The challenge… why we are here

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Introduction

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Agenda

1. **Reminder of the windfarm radar mitigation context**
2. **Deployment concepts**
3. **Developing requirements**
4. **Evaluation and testing**
5. **Next steps…**

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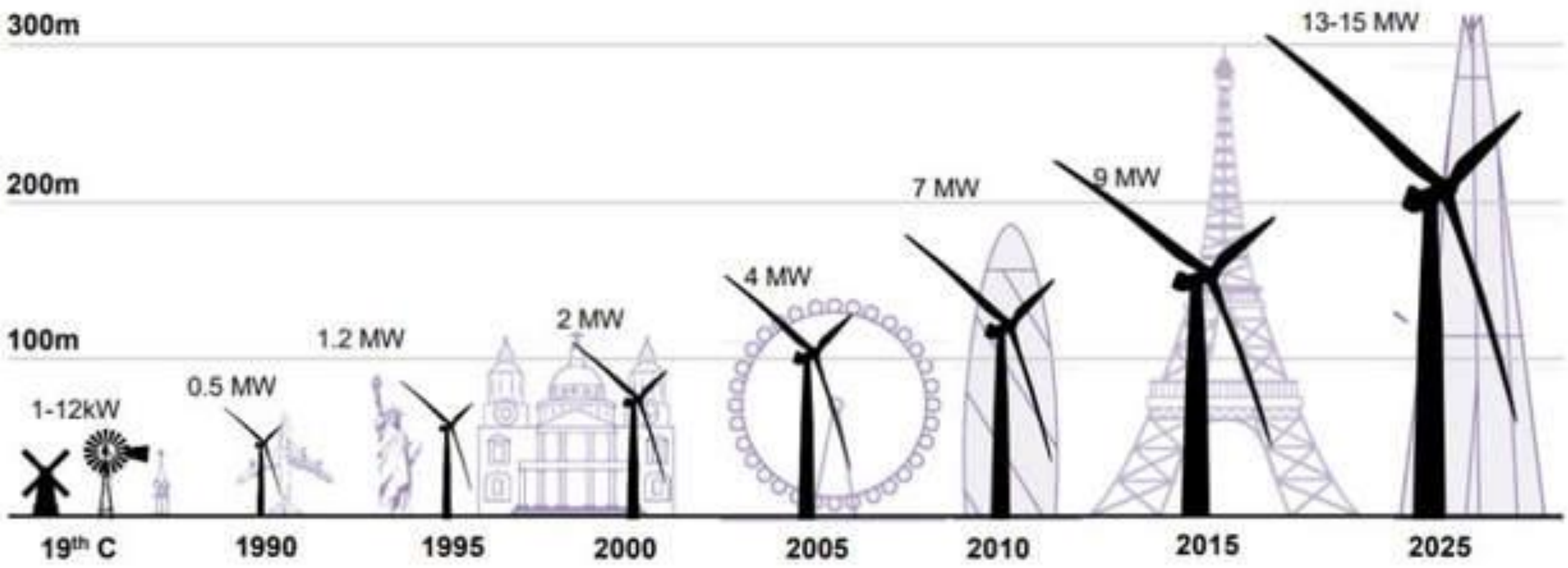

Wind Turbine/ Radar Impact Growth

Windfarm mitigation requirement evolution

- There is a global need windfarm/radar mitigation solutions: demand timelines depend on individual and regional windfarm market maturity
- UK, EU and many jurisdictions need potentially viable solutions to be identified in the next 1-2 years to meet windfarm development commitments
- Meeting the immediate needs for UK MoD air defence/offshore windfarm mitigation and onshore/ATC mitigation will provide reference solutions that can be replicated elsewhere
- Windfarm developers (notably Ørsted) and MOD are working together to create a variety of mitigation concepts – these are being evaluated for feasibility, viability and affordability
- We are seeking opportunities to test and evaluate radar suppliers capabilities (not just Thales) jointly with UK MOD

Demand-led, time-critical requirements

In UK >£30Bn of investment 2020-2030 at risk

- 11GW requires MoD ATC mitigation
- 15.7 GW requires MoD AD mitigation
- UK-ANSP (NERL) en-route requires 4.75 GW mitigation for three windfarms in Scotland
- Scotland requires 2.8 GW mitigation for five airports
- Moratorium on windfarm development in England and Wales likely to be lifted as shale gas 'fracking' developments will be suspended for forseeable future

In EU ~€300Bn of investment 2020-2030 faces increased risk

Eventually the existing radar estate must be upgraded/replaced with windfarm tolerant surveillance solutions

Complex business model

- Clustered solutions
- Multiple stakeholders
- Developers need through-life cost certainty

