WORLD CLASS MAINTENANCE

AIRTuB

Innovation Fieldlab Zephyros

Towards Zero downtime and Zero on-site maintenance

The partners

UNIVERSITY OF APPLIED SCIENCES
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STORK A Fluor Company
Eneco
TNO innovation for life
Hanzehogeschool Groningen University of Applied Sciences
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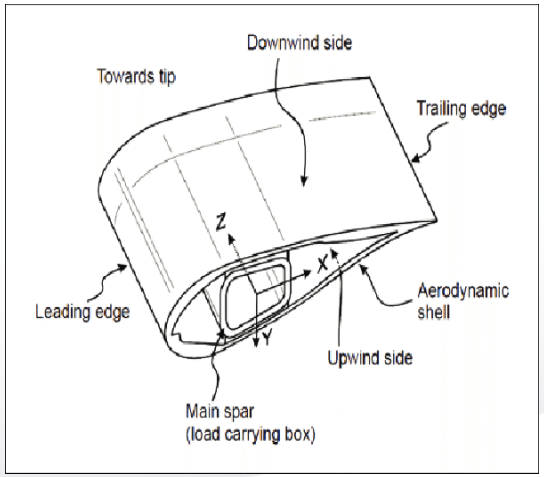
Fieldlab ZEPHYROS

smart industry

AIRTuB Problem definition

Blade damage (leading edge and structural) leads to:

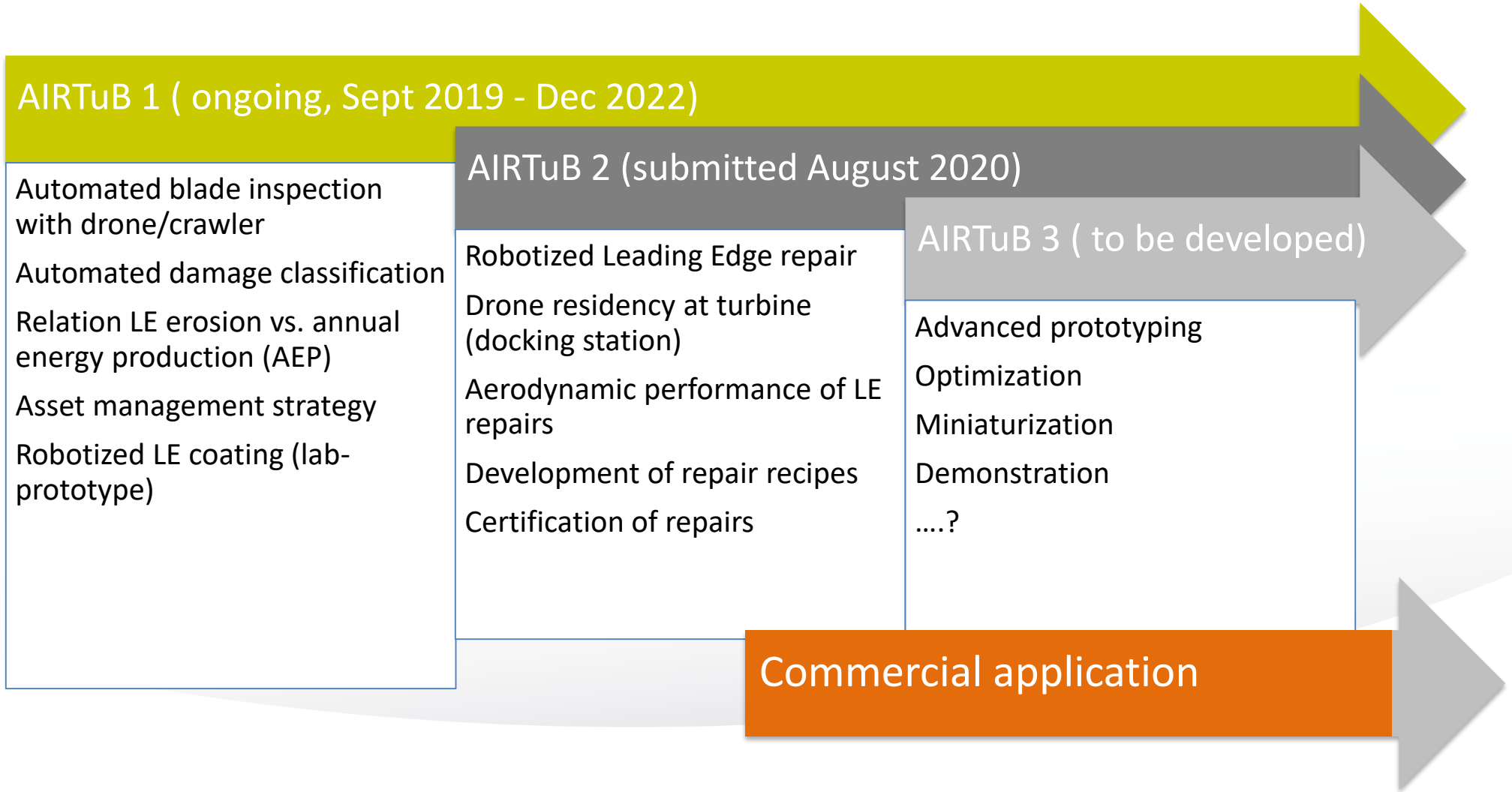
- (Manual) inspections
- Vessel movements
- Aerodynamic losses, lower AEP
- Expensive repairs
- Reduced up-time



