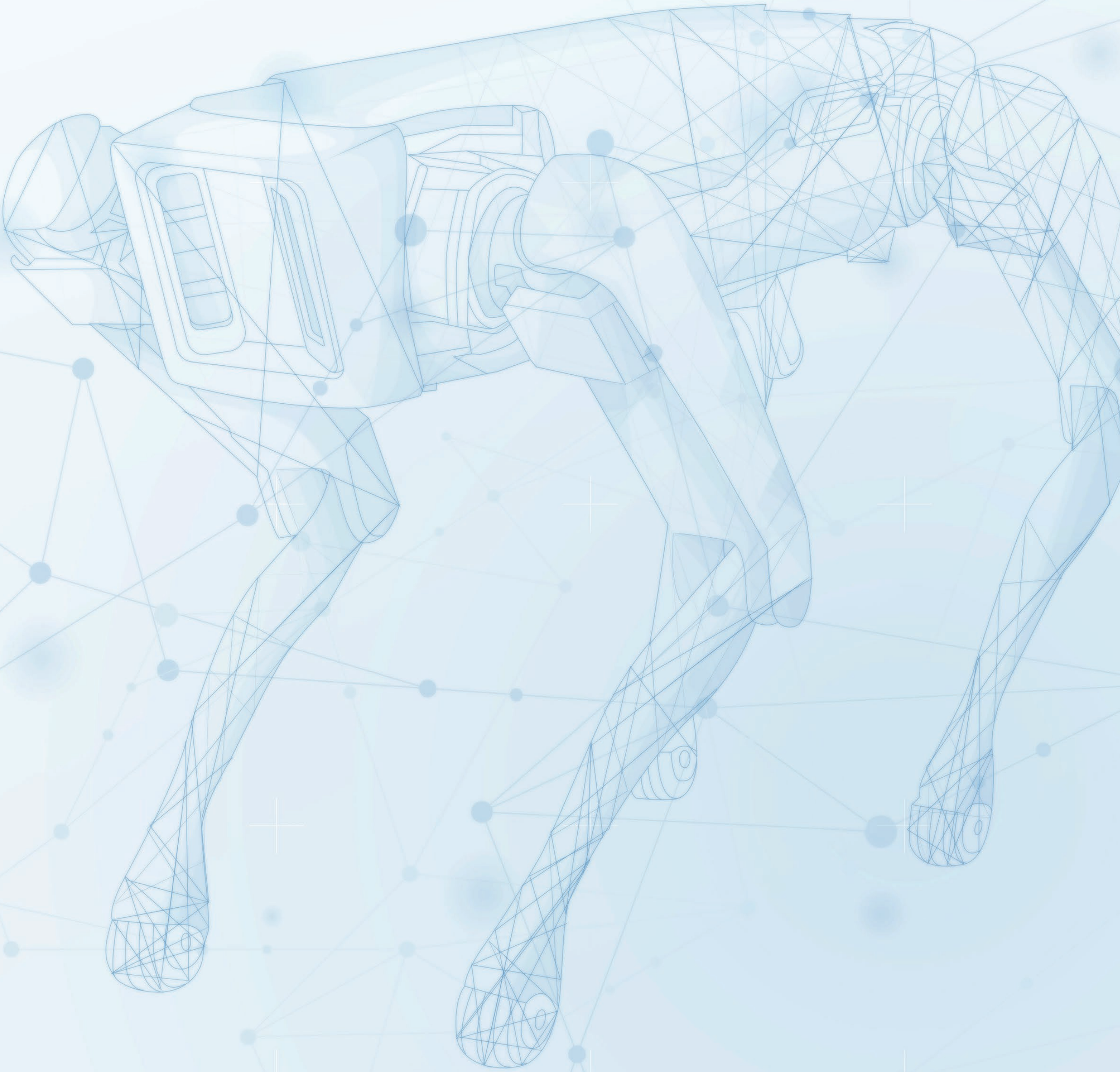
OLTER Offshore Energy RAS Report

NET ZERO TECHNOLOGY CENTRE



Net Zero Technology Transition Programme

Net Zero Technology Centre
Technology Driving Transition

OLTER NZTTP Programme

CONTENTS

1. PREAMBLE

This work is provided exclusively to OLTER by Drone Major Limited in accordance with the Terms and Conditions and Statement of Work detailed in Agreement SOS-048-V01 appended to Purchase Order Number 2256.

This is a time-bound study so where there are areas which are out of scope, but which is considered to be worthy of further enquiry, these have been highlighted.

We also note throughout where we have had difficulty in getting timely information from some of the potential contributors and where further enquiry might add richer insight and more depth.

The work has unearthed several lines of enquiry which might be worth further effort.

1.1 Intellectual Property

Where this report contains Intellectual Property that is owned by Drone Major Limited or one of its affiliates, that IP is clearly marked as such and, consistent with the Terms and Conditions of the agreement covering this work, Drone Major retains full and exclusive ownership of that IP.

OLTER does not acquire any rights or privileges over Background IP unless agreed in writing beforehand.

1.2 Scope

Drone Major has been tasked to deliver a landscape study designed to inform the future direction and activities of the Offshore Light Touch Energy Robotics and Autonomous Systems (OLTER) which was created to provide the benchmark for development and use of reliable, on-demand, standardised autonomous systems in the offshore energy industry.

Drone Major have canvassed OLTER officers and members, other experts, Government departments, industry bodies and companies across every lifecycle stage of the offshore energy industry and every sector of the drone industry to satisfy the following Requirements.

This paper[1] will examine the landscape study requirements as detailed in the contracted Statement of Work (SOWs). Drawing on the insights and recommendations of the study participants, Drone Major will provide the conclusions necessary to develop a possible strategy and roadmap for OLTER to achieve its aims and objectives.

Out of scope here but, within the context of RAS support to offshore engineering, the potential markets of wave and tidal energy should not be ignored.

[1] *Important Note: The report does not consider factors such as, for example, the impact of possible resistance to RPAS / MASS by Trades Union bodies*

1.3 Key Requirements

Key SoW requirements covered by this paper include:

- The current legislative environment with regards to the use of drone technology in the offshore air and maritime environment;
- The technological environment with specific focus on what is possible and where technology needs to advance;
- The challenges facing the offshore industry in the commercial deployment of drone technology;
- Possible ways in which the pathway to commercialisation could be expedited;
- Current, and where possible, future requirements for which RAS systems could be a solution (maritime, land and air) in the offshore wind industry;
- Challenges in the implementation of RAS systems (maritime, land and air) in the offshore wind industry;
- Requirements and challenges regarding data sharing and data use in the offshore wind industry;
- Identify and map other initiatives which are either covering some of the areas covered by OLTER or which could be complementary.

Reordering these requirements gives a logical flow for this report (note "RAS" always implies maritime, land and air (unless otherwise stated) and the "environment" is accepted to be offshore energy).

#	Requirement	Section
R1	Current and possible future applications for RAS in the offshore energy sector	4.1
R2	Challenges in the implementation of RAS	4.2
R3	Current legislative environment with regard to the use of RAS technology in the offshore energy sector	4.3
R4	The technological environment with a focus on what is possible and where technology needs to advance	4.4
R5	Requirements and challenges regarding data sharing and data use	4.5
R6	Possible ways in which the pathway to commercialisation could be expedited	4.6
R7	Identify and map other initiatives which are either covering some of the areas covered by OLTER or which could be complementary	Annexes A & B

Additional Requirements. Drone Major was asked to comment on the communications environment, particularly in the windfarm application.

2. EXECUTIVE SUMMARY

There are potentially high valuable applications for RAS in the offshore energy sector across a range of applications including surveying, logistics, inspection, security, and support to decommissioning across all domains (land, maritime and air).

OLTER must drive home the case that offshore engineering is a distinct application domain (i.e., requires specialist knowledge) and has a limited time frame (driven by competitors) to progress a "three thread" strategy based on developing its own strategic intent, managing stakeholders, establishing thought leadership and a development test bed.

The issues which face OLTER in this market sector are driven more by lack of understood, end-to-end, requirements than by regulation.

2.1 Findings

Each of the following "findings" correlates with a "requirement" from the Statement of Work, table 1.3.

2.1.1 Finding #1

There are clear areas where the use of RAS / drones could offer both hard and soft value, notably logistics, inspection, and surveillance / security. Whilst there are instances of RAS use, they are remotely piloted or supervised in some way; we couldn't find evidence of autonomous operation.

However, there is a lack of formal requirements decomposition from a credible, client-driven, use case. There is no evidence of an end-to-end business case, encompassing product and infrastructure, which would underwrite the validity of a service offering.

2.1.2 Finding #2

There are a range of complex and interconnected reasons which appear to be frustrating drone adoption, including lack of a business case base, lack of understanding of what is possible, risk aversion and an immature insurance market.

2.1.3 Finding #3 and #7

The legislative and stakeholder landscape is of extraordinary breadth, depth and complexity, ranging from Westminster and Holyrood Government departments through to global industrial entities, SMEs, trade and professional bodies.

CAA and MCGA are generally supportive and create drone and RAS legislation, particularly BVLOS, using both their own expertise and, crucially, information from trials enabled by CAA / MCGA risk analysis and funded / performed by various industrial groupings.

2.1.4 Finding #3a

There are many examples of industrial groupings, either clustered around a generic use case (e.g., medical logistics) or a drone agnostic offering, providing trial data to inform a RAS business case and influence the development of legislation.

OLTER has to press home the case that the offshore energy sector is domain-specific i.e., it requires specialised domain knowledge to avoid other parties encroaching on this market sector.

2.1.5 Finding #4

Without a formal decomposition of requirements from a credible, client-generated use case, specific technologies worthy of investment cannot be clear.

We assume that, where there are technology needs which arise from industry, then those industries will undertake the development. OLTER therefore seeks "market failure" opportunities.

The opportunity for OLTER would appear to be undertaking that high-level system engineering and the progressive creation of an enduring test / development facility which will form the basis for understanding issues (BVLOS being the obvious example) and specific technical areas such as reliable communications within a wind farm array, see 5.2.1.

2.1.6 Finding #5

There is no evident reason as to why commercially distinct entities would altruistically share operational, performance or health data unless they are contractually obliged (paid) to do so.

2.1.7 Finding #6

OLTER as a service provider would seem to offer the most attractive vein of enquiry with a number of sub-options. We note that there are elements of the academic option which might find synergy, creating a digital twin for example, providing the "glue" for an enduring trial programme and providing a route to trusted research undertaken by those with domain knowledge.

It may prove more practical to separate the "independent trusted advisor" role from that of commercialisation – realising commercial benefit – and taking risk – through the creation of, for example, services.

2.1.8 Finding (Communications)

If we can assume shore to service platform fibre, there are established techniques for satellite communications and private 5G networks which offer a definable LOS.

However, the effect of real-world interference from very close turbine blades and heavy current equipment is less that clear as are the provisions for multiple redundancy / denial of access.

The Cellnex trial under CAELUS will provide a useful reference point for the provision of remote 5G.

2.2 Recommendations

This report recommends that OLTER focus on the delivery of three principle and simultaneous "Threads" as follows:

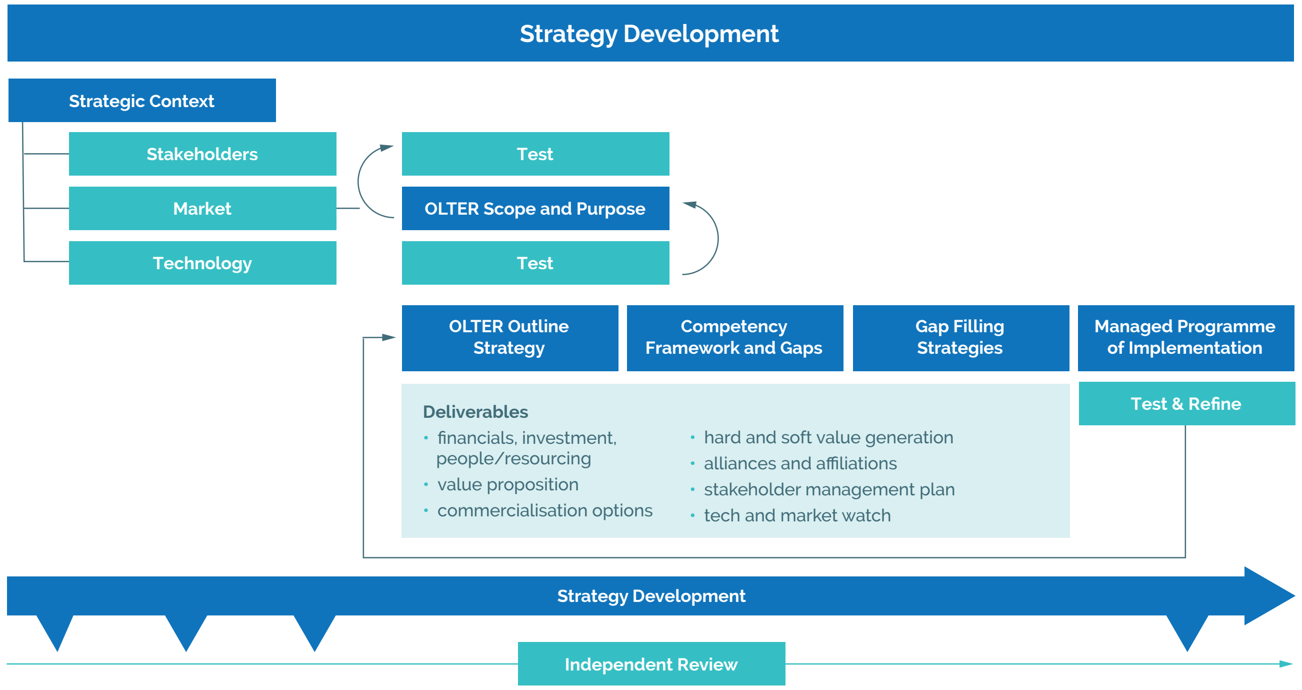
2.2.1 Recommendation #1

Thread One – Strategy Development – OLTER needs to be sure what it wants to be, for example:

- risk bearing and thereby profit taking;
- trusted advisor (to whom?);
- Not for profit;
- geographically bound.

