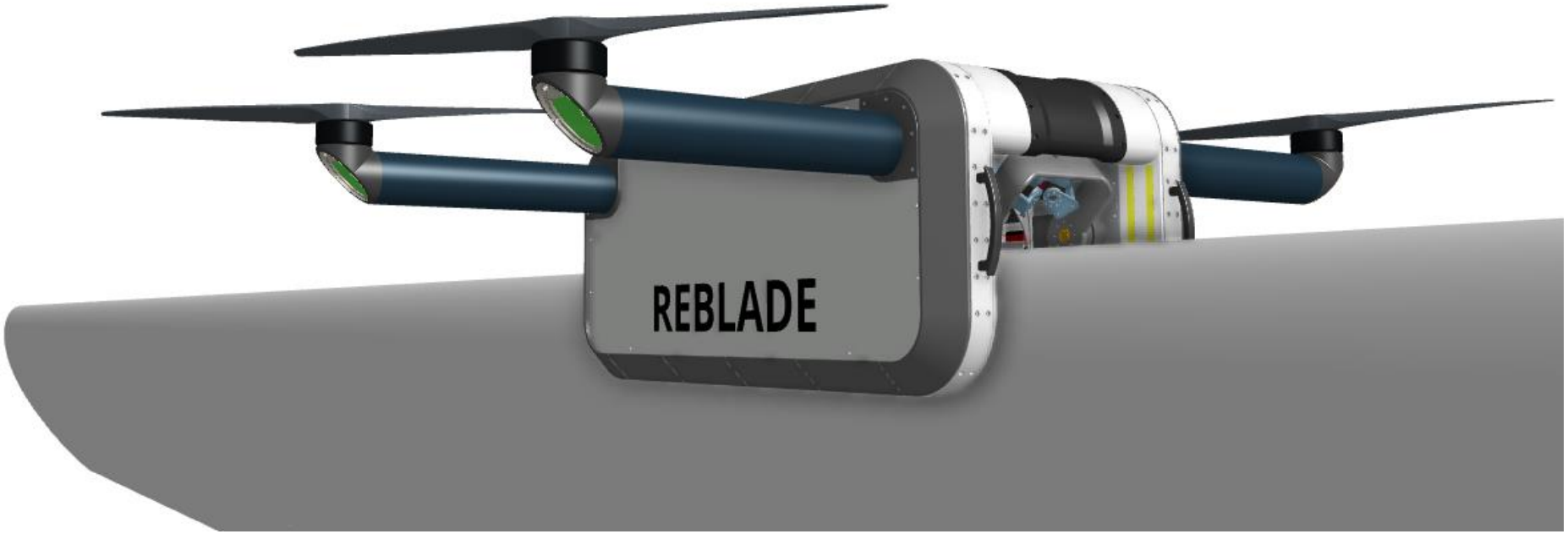
REBLADE

AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES



Flying Drone Repair of Wind Turbine Blades – Better, Safer and Faster

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

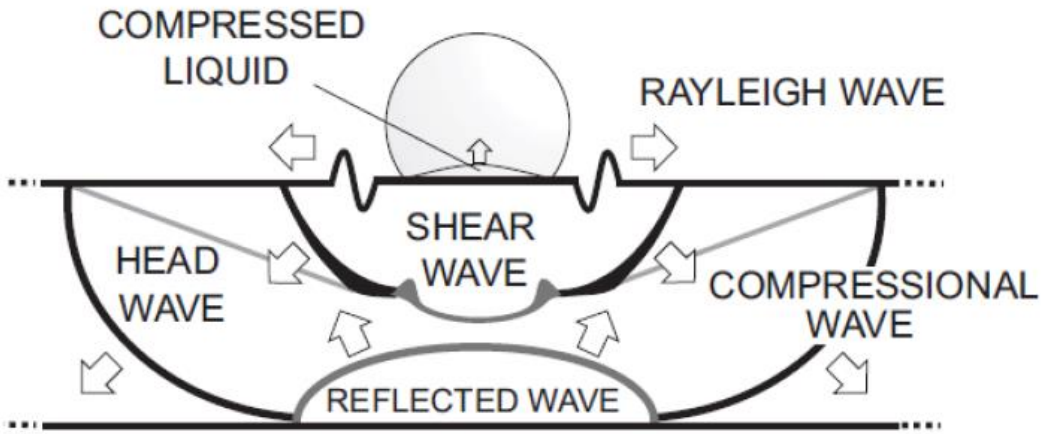
All one million+ wind turbine blades have erosion problems

- The leading edge is damaged by rain erosion
- Erosion causes structural integrity problems
- Blade repairs result in downtime and loss of revenue

Leading edge erosion basics

Caused by impact from

- Rain
- Sleet, snow and hail
- Salt spray (40% greater effect than rain)
- Dust and sand
- Insects



