ONE ENERGY
AN INDUSTRIAL POWER COMPANY

ONE ENERGY DRONE INSPECTIONS

JERROD CARNEY

2024-01-07

THE DRONE INSPECTION PROGRAM

- Started by Ben Mallernee in 2018
- Transferred to Mitchel Bumb in 2021
- Transferred to Jerrod Carney in 2022
- Ideally, each turbine will be inspected 4 times a year (approx. every 94 days)
- In practice, this has been more of a once or twice a year at most program.
  - Most critical after summers (lightning & hail) and winters (freeze & thaw)

BLADE INSPECTIONS – BEFORE

- Physical rappelling with Rope Partner LLC to hang off nacelle and move down blades to get up close photos.
- Slow, expensive, & hazardous. Had to re-ascend and retract ropes before moving to the next blade.
- Binocular & camera inspections were impractical.

ONE ENERGY DRONE OPERATIONS

- One Energy's drone inspection program utilizes UAVs capable of:
  - Prolonged flight times up to 30 minutes
  - High definition, high zoom imaging and video platforms
    - Up to 30x magnification
  - Forward and downward obstruction ultrasonic sensing capabilities
  - GPS-reference and real-time kinematic flight stabilization
- Matrice 210 V2 model was in service for 5 years
- Currently seeking a replacement

SUMMARY OF FAA REGULATIONS

- Pilot Licensing and Testing
- Drone Usage Limitations
- Drone Registration
- Airspace Flight Restrictions
- Local Airspace Notifications and Communications

PART 107 SUMMARY

1. Pilot licensed under FAA
2. License on-person when flying
3. Sober
4. Have +1 observer
5. 30 min buffer between civil twilights
6. Maintain visual contact with drone
7. Fly in class G airspace
8. Fly in class E airspace with LAANC authorization
9. Fly in class B, C, or D airspace with ATC authorization
10. Yield to manned aircraft
11. Not operate over non-participating humans
12. Operate below 87 knots (100 mph)
13. Within 400’ radius and 400’ above a tall structrure

BLADE INSPECTION PROCESS

1. Turbine CRO/ROC notice and shutdown
2. Drone integrity inspection and pre-flight checklist
3. Turbine rotor brake applied via PLC or JDJK
4. Drone inspects:
   - Leading Edges
   - Suction Surfaces
   - Pressure Surfaces
   - Vortex Generator Fin Strips
   - Nacelle and Tower (yearly)
5. Release brake and allow remote operation
6. Turbine CRO/ROC notice and restart

WEATHER CONDITIONS

- GPS stabilized in winds up to 12 m/s, with position-return correction after stronger gusts
- Turbine brake should not be applied over 11 m/s
- Ideally partly cloudy with high visibility
- Temperature range of operation from -4°F to 113°F
  - -20°C to 45°C

