Research Group Mechatronics

Autonomous Inspection & Maintenance of wind turbines

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Problem: Leading Edge maintenance

Averaged maintenance costs in lifespan turbine (Le & Andrews, 2015)

Overview	Freq [#/life]	Costs per time	Total costs
Gear Box	11,2	€ 421.300,00	€ 70.752,00
Turntable	9,59	€ 62.700,00	€ 76.318,00
Turntable blades	11,56	€ 68.200,00	€ 118.063,00
Tower	2,44	€ 602.800,00	€ 38.379,00
Hydraulic	13,16	€ 29.700,00	€ 195.426,00
Break	4,32	€ 8.800,00	€ 19.008,00
Rotor	9,77	€ 276.100,00	€ 156.783,00
Hub	4,07	€ 51.700,00	€ 26.059,00
Replacement	0,28	€ 48.400,00	€ 13.552,00
Corrosion	3,79	€ 3.300,00	€ 12.507,00
Blades (10%)	5,7	€ 224.400,00	€ 130.724,00
Replacement	0,49	€ 220.000,00	€ 107.800,00
Repairment	5,21	€ 4.400,00	€ 22.924,00
Power generator	14,55	€ 266.200,00	€ 716.694,00
Total	76,59	€7.135.800,00	€ 1.391.423,00

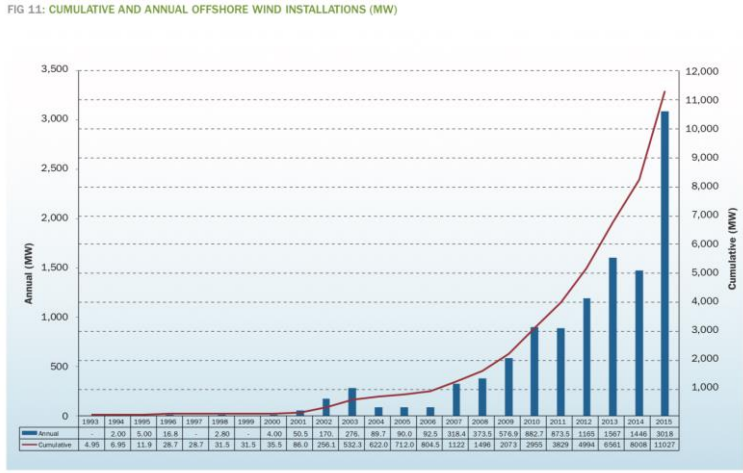
- Yearly increase of wind farms (+ 18% / yr)

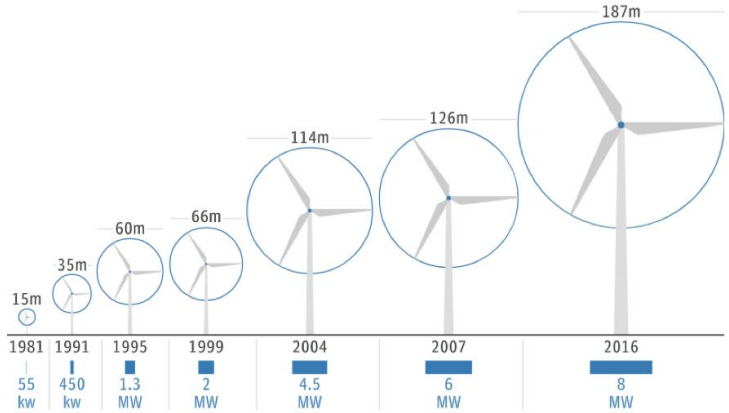
+

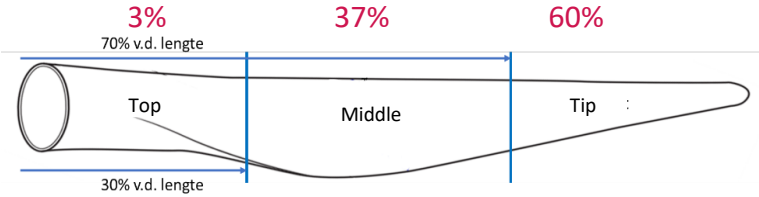
- Trend of increasing blade lengths giving a factor 6 higher wing tip speeds ($v = 2\pi r\varpi$) and thus more wear

=

- Exponential increase of wind turbine blade maintenance cost
  - ~ 130 kE per turbine
  - ~ 8 M€ Netherlands
  - ~ 250 M€ Europe
- Almost all LE (95%) & most (60%) tip