In short, OLTER should establish:

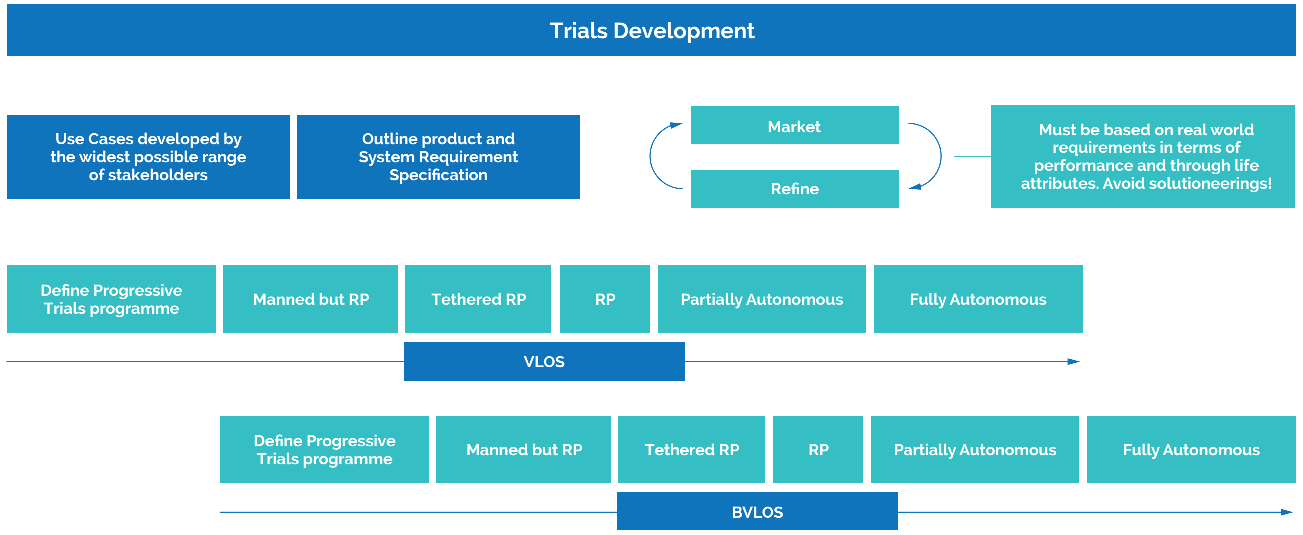
- a vision;
- mission and strategy (including capability gap analysis and plans organisational structure;
- business plans and KPIs.



2.2.2 Recommendation #2

Thread Two – Use Case, Requirements and Trials – On the assumption that part of OLTER's *raison d'être* is to be some form of a "corralling force" in offshore energy, OLTER needs engagement with prime contractors, tier one system providers and other entities, to facilitate: development of credible Use Cases; a formal decomposition of infrastructure and product requirements; market test and iteration etc. so as to create the environment needed to prove drone utility, help establish a regulatory framework and commercialise a service offering.

The Use Cases suggested by this limited and time-bound package of work would suggest attention is given to Logistics movement (shore to platform and inter array); above and below underwater monitoring and inspection.



2.2.3 Recommendation #3

Thread Three – Lobbying, Stakeholder Management and Thought Leadership – There is a high complexity of the stakeholder environment in terms of:

- Government ministries and departments (both Westminster and Holyrood);
- Industry (developers, Tier 1, Tier 2 and other service providers);
- Trade Bodies; and,
- Competitors – those who might aspire to a similar role as OLTER.

Out of scope here but – depending on OLTER's strategy – we might include Academia.

It is vital that OLTER has a leading understanding of the relationships and inter relationships across this diverse "client-side" and can effectively navigate through it to develop its (assumed) brand of an independent, trusted advisor.

Stakeholder Management

Government	Industry	Potential Sources of Competitive Advantage	OLTER – Lobby
• Scottish Gov Net Zero, Energy and Transport • Defra • BEIS • DFT • Gov Bodies: RUK, CATAPULTS, NZTC	• Competitors and those whose businesses might be negatively impacted by RAS • RAS providers • **PRIMES AND DEVELOPERS:** ORSTED, VATTENFALL, SSE, BP, SHELL, ENBW • **Tier 1s:** Siemens, Vestas, GE; Substations (DRAGADOS, EEW, SPFC, BLADT, SEAH, JDR Cables) • **Specialists:** FUGRO, A2SEA, Tideway, Balfour Beatty	• Academia • Specialist RAS	• Industry bodies, CBI, FSB, MAKE UK, IOD • Offshore Wind Trade Associations

3. LANDSCAPE ANALYSIS

3.1 Strategic Context

The strategic context in which offshore energy sits is referenced in UK's Integrated Strategic Review[2] (Global Britain in a Competitive Age) and enshrined in the April 2022 revision of the British Energy Security Strategy[3] which seeks, for obvious reasons, to repatriate energy supply to gain control of costs, reduce reliance on those who might seek to weaponise access to fossil fuels and transition to energy sources which don't involve the combustion of hydrocarbons.

Whether or not the commitment to renewables is only a "sticking plaster" to decarbonise the transition to nuclear is not clear and out of scope here. However, the Russian invasion of Ukraine has concentrated minds on the need for sustainable and reliable energy security which, in turn, reinforces the contribution from the energy sector.

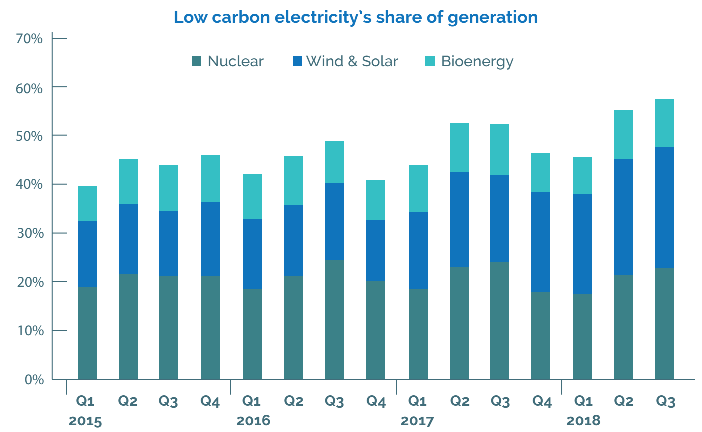
The general context of this report is offshore engineering, to include oil, gas and wind power.

There are estimates of around three billion cubic metres of oil and gas still to recover from the UK's offshore fields and forecasts that oil and gas will still provide two-thirds of total primary energy by 2035. Whilst most of this will be from existing rigs and installations, we note Deltic's and Shell's commitment to developing the Pensacola prospect in the UK Southern North Sea.

However, we also note that, whilst oil and gas have remaining life, the Intergovernmental Panel on Climate Change (IPCC), along with other climate and scientific expert bodies, conclude that emissions from fossil fuel combustion are the dominant cause of global warming. In 2018, 89% of global CO2 emissions came from fossil fuels and industry.

It is evident that the UK is in a (relatively) long-term transition from the oil and gas offshore industry to a wind-based industry. BEIS's own figures show that low carbon / renewable sources of power (including nuclear), contributed over 50% to the UK's total energy demand at the end of 2018.

Aside from developments such as Pensacola, the predominant Government, Industrial, Investor and new build focus will be on offshore wind, both monopile and tethered (FLOW). Whilst there might be value in offshore oil and gas, companies must bear in mind the negative impact on their balance sheet caused by reputational harm and damage to their ESG credentials.



[2] Global_Britain_in_a_Competitive_Age-_the_Integrated_Review_of_Security__Defence__Development_and_Foreign_Policy.pdf
[3] British energy security strategy – GOV.UK (www.gov.uk)

The authors are, perhaps optimistically, of the view that the wind farm industry is the more progressive energy sector and therefore more likely to be proactive in terms of adopting new technologies (such as RAS) which can be "built in" during the formative stages rather than be seen as a "rival" for established ways of doing things.

Whilst drones and RAS will have utility in the offshore oil and gas installations, and opportunities for investigation and possible development of a commercial offering should not be ignored as it will be a significant growth area of wind power generation.

3.2 Offshore Energy

Wind power sits within a portfolio of renewable energy sources and – in the context of carbon management – various CCUS initiatives.

Recognising the significance of Offshore Wind, HM Government published the Industrial Strategy Offshore Wind Sector Deal in 2019[4]. As a sector-wide partnership embracing all aspects of offshore wind to meet the then target of delivering 30GW of offshore wind by 2030, the deal includes several aspects which are relevant to this report. These include investment in research, development, demonstration, and driving innovation. The government has also committed to work collaboratively with the sector and wider stakeholders to address strategic deployment issues, including aviation and radar. Although the issues of aviation and radar are based on the need to identify technical and operational mitigations to remove barriers to the consent process, there are aspects with implications for offshore RPAS applications.

As a direct consequence of the Sector Deal, the Offshore Wind Industry Council (OWIC) established an aviation task force and workstream in conjunction with major stakeholders to progress air defence issues and secondly, civil aspects in relation to the provision of services and the communications, navigation and surveillance infrastructure in the offshore environment. The latter aspect will of necessity touch on offshore UTM and RPAS operations. This work is monitored by the Department for Business, Environment & Industrial Strategy (BEIS) Aviation Management Board with Ministerial updates as necessary.

3.2.1 The Cost of Offshore Energy

The Crown Estate's and Catapult's paper, penned by BVG Associates[5], provides an insight into the work breakdown structure and costs of every stage from securing initial planning consent through to decommissioning. Figures are difficult to reconcile but an "all up" figure of £1m/MWh LCOE seems a useful reference point. Costs of solar power are lower in comparison, but solar panels are less efficient and carry the knock-on cost of using farmland which potentially impacts food security.

Wind turbine lifetimes are limited to around 30 years[6] and decommissioning or repowering costs (financial and environmental) are non-trivial.

[4] *HM Government Industrial Strategy Offshore Wind Sector Deal 2019*

[5] *Guide to an offshore wind farm (thecrownestate.co.uk)*

[6] *lifecycle.pdf (ymaws.com)*

3.2.2 Offshore Energy and Net Zero

The case for wind farms as a zero-impact source of renewable power is not as clear as some might wish: benthic, pelagic, wildlife and other impacts all have an ecological cost along with portside construction and the currently low recyclability of materials used in, for example, blade manufacture. However, there seems little doubt that wind power will play a vital part in reducing both the environmental impact of reliance of hydrocarbons and those who might seek to control access to oil and gas. There is a clear HMG commitment to continue with anchored wind farm installations whilst expanding to geographically more dispersed floating wind farms[7] outside of UK territorial waters.

Wind power is, therefore, in "competition" with other renewables:

- primarily solar;
- hydrogen
- tidal; and,
- geothermal (and, in the limit, nuclear)

The industry must accept the pressure to continually develop differentiation and cost advantage.

The challenge to the industry is to demonstrate that pilot floating platforms are scalable and deliver against their expectations.

3.2.3 The Market

The offshore energy market is an attractive, high value, but risky marketplace.

Despite the contribution of wind being currently given as 10% of the UK's energy mix[8], solar and offshore wind are the fastest growing sectors of renewable power generation.

From Crown Estates own 2021 report[9], we copy the following summary, as position with which the UK and Industry should be rightly proud:

- Global offshore wind capacity in operation reached over 48.2GW, more than 20% of which was in the UK. By the end of 2021, the capacity of fully commissioned sites reached 11.3GW, an increase of 8% on the previous year.
- The average size of UK projects under construction is now 1GW, which is more than ten times bigger than the early projects awarded rights under offshore wind Leasing Round 1, held twenty years ago.
- Kincardine became the world's largest floating operational offshore wind farm, and Hornsea 2 – the largest site under construction in the world – started generating electricity.
- Sofia and Dogger Bank C projects achieved 'Financial Investment Decisions' and were granted leases in the first quarter of 2022.
- Offshore Wind Leasing Round 4 created the opportunity for at least 7GW of new offshore wind projects in the waters around England and Wales.
- 2021 ushered in an era of new floating wind technology in the UK, which has taken an important step forward with the announcement that 300MW of new projects have been given the green light, to progress to the next stage of assessment.

[7] *£60 million boost for floating offshore wind - GOV.UK (www.gov.uk)*

[8] *http://www.trade.gov/market-intelligence/united-kingdom-offshore-wind-market*

[9] *The Crown Estate's 2021 Offshore Wind Report reveals UK industry united in race to net zero | The Crown Estate's 2021 Offshore Wind Report reveals UK industry united in race to net zero*

3.2.4 Industrial Landscape

This is a high cost, high capex, long term market of value which attracts, at the upper tiers of the supply chain, high quality engineering companies and service providers with strong balance sheets and an engineering / project management strength and depth to deal with programmes of this risk and complexity.

The UK has proven to be an attractive market because of the Government's early commitment to carbon neutrality and specifically the "50GW by 2030" target, coupled with its inherent geographical and meteorological advantages, has created a strong attractor for inward investment and local development of capabilities.

This investment in UK-based businesses resonates well with the "Levelling Up" and post COVID "Build Back Better" agendas.

There is a neat "tiering" of the enterprise[10] and, whilst not exhaustive by any means, what follows is a minimal indication of OLTER's potential "industrial" stakeholder community. Each company will have business development, strategy, technology, and supply chain contacts which should at least be understood.

3.2.5 Developers

Ørsted, Vattenfall, SSE, SPR, Iberdrola, Innogy, Equinor, BP, Shell, EnBW, Eni, Grupo Cobra

3.2.5.1 Tier 1 WTG and Offshore Works

Siemens Gamesa, MHI Vestas, GE Renewable Energy, EEW SPFC, Bladt, SeAH monopiles, JDR Cables

3.2.5.2 Supporting capabilities

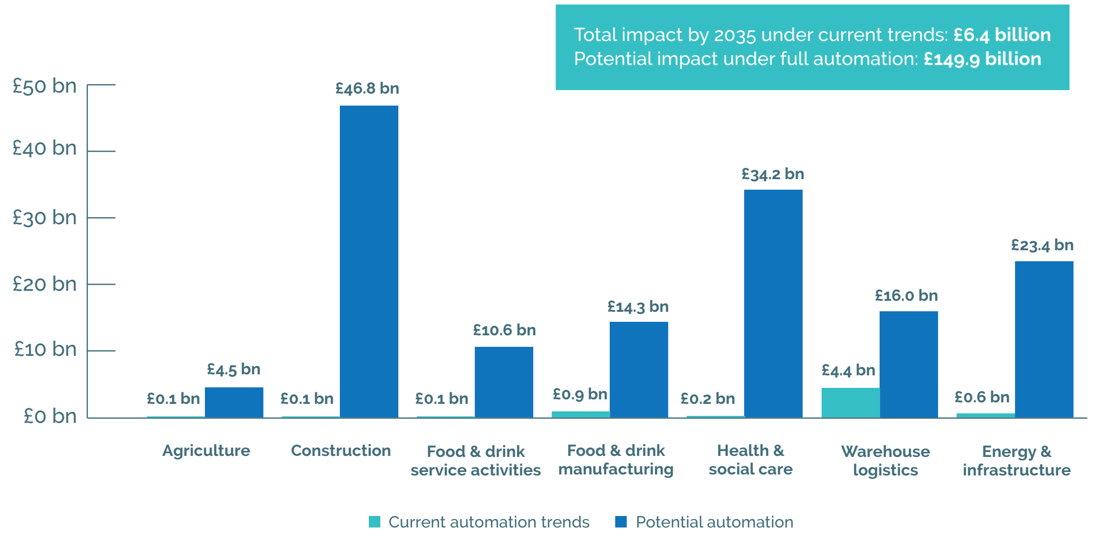
Monitoring, Guard boats, support vessels, rotary wind support etc

3.3 Robotics & Autonomous Systems (RAS)

The rise of drone[11] technology or RAS across all domains (land, maritime & air) is inevitable and there are many references to support this.

