An exciting and innovative project enabling radar friendly wind turbine energy.

THE CHALLENGE - Traditional radars think wind turbines are aircraft – they are unable to distinguish between them.

THE SOLUTION - Aveillant Theia Holographic Radar™, a radar surveillance technology which characterises both aircraft and wind turbines, reporting only aircraft to radar operators, eliminating the impacts of wind turbines on radar operations

PROJECT GREEN BLADE

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PROJECT GREEN BLADE

Introduction

Project Green Blade is working towards an open demonstration of a strategic solution to a persistent problem: how to "mitigate" the impacts of wind turbines on aviation radar.

It is relevant to many national and local stakeholders, such as government agencies, air traffic and air defence services, windfarm developers and energy suppliers. Any organisation that is experiencing similar issues will need to solve the same challenges that are outlined here, to enable green power and aviation to coexist without conflict.

Renewable energy generation is a key part of government policy to deliver clean growth: reducing greenhouse gas emissions, ensuring an affordable and secure energy supply and securing jobs and exports. Offshore wind farms have the potential to deliver much of this energy. A major obstacle to realising the full potential is due to the interference that wind turbines cause to existing defence and civil radar surveillance systems.

85% of UK public support the use of renewable energy for providing electricity, fuel and heat (BEIS Public Attitudes Tracker, Wave 25, 2018)

c. 13GW of UK offshore wind (Round 2 and Round 3 in construction, consented, in planning or scoping) still requires a technical solution to MoD radar objections, amounting to c.**65%** of the 20GW to be deployed by 2030 under the Offshore Wind Sector Deal (BEIS REPD July 2018 & 2017 RenewableUK/ AIFCL Aviation Survey)

To meet Scotland's 2030 energy target of **50%** of energy for heat, transport and electricity coming from renewables, Scotland will need 17GW of installed renewable capacity, up from 10GW in June 2017 (Scottish Government Energy Strategy)

A new, binding, EU-wide renewable energy target for 2030 of **32%** (i.e. for heat, transport and electricity), with provision for upwards revision by 2023

Governments around the world are looking to deliver clean growth:

- Reducing greenhouse gas emissions
- Ensuring an affordable and secure energy supply

Securing jobs and exports. Achieving clean growth, while ensuring an affordable energy supply for businesses and consumers, is at the heart of the UK's Industrial Strategy. It will increase productivity, create good jobs, boost earning power for people right across the country, and help protect the climate and environment upon which current and future generations depend.

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The Challenge

Radars and wind turbines

In short, primary radars think wind turbines are aircraft.

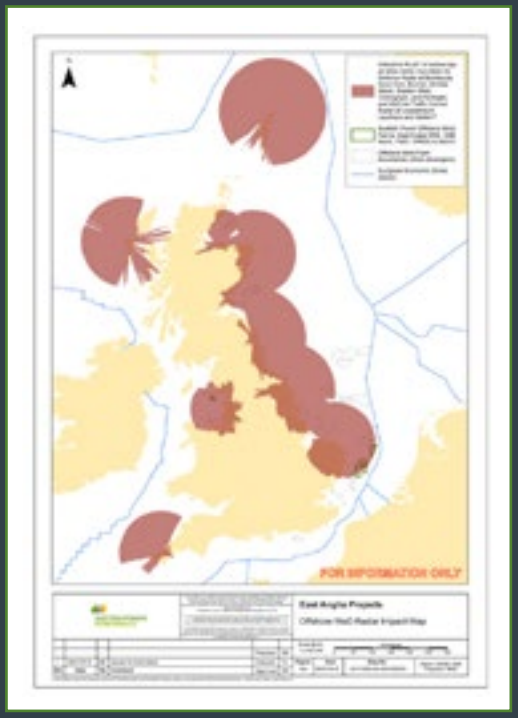
Primary radars are designed to detect moving targets – turbine blades move at equivalent speeds to aircraft, having similar / greater radar cross sections as aircraft.

Current military and civil air traffic control (ATC) primary radars are 2-D so cannot distinguish the elevation of the target and therefore differentiate tracks.

Military air defence (AD) PSR are 3D so are less impacted – but concerns remain particularly at low altitudes. This has led to national security concerns over wind farm deployment.

Applies to All Rotating Radar
Rotating Radar have limited time on target, resulting in insufficient target data to characterise targets (& so distinguish between wind turbines & aircraft).