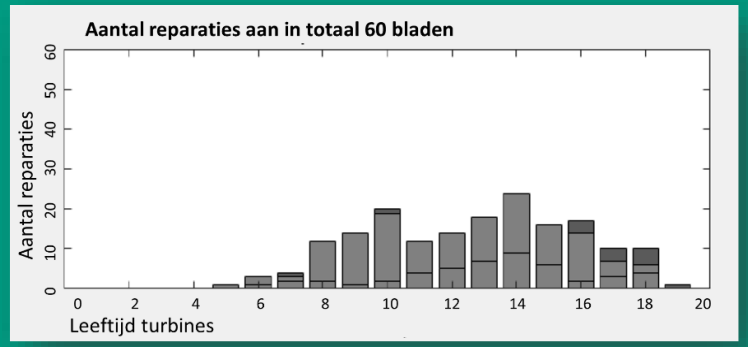


Locations of wind blade damages from typical WindPark Owner (Bevers, 2020)

Current Solution

Toekomst beroep servicemonteur windturbines

De kans op robotisering van de werkzaamheden van een servicemonteur windturbines bedraagt 64%. Dat betekent dat de kans gemiddeld is dat de taken en werkzaamheden van een servicemonteur windturbines binnen nu en 20 jaar door robots en slimme software zullen worden overgenomen.



Now

- Only reactive maintenance, done by people

+

- Very risky jobs

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- Too less employees to cope with this increasing maintenance demands

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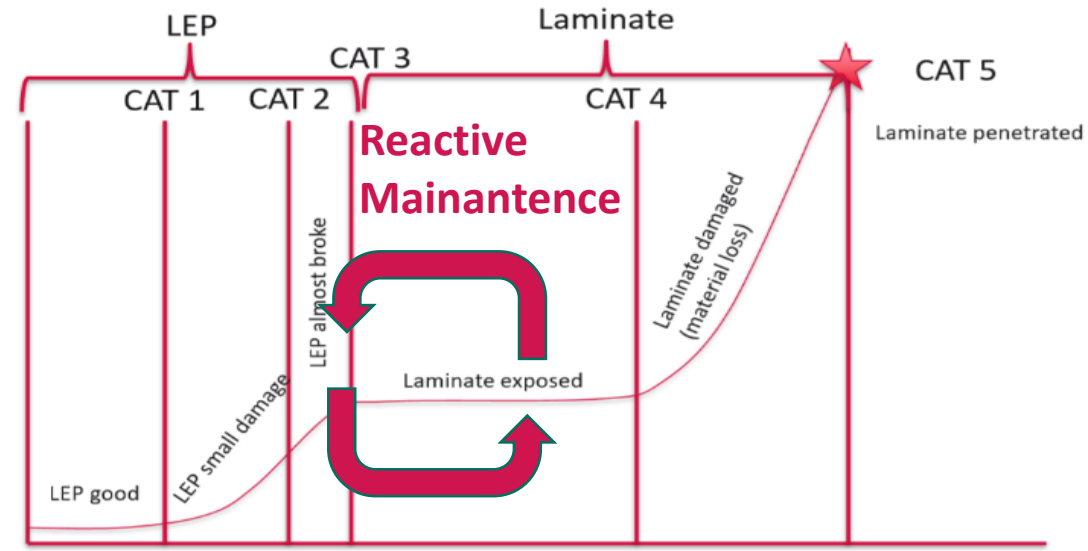
- Higher maintenance costs than necessary:
  - 1 windblade replacement per 2 turbines
  - even complete run-to-failure strategies



Five categories of turbine blade damages of a typical WindPark Owner, (Bevers, 2020)

Envisioned Solution

Currently inspection *can be done by drones and detection by AI algorithms, but* maintenace drones require new technology *!*

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- Maintenance done remotely by people on site

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- Less time consuming

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- Less risky, thus more employees doing more blades per day

