

**UNMANNED MAINTENANCE IN OFFSHORE WIND**

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# AIRTuB Dissemination log

(TEHE119002)



**Maintenance Robotics in Offshore Wind**

**WORLD CLASS MAINTENANCE**

**AIRTuB**

**Eneco** **STORK** **LM WIND POWER**  
A Fluor Company a GE Renewable Energy business

**avans hogeschool** **iholland hogeschool** **Dutch Cerahertz**  
SPACE QUALITY INSPECTORS

**SAXION UNIVERSITY OF APPLIED SCIENCES** **DEMCON advanced mechatronics** **FUSION ENGINEERING**

**Hanzhogeschool Groningen University of Applied Sciences** **Development Center for Maintenance of Composites**

**TNO innovation for life** **Scalda** **nlr**

**hiz UNIVERSITY OF APPLIED SCIENCES** **alayers** **TU Delft**

**TKI WIND OP ZEE** **FIXAR**

**Fieldlab ZEPHYROS** **NWEA** **MARS 4 EARTH** **Energy Port Zeeland**

**smart industry**

Auteur: F.C.Th. (Ferry) Visser MSc.

**AIRTuB meetings:**

- 13-09-19 : Kick-off meeting AIRTuB project at HZ-UAS and Scalda in Vlissingen and presentation of the Smart Industry label
- 16-09-20 : Robotisation in Offshore wind – streaming live event from Futureland Maasvlakte met NWEA & Blauwe Cluster
- 21-09-21 : Annual AIRTuB event / TKI-WoZ Live – De KAAP Vlissingen
- 12-04-22 : AIRTuB dissemination event WP1 - TU Delft
- 20-05-22 : AIRTuB dissemination event WP5 - Qlayers - Delft
- 22-09-22 : AIRTuB dissemination event WP2 en 3 - HZ/Scalda – de KAAP Vlissingen
- 14-10-22 : AIRTuB dissemination event WP4, 6 en 7 - ENTRANCE Groningen
- 24-11-22 : AIRTuB final dissemination event NLR – Marknesse

**Meetings in which the AIRTuB project was presented / discussed:**

- 09-10-19 : Round-table at Offshore Energy E&C with SPARTA
- 07-11-19 : Deelname aan kick-off FIXAR innovatieproject
- 13-11-19 : Matchmaking sessie Wind meets Maak AYOP regio
- 11-12-19 : korte introductie tijdens Q-meeting Van Oord / Siemens
- 10-01-20 : Sustainable Service Logistics for OWF's bijeenkomst – EnTranCe Groningen
- 16-01-20 : SPARTA Offshore Wind Benchmarking Workshop
- 04-02-20 : Presentatie op Matchmaking Day TKI WoZ 2020
- 18-02-20 : Presentatie at Conferentie Innovation in Offshore Wind Liverpool
- 30-09-20 : Masterclass Innovatie in Offshore wind – DOB Academy
- 25-11-20 : Grensoverschrijdende Samenwerking - Seminar Platform Energy Port Zeeland
- 13-04-21 : Feestelijke opening de KAAP Vlissingen
- 22-06-21 : Blade maintenance event
- 20-10-21 : Maintenance Technology and Robotics event - KIC-MPi
- 11-04-22 : Werkbezoek Ministerie van Economische Zaken en Klimaat (M. Adriaansens) - Vlissingen
- 14-04-22 : Nacelle-Go-live event - Vlissingen
- 24-05-22 : Studiebezoek Virginia Coastal Policy Center (William & Mary Law School) - Vlissingen
- 08-06-22 : Bezoek delegatie OWIC (samenwerkingsovereenkomst getekend) - Vlissingen
- 23-06-22 : Presentatie bij het DroneWest event – Oostende
- 15-09-22 : Presentatie bij de 'ontbijtbijeenkomst Platform EnergyPort Zeeland'
- 21-09-22 : Tribologie event by "Bond voor Materialenkennis"- Vlissingen
- 03-11-22 : Aanwezigheid bij en promotie van Zephyros en AIRTuB op 'De dag van het Klimaat akkoord' - Utrecht
- 01-12-22 : Kerstborrel PEPZ (samen met Orsted) en internationale RVO delegatie in de KAAP – Vlissingen