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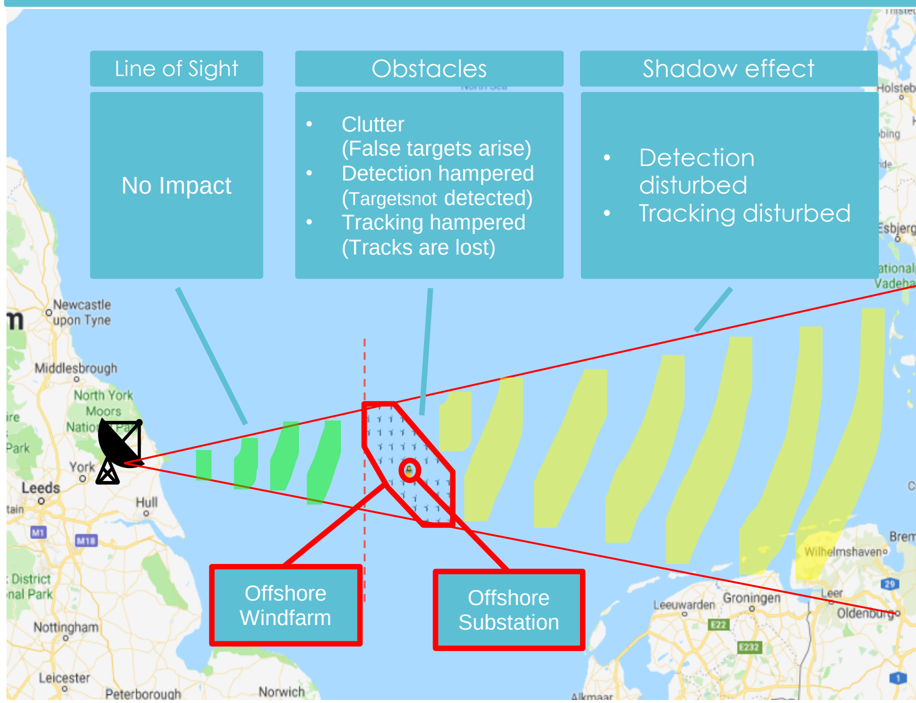
Concept Development… Understanding the issue

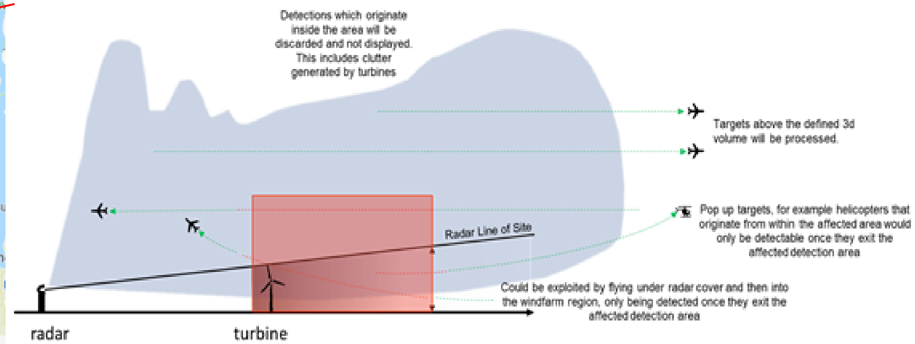
The unique impact and value proposition



Previously used mitigation

- The surveillance radar signal system has been adjusted to not allow new tracks to be generated within a 3D box of the radar coverage – this secures clutter from turbines does not generate tracks

3d Non-Auto Initiation Zones (NAIZs) Solution



A NAIZ is a defined zone in 3 dimensions within which plot extracted tracks are prevented from initiating, whist mature tracks are maintained and updated. It is established over the location of a wind turbine development and ensures that turbine blades do not create false tracks, but established aircraft tracks entering the volume continue to be updated. Targets above the defined 3d volume will be processed.
It is claimed the TPS 77 has 3d NAIZ capability, but exactly how well this works in practise is unknown.

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Typical onshore WFM Solutions

Infill

- using an existing radar asset;
  - e.g. using Berry Hill primary radar to mitigate Hallburn & Solwaybank Wind Farms at Spadeadam (the windfarms are impacting Deadwater Fell PSR but not Berry Hill PSR)
  - e.g. using an Inverness Airport radar feed to mitigate the impact of Meikle Hill Wind Farm on RAF Lossiemouth radar
- using new radar(s) specifically commissioned for this purpose;
  - e.g. Aveillant Theia radar to complement TPS77 over East Anglia 3 windfarm
  - e.g. Terma Scanter 4002 used to mitigate NATS CAS radars
  - e.g. 2 x networked C-Speed 'Lightspeed' radars deployed at Travis AFB (teamed with Harris)

Wind farm filters on existing or new radars (STAR-NG, BAES Watchman Upgrade)

Blanking of PSR sensor and use of Transponder Mandatory Zones and secondary sensors for ATC

Use of Tracker or RDP system to combine radar data from different radars to provide a combined ATC radar picture.

NB: These methods may be implemented in combination to provide robust windfarm mitigation solutions

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Example of Concept for meeting capability requirements Offshore WTG Foundation (TP) offshore perimeter

Characteristics of Concept

Deploy radar head or radar system on WTG foundation

- Radar is located at WTG foundation
- Could be rotating radar or fixed phased array
- Design integration to Foundation Design

The unique impact and value proposition

- The detect, identify, and track process chain becomes possible when adding the new radar system thus maintaining the RAP is enabled inside the OWF.
- The potential shadow effect and clutter is most likely mitigated as radar approach angle and height differs from that of existing radar.
- Designated air track ID maintained over OWF.