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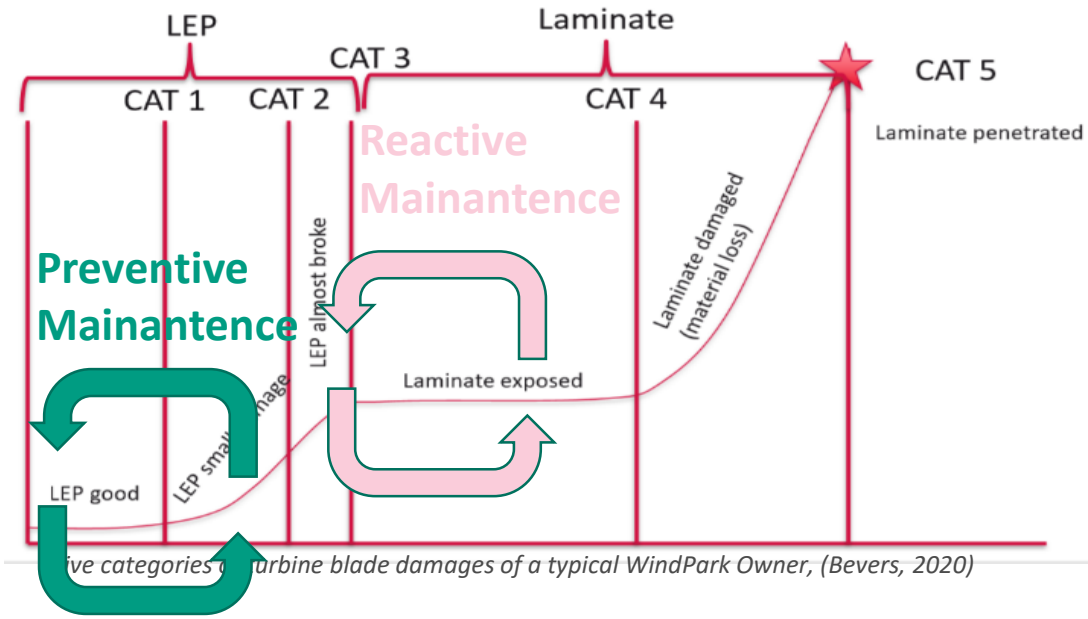
- **Preventive maintenance strategy reducing costs and improving turbine's energy output**

Now

Future



ive categories urbine blade damages of a typical WindPark Owner, (Bevers, 2020)

MARS 4 EARTH

Autonomous Outdoor Aerial Interaction

Modular Aerial Robotic System for Sustainable Living on Earth (MARS4Earth)

4 year project

1 million

12 partners

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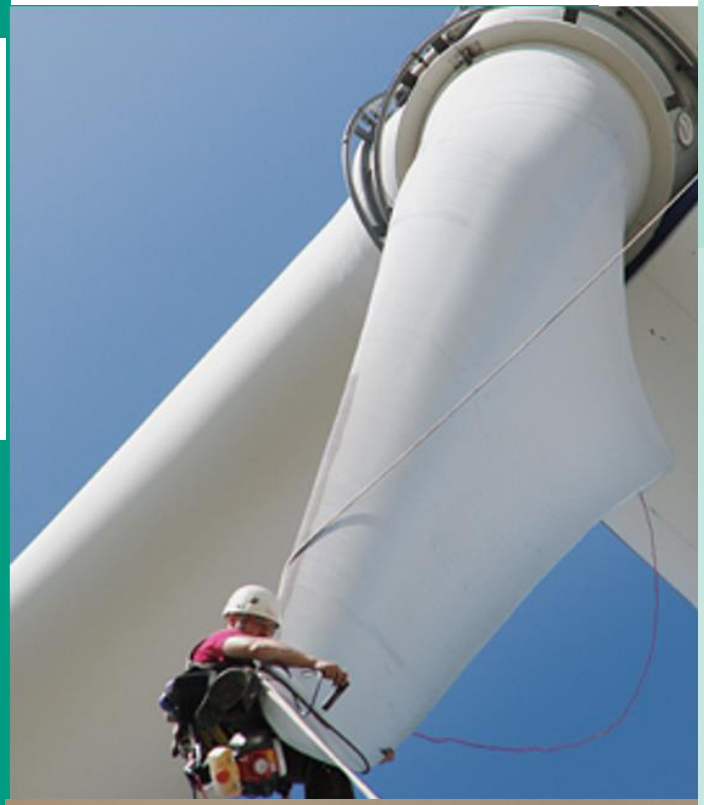

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MARS 4 EARTH

Autonomous Outdoor Aerial Interaction

Modular Aerial Robotic Systems for Sustainable Living on Earth (MARS4Earth)

The goal is to develop a new generation of modular and completely autonomous aerial manipulators that can physically interact with a realistic outdoor environment.

