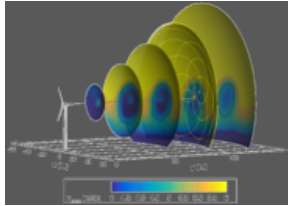




Blade Inspection Methods



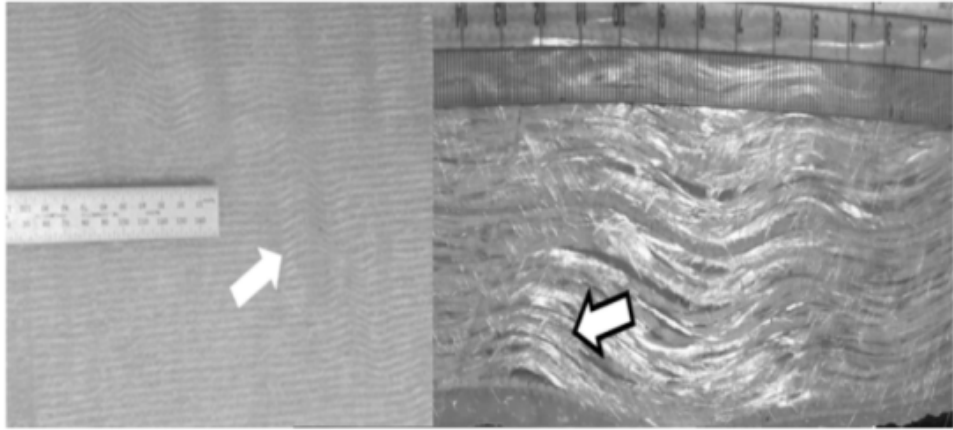
PRESENTED BY

Josh Paquette

ESIG 2022 Fall O&M Users Group Meeting,



Defects and Damage



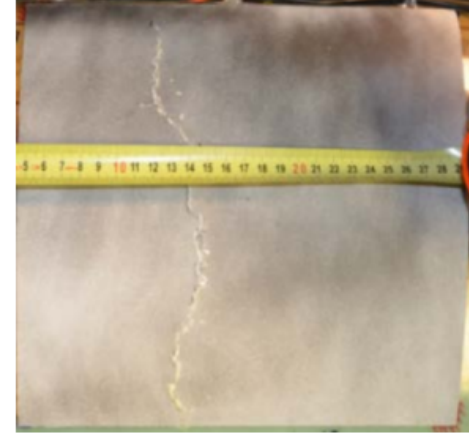
(In-Plane) (Out-of-Plane)
Fiber Waviness