Industry leaders and groups[12] have been lobbying government and industry to ensure that a holistic systems view is taken: the issue isn't always the RAS per se, but the physical, digital and human infrastructure needed to ensure their safe and secure operation.

The London Economics 2021 paper[13], commissioned by BEIS some eighteen months earlier, takes an industrial sector view of the impact of RAS, albeit based on PWC's forecasts, and offers the potential Gross Value Added (GVA) that could be attributable to RAS, by 2035, if potential rates of automation were achieved.



Source: London Economics' analysis

The report offers a cautionary note "The comparison suggests that up to 39% of tasks in the energy and infrastructure sector could technically be automated by 2035, equivalent to an estimated £23 billion of GVA. Under current trends, however, RAS adoption is expected to result in the automation of just 1% of tasks in this sector, equivalent to an estimated £0.6 billion of GVA. This indicates a significantly lower economic impact of RAS than could be achieved if its automation potential was reached"

"In terms of Barriers to Adoption, the energy and infrastructure sectors encompass a wide array of different segments (such as offshore wind, oil & gas, nuclear, etc.), each facing their own distinct challenges. Nevertheless, major challenges include risk aversion in the sector and high standards for validation, driven by the critical nature of tasks and resulting high stakes of failure across many segments, as well as technical challenges presented by the complexity of energy and infrastructure projects. Policy cannot remove these barriers immediately, but it can support the proper networks and funding of research and development aimed at solving these challenges. Moreover, policy can also help by addressing the need for safety validation and the establishment of the right legal [regulatory][14] frameworks."

Within the offshore energy industry, the potential for exploitation of Remotely Piloted Air Systems (RPAS) capabilities, a subset of RAS has been recognised. Consequently, RenewableUK has incorporated this topic in specific aviation and wind conferences and workshops held in 2019 and 2020. Through the RenewableUK Aviation Working Group, guidelines on RPAS have been developed to assist wind developers[15].

It should also be noted that ORE Catapult embrace RAS within its workstreams including research, innovation, testing and validation, and supply chain growth. The organisation provides test, validation and demonstration facilities for robotics technology including data and digital integration.

The work is conducted through sites at:

- Offshore Wind Robotics and Autonomous Systems Centre, Blyth;
- Operations and Maintenance Centre of Excellence, Grimsby;
- Levenmouth Demonstration Site.

Given the ORE Catapult work across air, surface and sub-surface applications, there is a clear need to coordinate closely.

[10] *United Kingdom Offshore Wind Market (trade.gov)*

[11] *Drone – 'Any unmanned system that is autonomously or remotely controlled' – ISO 21384-4*

[12] *Examples include Drone Major and the Drone Delivery Group*

[13] *Economic impact of robotics and autonomous systems (RAS) across UK sectors (publishing.service.gov.uk)*

[14] *Author's insert*

[15] *Renewable and Unmanned Aircraft Systems Guidelines for Operators (RUGO) – Issue 1 – RenewableUK 1 January 2020.*

4. ANALYSIS OF REQUIREMENTS

4.1 Current and Possible Future Applications for RAS in the Offshore Energy Sector

The following section analyses a range of possible applications for RAS across the entire lifecycle of an offshore energy installation.

4.1.1 Offshore Energy Installation Life Cycle

Various sources, including RenewableUK's paper and material provided by BVG[16] in an ORE Catapult / Crown Office paper alludes to four distinct phases in the life cycle:

4.1.1.1 Scoping and Development

Including: Development and consenting services; Environmental surveys; EIAs; Resources and metocean assessment; Geological and hydrographical surveys; Engineering and consultancy.

4.1.1.2 Installation and Commissioning

Including: Foundation installation; Offshore substation installation; Onshore substation construction; Onshore export cable installation; Offshore cable and pipework installation; Turbine installation; Construction port; Offshore logistics

4.1.1.3 Operation, Maintenance and Service

We note that support to equipment (rigs, boring, wind turbines etc.) will likely be provided by the Original Equipment Manufacturer (OEM) but transmission assets will be owned and supported by an Offshore Transmission Owner (OFTO).

Including: Operations; Maintenance and Service

4.1.1.4 Decommissioning / Repowering

Including: Platform, drilling rig and turbine decommissioning or replacement; Any foundation decommissioning; Cable and Pipework decommissioning or upgrade / replacement; Support Platform and Substation decommissioning, upgrade, or replacement; Port decommissioning or upgrade; Reuse, recycle or disposal; Surveys

4.1.2 Potential Drone Functionality

Through discussion with parties[17] and desk-top research, it is considered that the following four groups of potential drone functionality which might be applied to each of the life cycle phases.

We note that, throughout, whilst drones may be in use, they are generally remotely controlled or supervised in some way: we could not find any credible reference to partially or fully autonomous operation.

[16] *https://guidetoanoffshorewindfarm.com/lifecycle*

[17] *Various conversations with, for example, BP, EnBW, drone companies engaged in trials in relevant domains.*

4.1.2.1 Logistics

This section covers surface or air transfer of goods and potentially staff from shore to support platform as well as support to "in array" operations. There may be some scope to investigate this further as part of a future work package but not enough to warrant attention here.

However, for installation and commissioning, operation, maintenance, serving and decommission / repower there would appear to be significant scope in providing both one-off or routine ferry services from shore to service platform or inter-array particularly where the reasonable repeatability of the tasks lends the work to RAS.

It is understood that Equinor have a Use Case in this area (air movement of emergency spares).

A review of possible Logistics Use Cases (preferably covering air, surface, regular ferries, and one-off movements) is recommended, working with as wide an array of stakeholders as possible.

These would inform the generation of Outline Requirement Specifications which would cover not only the platform requirements but also those of the infrastructure needed for safe and secure operation and support.

RenewableUK Aviation workshops and conference discussions[18] have highlighted that the offshore industry requires a multi-modal integrated logistics support which provides safe and efficient services. Costs are clearly a factor in how this can be delivered, but the perception of a lack of certainty and infrastructure and the need to progress developments within challenging timeframes and dealing with a multitude of implementation issues has constrained the appetite for innovative solutions.

4.1.2.2 Inspection and Monitoring

Remotely piloted drones already find ready application in support to EIAs, seabed inspection, dealing with UXO and similar work, most notably during the Scoping and Development Phase.

During Installation and Commissioning, Operation, Maintenance and Service and Decommissioning / Repowering, there could be requirements for a relatively frequent underwater presence to monitor seabed, marine life, cables, junctions, and other structures, particularly demanding over a large geographical extent.

Whilst use of a manned or RP surface vessel might be acceptable, there are no technical reasons why such a surface vessel, with its underwater drones, could not be fully autonomised, providing a near-continuous service. The Royal Navy, through its Navy X and other programmes, is having considerable success with autonomous towed array mine surveillance and countermeasures.

Above water inspection of blades and other components presents a challenge in terms of the existing use of manpower in a hazardous environment. Drones might be able to provide a means of regular surface inspection to identify potential issues.

Drones are ideal for near-persistent underwater inspection and monitoring of assets, cables, seabed, wildlife, habitat and other long-term variables.

The application of Remotely piloted Air Systems (RPAS) in the onshore environment to assist surveying, assessing, and collecting visual data for environmental impact assessments, and inspection of above water equipment is already being practised. However, this is within the context of remaining within visual line of sight of the RPAS operator.

[18] *RenewableUK Wind & Aviation 2019 Post Event Report November 2019*

4.1.2.3 Automation

Whilst there is most likely to be a role for automated drone applications to replace, or support, tasks which are hazardous (to operators) or costly, in the time available for this report, credible examples worthy of further investigation could not be found.

4.1.2.4 Surveillance and Security

There will be a need for continuous investment in maintaining and updating security systems both physical and cyber (digital and human), to stay ahead of emerging threats, security and resilience will need to be a central part in operational technology development and selection[19].

It is noted[20] that, in the aftermath of "damage" to Nord Stream, Norway's Petroleum Safety Authority has deployed drone detection equipment on offshore rigs, following a number of unaccounted drone sightings.

Whilst physical location might be seen by some to provide some level of insulation from military or terrorist activity, geography alone cannot provide a robust defence and this aspect is a serious consideration for offshore energy windfarm developers and operators.

For all but the initial scoping phase, drones, both above and underwater, have an unparalleled ability to offer wide area surveillance and data input to build a pattern of normal behaviour, provide safety to shipping and advanced warning of suspicious activity, particularly where manning levels are lower than normal due to progressive use of automation.

Again, this might appear to be a worthwhile line of enquiry in terms of developing a use case and an Outline Requirement Specification.

<table>
<tr><th></th><th>Scoping and Development</th><th>Installation and Commissioning</th><th>Operation, Maintenance and Service</th><th>Decommission or Repower</th></tr>
<tr><td>Logistics</td><td>Low opportunities, low value.</td><td colspan="3">High net value, relatively low operational risk: barriers to adoption include BVLOS regulation and a compelling, evidenced business case.</td></tr>
<tr><td>Inspection and Monitoring</td><td colspan="4">Relatively high value and low implementational risk: capabilities could form the backbone of an enduring service offering.</td></tr>
<tr><td>Above water</td><td>Minimal value – survey and visual impact assessments.</td><td colspan="2">Value in inspection of above water assets, rigs, blades and turbines, avoiding dangerous human deployment. Technical challenges due to sustained operation in a hazardous environment.
Some value in a near-automated, near-persistent, monitoring of sea-bed movement, pipe integrity, cable movement, impact on wildlife etc. Relatively low cost and low risk. Good "social" value.</td><td>Some value in "end of life" assessment and inspection.</td></tr>
<tr><td>Below water</td><td>High value for seabed, metocean and wildlife surveys.</td><td colspan="2">Some value in sub-surface inspection. Potential to avoid use of divers.</td><td>Some value in "end of life" assessment and inspection.</td></tr>
<tr><td>Physical Security</td><td>Limited value.</td><td colspan="3">Some value in boundary surveillance, augmentation to automated buoys to assure safe passage. low cost, low risk.
Some value in installation security and surveillance. Whilst the location of offshore energy installations might be thought of as inherent defence against attack, Russia's recent sabotage of the Nord Stream pipeline, in around 100 meters of water, illustrates the value of weaponizing energy supplies.</td></tr>
</table>

Summary of Potential Drone Functionality

FINDING #1

There are clear areas where use of RAS / drones could offer both hard and soft value, notably logistics, inspection, and surveillance / security.

However, whilst there are numerous "trials", there is a distinct lack of formal requirements decomposition from a credible, client-driven use-case.

Drone Major has been unable to find evidence of an end-to-end business case, encompassing product and infrastructure, which would underwrite the validity of a service offering.

[19] *Richard Westgarth, Head of Campaigns at BMT, 14th April 2020*

[20] *https://www.reuters.com/business/energy/norwegian-police-put-drone-detectors-offshore-oil-gas-platforms-newspaper-vg-2022-10-04/*

4.2 Challenges in the implementation of RAS

This section draws out some common themes from discussions with various stakeholders and a consideration of each "cell" in the Function / Lifecycle matrix in Section 7.

4.2.1 Technical

- Lack of awareness of what's possible;
- Identification of technical risks;
- Perceived difference between "domestic" drones applications and systems designed to operate in harsh, offshore, operating conditions;
- Durability of devices and systems;
- Achieving operational assurance.

4.2.2 Regulatory

- Lack of a regulatory framework into which, specifically, BVLOS surface and air operations might "fit";
- Although RPAS and BVLOS are acknowledged with the key airspace and regulatory programmes, the need for an integrated approach for all airspace users means the specific issues are addressed within the overall framework and timescales; and,
- A perception of complexity around this regulatory space and some evidence of risk aversion, perhaps caused by badly conducted unmanned vehicle trials.

4.2.3 Business/Economic

- Absence of a compelling business case or commercial incentive;
- Absence of a compelling cost benefit analysis / belief that that the final costs will be far greater than initial forecasts;
- Difficulties in monetising changes in soft value (job creation, reduction in CO2 emissions, removal of hazardous work etc.);
- Insurance market shortfalls; and,
- Concern that the costs of replicating the same functionality / assurance as a "trained pilot" on the aircraft or a "responsible person" on a ship, marginalise any assumed benefit from drones.

4.2.4 Behavioural

- Risk aversion on the part of the developer or operator;
- Shortage of ways of removing an "old way of doing something" and replacing it with a risk-understood "new way";
- Reluctance to be "first" in a relatively conservative, high-risk market;
- Lack of consideration of new possibilities that air/maritime drones enable (not just replacing existing tasks); and,
- Recognition that, although many support aspects are not considered optimal, there are many complex barriers to deployment which are higher priority.

FINDING #2

There are a range of complex and interconnected reasons which appear to be frustrating drone adoption, including lack of a business case based on a service offering, lack of understanding of what is possible, risk aversion and immature insurance market.

4.3 Current Legislative Environment with Regard to the Use of RAS Technology in the Offshore Energy Sector

This section lays out the operational complexity and the governmental / regulatory complexity and industrial complexity.