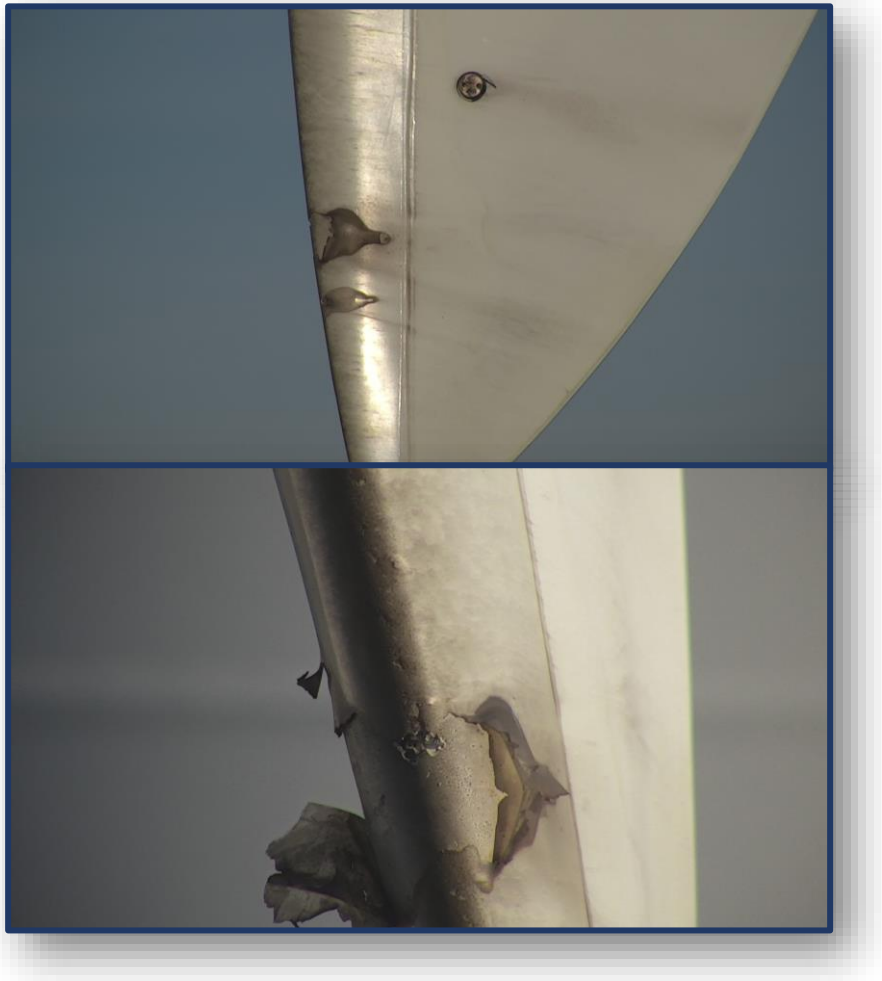
DRONE VIDEO

BLADE DAMAGES: NONE

- Leading Edge Protection (LEP) completely intact
- No wear to the gel coat

BLADE DAMAGES: MINOR

- Beginnings of LEP fraying, peeling, or tearing
- Minor hailstone or debris impacts with blade causing gel coat chips
- Non-impact related gel coat wear/cracking



BLADE DAMAGE: MODERATE

- Significant LEP tearing and fraying over span of leading edge
- Areas of low severity erosion to underlying gel coat
- Holes in LE present of <1 in. diameter.