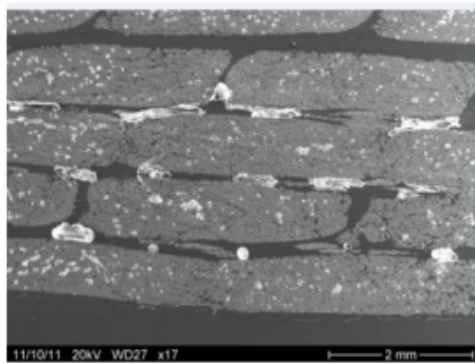
Delamination



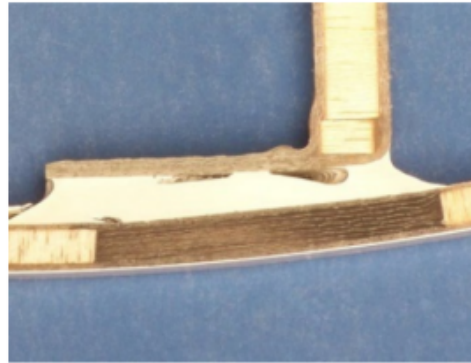
Disbond



Crack



Porosity



Voids



Lightning



Erosion



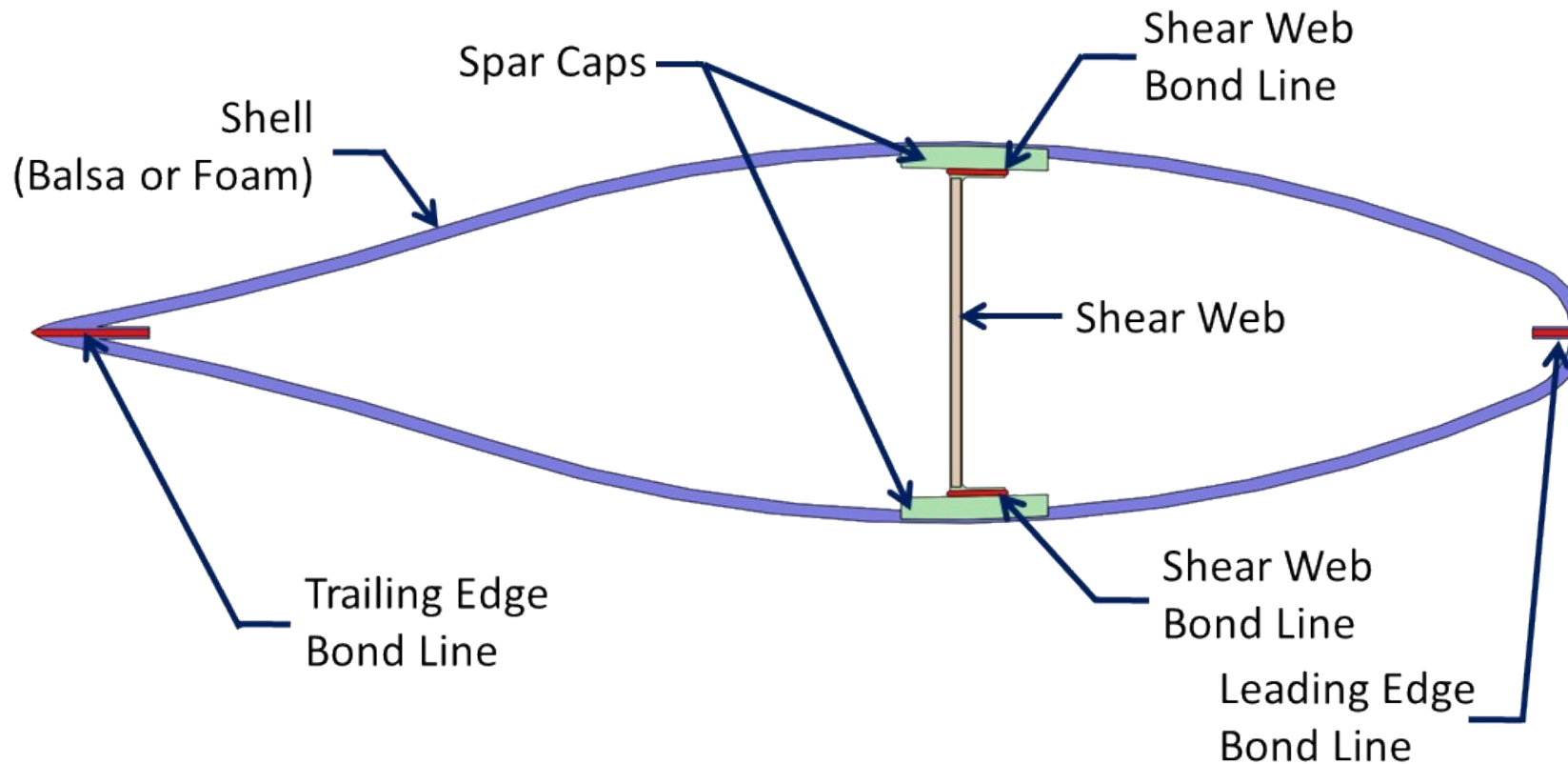
Inspection Areas

Sparcaps – Thick, unidirectional laminates, glass or carbon

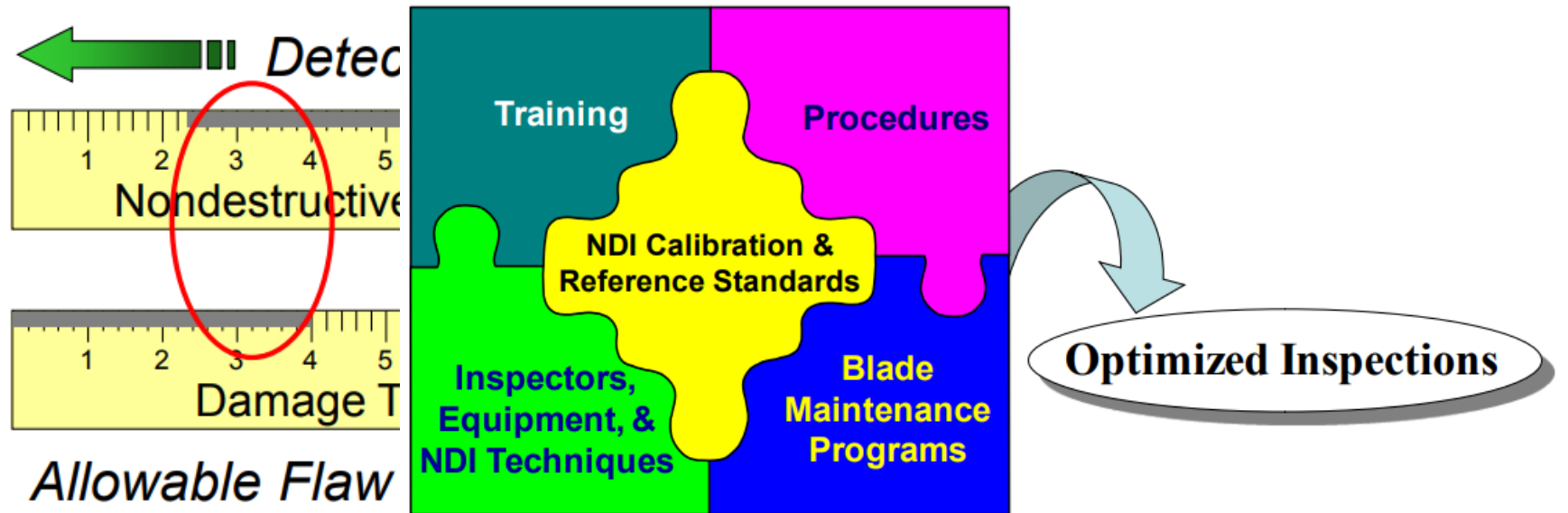
Shell – Multi-directional laminates with core material in between

Bondlines – Shear webs and trailing edges, underneath laminate

Roots – Very thick, multi-piece laminates



Inspection Goals and Process



Visual

Simple, cheap, and effective at finding larger and surface-visible damage

Newer imaging methods and AI processing allow for faster and better inspection results



Drone



Rope Access





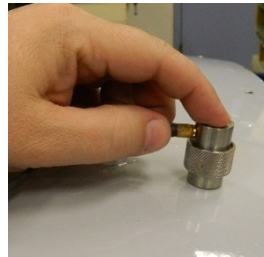
Pulse-Echo Ultrasonics (UT)

1 or 2 transducers that transmit and/or receive high frequency sound waves

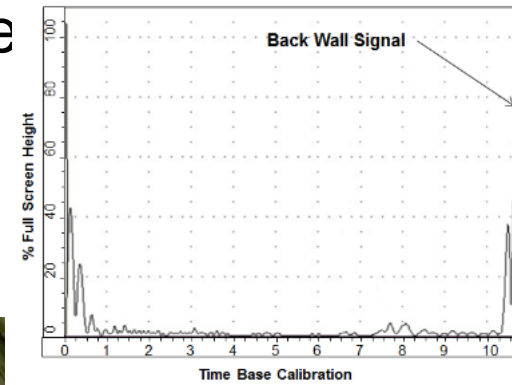
Detects delaminations, most disbonds, voids, and even porosity