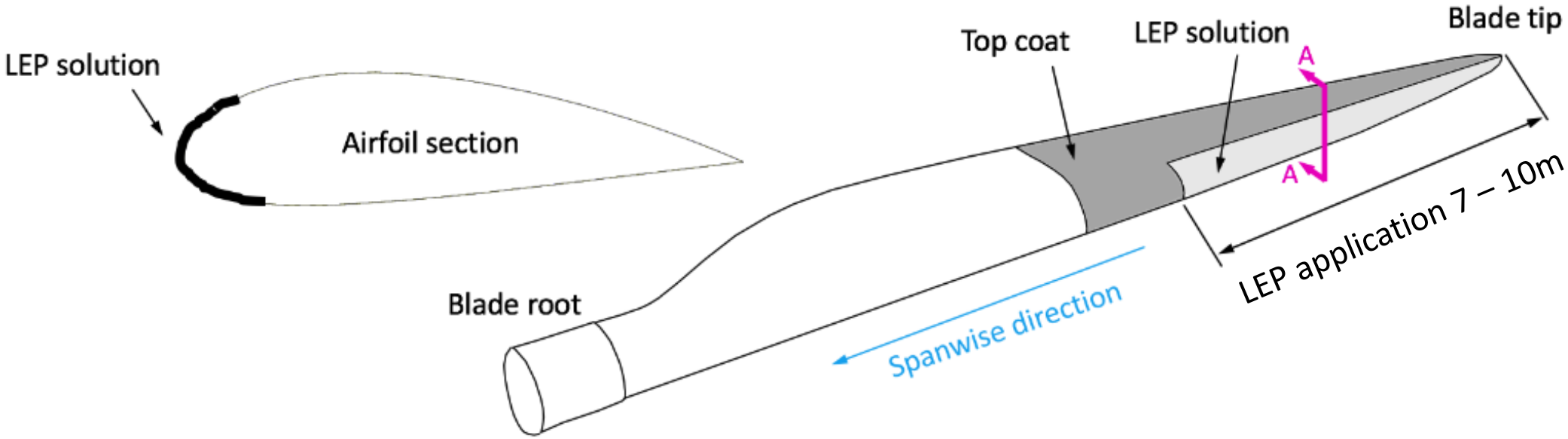
Erosion rate proportional to

- Rotational impact velocity to the 5^{th} power
- Rate or volume of rain

Blade tip speed

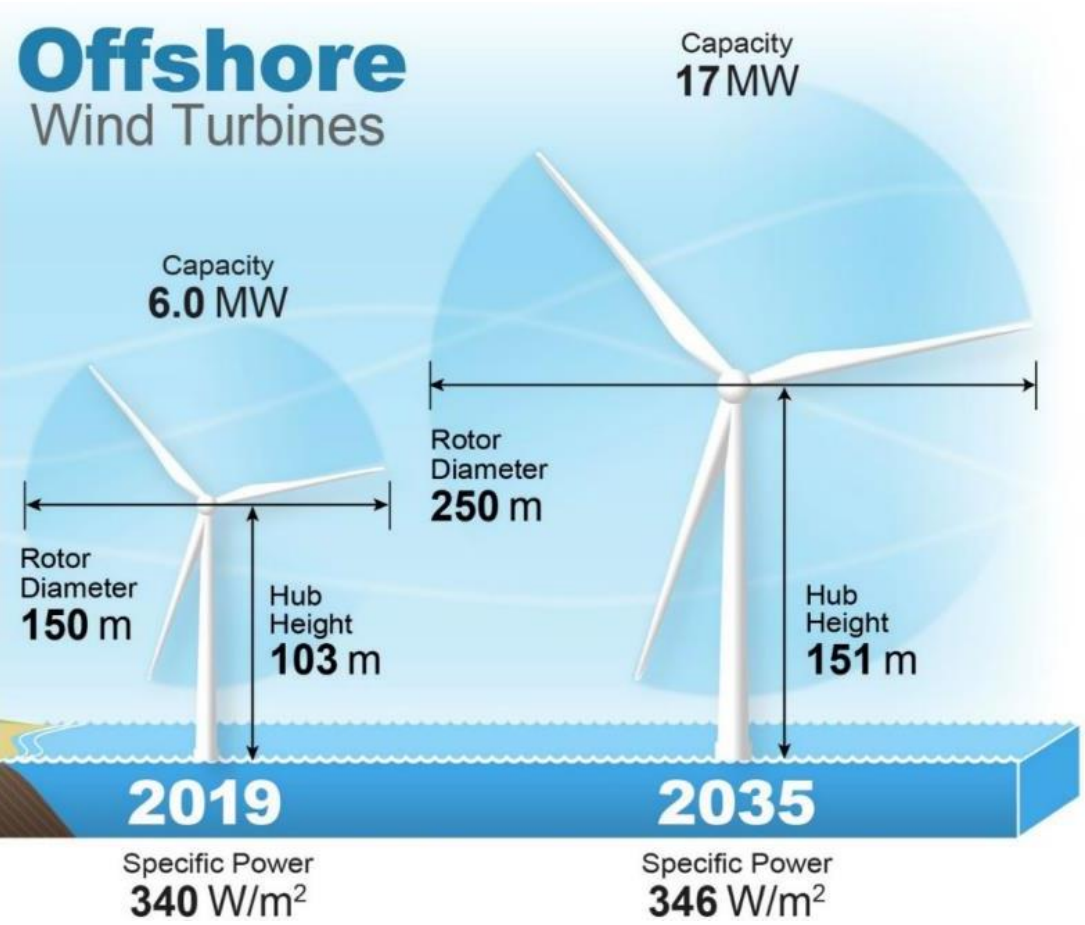
- Onshore typically at least 80m/s
- Offshore 80-100m/s

