility, which is considered to be an infrequent occurrence (further information on visibility parameters can be found in section 11 Volume 5, Annex 7.1: Navigational Risk Assessment (APP-112). The system can use Merlin software which cues the operator to possible survivors and so enhances the search capability.

Radar Honeywell Primus 701A

6.3 The S92 is equipped with the Primus 701 Radar which has a minimum range of 137m (450 ft). This system enables ground/sea mapping and weather detection optimised for SAR operations. The Primus 701A has a variable pulse width that is automatically optimised for range and mode setting. The system also includes selectable sea clutter reduction and operator modified gain and tilt thereby allowing for optimum search capability. The Radar is capable of discriminating between individual turbines and mapping an obstacle free track between turbines. Ørsted has commissioned a Radar Early Warning Technical Report[3] (APP-119).

6.4 The Radar system has 120° coverage and has selectable ranges of 0.5, 1, 2.5, 5, 10, 20, 40, 80, 160, 240 and 320 nm which can be displayed on the cockpit multi-function displays. The 701A system is also fully compatible with 9.735 Megahertz (MHz) six pulse, two pulse and one-pulse beacons. The system will display Search and Rescue Transponder (SART) beacons when selected in ground mapping mode. The 701A Radar is integrated with the Flight Management System (FMS). This allows the pilots to fuse navigation information with the Radar picture for more accurate and safer searches. This overlay of FMS navigation information also allows for the integration of SAR search patterns with the Radar picture.

[2] https://infrastructure.planninginspectorate.gov.uk/projects/eastern/hornsea-project-three-offshore-wind-farm/?ipcsection=relreps&relrep=25754
[3] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-000589-HOW03_6.5.11.1_Volume%205%20-%2011.1%20-%20Radar%20Early%20Warning%20Technical%20Report.pdf

Automatic Identification System

6.5 The MCA SAR helicopters are equipped with AIS which will allow them to identify any equipped vessels or turbines fitted with AIS.

Navigation Systems

6.6 The MCA SAR helicopters are equipped with integrated navigation and display systems which will show the crew all obstacles held in the database. As the turbines will be accurately mapped, the system will provide a clear display of the obstacles. There is the ability to add the turbines to the Enhanced Ground Proximity Warning System (EGPWS) database giving approximately 20 seconds of warning before an obstacle, but this should be balanced against the frequency of nuisance alerts. The statement that a 300 m Development Lane (± 150 m of the centreline) would result in 23% of the array not being searchable is overly pessimistic and takes neither account of the systems fitted to the MCA SAR helicopter nor the widely spaced turbines.

7. Summary

7.1 The MCA SAR helicopter trial undertaken in summer 2018 used an inconsistent angle of bank with the diameter of the turns not measured accurately, based upon imagery presented. Use of the FDM system fitted to the Bristow aircraft would allow accurate position, angle of bank, heading and airspeed to be computed.

7.2 Based upon consultation with the MCA a relatively high angle of bank will be used operationally by a SAR helicopter when undertaking a turn within the Hornsea Three array. This will result in a diameter of turn of less than 0.5 nm which challenges the need for a 1 nm wide Helicopter Refuge Area, particularly given the low likelihood of the Helicopter Refuge Area being near to a rescue location. Additionally, in an emergency a Helicopter Refuge Area would have to be aligned with the ambient wind direction in order to allow the safe climb of the aircraft out of the array.

7.3 A SAR helicopter searching a 300 m Development Lane can utilise a range of already available technology to allow a close approach and search of the area between the widely spaced turbines, including the Star SAFIRE HD, Radar Honeywell Primus 701A, AIS and navigation systems.

8. References

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