General considerations – for and against the value proposition

Pro:
Solid platform, easy accessible.
Cabinets inside foundation or micro shelter outside.
Cost of radar equipment
Maintenance
Con:
Site Protection and surveillance
Communication Infrastructure → Dissemination of data
Responsibility, ownership and maintenance of radar equipment.
General interface considerations both with own system and OWF
Data integrity considerations
Angle of beam may impact detection and tracking
Cost (WTG design integration with OEM)
Access points from SOV Walk-to-work potentially limited pending design.
UNCLOS/militarization of North Sea → Political/MoD issue

Examples of systems/equipment (operational test required)

- Terma Scanter 4002
- SAAB Sea Giraffe 1X
- Thales NS series

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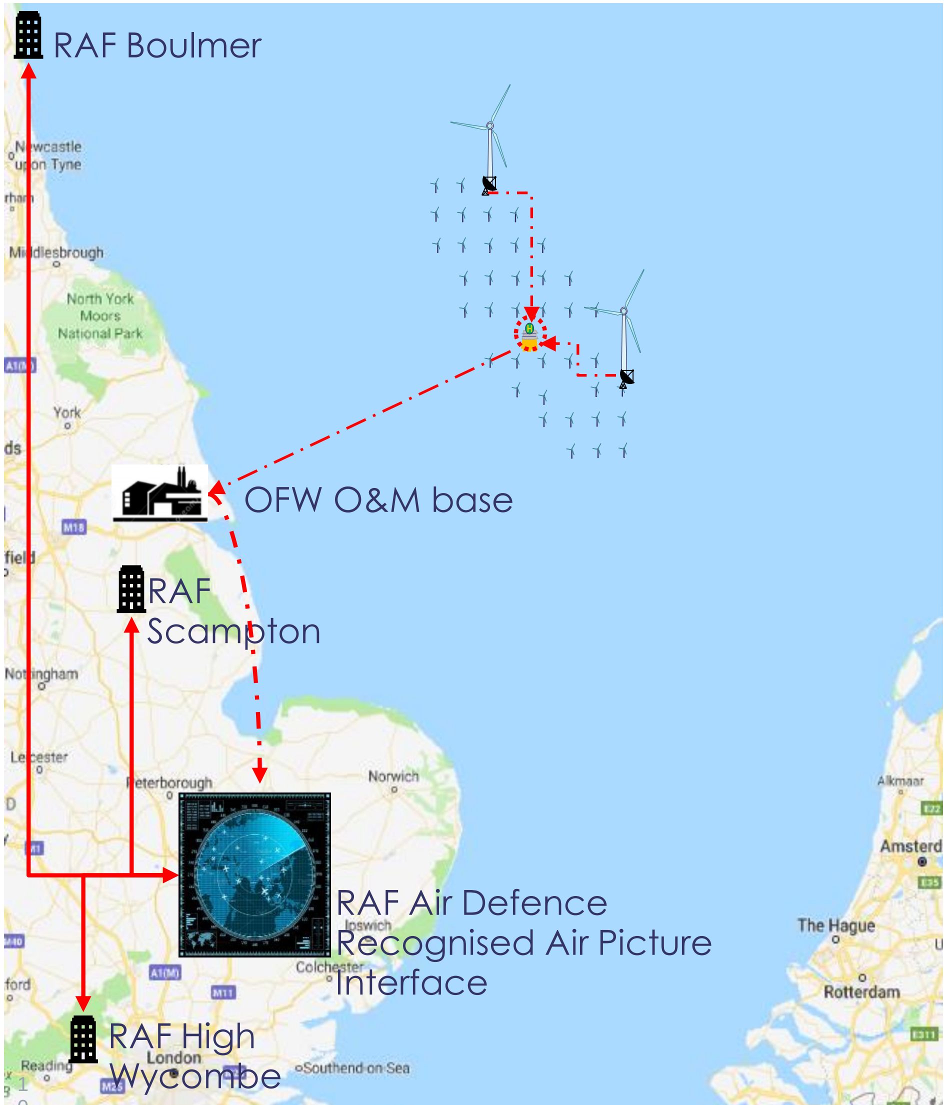
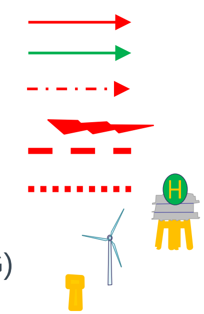
Example of Concept for meeting capability requirements Offshore WTG Foundation (TP) offshore perimeter



Explanation

Legend

Existing Secure Comms
Unsecure Communication
Fibre Optic Secure comms
Wireless secure (Link 16 etc)
Secure perimeter
New secure perimeter
Offshore Substation
Wind Turbine Generator (WTG)
Transition Piece (TP)



Concept

Deploy radar head or radar system on WTG foundation.
Red secure server room allocated radar feed on OSS.
Allocated secure fiber allocated radar feed in export cable.

