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WASP

The Windfarm Autonomous Ship Project

REPORT AND ROADMAP

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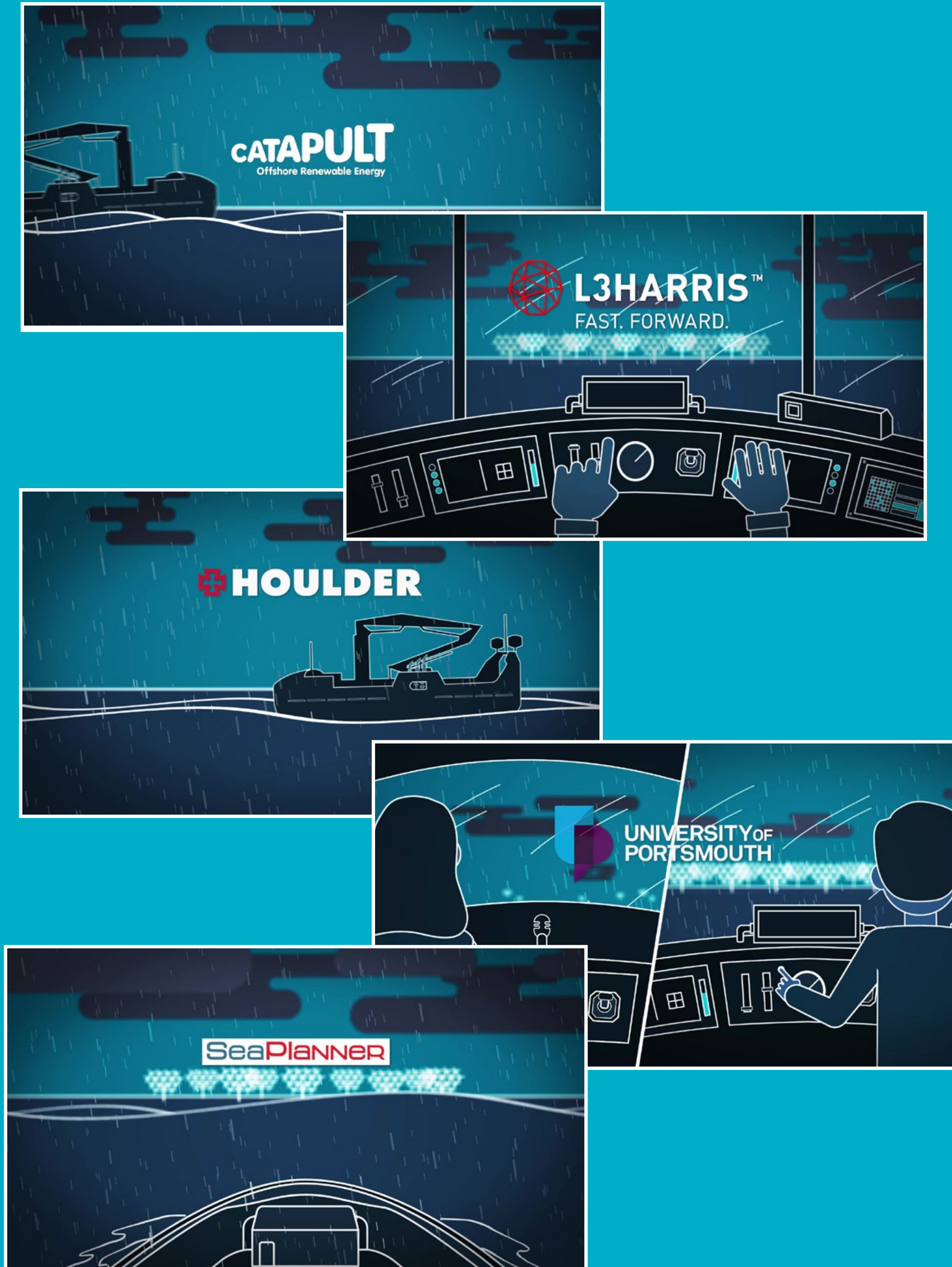
ABBREVIATIONS

AI	ARTIFICIAL INTELLIGENCE
BVLOS	BEYOND VISUAL LINE OF SIGHT
CTV	CREW TRANSFER VESSEL
COLREGS	COLLISION AVOIDANCE REGULATIONS
FEED	FRONT END ENGINEERING DESIGN
ISR	INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE
LOSC	THE LAW OF THE SEA CONVENTION
MASWG	MARINE AUTONOMOUS SYSTEMS WORKING GROUP
O&M	OPERATIONS AND MAINTENANCE
OSS	OFFSHORE SUB-STATION
OSW	OFFSHORE WIND
OWA	OFFSHORE WIND ACCELERATOR
OWIH	OFFSHORE WIND INNOVATION HUB
RAI	ROBOTICS AND ARTIFICIAL INTELLIGENCE
ROV	REMOTE OPERATED VEHICLE
SOV	SERVICE OPERATIONS VESSEL
USV	UNCREWED SERVICE VESSEL
UUV	UNCREWED UNDERWATER VESSEL
VLOS	VISUAL LINE OF SIGHT



THE WINDFARM AUTONOMOUS SHIP PROJECT

REPORT AND ROADMAP

1. Purpose of Document

The purpose of this document is to set out the strategic roadmap for the introduction of autonomous vessels in support of offshore wind farm operations. It takes a view on the potential benefits, articulates the challenges, and describes a timeline for a phase-in of autonomous capability.

2. Background

The Windfarm Autonomous Ship Project (WASP) addressed the identified need, challenge and market opportunity by researching and designing the world's first integrated autonomous vessel and robotic cargo transfer mechanism for delivery of spares to offshore wind farms (OSW).

WASP utilised existing technology from project lead **L3Harris** (vessel control, as well as advanced autonomy and AI) and from project partner **Houlder** (creating the vessel design and motion compensated marine equipment), demonstrating their integration into a range of autonomous vessels.

The University of Portsmouth developed on-board AI health diagnostics algorithms for autonomous vessels. They also produced a set of novel decision support algorithms for efficient and real-time route planning and scheduling of autonomous vessels for cargo distribution, which will enhance SeaPlanner Ltd's own command and control products. In addition, **SeaPlanner** expanded the use of its current software and hardware functionality to manage the data flow and logistics management.

ORE Catapult's cost and performance analysis pinpoints how this new capability increases uptime of OSW turbines.

Key objectives of the WASP project were:

- Produce a definitive sector roadmap;
- Define and quantify technology, integration (crewed operations), regulatory and societal challenges;
- Develop the case for follow on technology development and trials, including targeted discussions in key forums and one or more follow-on project proposals.

Project deliverables included this report and roadmap, which will inform the Offshore Wind Innovation Hub (OWIH) and Off-Shore Wind Accelerator (OWA) programmes. Follow-on funding will be sought for a FEED project to design, build and test the capabilities developed within the WASP project.

3. Autonomous Vessel Capability in Today's World

The growth of autonomous systems has been fed by the rapid increase in processing power, enabling the advance of machine learning, and the evolution and miniaturisation of sensor technology. Today, the aerospace, automotive, and space sectors lead the way with investment in autonomous systems.