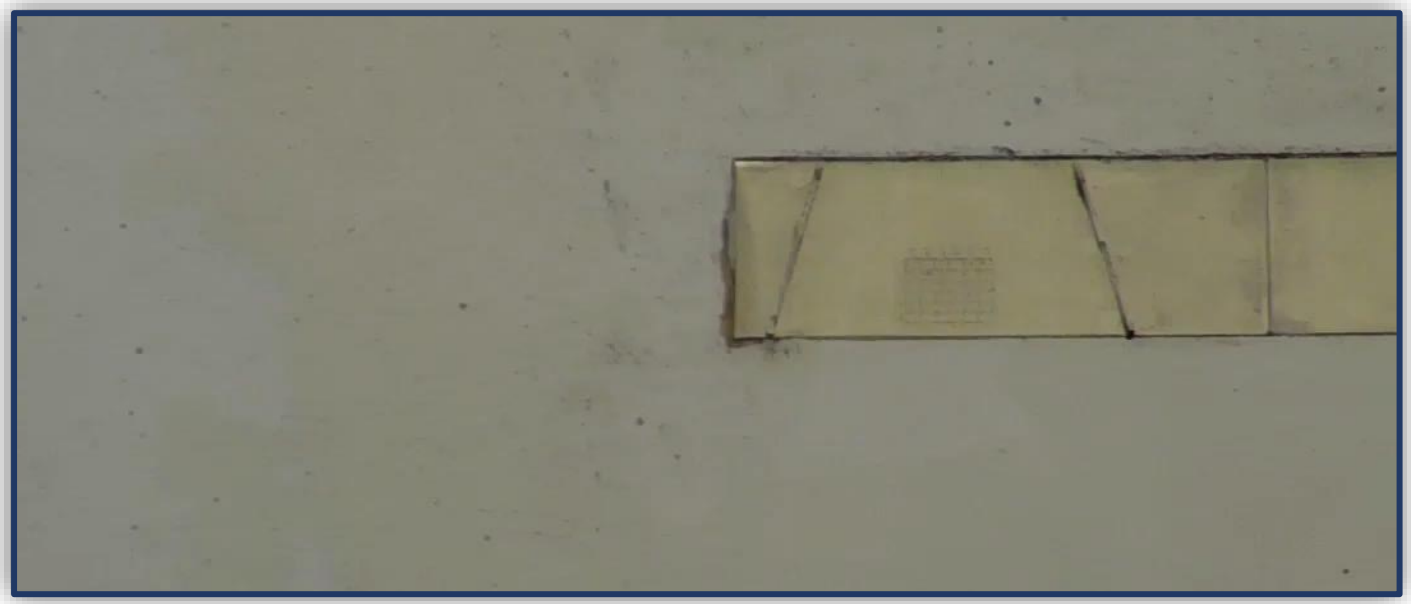
BLADE DAMAGE: MAJOR

- LEP completely eroded
- Underlying fiberglass or balsa wood filler exposed
- Holes, gashes, cuts, crushing damage visible on blade
- Split blade tips
- >50% of VG fins dislodged

COOPER FARMS T2, GREEN BLADE (2022)

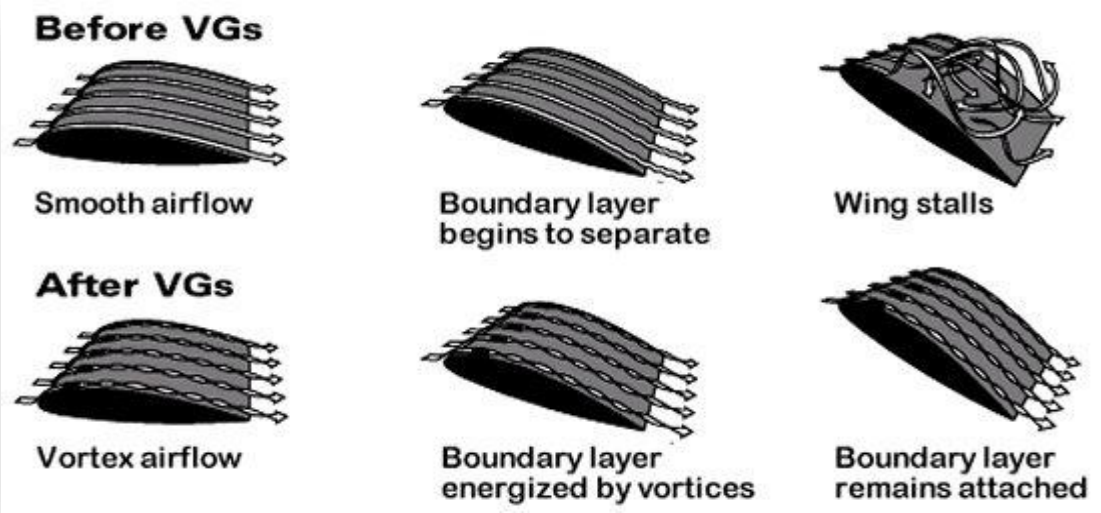
VORTEX GENERATOR FINS

- Fins that exchange “used” turbulent air with “fresh” laminar air from the surface of the blade via lateral vortex couplets.
- Thin and plastic, very prone to damage from hail, UV degradation, and turbulent fatigue forces.
- Count of the # of fins damaged per blade.