Radar sensor give input to RAF Air Defence Recognised Air Picture (RAP).
RAP distributed to RAF Boulmer, RAF Scampton and RAF High Wycombe

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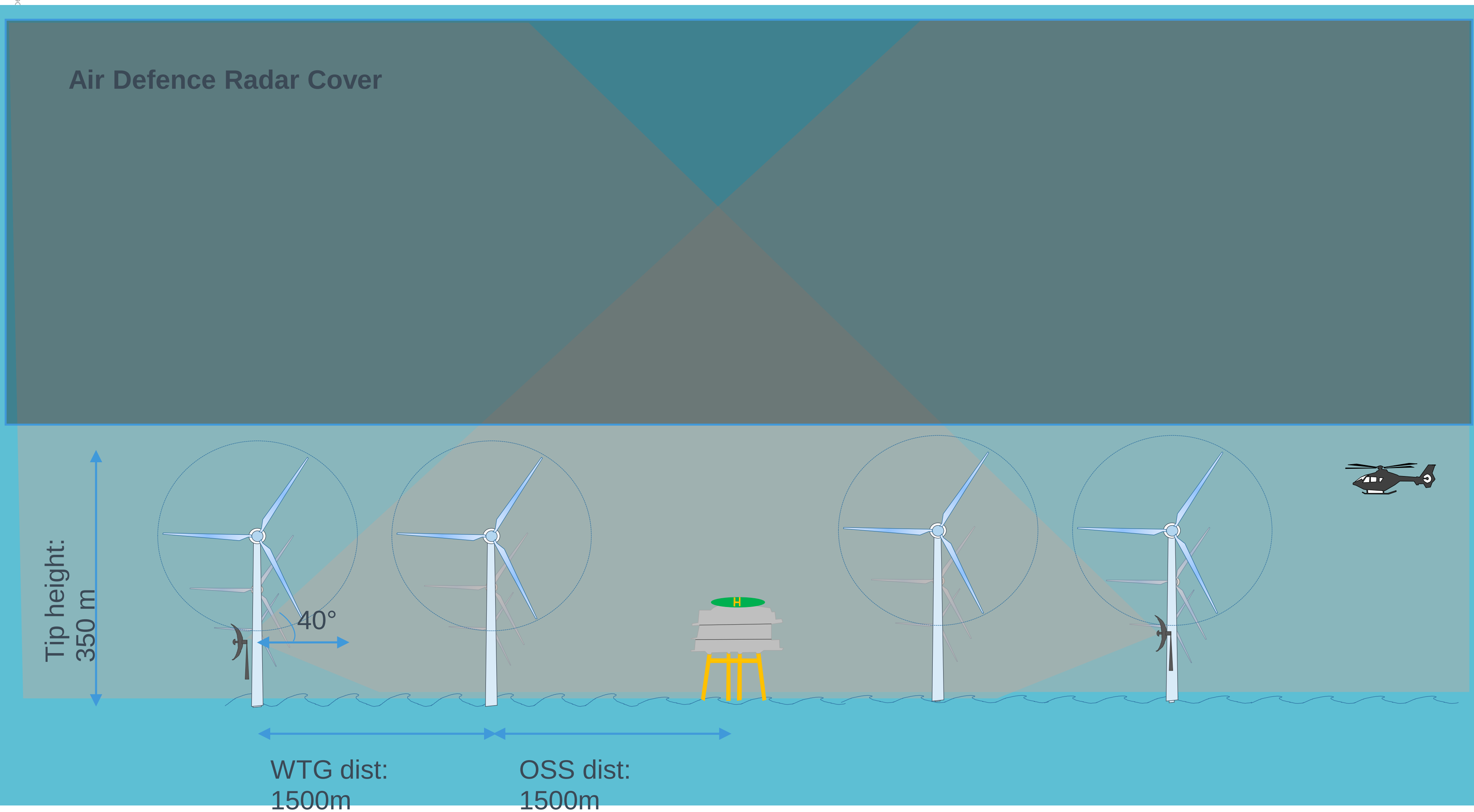
Example of Concept for meeting capability requirements Offshore WTG Foundation (TP) offshore perimeter