Blade area to be repaired



- Leading edge erosion occurs mainly towards the tip
- Usually repair last ~7m but can be 10m for larger blades

Erosion rate of larger blades



- Turbines are getting larger
- Erosion develops exponentially faster with size
- Offshore turbines are typically very large
- Salt water and wind conditions increase erosion
  - Erosion from salt water is 40% greater than rain
  - Steady state wind 14m/s (onshore 6 - 9m/s)

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Repair of offshore blades

- Repairs performed manually
- Reduced weather window
- Access by crane ship is expensive
- Current robotic technology cannot be used
- Downtime causes large revenue loss

Manual repair and LEP coating

- Blade rotated to vertical and pin-locked
- IRATA qualifed technicians access blade
- Typically work in maximum wind of 10m/s
- Recoating LEP takes one day per blade in ideal conditions
  - Grind surface to required finish
  - Cleaning of surface
  - Application of coating
- Weather window will vary acording to location
  - Fewer suitable days offshore
- Turbine will not produce power for three day shifts + cure

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Leading Edge Repair Drone

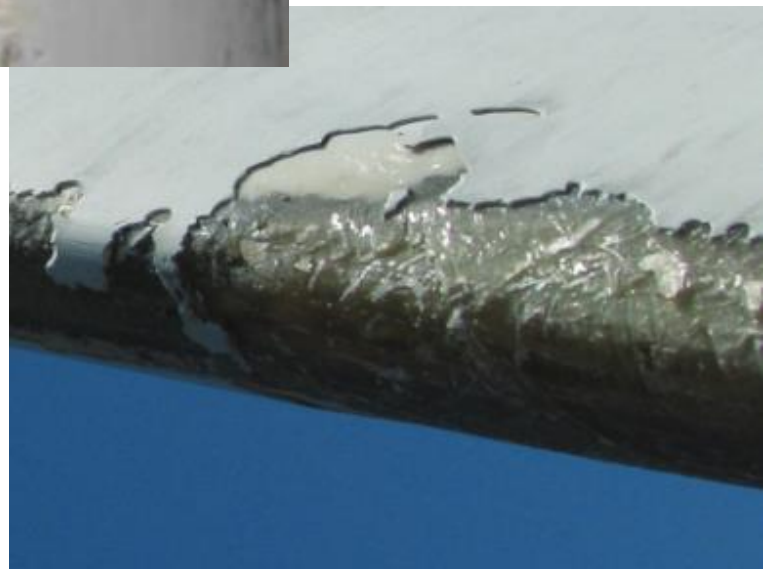
- Developed for on- and offshore
- Downtime reduced by 90%
  - only 4½ hours per turbine
- Drone flies onto blade
  - No transition zone
  - No technicians on turbine
- AI-assisted total solution
  - Easy to use by regular service teams

Leading edge erosion damage Levels

Cat 1
Looks like dirt, hard to detect visually

Cat 2
Cosmetic, can see visually. AEP loss up to 2%

Cat 3
Fibres exposed. Minor structural damage.



Cat 4
Greater structural damage. AEP can drop by up to 5%

Cat 5
Severe structural damage. Turbine must be stopped and repaired urgently

Consequences of structural damage repair

Repair patches

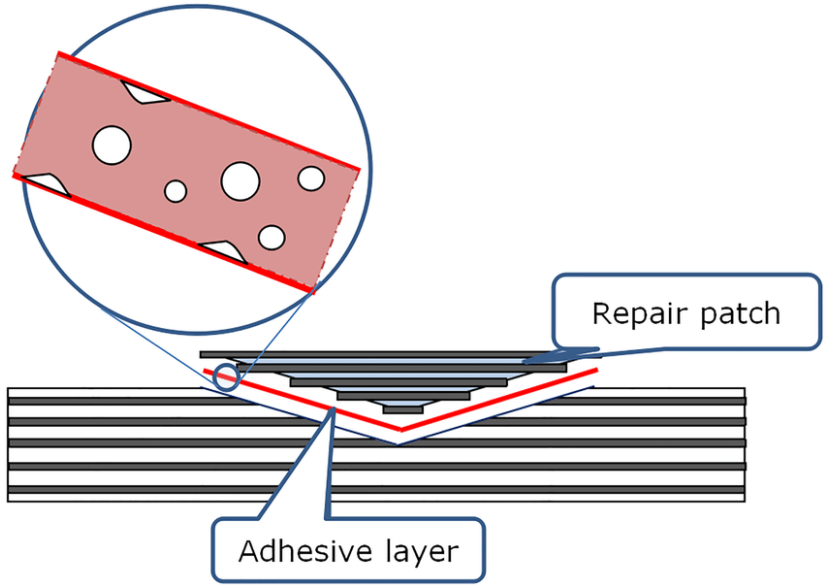
- Required once surface coating is breached
- Temperature, humidity and UV radiation affect the performance and curing of coating systems, resins and fabrics used in repair patches

Weather window

- Hard to achieve correct repair conditions

Repair quality

- Highly dependent on operator skill and experience
- Repairs often lower quality than designed to be
- Repair patches can fail within six to 12 months
- Many do not last longer than two years