VORTEX GENERATOR FINS

- Unknown at the moment as to how much VG fins affect turbine production
  - <25% = Minor
  - (25,50)% = Moderate
  - >50% = Major
- Internal metric based off previously observed damage
- VG fins have been repaired once on cooper when a section was dislodged



FILE LOCATIONS

Raw photos are saved to:

Dropbox (OEE)\Photos - Project Specific\0-Blade Inspection \[ProjectName]

Completed blade reports are saved to:

Dropbox (OEE)\Projects - Operating\[ProjectName]\Maintenance & Inspection

BI_YYYYMMDD_S0XX_WTGX

Blade inspection tracker sheet is saved to:

Dropbox (OEE)\Projects - Operating\02 - Administrative\Blade Management

BLADE ASSESSMENT REPORT

BLADE ASSESSMENT FORM

Project	S019 Ball Findlay	Inspector	Jerrod Carney			
Turbine	Z3	Inspection Type	Drone – DJI M210			
Date	2023-12-19	WTG Down Time:	Start:	10:17 AM	End:	10:58 AM

BLADE 1 – BLUE

	Damage				Notes
	None	Minor	Moderate	Major	
Leading Edge			X		Approx. ¼ of LEP completely eroded; ¼ of LEP exhibiting heavy fraying; ½ in passable condition but early signs of wear present. Two small points (~1/8" diam.) of gel coat erosion visible on blade tip.
Trailing Edge	X				Light black markings on trailing edge of no concern.
Vortex Generators			X		50 bent/broken VG fins, 44% of total
Other	X				Large black stain on suction side by tip, approx. center of protected span. Imprint of wing shape suggests old avian impact. Present since last inspection.

Additional Notes: Blade exhibited icing during inspections on root leading edge/pressure side.

BLADE ASSESSMENT REPORT

TURBINE NOTES

Blade OEM: LM Windpower
Blade LEP is original to installation
No prior blade repairs performed, active NCRs, or prior major damage.
Last Inspection: 2023-05-14

ACTION

Blade	Repair				
	None	Monitor	<12 months	<3 months	Shutdown
Blue		X			
Green		X			
Red		X			

Signature: _____

BLADE ASSESSMENT REPORT

BLADE 2: GREEN

RECOMMENDED ACTION – MONITOR

Approx ¾ of LEP exhibiting heavy fraying; first ¼ in passable condition. Start of LEP also peeling. 35 bent/broken VG fins, 31% of total.

SUCTION SURFACE

BLADE ASSESSMENT RUBRIC

	None	Minor	Moderate	Major
Leading Edge	•No visible damage. •Minor cosmetic blemishes. •Minimal wear, tears, bubbling, or ripping on LEP.	•LEP is torn, ripping, or fraying in spans < 1ft. •Erosion to the gel coat or primer underneath is visible. •Any chipping, crushing, or impact damages are visible of diameter < 1in.	•LEP has completely eroded in spans >1ft. •Any fiberglass underneath is exposed. •Any chipping, crushing, or impact damages are visible of diameter > 1in. •Any holes present with a diameter < 1in. •Visible lightning damage.	•LEP has completely eroded in spans >3ft. •Holes in fiberglass are of a diameter > 1in. •Structural balsa wood is visible. •Blade tip split or completely absent. •Leading edge has collapsed, buckled, or caved in on itself.

Dropbox (OEE)\Operations - SOP - Draft\O&M\"Blade Inspection Outline and Process"

