Final report

1. Project details

Project title	FOD4WIND
File no.	64021-2053
Name of the funding scheme	EUDP
Project managing company / institution	Energy Cluster Denmark
CVR number (central business register)	41343788
Project partners	Upteko, SDU, Esvagt, SGRE, ECD
Submission date	February 2025

2. Summary

Describe the objectives of the project, the obtained results and how they will be utilized in the future, both in English and in Danish. The summary will be published on www.eudp.dk and www.energiforskning.dk.

Project summary :

The purpose of the project

The project did succeed to develop new service technologies within offshore wind which ultimately will support the wind industry's challenge of reducing downtime and overall O&M costs while improving the LCOE and reduction of CO_2 emission. The project developed a drone system with specialized payloads and navigation software, that performs autonomous package deliveries from the SOV to the nacelle and autonomous blade inspections, enhancing maintenance efficiency and reducing downtime. The project did achieve a technology level of TRL7 (prototype demonstration in an operational environment (integrated pilot system level)).

Results, conclusions and perspective

- Successful development of an autonomous drone system, including the Lark drone able to handle small payloads, and navigation software (TRL 7).
- Successful demonstration and validation of offshore package delivery (TRL 7) and onshore wind turbine inspections (TRL 6).

The package delivery solution will streamline offshore maintenance operations, reducing the logistics costs and the efficiency of the service technicians and ultimately improve the uptime of the windturbine, substantially. The autonomous drone system will also be used for ongoing and future offshore wind turbine inspections, and enhance maintenance efficiency.

The expected effects of this autonomous technology include a significant reduction in wind turbine downtime through efficient delivery of spareparts, tools etc and improved inspection procedures, i.e preventive maintenance. Package delivery application is by far the lowest hanging fruit and will be able to secure commercial market expansion as early as second half of 2025. Operational costs will be lowered, and flexibility for offshore wind farm maintenance will be increased. Enhanced data collection will support predictive maintenance and improved decision-making processes. Additionally, optimized vessel utilization and reduced inter-windfarm logistic trips will be required for maintenance tasks and thereby contribute to reduced CO_2 emissions.

The project has demonstrated resilience and adaptability in the face of various challenges throughout the project period. The successful mitigation of both technical and market risks has not been trivial and has posed an ongoing and critical risk profile during the project period. The project has not only achieved its primary objectives but has also set a strong foundation for future advancements in and maturation of autonomous drone technology for offshore applications. The market potential is tangible as the market demands solutions that can make offshore operations more efficient.

The FOD4Wind technology outcome and the lessons learned combined with the strategies developed during this project will undoubtedly support the near term market offerings and initiatives in this field.

Projektresumé:

Formålet med projektet

Projektet tacklede den vindustriens udfordringer med at reducere nedetid, forbedre logistikken internt i windfarmen, forbedre service effektiviteten (spare part leverancer, tools etc) og energiomkostninger, incl CO2. Projektet udviklede et dronesystem med specialiserede payloads og navigationssoftware, der udfører autonome pakkeleverancer til nacellen og autonome vingeinspektioner, hvilket forbedrer vedligeholdelses-effektiviteten og reducerer nedetiden.

Resultater, konklusioner og Perspektivering

- Succesfuld udvikling og demonstration af et autonomt dronesystem, inklusive Lark-dronen med hoisting system til håndtering af mindre autonome pakkeleverancer fra SOV til WTG nacelle (payloads op til 5 kg) og tilhørende navigationssoftware.
- Succesfuld autonom demonstratione og validering af blade inspektioner af onshore vindmøller og pakkelevering fra Esvagt skib til offshore vind turbine.

I fremtiden vil det autonome dronesystem blive brugt til løbende og fremtidige inspektioner af vinger på offshore vindmøller, hvilket vil forbedre vedligeholdelseseffektiviteten.

Pakkeleveringsløsningen vil strømline offshore vedligeholdelsesoperationer, reducere omkostninger til logistik qua substantiel forbedring af effektiviteten af serviceteknikkerne allokeret til de enkelte jobs samt forbedring sikkerheden. Bundlinjen er reduceret CO2 emission samt forbedret oppetid og deraf højere energiproduktion.

De forventede effekter af denne teknologi inkluderer en betydelig reduktion i vindmøllers nedetid gennem effektive inspektioner og forebyggende vedligeholdelse. Driftsomkostningerne vil blive sænket, og fleksibiliteten i vedligeholdelsen af offshore vindmølleparker vil blive øget. I forhold til de løbende vedligeholdelsesopgaver (vinger) vil forbedret dataindsamling understøtte prædiktiv vedligeholdelse qua forbedrede beslutningsprocesser. Derudover vil optimeret udnyttelse af de allokerede servicesteams, SOV/CTV fartøjer og hurtigere sikring af driften optimeret logistik (færre sejlture), der kræves til vedligeholdelsesopgaver, bidrage til reducerede CO2-udledninger.

Projektet har demonstreret modstandsdygtighed og tilpasningsevne i forhold til forskellige udfordringer igennem projektets levetid. Den vellykkede reduktion af både tekniske og markedsmæssige risici har ikke været triviel og har udgjort en løbende og kritisk risikoprofil i projektperioden. Projektet har ikke kun nået sine primære mål, men har også sat et stærkt fundament for fremtidige fremskridt inden for autonom droneteknologi til offshore applikationer. Erfaringerne og de strategier, der er udviklet i løbet af dette projekt, vil uden tvivl gavne fremtidige initiativer på dette område.

Resultaterne og erfaringerne, der er udviklet i dette projekt, vil utvivlsomt understøtte de kortsigtede markedstilbud og -initiativer på dette område.

3. Project objectives

What was the objective of the project?

The objective of the FOD4Wind project was to develop a fully integrated autonomous solution for offshore wind operations. This solution aimed to enable autonomous drone-based inspections of wind turbines as well as enable package delivery in offshore environments from an SOV to the WTG nacelle. The project focused on creating key components such as the Lark drone, specialized payloads for various missions, and navigation software that allows the drone to take off and land on a moving SOV vessel (Service Offshore Vessel) platform. The system was designed to be scalable and modular, making it adaptable for additional applications in the future.

Which energy technology has been developed and demonstrated?

The FOD4Wind project developed and demonstrated an advanced autonomous drone system for on- and offshore and wind operations. This technology included:

- **Autonomous Package Delivery**: The drone system facilitate the delivery of tools, spare parts, and other necessary items up to 5 kgs to offshore wind turbines from the SOV. This reduces the time and cost associated with traditional delivery methods, enhancing the overall windfarm uptime, efficiency, and Total Cost of O&M, including the improvement of safety of maintenance operations.