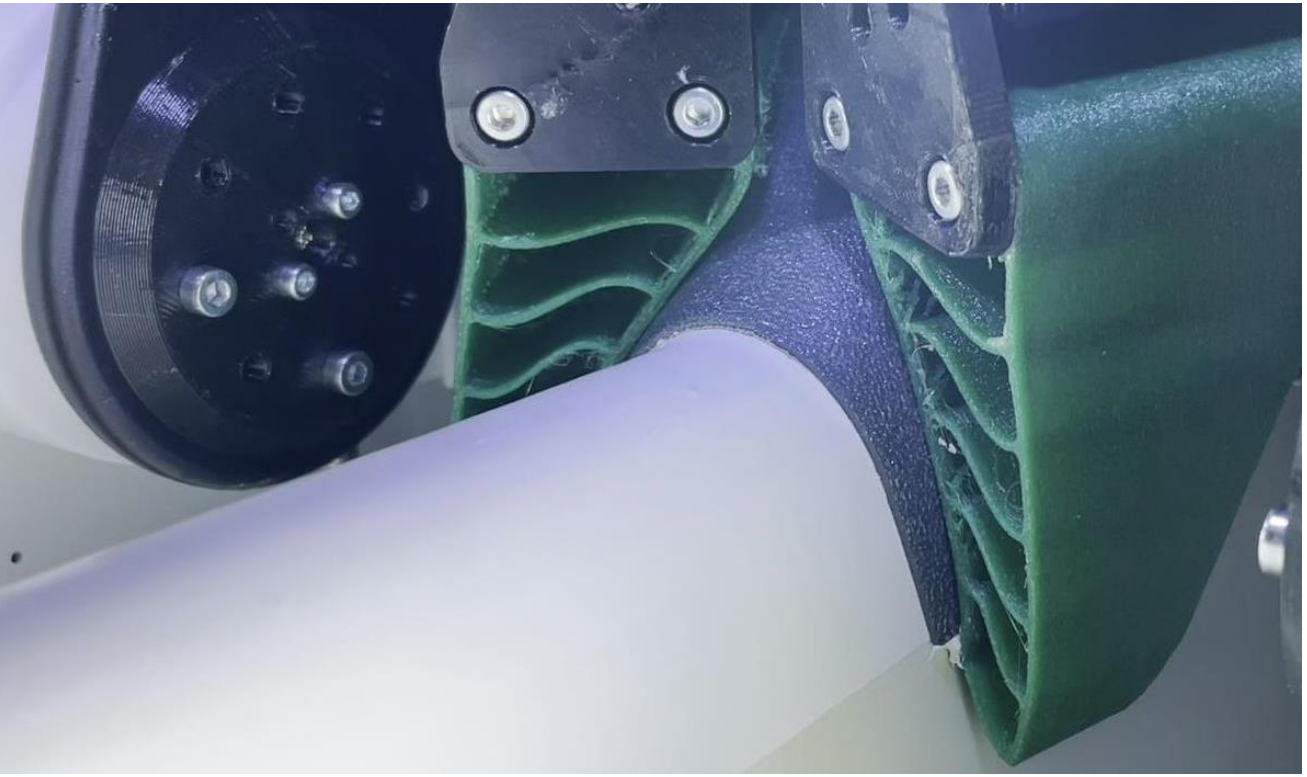
REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Damage repairable by drone

- Cat 1 to 3 is repairable
- Goal is to repair at Cat 1 or 2
- Cannot repair delaminations by drone alone
- Unlikely to see type 3 or worse if have proactive maintenance

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Drone tool modules



Four modules carried

1. Grinding
   - Custom designed lightweight system
2. Cleaning
   - High pressure air
3. Washing
   - High pressure solvent wash
4. Coating
   - Any wet LEP
   - Coatings supplied in bespoke dispensers

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Drone repair process

1. Blade damage inspected for suitability

2. Document environmental conditions acceptable

3. Grinding of surface

4. Surface preparation
   - Removal of larger dust particles by air pressure
   - Removal of minute dust particles by IPA under pressure

5. Application of coating

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Coating application

- Any wet leading edge protection (LEP) can be used
- Coating thickness can be preset
- Mechanical assurance of coating thickness
- 5m/min coverage (2 mins for 10m)
- Thermodynamic control within dispenser
- Turbine can produce energy after cure
  - 1 hour for rapid curing LEP,
  - e.g. Teknos - TEKNOBLADE REPAIR 9000-40

Ease of use

- Drone under 25kg
  - No flight permission
  - Two-day drone pilot certificate
- Drone will land on blade itself (ML assisted)
- Can train standard service personnel
- No transition zone as no need to apply pin-lock
- Needs only 2.5m * 2.5m deck space
- Can use low-cost crew transfer vessel (CTV)