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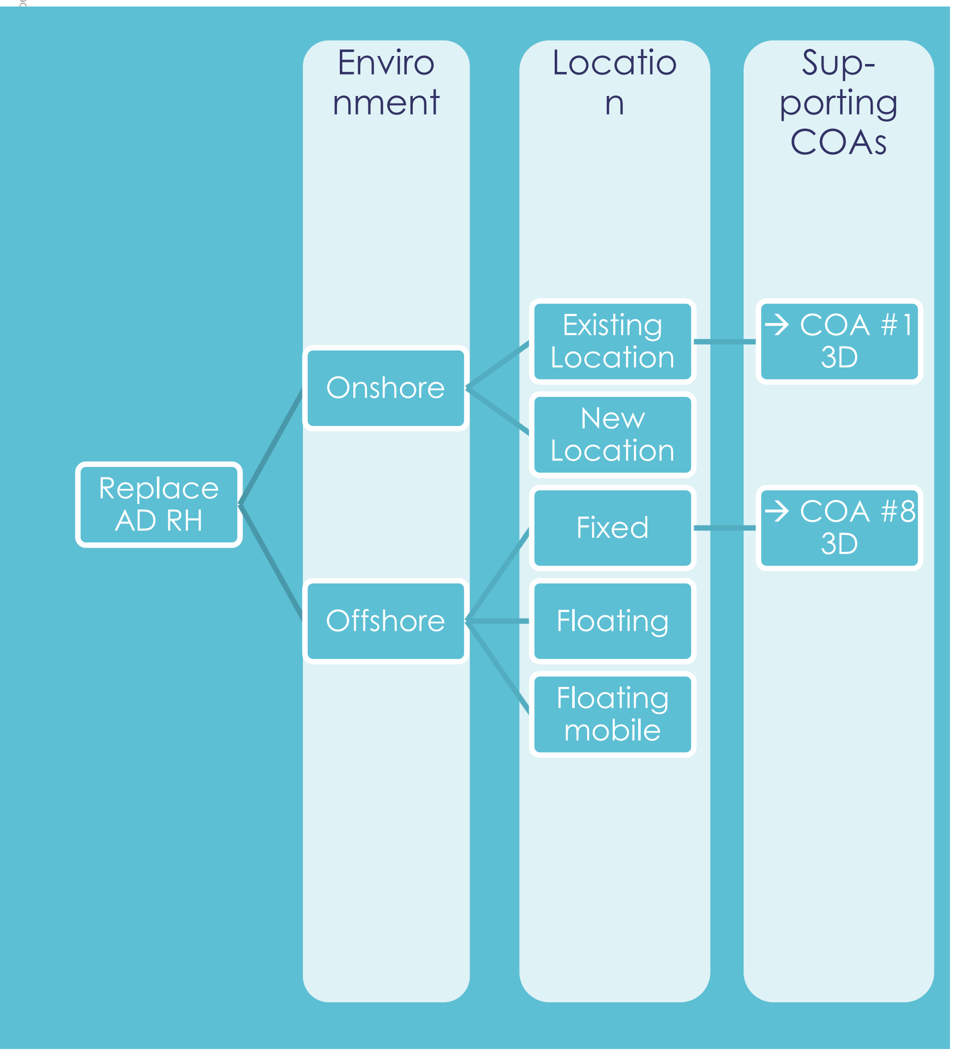
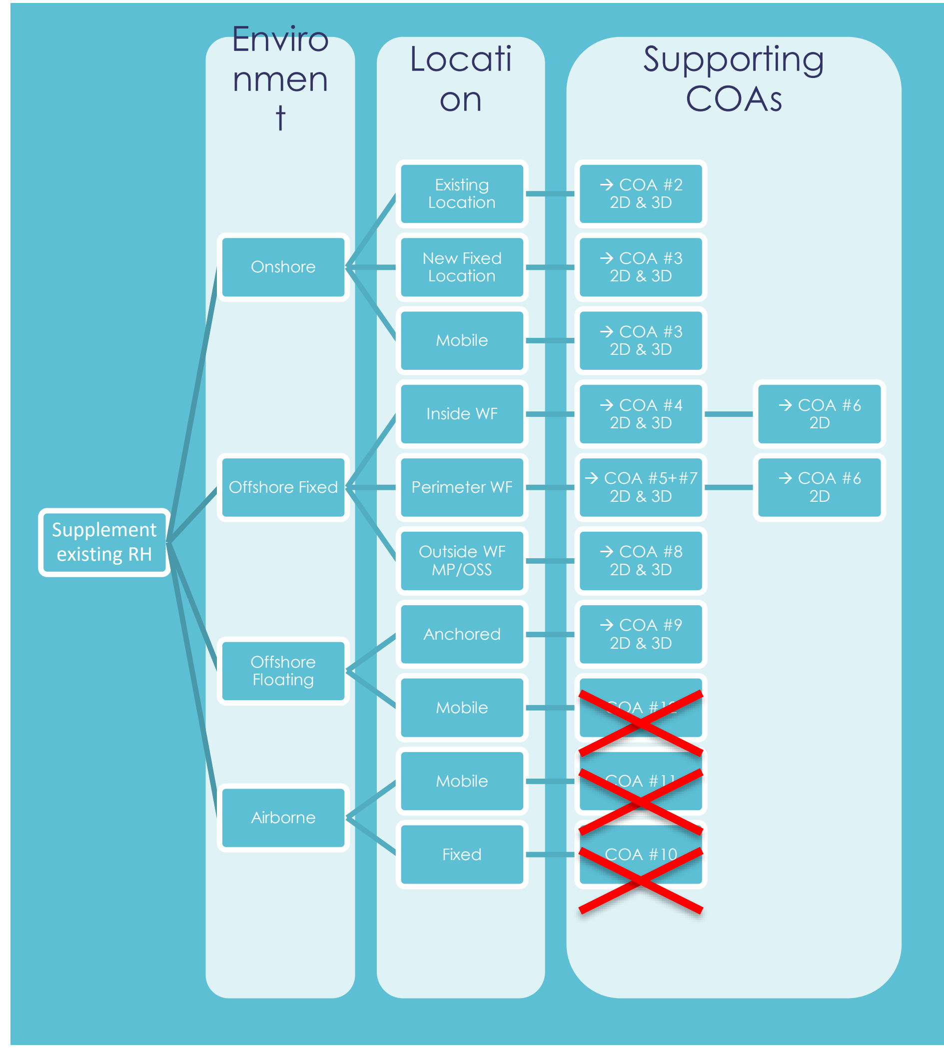
Two Scenarios: Update/Replace or Improve/Supplement existing Air Defence capability