Technology advances and the desire to reduce the need for humans working in dull, dangerous and repetitive situations is now driving the study of autonomous systems across every area of business activity. These are as diverse as financial services, insurance, recruitment, fruit picking, defence, nuclear waste handling, marine operations, air freight, health and social care, oil and gas, and space applications.

3.1 Maritime

Like all other sectors, the marine industry is showing a rapidly growing interest in autonomous vessels. The focus is in two distinct areas: very large container vessels and small specialist data collection platforms. Driven by the twin needs for greater efficiency and performance optimisation to minimise costs, there has been a steady advance towards greater levels of automation on large vessels. This has resulted in reduced crew sizes and an increase in land-based operations and condition monitoring. In addition to the developments in larger vessels, small Uncrewed Surface Vessels (USV) (2-7m) are increasingly being used for data collection tasks such as hydrographic survey.

3.2 Other sectors

The motor industry leads the introduction of greater levels of autonomy, through an ever-increasing range of driver and safety aids that are either operating all the time or can be dialled in. In the space industry sensor technology, data management and remote monitoring of activities are commonplace.

3.3 Offshore Renewables

The offshore renewables sector has been slow to react and consider how it can utilise autonomous systems. The sector is still intensely dependent on human intervention across the entire lifecycle – from site assessment and installation to routine operations and maintenance (O&M).

Until recently, autonomous systems were limited to the experimental use of small surface platforms to collect environmental and resource data. However, the launch in 2017 of the UK Government's Industrial Strategy's research funding came with an acute focus on Robotics and Artificial Intelligence (RAI).

Since then, we have witnessed a huge growth in autonomous systems and the identification of a wide range of potential tasks that could be conducted by machines. This includes environmental data collection, wind turbine blade inspection, offshore asset inspection, subsea asset inspection, spares provisioning, crew transfer and array security patrol.

4. Crewed Vessel Operations

4.1 Scene set

Crewed vessel operations occur for a variety of reasons during the life-cycle of an offshore wind farm. The four use cases under consideration for WASP are described below:

- **Geophysical Surveys** - geophysical and environmental monitoring to comply with licence requirements;
- **Security operations** – asset protection, liaising and assisting during emergencies;
- **Cargo delivery** - transfer of spare parts and consumables to turbines, offshore substations (OSS) or Service Operations Vessels (SOVs);
- **Crew Transfer** - transfer of personnel to wind turbines and onshore/offshore substations to perform maintenance tasks.

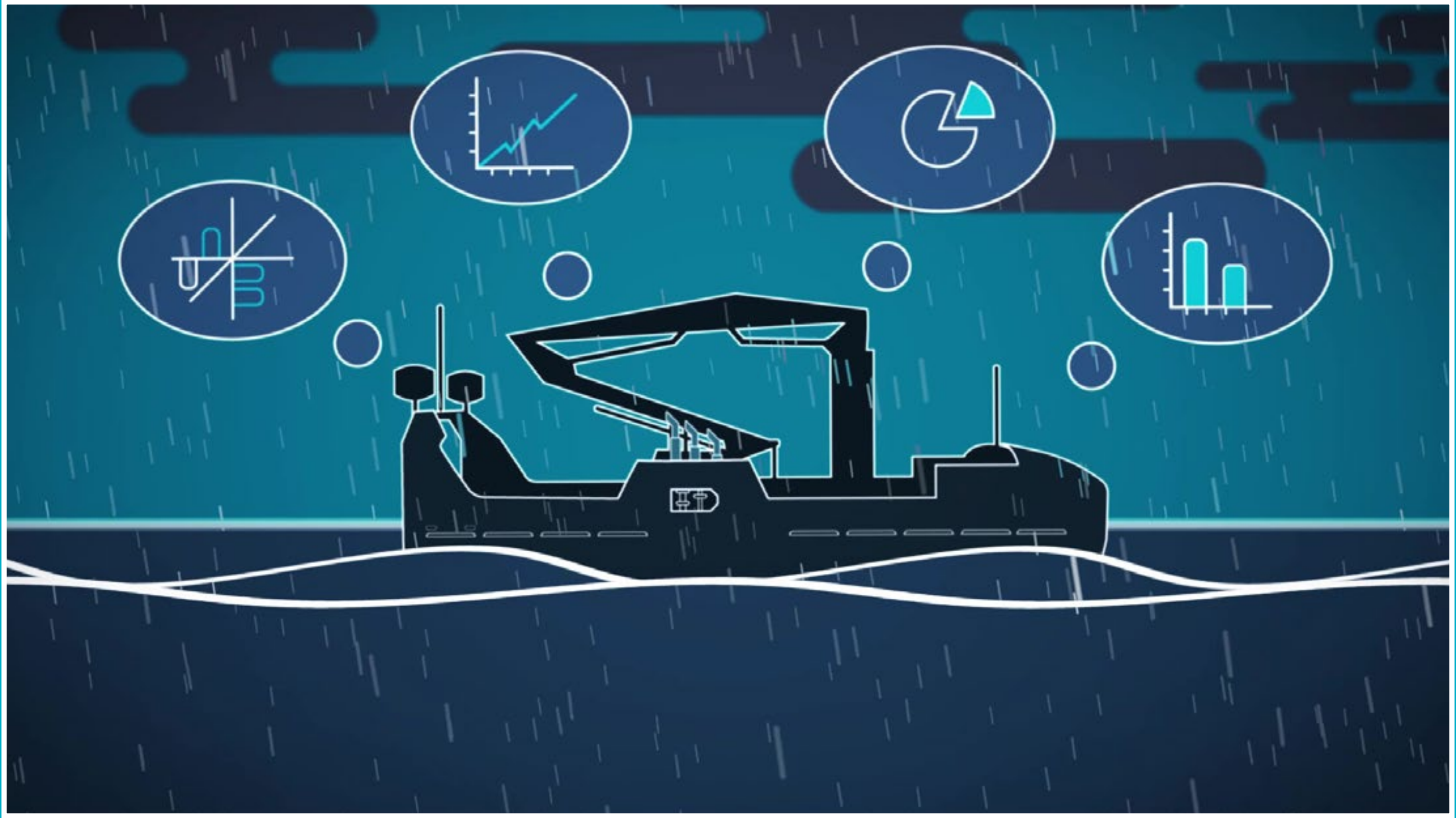
Typically, wind farm operators use the nearest port that meets its specifications for vessel operations in order to minimise time lost due to bad weather. O&M facilities need 24/7 access, 365 days a year. For wind farms located further offshore, the use of offshore accommodation and other facilities (possibly shared with other wind farms) is an attractive prospect.