Solution:

Automated inspection and early repair
Resident drone and crawler

Roadmap of AIRTuB program



Levelised cost of energy (LCOE) impact

- **Avoiding vessel movements and on-site man-power**:
  - Inspections and repair by rope access is costly
  - Availability of man-power gets more critical given the anticipated scale-up in WPP's
  - Avoiding vessel movements is extremely cost- and emission effective
  - Estimated effect: -2% reduction in OPEX

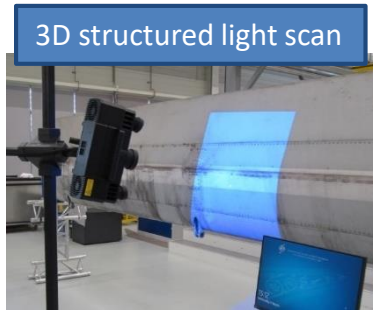
- **Less downtime**:
  - Inspection and repair by resident robots is faster
  - Avoids weather windows (with a resident drone)
  - Expected to lead to an increase in AEP of 0,1%

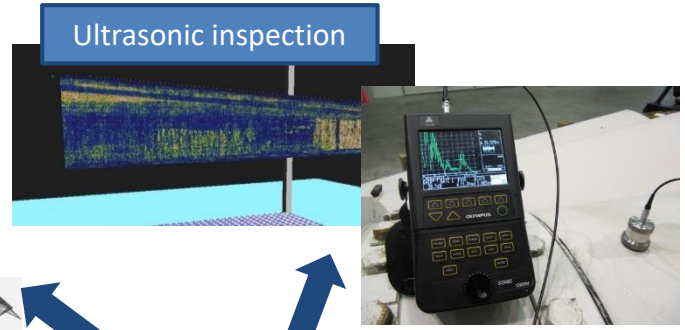
- **Higher AEP due to less blade erosion**:
  - More frequent inspections and repairs reduces grade of damage
  - Estimated increase in production of 2%

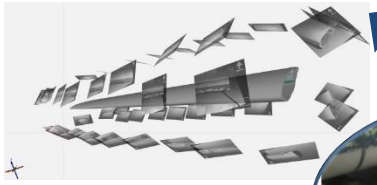
Sensor package development

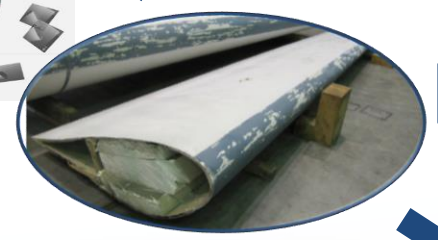
Workpackage 1

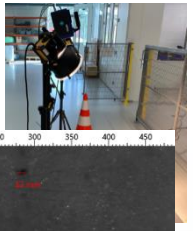
- **Goal:**
  - Solid foundation for business cases of drone/crawler inspection.
    - Design criteria sensors - the minimum size of damages to be detected.
  - Sensor development:
    - 3 D camera; laser line scanner
    - Utrasound, terahertz technology
- **Blade damage classification:**
  - State of the art wind turbine rotor blade design?
  - Relation design philosophy wind turbine rotor blades & inspection/maintenance/repair?
  - Damages in field; locations and sizes?
  - Damage effect on wind turbine operation?
  - Erosion/roughness measurement on wind turbine rotor blades?
  - Impact erosion/roughness on aerodynamic performance?
  - Blade erosion affecting structural blade properties?