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Capability Comparison Criteria

Comparison Criteria (Longlist)	Remarks & explanation
Overall Performance	
Effectiveness	How well does the Radar solve the task and mitigate the OWF interference
Supplementary capacity	Does the concept deliver full capability of the OWF cover and/or deliver extended RHLOS
Protection of radar head	Physical site security and access control - Fence/Water fence
Protection of data integrity	Threat both digitally and physically interference
Implementation Complexity	Changes in and to RAF systems and with OWF ie. technical risk development/low TRL
Performance Flexibility/Agility	How flexible is the system when implemented - can it be reconfigured, used else where, operative flexibility?
O&M	
Responsibility of asset	Needs definition and requires clarification --> who owns the asset ie. mixed responsibility or 100% RAF? Initially: 100% RAF owned = Good Shared ownership = Moderate
Operational Complexity	Simple to operate --> Good Complex to operate --> less good High technical complexity demands high training requirements. Low technical complexity demands little or none extra training.
System Availability	
Maintenance Complexity	Combination of required/needed maintenance and repair in relation to accessability and system complexity ie. 2D radar is simply changed - 3D radar needs onsite repair.High technical complexity demands high training requirements. Low technical complexity demands little or none extra training.

Economy - Low cost good, high cost bad	
Cost Development	Technology, Procedure, Organisation
Cost Implementation	Technology, Procedure, Organisation
Cost Operations & Maintenance	Technology, Procedure, Organisation
Implement	
RH location consent	Frequency allocation Electromagnetic emmission EIA
RH Access to Utility	Power HVAC SCADA Surveillance/Control Surveillance of asset Fire detection and suppression
RH Foundation	Structure
RH Support facilities	Perimeter surveillance Access control
RH Data Network	Closed wired network Secured wireless network (Link 16?) (Radio or satellite) Public or private fiber Multible or single string communication from RH to shore and redundancy
UNCLOS issue	The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea treaty.
Risk	
Performance Risk	What is the risk to main system components
- Risk to utility support	
- Risk to data integrity	
- Risk to RH integrity	

Capability comparison matrix

Comparison Criteria (Lengthy: Remarks & explanation)		WT (Level of significance)	COA 01 Onshore [illegible]		COA 02 Onshore Infill		COA 03 Onshore Mobile		COA 04 Offshore OSS		COA 05/07 Offshore WTG		COA 06 [illegible] Radar		COA 08 Offshore TP		COA 09 Offshore Floating	
Overall Performance																		
Effectiveness	How well does the Radar solve the task and mitigate the OWF interference	3	1	3	2	6	3	9	3	9	3	9	3	9	3	9	3	9
Supplementary capacity	Does the concept deliver full capability of the OWF cover and/or deliver extended RNLOS	3	1	3	1	3	3	9	2	6	3	9	3	9	3	9	3	9
Protection of radar head	Physical site security and access control - Force/Water Force	1	3	3	3	3	1	1	3	3	3	3	3	3	3	3	3	3
Protection of data integrity	Threat both digitally and physically interference	3	3	9	3	9	2	6	2	6	2	6	3	9	2	6	2	6
Implementation Complexity	Changes to and in RAF systems and with OWF i.e. technical risk development/low TRL	2	3	6	3	6	1	2	2	4	2	4	2	4	2	4	1	2
Performance Flexibility/Agility	How flexible is the system when implemented - can it be reconfigured, used elsewhere, operation flexibility	1	1	1	1	1	3	3	3	3	3	3	3	3	2	2	3	3
O&M																		
Responsibility of asset	Needs definition and requires clarification --> who owns the asset i.e. mixed responsibility or 100% RAF? Initially: 100% RAF owned = Good Shared ownership = Moderate	1	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
Operational Complexity	Simple to operate --> Good Complex to operate --> less good High technical complexity demands high training requirements. Low technical complexity demands little or none extra training.	3	3	9	3	9	3	9	2	6	3	9	3	9	3	9	2	6
System Availability		2	3	6	3	6	2	4	3	6	3	6	3	6	3	6	2	4
Maintenance Complexity	Combination of required/needed maintenance and repair in relation to accessibility and system complexity i.e. 2D radar is simply changed - 3D radar needs onsite repair. High technical complexity demands high training requirements. Low technical complexity demands little or none extra training.	2	2	4	3	6	2	4	2	4	2	4	3	6	2	4	1	2
Economy - Low cost good, high cost bad																		
Cost Development	Technology, Procedure, Organisation	3	2	6	2	6	2	6	3	9	3	9	1	3	3	9	1	3
Cost Implementation	Technology, Procedure, Organisation	1	2	2	3	3	2	2	3	3	3	3	2	2	2	2	2	2
Cost Operations & Maintenance	Technology, Procedure, Organisation	2	2	4	2	4	3	6	3	6	3	6	3	6	3	6	1	2
Environment																		
RH location consent	Frequency allocation Electromagnetic emission EIA	2	3	6	3	6	2	4	3	6	3	6	3	6	3	6	3	6
RH Access to Utility	Power HVAC SCADA Surveillance/Control Surveillance of asset Fire detection and suppression	1	3	3	3	3	1	1	3	3	3	3	3	3	3	3	3	3
RH Foundation	Structure	1	3	3	1	1	3	3	3	3	3	3	3	3	3	3	2	2
RH Support Facilities	Perimeter surveillance Access control	1	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
RH Data Network	Closed wired network Secured wireless network (Link 16?) (Radio or satellite) Public or private fiber Multiple or single string communication from RH to shore and [illegible]	2	3	6	3	6	1	2	2	4	2	4	3	6	2	4	1	2
UNCLOS issue	The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea treaty.	1	3	3	3	3	3	3	1	1	1	1	3	3	1	1	3	3
Risk																		
Performance Risk	What is the risk to main system components	3	3	9	3	9	2	6	3	9	3	9	3	9	3	9	2	6
- Risk to site consent		2	3	6	3	6	2	4	3	6	3	6	3	6	3	6	2	4
- Risk to data integrity		3	3	9	3	9	2	6	2	6	2	6	3	9	2	6	2	6
- Risk to RH integrity		1	3	3	3	3	2	2	3	3	3	3	3	3	3	3	2	2
Totals			59	110	60	114	50	97	58	110	60	116	63	121	58	114	48	89