**Guest lectures in which the AIRTuB project has been discussed:**

- 10-12-19 : Minor Asset Management TU Delft Faculty of Aerospace Eng. & Wind Energy
- 11-12-20 : Minor Asset Management TU Delft Faculty of Aerospace Eng. & Wind Energy – on-line edition
- 11-02-21 : HZ-UAS Minor Offshore Renewable Energy
- 02-12-21 : HZ-UAS Minor Offshore Renewable Energy
- 07-12-21 : Minor Asset Management TU Delft Faculty of Aerospace Eng. & Wind Energy
- 19-05-22 : HZ-UAS Minor Offshore Renewable Energy
- 07-06-22 : Frontiers to Maintenance- U-Twente
- 01-12-22 : HZ-UAS Minor Offshore Renewable Energy

**Publications / video's / interviews:**

- Voorjaar 2022 : Launch van de Fieldlab Zephyros LinkedIn pagina
- 31-01-22 : Opname van on-line colleges voor de 'Nationale AI cursus' - Vlissingen
- 14-04-22 : Nieuwsartikel WCM website - <https://www.worldclassmaintenance.com/successful-airtub-event-sensors-for-damage-inspection-of-wind-turbine-blades/>
- 05-05-22 : Nieuwsartikel WCM website - <https://www.worldclassmaintenance.com/successful-airtub-event-smart-maintenance-for-offshore-windturbine-blades-by-robotized-coating-technology/>
- 21-10-22 : Artikel in WCM jaaroverzicht
- 25-10-22 : Nieuwsartikel WCM website - <https://www.worldclassmaintenance.com/interesting-airtub-event-erosion-modeling-and-repair-recipe/>
- 23-08-22 : Opname van een vlog voor een TKI-WoZ webinar over Maintenance – Vlissingen
- 15-09-22 : Opname van een video over het AIRTuB project – Delft
- 15-09-22 : Project in the Spotlight – TKI-WoZ
- 03-11-22 : Interview RTLZ op Dag van Klimaatakkoord - <https://www.worldclassmaintenance.com/airtub-bij-rtl-nieuws-energietransitie-loopt-vertraging-op/>
- 24-11-22 : AIRTuB deliverables film NLR
- 2019 Interview in Offshore Industry: [Fieldlab-Zephyros-LR.pdf \(worldclassmaintenance.com\)](#)
- Publicatie op website TKI-WoZ: [Zephyros AIRTuB - Topsector Energie](#)
- Publicatie op website Wind Innovators: [Subsidy for Fieldlab Zephyros project... | Offshore Wind Innovators](#)
- Publicatie op CoE-W&E: [Fieldlab Zephyros start met project AIRTuB | Centre of Expertise Water and Energy \(coe-we.com\)](#)
- Publicatie op website Energy Port Zeeland: [Fieldlab Zephyros start met project AIRTuB | Centre of Expertise Water and Energy \(coe-we.com\)](#)
- Nieuwsbericht Energy Port Zeeland: [Living Lab Fieldlab Zephyros de KAAP biedt ruimte voor onderwijs en ontwikkeling](#)
- Nieuwsbericht in PZC: <https://www.pzc.nl/zeeuws-nieuws/drie-miljoen-subsidie-voor-drone-die-windmolens-repareert~a70e8219/>
- Nieuwsbericht Windenergie: <https://www.windenergie-nieuws.nl/16/fieldlab-zephyros-ontvangt-subsidie-voor-smart-maintenance-innovatieproject-airtub/>
- Demonstratievideo van Fusion Engineering: [Fusion Engineering windtunnel\\_withlog\\_lq.mp4](#)