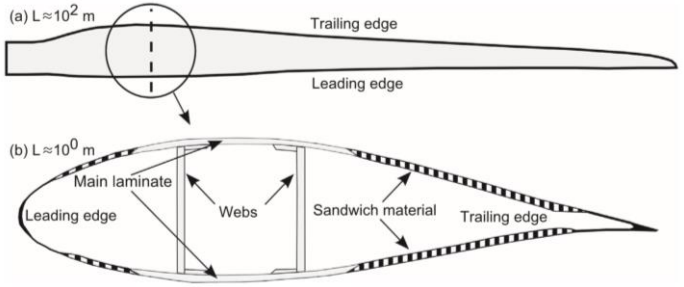


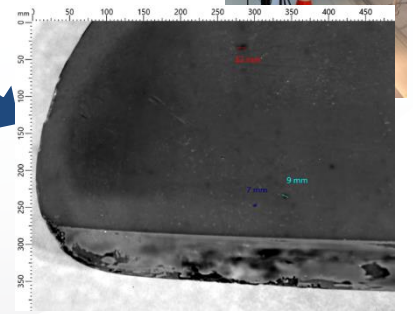


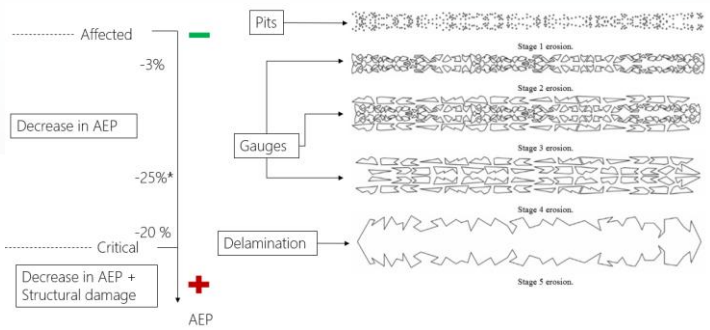












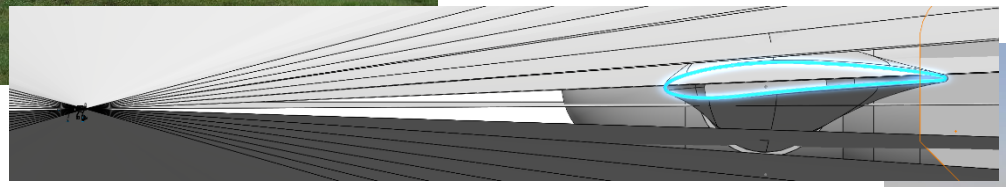
Type	Location	Minimum detectable depth [mm]	Minimum detectable diameter [mm]	Motivation
Leading Edge Erosion (LEE)	20-30% outboard, leading edge. Superficial	0.3	2	Affected AEP
Lightning	Near receptors (blade tip and mid-airfoil, pressure and suction side, black spots)	0	15	Typical lightning damage, repairable
Structural (gelcoat cracks indicating deeper damage)	Trailing edge	0	Hairline, 100mm length	*Larger than Quality Assurance*
Structural (delamination in root laminate)	20% inboard	75	100	*Larger than Quality Assurance*
Structural (delamination in outer skin-core bond of sandwich)	60% inboard, sandwich panels between spar caps and leading/trailing edge	2-5	100	Larger than sandwich block grid size
Structural (bondline tunneling or disbond cracks)	Web-spar cap, leading/trailing edge	0-30	Hairline (tunneling) or 25 (disbond)	*Larger than Quality Assurance*

Drone & Crawler Development

Workpackage 2 & 3

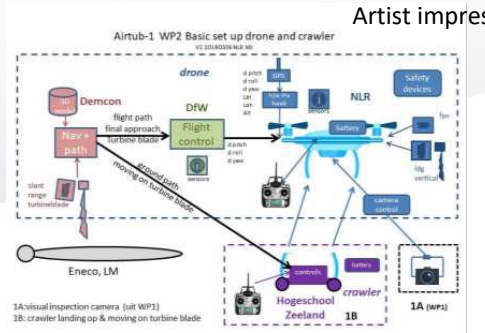
AIRTuB

Artist impression pictures courtesy of NLR©



- **Goal:**
  - Drone and Crawler development
    - Bringing sensor packages to the blade
    - 3D visual inspection or laser line scan
    - Structural damage inspection (crawler!)