- **Autonomous Offshore Wind Turbine Inspections**: The drone system enables continuous, efficient inspections of wind turbine blades. This technology improves the efficiency of maintenance operations by allowing inspections to be conducted day and night, thereby reducing turbine downtime.

These innovations provided significant value to service operation vessels (SOVs), turbine manufacturers, and wind park owners by improving operational efficiency, reducing CO_2 emissions, and enabling data-driven decision-making through comprehensive data collection.

4. Project implementation

How did the project evolve?

The project has been successful overall, but it has faced several challenges. Despite these obstacles, the team has managed to develop both hardware and software, achieving optimal integration between the two. This has enabled the demonstration of autonomous offshore flight and package delivery to the nacelle top of an offshore wind turbine, as well as an automatic turbine inspection, of which only a single blade could be inspected at the current software state. The package delivery drone operations were conducted from one of Esvagt's SOVs (Service Offshore Vessels), showcasing the project's practical applications in an operational environment.The automatic turbine inspection drone operations were conducted onshore using a wind turbine identical to the offshore wind turbines.

However, due to delays in several of the project's development activities and resource allocation, the original scope had to be adjusted. This adjustment meant that the scope concerning the drone Nest was aremoved, and instead the drone operations took place from a designated area on the service vessel. This decision was made in 2023 to ensure that the offshore demonstration could be completed successfully. Despite these changes, the project has still managed to achieve its primary objectives, demonstrating significant advancements in autonomous drone technology for offshore applications.

The Project has developed a comprehensive and full safety and operation manual incl detailed operational procedures and checklists for obtain the required flight approvals from both the authorities and the wind park operators. The based on ESVAGTs and SGREs, which have extremely high HSE requirements, Strict safety protocols with associated procedures were developed and were used to log progress during flights. This to permit access and operation with the drone in the wind farm This set of manuals has been built on the ESVAGT HSE and operational framework for SOV operation.

Describe the risks associated with conducting the project.

Throughout the project period, the team has successfully mitigated several risks. One of the major technical challenges was developing software for autonomous takeoff and landing on a SOV that moves both vertically and horizontally (heave), sway and surge due to wind, waves, and other factors in an operational environment. This was a significant technical challenge and risk, but the team managed to address it effectively, using a custom designed drone LARK™ and custom software utilizing sensor fusion from drone data and camera stream.

In addition to technical challenges, the project also had to embark on high safety standards typical for offshore industries. To meet these requirements, the team continuously worked on developing and validating flight manuals and safety protocols. These efforts were crucial to ensure that the commercial solution would comply with the demands of market stakeholders, including ship owners and wind asset owners.

The project also encountered some unforeseen market risks. One significant risk was the requirement for business interruption insurance to cover potential production interference in the event of a collision between the drone and a turbine blade. Although the actual risk of damage to the turbine was assessed to be minimal, if not negligible, the operators of the offshore wind farm where the demonstration took place insisted on such insurance. This risk was mitigated through close and coordinated collaboration between project partners, which enabled the demonstration to proceed successfully.

Did the project implementation develop as foreseen and according to milestones agreed upon?

The milestone of package delivery has been successfully conducted on an offshore turbine in January 2025, thereby achieving Technology Readiness Level (TRL) 7.

Due to weather challenges and last-minute technical challenges within the last part of the year, the final milestones of flying turbine inspection using the local planner has been delayed until January. The global planner (a vital part of the blade inspection) was successfully tested and validated on an onshore wind turbine to TRL 6.

Did the project experience problems not expected?

The project has experienced significant staffing changes within the project team and the steering committee across several partners. These changes have slowed down some of the project's activities and resulted in a loss of knowledge within the project group.

To address these issues and to mitigate the impact, the project has held very frequent steering committee meetings for an extended period to ensure close coordination of activities and collaboration among the partners.

The final offshore tests and demonstrations were planned to be conducted in the fourth quarter of 2024. However, we faced challenges due to poor weather conditions, and to obtaining flight permits as well as drone-related challenges. To achieve our goals, we found it necessary to extend the project into January 2025 to create more opportunities for demonstration windows.

5. Project results

Was the original objective of the project obtained? If not, explain which obstacles that caused it and which changes that were made to project plan to mitigate the obstacles.

Almost all the objectives were met. An early decision to phase out the NEST charging station was made within year 1 of the project. This was due to resource allocations and the decision that the Package delivery and Turbine inspection was more viable and commercially successful roadmap to success.

Due to the need for reallocation of resources into inspection software, the decision to rescope the original goal from full turbine inspection to three blade was made. Software for local and global planner around a turbine was prioritized and, in the end, due to extensive integration testing, it was shown that it is possible to inspect a full turbine on a single charge. Furthermore, the software to handle the starting position of turbine rotation was irrelevant.

Describe the obtained technological results. Did the project produce results not expected?

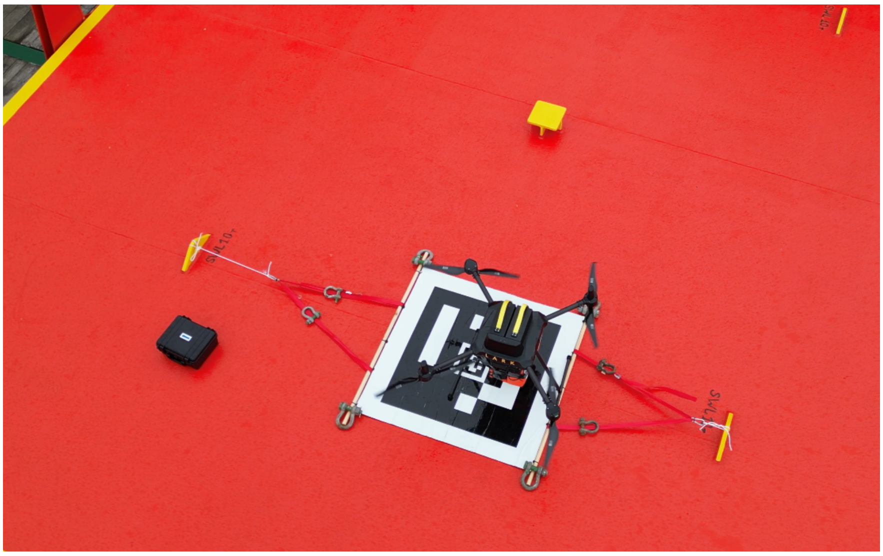
Many technological results came from this project. Below is a summary of what has been developed in this project

- Autonomous take-off and landing on an ESVAGT SOV vessel

This development has been through iterations: “Simulation tools - Gazebo”, “Automatic take-off from designated stationary ground area, and automatic landing using fiducial marker”, “Repeated light in controlled Airspace with motion table simulating wave motion”, “Manual take-off and landing on vessel” and lastly “Automatic take-off and landing on vessel using previous proven flight strategy”.