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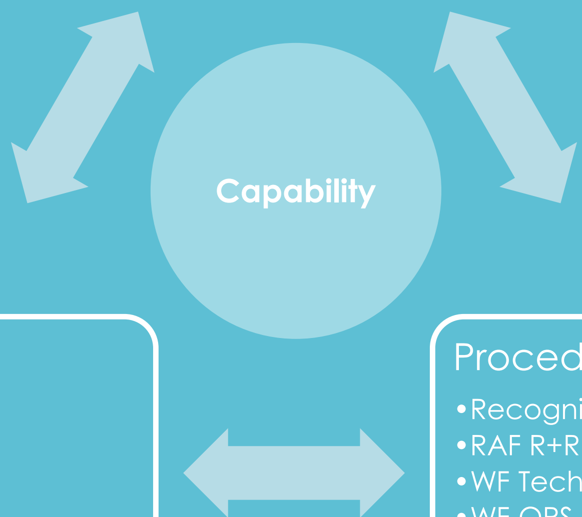
Capability Approach

TECHNOLOGY
- RH
- Signals process
- Data Network
- UK CCS/ Guardian
  - Signal
  - Control
- SITE → Structure, Utilities, Equipment surveillance

legend:

WF = Wind Farm

MHCC = Marine & Helicopter Control Centre



Organisation
- OPS Centre
- Management
- RAF Maintenance
- WF O&M and MHCC

Procedure
- Recognised Air Picture compilation
- RAF R+R
- WF Technicians
- WF OPS
- Maintenance
- WF MHCC

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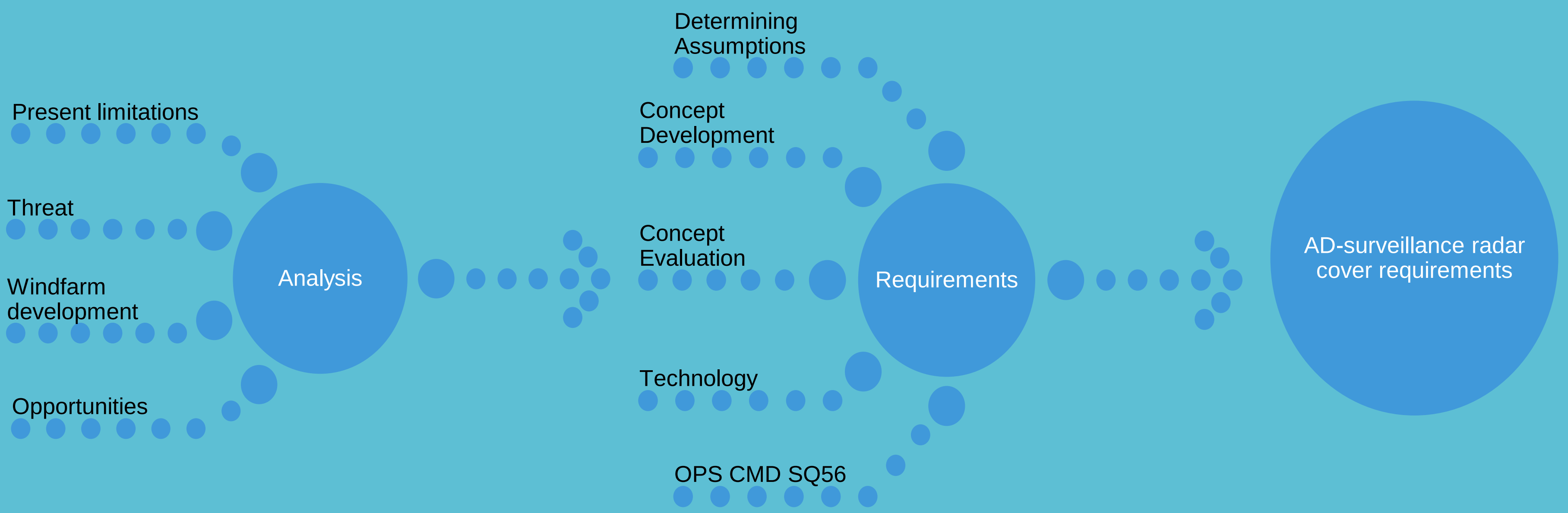
Process towards requirements