- **Developments:**
  - Existing drone adaptation
    - Reliability, robustness,
    - Safety; a.o. parachute & floating device
  - Flight controller for wind gusts
  - Path planning: lidar sensor
    - Keeping track of leading edge/turbine blade
  - Crawler development for structural damage inspection sensor
  - Test & demonstration indoor/outdoor; onshore & offshore demo



Artist impression pictures courtesy of NLR©

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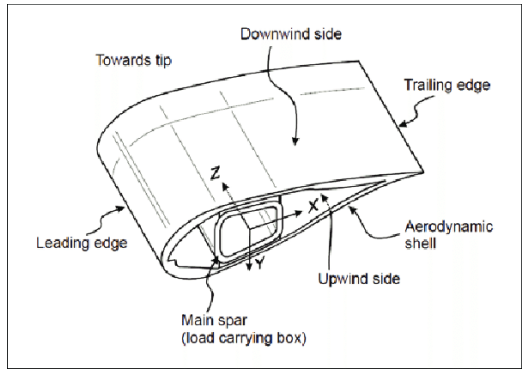
Data analysis development

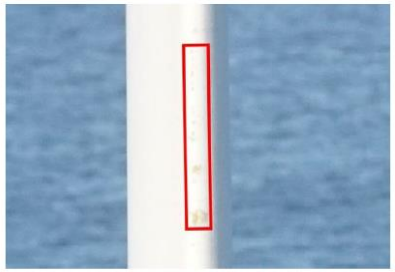
Workpackage 4

- **Goal:**
  - Learning from data
    - Impact damage on Annual Energy Production
    - Cost: operation & maintenance
- **Steps:**
  - Acquisition
  - Cleaning
  - Enrichment
  - Data storage (no live streaming)
- **Data Sources:**
  - Historical Performance data
    - Operations
    - Maintenance



Princess Amalia - WPQ7-30 | Erosion - Severity 2

Turbine Information	
Manufacturer	Vestas
Model	V80
Latitude	52.5817552264286
Longitude	4.24583791257143
Hub Height	
Rotor Diameter	
Blade A Serial	51216 (Unconfirmed)
Blade B Serial	51462 (Unconfirmed)
Blade C Serial	51387 (Unconfirmed)

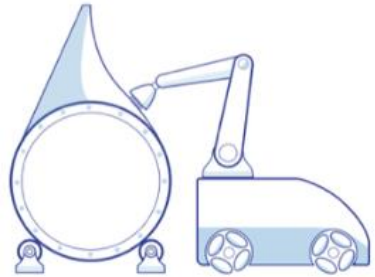


Damage Information	
Number	QI5PPQ7G-0
Blade	A
Date	2020-05-28
Type	Erosion
Width	0.03
Length	0.21
Distance	37.3
Material	Top Coat
Severity	2
Component	Blade
Blade Side	Leading Edge
Inspection Date	2020-05-28
Inspection Time	01:09:32

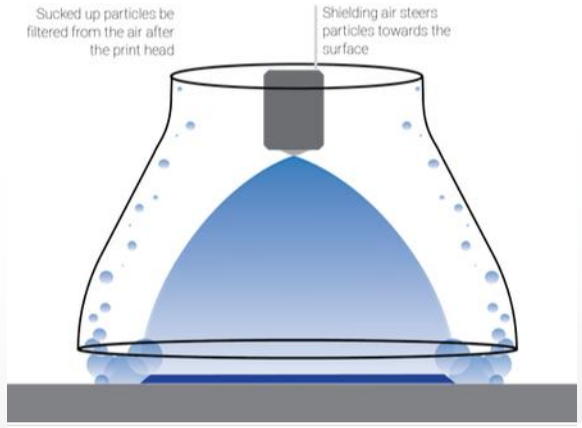
Repair Technology development

Workpackage 5

- **Goal:**
  - Renewal of Leading Edge Protection
  - Automated alternative for manual repair
- **Parallel development:**
  - Lab demo of repair technology
  - Development will start soon
- **Process steps:**
  - Pretreatment necessary?
  - Printing
  - Curing
- **Wind tunnel testing:**
  - Effect of protection on aerodynamic efficiency