The software package in this project is using Mavros to communicate with the flight controller. Here the API call to do automatic take-off has been implemented in the code with custom finetuned parameters, defined and updated in each step mentioned above. For landing a combination of a custom designed GPS ground unit, for rough estimation of landing target, and a fiducial marker has been used as the ground unit landing site. This together with CV ROS node is used for precision landing on a moving target. It is possible for the target to move in the plane as if the vessel is sailing while landing, but it is also possible for the drone to adjust the landing trajectory to match the heave, roll and pitch of the vessel caused from the waves.

Figur 1 - Automatic landing, approach



Figur 2 - Automatic landing, landed. Fiducial marker and GPS ground unit is in view

- Package delivery from vessel to Wind turbine via drone

This development has been through many iterations: “Simulation tools - Gazebo”, “Hardware, GUI and tabletop”, “Flight in controlled Airspace – no turbine”, “Onshore - real turbine” and “Offshore – Real turbine”.

First iteration of the software for package delivery has been developed in order to navigate from point A to point B in a straight line. This development is not groundbreaking but a necessary step to the final objective.

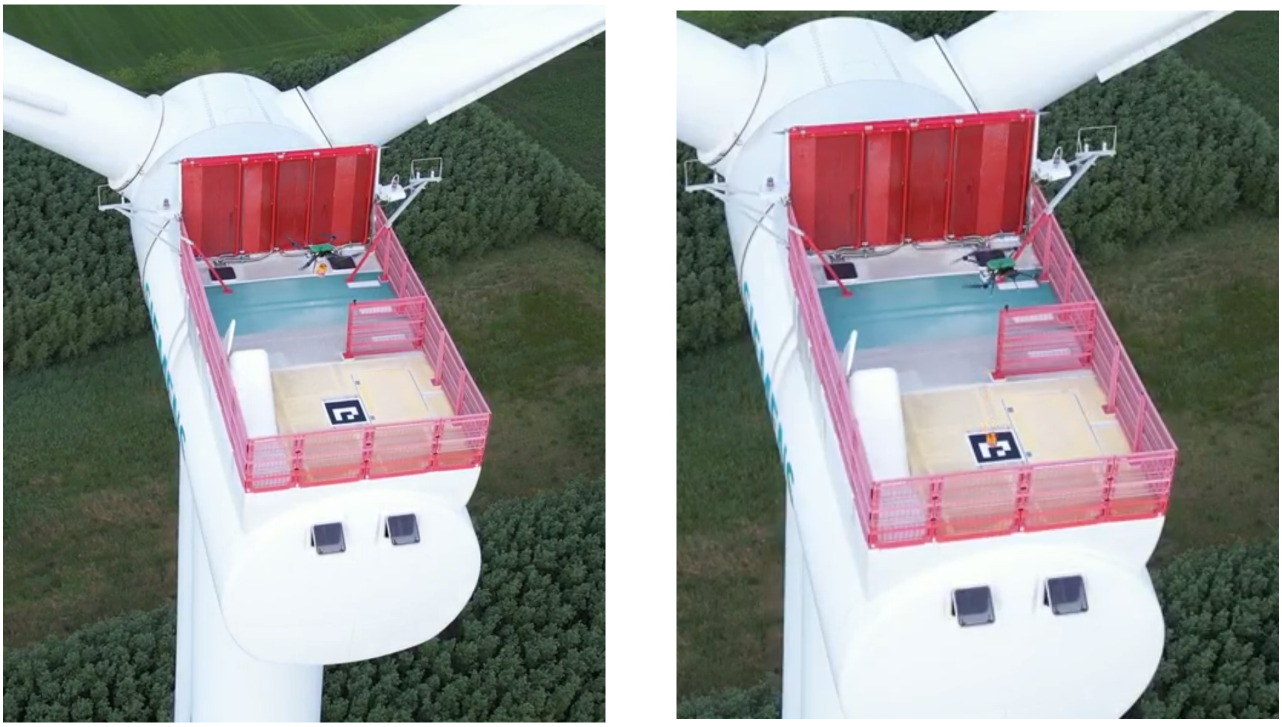
With the custom software it is possible to control the velocity and acceleration of the drone in the path, this is necessary as the drone is carrying a heavy load underneath its body that is nearly-rigid connected and can transfer its inertia to the drone if the acceleration is too high in a change of direction. As such the delivery trajectory takes place in multiple steps where it is more agile and faster the further the drone is from the delivery point, slowing down when approaching turbine.

The package delivery mission is started from the GUI by the user. Here the user picks the desired destination from the database of turbines. This database includes all necessary information about each valid turbine. Here the user sorts the turbines first by site then by turbine number. When the user picks the desired turbine, the system automatically fetches the necessary information such as GPS location and hub height based on the turbine model and site information. From this point the user initiates a take-off and after the drone is airborne, he can start the mission allowing the drone to enter “mission state”. Now the drone will automatically navigate towards the geolocation of the turbine whist raising in altitude toa target of 20 meters above the nacelle. When the drone is within 30 meters horizontal distance to the turbine, and it has not reached the full height it will stay at the position and fly up until desired height is reached, afterwards it will go the destination above a nacelle.