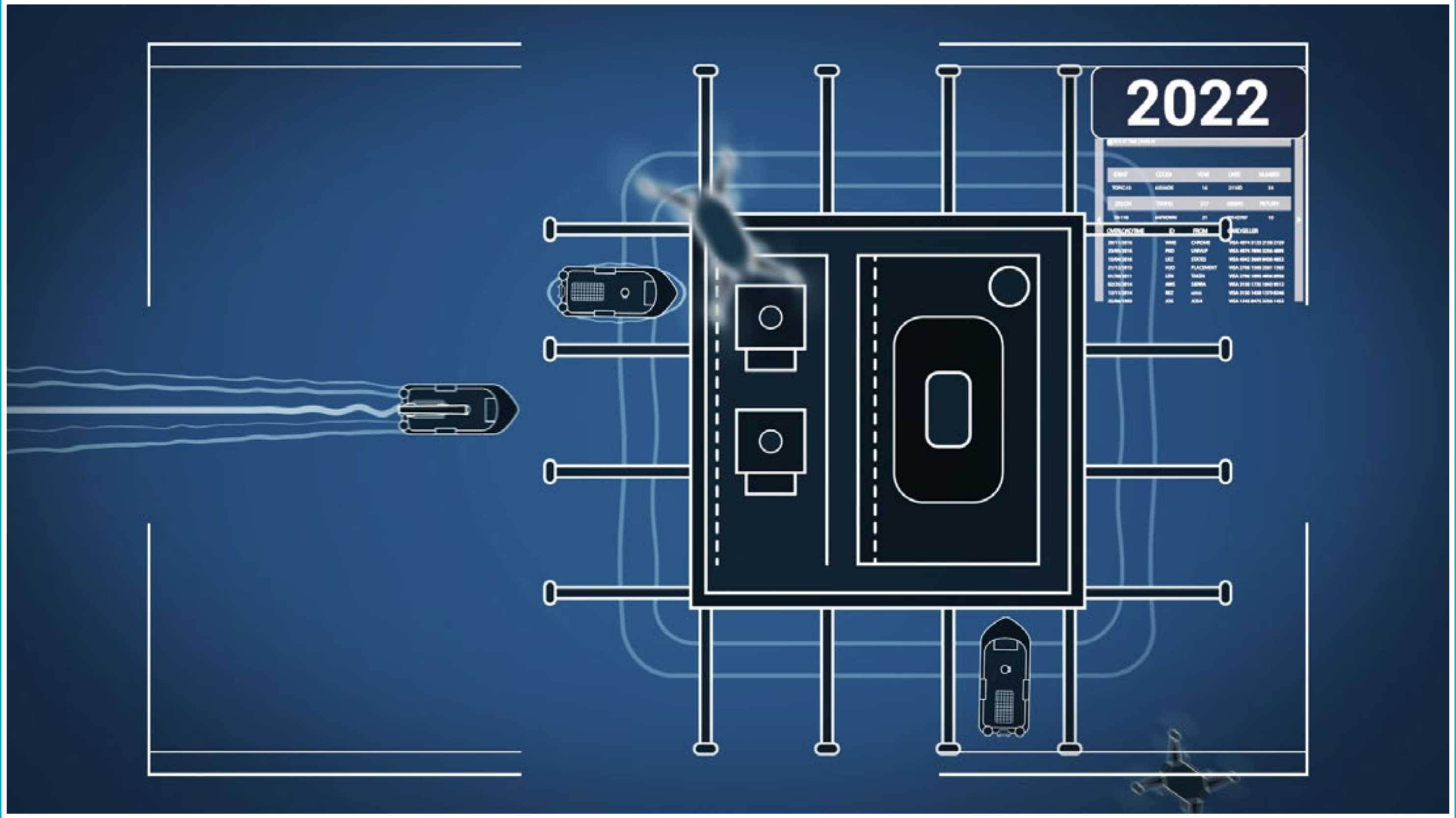
Technician welfare during transfer is an important consideration in port location and vessel choice: sea-sickness can severely impact technicians' health and productivity. For context, a 500MW wind farm may employ up to 100 people, of which three quarters are likely to be technicians.

4.2 Crewed Vessel Operations

A 500MW wind farm may require the operation of around seven vessels, depending upon distance from shore. Marine coordination in offshore wind involves planning and oversight of marine operations undertaken within a wind farm, in addition to cooperation with national authorities in providing effective incident response. While it has been used in other offshore (especially construction) activities, the large numbers of people and vessels associated with offshore wind has led to an expansion of marine operations function.

Marine co-ordination's responsibilities may include continuous monitoring of wind farm (and non-wind farm) marine traffic, providing navigational advice to





Visualisations of the WASP vessel and docking at a charging station - **see the WASP animated film**

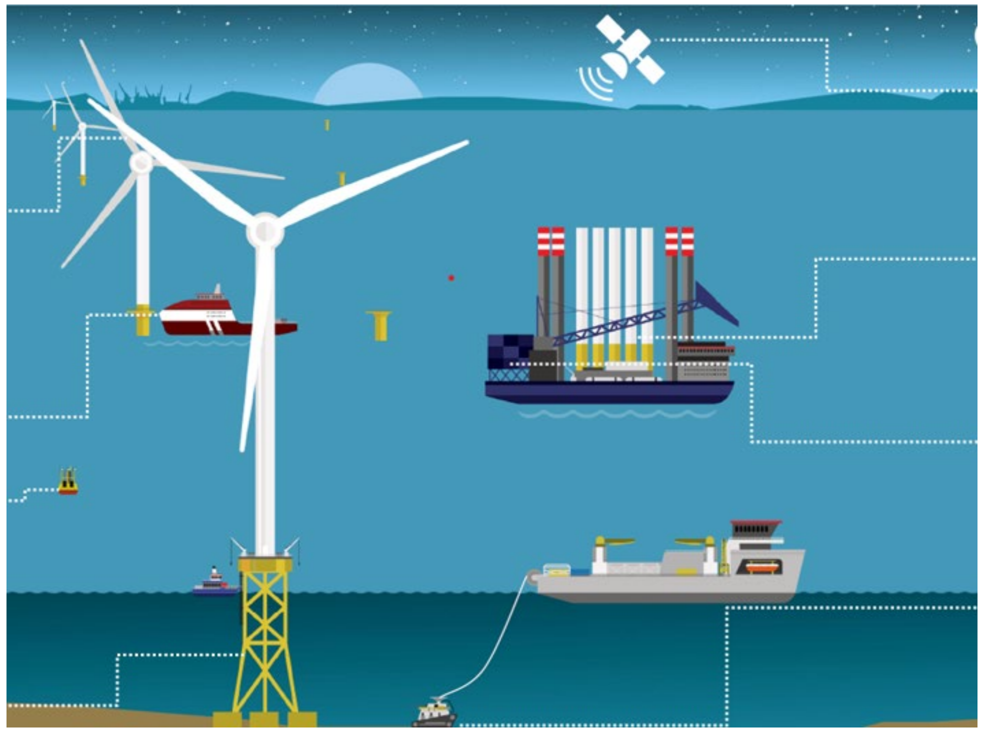


Figure 1. Potential tasks for ASVs

Vessel Masters and project staff (in planning and during operations) and authorisation for specific marine operations (such as personnel transfer).