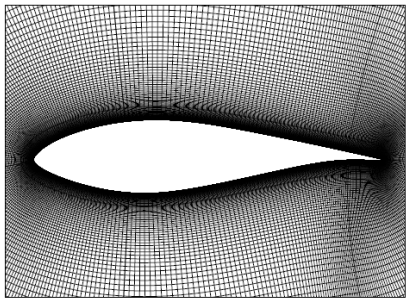


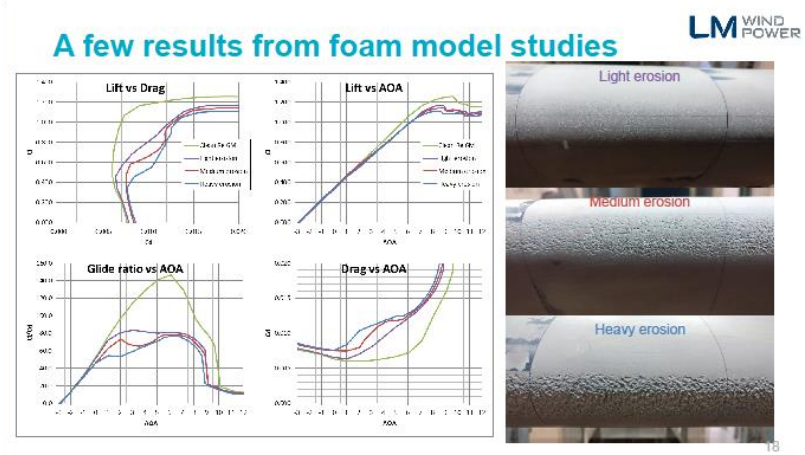
Coating wind turbine blades



Erosion Modeling & Repair Strategies

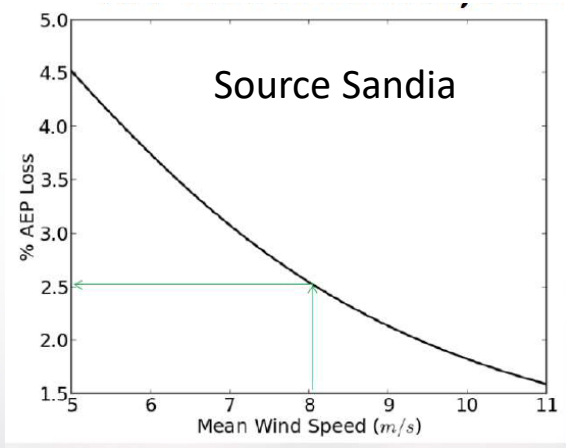
Workpackage 6





- **Goal:**
  - Estimate loss Annual Energy Production (AEP) related to erosion
  - Decision tool for repair strategy

- **Aerodynamic modelling of erosion:**
  - Validation against existing and new wind tunnel measurements



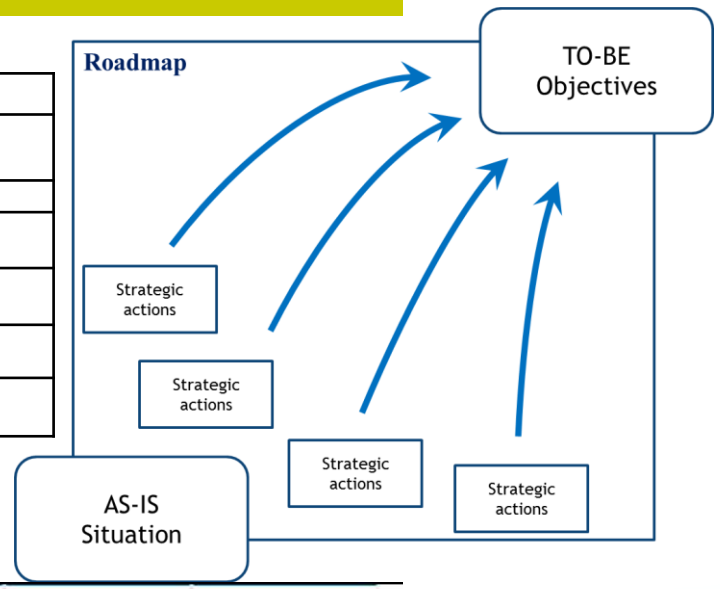
Business model development

Workpackage 7

- **Goal:**
  - New Asset Management Strategy
    - business models

- **Business Goals and baseline definition:**
  - Current cost level
- **Development of new Strategy scenarios:**
  - Comparison analysis
    - Benefits, Investment, Risk analysis for 2 scenarios compar with the baseline
  - Report of overall results

	AM Objectives				
	Performance	Energy consumption	Maintenance costs	Reliability	Strategic action
Option 1					Working in shifts (OPEX)
Option 2					"Base Operation & Maintenance"
Baseline					Modification study



AIRTuB programme

Dutch innovators are welcome to join!

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