Requires surface couplant (water/gel), does not work in hollow regions and is rather slow

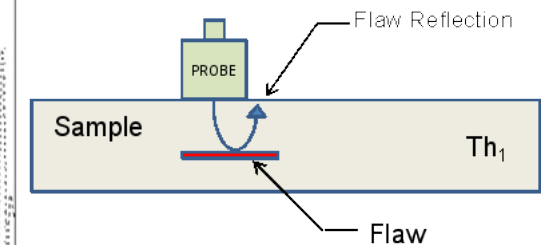
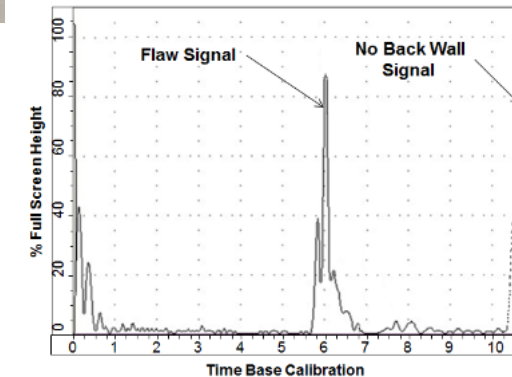
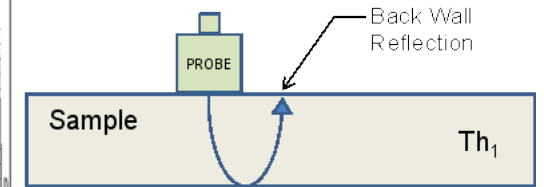
A-Scan,
Pulse Echo UT - No Flaws



A-Scan,
Pulse Echo UT - Shift in Backwall Signal Due to the Presence of a Flaw



hollow/panel



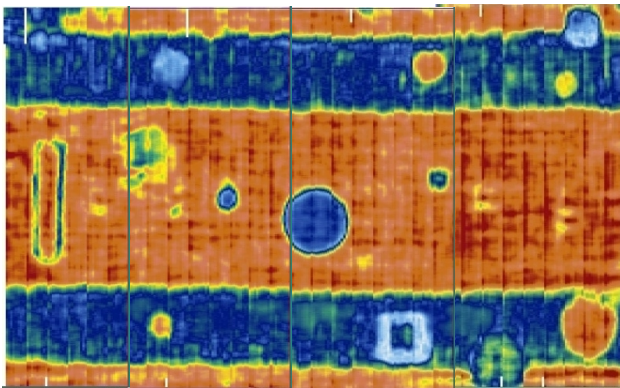
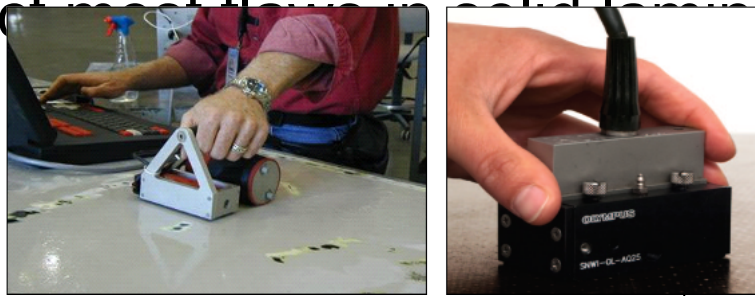


Phased Array Ultrasonic

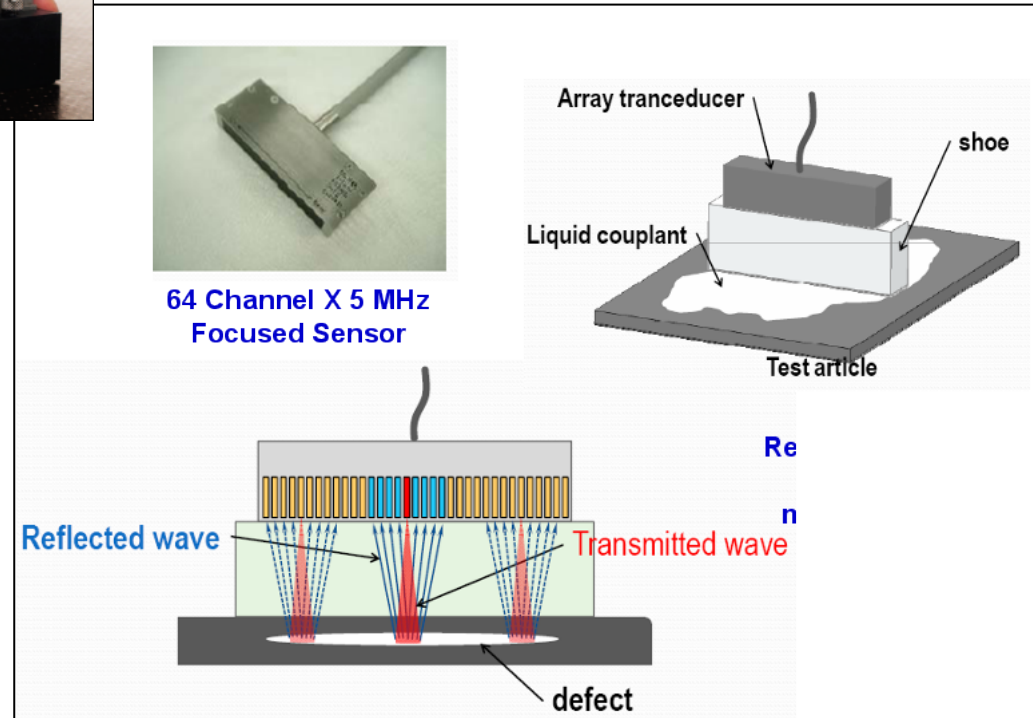
Same pulse-echo UT technology but with multiple transmitters and receivers

Rapid coverage with high definition two-dimensional images, including cross-sections