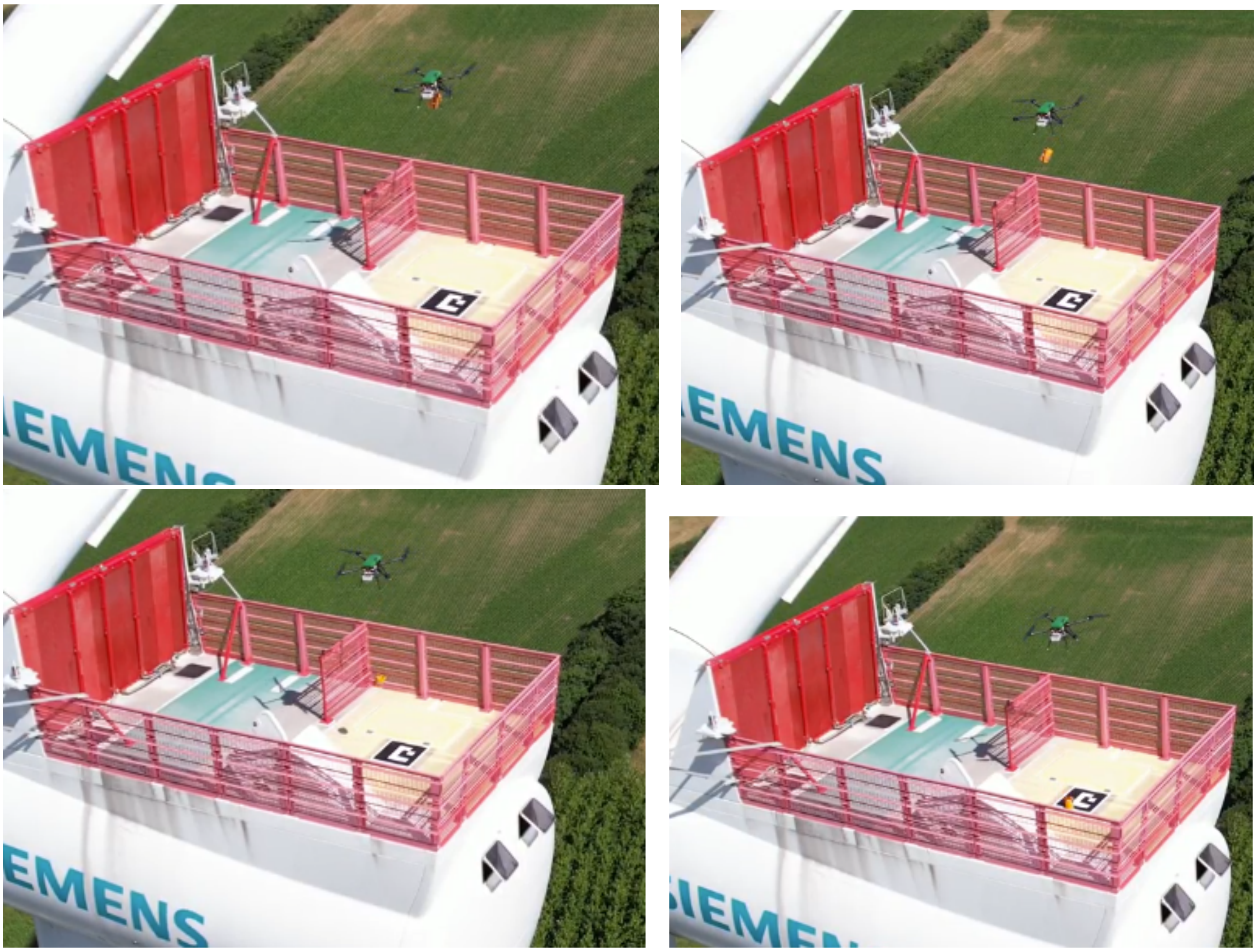
At the nacelle a fiducial marker is places as the delivery point, marking it as a safe area, where any recipient of the “package” can pick up said delivered package. The drone is fitted with an RGB camera attached to a gimbal for stabilization. The drone has an onboard computer for image analysis. The fiducial marker is a special marker utilizing an algorithm - developed at the University of Michigan[1] called AprilTag and customized by Upteko to fit the applications need. The onboard computer is able to judge the pose of the marker, and by having a properly calibrated camera sensor, also able to obtain a distance to target. The goal of the delivery drone is to hover 4 meters above the marker and initiate the delivery.

Through collaboration with Maxon motors (motor specialists) a motor for the delivery mechanism has been found that is small and powerful. Using this motor, it is possible to slowly and safely deliver packages of up to 5kg in a distance of 4 meters, ensuring the drone is not close the recipient of the delivered package. After delivery the drone will return to the landing site and proceed to land as described earlier.


[1] https://april.eecs.umich.edu/software/apriltag



Figur 3 - Package delivery in sequnece images. Video avalible upon request. From video DJI_0992



Figur 4 - Pacakge delivery from another angle from video: DJI_0991

- Turbine inspection from vessel

Software has been developed that can autonomously inspect all blades of a turbine in one flight. The drone inspection starts by taking an image in front of the hub which gets analyzed by Computer Vision software to estimate the turbine pose. The software utilizes the global planner to make a flight plan with all positions that have to be visited to cover all blades with the requested image overlap. The flight is controlled by a state machine that manages the drone and flight plan. The local planner is used to interpret the lidar data and correct the current flight plan to keep the blade in the center of view with the correct distance from the blade.

The developed software includes safety mechanisms to ensure that outliers in the local planner corrections are discarded and to disallow corrections that would place the drone closer than 5m to the detected blade. The software requires the operator to set which image overlap and distance from the blade the inspection should be conducted at.

The software supports turbine poses with the first blade between 0 and 40 degrees counterclockwise from vertical. Within this margin the software automatically adapts to the pose and can conduct the inspection.

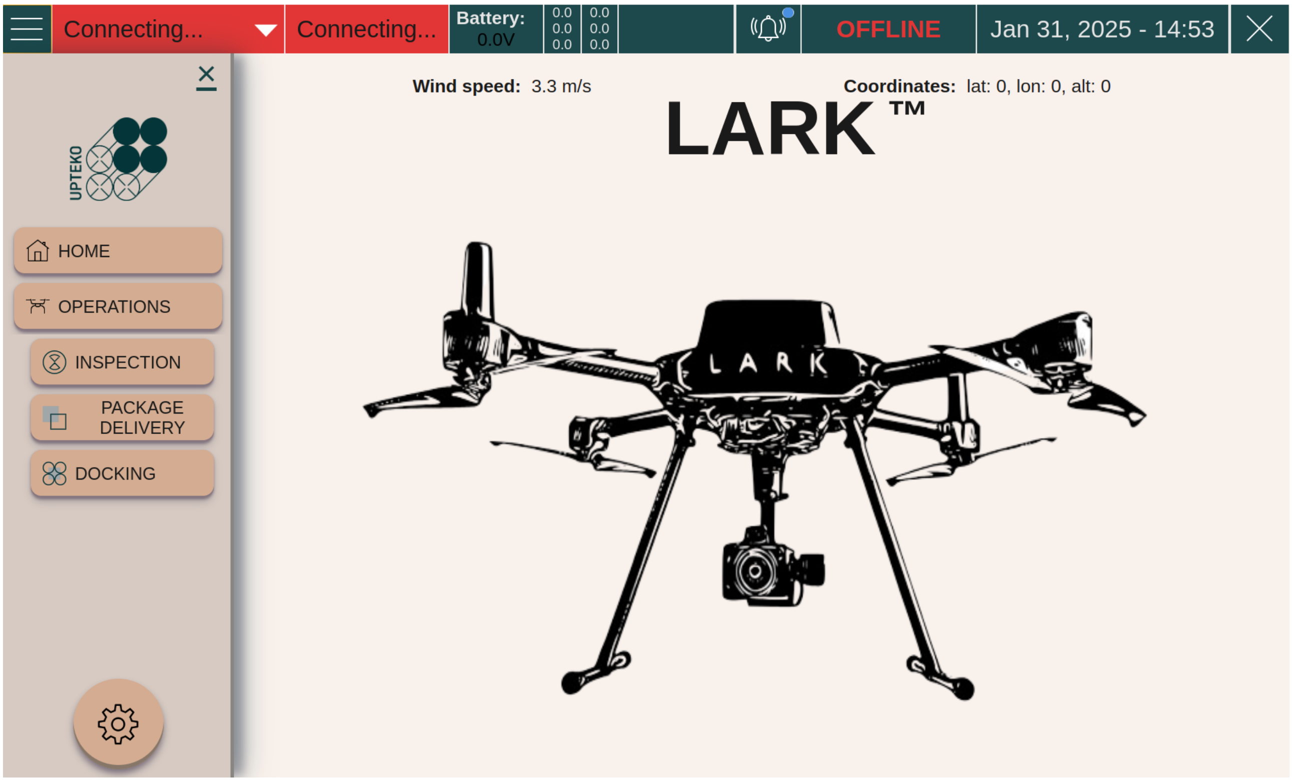
Software to autofocus on demand has been developed, but is currently not triggered automatically, but controlled by the operator. Computer vision software was developed to help analyze the image quality and suggest changes to camera settings, but this was not integrated to be done automatically during flight.