4.3 Lifecycle Stages

Consenting

During the initial consenting period, environmental and seabed surveys will be undertaken using survey vessels covering the proposed site.

Construction

During construction, the development site will have specialist heavy-lift vessels known as 'jack-up' vessels for laying the turbine foundations and lifting tower, nacelle and blades into place, as well as specialist cable installation vessels. These will be accompanied by a fleet of various support vessels to provide supplies, technician transfers and security duties.

O&M

Once the site enters the O&M phase, Crew Transfer Vessels (CTVs) often become the primary mode of transport, ensuring technicians and spare components are taken to the assets for both preventative and corrective maintenance tasks. Figure 2 (right) shows a CTV transferring cargo using the turbine Davit crane.

Jack-up vessels may also be required if an asset's largest and heaviest components require removal for maintenance. Environmental surveys can also be a licence requirement for 1-5 years post construction depending on the local environmental conditions.

As windfarm development is moving further offshore into deeper waters, SOVs are becoming necessary. Advantages include capacity to stay offshore for up to 28 days and a larger cargo payload capacity. They can act as an offshore O&M warehouse with heave compensated walkways and cranes, increasing their ability to transfer cargo and technicians. An example of such a vessel, a 'Siemens Esvagt' is shown in Figure 3 (overleaf).

Decommissioning

Present decommissioning operations primarily require a jack up vessel. The non-repetitive nature of decommissioning activities suggests that now it is a challenge to see how autonomous systems can support this type of work. This should be subject to a separate specialist study.

However, where future systems will be designed by robots, to be maintained by robots, then it can be foreseen that decommissioning by autonomous systems will be designed into offshore structures.

5. Autonomous Vessel Operations

5.1 Scene Set

While USVs are still widely regarded as a new and emerging technology, they are already commercially active around the world for a variety of tasks. The past decade has seen an ever-increasing growth in terms of operations completed and subsequent scope for future maritime capabilities.

There are many advantages to using USVs alongside or instead of traditional crewed vessels, but it has consistently been demonstrated that the use of USVs in commercial applications can lead to two overriding main benefits:

- **Improvements in safety**: removing or relocating personnel from potentially unsafe scenarios, or from undertaking dull and repetitive tasks.

- **Cost savings:** typically realised by reducing/minimising the need for large crewed ships and/or personnel on deployment, thus reducing the total overheads.

5.2 Uncrewed Vessel Operations

USV operations specifically in support of wind farms have been very limited to date. That said, the types of USV operations that have been conducted in similar arenas have successfully proven the capability of the technology and highlighted use cases that encompass the following major areas:

Figure 2. Crew transfer vessel off-loading cargo

Figure 3. Siemens Esvagt SOV

Operation near marine structures – ports, harbours and inland waterways, necessitating the optimisation of situational awareness capabilities onboard the USV to react quickly and facilitate safe operation around other marine users and infrastructure. This has also encouraged collaborative working partnerships with local harbour authorities and national bodies.

Operation of USVs in controlled waters – sea channels, local navigational channels and controlled waterways.

Launch and recovery of USVs: from simple slipways and marinas, up to generic and bespoke integrated ship launch and rescue systems.

Operation of USVs 'over the horizon' utilising communications links beyond conventional line-of-sight systems.

Geophysical and hydrographic surveys, working as a single USV, or acting as a force multiplier to conventional crewed survey vessels.

Ship support operations such as pipe-laying touch-down monitoring, subsea data gathering, and ROV/UUV tracking and monitoring.

With an ever-increasing range of capabilities and case history, it is recognised that the major challenge ahead lies less with the development of capability of the USV, but more with aligning the existing technology and concept of operation to the specific requirements of wind farm applications.

5.3 Assumptions

The development and operation of USVs to date has predominantly relied upon the safety principle that there is always a 'man in the loop'; some form of constant supervision from a suitably qualified and experienced remote operator and/or local marine support vessels. While the capability currently exists for fully autonomous USVs adopting COLREG-aware behaviours, the need for constant watchkeeping by personnel is assumed to be an ongoing requirement to comply with existing and future maritime regulations.

Regarding maritime regulations, whilst there are currently no specific regulations solely for autonomous vessels, it is anticipated that this will arrive over the coming years. Until such time, it is assumed that compliance with the appropriate equivalent regulations for crewed vessels will be mandatory and should not hinder the roll-out of autonomous systems.

As such, the human is always responsible for the monitoring and safety of the USV. Safety cases, risk assessments, voyage and trials plans should be addressed on an individual, case by case basis.

5.4 Conclusions

Proven technology already exists for USVs to operate safely and reliably in a wind farm environment, with a minimum and understood risk. The opportunity is now there to utilise this existing capability to prove new concepts of operation in different environments and functions to those that have gone before.

There is no major change envisaged in the short term to the methods utilised for the control and monitoring of USVs. While fully autonomous capabilities will no doubt be developed further over the coming years, the concept of a 'man in the loop' will remain (albeit shifted from on board a traditional crewed vessel to a remote station for an USV, either in close proximity or from a land-based site).

The capability of the USV is far ahead of the adoption of the technology by industry and by the drafting of bespoke regulations. Until such a time as the industry is prepared to adopt new methods, USVs will look to replicate crewed requirements for safety and watch-keeping.

6. Technology Challenges

6.1 Scene set

The technology and capability to operate autonomous vessels travelling to, and within, a wind farm already exists today. If you exclude any bespoke hull designs or cargo handling systems, the navigational and vessel control system can already be bought off-the-shelf to deliver real in field capability. From a capability delivery perspective there are no technological barriers, nor technological blockers, to an uncrewed vessel carrying out its mission today. In a major step change, this technology has enabled the transition from a crewed vessel to an uncrewed vessel.

The next major step change hangs on the question: ***How autonomous is autonomous?***

Rapid technological advances are actively progressing and raising the 'intelligence' capability of vessels. However, from the perspective of the wind farm-operators or stakeholders, this is a concern only within the 'black box' of the vessel. What is of interest to the operator is whether the autonomous vessel is:

a) At least as safe, if not safer than a crewed vessel;

b) The total risk / benefit trade-off is equal to or better than a crewed vessel;

c) The lifecycle cost is equal to or cheaper than a crewed vessel.

Whether the operator of the system is a human driving via remote control or an AI supercomputer makes little difference, and the best / cheapest / safest system will be selected. L3Harris, as an autonomous vessel company, believe that autonomy is the means by which costs and risks can be reduced and safety improved. Beyond the step to make the vessel fully uncrewed, autonomy is not a goal or requirement in and of itself.

This is in stark contrast to the automotive self-driving car, where speeds, proximities and risk to life are all significantly higher. In the automotive world, there is a significant technological barrier to taking the human out of the car, before most of the benefits can be realised. In the maritime world this is largely inverted; taking the human off the boat is practically the first step. This means the self-driving vessel can deliver significant benefits early on, with increased autonomy delivering incremental and marginal gains thereafter.

6.2 Challenges

Command & Control

Teleoperation and human-in-the-loop supervision of onboard systems and autonomy are well-established and dependent upon communications technology.