Technologies

- mission-specific interaction modules
- intelligent surface exploration
- adaptive interaction control algorithms
- onboard perception & decision modules

INSPECTION & MAINTENANCE

AGRICULTURE

SAFETY & SECURITY

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UNIVERSITY OF TWENTE.

SPACE53

DRONExpert.nl

Drone4Agro

GRONINGEN SEAPORTS

BRANDWEER TWENTE

tvalley

AMPERAPARK

Field Lab ZEPHYROS

Project Details

Start date: Nov. 25, 2019
Duration : 48 months
Consortium : 12 partner

www.saxion.nl/mars4earth

SCAN ME

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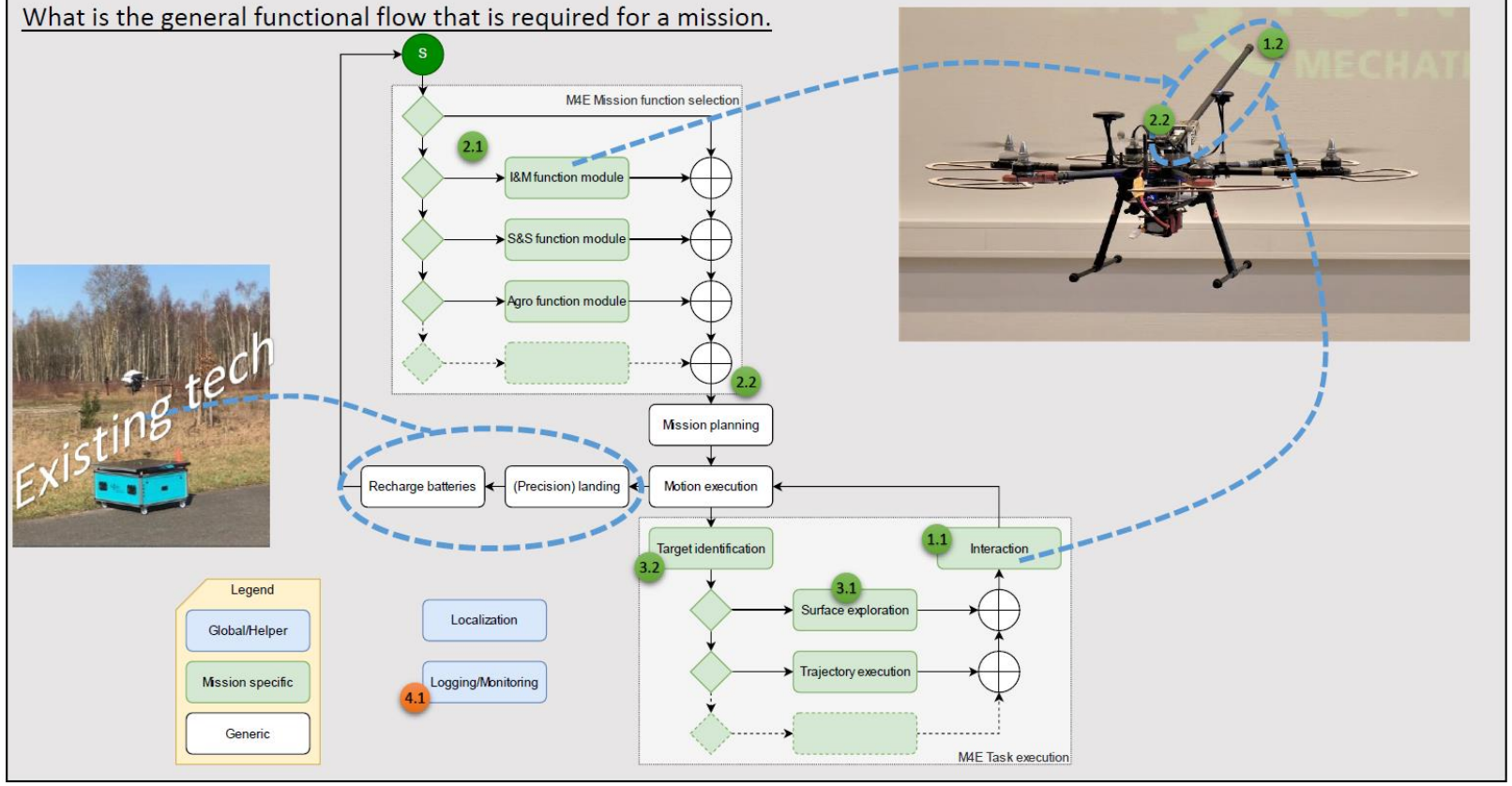
I: Functional Flow

What is the general functional flow that is required for a mission.