The software has been tested in multiple iterations, first in simulation-in-the-loop with “Gazebo”, then outdoors on the blade-stand with a smaller turbine blade attached and at a real turbine onshore.

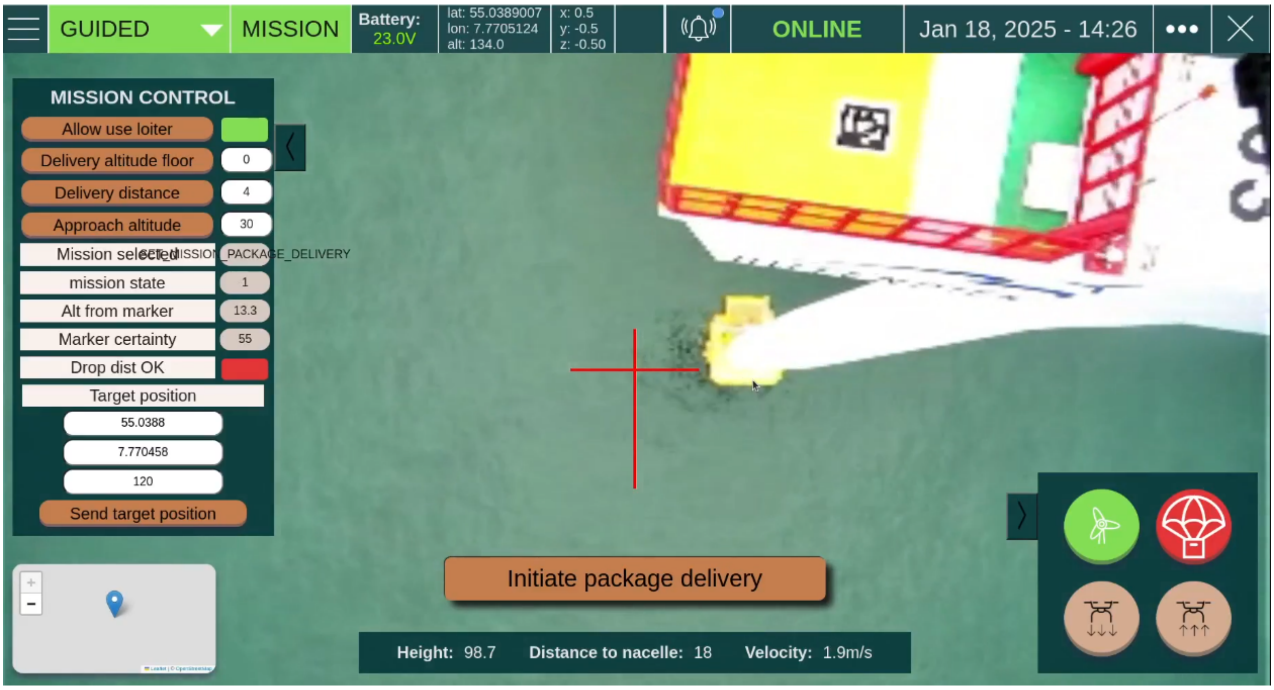
- GUI development

The graphical user interface has been through multiple iterations: "TKinter GUI", "Electron GUI with ROS2", "Electron GUI without ROS with TCP". These stages have ensured an intuitive and well working user interface.

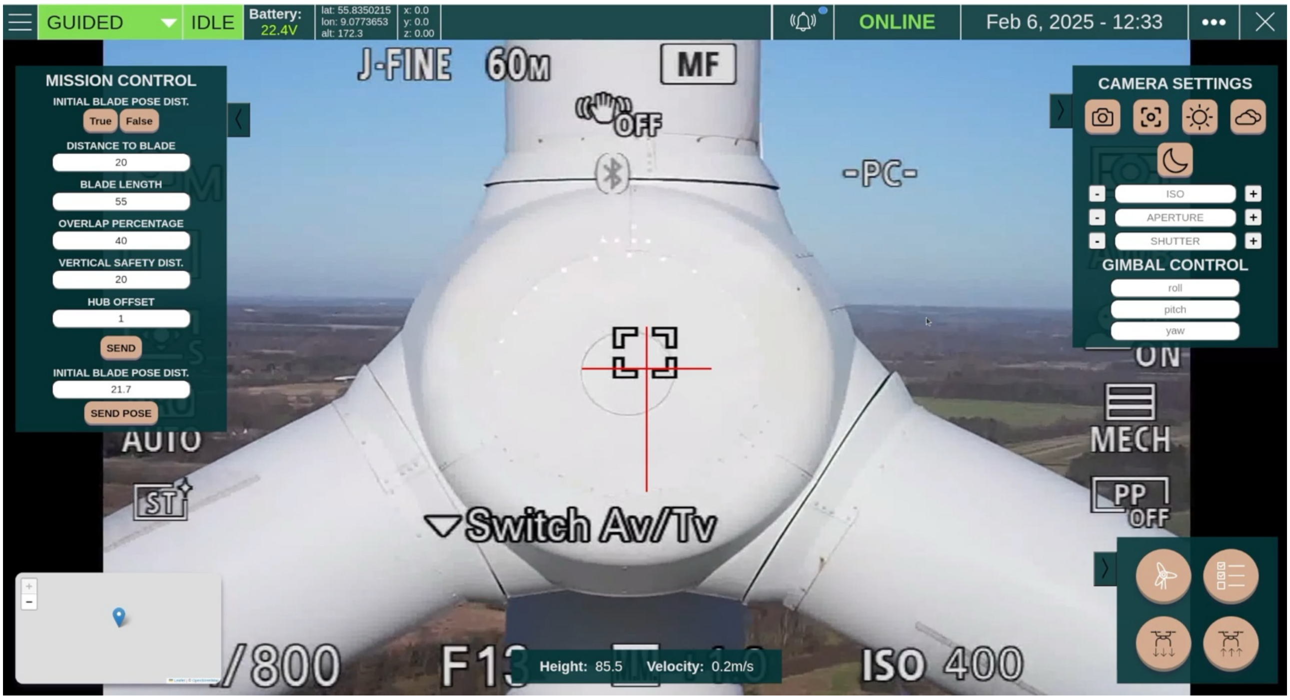
In the start of the project the focus was to develop the drone platform and software layer. The "GUI" was only the raw terminal with commands typed out each time. As the project progressed and more features were needed, the task of using CLI (Command Line Interface) was too cumbersome. A simple GUI in TKinter was designed with a ROS wrapper for backend communication. This application was only meant for debugging and basic functionality. The project and functionality grew once again when both Inspection and Package delivery was focused on, so the TKinter was ported over to use Node.js and electron for front- and back-end. This change made the GUI into a user friendly and beautiful application that, with little effort, could be used with outside collaborators or even customers.