There is a balance between the availability of affordable communications bandwidth and on-board autonomy required. It is possible to operate safely over limited and reasonably cheap communications, with the right safety case. Fortunately, in the most challenging environments where communications are most important, better communications infrastructure typically already exists or is cost effective to install (i.e. in port and and at the wind farm), which mitigates many of the costs and challenges.

Research and development continues to reduce bandwidth requirements, provide better onboard decision-making, and reduce the cognitive burden on the operator. These developments will continue to incrementally reduce the requirements on communications system and level of human supervision engagement, thereby reducing costs.

Full operation without communications links or human supervision is not likely to be practical, desirable or approved by regulators for the foreseeable future. Hence for all practical purposes it should be assumed that the human can always step in to take over, if needed. This means adoption of the technology is possible incrementally rather than having to wait for 'fully self-driving' to come to fruition.

Navigation techniques

At this time the basic challenges of safe navigation are solved with a human in the loop. Multiple communication systems are required for smooth operations with human-in-the-loop. Collision avoidance systems developed to date can operate safely in most offshore scenarios and work is ongoing to ensure safe operations in more congested waters.

The development of collision avoidance systems may ultimately enable systems to operate without communications, however in the short term these systems will increase the safety of navigation and reduce operator load, enabling multiple vessels to be operated or supervised by a single person.

Navigation techniques are well established for uncrewed systems. There is a general assumption that GNSS or some form of aided GNSS position will be available. Given the availability of constantly updated satellite derived positioning, navigational radar and accurate charting of the locality/installation, then navigation in routine circumstances is not a challenge.

Communication loss 'fail-safe' modes are already implemented as standard, as are emergency stop systems and on-board systems analogous to automotive emergency braking. These rules-based systems only rely upon simple protocols and algorithms that are relatively easily certified and assured.

In situations where other vessels are present, then dynamic techniques are desirable to operate safely. Collision avoidance must address potential interactions with fixed structures, other vessels and floating objects. These systems are already being commercialised, and autonomy pathplanning systems can deliver large portions of the capability, with the human able to step in for the most challenging aspects. Work on these topics is the source of continuous development, and as the autonomy improves, so the intervention rate of the human operator reduces. At some point, over fairly short time horizons, these rates will drop sufficiently to allow human operators to take responsibility for multiple vessels simultaneously (regulations permitting), which brings a step change in cost reduction.

Vessel/system health monitoring

Development of vessel health monitoring systems will support efficient autonomous vessel propulsion systems. Vessel health will be monitored by measuring a combination of battery supply current and engine torque/ power, thereby identifying the capability of the propulsion system including the dynamic influence of the sea state and the cargo load. A two-phase AI algorithm is being developed using Deep Learning to classify and ensure vessel safety and reliability.

Vessel Design

Naval architectural design of an autonomous vessel of significant size (about 24m) and facilitation of autonomous operation are the key challenges for vessel design and cargo handling requirements.

Identifying related hazards, prioritising these and engineering design solutions to avoid, control, mitigate, modify, minimise or accept design associated risks are part of the design process. Risks of collision and loss of control are examples that may be high risk.

Engineering challenges involve automation of cargo handling in the windfarm environment, using the existing infrastructure, and being aspirational at the same time. Dearth of experiential knowledge in seagoing autonomous vessels of significant size poses challenges, while also providing opportunities for innovation.

Novel algorithms for efficient, real-time autonomous vessel route planning and scheduling for cargo delivery in the presence of uncertainties are also key to the integration of autonomous vessels into windfarm operations. This needs to include real-time routing and scheduling systems to ensure optimal allocation of available vessels and their routes for cargo distribution. This optimisation needs to consider an optimisation between fuel efficiency and time underway. The optimisation models and algorithms consider real-time information on forecasts of weather and sea conditions, vessels' individual characteristics for a transit, cargo load, frequency of transport, availability and capacity of the vessels.

Sensors

Sensors are critical for the autonomous vessel to provide situational awareness. Technologies exist that will provide effective solutions for benign maritime environments. However, the extreme marine environment reduces performance and forces the vessel designer into working with fused data from combinations of sensors in order to mitigate the effect of the environment.

Optical systems form the baseline human situational awareness sensor fit. Both visible spectrum and infra-red technologies will be required to provide 24-hour operational capability. Trade-offs are required between resolution at range and field of view. It is general assumed that 360-degree coverage is required, but with an emphasis upon the forward sector. High resolution cameras with stabilised optical zoom are widely available and so it is already possible to ensure a 'good enough' lookout as far as safety is concerned.

Navigational radar is another key sensor, albeit this only detects targets at range and has little benefit for close range obstacle detection and avoidance. High frequency short range radar technology is available straight from the mass-produced automotive industry that can detect humans and fixed infrastructure reliably. Lidar has similar challenges to high frequency radar in that it is only short range and usually expensive for limited benefit in the marine world. AIS is a further sensor technology but is not comprehensively used and can suffer from substantial latency, although it is a ubiquitous marine standard.

A challenge for sensing is that small vessels have a low height above the sea surface for the sensors. This results in a range limitation in all conditions due to the earth's curvature and reduction in performance with increasing wave heights obscuring the field of view. The solution to this challenge is data fusion to provide a coherent situational awareness based upon the information available. Many systems already provide such capabilities and they continue to improve. As the vessel becomes larger, the impact of this issue diminishes, and is negligible for even small vessels.

Areas for development are better resolution and range across the board; more intelligent data fusion to track ever more robustly across a wider environmental envelope; and reasoning about sensor performance providing a 'confidence"'measure to the operator, and self-adapt the navigation and decision making to the sensing abilities.

6.3 Cyber Security

Another aspect associated with the operations of autonomous vessels is data and communication security, including security in relation to cyber-attacks and hacking.

Whilst the absence of crew may make a vessel more vulnerable to piracy (Rødseth 2014), some believe an uncrewed ship has a lessened risk due to the lack of crew to hold hostage (Arnsdorf 2014; Mooney 2015). There is also the inherent possibility of extortion by cyber-attack on an uncrewed vessel.

If critical systems are infiltrated, the vessel may lose its ability to navigate, resulting in a collision causing casualties or pollution and environmental damage. Unauthorised access to intellectual property, manipulation of data and identity theft would all have significant consequences to a company. Vessels may be hijacked and used for illicit purposes. Companies will have to assess their vulnerabilities and implement robust cyber security contingency plans to protect against these threats, all data will need to be encrypted and systems protected from hackers (Hogg & Ghosh, 2016).

To a large extent this is an engineering challenge which has been solved and what needs to happen is a balancing of risk versus investment to ensure that the risk is as low as reasonably practical. In addition to this the need to a fail-safe system which can stop the vessel ensures that it cannot be harnessed operated if the system is infiltrated.

6.4 Conclusions

There are many exciting technology developments that will improve the systems over time, but the threshold has already been crossed for autonomous vessels to operate commercially today. Standard commercial-off-the-shelve technologies, in all areas, are already able to deliver above the minimum requirement for safe and cost-effective autonomous boat operations.