BLADE INSPECTION TRACKER SHEET

PROJECT #	S014																				
STATE	OH																				
CITY	Haviland																				
COMPANY	Haviland Drainage Products																				
PROJECT	Haviland Wind																Haviland Wind Expansion 1				
WTG		A							B							C					
BLADES		1	2	3	Report?	Notes?		1	2	3	Report?	Notes?		Yell	Gre	Ylw	Report?	Notes?			
	2016-11-22	X	X	X	SEE LEFT	Fairwinds	2016-11-22	X	X	X	SEE LEFT	Fairwinds	2016-11-22	X	X	X	SEE LEFT	Fairwinds			
X = INSPECTED	2016-12-06						2017-05-19	X	X	X			2017-01-21				LINK	RP			
	2017-05-19	X	X	X			2018-04-20	X	X	X			2017-03-09	X	X	X					
	2017-10-12						2020-01-22	X	X	X	LINK		2017-05-19								
	2018-04-20	X	X	X			2020-09-14	X	X	X	LINK		2017-06-21	X	X	X	LINK				
	2019-06-28	X	X	X	LINK		2021-08-23	X	X	X			2017-10-20								
	2020-09-14	X	X	X	LINK		2022-08-31	X	X	X	LINK		2018-04-20								
	2021-08-23	X	X	X			2023-02-01	X	X	X	LINK		2020-01-23	X	X	X	LINK				
	2022-08-25	X	X	X	LINK		2023-11-15	X	X				2020-09-14	X	X	X	LINK				
	2023-02-01	X	X	X	LINK								2021-08-24	X	X	X					
	2023-11-15	X	X	X	LINK								2022-09-07	X	X	X	LINK				
													2023-11-15	X	X	X	LINK				

BLADE INSPECTION TRACKER SHEET

WP GV	W1-B	LM	Good condition
	W1-G	LM	40 out of 114 VG fins have been damaged, otherwise good condition
	W1-R	LM	Good condition
	W2-B	LM	<1" hole in blade tip, minor LEP fraying
	W2-G	LM	LEP peeling, no gel coat damage, 46 out of 114 VG fins damaged
	W2-R	LM	Good condition
	W3-B	LM	Good condition
	W3-G	LM	Good condition
	W3-R	LM	Good condition
LAF. PAUL	L1-B	LM	Good condition
	L1-G	LM	Good condition
	L1-R	LM	LEP peeling, minor scrape on pressure side to gel coat
	L2-B	LM	Good condition
	L2-G	LM	Good condition
	L2-R	LM	Good condition
	L3-B	LM	Good condition
	L3-G	LM	Good condition
	L3-R	LM	LEP peeling, no gel coat damage

REPORT REVIEW PROCESS

- Once inspected and a report written, approved by either:
  - Head of Construction (CB)
  - Fleet Field Manager (LN)
  - Project Engineer (EJ, DB)

- Reports are mostly for internal reference, but oftentimes can be sent to customers
  - Mostly Cooper and Haviland as these are CAPEX projects.