Robot and platform solutions

Several days of downtime during blade repairs

Solutions are heavy

- Offshore repair out of scope

All solutions require specialized workers

- Workers at risk

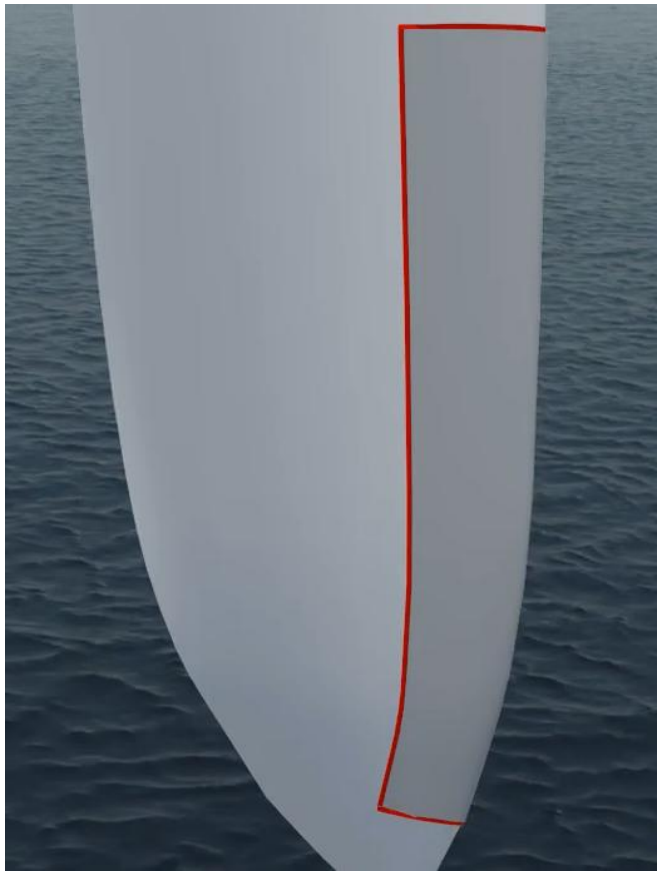
Robot solutions have a multi-tool approach

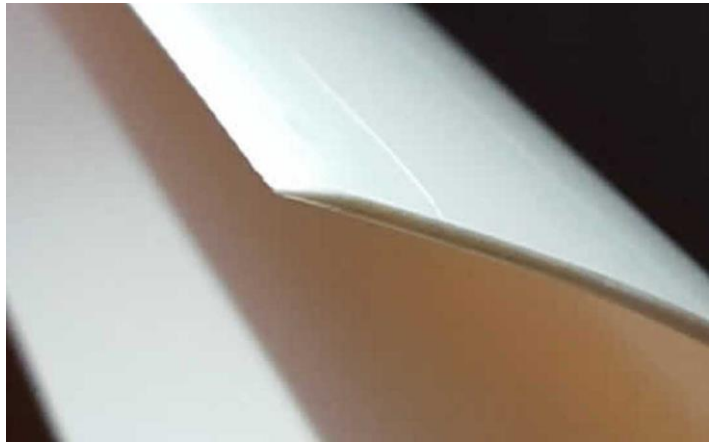
- Not optimised for erosion repair
- Significant time to set up on blade