Figur 5 - GUI landing page, Operation overview folded out, offline



Figur 6 - GUI package delivery, active mission



Figur 7 - GUI turbine inspection, active mission

Describe the obtained commercial results. Did the project produce results not expected?

Since the start of the project beginning of 2022 the market has substantially matured and most all operators of wind parks, including service and vessel operators have matured their view on the feasibility improvement of service operations during the period.

Without doubt the market has matured and is awaiting solutions ready for market introduction.

Upteko have been working hard to build the software that should commercially carry out the missions for the drone, and for each test cycle before the actual demos, many developments to this code have been made. What has surprised us, though, is that these changes and upgrades along the way have commercialized and built our platform “the drone” much more than expected, and we have gone from one type to another type of drone platform in this unexpected project.

Target group and added value for users: Who should the solutions/technologies be sold to (target group)? Describe for each solutions/technology if several.

The inspection solution should be sold to project partners like Esvagt. Their service ships very often carry out these types of inspections in the wind farms today. There are several companies out there, who deliver similar services to whom this service can be sold to as well. When we started the project, this was very innovative, but today this is no longer a blue ocean market, but one where you have to guarantee a certain quality that lives up to end user’s expectations.

Regarding package delivery offshore, this service is still very innovative, one reason being the heavy regulation on the area. The service should also be sold to companies similar to Esvagt. A commercial MoU between Esvagt and Upteko was signed i October 2023 and currently commercial go-to-market negotiations are ongoing and to be concluded as the FOD4Wind project is closing.

Initial commercial introduction is expected mid 2025. Key clinets are SGRE and Vestas who have a significant market demand and are keen to understand the performance and the commercial conditions by operating the drone. Especially focussed on package delivery.

The proof-of-concept roadmap developed by Upteko supported jointly with ESVAGT will allow for a further commercial introduction to the operators of SOVs, CTVs and to OEMs as well as park owners. Dialogue to be initiated during Q2/2025.

From a SGRE point of view this option is preferable to be an ad-on service to what we can choose as additional services when chartering an SOV for maintenance or installation operations offshore.

Where and how have the project results been disseminated? Specify which conferences, journals, etc. where the project has been disseminated.

The results of the FOD4Wind project have been disseminated through various channels throughout the project period and includes films, press releases, and LinkedIn posts. Here is a detailed overview of the communication and dissemination activities:

Films

- FOD4Wind: Afsluttende projektvideo (optagelser)
- FOD4WIND: validering af inspektion
- FOD4Wind projektfilm - Testflyvning af drone
- FOD4Wind film - Siemens, Upteko, Esvagt, SDU, Energy Cluster, EUDP

Press Releases

20 | LOGISTIK

MANDAG 28. FEBRUAR 2022 BØRSEN

Droner skal levere grej offshore

Esvagt, Upteko og Siemens Gamesa vil gøre det lettere at levere udstyr fra skibe til havvindmølleteknikere. Et nyt projekt ser på muligheden for at løse logistikken med fuldautomatiske droner

Af Jørgen Høg

Hvis en tekniker i en havvindmølle mangler et stykke værktøj, en møtrik eller andet udstyr under arbejdet med servicering, bliver det i dag sejlet til møllen med et mindre serviceskib. Den proces er både dyr, tidskrævende og miljøtung, og derfor vil partnerne i det nye innovationsprojekt FOD4Wind se på, om skibene kan erstattes af droner, som opstartsvirksomheden Upteko leverer.

"I dag sejler man udstyr hen til den enkelte mølle med et såkaldt service operation vessel. Det, som vi vil i projektet FOD4Wind, er at erstatte den sejlads med droneflyvninger fra større skibe fra Esvagt, så man sparer turene rundt i vindmølleparken. Dronen skal kunne flyve fuldautomatisk fra et af Esvagts skibe og op til havvindmøllens nacelle, hvorpå der er en landingsplads. Her kan dronen så afsætte det værktøj, den flyver med," siger Benjamin Meinertz, partner i Upteko.

Last på 12 kg

Planen er, at dronen på sigt skal kunne fragte gods op til 100 kg. I projektet FOD4Wind arbejder partnerne dog med laster på 12 kg til en start.

Ifølge Siemens Gamesa, der producerer og servicerer havvindmøllerne, er der et stort potentiale i at benytte droner på havet.

"Vi begyndte at se på anvendelsen af droner i 2016, og vores business case er positiv – både når det gælder leverancer og måske også inspektion af havvindmøller. Vi ser et stort potentiale i at have droner på serviceskibene permanent. Vi fokuserer hele tiden på at gøre tingene smartere, og ved at bruge droner til vedligehold af vores vindmøller kan vi både reducere vores omkostninger og vores miljømæssige aftryk," siger Lars Holm Nielsen, chef for R&D service operations ved Siemens Gamesa.

Nye forretningsområder

Projektet bliver faciliteret af Energy Cluster Denmark, og er ifølge adm. direktør Glenda Napier et godt eksempel på, at samarbejde om innovation betaler sig.

"Det fantastiske ved Fod4Wind er, at projektet på en gang er med til at definere nye forretningsområder for de medvirkende partnere – samtidig med at det løser en klimamæssig udfordring. Hvis vi begynder at benytte droner frem for skibe offshore, gør vi både en forskel for den sorte og den grønne bundlinje," siger Glenda Napier.