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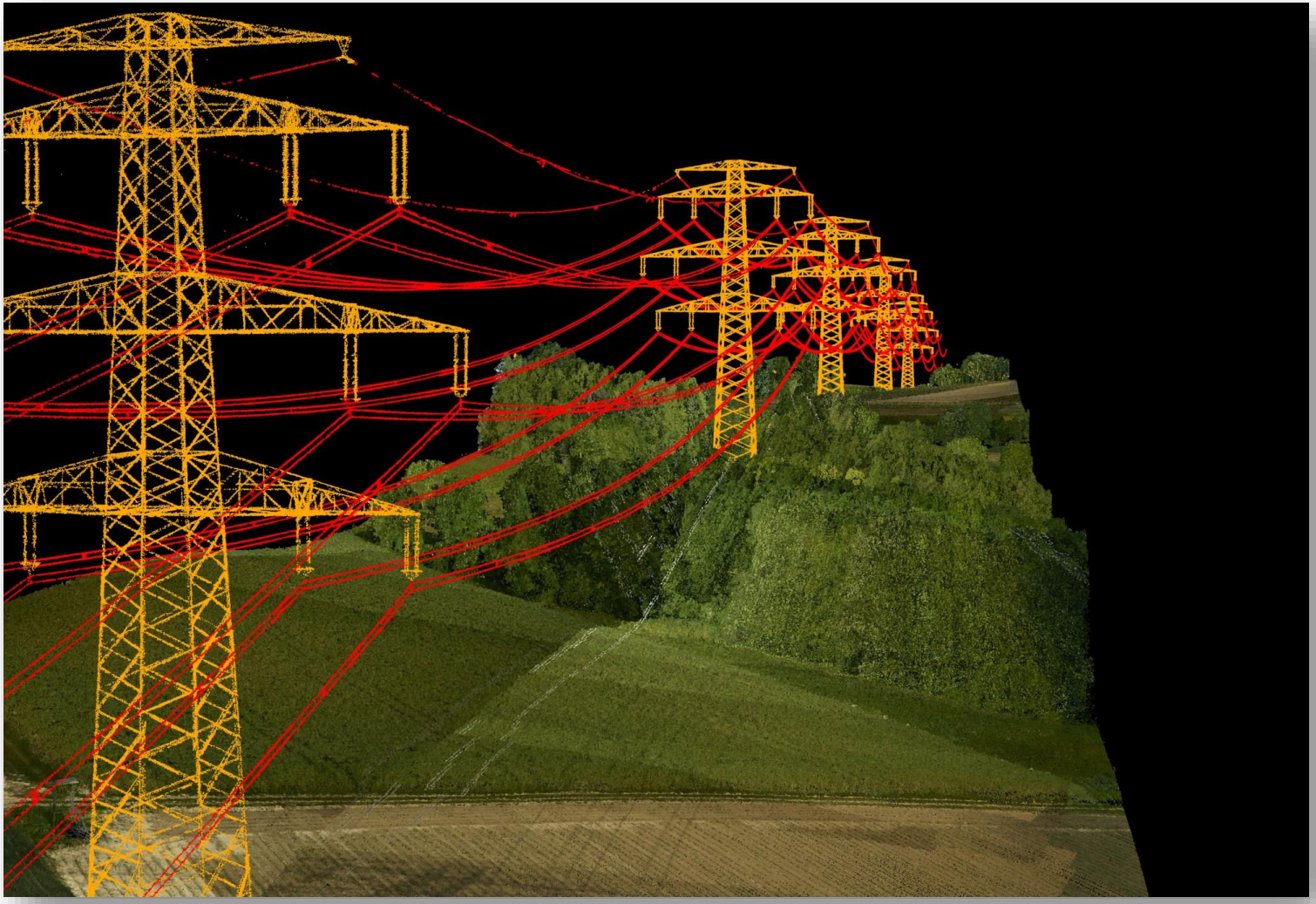
EMERGING TECHNOLOGIES IN BLADE INSPECTIONS