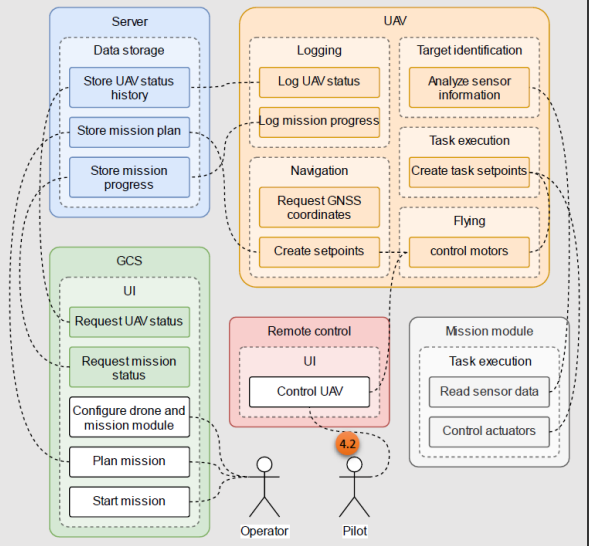


III: Key Parameters

1. Interaction
   - 1.1 Controller (Active and passive interaction)
   - 1.2 Tool/End effector (Mission specific module)
2. Modularity
   - 2.1 Mission specific modules
   - 2.2 Interfaces (hard- and software)
3. Autonomy
   - 3.1 Flight controller (Surface exploration algorithms)
   - 3.2 Target identification algorithms
4. Safety
   - 4.1 Logging
   - 4.2 Emergency procedures (pilot takeover)