> *Ved at bruge droner kan vi både reducere vores omkostninger og vores miljømæssige aftryk*
>
> Lars Holm Nielsen, Head of R&D service operations ved Siemens Gamesa

Safety first

Hos Esvagt, der leverer de SOV-skibe, som dronen skal flyve fra, er sikkerhed også en væsentlig del af projektet.

"Som den førende udbyder af SOV-skibe i Europa er vi meget fokuserede på at tilbyde nye services til vores kunder. Her har dronerne en vital rolle og vil fremover effektivisere serviceringen af vindmøller. Vores fokus er altid safety first og derfor lægger vi stor vægt på forholdene omkring de løsninger, som projektet leverer. Det skal være sikkert at operere dronen offshore," siger Nils Overgaard, Head of Special Projects, Esvagt.

Planen er, at de første flyvninger i projektet sker fra et Esvagt-skib til en Siemens Gamesa-mølle i andet kvartal af 2022.

Esvagt, Upteko og Siemens Gamesa samarbejder i FOD4Wind om at levere værktøj og reservedele direkte til teknikeren på havvindmøllens nacelle. De skal leveres ved brug af droner, som skal lette fra specialbyggede service operation vessels som f.eks. Esvagt Faraday. PR-foto

OVERBLIK
Fod4Wind

PROJEKTET ER støttet af Det Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP) og har et samlet budget på 17 mio. kr.

DET ER tidligere støttet af EU's Regionalfond. Det løber til udgangen af 2024 og har en partnerkreds bestående af Upteko, Siemens Gamesa, Esvagt og Syddansk Universitet.

ENERGY CLUSTER Denmark faciliterer og administrerer projektet.

- FOD4WIND: Presse på milepæle
- Project Using Automated Drones for Offshore Wind O&M Aims for Reducing Downtime and CO2 Emissions (OffshoreWind)
- Droneleverancer skal effektivisere havvind (Electronic Supply)
- Droneleverancer skal effektivisere havvind (Energy Supply)
- Droneleverancer skal effektivisere havvind (Metal Supply)
- Firkløver vil lade droner i stedet for skibe forsyne havvindmøller (Doi)
- Nyt projekt vil erstatte sejlads med droner (Søfart)
- Droner skal levere vindmøllegrej offshore (Søfart)
- Droner skal levere vindmøllegrej offshore (Energy Supply)

- Droneleverancer til vindmøller skal spare tid og penge (Vindkraft)

Websites

- Energy Cluster Denmark
- University of Southern Denmark
- www.esvagt.com

LinkedIn Posts

- FOD4WIND: Video
- 🚀SUCCESFULD TEST AF NY DRONE TIL SERVICE AF HAVMØLLEPARKER 🌊🚁
- PROJECT USING AUTOMATED DRONES FOR OFFSHORE WIND O&M AIMS FOR REDUCING DOWNTIME AND CO2 EMISSIONS
- DRONELEVERANCER KAN EFFEKTIVISERE HAVVIND
- Droner skal levere grej offshore

Fairs and meetings

- RF24 – 2023: Presentation of project (Upteko)
- RF24 – 2024: Upteko presentation incl. FOD4W activities (Upteko)
- EIFO – Censec – Center for Defence, Space & Security: Presentation on funding partnerships (Upteko)
- IDS 2024, 31.05.24: General Upteko presentation incl. FOD4W activities
- European maritime days in Svendborg, 30.-31.05.24: Presentation of maritime drone solutions
- Workshop: På vej mod Danmarks første automatiserede havvindmøllepark, arrangd by Klimadatastyrelsen and Dansk industri
- Participation in the working group on drone airspace integration behind the upcoming Danish National Drone Strategy.

Articles

- https://www.soefart.dk/article/view/894912/nyt_projekt_vil_erstatte_sejlads_med_droner
-
- https://www.doi.dk/vindkraft/artikel/firkloever-vil-lade-droner-i-stedet-for-skibe-forsyne-havvindmoeller
- https://www.energy-supply.dk/article/view/894891/droneleverancer_skal_effektivisere_havvind
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- UST top five most read articles of the week: Recognising the advantages of drones in delivering data-driven insights across multiple industries, Upteko has delivered the LARK drone with focus on ensuring the integrity and safety of drone-collected data.

These dissemination efforts have ensured that the project's findings and advancements are shared widely across different platforms, reaching a broad audience.

Given that it is an EUDP project, SDU has not published anything scientifically. It has not yet been decided whether SDU will do this.

6. Utilisation of project results

Describe how the obtained technological results will be utilised in the future and by whom.

Upteko will continue utilizing the developments from the project group, and the developments made by Upteko is now being utilized in further planned developments in Upteko's products and upcoming products.

A key innovation of the FOD4Wind project lies within having a flexible drone capable of autonomously conducting different tasks relevant to wind turbine inspection and logistic services. The turbine inspections made available will result in a much cheaper and faster way to repair and detect deficiencies of a turbine.The autonomous package deliveries to a turbine will secure the repair of a turbine much faster by ensuring that the right tools and spare parts can be swiftly delivered to the turbine while the service technicians are on board the nacelle, already..

This is a game on improving turbine uptime and not least improved efficiency of the service crews. The overall service logistics complexities are reduced. This qua they by using drones to deliver spares or forgotten tools do not need to request 3 service technicians to climbe down the nacelle (leave the turbine) or alternatively to request a separate STB boat f to get launched rom the SOV and to transfer with tools and/or spare parts to the WTG.

Conceptually these results should be an upgrade to any turbine maintenance crew.

Describe how the obtained commercial results will be utilised in the future and by whom the results will be commercialised.

The work done by Upteko will be utilized in Upteko's upcoming products, many things regarding the built software will be a part of Upteko's products moving forward.

In Upteko's future plans, several developments from the project are being built into future commercialize a solution to be sold to companies like Esvagt, servicing companies like Siemens.

Did the project so far lead to increased turnover, exports, employment and additional private investments? Do the project partners expect that the project results in increased turnover, exports, employment and additional private investments?

The project has not yet led to any increased sales in Inspection or package delivery sales, more actual and also commercial flights have to be performed to come to that stage. However, work in progress in regard to future commercial plans.

Describe the competitive situation in the market you expect to enter. Are there competing solutions on the market? Specify who the main competitors are and describe their solutions.

As the project has been running, several companies have been working on the inspection solution and fewer but also many have been working on transportation of goods offshore. But nobody has an autonomous operation set-up. By the knowledge of the partners, this is the current market gap in commercial terms the project has been addressed.

One competitor worth mentioning is Sky Specs, who deliver a full inspection of wind turbines offshore. In package delivery we are seeing that DSV is attracting talent from HOLO. A direct solution we believe is not yet made, but several project-based flights have been performed over great distances. Great collaboration opportunities arise in this area.

ESVAGT, as the market leader with more than 40% SOV market share in Europe has a ongoing

Describe entry or sales barriers and how these are expected to be overcome.

The entry and sales barriers are to Upteko with the project's partners very uncomplicated. We simply have to conduct commercial and paid for flights with delivery of valid and usable data. Some of the issues that have to be solved is access to the wind turbines with paying customers or end users. We expect to collaborate further with both Siemens and Esvagt to both find these customers and conduct the necessary flights to come to a finished and ready to scale product.

How does the project results contribute to realise energy policy objectives?

Introducing autonomous drones within the wind industry help to reduce the overall operational and maintenance (O&M) costs, increase annual energy production, and lower CO_2 emissions. This contributes to the broader goal of improving the Levelized Cost of Energy (LCOE) for offshore wind energy, making it more competitive and sustainable.

7. Project conclusion and perspective

State the conclusions made in the project. What are the next steps for the developed technology?

Package Delivery: While the developed solution is commercially viable, there is a need for some more technical development as the need we see from an operational point for maintenance and repair on an offshore wind turbine. Upteko and ESVAGT are in process to conclude a roadmap to commercialize the drone operation. The first commercial flights are expected early Q3/2025

The package load needs to be increased from 5 kg. To minimum 12 kg and preferably up to 40 kg.

The drone needs preferably to be able to fly Beyond Visual line of sight (BVLOS) in order to fly from one end of the windfarm to the other (Max. 30 min. Sail time).

Inspection Drone: In SGRE we already have suppliers operating with Autonomous drones for blade inspection similar to the drone developed here.

An advantage for the Lark drone is, that the camera chosen has higher resolution and better picture quality, but it is not given that this is needed in order to do blade inspections.

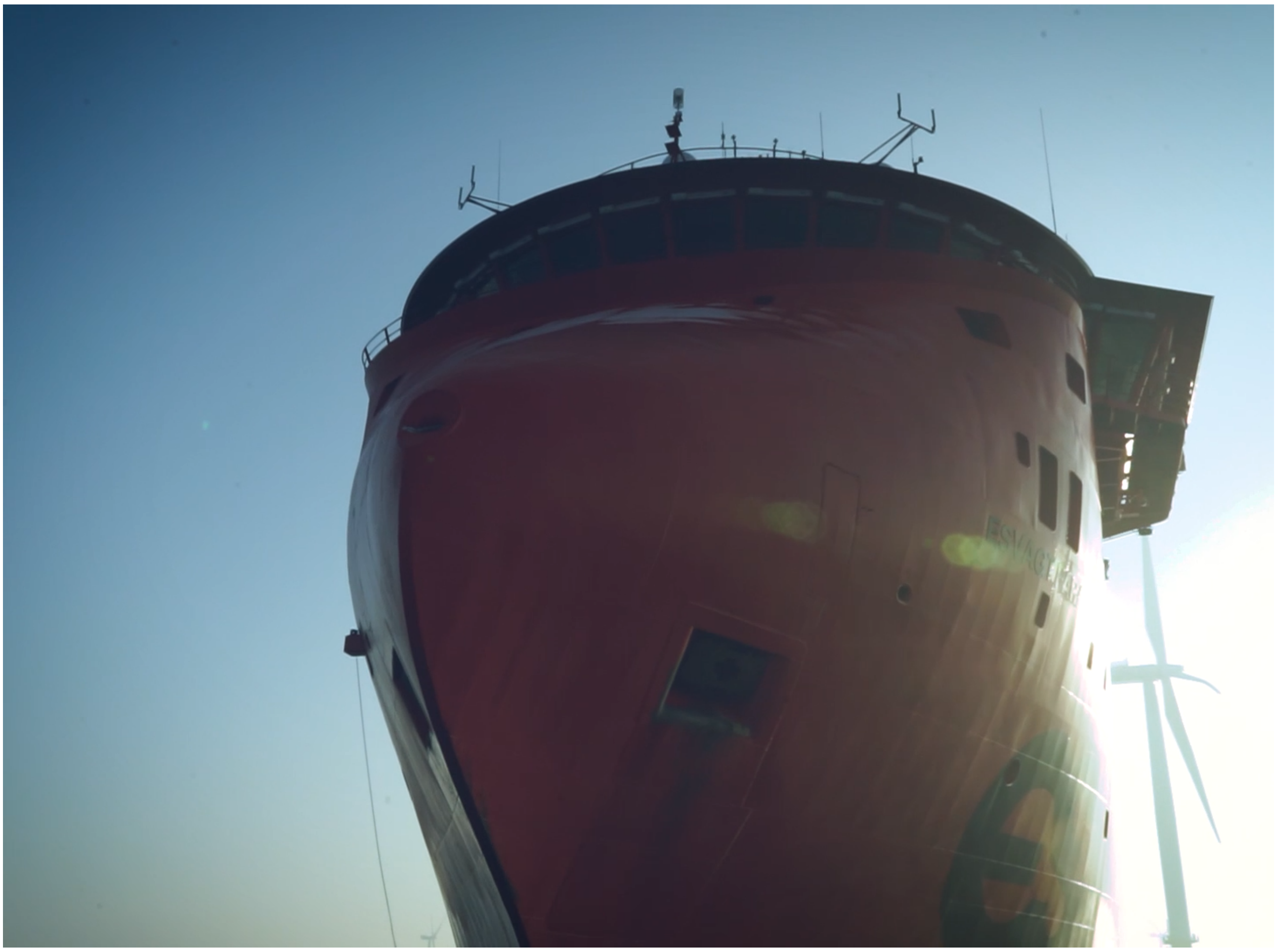
Put into perspective how the project results may influence future development

The innovation perspectives and market opportunities for autonomous drone solutions in package delivery and inspection of offshore wind farms are vast and promising. As the demand for renewable energy sources continues to grow, the offshore wind industry is expanding rapidly, creating a significant need for efficient and reliable maintenance and logistics solutions. Autonomous drones offer a transformative approach to addressing these needs, providing numerous benefits and opening up new market opportunities.

Although the project's results are promising, there is still room for further development. By leveraging advanced technologies, improving operational efficiency, new regulation supporting drone operations at sea, autonomous drones can play a crucial role in the sustainable growth of the renewable energy sector. As the market continues to expand, there will be significant opportunities for companies to develop and deploy innovative drone solutions, driving progress and creating value in the offshore wind industry and beyond.

8. Appendices

- Images documenting the offshore demonstration




ESVAGT
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