MOD objects to wind turbines in radar line of sight
On grounds that wind turbine radar interference degrades MOD Air Defence and Air Traffic Control capability & that wind turbines continue to be “new” features in the built environment.



The MoD is more likely than not to object to any wind turbine in the red zones – this is where most of the UK’s offshore wind capacity resides

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The Solution

The Theia is unaffected by the windfarm rotor effect, so it is able to correctly and accurately display an aircraft track whether that aircraft begins to be tracked over (or within) a windfarm area, or has been tracked from outside of the windfarm area for some time previously and is now overflying a windfarm.

The Theia solution is scalable to meet different requirements of range and angular coverage. The radar does not need to be collocated with a standard rotating PSR, as it is a completely standalone system. It can be mounted in a variety of ways, including on a custom designed tower, to ensure it has visibility of the wind turbines which are affecting the PSR

The Theia output data is fed to a 3rd party unit (i.e. Cyrrus' Aerium™), along with the PSR output data and the unit deals with the integration of the two data streams. The unit may be located anywhere. Two units may be used in a dual-redundancy mode for additional robustness.

A polygon area is defined enclosing the windfarm area within the Integration Engin, and data from the PSR within the polygon is blanked out and replaced by data from the Theia radar. This combined data stream is then fed to the Controller presenting a completely seamless, fully integrated, clear and accurate picture of radar tracks with both the PSR data and the Theia data present, but no radar returns from the wind turbines.

More than one polygon can be defined to account for several separate and individual windfarms.

Ultimately, an entire chain of Theia's could be located at strategic positions along the East coast and networked together to provide a complete set of infill radars for all the offshore North Sea based windfarms for use by both civil and military users.

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The Project

Theia and Project Green Blade

Project Green Blade will continue to see enhancements to the Theia system, increasing both capacity and capability:

Phase 1– Range extension to 60NM with a 128-tile array

Phase 2 – Improving turbine resilience and aircraft dynamics, using 768 tiles in a 12-face array

Phase 3 – Will site the array to address East Anglia THREE and other WTFs

Theia and Project Green Blade Project Development Steps

EA3 Configuration
- Sector coverage for EA3, EA1N and EA2
- Standard modular construction
- COTS components

Proof of Concept
- Quadrant demonstration at Deenethorpe
- Range extension to 54NM
- Site at Muckleburgh for Sheringham Shoal

Product Specification
- 60NM range, 1m2 target
- Air Defence target specs?
- EW requirements?
- Communications & integration
- MTBF, maintainability, environment

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Theia Benefits

Theia: a key enabler for Project Green Blade

Highly configurable conical array with a range of up to 54 nautical miles and up to 360 degree Field of View.

Holographic Radar development is based on the goal of achieving a spectrum efficient, networked solution that can manage an extended airspace from ground level up to 60,000 ft.

Theia achieves immunity against wind farm false alarms

Theia is a next generation non-cooperative surveillance radar – new standards of performance (independently proven and field tested). Surveillance of ALL the volume and ALL the targets ALL the time

- Helicopter, propeller vs. jet plane, wind turbine
- Clutter free – wind turbines
- Spectrum efficient – L-Band, all HR units have the potential to use a single common frequency
- High update rate – Up to 4x/sec
- 3D radar – Position (x,y,z), velocity, detailed Doppler & target characteristics
- Seamless, simple integration
- Low cost of ownership -100% solid state, no moving parts or rotating joints

Theia 384 was designed to provide extendable hemispheric coverage using building blocks and a modular design approach

Theia is the technology underpinning Project Green Blade and will continue to see continuous development in:

- Target analysis/clutter discrimination (eg. aircraft vs wind turbines)
- 4D+ target resolution