#### Substantive publications and presentations:

- Remote Ultrasonic Inspection of Offshore Wind Turbine Blades, D.J. Platenkamp, V.S.V. Dhanisetty, A. Chabok, A.F. Bosch, NLR-CR-2021-177
- Cheng, L., Nokhbatolfoghahai, A., Groves, R. M., & Veljkovic, M. (2022, June). Acoustic Emission-Based Detection in Restricted-Access Areas Using Multiple PZT Disc Sensors. In European Workshop on Structural Health Monitoring: EWSHM 2022-Volume 1 (pp. 619-629). Cham: Springer International Publishing.
- Cheng, L., Nokhbatolfoghahai, A., Groves, R.M. and Veljkovic, M 2023. "Using Deep Learning for multi-sensor data fusion of signals from commercial acoustic emission and piezoelectric disc sensors". Structural Control and Health Monitoring, Under review.
- A Literature Survey on Remote Inspection of Offshore Wind Turbine Blades, Automated Inspection and Repair of Turbine Blades (AIRTuB) - WP1, J.S. Hwang, D.J. Platenkamp, R.P. Beukema, NLR-CR-2020-223, May 2021
- Off-Shore Wind Turbine Blade Erosion Inspection Sensors using an Unmanned Vehicles – WP1, J.S. Hwang, R. Beukema, A. Anisimov, NLR-CR-2021-248 (DRAFT)
- Anisimov, A. G., Beukema, R., Hwang, J., Nijssen, R., & Groves, R. M. (2021, June). AIRTuB: towards automated inspection of leading edge erosion of wind turbine blades by shape analysis. In Multimodal Sensing and Artificial Intelligence: Technologies and Applications II (Vol. 11785, p. 117850W). SPIE.
- K. Vimalakanthan *CFD transition model for rough surfaces* TNO 2021 R12579, Public report, December 2021
- K. Vimalakanthan *Aerodynamic performance prediction of eroded and rough wind turbine blade sections using RANS CFD. EERA workshop on blade erosion from the perspective of loads, controls and aerodynamics*, December 14, 2022 [SP4 WORKSHOP on Blade Erosion from the prospective of loads, controls and aerodynamics | EERA JP Wind](#)
- I. Lallelis *Model Validation for Simulating the Effects of Leading Edge Erosion* Hanze/TNO Student thesis report, January 2019.
- O. Shamir: *Analysis of LM wind tunnel measurements at erosion*. Public Hanze report, November 2020
- J. Nwaehie: *Automation of IRPWIND roughness experiment*, InHolland/TNO Student thesis report September 2020
- M.J. Vermeulen: *Erosion on wind turbine blade wind tunnel test*, NLR-CR-2021-516, September 2021
- Kisorthman Vimalakanthan, Harald van der Mijle Meijer, Iana Bakhmet, and Gerard Schepers *Performance modeling of eroded wind turbine blade using CFD*, Preprint for Journal of Wind Energy Science <https://wes.copernicus.org/preprints/wes-2022-65/>
- J.G. Schepers et al: *Summary of Airtub WP6.1 results*, TNO report
- Literature review of structural and non-structural wind turbine blade damage, Rogier Nijssen, Emilio Manrique, TNO 2020 R10402, September 10, 2020.

Op de [WCM AIRTuB webpage](#) zijn publicaties en AIRTuB presentaties met een link beschikbaar. Onderstaand een aantal hieruit..

- [AIRTuB onderzoekt mogelijke kostenreductie door geautomatiseerd onderhoud | Hanze](#)
- [Remote Ultrasonic Inspection of Offshore Wind Turbine Blades – NLR](#)
- [Recording of the AIRTuB event 'Erosion modeling and repair recipe' d.d. 14.10.2022](#)
- [Article Fieldlab Zephyros in PortNews](#)
- AIRTuB-publication door TU Delft: [AIRTuB: towards automated inspection of leading edge erosion of wind turbine blades by shape analysis](#)
- **Presentations workshop/demo Blade Maintenance d.d. 22 juli 2021**
  - Jason Hwang: [Literature study review NLR](#)
  - Robin Maljaars: [Presentation Driving Factors in the LCOE trend of offshore wind power.](#)
  - Robin Maljaars: [Research report Driving Factors in the LCOE trend of offshore wind power](#)
  - Loek van der Linden: Link naar [Spotting erosion in SCADA dating from live wind turbines.](#)
- AIRTuB WP1 report NLR – [A Literature Survey on Remote Inspection of Offshore Wind Turbine Blades](#)
- [TNO report Literature review of wind turbine blade structural and non-structural damages.](#)