4.3.1 Operational Complexity – the scale of the problem

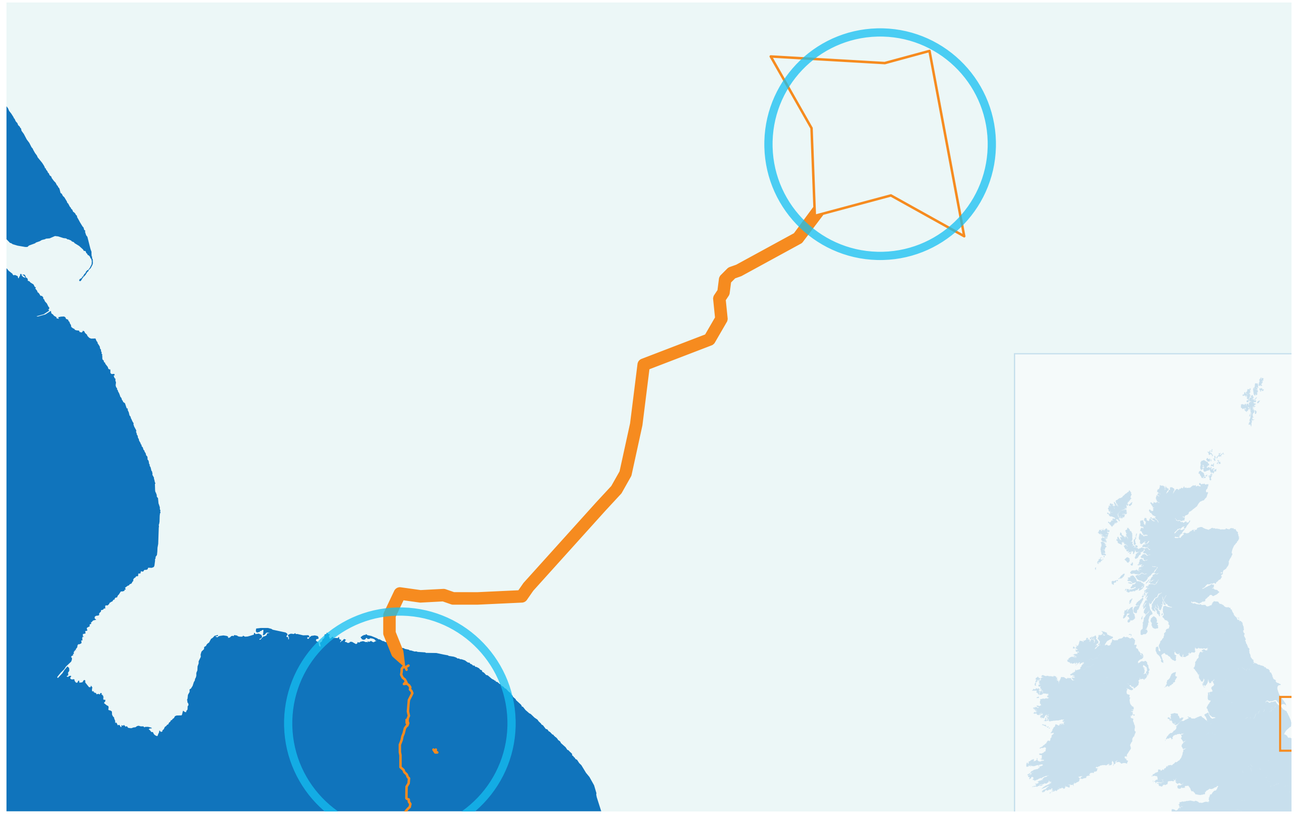


Figure 1. Hornsea Project 3, showing a 696 kms² windfarm envelope, cable corridor and onshore siting. Each blue circle shows the theoretical VLOS range[21] for an observer 30m ALAT (say in an ops tower on or a service / accommodation platform and a surface vessel. VLOS ranges move into the upper 10s of kms for air drones, depending on their altitude.).

[21] R-356lh

The physical / geographical extent of a windfarm installation will increase through the adoption of larger, floating, turbines at greater distance from shore.

Surface drones operated from shore will be BVLOS (assuming they are large enough and under favourable meteorological conditions) at around 20km for an observer at 30m elevation.

Air drones may be visible for further (because of their elevation), again assuming appropriate meteorological conditions and that they are large enough.

An air or surface drone operated from a notional 30m high service platform in the middle of a wind farm field of the size contemplated by Hornsea 3 ought to be visible.

4.3.2 Regulatory Bodies

In the 'Regulation for the Fourth Industrial Revolution' policy paper which was published in June 2019[22], the then 'Her Majesty's Government (HMG)' committed to the following with regard to regulation for the 4th Industrial Revolution.

"Facing the future

- We will establish a Regulatory Horizons Council to identify the implications of technological innovation and advise the government on regulatory reform needed to support its rapid and safe introduction.
- The Council will prepare a regular report on innovation across the economy, with recommendations on priorities for regulatory reform to put the UK at the forefront of the industries of the future.
- The Ministerial Working Group on Future Regulation, chaired by the Business Secretary, will oversee the government response to the Council's recommendations."

There is little evidence that these recommendations were enacted which is a lost opportunity bearing in mind the apparent lack of "front foot" thinking. However, it is likely that this is due to the attention placed on COVID 19 and lockdowns.

4.3.3 Regulatory Stakeholder Mapping

An understanding of the stakeholder environment is important, particularly if one of OLTER's options is to lobby for acceleration of regulation and / or the use of offshore wind as an extended test / evaluation capability.

Note – Annex A gives a more detailed overview of the current DfT, BEIS and DEFRA, highlighting stakeholders of interest to OLTER.

The authors experience highlights a further layer of complexity which underlies the apparent relative simplicity of the Government organisations. Secondments, joint working groups, a "matrixed" organisation, all add to the nuanced way in which the Departments function.

4.3.3.1 Department for Transport (DfT)

Aviation, maritime and security) are combined to one group reporting to Rania Leontaridi, the latter reporting to the 2nd PUS and therefore not a first line report (unlike, for example, Rail). This may be taken to infer a strategic imbalance across the Department.

We note also that Maritime and Coastguard Agency (MCGA) is organisationally separated from the Maritime Regulator – the International Maritime Organisation (IMO).

[22] *Regulation for the Fourth Industrial Revolution – GOV.UK (www.gov.uk)*

4.3.3.2 Business, Environment & Industrial Strategy (BEIS)

We note several posts of relevance to OLTER: two first line reports (Ministers of State for Climate and Industry) and six senior officers: Strategy and Policy; Energy and Security; BEIS' CSA; Science Innovation and Growth; Net Zero Strategy and, possibly, Energy Supply Task Force.

BEIS chairs the Aviation Management Board which addresses aviation related issues that are barriers to deployment. With cross-sector representation from government, wind and aviation, the work programme does not currently address RPAS issues but is prioritised with surveillance mitigation. However, this may include aspects affecting the offshore environment and may be a future body of interest.

4.3.3.3 Department for Environment, Food & Rural Affairs (DEFRA)

Whilst it's difficult, without a more intrusive and therefore longer-term investigation, to be sure of the respective "weights" of the Offices of State, it is noted that DEFRA, now under Thérèse Coffey (25th October 2022) have positions of relevance. Under the first line position of Director General (DG) Environment, Rural and Marine sit Environment Strategy, which includes Environmental Analysis Unit and Climate Mitigation and Adaptation, Marine and Fisheries. Various other posts have a tertiary bearing on issues such as the welfare of the maritime environment, food security and so on.

In addition, the Marine Management Organisation is a non-departmental public body which sits under the office of the Chief Scientific Advisor in DEFRA.

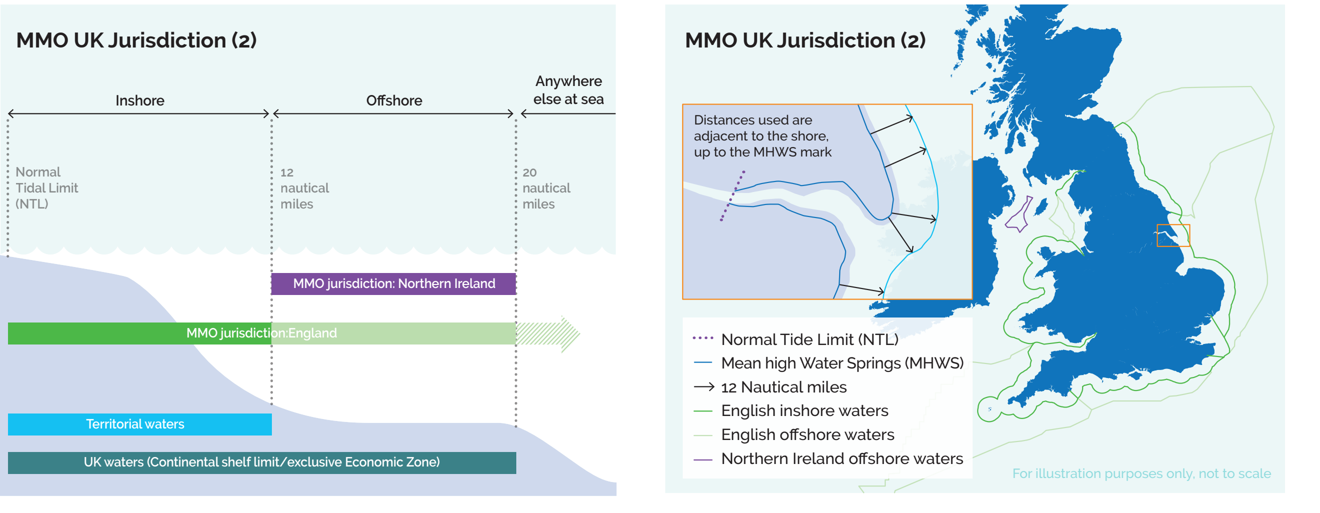


Figure 2 Marine Management Organisation is responsible for marine licencing in English and offshore waters.

The Marine Management Organisation's (MMO's) 2020 paper entitled 'MMO – the next ten years'[23]

"We will actively support government's huge ambitions in its 25 Year Environment Plan, including net zero carbon emissions by 2050 and protecting 30% of the world's oceans by 2030".

In addition, the "MMO's role in planning and licensing marine development is to deliver win-win-win solutions that protect the sea and deliver environmental, economic, and societal benefits. We are currently in the final stages of completing comprehensive, evidence-based marine plans that cover all our seas and coasts (an area almost twice the size of England).

[23] *mmo_the_next_10_years_web.pdf (publishing.service.gov.uk)*

These plans will become the definitive guide and planning framework for all marine development in the future. We've supported £27 billion of marine developments by licensing, permitting, and advising upon developments ranging from subsea cabling for telecommunications and power and offshore wind farms to ports and quay constructions, dredging and extracting aggregates for construction and transport infrastructure."

4.3.3.4 Scottish Government

Whilst air and maritime regulation are not devolved matters, Scottish Government does have devolved powers to cover leasing of seabed and licencing of works.

It is noted that the Scottish Cabinet has a Cabinet Secretary (Michael Matheson) for Net Zero, Energy and Transport, which would appear to encompass all the issues of relevance here. One of his support ministers (Lorna Slater) has a responsibility for Green Skills and Green Industrial Strategy.

It should be noted that Transport Scotland is closely engaged with the Energy and Climate Change Directorate to assist in aviation related issues affecting wind energy deployment. In this respect, Transport Scotland liaises with DfT on relevant issues.

There is a Marine Scotland Directorate, currently under the Management of Annabel Turpie (Director of Marine, Scotland) and comprising Mairi Gougeon (CabSec for Rural Affairs and Islands), Michael Matheson and Mairi McAllan (Minister for Environment and Land Reform).

This Directorate has a Sectoral Marine Plan for Offshore Wind Energy[24] which "aims to identify suitable plan options for the further development of commercial scale offshore wind energy in Scotland, including deep water wind technologies, and covers both Scottish inshore and offshore waters."

The Scottish Government is now developing a Sectoral Marine Plan for Offshore Wind Energy for Innovation and Targeted Oil and Gas Decarbonisation (INTOG), which encompasses spatial opportunities and the strategic framework for future offshore wind deployment in sustainable and suitable locations that will help deliver projects to meet the above goal and our wider net zero commitments.

"The Initial Plan Framework (IPF) outlines the process for development of the Sectoral Marine Plan for Innovation and Targeted Oil and Gas (INTOG) Decarbonisation. The IPF also sets out the areas that will be used for future seabed leasing."

4.3.4 Air and Maritime Regulation

The following sub-sections offer a synopsis of various desk-top research and conversations with government bodies and industry. There are undoubtably a wide range of opinions about what is actually happening, what should be happening and who is doing it.

However, in the UK, only the DfT can be the catalyst for appropriate policy and strategy to enable the effective regulation of the use of piloted, remotely piloted and autonomous vehicles, whether land, sea or air.

This work is being informed from a number of "professional" bodies, individual industries and industrial groups.

The burden of work for the foreseeable future appears to be the creation of trials or trial-type environments (the closer to real-world, lived experience, the better) to both develop the compelling business case for drone adoption and inform the process of developing regulation.

[24] *Sectoral Marine Plan for Offshore Wind Energy (www.gov.scot)*

It is well understood that BVLOS is particularly problematic, specifically in the areas of safety and assurance and whether or not the costs of the systems which provide that safety and assurance negate any perceived business benefit of drone adoption, noting the additional issue of monetising non-business benefits (use of greener equipment, supporting net zero etc.). Of import would appear to be the matters of conspicuity, detect, and avoid, clarity on "safe enough" (ALARP) and the range of "what if?" questions around, for example, network denial, failure of a support system.

The 'high ground', if such exists, is being taken by industries or groups of industries who are establishing programmes of technical work to develop the case for drone adoption and inform regulation. Some examples are given in 4.3.5.

4.3.4.1 The Air Domain

4.3.4.1.1 International Civil Aviation Organization (ICAO)

In summarising the regulatory framework, the first consideration is the role of the UN International Civil Aviation Organisation (ICAO) which sets the global Standards and Recommended Practices (SARPs) for aviation. This is promulgated through the Annexes to the Chicago Convention and specific manuals[25]. ICAO monitors State compliance through the Universal Safety Audit Oversight Programme (USAOP). However, States may file a difference to a specific requirement, but this must be supported by a substantiated justification. The operation of RPAS is within the ICAO remit to ensure safe operation and interoperability with all airspace users is achieved.

ICAO is currently in the process of developing international SARPs covering Remotely Piloted Aircraft Systems which are conducting international Instrument Flight Rules (IFR) operations within controlled airspace and from aerodromes. These SARPs fit into the Certified category of UAS operations and the appropriate UK regulations will be adapted in accordance with these SARPs when they are completed.

ICAO is not currently developing SARPS for the Specific category of UAS operations.

Although the UK is no longer a member of the EU, aviation standards and regulation are influenced by the work of the European Aviation Safety Authority (EASA) which has competency in aircraft and air traffic management (ATM) regulations. Additionally, EUROCONTROL, the European Organisation for the Safety of Air Navigation, of which the UK is a member, develops significant input on all aspects including RPAS.

Finally, EUROCAE is the European organisation for civil aviation equipment which develops industry standards for civil aviation.