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Theia Benefits continued

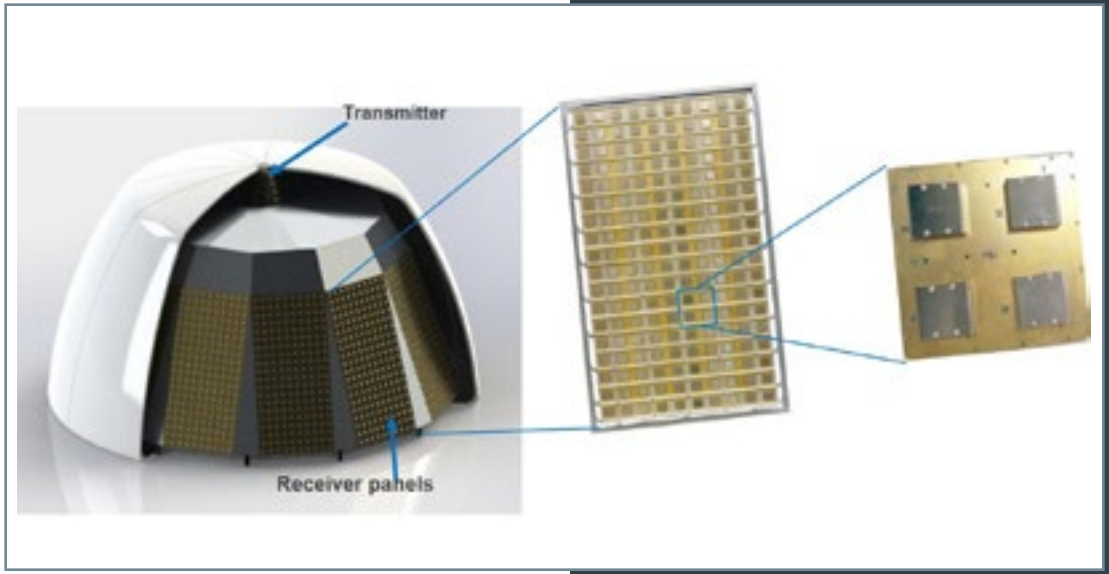
- Spectrum efficiency
- Networking capability
- Capacity and Resilience

Theia continually observes every object to determine if there is a target or clutter. Based on high resolution target characterisation, Theia determines whether the target is a turbine blade or an aircraft. If there is a turbine blade AND an aircraft, it will report the aircraft.

Theia – Innovative Technology

With range up to 40NM, and using its time- and frequency- domain signal discrimination, Theia's turbine rejection has been successfully and repeatedly demonstrated

Modularity is intrinsically embedded into the Theia system which has been assembled with 16, 64 and 128 receiver tiles. Considering the various climatic conditions that exist in offshore wind farm locations, L band is resilient to precipitation – essential for operational support across Britain's North Sea.



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Technology Review

Theia Holographic Radar

Sequential-scan radar is efficient in detection and positioning but inevitably yields intermittent (~1%) target contact.

Theia, an industry leading Holographic Radar technology yields 100% time on target and has been realised as a modular, configurable structure. Its fundamental approach is based upon Target Centric Surveillance using an advanced embodiment of Skolnik 'Ubiquitous Radar'.

It surveys its whole Field of Regard permanently instead of scanning a narrow beam around it.

Theia dwells on all targets, all the time, yielding information to characterise targets:

- Its sensitivity matches that of scanning radar
- It acquires continuous detail about each object
- It can be specified to acquire sufficient detail to resolve and discriminate each object type's dynamics
- Theia acquires all fine-motion detail in the Doppler spectrum
- Turbine motions are repetitive in fine detail
- Aircraft follow trajectories, or hover
- Doppler signatures are different
- Theia can therefore reliably differentiate the two, reporting aircraft but not turbines

Wind Farm Mitigation

What is the Problem?
Civil and military radars operate on the principle of detecting the reflected energy from a transmitted radar pulse, and also detecting the frequency Doppler shift of returned radar pulses. Any source of large radar pulse reflected energy and Doppler shift return that emulates the typical signature of a legitimate airborne target generates uncertainty, confusion on an ATC display and creates potential

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Technology Review continued

airspace safety and air surveillance security concerns. Wind turbines generate large radar returns and rotating wind turbine blades generate radar pulse Doppler shift and so are a source of interference or clutter on existing radars.

Aircraft – helicopters, aeroplanes or UAV/drones – can be indistinguishable within the clutter caused by the wind turbines. Track seduction can occur, where the aircraft track is displayed incorrectly as the radar confuses the aircraft and the turbine, or it may not be detected at all in the area around the turbines, known as shadowing and obscuration.

Holographic Radar™ clearly distinguishes between the wind turbines and the aircraft and feeds only the aircraft positional information without the turbine clutter to the airport radar. The Air Traffic Controllers will then have a consistent and accurate view of the aircraft the entire time it is over the wind farm.

How it Works

The distinguishing feature of Aveillant Holographic Radar's solution for wind turbine mitigation is that the surveillance capability is fully maintained at optimum performance levels while any wind turbines detected are not reported to the ATC system.