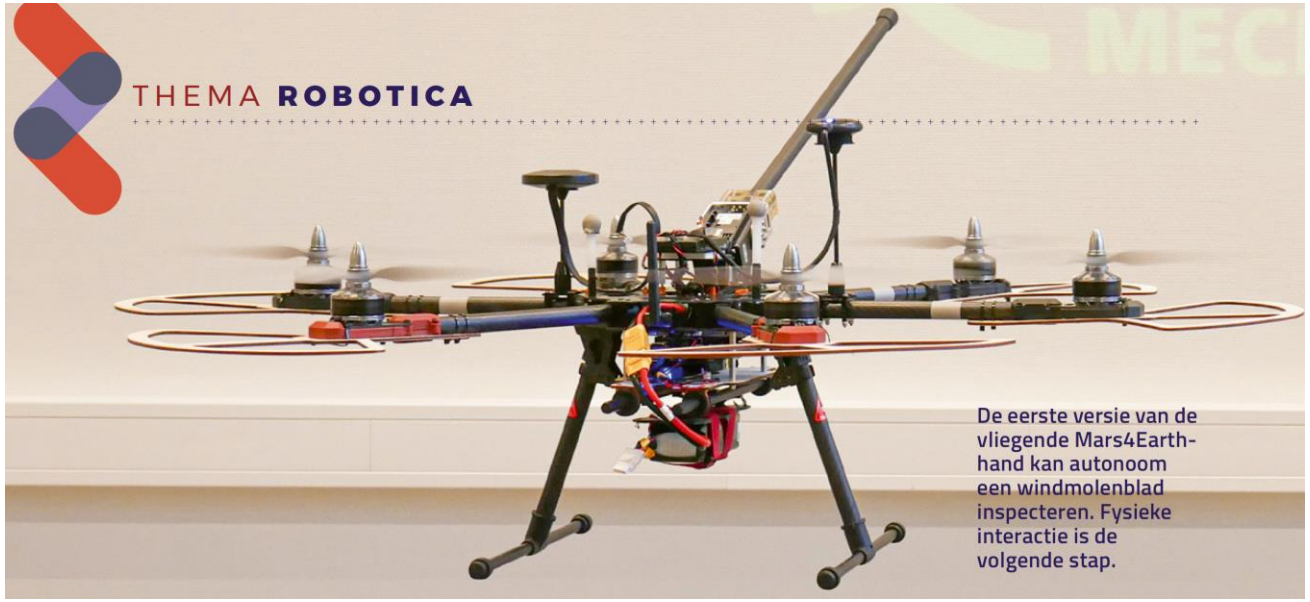
II: Physical View

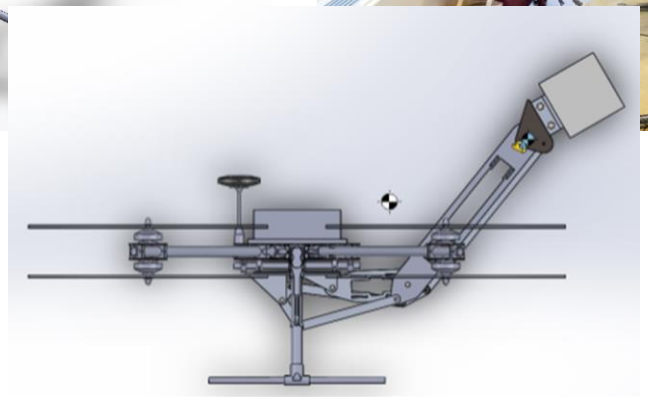
What actions and where are the actions being performed during a mission.



Modular Aerial Platform

- Modular construction
- Tilting rotors
- Standardized interface for mission specific modules
- Suitable for physical interaction with various surfaces
- Can apply significant amount of force at any direction





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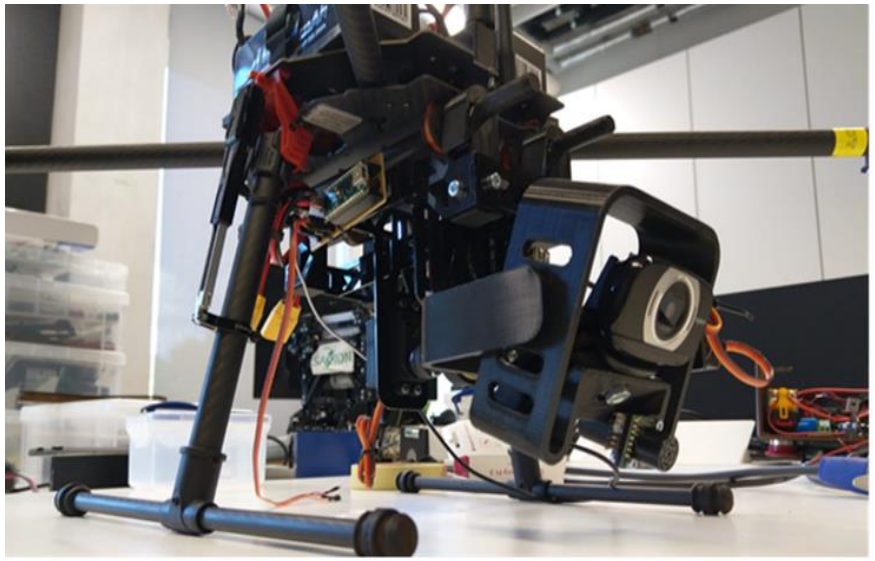
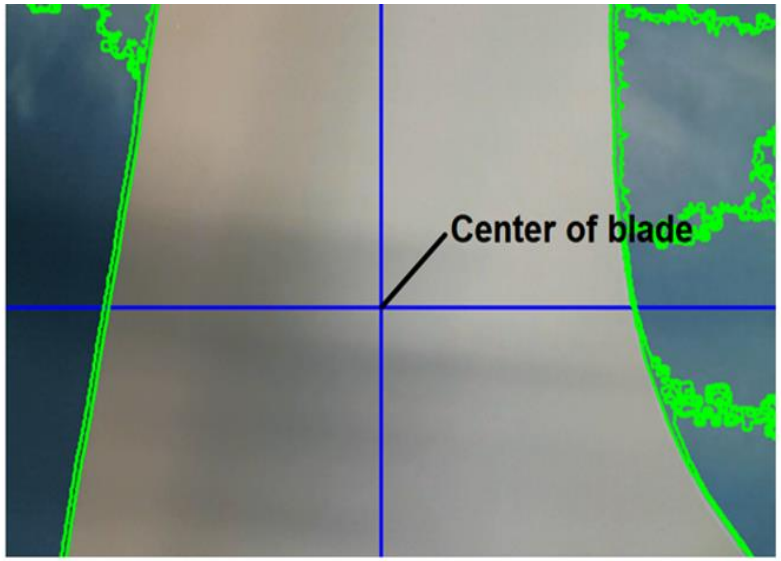
Localization and exploration