4.3.4.1.2 Department for Transport (DfT)

At the National level, DfT sets out the national policy and strategy on behalf of the Government and sponsors the CAA. In 2018, DfT published Aviation 2050 – the future of UK Aviation outlining the planned approach taking into account future developments and environmental challenges. The COVID-19 Pandemic and its impact on aviation, together with the responses to the 2018 consultation, and the post-Brexit scenario have led to a fresh document "Flightpath to the Future" published on 26 May 2022.

> *"Flightpath to the future' is a strategic framework for the aviation sector that supports the Department for Transport's vision for a modern, innovative, and efficient sector over the next 10 years. This 10-point plan focuses on how government and industry can work together to deliver a successful aviation sector of the future."*

[25] *Examples are ICAO Annex 10 Aeronautical Communications Volume VI Communications Systems and Procedures relating to Remotely Piloted Aircraft Systems C2 Links, and ICAO Doc 10019 Manual of Remotely Piloted Aircraft Systems (RPAS).*

Within the document's 10-point plan, the strategy refers to the UK drone sector within capturing the potential of new technology and its uses. In addition, the Government is investing in initiatives to develop new technology, and trial and demonstrate new aviation uses. Key elements of direct relevance are the establishment of a Future of Flight Industry Group and the publication of a joint statement with the Drones Industry Action Group. This will set out the DfT commitment to deliver the necessary policy and regulatory framework to realise the economic, social, and environmental benefits for the sector.

As part of the Future of Flight plan, the Government will set milestones and targets for achieving routine beyond visual line of sight RPAS operations and advanced air mobility trials.

A key initiative which will impact the integration of RPAS is the Airspace Modernisation Strategy. The DfT has tasked the CAA with preparing and maintaining a co-ordinated strategy and implementation plan for UK Airspace up to 2040.

The DfT sponsors the CAA and provides guidance to the CAA through Ministerial Directions[26] and establishing the SoS priorities for the CAA in relation to specific aspects. These amplify the statutory obligations of the CAA in accordance with the Transport Act 2000 and its subsequent amendments.

4.3.4.1.3 The Civil Aviation Authority (CAA)

The CAA is established as an independent regulator for aviation sponsored by DfT. In addition to the Transport Act 2000 and Ministerial Directions, the key regulatory tool is CAP 32 The Air Navigation Order. This is supported by the relevant CAA publications which document the specific regulatory requirements for the diverse elements within the sector.

As the partner to DfT in delivering the Airspace Modernisation Strategy (AMS), the CAA has recently consulted on an update to the Strategy in the post-COVID19 scenario. This update will:

- extend the strategy out to 2040;
- place integration of all airspace users at the core of the strategy, including accommodating new aerial vehicles like drones, advanced air mobility and spacecraft;
- aim for simpler airspace design and supporting regulations;
- introduce sustainability as an overarching principle to be applied through all modernisation activities, including better managing noise and helping achieve government commitments to net zero emissions;
- align delivery of the strategy with the ICAO Global Air Navigation Plan and provide a clear strategic path for rulemaking activities, now that the UK has left the EU and the European Aviation Safety Agency.

The AMS is in the process of being updated based on the consultation results[27] and will comprise three parts:

- CAP1711 Pt 1 Strategy Objectives and Enablers
- CAP1711 Pt 2 Delivery Elements
- CAP1711 Pt 3 Deployment Plans (to be developed, tbc)

Within the AMS, a key output affecting RPAS operations will be that produced by the Integration Steering Group addressing the challenges of managing the diverse range of airspace users. In addition, DfT have funded a Surveillance Study Task Force, which is independently chaired, to address the surveillance environment requirements. A report has been produced and is currently at DfT awaiting Ministerial consideration.

[26] CAA (Air Navigation Directions 2017, CAA (Air Navigation) Amendment) Directions 2018 and 2019, and SoS DfT Priorities for the CAA 01 December 2020 (CAP2001)

[27] CAP2404 Outcome of the Consultation on a draft Airspace Modernisation Strategy 2022-2040 November 2022

Turning to specific RPAS regulation in amplification of the statutory regulations, the CAA has published and maintains the CAP 722 series:

- CAP722 – Unmanned Aircraft System Operations in UK Airspace – Guidance.
- CAP722A – Comps and Risk Assessment Methodology
- CAP722B - The Recognised Assessment Entity
- CAP722C – UAS Airspace Restrictions Guidance and Policy
- CAP722D – UAS Master Glossary and abbreviations
- CAP722E – UAS Rotary Wing Swarm Operations – Visual Line of Sight Requirements Guidance and Policy.

The CAA has also published briefings and documents on various RPAS related issues including the detect and avoid ecosystem for BVLOS in non-segregated airspace and information on the Regulatory Sandbox approach to BVLOS operations. Although not regulatory material, they are indicators to the CAA approach[28].

The CAA Innovation Team stands ready to work with those sectors developing applications for RPAS and autonomous systems and has a defined process for a formal approach for assistance[29].

It should be noted that the EU introduced Commission Implementing Regulations in 2019 are covering UAS operations. These have been updated and, as a consequence of the UK leaving the EU, are adopted into UK legislation[30]. Given the international context of offshore operations, these are relevant notwithstanding UK regulatory and policy initiatives.

ANO 2016 was amended on 31 December 2020 to accommodate the introduction of new regulations within the UK and EU on the same day. The amendment was published as a Statutory Instrument (SI) No 2020/1555[31].

Responsibility for these documents lies with the General Aviation and Remotely Piloted Aircraft Systems department which sits within the Safety and Airspace Regulation Group (SARG) of the CAA.

Note that the CAA guidance only concerns civilian UAS[32]: military systems are regulated by the Military Aviation Authority.

CAP 722 currently covers "guidance" for flights within VLOS, generally taken to be 120m above ground, out to a maximum range (assuming visibility) of 500m and outside of an FRZ. CAA approval of a safety case is required for flights which, whilst still VLOS, are outside of these limits.

PDRAs exist for some relatively straightforward VLOS operations with well-bounded conditions.

Regarding BVLOS, CAP722 requires DAA compliant with EU 923/2012, operation in segregated airspace and "clear evidence" that there is no threat to aviation and that safety of persons and objects on the ground has been properly addressed.

Operators in non-segregated airspace are required to flag the unmanned status to ATC, to be able to respond to all ATC instructions in a timescale comparable with manned aircraft and be able to immediately remotely take control of the aircraft. SSR, ground avoidance and compliance with IFR or VFR are required.

EVLOS requires that collision be avoided through the "unaided visual observation" of a human, either using additional observers and / or visually scanning a block of airspace for conflicts. Risk assessment is still required.

[28] CAP1827 BVLOS in Non-Segregated Airspace – Sandbox Call & CAP 1861 BVLOS in Non-Segregated Airspace: Fundamental Principles & Terminology

[29] https://www.caa.co.uk/our-work/innovation/submit-your-challenge-to-the-innovation-team/

[30] EU Commission IRS 2019/947 and 2019/945.

[31] CAP2013 – The 2020 Amendment to the Air Navigation Order 2016 – Guidance for Unmanned Aircraft Users

[32] CAP 722D

Most of the operations contemplated here would fall under the "Specific" category, which means that the UAS operator must hold a CAA issued authorisation, which, in turn, needs an operation specific risk assessment.

Some may fall under the "Certified" category, which is analogous to piloted flight and for which regulations are still being developed.

Quote from The Drone Rules….

"The United Kingdom's UAS regulatory framework has been affected by a number of significant changes to government such as the withdrawal process of the United Kingdom (UK) from the European Union (EU) and therefore from a requirement to inherit and align to some of EASA's regulatory components such as the SORA."

The SORA contains the requirement to conduct BVLOS operations.

BVLOS Operations do currently take place and have taken place with Unmanned Aircraft in the UK Specific and Certified Category. This has been ongoing for a considerable number of years for which some have supported from a technical and training standpoint. However these are not routine apart from large Unmanned Aircraft such as watchkeeper (utilising the MAA BVLOS framework – RA1600 series), and additionally this would now be classified as the Certified Category.

In the Specific Category, there have been successful trials of BVLOS operations. This included sees.ai to trial a concept for routine BVLOS operations, to prove the concept ahead of potentially opening it up to industry. The data gathered from that operation was essentially to inform the CAA and the DfT with credible information that could shape regulation and guidance going forwards. At the time of writing, there is no published 'public' plan to go from (current) manned operations through to remotely piloted (BVLOS) ops, however there is guidance with a generalised legally enforceable regulatory framework, ANO (Air Navigation Order). It is important to note that the more BVLOS trials are introduced to the UK's ecosystem the better informed and potentially faster the CAA guidance and/or UK laws are realised.

The CAA has a plan, and is working to develop this, facilitated by industry pressure due to the relatively passive regulatory progress in comparison to neighbouring countries. However that being said, most companies have supported over the past year have attained an Operational Authorisation in both the UK and Ireland in the areas of close proximity VLOS, EVLOS and high mass operations (400kg+) and more in the Specific Category.

In addition, there is also a considerable difference between a fully autonomous BVLOS operation and a Remotely Piloted semi-autonomous BVLOS Operations. The latter is easier to attain of course based on CAP722. This is possible to do now based on guidance documentation from the CAA and the use of Operational and manufacturing British Standards, to which you will receive an Operational Authorisation which becomes a 'legally enforceable document underpinned by proper associated and related standards'."

4.3.4.2 The Maritime Domain

The Maritime Environment in the UK falls under the Maritime and Coastal Agency (MCA), the overarching strategy being captured in "Maritime 2050, Navigating the Future[33]. MCA formed MARLab (Maritime Autonomy Regulation Laboratory) which published the final report[34] in November 2020.

Amongst other recommendations the newly formed MFT (Maritime Future Technologies) team was established by MCA to "facilitate the implementation of trials and projects, support regulatory updates and drive forward change in industry in the uptake of innovative technologies in both Emission Reduction and Autonomy". The issue of BVLOS, one of 10 post MARLab workstreams, is the subject of a PhD at Southampton University, specifically to read across any best practice from CAA.

[33] *Maritime 2050 – Navigating the Future – Executive summary (publishing.service.gov.uk)*

[34] *Maritime Autonomy Regulation Lab (MARLab) Report – GOV.UK (www.gov.uk)*

From reference[12] "The 'MARLab' brand, which has been embraced by industry, will transition to Maritime Future Technologies where all the work is fully embedded. MFT will be the interface between MCA and industry for specific projects, providing the facilitation and support elements to ensure UK MASS industry are able to successfully get their projects on the water with suitable certification…further work to consider and address legal barriers for larger and fully autonomous vessels, and engagement with the wide range of stakeholders [which][35] now form the day-to-day business of the MFT team." However, it appears that MFT (which received most, if not all, of its funding from Innovate UK) ceased to exist and most of it is subsumed into the Survey and Operations branch of MCA.

The MCA is currently going through a consultation process on Workboat Code Revision 3[36]. Critically, this code includes updates which allow remotely controlled vessels (not full autonomy), hybrid and full electric vessels. This code is applicable to vessels in commercial use under 24m in length and carrying less than 12 passengers (or industrial personnel).

If the vessel is designed to carry more than 12 Industrial personnel, then it will need to comply with the High-Speed Offshore Craft Code and the High-Speed Offshore Service Craft Code (HSOSC)[37]. At this stage, this code has not been drafted to include any provision for autonomy or remote operation.

Informal discussions with MCA and related stakeholders confirm that there is a cautious but positive approach to Remotely Piloted Vessels but a real – and understandable – nervousness about anything which claims to be fully autonomous.This confirms the widely held notion of the need for an incremental approach, perhaps over decades, particularly
in high-risk environments.

Quote from the Maritime and Coastguard Agency (MCGA) – 31st October 2022

"In terms of existing legislation governing MASS of various forms; SI 1998 No. 2241 – The Merchant Shipping (Load Line) Regulations as amended apply to United Kingdom ships wherever they may be and to other ships while they are within United Kingdom waters, except:

a) *ships of war, naval auxiliaries or other ships owned or operated by the United Kingdom government and engaged only on governmental non-commercial service;*

b) *ships solely engaged in fishing;*

c) *pleasure vessels;*

d) *ships which do not go to sea (e.g. those which remain within categorised waters);*

e) *ships under 80 net tons falling within one of the classes specified in paragraph (2) engaged solely in the coasting trade, and, subject to paragraph (3), not carrying cargo –*

f) *new ships of 24 metres or more in length engaged on an international voyage; and (These are covered by SI 2018 SI 2018 No. 0155 – The Merchant Shipping (International Load Line Convention) (Amendment) Regulations 2018)*

g) *existing ships of 150 gross tons or more engaged on an international voyage."*

[35] *Author's insertion.*

[36] *The Merchant Shipping (Small Workboats and Pilot Boats) Regulations 2023 - GOV.UK (www.gov.uk)<https://www.gov.uk/government/consultations/ the-merchant-shipping-small-workboats-and-pilot-boats-regulations-2023*

[37] *www.gov.uk)<https://www.gov.uk/government/publications/the-high-speed-offshore-service-craft-code-hsosc*

This is the legislation which mandates a 'UK Load Line Exemption' (UK LLE) (where full compliance is not possible). Attention is also drawn to paragraphs 1.3 and 1.7 of The Workboat Code Ed.2 Ammd.1, (a regulatory framework which provides a certification scheme for workboats under 24m), which describe the application of other Merchant Shipping regulations and local bylaws. The Workboat Code is currently in the process of being updated to incorporate a specific category of MASS; 'Remotely Operated and Unmanned Vessels' (ROUV) and is available for public consultation until 29.12.22. You can access a copy of the current draft of The Workboat Code Ed.3 (WBC3) and the consultation documents here.

Until WBC3 comes into force, and for other types of vessel and forms of innovative technology including MASS, which would not be eligible for certification under WBC3, you may consider the use of MGN 664 (M+F) Certification process for vessels using innovative technology; which defines a process by which evidence of an equivalent level of safety may be produced as a basis for certification (UK LLE)."

Quote from R Taylor – MCGA

"Progress is being made at a great pace to support and enable the use of autonomous vessels with the appropriate regulation in the UK and internationally. Building on the work of MARLab, the Maritime and Coastguard Agency are now updating regulations to enable the safe operation of smaller under 24m MASS in the UK and have started to develop the regulatory framework required for all MASS to operate safely in UK waters. The Maritime and Coastguard Agency has developed a leading team, the Maritime Future Technologies team, who are at the forefront of researching and instigating change for future MASS in maritime.

The MCA will give insight into the regulatory updates and how they will support autonomous vessels in the UK and present our latest thinking on how the MCA will facilitate and support industry in the future. With key developments planned over the next six months, presenting at the conference will gives us the opportunity to explore with industry key areas or issues highlighted in the development of new regulatory frameworks. These developments and push for change in domestic legislation continue to put the UK in a leading position amongst regulators across the world.