7. Regulatory Challenges

7.1 Scene Set

There is currently no legal framework for marine autonomous systems to operate in international waters. Existing conventions and regulations need to be updated to account for their existence, however in broad terms small autonomous vessels (<24m) are able to operate under current regulations providing that the manufacturer/operator can demonstrate suitable situational awareness to maintain a safe look out.

The Law of the Sea Convention (LOSC) makes reference to the master, officers and crew in relation to the flag state exercising its jurisdiction, control and ensuring safety at sea (Van Hooydonk 2014, 409–411) and also places the obligation on Masters of the vessels to render assistance in the case of a collision or to any person at sea lost or in danger. Van Hooydonk (2014) suggested that the LOSC will need a major overhaul to incorporate uncrewed vessels in areas such as carriage of onboard certificates, right of pursuit, right of visit, control of the ship being taken over in the case of cyber hacking and rules regarding prompt release of crew. It will need to be decided if the shore-based controller fulfils the title and role of a 'Master' as defined by LOSC and other legislation; and, if other shore-based workers can be classified as 'crew' or 'seafarers'.

The Marine Autonomous Systems Working Group (MASWG) was established by the United Kingdom Marine Industries Alliance in September 2014 to identify the regulatory voids that exist for USVs within International Maritime Organisation legislation and has also developed The Maritime Autonomous Systems Surface Industry Code of Practice (UKMIA 2015). The MASWG is focusing on USVs in relation to COLREGS, issues of ownership, structural integrity, registration and insurance with a view to developing a set of classification rules and requirements for additional training, accreditation and certification

7.2 Challenges

As autonomous vessels grow greater than 24m current definitions within regulations such as the Safety of Life at Sea Convention (SOLAS) and Standards of Training, Certification and Watchkeeping (STCW) for Seafarers Convention will likely become an obstacle for the operation of marine autonomous systems in open seas if not amended. As unlike collision regulations these require the operator to be aboard the vessel.

7.3 New Code of Conduct

As an area of continued development, autonomous vessel developers and wider industry partners are continuously developing industry wide guidelines to support the drafting of new regulations and adoption of autonomous systems in the maritime space.

L3Harris have been actively involved in developing the code of conduct and code of practise and use these as guidance for both the development and safe operations of autonomous vessels.

Vessels developed and operated are assessed against the guidelines to ensure that industry best practise is followed. By utilising these guidelines, the adoption of autonomous vessels can be completed in a safe and practical way.

7.4 Conclusions

Regulations are under review at this time at both a national and international level, it is anticipated that this will produce a pragmatic outcome to the issue of regulation. The industry's active involvement ensures that regulators have a full awareness of state of the art and case studies of the applications of autonomous systems.

8. Environmental Health & Safety

8.1 Scene set

The requirement to minimise the risk to human safety offshore is paramount. There is no better way to meet this requirement than not having to send people offshore. The offshore renewables sector, like many other sectors, is looking at ways to automate routine operations. Technology is at the point where it is now feasible that automation can be applied in the design phase and used onshore in the turbine design and build phases so that equipment is capable of being installed and maintained offshore without human intervention.

It has previously been stated that, in the short term at least, USVs will look to replicate crewed requirements for safety and watch keeping. Safety cases, risk assessments, voyage and trials plans should be addressed on an individual, case by case basis.

Collaboration with local and national maritime authorities is well underway, both in terms of defining the regulations required, and with the control systems employed in the remote operation of USVs.

Bespoke Maritime Coastguard Agency-recognised training courses are available for new users in the operation of USVs, courses which fully satisfy the requirements of the industry code of practise.

8.2 Challenges

The challenges are to change the mind set and culture of the designers contributing to the system; vessels, turbine, infrastructure. To recognise and understand the future capability of autonomous systems, so that machine to machine installation, health monitoring and repair is considered routine.

At present, whilst there are regulations and standards for offshore working, e.g. offshore engineering, maritime operations, there are no specific regulations for autonomous systems. Technology developers must provide evidence to demonstrate that they are no less safe to operate than crewed systems.

8.3 Conclusions

Autonomous systems are increasingly being accepted into different sectors. The contribution they can make to improving offshore safety is implied and evidence needs to be gathered to prove they can operate safely in conjunction with crewed operations.

9. Societal Challenges

9.1 Scene set

There is naturally a lot of resistance to the notion of autonomous systems operating alongside or replacing crewed operations. Concerns regarding safety, data security and job protection must all be addressed if the industry wants to enable the integration of autonomous systems offshore. There will be some read across from other sectors that are also embarking on automation of processes and operations such as aerospace (freight transport between airports), automotive (driverless cars), defence (minesweeping, bomb disposal, battlefield transport), maritime (freight), space (off world operations).

9.2 Challenges

Some of the most urgent questions which need to be answered are:

- Safety - How do we prove these systems are safe to operate?
- Data Security - How do we protect our data from accidental leakage and malicious corruption, or loss?
- Job security - How do we translate lost jobs

at sea into high skilled jobs onshore monitoring and controlling offshore operations and maintaining high tech USVs? What are the new high skill roles created by activities enabled by USVs, previously unimagined by manual operations?

- Technology – With the evitable leap in technology, what new skills, training, tooling will be required?

9.3 Conclusions

Societal acceptance of varying degrees of autonomy and the safe operation of AI will continue to grow. Evidence will be gathered that may indicate autonomous systems can be safe to operate and that a manual dialling in and out of the level of autonomy is a practical means to enable interoperability with crewed systems.

10. Levelised Cost of Energy

10.1 Cost reduction in offshore wind

Several vessel strategies are available for offshore wind sites for operations and maintenance. The most common approach is the use of crew transfer vessels (CTVs) which deliver both crew and equipment to turbines daily. For sites which are further from shore, this approach is unfeasible due to the long commuting time to get to shore. In these situations, a Service Operated Vessel (SOV) which stays on site for longer durations may be appropriate.

USVs can work with both scenarios to deliver equipment and replacement parts to turbines, either before crew arrives from port, or to deliver resources from port quickly where they are not available on a nearby SOV.

10.2 Potential cost and performance benefits

ORE Catapult has prepared a standalone report *"Life Cycle Cost Modelling of USVs for Offshore Wind Farms"* part of Work Package 5 in the WASP project. Key findings from this work are:

When it comes to considering the levelised cost of energy, incorporating the use of a USV into site vessel operations has a net benefit in the medium, far shore site and cluster site. For the nearshore site, the fixed cost of the vessel is needed to see a real benefit for a small site.

Initial analysis has used high level assumptions and publicly available data. Access to historic data from an operating site would provide more a more granular understanding of vessel use and where cost savings could be made through the availability of a USV on a task by task basis.

Site specific studies would also enable analysis of a range of disembarkation methods, including walk to work from an SOV which increases the number of crew per vessel and limits flexibility of the vessel to move across wider areas of the site.