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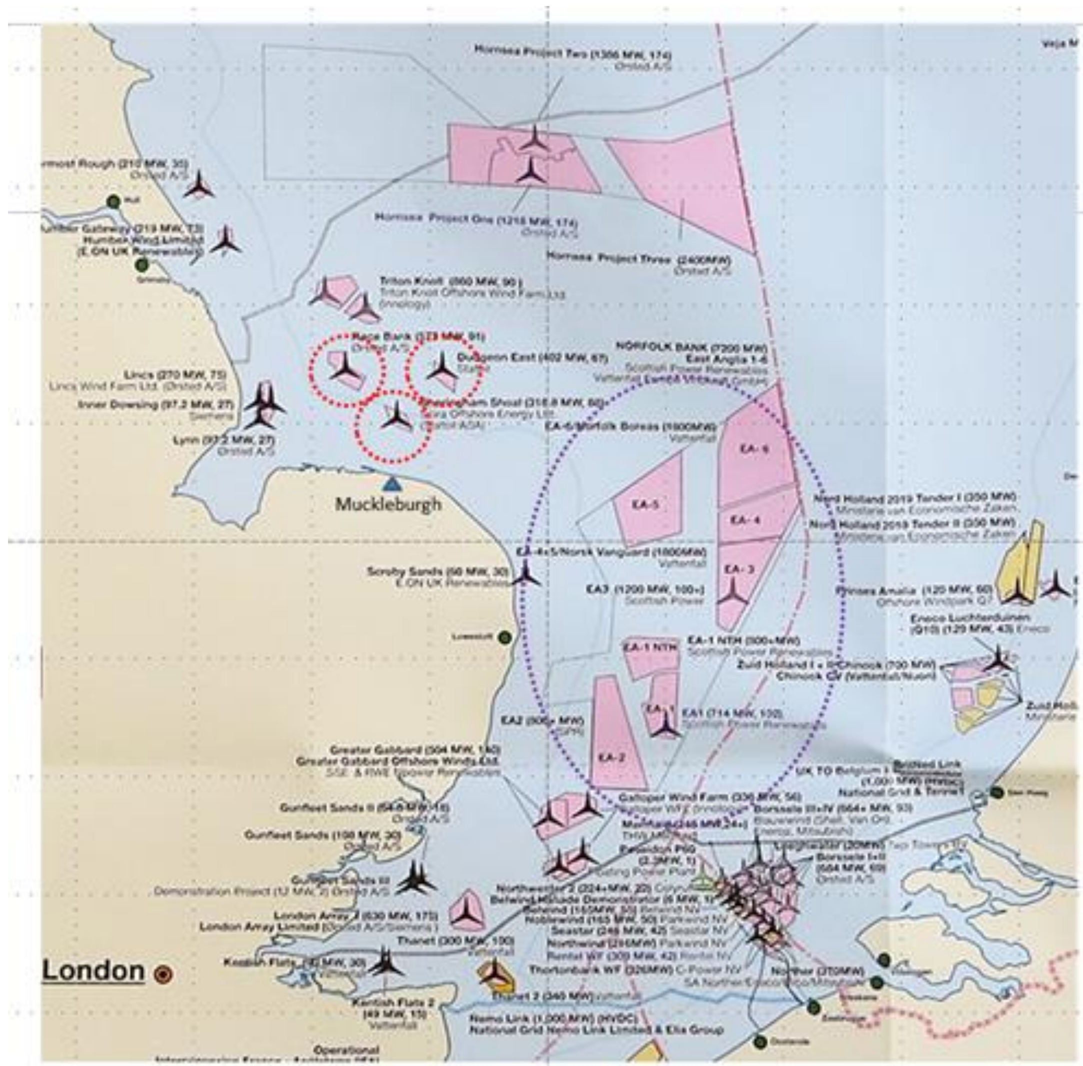
North Sea/East Anglia Zone – Proposed T&E locations

'Mucklebburgh windfarms':

- Sheringham Schoal
  - 317MW - 88 WTGs – 132m
- Race Bank
  - 573MW – 91 WTGs – 132m
- Dudgeon
  - 400MW – 77 WTGs – 190m

'East Anglia' windfarms, e.g.:

- EA1N & EA2
  - 2,300MW – 140 WTGs – 300m



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Next steps…

- Many jurisdictions do not have definitive requirements, so there is a wide variety of deployment concepts being considered, land-based and offshore, that have a range of costs and benefits
- Existing radar technologies can be adopted and adapted to provide effective mitigation in an offshore environment
- Test and evaluation is needed to select a range of solutions that are suitable for different situations – results should be shared
- Regional solutions should be considered: one system can serve a cluster of windfarms as a shared service
- Best practice should be shared between aviation stakeholders so that the industry can converge and obtain economy of scale-
- Dialogue between all stakeholders in a neutral environment is essential to establish trust – this is essential to make progress