- Vision based detection and localization of wind turbine
- Ultrasonic sensor is used for distance (drone-turbine) measurement.
- Frontier based exploration





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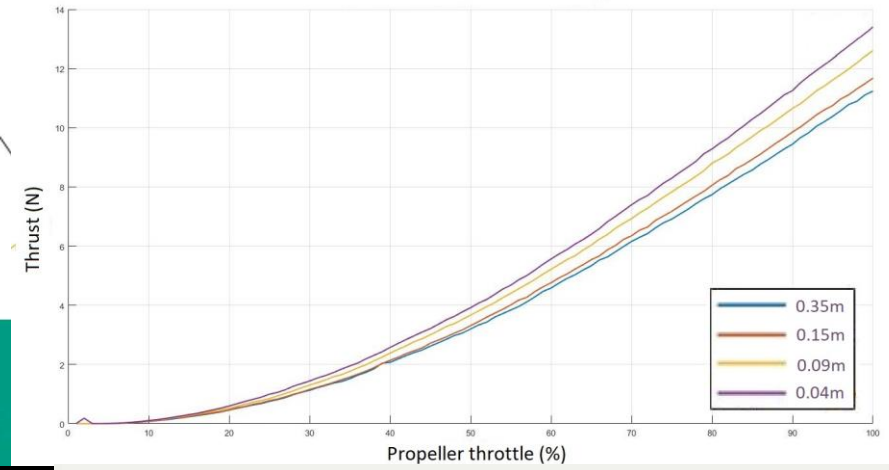
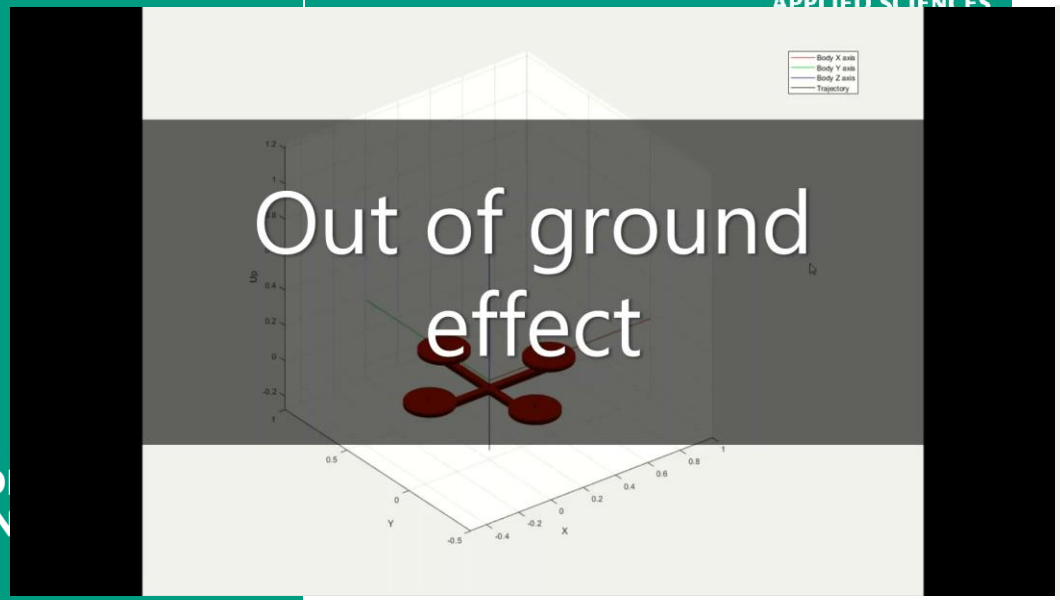
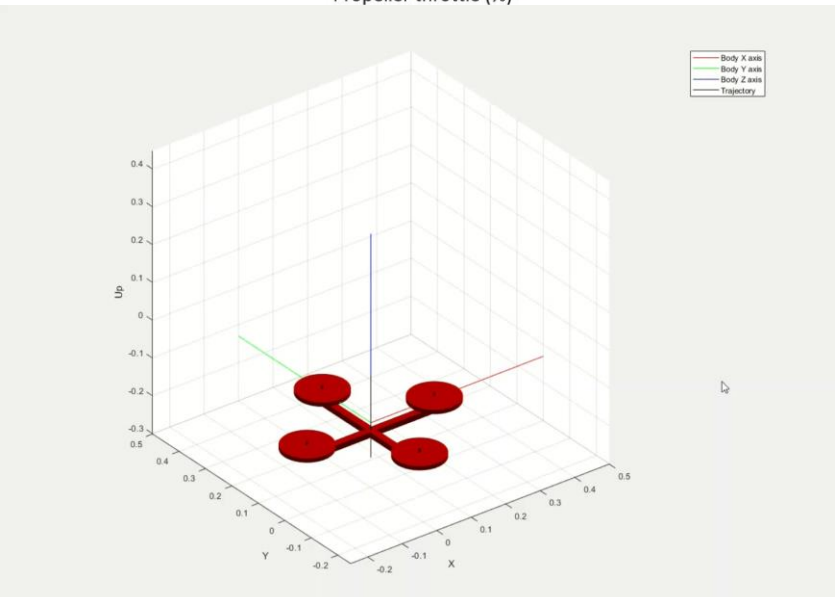
Interaction control

