SAND2018-6482PE

Structural Health Monitoring and Operational Modifications for Wind Blades

PRESENTED BY

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Bozeman, MT

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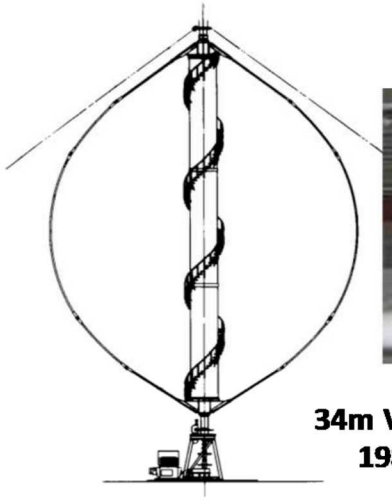
Sandia Wind Program History

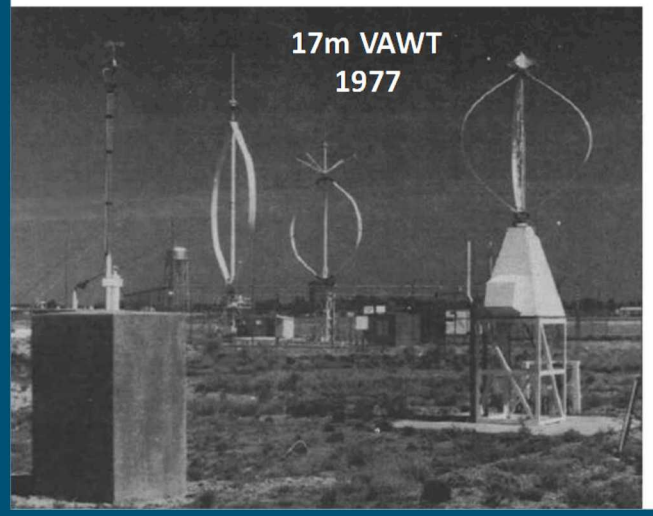
Wind Program Established 1975



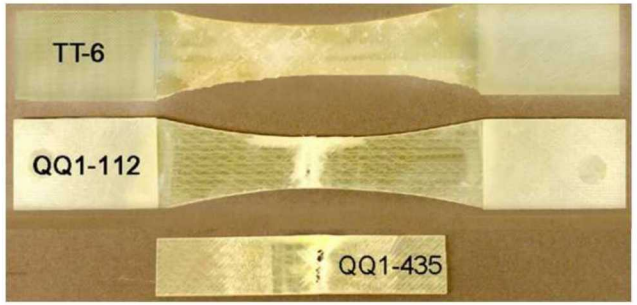
34m VAWT 1984

HAWT Blade Program 1994

SWiFT Facility 2013



Composite Materials Database 1988



Advanced Manufacturing Initiative 2008

Wind Structural Health Monitoring

Structural Health Monitoring is a mature and widely used technology for rotating metallic machinery, but

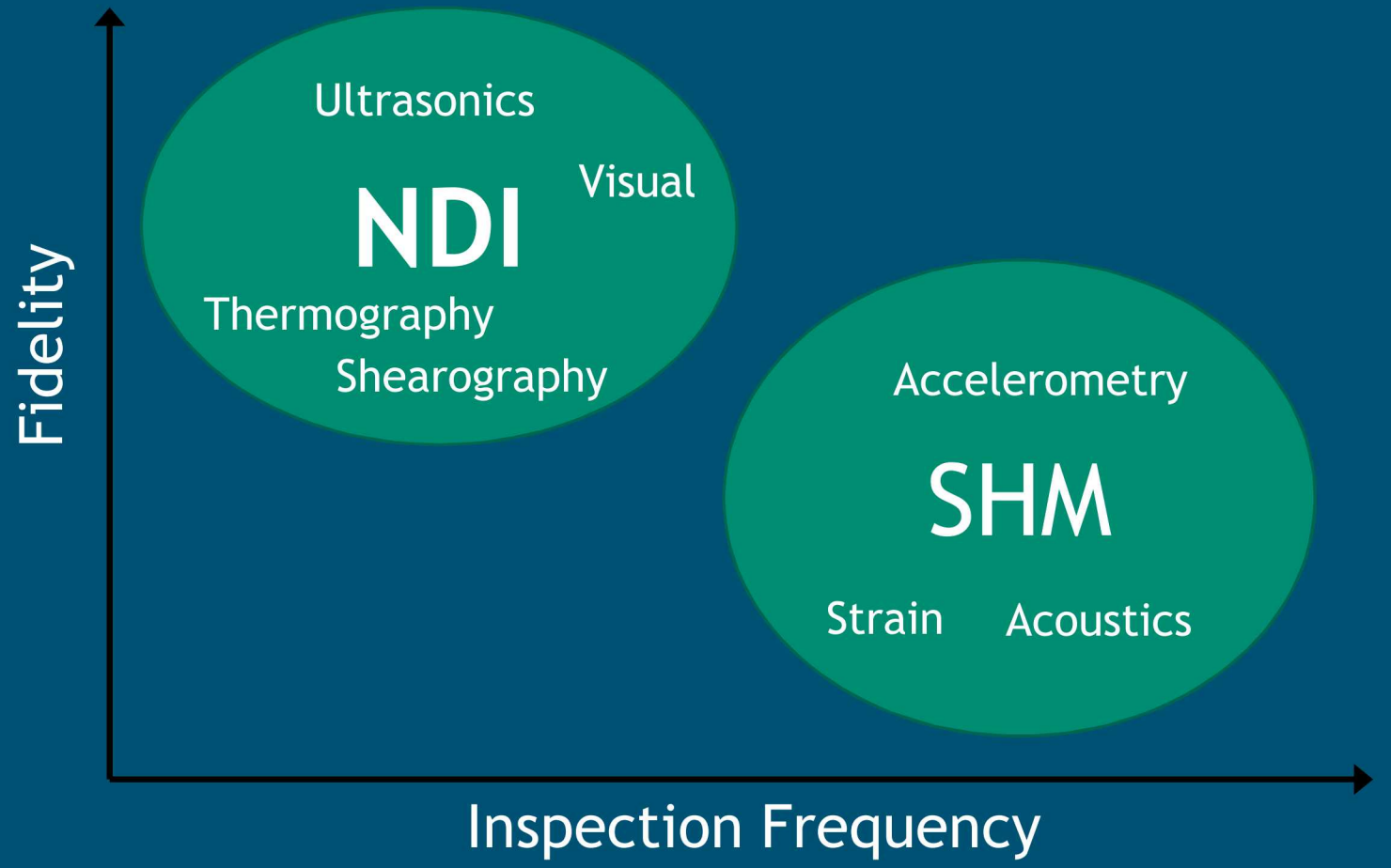
Modern wind blades have little to no sensing specifically for blades

- