

# PUBLIC

# PROGRESS REPORT 1

## MOOI124039



## Aerial Quadcopter Units for Aquatic Flow Investigation and Nautical Data [AQUAFIND]

1 December 2025

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# 1. Project information

TSE subsidy:	MOOI
Project number:	MOOI124039
Project title:	Aerial Quadcopter Units for Aquatic Flow Investigation and Nautical Data [AQUAFIND]
Lead applicant:	SpectX B.V.
Co-applicants:	Fusion Engineering Technologies B.V. Delta-N B.V. TU Delft Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek (TNO) Deltares
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The cooperation between the consortium partners is going well.

*“The project was carried out with Topsector Energy funding from the Ministry of Economic Affairs and Climate Policy, administered by the Netherlands Enterprise Agency (RVO). The specific funding for this project concerns the 2024 round of the MOOI subsidy programme.”*

## 2. Project principles and objectives

At the end of the project, the key objective is to have developed a swarm of autonomous aerial drones to monitor real-time wave profiles of the sea, and by integrating the gathered data with other environmental parameters create precise wave, weather and vessel motion prediction. This can be utilised for installation and maintenance activities for offshore wind turbines.

The AQUAFIND project is aimed at the MOOI mission “Electricity”, where it contributes specifically to the objective “Accelerating the construction of offshore wind farms”. According to the MOOI-manual, this objective is achieved by:

*“... increasing labour productivity by standardisation, digitalisation, robotisation and automation. Reducing the demand for personnel in the development-, installation- and exploitation phase contributes to the acceleration and labour-saving innovations. Safeguarding or improving the safety of personnel and the environment is essential ...”.*

The swarming system can be used in offshore situations for real-time and automated wave analysis and profile prediction, vessel motion forecasting, and weather predictions and early warnings. This digitalisation contributes to the acceleration of the installation of offshore wind turbines, through optimisation of routes and installation times and by minimizing downtime, and increasing labour productivity. Currently, operations are being terminated prematurely when unexpected weather conditions arise, resulting in multiple deployments of personnel to finish the job. By providing these valuable weather and wave analyses, AQUAFIND has the opportunity to significantly reduce the demand for personnel and crew costs in maintenance operations by giving optimal deployment timeframes. It is expected that AQUAFIND will prevent unnecessary callbacks of the vessels and other delaying factors, reducing delays in operations.

## Result 1. Dynamic Swarming Map and Autonomous System

### 1.1 Algorithm design

Formation control techniques may be categorized into centralized, decentralized, and distributed schemes. With a centralized approach, all agents share information with and receive commands from a centralized controller. While centralized schemes are simple and easy to implement, they suffer from scalability issues, contain a single point of failure, and require a large communication overhead. In decentralized control schemes, each agent makes its own decisions based on predefined rules and information gathered by sensors or communication. The decentralized approach has many advantages, including scalability and adaptability. However, because each agent acts according to its individual goals, it can be challenging to coordinate agents in pursuit of a system-wide goal. Distributed control schemes leverage extensive communication between agents, enabling them to act cooperatively in pursuit of a wider goal. Unlike decentralized control schemes, distributed control schemes emphasize teamwork and collaboration among agents. In multi-agent formation control problems, distributed control schemes can grant the swarm greater autonomy from a central control station, as well as resilience and redundancy. However, distributed control schemes are more challenging to implement and demand more computational and communication resources than centralized and decentralized schemes. So far, four different distributed and decentralized formation control methods have been tested in Python simulations. Furthermore, swarming flight tests were performed to test decentralized formation control methods.

### 1.2 Data integration and processing

This activity has not started yet.

### 1.3 Visualisation and UI design

For swarm flight tests, we have added a GUI which allows the user to set the swarm configuration, take off all drones at once, get the drones into formation, and send periodic waypoints indicating where the swarm should navigate to. This GUI is useful for flight tests because it gives the user more control over each stage of the test, rather than relying on automatic transitions.

### 1.4 Optimization and performance tuning

This activity has not started yet.

## Result 2. Sensor Integration and Calibration

### 2.1 Identify Suitable Sensors

This section translates the required input data into spatial and temporal requirements for the sensor system. The derivations in this section originate from a recent meeting, where the AQUAFIND problem was presented, and possible radar solutions were discussed. It became clear that, without explicit constraints on parameters, it is not possible to select suitable sensors in a principled way. Based on the requirements derived, several families of sensors that can be integrated on a drone or fixed rig were reviewed and a primary sensor choice was presented.