It will include an overview and analysis of the principal regulatory requirements for lookout and watchkeeping for example; COLREGS – Rule 5 "Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate to the prevailing circumstances and conditions so as to make a full appraisal of the situation and risk of collision". Regulation 22 of SOLAS V, specifies bridge visibility requirements, STCW – Section A-VIII/2 covers watchkeeping arrangements and principles to be observed - technically applies only to seafarers serving on board seagoing ships which is interesting, especially when considering shore-based control centres for ships."

All the above Departments of State recognise five major industrial lobby groups, namely:

- Confederation of British Industry (CBI);
- Federation of Small Businesses (FSB);
- MAKE UK;
- Institute of Directors (IoD); and
- British Chamber of Commerce.

FINDING #3

This is a legislative and stakeholder landscape of extraordinary breadth, depth and complexity, ranging from Westminster and Holyrood government departments, through global industrial entities, SMEs, trade and professional bodies.

CAA and MCGA are generally supportive and creating drone and RAS legislation, particularly, BVLOS, using both their own expertise and, crucially, information from trials enabled by CAA / MCGA risk analysis and funded / performed by various industrial groupings.

4.3.5 Examples of BVLOS trials

Far from exhaustive, what follows is an overview of the collaborative landscape, elements of which OLTER is aware and, in some cases, a part. The intention here is to illustrate – accepting that there may be work to establish the veracity of some claims – that there are multiple players in the space which seek to use trials to demonstrate utility whilst informing both the business case and developing legislation.

4.3.5.1 COVID 19

During a period of reduced ferry crossings to the Isle of Wight, flights of a petrol-fuelled Windracer Ultra fixed wing unmanned aircraft were trialled, flying up to four flights per day from Leigh-on-the-Solent to the Isle of Wight.

The initial intent was to carry PPE, with the expectation of moving to more time-critical supplies (drugs, blood, and organs).

We note, however, accepting this is a trial but consistent with themes elsewhere in this report, that two remote pilots – one at airfield – were required.

Subsequently (September 2021), further trials used medical drone company Apian, as well as the University of Southampton, Solent transport and Portsmouth Hospitals NHS Trust trialled a similar service for chemotherapy drugs using a 20kg payload electrically powered drone.

Figure 3 - The Airspace Change Proposal

This initiative has stalled, not because of the efficacy of the drone per se, but according to some reports, the end-to-end service fell short of what the client wanted. It seems likely, with the benefit of hindsight, that the initial requirement was poorly specified from a user-driven, end-to-end perspective and all that was demonstrated was the ability to fly a drone from point A to point B.

4.3.5.2 Mercury Drone Ports

Mercury Drone Ports[38] would appear to be a feature on OLTER's landscape. Formed in 2020, Scotland's "First Drone Port" is a public-private partnership funded by Angus Council's Mercury Programme, as part of the Tay Cities Region Deal working in partnership with DTLX and supported by a number of local and national businesses.

It seeks to establish Angus as an international centre for the development of drone technologies and logistics, both onshore and offshore.

BVLOS demonstrations and underway and there is a programme to work with NHS Tayside trialling an on-demand drone collection and delivery service, transporting medical samples via an unmanned aircraft to and from multiple healthcare facilities in Angus to the pathology laboratory at Ninewells Hospital in Dundee. This is a good example of a drone agnostic service provider.

4.3.5.3 Sees.ai[39]

A good example of a (seemingly) well understood Use Case and significant stakeholder engagement.

Sees.ai is an industrial grouping with the stated objective "Ten years from now, connected & autonomous aerial vehicles will be part of our everyday lives – flying routinely through our world, inspecting, monitoring, and carrying cargo and people. Our mission is to develop the Operating System that makes this possible."

Quote from the Sees.ai website[38]

"Now we have earned the trust of the UK aviation regulator and we are building a world-class team that shares the short-term aim of unlocking the use of drones at scale for industry – and the long-term ambition to unleash the full potential of unmanned flight."

From CAA website[40](20th April 2021)

"In a significant step forward for the drone industry, beyond visual line of sight (BVLOS) command & control solution developer sees.ai has become the first company in the UK to secure authorisation from the UK Civil Aviation Authority (CAA) to trial a concept for routine Beyond Visual Line of Sight (BVLOS) operations. The permissions come as part of a test project to prove the concept ahead of potentially opening it up to the wider market.

The authorisation enables sees.ai to fly BVLOS at three nominated sites without needing to pre-authorise each flight. By removing this limitation, this permission fires the starting gun for the next phase of growth of the drone industry, during which the potential of BVLOS to significantly increase operational effectiveness and efficiency will be considered.

The authorisation allows BVLOS flights to occur under 150ft and initially requires an observer to remain in visual line of sight with the aircraft and able to communicate with the remote pilot if necessary. By testing the concept in industrial environments for inspection, monitoring and maintenance purposes, sees.ai aims to prove the safety of its system within this context initially, before extending it to address increasingly challenging missions over time.

[38] Home – Mercury Drone Ports

[39] https://www.sees.ai/

[40] Drone trial of routine BVLOS operations concept authorised | Civil Aviation Authority (caa.co.uk)

This significant step forward was delivered under guidance from the UK CAA Innovation Sandbox. The Sandbox was set up in May 2019 to create an environment where innovation in aviation can be explored in line with CAA core principles of safety, security, and consumer protection. sees.ai, whose senior team includes ex Arup, Apple, CERN, McLaren and hedge fund employees was one of the first entities selected into the Sandbox in September 2019.

The authorisation is also an early win for UK Research & Innovation's recent aviation and aerospace initiative, the Future Flight Challenge. Within the current 'Phase 2' of this Challenge, sees.ai is leading a project to enable commercial BVLOS drone services at scale alongside manned aviation. Backed by government grant funding and supported by technical partners including NATS, BAE Systems, Vodafone, Met Office, Flock Cover and the University of Bristol's Smart Internet Lab, this project will put sees.ai's BVLOS solution in the hands of two of the world's leading drone service providers, TerraDrone and SkyFutures, to address ten increasingly challenging trials with end-clients including Skanska, Skanska Costain STRABAG working in partnership with HS2, Sellafield, Vodafone, Lancashire Fire and Rescue Service, Network Rail and Atkins."

Quote from the sees.ai website[41]

"28 JUL SEES.AI WINS FUTURE FLIGHT CHALLENGE PHASE 3 FUNDING….

…Phase 3 has been successful, and we have won another significant grant from the Future Flight Challenge and UK Research & Innovation. In Phase 3 we led a consortium of partners including National Grid, Network Rail and BT. We presented a project aiming to secure UK first approval from the Civil Aviation Authority for routine and safe BVLOS operations in non-segregated airspace at national scale.

Our software puts remote pilots in charge of connected and autonomous drones. The software is capable of remotely addressing even the most complex, close-quarter missions and can deliver safe and efficient operation of drone fleets at a national scale. It is already being deployed for asset inspection purposes on the electricity transmission network through trials with NGET to automate corrosion inspection[42].

In Future Flight Phase 3 (FFP3) we will be advancing the software and our operational safety case to extend our current capabilities to:

- *Enable Atypical Airspace (AA) BVLOS inspection of assets in the public domain by leveraging our advanced spatial awareness and our integration into the aviation ecosystem. Our aim is to create a solid Concept of Operations that will allow us to obtain UK first approvals for routine and safe BVLOS operations in non-segregated at national scale flying in atypical airspace.*
- *Enable a pilot to control multiple Unmanned Aerial Systems (UAS), an important step towards increasing the efficiency and scalability of UAS operations. We will also be aiming to be one of the first companies to obtain regulatory authorisation to fly multiple UAS simultaneously in AA.*
- *Develop software that can provide comms between UAS and pilot in areas with poor or no 4G/5G coverage.*

Work has already commenced by the consortium, comprising the following partners:

BT, National Grid Electricity Transmission Network (NGET), Network Rail, Imperial College London, Lancashire, and Rescue Service, TerraDrone, Keen AI, DScience, Livelink Aerospace and Across Safety Development.

With these advancements our consortium will be hoping to contribute to the BVLOS infrastructure of the future."

Their recent collaboration with Marshall Futureworx is of note[43].

[41] Sees.ai | sees.ai wins Future Flight Challenge Phase 3 funding

[42] https://www.nationalgrid.com/age-ai-national-grid-trial-futuristic-automated-corrosion-inspection-electricity-transmission

[43] https://www.sees.ai/2022/09/26/marshall-futureworx-signs-memorandum-of-understanding-with-sees-ai-and-iss-aerospace/

4.3.5.4 Mayflower

High visibility example of extended BVLOS and endurance from a surface drone.

Image Source – IBM Newsroom[44] – In a voyage lasting 40 days and conquering approximately 3,500 unmanned miles at sea, the Mayflower Autonomous Ship arrived in North America in Halifax, Nova Scotia on June 5, 2022.

Whilst not without significant operational issues, following two years of design, construction and AI model training, the Mayflower Autonomous Ship (MAS) was launched in September 2020 and arrived in Halifax, Nova Scotia on June 5, 2022.

With no human captain or crew onboard, MAS is the first self-directed autonomous ship with technology that is scalable and extendible to traverse the Atlantic Ocean.

MAS was designed and built by marine research non-profit ProMare with IBM acting as lead technology and science partner, with IBM automation, AI and edge computing technologies powering the ship's AI Captain.

Mayflower has 6 AI-powered cameras, more than 30 sensors and 15 edge devices, all of which input into actionable recommendations for the AI Captain to interpret and analyse. This makes it possible for the AI Captain to adhere to maritime law while making crucial split-second decisions, like rerouting itself around hazards or marine animals, all without human interaction or intervention.

The AI Captain has learned from data, postulates alternative choices, assesses, and optimizes decisions, manages risk, and refines its knowledge through feedback, all while maintaining the highest ethical standards. There's a transparent record of the AI Captain's decision-making process that can help humans understand why the captain made certain decisions."

[44] *The Mayflower Autonomous Ship Has Reached North America (ibm.com)*

4.3.5.5 Turnchapel Wharf

Turnchapel Wharf in Plymouth brands itself as the "Home of UK Maritime Autonomy.

Formed in 2014 after the former RM site was purchased by Yacht Havens Group, Turnchapel hosts a number of Maritime businesses, notably, in the autonomous space: the Fugro Academy (geotech and geoscience surveying); UKHO Boarder Force; Marine AI Ltd, home port for Mayflower and Thales UK's Maritime Autonomy Centre (AI, digital security and marine autonomy). Thales have some success with autonomous towed-array mine hunting capabilities for the RN.

4.3.5.6 Snowdonia[45] Aerospace Centre

Llanbedr is possibly the only non-MoD trial range for BVLOS trials with its own ANSP and the ability, via NOTAM, to declare a permanent danger area, achieving certification in September 2021.

[45] *Snowdonia: Drones to create mobile signals for remote rescues – BBC News*

Work includes BVLOS flights with Skyfarer which started in October 2022 and were the result of two years of regulatory submissions. Altitude Angel provided UTM capability and detect and avoid functionality.

The application covers communications support to mountain rescue. An unmanned aircraft developed at the Snowdonia Aerospace Centre will have a 4G or 5G mast on-board, enabling 999 calls in otherwise so-called "not spots".

The drone can also fly above the scene of an incident to allow rescue teams and those in trouble to stay in touch and perhaps carry emergency aid.

£500k and 18 months have been invested to date with a further £500k estimated to bring the project to fruition. The current prototype has circa three-hour endurance, but larger aircraft and longer durations are planned[46].

4.3.5.7 Caelus (Care & Equity – Healthcare Logistics UAS Scotland)

AGS is leading a consortium that brands itself as the first national distribution network to use drones to transport essential medical supplies[47]. Caelus has partners running from Academia, through NATS, Skyports, Cellnex (providing private 5G) to NHS, the "user": their website claims completion of drone landing stations and a digital twin. Whilst their video references the PWC Future Skies report in terms of value generation, they seem focussed on using the trials programme to measure the hard and social value of, for example, being able to deliver medicines to remote parts of Scotland.

> **FINDING #3a**
>
> There are many examples of industrial groupings, either clustered around a generic use case (e.g., medical logistics) or a drone-agnostic offering, providing trials data to inform a RAS business case and influence development of legislation.
>
> OLTER has to press home the case that the offshore energy sector is domain specific i.e., it requires specialised domain knowledge, to avoid other parties encroaching on this market sector.

[46] Drone Major understands that there are discussions underway with the Offshore Renewable Energy (ORE) Catapult

[47] AGS | Drones (agsairports.co.uk)

4.4 The Technological Environment with a Focus on What is Possible and Where Technology Needs to Advance

From our initial investigation, there appears to be a significant gap between an established, client-driven Use Case and the formal system engineering needed to decompose product and infrastructure high level system and sub-system requirements which can be tested with the market and refined into a total solution, including infrastructure and through life considerations.

Without this structured decomposition, specific technologies which require focus or investment are difficult to identify with any credibility and certainty.

Attention must certainly be given to this approach. At least one "end to end" case needs to be holistically outlined and then defined to include the operational environment, a functional decomposition, an outline safety case, data management, physical and cyber security, through life requirements (logistics, training, spares) etc.

This is a perceived market and application gap which could be addressed by OLTER.

A review of Drone Major suppliers, affiliates and other related companies would suggest that the key sub-system building blocks required by offshore wind industries (air and maritime drones, mission managements systems, communications, means of conspicuity...) either exist or are under development and that, in the broadest terms, this is a highly competed space.

In terms of market segmentation, drone providers seek to provide the "best" drone to the markets they seek to serve. Many, however, presumably in response to excessive competition, are trying to vertically integrate to provide end to end services based on their drone technologies. Others offer drone agnostic services.

Following discussions with drone manufacturers and drone service providers with offerings in the logistics / material movement space, inspection, and monitoring and in maritime and coastal security and surveillance.

We assume that technologies which are required by the offshore wind industry and drone providers will be organically developed and deployed by them where there is a strong business case for doing so.

OLTER, therefore, needs to address areas of "market failure" i.e., where there is a case for development of a capability, but, for various reasons, no single or group of actors can justify the investment.