Able to detect most flaws in solid laminates, including fiber waves



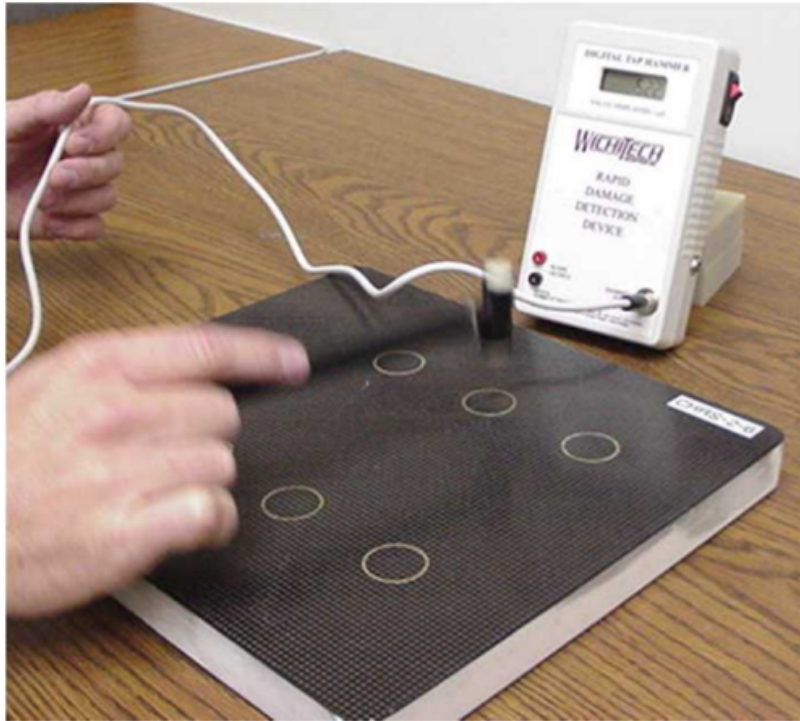
C-Scan Image with Two Bond Lines (dark blue)



Mechanical Impedance

Measures frequency response to impulse (tap)

Detects flaws in shells and some delaminations in solid composites



Tap Tester

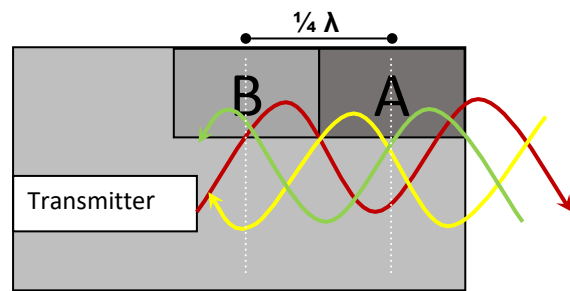
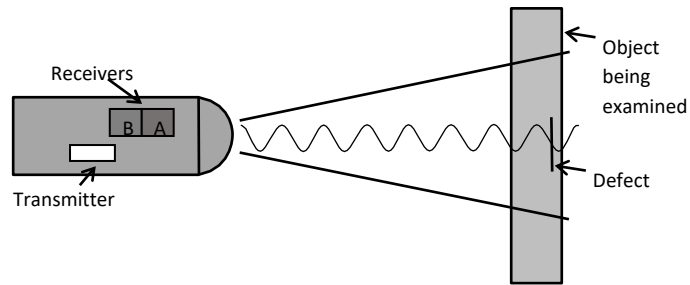


Mechanical Impedance Probe

Microwave

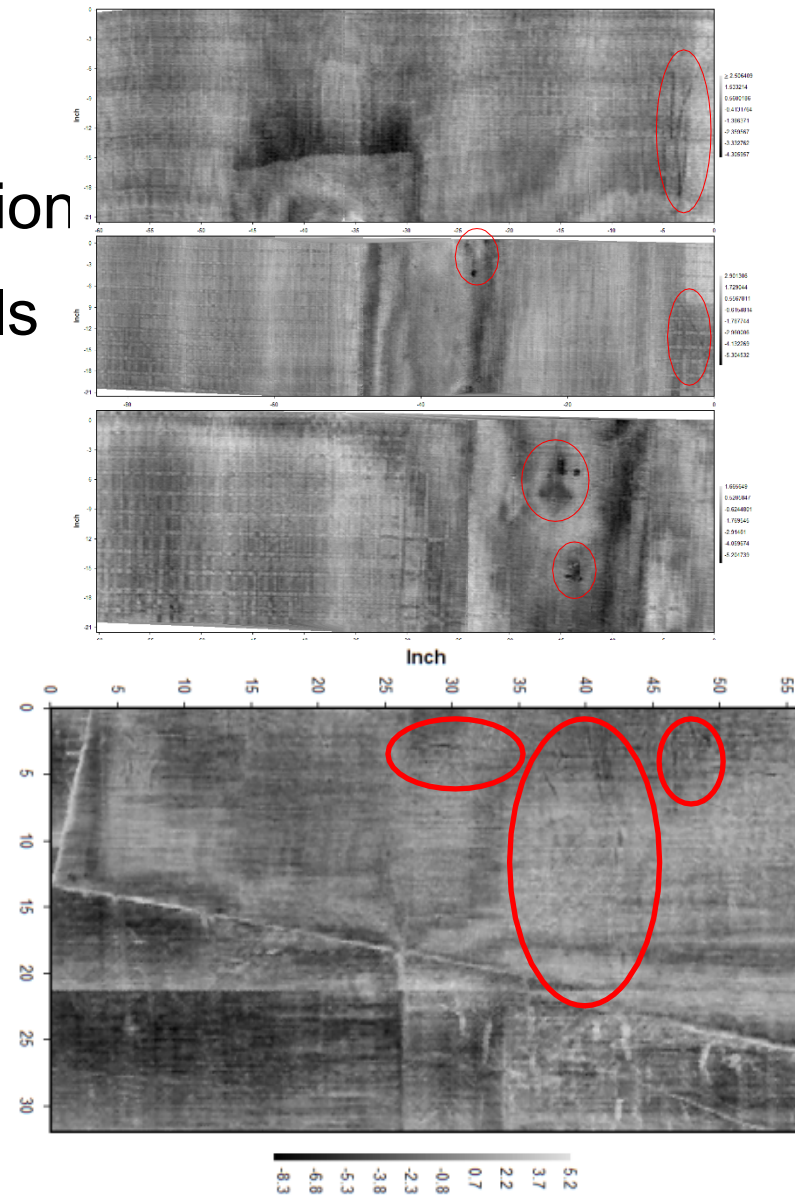
Emits and detects microwave radiation reflection