To test and refine multi-drone coordination strategies before real-world deployment, a high-fidelity simulation environment was developed. To evaluate the readiness of the flight software and establish the foundation for multi-drone coordination in future offshore operations, a two-drone swarm

demonstration campaign was conducted. SpectX conducted a real-world feasibility demonstration of a two-drone swarm at Katwijk Aan Zee. Pre-testing took place as well to determine safety issues.

## **2.2 Sensor Integration**

Parallel to flight testing, research was conducted into sensor selection and data fusion algorithms suitable for capturing sea state characteristics. Data were collected and evaluated for wave pattern recognition. Correction algorithms were developed to convert skewed data into normalized and directional data.

## **2.3 Testing Sensor Performance**

The AQUAFIND project aimed to determine whether a swarm of autonomous drones could reliably collect sea state data and process it into real-time wave predictions in offshore environments. The technology successfully executed multi-UAV missions. This validates our control logic and scalability premise. However, technical risks were also identified. All identified risks were paired with concrete mitigation strategies, such as hardware upgrades, fallback algorithms, alternative launch mechanisms and staged regulatory engagement. Residual risk levels are manageable given the high upside of operational gains and market interest.

# **Result 3. Aerial Drone Hardware**

## **3.1 Requirements & specifications**

To design and validate the AQUAFIND multi drone swarming concept before field trials, we developed a high fidelity simulation environment. This environment reproduces both the kinematics of a drone swarm and the dynamic behaviour of the ocean surface (simulated by a wave simulation plugin) to a level that is sufficient for testing coordinated data collection strategies. On top of this, we integrated a wave simulation plugin to simulate ocean waves, including spatially and temporally varying sea states that could be parameterized to match expected offshore conditions. The wave plugin is configured to represent an open sea scenario to some level with a sufficiently large water surface around the vessel. The plugin synthesizes the wave field. By varying the parameters, we can emulate different sea states (from relatively calm to rough conditions) and analyse the effect on the drones.

The swarm mission logic is implemented, which allows programmatic control of multiple vehicles. Each drone in the swarm is assigned a role in the data collection pattern. The drones fly at predefined altitudes and lateral offsets while onboard sensors are simulated to generate synthetic data. These trajectories can be rerun under different wave configurations, allowing controlled evaluation of how sea state conditions impact data generation.

## **3.2 Develop physical aerial drone structure**

This activity has not yet been started.

## **3.3 Develop machine vision assisted drone take-off and landing procedure**

One of the key technological challenges in the AQUAFIND system is the ability for drones to autonomously take off from and land on moving vessels with high precision. Due to the dynamic and often unstable nature of maritime platforms, traditional drone landing methods relying on static and predictable surfaces, are not suitable for such operations. Achieving safe landing requires not only accurate information about the current state of a vessel and its predicted motion, but also robust and responsive trajectory control.

To ensure a safe and reliable strategy for the autonomous Vertical Take-Off and Landing (VTOL) of AQUAFIND UAVs on dynamic maritime platforms under the influence of external disturbances, a comprehensive system architecture has been established.

### **3.4 Testing and validation**

To assess the feasibility and performance of the proposed architecture under realistic conditions, an indoor experimental setup, is being used to complement the simulation studies. Currently, experimental tests are still ongoing, with multiple UAV control strategies being compared and evaluated. This indoor setup provides a highly controlled and repeatable testbed that effectively bridges the gap between simulation and field testing. While it does not fully replicate the complexity of offshore operations, it allows rigorous validation under dynamic yet reproducible conditions, forming a critical step toward eventual real-world deployment.

## **Result 4. Data Transmission & Communication**

### **4.1 Communication system definition**

This activity has not yet been started.

### **4.2 Robot Operating System based interfaces between flight controller and companion computer**

This activity has not yet been started.

### **4.3 Communication protocols between GCS and companion computer**

This activity has not yet been started.

### **4.4 Testing and validation**

This activity has not yet been started.

## **Result 5. Flight Controller & Control System**

### **5.1 Software in the loop simulation Flight Controller**

This activity has not yet been started.

### **5.2 Stabilization control implementation**

This activity has not yet been started.