Other leading edge solutions

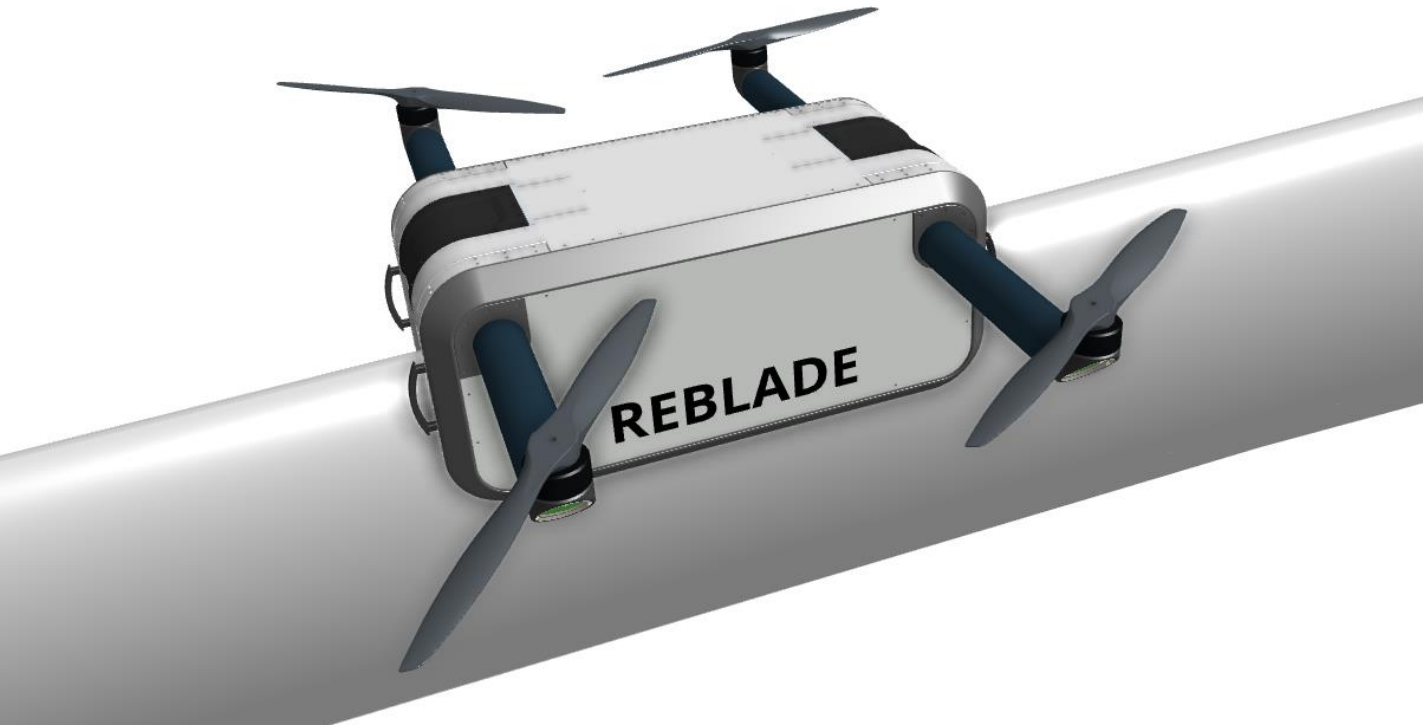
Shells & tape

- Polyurethane or thermoplastic
- Elasticity absorbs kinetic energy from impact
- Expensive
- Complex and time-consuming to install
- May need to be replaced (esp. tape)





Leasing Business Model



Hardware-as-a-Service

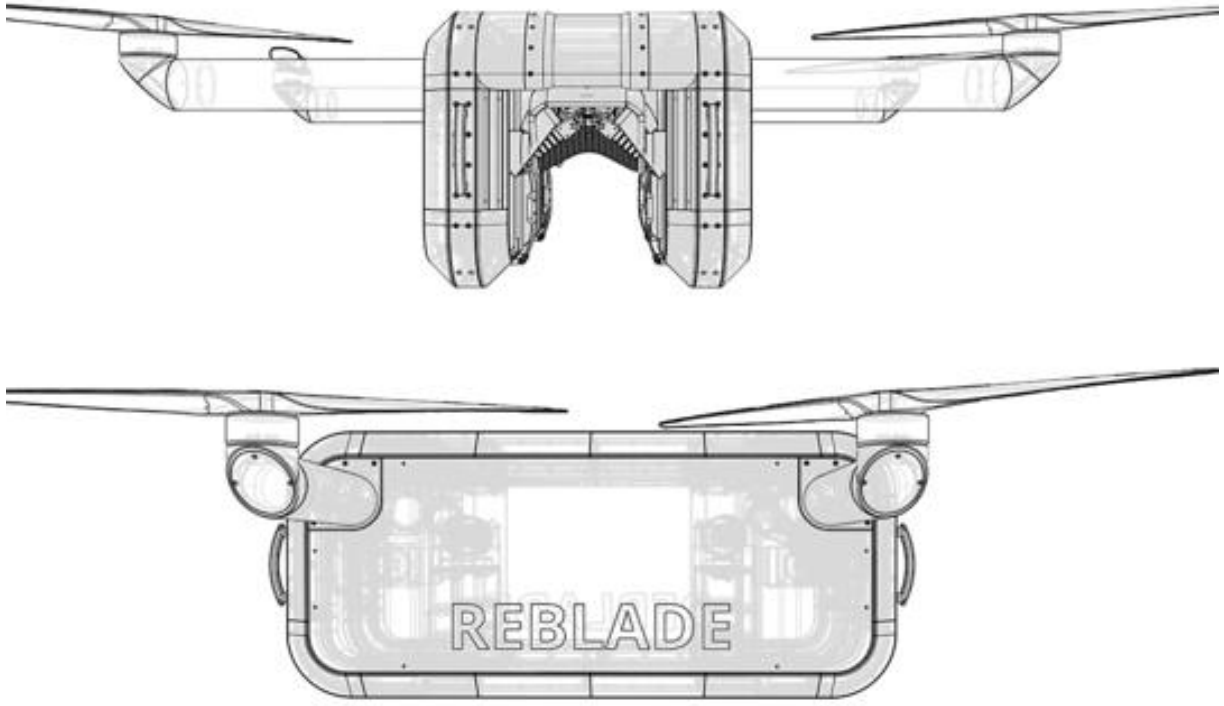
- Leasing of drones
- Fee per blade repair
- Consumables supply
- Maintenance of drone
- Service team training

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Operational Benefits

- Service window improved by up to 50%
- Protects assets, workers and environment
- Reduction of downtime, LCoE and other costs
- Fossil fuel energy stabilizes supply during downtime
  - 450 ton CO2 reduction per turbine repair