Detects most flaws in non-conductive materials



Microwave Inspection

Figure and images courtesy of Wetzel Wind



Microwave Inspection Images Showing Waves and other Defects



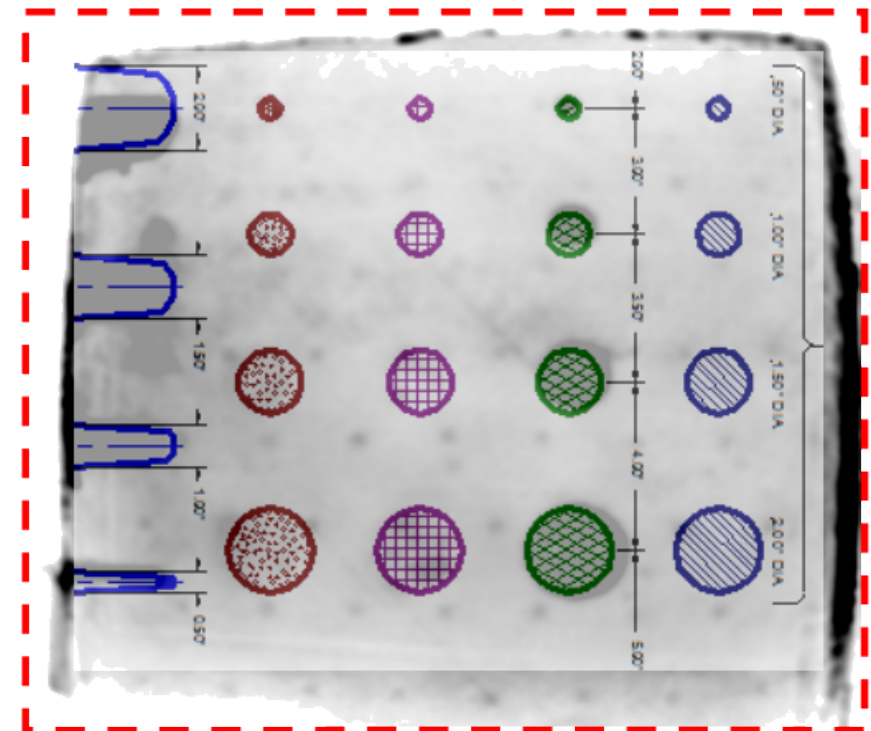
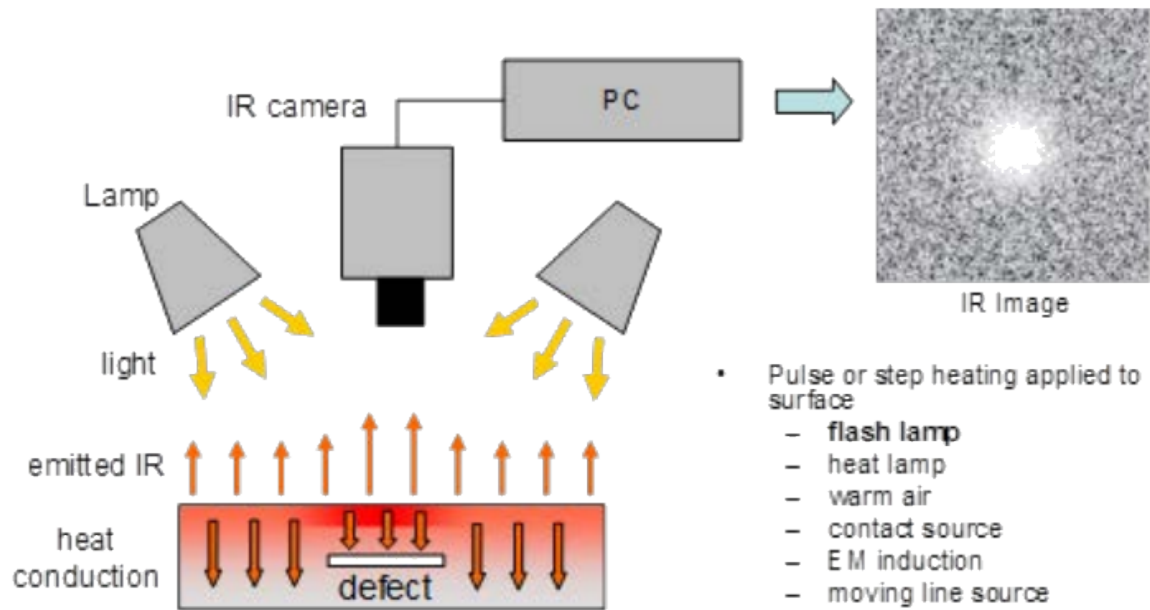