Various conversations lead to the conclusion that the following areas are worthy of further examination, noting these are less technology per se but more concerned with overall system engineering:

- Generation of real-world system and requirement specifications (covered earlier) from client-generated Use Cases.
- Creation and management of an enduring, real-world, test / development bed:
  - Underwriting the safety case; proving multiple-redundant independent systems for, for example, position, conspicuity, within the surveillance environment, detect and avoid and exploring reversionary modes: modelling the "what ifs?"
  - Comms around the array: underwriting the performance / LoS, 5G private networks, satellite comms etc. to explore system resilience in a harsh EM environment, establish cyber credentials and demonstrate redundancy and reversionary modes;

  - Survivability of RAS in hostile environments, particularly building a body of evidence which will support a business case and service offering;
  - Providing a progressive path to build confidence in de-risking the route from manned to autonomous – a decade long programme. From VLOS, through EVLOS to BVLOS;
  - Digital tethering – exploration of techniques to provide assurance and reversionary mode for BVLOS operations;
  - Use of combined radar / beacon technologies;
  - Understanding the issues around data management and ownership.
- Creation of a digital twin as a capability in its own right and to support the above:
  - Underwrites RAS utility;
  - Provides capability for exploring emerging use cases;
  - Creates a potential development capability for new tasks without disturbing ongoing work;
  - Understanding progression towards ML and AI enabled operation, where system behaviours are less deterministic.
- An offshore wind equivalent of UK MoD's Unmanned Warrior[48] "Exercise Unmanned Warrior is a showcase of autonomous robotic systems that perform [....] air, surface and sub-surface tasking, from underwater surveying to mine countermeasures. The exercise is a truly collaborative effort between the Royal Navy and its partners in industry and academia. Some 400 participants from more than 40 organisations are involved in producing several world-firsts, including the largest ever UK deployment of ocean gliders, the first-ever competitive mine-hunting trials between manned and unmanned systems, and a record-breaking oceanographic survey.

The collator of this note was intimately involved in UW, which has led to the development of CONOPS / CONEMP and the creation of other Service initiatives to accelerate adoption of drones.

- Underwater communications:
  - A significant amount of work is underway within various military activities.
  - An interim solution might be RAS to surface buoy for onward transmission for real time information or periodic surfacing for download.

FINDING #4

Without a formal decomposition of requirements from a credible client-generated use case, specific technologies worthy of investment cannot be clear.

We assume that, where there are technology needs which arise from the industry, then those industries will undertake the development. OLTER therefore seeks "market failure" opportunities.

The opportunity for OLTER would appear to be that high level system engineering and the progressive creation of an enduring test bed which will form the basis for understanding high level issues (BVLOS operation being the obvious example) and specific technical areas, such as reliable communications within a windfarm array, see 5.2.1.

[48] *Unmanned Warrior | Royal Navy (mod.uk)*

4.4.1 Communications

In addition to the SoW, this paper will comment on communications in the context of offshore energy.

A rise in inter array communications, plus array to mobile platforms / drones and rig / array to shore – both voice and data – is inevitable.

In addressing the communications aspects, consideration must be given to the regulatory framework.

For example, in aviation, the communication bearers must be consistent with aeronautical spectrum management as determined by ICAO in conjunction with the ITU Radio Regulations. This is essential in terms of providing the necessary interoperability to meet safety of life requirements. Although there is serious consideration of how mobile networks may assist in providing the necessary links, the safety case and risk assessment will need to be satisfied that the level of assurance in an interference free environment can be delivered. The determination of a satisfactory outcome in establishing the appropriate communications networks will be key to delivering BVLOS approvals.

The current use of VHF is being augmented with satellite comms and, in some cases, fibre being laid alongside power cables – the latter enabling connectivity to a hub and wireless to reach other platforms thereafter. Neural Host and VPNs based around 4G LTE (Long Term Evolution) have been installed to enable handset comms by crews to connect computing devices, cameras, IoT and so on. It is assumed that both autonomous and surface platforms will have AIS (or, more likely, VDES[49]) which, along with GPS and other systems will provide adequate positioning and data exchange to support currently envisaged operations.

We note in passing that many commercial communications subsea cable providers are offering built in sensors to help better understand oceanographic conditions along with sensors to help understand whether or not the cable is moving or under stresses which encroach on its design margins. This is a good example of how the local communications load could be increased.

Fibre and similar connectivity provide good resilience to general interference; there are guidelines for installation of 4G and small cells (such as avoiding co-location with generators and other local sources of interference), although some screening – both electrical and procedural – is possible. Turbine blade motion can be an issue for 4G and 5G and other high frequency wireless services because of the creation of abnormal reflections.

Other considerations are connected buoys (particularly ones with weather sensors, radar etc.) and the use of exclusion zones to protect platforms in bad weather.

The use of one or more methods of communication for voice and data in the specific case where a given LoS is required to underwrite the drone safety case would warrant further attention as part of the safety case creation. Multiple levels of independent redundancy create additional costs and security during a time of potential conflict.

[49] *Sternula AS – Company Webpage VDES VDE-SAT AIS 2.0*

FINDING #COMMS

If we can assume shore to service platform fibre, there are established techniques for private 5G networks which offer a definable LOS.

However, the effect of real-world interference from very close turbine blades and heavy current equipment is less than clear as are the provisions for multiple redundancy / denial of access. The Cellnex trial under Caelus will provide a useful reference point for the provision of remote 5G.

4.5 Requirements and Challenges Regarding Data Sharing and Data Use

It is noted that the ORE / Accenture Wind Industry Landscape Review[50] which cites six main O&M use cases (alerts, alarms, warnings, and faults; troubleshooting and minor corrective maintenance; failure prediction and major component replacement; scheduled maintenance; wind power curve analysis and production losses and product forecasting) and offers a number (author's numbering) of recommendations:

1. Wi-fi installation and 5G to improve connectivity between wind farms and the operations centre;
2. Linkage to IEC standard and to standardise alarms, tags, faults across OEMs, asset models;
3. Sensor analysis and inspection to ensure accuracy of measurement;
4. Investment in advance domain and analytic expertise to predict asset health threats;
5. Right domain expertise during handover period at end of warrant;
6. Defining rights to data at contract negotiations;
7. End user centricity and change management approach.

Taking other markets[51] as an example, it is suggested that these recommendations form a group of three elements. For example:

- Items 1 and 2 are provisions which should be in place during construction i.e. standardisation of format, satellite comms, 5G and wi-fi are there as a prime contractor service to all windfarm sub-system providers (a) to avoid duplication and cost and (b) to have an agreed LoS with all users.
- Items such as 3 and 4 are rightfully the province of the sub system provider and should be part of the requirement specification. If the prime contractor (who presumably takes the risk for power output and reliability) wants a given LoS or reliability from a system element, that is made clear in the requirement specification, and it becomes the job of the provider to ensure that their sensors are of adequate accuracy and the analysis is such that asset health threats can be appropriately predicted.
- Item 6 is the pivotal point. OEMs of complex equipment arrange, insofar as they are able, to collect health and performance data (onboard BITE and SCADA systems) from their system and its major contributing parts.

We assume that "data" such as alarms and warnings, what triggers them and what consequent action must be taken, will be a contractual requirement.

They do this to

- verify their own design margin calculations;
- as part of converting all maintenance to planned (i.e., not unscheduled) work;
- understand what actions they might take if their system fails to meet the performance or SLA requirement (audit trail and liability apportionment);
- inform their own design processes (perhaps using a digital twin or other modelling approach) to reduce future factory (material and build time) and through-life costs (reduced maintenance, refined spares holdings);
- drive innovation.

Collection and analysis of this data is key to the companies' competitive position in, in this case, a rapidly evolving market: Orsted's website[52] notes that the turbines for the Hornsea Two installation are almost 18 times as powerful as those in Vindeby which started operating some two decades ago. This massive growth in capability has been driven by innovation and that innovation, in part at least, has been a result of an intrusive knowledge of how their system performs in the real world.

OLTER's own Data Hub Architecture (September 2022), whilst technically valid, notes the assumptions…

- OLTER will be the appointed Data Trust stewards and will implement governance for sharing data.
- Data loaded onto the platform will be for the purpose of sharing, subject to reasonable criteria on who is granted access and why it would be used.
- Data will be discoverable by all parties. Access to the contents of the data will be subject to access requests being approved.
- Data exfiltration is to be restricted i.e., all analysis will take place on the platform.

The need for legitimacy to assume the role of data trust stewards (and the need for several months of collaboratively defining what that might mean), the commercial minefield of points 4 and 5, the ambiguity of "subject to reasonable criteria…" and the OEM's response to restriction exfiltration.

We would also point out the difficulty in "monetising the upside" i.e., it may be technically possible to share data as envisaged but the fiscal and other benefits of so doing can prove elusive.

This data is a strong contributor to the company's distinctive competence; their "know how"; their "smarts" – it is not in their interests to altruistically share performance and health data with their clients or risk it being made available to their competitors.

The authors here cannot imagine what commercial pressures might be brought to bear to encourage OEMs to share information in the way contemplated. It seems generally the case that monetising the value of collected data has proved problematic, but the authors note the relatively new area of adversarial data whereby the above assumptions might be challenged if it could be proven that there was greater value to be gained through the fusion of multiple data sets which would have hitherto been protected.

However, scope and time preclude further considerations here.

An exception could be, for example, turbine providers collecting data which, along with meteorological data, would be used to predict overall windfarm performance.

[50] *Wind Industry Digital Landscape Review – ORE (catapult.org.uk)*

[51] *Example is the collation of sub system data from the several hundred tier one and two equipment and service suppliers to the Queen Elizabeth and Prince of Wales aircraft carriers across the major systems elements of Power and Propulsion, Platform Management, Aircraft Management and ATC, Sensors and Command systems, Bridge, Comms and Nav and hotel management. Whilst we were able to create a system to harmonise over one hundred disparate sets of technical documentation and handbooks, access to more intrusive information become more problematic. Even within the technical documentation space, the upside of the harmonisation process was very difficult to enumerate – it most certainly made the life of the on-board maintainer "easier" but tracking the benefits in any auditable sense was a challenge.*

Another parallel is work undertaken by a global mining operator and mine machine manufacturer where complex machines, in a hostile operational environment, contribute to overall quarry performance. A, fortunately temporary. side issue here was that remote maintainers would video their approach to certain faults and post that video on You Tube, thus eroding the OEM's value chain in support.

[52] *Offshore Wind Energy | Ørsted (orsted.co.uk)*

It may be that a windfarm installation operator could contemplate a drone application which would provide either a further data feed to OEMs or, where its data might be fused with other data, adds value but such a consideration is out of scope here.

> **FINDING #5**
>
> Within the confines of this study, Drone Major cannot find any reason why commercially distinct entities would altruistically share operational, performance or health data unless they are contractually obliged (paid) to do so.

4.6 Possible Ways in which the Pathway to Commercialisation Could be Expedited

OLTER currently sees itself as a project – and a future advisory body – formed from a number of constituent parts with a three-year project to "deliver Robotics and Autonomous Systems (RAS) industrial services that help to reduce the carbon footprint and enhance cost efficiency in the offshore energy sector[53]."

In addition to OLTER, there are other formal and informal bodies with various levels of overlap. In order to achieve pre-eminent leadership in its chosen field, OLTER needs to (i) press home the case that offshore energy is a distinctive market (i.e. specialised domain knowledge is needed) and (ii) develop a clear and compelling vision statement, a view of its differentiating competencies and a business model which delivers value to the key elements of its stakeholder community.

OLTER's Strategic Options are very much for OLTER to develop (see Recommendations) and there are many processes and frameworks that would guide that work.

However, it would seem that the options might run along the following lines:

- The Do-Nothing Option: Dissolve OLTER:
  - Technically an option but not for consideration here.
- The Academic Option: Become an "Intellectual" / thought leader / Centre of Excellence for the application of drone technology in offshore markets:
  - The underpinning economics would have to be that OLTER is amortising costs which none of their competitors or client-side primes and tier ones would choose to bear.
  - OLTER would have to be sure why the current players would allow market entry: what value; what's the value to them?
  - What capabilities does OLTER need to acquire in order to deliver a differentiated and sustainable position?
  - Can OLTER organically acquire those capabilities?
  - Are there valuable links into Academia and how might OLTER exploit those links to the benefit of its clients?
  - Would the market warrant the costs of – and support commitment to – a managed, through life, digital twin?
  - A key market gap would seem to be a "guiding mind" which would define and manage a multi- stakeholder trials programme to (i) underwrite the utility of a RAS based solution and (ii) help inform the case for regulation.
- The Product Option – Develop a capability which would insert OLTER into the overall "offshore windfarm" value chain, deriving revenue for undertaking work and managing risk:
  - It is far from clear, without further work, what this product offering might be, and the investment needed to gain a position of differentiated competitive advantage.
- The Service Option – Become a service provider for RAS related services:
  - Be the "thought-leading" bridge between one-off trials and an enduring capability based on real-world data.
  - Enact the role of trusted advisor to potential drone users, ensuring appropriate SLAs are developed, metricated, and delivered.
  - Provide physical and electronic support services but these would likely need to be housed with each specific wind farm's shoreside infrastructure.
  - Another potential role could be as a broker between drone suppliers and a managed service offered to wind farm operators.
  - Establish a common infrastructure and offer manged services to operators:
    - UTM, shore to array and inter array voice and data communications, launch and recovery sites, asset management.
    - OLTER would have to be clear why the current industrial landscape would allow a new entry, including existing drone providers who might seek to offer similar services.

The sub options under the Service Provider route follow a curve of increasing investment / risk and increasing return.

> **FINDING #6**
>
> OLTER as a service provider would seem to offer the most attractive vein of enquiry with a number of sub-options. We note that there are elements of the academic option and service option which might find synergy, creating a digital twin for example, providing the "glue" for an enduring trial programme, and providing a route to trusted research undertaken by those with domain knowledge.
>
> It may prove more practical to separate the "independent trusted advisor" role from that of commercialisation – realising commercial benefit – and taking risk – through the creation of, for example, services.

[53] *Strategic Outline Business Case (SOBC)*

5. CONCLUSION

Following extensive interviews of stakeholders across the energy and drone markets and polled experts from government, industry, and other advisory bodies. It is evident that there are use cases for RAS, particularly logistics, inspection and security.

However, a fully "worked up" business case is not yet evident; the focus appears to be on point-to-point demonstrations rather than enduring trials under real-world conditions to build the body of evidence needed to both make the case for drone adoption and inform the regulatory process.

The issues facing RAS in the offshore sector are more to do with requirements capture and specification than any regulatory barriers.

We note also that there are other groupings who would seek to create business in the offshore energy sector.

OLTER should now, as a priority, make the case that working with offshore energy providers requires domain specific skills due, in some part at least, to the hazardous conditions and operational risks. This will underpin the recommendation of a "three thread" approach:

- OLTER needs to be clear on its strategic intent;
- it needs are far more intimate relationship with its key stakeholders; and
- it needs to "take the high ground" by turning client-supported use cases into properly engineered requirements – both product and infrastructure – for extended trial in a real-world environment.