Artist Impressions / Project roll-up banners (distributed over all partners and exposed at several events)

## AIRTuB

### Automated Inspection & Repair of Turbine Blades

UNIVERSITY OF APPLIED SCIENCES TNO innovation for life iqholland nlr  
STORAG Eneco TU Delft DEMCON  
Scalda LM WIND POWER IAS WIND POWER cLayers  
Dutch Concreta Haaslogerboord Saxon

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## AIRTuB

### Fieldlab ZEPHYROS

#### WP1: Sensing

Goal: Develop sensor packages suitable to perform internal and external inspections that can be carried by AIRTuB drone and crawler

**External**

TARGET: Leading edge erosions  
Improving AEP significantly

SENSOR DEVELOPMENT: Laser line scan

Concept Algorithms development

Custom hardware (iKit64 632) Prototypes

**Internal**

TARGET: Disbond in critical structural joints

SENSOR DEVELOPMENT: Rollerprobe UT

UT probe development System design

Prototypes Evaluation

NEXT STEP: Further miniaturization & automation

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## AIRTuB

### Fieldlab ZEPHYROS

#### WP2/3 Automated Drone Research Integration & Testing

**WP2 & WP3 Activities/deliverables:**

**Key question for AIRTuB involved development:**

- Minimum payload size to deliver 5kg sensor package
- Maximum operation of sensor
- Interoperability with existing infrastructure
- Operation type/size of crawler
- Operation type/size of drone

**Drone development including integration:**

- Full blown operation crawler: Safety sensor damage sensor along leading edge of turbine blade and fly/crawly sensor including internal damage sensor and leading edge turbine blade
- Drone development includes:
  - Concept
  - Development
  - Integration
  - Integration
- Drone development includes:
  - Concept
  - Development
  - Integration
  - Integration
- Drone development includes:
  - Concept
  - Development
  - Integration
  - Integration

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## AIRTuB

### Fieldlab ZEPHYROS

#### WP4: Data processing

Data Sources:

- Historical Performance data
- New sensor Data

Acquisition  
Cleaning  
Enrichment  
Data storage (no live streaming)

#### WP7: NEW Asset Management Strategy

From baseline to new operator's

Maintenance Cost Baseline 1 -> new scenario 1 and 3

- Logic cost
- Postpone end of life
- Higher AEP (less downtime due to early warning)
- Early warning
- Factor insight less planning

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## AIRTuB

### Fieldlab ZEPHYROS

#### WP5: Automated Coating of Blades

##### INTRODUCTION

The aim of WP5 is to develop a robot that can automatically inspect and repair the surface of a wind turbine blade. During the project, the robot will be used to inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade.

##### RESULTS

For every wind turbine, the data is processed for 10 days and gives the following results:

- 100% of the blade is inspected
- 100% of the blade is repaired
- 100% of the blade is inspected
- 100% of the blade is repaired

##### BACKGROUND INFORMATION

The aim of WP5 is to develop a robot that can automatically inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade.

##### METHODOLOGY

##### CONCLUSION

The aim of WP5 is to develop a robot that can automatically inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade. The robot will be used to inspect and repair the surface of a wind turbine blade.

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## AIRTuB

### Fieldlab ZEPHYROS

#### WP6: Modelling aerodynamic losses from erosion

List of publications:

1. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
2. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
3. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
4. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
5. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
6. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
7. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
8. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
9. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.
10. Wind tunnel investigation of the aerodynamic losses due to erosion on wind turbine blades. Wind Energy Science, 2021.

Classification of erosion through machine learning

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