Thermography

Object is actively or passively heated

IR image is taken before/after, showing differential temperatures at the surface

Detects flaws that interrupt heat transfer or results from load re-direction



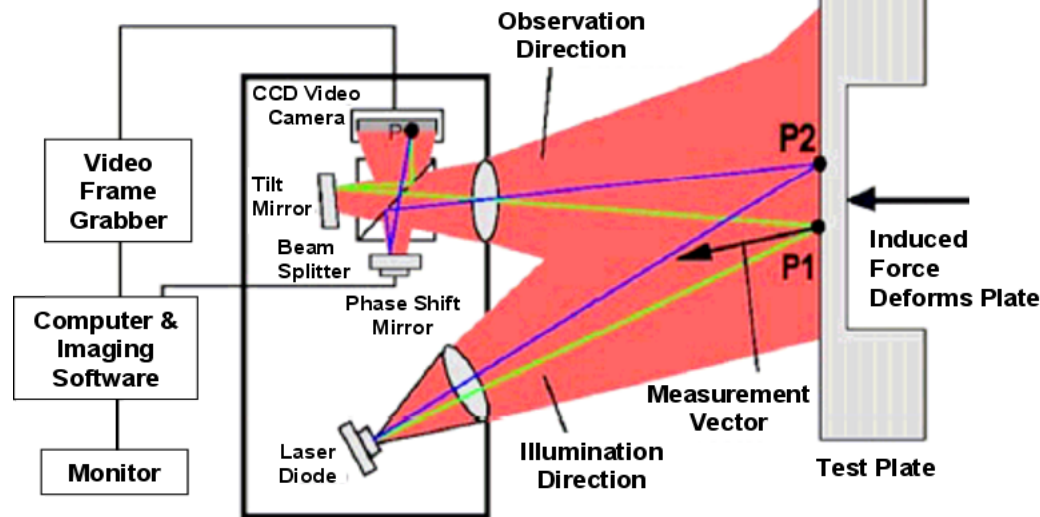
Shearography

Object is illuminated with laser light

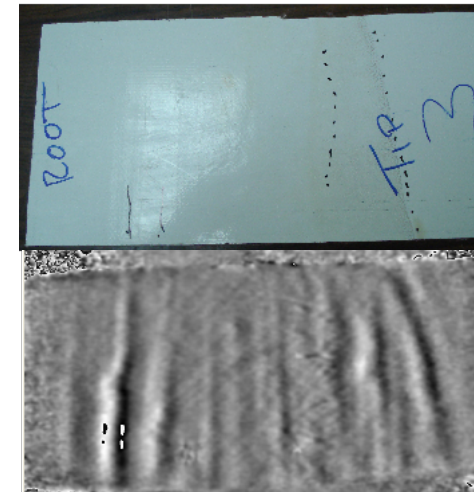
Deformation of surface is created by vacuum, thermal, vibration or mechanical load which induces some deformation of the outer surface.

Comparison of images captured before and after loading

Can detect wide variety of flaws that produce varying strain fields



Basic Principal of Shearography



Test Specimen (above) and Q-810 Shearography Image of Wrinkles in a Composite Laminate



Method	Strengths	Weaknesses	Areas
Pulse Echo UT	Simple, detects most flaws, depth of penetration	Speed, Shells, interpretation of results, contact method	Roots, Spars, Bondlines
Phased Array UT	Hi-res images, detects most flaws, faster	Shells, contact method	Roots, Spars, Bondlines
Mechanical Impedance	Great for inspecting shells	Depth of penetration, contact method	Shells
Microwave	Detects most flaws, non-contact	Doesn't work with conductive materials (carbon)	Roots, Spars, Bondlines, Shells
Thermography	Can detect many types of flaws, non-contact	Interpretation of results, depth of penetration	Spars, Bondlines, Shells
Shearography	Good at detecting waves and most other flaws	Depth of penetration, mostly contact method	Spars, Shells