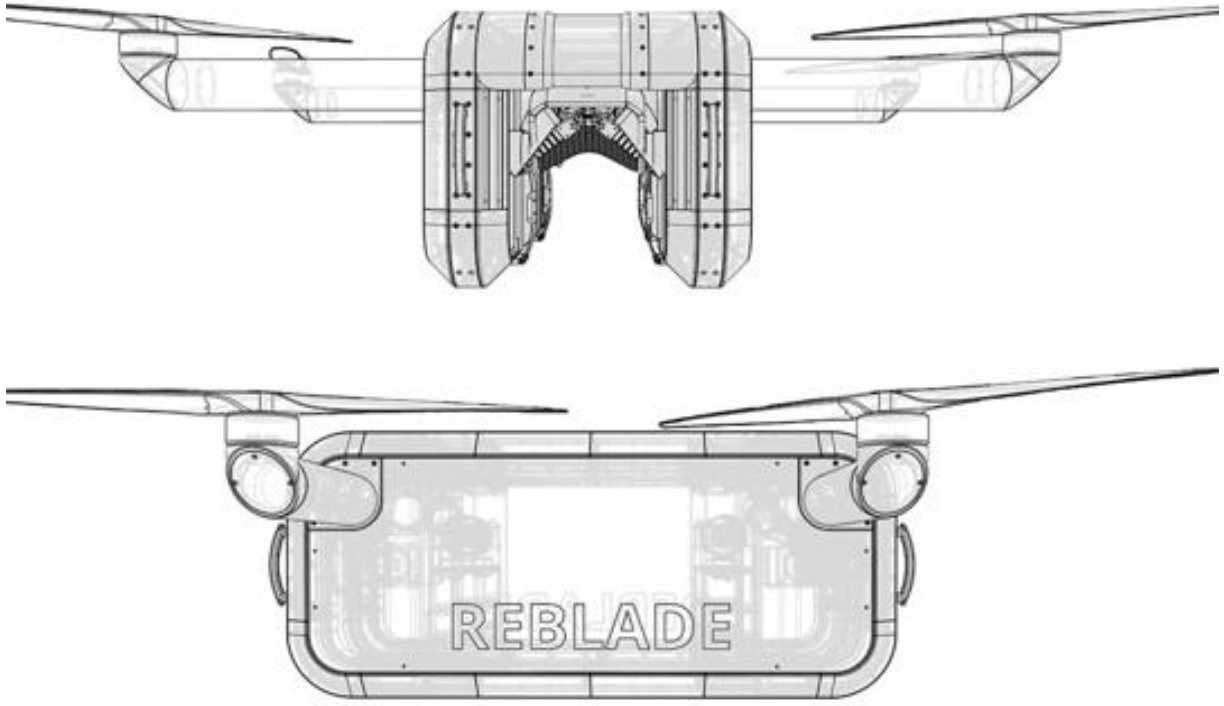
Hybrid Coating Drone



- Initial product
- Abrasive grinding and coating modules
- Technicians perform fine surface preparation
- Increases repair capacity of workers three-fold
- Blade repair of one full wind turbine per day
- Available H2 2024
- Upgradeable to All-in-One Drone

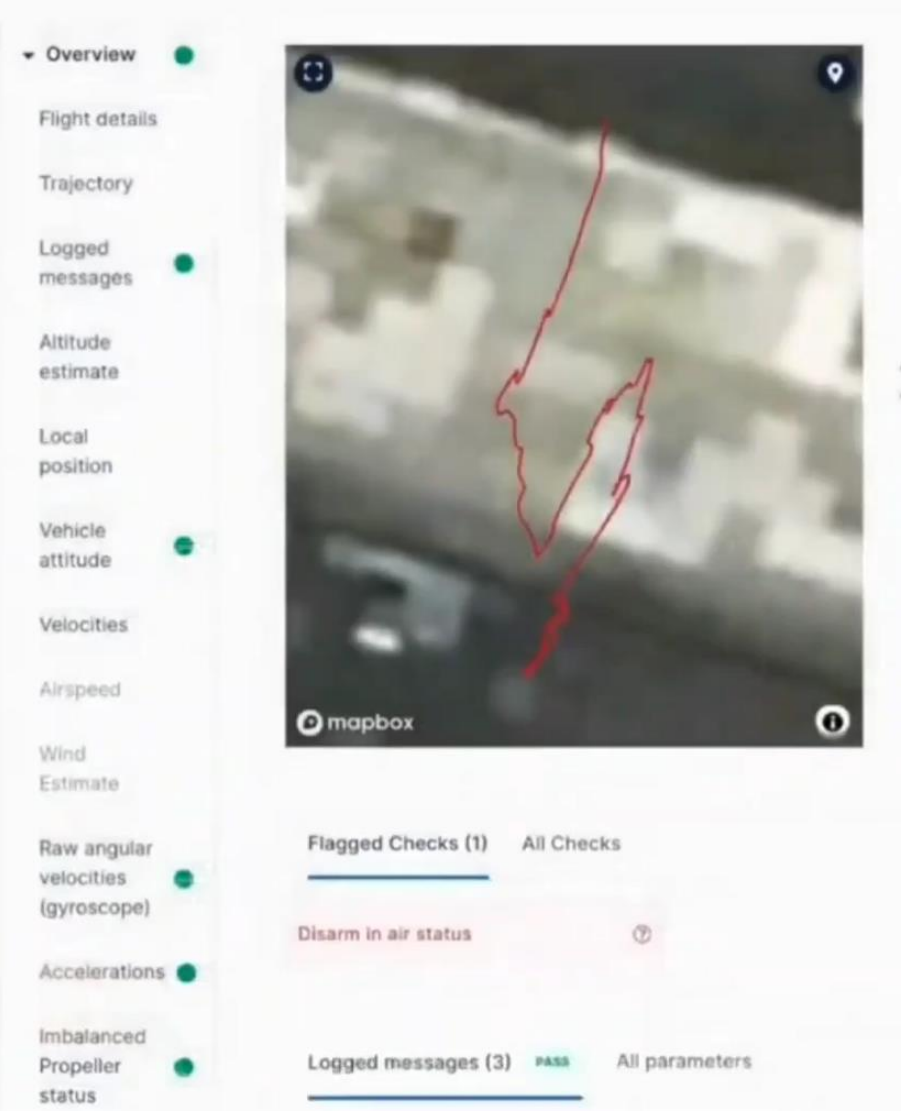
REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