Aveillant's approach is insensitive to range and to the size or layout of current and planned wind turbine deployments. It does not depend on high cross-track resolution (which dilutes with range and is inevitable for a beam-scanning radar) or high-range resolution (that consumes radio spectrum).

It is also insensitive to the effects of beam side-lobes and their interaction with time-varying turbine signatures.

The Holographic Radar™ operates by successfully achieving aircraft/turbine resolution in both elevation and the Doppler domain. This does not degrade with range. It also benefits from a

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Technology Review continued

narrow spectrum, and is achievable because of the continuous dwell time that is available from a static, staring radar.

Wind Turbine Clutter Suppression
All ground clutter suppression, including wind turbines, is enabled by the very high-precision Doppler measurements and target histories provided by continuous target observation.

Wind turbine radar cross-sections tend to be in the region of 100-1000 square metres, whereas the minimum cross-section required for aircraft targets is 1 square metre. To discriminate aircraft from wind turbines without geographic desensitisation (which leads to reduced probability of detection and vulnerability to extended wind farm deployments), a processing gain of 30-40dB (a factor of 1,000 – 10,000, to yield a 10:1 signal-to-clutter margin) is required.

For a traditional, rotating Primary Surveillance Radar, both aircraft and wind turbine are sampled for between 5 and 50 milliseconds, and typically allow integration of between 10 and 200 pulses. This is insufficient to provide the necessary gain and cannot be improved with a narrow swept beam.

Holographic Radar™ acquires signals over a period of 0.5 to 2 seconds. An aircraft is observed over the whole of this time, compared with the duration of a turbine blade 'flash' of 20-50 milliseconds. At the same time, the 'flash' yields a Doppler spectrum spread (unevenly) over some hundreds of frequency 'bins'. This is sufficient to resolve aircraft from turbines even in the worst conditions.

This process is applied over the whole field of view. It is computationally demanding, but HR uses modern graphics processors which provide up to many TeraFlops processing capability (1 TFlop is 1012 operations per second).

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Sponsors

Project Green Blade has been pulled together by organisations with expertise in the sector. With both windfarm industry knowledge and aviation mitigation solutions, Project Green Blade has the essential ingredients to deliver a practical and cost effective solution to the challenges facing windfarm energy supply.

Wind Farm Developer and Operator

SCOTTISHPOWER RENEWABLES

Wind Farm Developer and Operator

ScottishPower Renewables is part of the Iberdrola Group, a world leader in clean energy with an installed capacity of over 29,000 MW, and the leading wind energy producer worldwide.

ScottishPower Renewables is helping to drive the Iberdrola Group's ambition of being the Utility of the Future and is at the forefront of the development of the renewables industry through pioneering ideas, forward thinking and outstanding innovation. Our ambitious growth plans include offshore windfarms in East Anglia with our team leading the Group's international offshore development.

With over 40 operational windfarms, we manage all of our sites through our innovative and world leading Control Centre at Whitelee Windfarm.

Radar Technology Developer

THALES

Thales knows radar! No1 in Europe and No3 in the world for civilian and military surface radar. Partner for the whole aviation/windfarm issue life cycle: Impact assessments, Trials and analysis, Mitigation solutions, Through life support.

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Holographic Radar Developer

AVEILLANT
A Thales company

Radar technology has been with us for over seventy years, yet many of the fundamental elements of radar design have changed little over that time. The vast majority of radars are based on mechanical scanning – a rotating antenna which sends out a pulse of radio waves, receives the echo and so can calculate the range and direction of a target. This gives the classic "blip" on a radar screen every few seconds.

Aveillant's Holographic Radar system differs fundamentally from both traditional mechanically scanned radars and from more advanced electronically scanned systems. Holographic Radar floodlights a volume of interest on transmit, and forms multiple simultaneous receive beams that fill the illuminated volume.

Aviation Technology Specialist

CYRRUS
Enabling Excellence in Aviation

Specialist CNS/ATM consultants with ISO 9001:2015 accreditation. Proven track record of providing innovative solutions to otherwise intractable Operational and Engineering problems.

A solution developed by Cyrrus is the Aerium which can take in multiple data streams, integrate them and output seamless data to displays in a selected format. The Aerium is to be used as the data integrator for the Theia in Phase 2 of Project Green Blade.

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