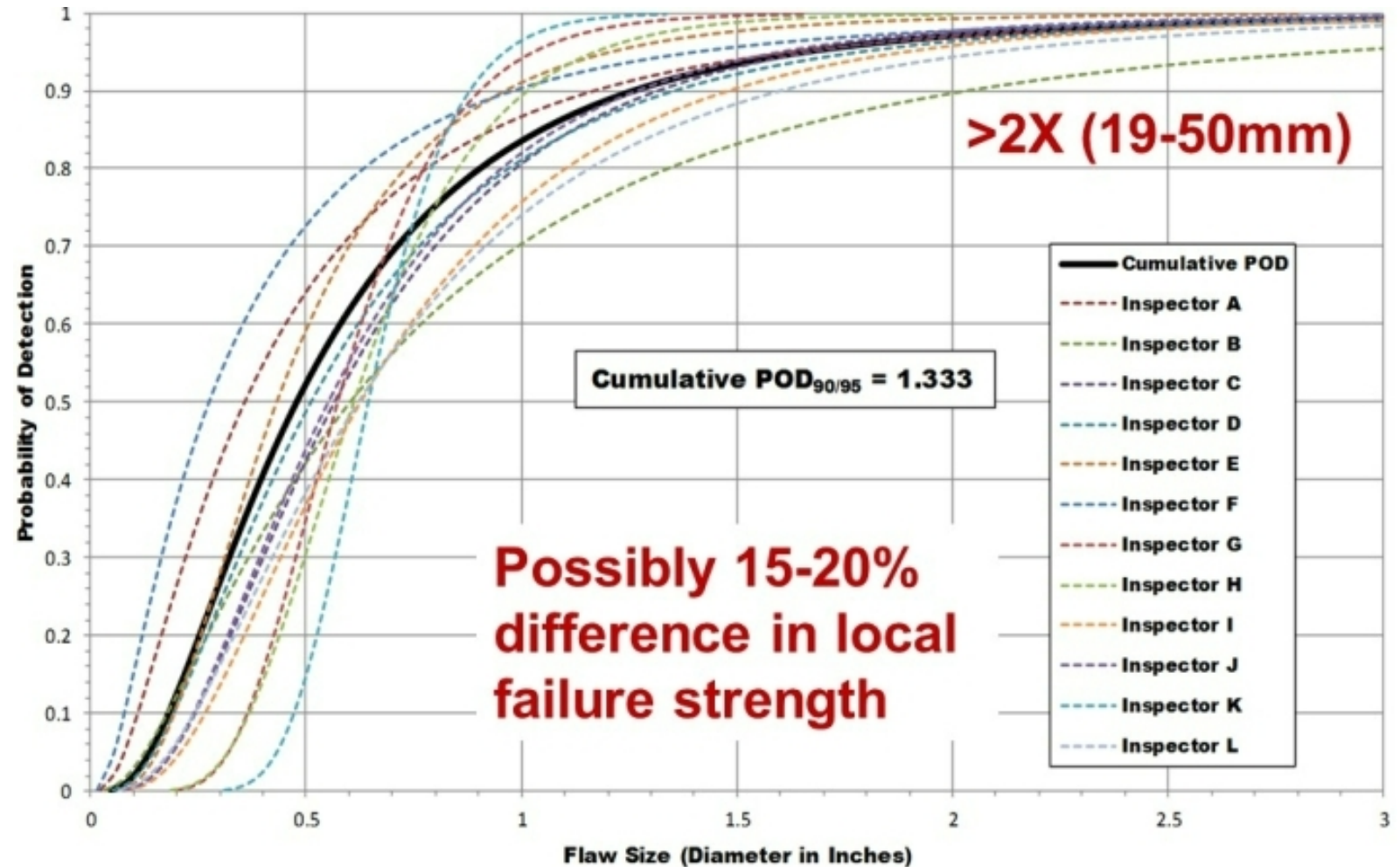
Inspector Training



Inspector training is not standardized in the wind industry to the same level as aerospace

and

Wind composites are often more difficult to inspect due to size and quality



Deployment Technologies



Currently aerial platforms

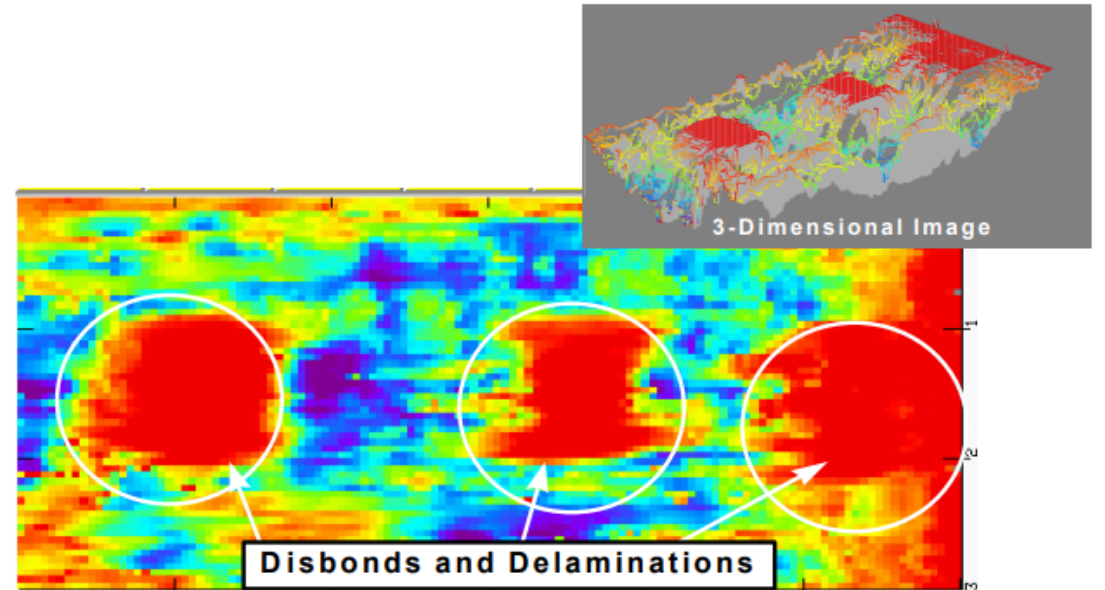
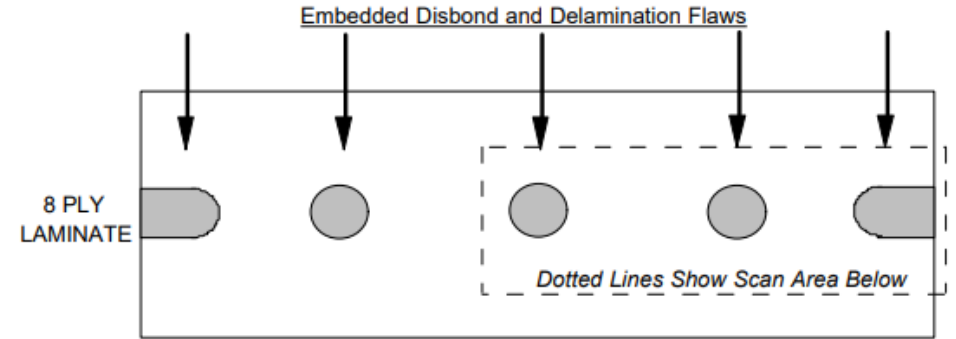
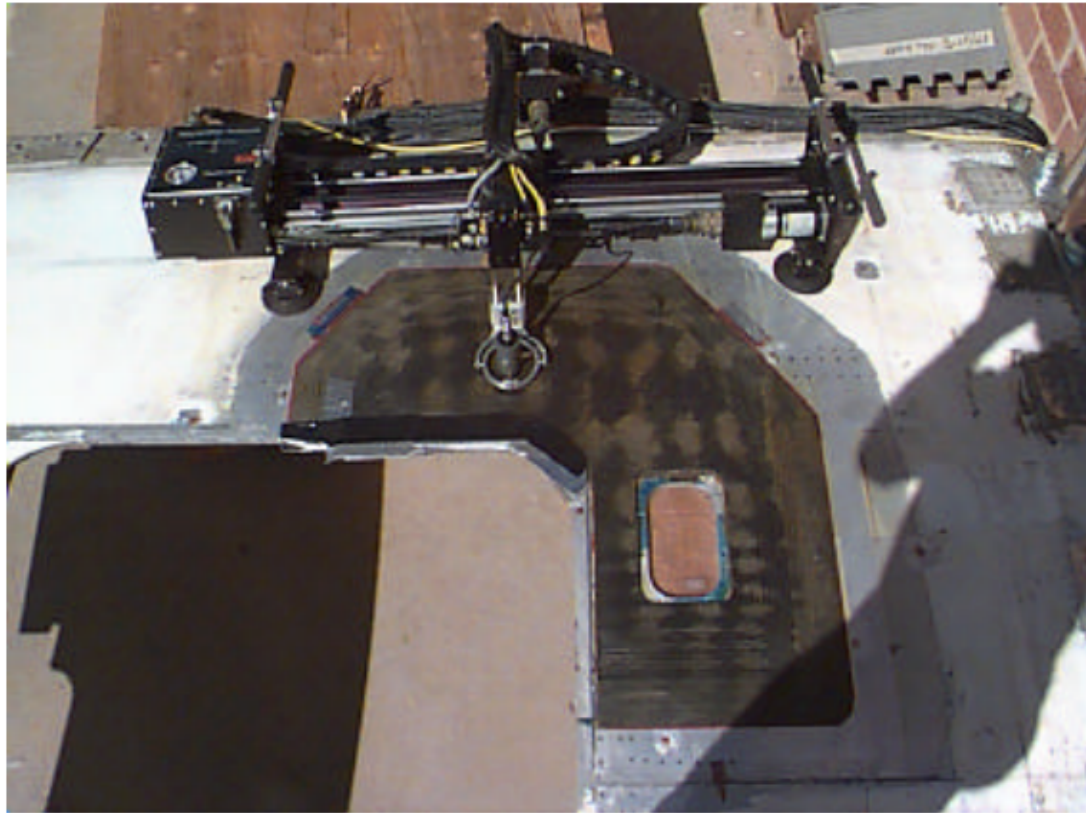
Multiple projects developing UAV and crawler-based systems