All-in-One Drone



- All four modules
- Technicians do not require turbine access
- Suitable for offshore repairs
- Repair in poor weather conditions
- Leading edge repair of two WT’s per day
- Increases capacity of workers six-fold
- Available 2025

Quality Assurance report



- Environmental conditions
  - Surface temp
  - Ambient temp
  - Dew point
- Video/photo
  - Before, during and after repair
- Names of operators
- Prerepair check list verified
- All operator inputs reported

REBLADE
AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES

Significant Industry Engagement

- Wind Developers
- OEMs
- Service Companies

Summary

Problem

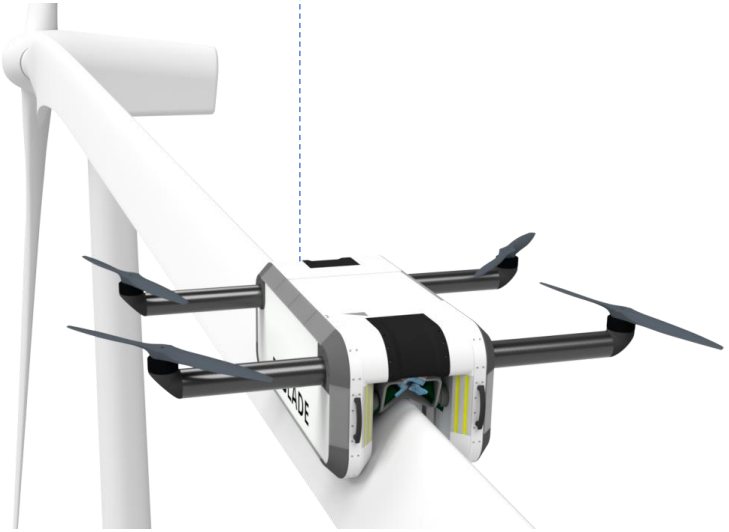
Expensive repair
Slow and complex
New tech for onshore only
Slow global roll-out

Reblade

Innovative team
Relentless focus
Patented engineering

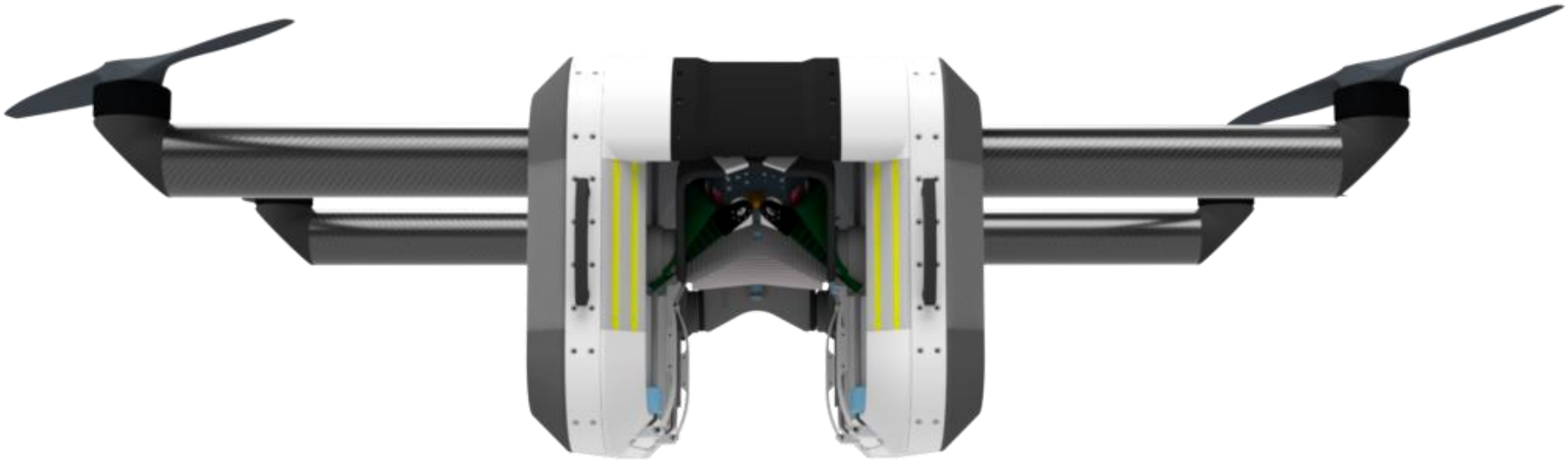
Solution

Cost effective repair
Fast and automated repairs
On- and offshore tech
Fast global roll-out



REBLADE

AUTOMATED DRONE REPAIR OF WIND TURBINE BLADES



To find out more, please contact:

EU/Global

Frank Kjerstein
fk@reblade.dk
+45 3022 3612

UK

Chris Kirby
ck@reblade.dk
+44 7899 913487