### **5.3 Collision prevention**

A major pitfall of the control algorithm is producing suboptimal output. However, it could be useful for preventing collisions between agents, especially when they are getting into formation. Python simulations were run, with and without collision avoidance. This resulted in the need for extra safeguards to prevent collisions.

## Result 6. Hardware and Software Integration

### 6.1 Work Package Results integration

This activity has not been started yet.

### 6.2 Software Platform Interfacing

This activity has not been started yet.

### 6.3 Software Platform UI Design and Implementation

This activity has not been started yet.

## Result 7. Machine Learning Wave Time Series Forecasting

The final result of WP7 is a prototype AI model able to forecast wave time series at the location of a vessel in operation. Currently, only WP7.1 has been finished. For WP7.2, the numerical model has been selected and calibrated, but the training dataset has not been created yet. Logically, the AI wave model is not developed yet, but preparation steps have been taken.

### 7.1 Prepare observation and drone input datasets

An overview of time and spectral domain observation data in the North Sea is created to calibrate the numerical model approach in WP7.2.

### 7.2 Determine model approach

For the training of the AI model for wave time series forecasting, a training dataset is needed. In this work package (WP) 7.2, a numerical model approach is chosen, which is then used to create the dataset for the AI model training. There are three important aspects that determine how the AI model eventually can be used:

- The available input, determined by the sensor selection in WP2,
- The output from the AI model, determined by the use cases,
- The forecast time window, determined by the use cases.

These aspects are critical in the selection of a numerical model approach and the creation of the dataset for the AI training. However, as none of these aspects are yet fully certain, assumptions have been made based on 1) agreements with project partners, 2) one use case and 3) the currently available information. Based on the starting points, the objective is to obtain a prediction of the wave field. Two types of models arose, and these were checked on feasibility and underwent calibration and sensitivity test to determine which model settings and inputs should be used. It must be noted that the optimal choices of certain settings should be aligned with the information that is available during the actual use of the end-product, and what is necessary for model stability.

### 7.3 Developing AI wave model

Cooperation between the project partners has enabled the development of machine learning models for partially approximating both numerical models. As more data becomes available from result 7.2, additional models and approaches will be tested to further improve predictive performance and resolution. Additionally, the model will need to use not one but multiple (drone) input points for a singular prediction, which will be integrated in the modelling approach later on.

## Result 8. Predictive Model for Vessel Motion and Decision Support

### 8.1 Develop Predictive Models for Vessel Motion

This activity has not been started yet.

### 8.2 Develop short-term operational decision support

This activity has not been started yet.

### 8.3 Develop long-term logistic decision support

This activity has not been started yet.

## Result 9. Pilot testing: System Testing & Improvement

### 9.1 Indoor testing

This activity has not been started yet.

### 9.2 Onshore testing

This activity has not been started yet.

### 9.3 Offshore testing

This activity has not been started yet.

### 9.4 Evaluation of AQUAFIND performance

This activity has not been started yet.

## Result 10. Project Management, Evaluation and Knowledge Dissemination

### 10.1 Project management

The project leader has setup a Project Management system on their Internal systems with access provided to all active consortium members, which contains deliverables, test reports, and datasets accessible to all partners.

### 10.2 Project management

Technical, regulatory and operational risks identified during earlier phases are being actively mitigated. Hardware upgrades, redundancy in sensing and early engagement for offshore permissions have reduced risk impact levels from “High” to “Moderate.” Quality assurance is ensured through validation at each integration stage:

- Simulation hardware cross-checks for validation.
- Controlled environment sensor data calibration before field deployment to be performed in December 2025.

Furthermore, the stakeholder needs analysis was documented. Each stakeholders needs were identified. Each need is given an unique identifier. Similar needs across different stakeholders were clustered and a final list of common stakeholders needs was documented. With these needs identified, the next step is the breakdown towards the system requirements.

### **10.3 Technical evaluation and validation of the pilot results**

This activity has not been started yet.

### **10.4 Knowledge dissemination**

A presentation has been given about the AQUAFIND project:

- The project in general during the [CoP Noordzee](#) (3 April 2025, 'Innovation projects North Sea and matchmaking PPS calls),
- About the AI model specific during an [AI in waves workshop](#) at Northumbria University, Newcastle upon Tyne, UK (5 – 6 June 2025).