DRONE LIDAR CAPABILITIES



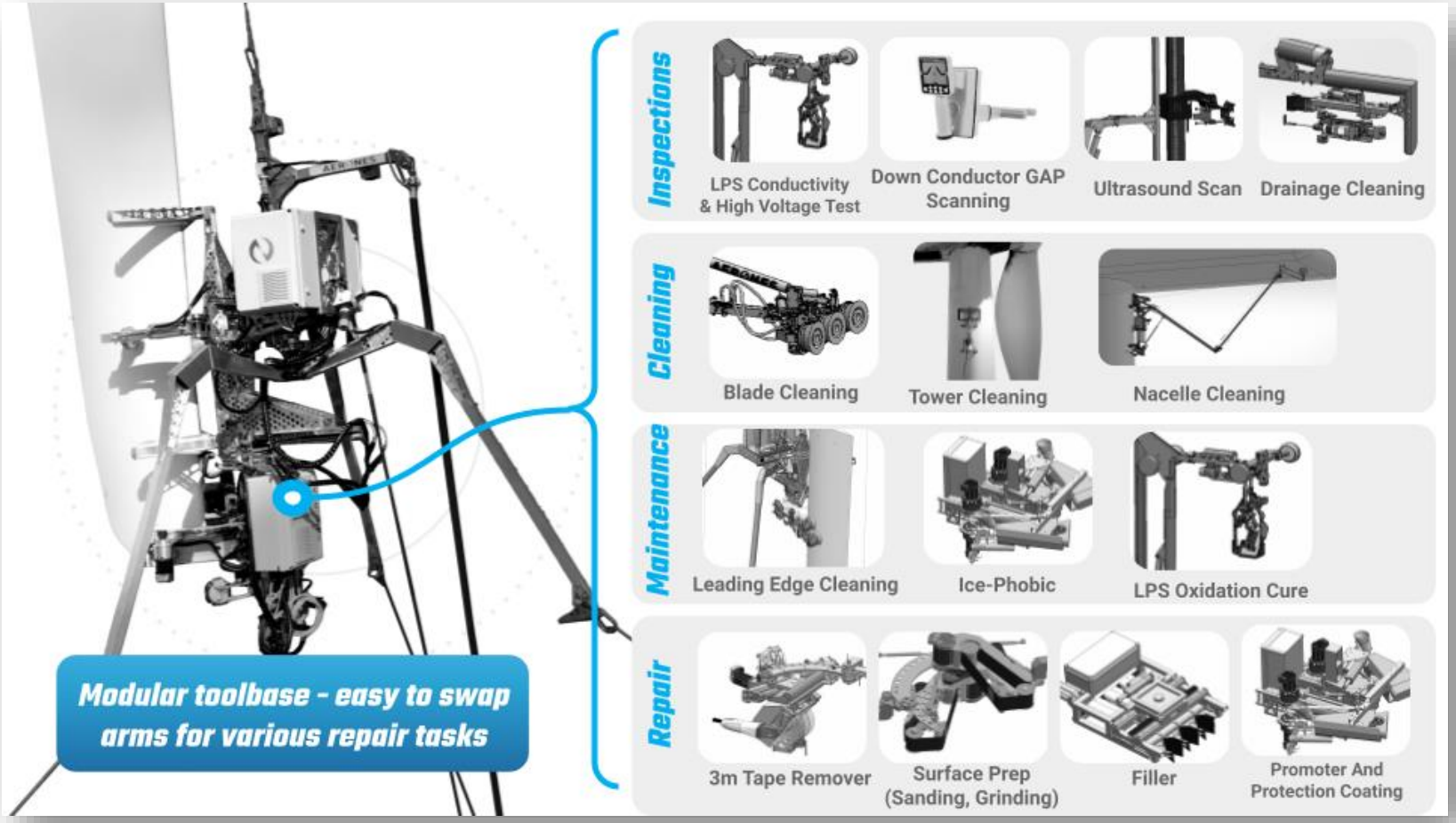
DRONE LIDAR CAPABILITIES

- Drones can now be equipped with LIDAR scanners
- Capable of gathering 3D point-maps of objects in real time
- Use case include mapping major damages to blades in case of gouges/holes, or scouting for very small holes unseen by observer during inspection process

AERONES

- https://aerones.com/
- Company that provides ground-based robotic blade inspection, washing, scanning, coating, LEP application, and repairs

AERONES


Modular toolbase - easy to swap arms for various repair tasks
Inspections
LPS Conductivity & High Voltage Test
Down Conductor GAP Scanning
Ultrasound Scan
Drainage Cleaning
Cleaning
Blade Cleaning
Tower Cleaning
Nacelle Cleaning
Maintenance
Leading Edge Cleaning
Ice-Phobic
LPS Oxidation Cure
Repair
3m Tape Remover
Surface Prep (Sanding, Grinding)
Filler
Promoter And Protection Coating

PING MONITORS

- Formerly used by OE
- Data gathered from sonic monitoring system was unusable by O&M
- External microphone monitoring systems are a developing field
  - While flawed now, neural network audio processing technology may allow for more advanced early warnings

PING MONITOR

- Magnetically mounted microphone array at base of turbine
- Solar powered
- Received ambient noise made by turbine blade air displacement
- Returned a blade condition value from 1 to 5 with 1 being in good condition and 5 being poor condition