Post Repair Inspections

Standard in aviation

Improve repair reliability

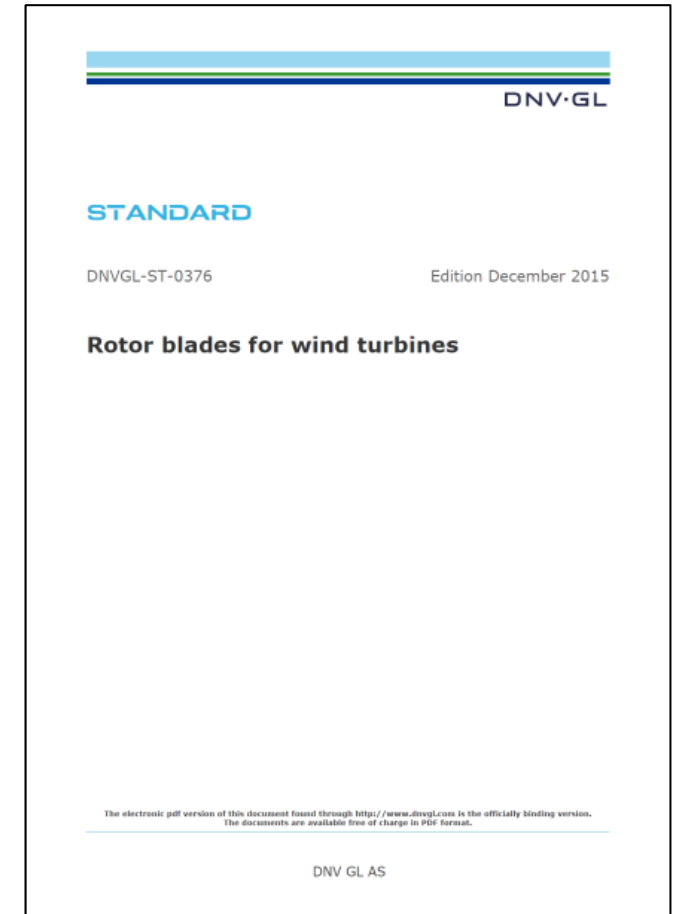
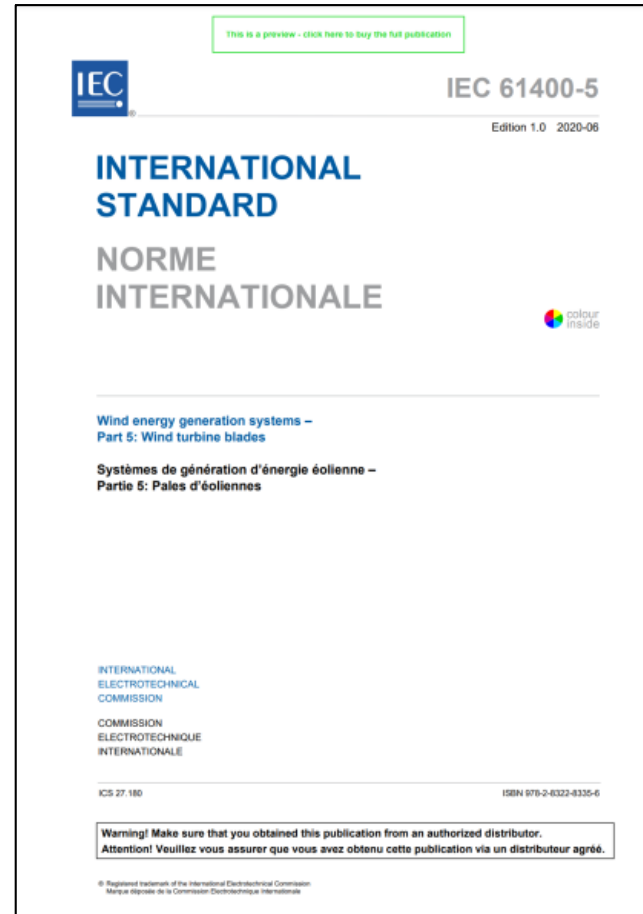


Standards

Standards have some language referencing inspection

Future editions could have more requirements to define inspection intervals and types

Inspection of repairs





Thank you



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