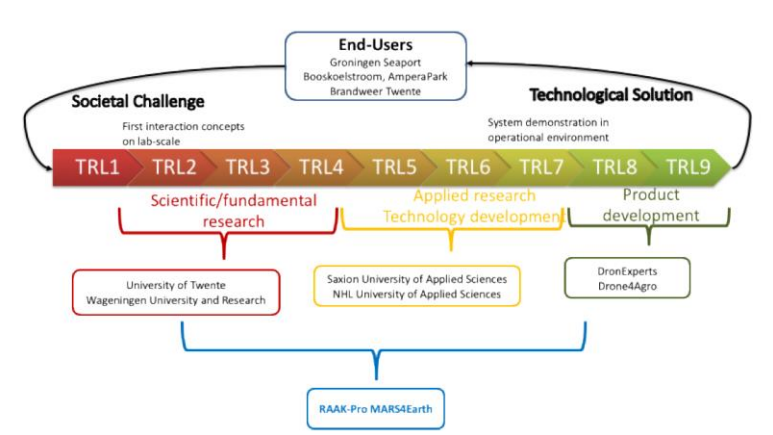
- Analyzing ground effect on thrust generation
- Cascaded control for smooth transition between free-flight and close-to-surface flights







Resources & capabilities



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Next Steps and other Initiatives

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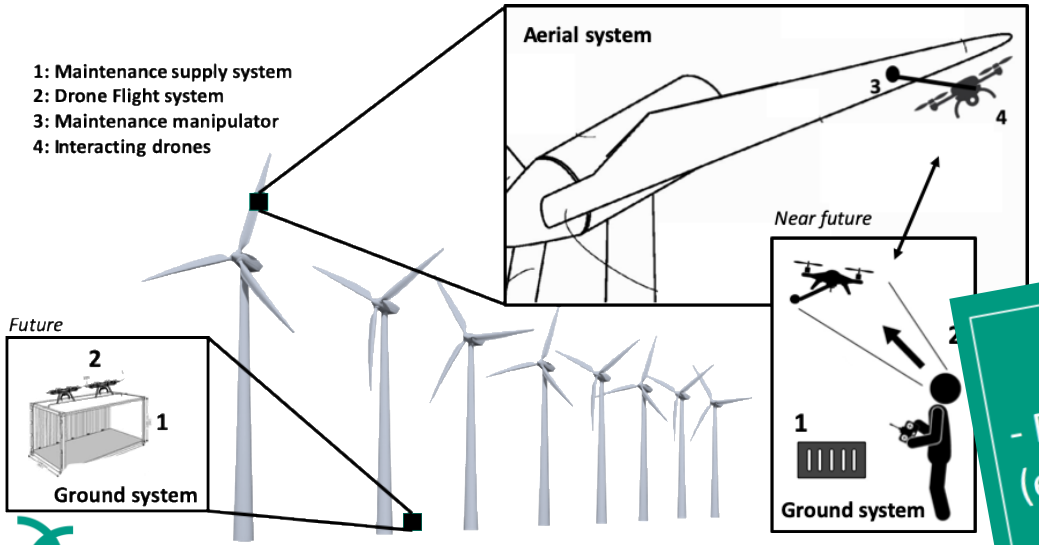
Consortium forming

- **Predictive maintenance**



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Autonomous Outdoor Aerial Interaction

Ongoing

- **Aerial interaction-based inspection**

Just started

- **Holistic inspection**

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