BLADEBUG AND OTHERS

- https://bladebug.co.uk/
- Robotic suction cup blade crawlers to utilize up close ultrasonic structural examination and other nondestructive testing methods.
- Rope access teams are still required

CONFINED SPACE DRONES AND INTERNAL BLADE INSPECTIONS

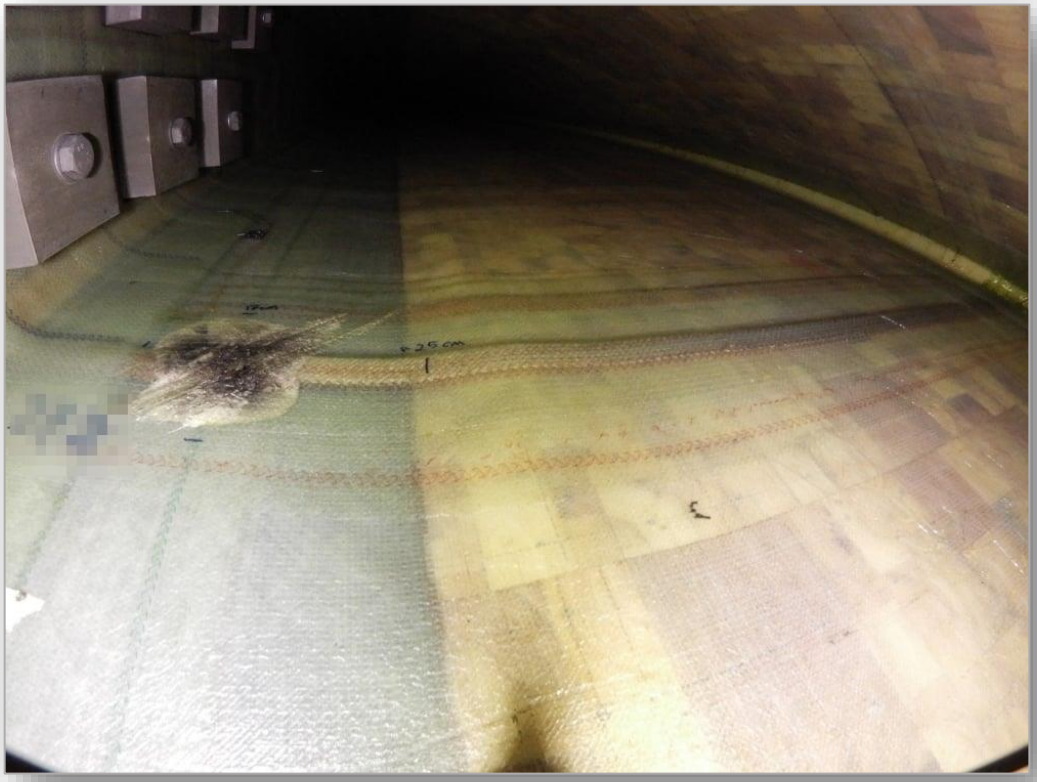
- Development in confined space, collision-tolerant "cage drones" allows for internal views and inspections of blades.
- Otherwise-unseen damage to stringers and spars that could pose structural threats to blade could be detected early

INTERNAL BLADE INSPECTIONS

- Crawler-type drones can be used in situations where blades can be held horizontally are also options for internal inspections

LPS CABLES

- Damage to lightning protection system cables could pose critical fire and structural hazard to blade and turbine integrity



OVERVIEW

- Flight-capable drones and robotics provide unparalleled ease of access and minimized downtimes

- Robotic tool arms and blade crawlers can be used for actual repair work as well as non-destructive structural testing, but require rope access teams and skilled operators

- Non-destructive tests via ultrasonic scans or electrical capacitance provide data on invisible damage to the blade composites

12385 Township Rd 215 | PO Box 894
Findlay, Ohio 45840
877-298-5853 | www.oneenergy.com
[Name]
[Date]