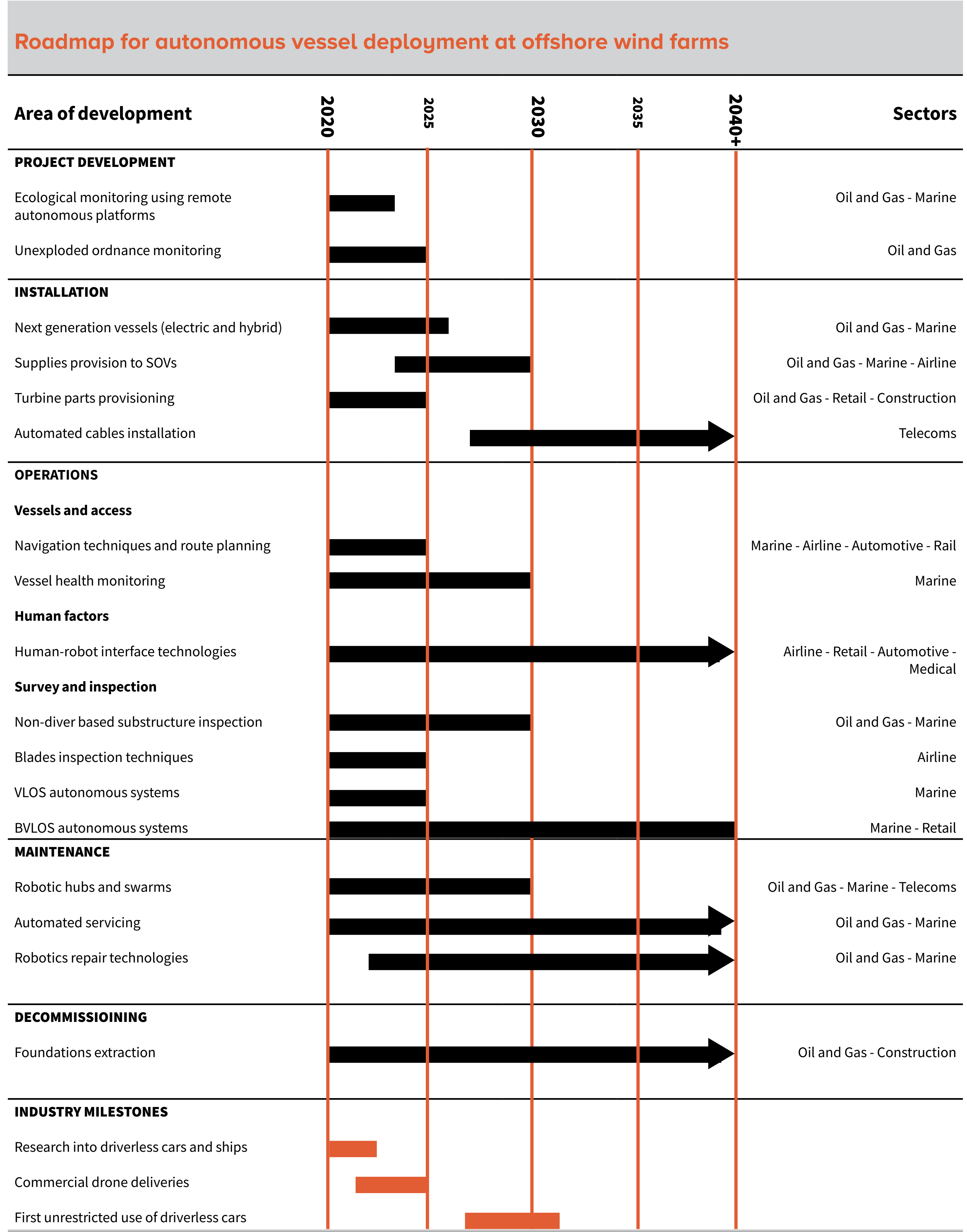
There may be an opportunity to use a USV during the construction phase of the project. The WASP project USV vessel has been designed to have a larger deck space than typical vessels of its size, as there is no requirement for auxiliary facilities for crew. As the vessel can operate in wider weather windows than a similarly sized vessel, it may be capable of carrying larger loads with fewer trips and with a lower risk of weather downtime.

As well as providing equipment transfer, the autonomous functionality of the USV lends itself to many other purposes. This could include patrols for site security and autonomous surveying.

11. Roadmap

The WASP project has carried out an analysis of how USVs could support offshore renewables and could be integrated into crewed operations.

The analysis includes a study of global autonomous systems and AI development, autonomous surface vessel performance, vessel health monitoring, marine coordinator operations, offshore operations and likely developments. A synthetic trial was conducted that looked in more detail at some of the higher risk areas of operation and integration.



Name of innovation area	Description	Expected start/ end	Other sectors
Category: Project Development			
Ecological monitoring using remote, autonomous platforms	Ecological monitoring using remote, autonomous platforms would allow efficient gathering of data on abundance, distribution and behavioural consequences of construction activity at offshore wind farms. The main aim would be detecting, locating and identifying cetaceans and pinnipeds to species level. Results would then feed back into impact assessments undertaken by developers and strategic planning undertaken by government.	2020-2022	Marine Oil & Gas
Unexplored ordinance monitoring	Identification, classification, safe removal and disposal of subsea Unexploded Ordnance that extend from the high water mark out to deep water.	2020-2025	Defence & security Oil & Gas
Installation			
Next generation vessels (electric and hybrid)	Next generation CTVs should consider new hull forms for increased efficiency and investigate alternative propulsion and fuelling methods. These could include electric, hybrid and hydrogen and offer off-shore charge. Longer term it would include a universal charging system for standardisation of vessels across the offshore wind industry.	2020-2025	Marine Oil & Gas
Supplies provision to SOVs	One of the advantages of SOVs is the capacity to stay offshore for up to 28 days. SOVs have larger cargo payload capacity and usually return to the port for supplies or spare parts. A small autonomous vessel or a drone that could deliver supplies to SOVs could extend its time without returning to the port.	2023-2030	Marine Oil & Gas Aerospace
Turbine parts provisioning	During construction the development uses specialist heavy-lift vessels known as 'Jack-up' vessels to place the turbine foundations and lift the tower, nacelle and blades in place. In the future they will be accompanied by a fleet of various autono-mous support vessels to provide supplies and turbine parts.	2020-2025	Oil & Gas Retail Construction
Automated cables installation	Automating the installation process of cables. This will probably be one of the last stages of automation as there are issues with bend-ing and fatigue in crewed vessels that should be addressed.	2020-2028	Telecoms