5.1 Findings

Each of the following "findings" correlates with a "requirement" from the Statement of Work, table 1.3.

5.1.1 Finding #1

There are clear areas where the use of RAS / drones could offer both hard and soft value, notably logistics, inspection, and surveillance / security. Whilst there are instances of RAS use, they are remotely piloted or supervised in some way; we couldn't find evidence of autonomous operation.

However, there is a lack of formal requirements decomposition from a credible, client-driven, use case. There is no evidence of an end-to-end business case, encompassing product and infrastructure, which would underwrite the validity of a service offering.

5.1.2 Finding #2

There are a range of complex and interconnected reasons which appear to be frustrating drone adoption, including lack of a business case base, lack of understanding of what is possible, risk aversion and an immature insurance market.

5.1.3 Finding #3 and #7

The legislative and stakeholder landscape is of extraordinary breadth, depth and complexity, ranging from Westminster and Holyrood Government departments through to global industrial entities, SMEs, trade and professional bodies.

CAA and MCGA are generally supportive and create drone and RAS legislation, particularly BVLOS, using both their own expertise and, crucially, information from trials enabled by CAA / MCGA risk analysis and funded / performed by various industrial groupings.

5.1.4 Finding #3a

There are many examples of industrial groupings, either clustered around a generic use case (e.g., medical logistics) or a drone agnostic offering, providing trial data to inform a RAS business case and influence the development of legislation.

OLTER has to press home the case that the offshore energy sector is domain-specific i.e., it requires specialised domain knowledge to avoid other parties encroaching on this market sector.

5.1.5 Finding #4

Without a formal decomposition of requirements from a credible, client-generated use case, specific technologies worthy of investment cannot be clear.

We assume that, where there are technology needs which arise from industry, then those industries will undertake the development. OLTER therefore seeks "market failure" opportunities.

The opportunity for OLTER would appear to be undertaking that high-level system engineering and the progressive creation of an enduring test / development facility which will form the basis for understanding issues (BVLOS being the obvious example) and specific technical areas such as reliable communications within a wind farm array, see 5.2.1.

5.1.6 Finding #5

There appears to be no reason why commercially distinct entities would altruistically share operational, performance or health data unless they are contractually obliged (paid) to do so.

5.1.7 Finding #6

OLTER as a service provider would seem to offer the most attractive vein of enquiry with a number of sub-options. We note that there are elements of the academic option which might find synergy, creating a digital twin for example, providing the "glue" for an enduring trial programme and providing a route to trusted research undertaken by those with domain knowledge.

It may prove more practical to separate the "independent trusted advisor" role from that of commercialisation – realising commercial benefit – and taking risk – through the creation of, for example, services.

5.1.8 Finding (Communications)

If we can assume shore to service platform fibre, there are established techniques for satellite communications and private 5G networks which offer a definable LOS.

However, the effect of real-world interference from very close turbine blades and heavy current equipment is less that clear as are the provisions for multiple redundancy / denial of access.

The Cellnex trial under CAELUS will provide a useful reference point for the provision of remote 5G.

6. GLOSSARY

AA	Atypical Airspace
AIS	Automatic Identification Systems
APF	Automated Piloting Framework
ALARP	As Low as Reasonably Possible
ANO	Air Navigation Order
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
AUV	Autonomous Underwater Vehicle
BEIS	Department for Business, Energy and Industrial Strategy
BITE	Built-in Test Equipment
BVG	BVG Associates
BVLOS	Beyond Visual Line of Sight
C2	Command and Control
CAA	Civil Aviation Authority
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditures
CCSS	Carbon Capture Sequestration and Storage
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea, 1972
DfT	Department for Transport
EASA	European Aviation Safety Agency
EIA	Environmental Impact Assessment
EVLOS	Extended Visual Line of Sight
FFP3	Future Flight Phase 3
GWh	Gigawatt Hours
GPS	Global Positioning System
GVA	Gross Value Added
HMG	Her Majesty's Government or His Majesty's Government (dependent on date referred to)
HSOSC	High Speed Offshore Service Craft Code
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMO	International Maritime Organization
ITU	International Telecommunications Union
LCOE	Levelised Cost of Energy
LLE	Load Line Exemption
LTE	Long Term Evolution
MAA	Military Aviation Authority
MARLab	Maritime Autonomy Regulation Laboratory
MAS	Mayflower Autonomous Ship

MASS	Maritime Autonomous Surface Ship
MCA	Maritime and Coastguard Agency
MCGA	Maritime and Coastguard Agency
MFT	Maritime Future Technologies
MGN	Maritime Guidance Notice
NATS	National Air Traffic Services
NERC	Natural Environment Research Council
NGET	National Grid Electricity Transmission
NOC	National Oceanographic Centre
NOTAM	Notice to Aviation
OEM	Original Equipment Manufacturer
OFTO	Offshore Transmission Owner
ORE	Offshore Renewable Energy
PDRA	Pre-defined Risk Assessment
RAS	Robotics and Autonomous Systems
RINA	Royal Institute of Naval Architects
ROUV	Remotely Operated and Unmanned Vessels
RP	Remote Pilot
RUK	Renewables UK
SAR	Search and Rescue
SCADA	Supervisory Control and Data Acquisition
SME	Small and Medium Enterprise or Subject Matter Expert, depending on context
SOLAS	International Convention for the Safety of Life at Sea (SOLAS), 1974
SORA	Specific Operations Risk Assessment
SSR	Secondary Surveillance Radar
STCW	Standards of Training, Certification, and Watchkeeping
UAS	Unmanned Aerial Systems
UKRI	UK Research and Innovation
USV	Unmanned Surface Vehicle
UTM	Unmanned Traffic Management
UXO	Unexploded Ordnance
VDES	VHF Data Exchange System
VFR	Visual Flight Rules
VHF	Very High Frequency
VLOS	Visual Line of Sight
VPN	Virtual Private Network
WBC	Workboat Code
WTG	Wind Turbine Generator

ANNEX A - NON-GOVERNMENT BODIES

This is by no means an exhaustive list, but we have attempted to identify the most relevant non-executive bodies with which OLTER should consider establishing relationships.

1. Lloyds Register

Lloyd's Register

Lloyds published the Unmanned Marine Systems code[54] in 2017, which sets out the conditions which must be met by a vessel in order to be registered as safe. In July 2021, SEAKIT was the first unmanned system to achieve Lloyds Certification.

2. International Maritime Organisation (IMO)

IMO INTERNATIONAL MARITIME ORGANIZATION

The International Maritime Office's paper entitled "Outcome of the Regulatory Scoping Exercise for The Use of Maritime Autonomous Surface Ships (MASS)[55]" is a complex scoping exercise which maps existing instruments onto perceived demands of MASS, examining some fundamentals such as assumed definitions e.g., "crew" and "master".

The paper's conclusions[56], state that – "In line with the outcome on "the most appropriate ways of addressing MASS operations" in appendix 2, the many common potential gaps and/or themes, which cut across several instruments, could preferably be addressed holistically through a new instrument MSC.1/Circ.1638 Annex, page 9 I:/Circ/MSC/1/MSC.1-Circ.1638.docx (e.g. a MASS Code). Addressing every instrument or SOLAS chapter separately could lead to inconsistencies, confusion and raise potential barriers for the application of existing regulations to conventional ships. Therefore, a MASS instrument, instead of amending individual instruments, may be considered which can be made mandatory by means of amending an existing IMO convention, such as SOLAS. This instrument could preferably be developed following a goal-based approach, 4 in line with the Guidelines developed by the Organization. 5 6.3 In order to facilitate the operation of MASS at an early stage, establishing interim guidelines for MASS may be beneficial for ensuring safe, secure and environmentally friendly MASS operations."

Time precludes a detailed analysis, but the conclusion appears to be that, whilst there is a mapping of existing instruments (SOLAS etc) to the requirements of MASS, a new instrument is required to resolve gaps and prevent potential confusion in read-across.

[54] *Unmanned Marine Systems Code (lr.org)*

[55] *MSC.1-Circ.1638 – Outcome Of The Regulatory Scoping Exercise For The Use Of Maritime Autonomous Surface Ships... (Secretariat).pdf (imo.org)*

[56] *https://www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx*

3. National Oceanographic Centre (NOC)

The National Oceanographic Centre's Future Marine Autonomous Systems[57] highlights the growing use of drones, particularly the use of swarming drones for seabed monitoring, seismology and other tasks.

Despite the specialised domain of underwater research, the report makes some useful technology recommendations which are applicable to a wider set of applications.

The progressive use of Artificial Intelligence (Ai), sometimes referred to as the "brains" of marine robots are critical to their ability to undertake more complex behaviours and thereby increase their capabilities. Specific areas of development include the Automated Piloting Framework (APF) of the C2, which allows machine-based control of the long-range fleet.

The demands of D&A to operate near boundaries and on the seafloor, so work should be undertaken to further develop hover capable and crawling vehicles.

The practicality of platform deployment… Launch and recovery systems should be developed at pace for greater flexibility in the use of MAS platforms to support oceanographic research by increasing endurance and data transfer options.

Marine battery/fuel cell technology will underpin much of the expansion in use of MAS platforms and should be a priority for UKRI/NERC (Innovate UK) working in tandem with industry.

Support burden… NERC should expect to double the size of the autonomous fleet it supports every 5 years. A total fleet comprising over 200 gliders, 25 long-range AUVs, 2 short-range AUVs and the associated USVs as well as smaller AUVs deployable by hand.

4. Royal Institute of Naval Architects

A strong and inherently risk adverse body with a wide-ranging brief across all maritime matters including, of course, autonomy[58]. Various papers published.

[57] https://noc.ac.uk/facilities/ships/future-marine-autonomous-systems

[58] Autonomy in small doses (rina.org.uk)

5. Airport Operators Association

Since 1934, the Airport Operators Association[59] has represented UK airports as the trade association representing their interests and principal body engaged with the UK Government and associated regulatory authorities for airports matters. Its members cover almost 50 airports and 100 associate members.

Its mission is to:

- influence governments, regulators, and opinion formers at national and international level to deliver policy outcomes that deliver its vision; and
- playing a lead role in security, economic development, operations and safety and environmental stability issues.

6. National Air Traffic Services

NATS[60] is the UK's leading provider of air traffic control services. Based on a typical throughput (prior to Covid restrictions) NATS would handle over 2.5 million flights and 250 million passengers travelling over the UK and across the North Atlantic. In addition to the UK, NATS would offer air traffic services to customers including airports, airlines, air traffic service providers and governments, which include across parts of Europe, the Middle East, North America and Asia.

NATS details its purpose as follows:

- to make the skies an even safer and more efficient environment for aviation (includes a duty of care for the skies)
- second is a constant striving for improvement, to ensure aviation best meets the needs of a changing world.

NATS details the core of its purpose – Advancing aviation, keeping the skies safe.

7. Renewable UK

RenewableUK's[61] objective is to build a future energy system powered by clean electricity. Through bringing together business leaders, technology innovators and expert thinkers from across the industry.With over 400 member companies (employing 250,000 people) the organisation, the role of the organisation is to maximise this opportunity and create the conditions that will see the renewable sector continue to thrive. The organisation focuses on offshore and onshore, wave & tidal energy storage and hydrogen, as well as the future energy system. Delivery of the above is through focus groups and member forums which includes the Offshore Wind Member Forum.

[59] https://www.aoa.org.uk/

[60] https://www.nats.aero/about-us/company/

[61] https://www.renewableuk.com/event/ofshoremfoct

8. Catapult – Offshore Renewable Energy

The ORE Catapult[62] is delivering the UK's clean growth opportunity by accelerating the creation and growth of the UK in offshore renewable energy. The organisation provisions facilities to bring together research and engineering capabilities to help deliver innovation.The scope of the organisation includes 1040 SMEs supported, 1051 Industry Collaborations and 705 Academic Collaborations (current as of March 2021).

The focus for delivering services and products is divided into four areas:

- Research in exploiting and addressing disruptive technology for the offshore renewable energy sector;
- Accelerating the creation and growth, of UK companies in the sector to drive innovation and commercial opportunity;
- With testing and validation provision for companies, enabling the scaling up of renewable energy technologies; and
- Helping to build a strong and competitive supply chain of such businesses, providing the innovations and products and ensuring this sector becomes a global success.

9. Offshore Wind Innovation Hub

The Offshore Wind Innovation Hub's[63] primary purpose is one of coordination of innovation across this sector.

This includes:

- collaboration with industry and academia to identify the sector's challenges, creating technology roadmaps identifying the innovation needs of the 'offshore' sector;
- convening the supply chain to help address and help to respond and address these challenges;
- stimulating UK activity in the offshore wind market in the UK and globally to help develop ideas into market-ready technology; and
- provide a linkage to UK Government in terms of providing detail of the sector priorities and delivering content and evidence for funding opportunities.

10 The offshore Wind Growth Partnership

The OWGP[64] aims to maximise the economic benefits of the UK's world-leading position in offshore wind. This will be achieved by increasing productivity and competitiveness and as a consequence increase UK content in the global marketplace for offshore wind farms. OWGP will facilitate and promote greater collaboration, increasing business competitiveness, help support increased innovation whilst also attracting new entrants and growing existing companies.

It's main strands of operation:

- Collaborating for growth through engagement between developers and the supply chain to leverage competitiveness and increase capacity;
- Delivering an improvement programme to the existing supply chain, with support from specialist delivery partners to improve competitiveness;
- Increasing the breadth of the UK supply chain through attracting cross-sector engagement and identifying new entrants; and
- Developing new innovations and UK intellectual property notably in areas of robotics, advance manufacture, new material, and automation.

11 Other Organisations

There is a seemingly endless supply of trade and other allied bodies which have an interest in the Offshore Energy or RAS sectors. While they fall outside the scope of detailed analysis, they are worthy of investigation (again, another good indicator of market attractiveness):

Offshore Windfarms logo

[62] https://ore.catapult.org.uk
[63] https://offshorewindinnovationhub.com

ENCLOSURE 1 TO THE OLTER OFFSHORE ENERGY RAS REPORT – A NATIONAL STRATEGY FOR DRONES ACROSS LAND, SEA AND AIR

This enclosure is a pre-release draft of a report developed by the Drone Delivery Group and has been included for background information only. This enclosure is outside the deliverables set out in the SoW and has been provided as a separate document which should not be distributed beyond the membership of the OLTER Steering Committee.

[64] *https://owgp.org.uk*

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