Name of innovation area	Description	Expected start/end	Other sectors
Operations			
Vessels & Access			
Navigation techniques and route planning	See 6.2.2.	2020-2025	Automotive Rail Marine
Vessel health monitoring	See 6.2.3.	2020-2030	Marine
Human Factors			
Human - Robot interface technology	In order to support an increasing penetration of robotics and au-tonomous systems interfaces which aid the interface between these systems will be required. This may involve natural language trans-lation or interfacing of autonomous systems with existing workflows such as marine control.	2020-2035	Healthcare Aerospace Automotive Retail
Survey & Inspection			
Non-diver-based substructure inspection	These are ubstructure and cable inspection systems that do not require a human to dive or make real-time decisions (e.g. using advanced camera systems or uncrewed subsurface vessels). Ap-plications would include visual inspection of anodes, corrosion protection, weld integrity, cable depth burial, disposure and marine growth.	2020-2030	Marine Oil & Gas
Blades inspection techniques	Wind turbine blades are complex composite structures which are subject to complex loading. It is therefore potentially valuable to be able to conduct non-destructive inspections which will highlight defects not visible on either inner or outer surface of the blades either remotely or without the need to deploy rope access techni-cians.	2020-2025	Aerospace
VLOS autonomous systems	An example would be a blade inspection drone that can fly a programmed route under its own control, but where an operator is still present to launch, recover and supervise the vehicle at all times.	2020-2025	Defence Security Oil & Gas
BVLOS autonomous systems	An example is a blade inspection drone where the pilot does not need to see the vehicle at all times. There are significant technical challenges involved, but it would remove the need for humans to be present close to turbines.	2021-2035	Defence Security Oil & Gas

Name of innovation area	Description	Expected start/ end	Other sectors
Maintenance			
Robotic hubs and swarms	Incremental cost reduction is possible: robots perform inspection, maintenance and repair (IMR) tasks, recharged and recovered by crewed vessels i.e. semi-autonomous. They could use uncrewed vehicle hubs that can autonomously transport, deploy, recover, recharge multiple robots.	2020-2030	Marine Oil & Gas
Automated servicing	Wind Farm scheduled maintenance (aka servicing) involves every single turbine receiving the same checks, top ups, tightening etc., every year. It is a time-consuming annual task. There is a big opportunity to automate many of these tasks to minimise H&S risks by avoiding people transiting and visiting turbines (e.g. marine growth cleaning is not happening as frequently as it could be and could be automated). Examples could include tightening of wind turbine bolts, removal of guano; removal of marine growth from substructures.	2020-2040	Marine Oil & Gas
Robotics repair	A logical progression from performing inspections and repetitive maintenance tasks will be robotic systems that can conduct physical repairs. As with other industries these are most likely to see applications in challenging environments first. Examples could include robotic systems to intervene in cable reburial, scour remediation or in situ cable repair, in situ remediation of damage to surface coatings where access is challenged by confined spaces or rope access, repair of wind turbine blades; testing of blade lightening protection systems.	2022-2045	Marine Oil & Gas
Decommissioning			
Foundations extraction	Dismantling and transporting turbines can be costly and current techniques require expensive, short in supply, crewed vessels to facilitate the work. The same installation jack-up vessels can decommission all turbine components. With the size and complexity of these vessels the automation is not expected to happen in the near future.	2020-2050	Oil & Gas

INSIGHTS

The project has drawn several critical observations and findings for future study:

OBSERVATIONS

The adoption and increase in autonomous systems in other sectors, automotive, aviation, maritime and defence is increasing year on year;

There is evidence of read across of USV technology from these other sectors into offshore renewables (navigation, surveillance, launch and recovery, cargo transfer).

FINDINGS

- Through a land based central control the operation of USVs within an offshore wind farm is entirely feasible and achievable at the time of writing (Jan 2020);

- The integration of sensors, cameras, radar and proximity detection is feasible today and will enable beyond line of sight operations of USVs to support far offshore operations;

- The development of a 25 to 30 metre USV (suitable for cargo transfer and other duties) is possible and is simply subject to the creation of the right commercial opportunity to initiate the build programme;

- USV operations offshore can be safely integrated with crewed vessel operations, although more operational data and experience is required to fully embed USV systems; and

- Autonomous cargo transfer is technically feasible with technology available at the time of writing. More work is required to determine the efficient deployment and usage of technicians where cargo is moved autonomously between point of embarkation and offshore wind turbine.

CONCLUSIONS

The increased use of robotics and artificial intelligence is dominating technology advances in all sectors. The processes for the design, deployment and operation of offshore wind farms can take advantage of these RAI technology developments from other sectors to minimise adaptation costs and de-risk technology readiness.

USVs can be used to help and advance the following sectors: defence; maritime & border patrol; search & rescue; oil & gas; and offshore wind. The biggest investments are generally in the defence and maritime & border patrol sectors where USVs tend to be larger. This is mainly due to the demand for these vessels from navies for Intelligence, Surveillance and Reconnaissance (ISR), particularly in Europe. Larger USVs can hold more advanced electronics and equipment onboard such as drones and surveillance cameras that require a lot of data to be stored, creating a host of opportunities within the sector. Due to their endurance, USVs are unmatched when it comes to surveillance and patrols. As a result, USVs with high storage capacity are set to drive the growth of the market. In line with this, the driving forces onboard are expected to be ISR, water quality monitoring, maritime security & threats and ocean & data mapping.

Newer designs are looking at ways of using alternative energy sources to power the USVs. This is an attempt to save money on fuel costs while also increasing the amount of time that can be spent on the water. Doing this could increase productivity and would make surveillance easier and allow surveys to be completed quicker. Being available on the water for up to 24 hours or longer suits the maritime & border patrol sector as it would make it easier to stop illegal fishing as well as smuggling and trafficking.

Offshore wind has yet to be fully explored when it comes to USV advancements meaning there is great potential in the market. There are opportunities for start-ups throughout the USV industry which will fragment the market and create competition which could benefit offshore wind due to the lack of big investment thus far. Smaller USVs are better suited for working with turbines since they can get closer to the turbines than bigger vessels making them suitable for O&M and surveys. However, some maintenance will require larger USVs depending on the scale of the issue. An example of a USV that can be used for windfarm operations is the L3Harris C-Worker 5. It has a small and flexible survey platform so it can get closer to the turbines to give better coverage. Economic benefits include the lower cost due to a smaller workforce and less fuel required. At present, there is not a common commercial use for USVs within offshore wind, but it is hoped they will be able to be used for logistics, surveying, monitoring and for aerial drone deployment. There are several roles where USVs (and uncrewed sub-surface vessels) are already technically capable to perform offshore, albeit in segregated sea space and under strict crewed observation and control – asset surveillance, survey, environmental data collection and security patrol.

USVs are capable of point to point navigation in open waters. There remains a challenge to prove they can operate safely in the close confines of a harbour or an offshore windfarm in amongst crewed vessels. There are many organisations addressing this challenge and through improved sensor integration and maturing collision avoidance algorithms. It is most likely that by 2025-2030 USVs will operate seamlessly together and amongst crewed vessels.

RECOMMENDATIONS

The WASP project has embedded its findings and conclusions into this document. The recommendations for the offshore wind sector are:

1. Embrace the adoption of autonomous systems, learning from other sectors;

2. Further study is required of specific sites, comparing crewed vessel operating costs and performance with USVs to validate the boundary benefits. Boundary benefits can then be exploited to extend USV cost and performance benefits;

3. ORE Catapult should be charged by the Offshore Wind Industry Council to maintain a proactive position in monitoring best practice and lessons from other sectors and measuring adoption and integration into the offshore wind sector.

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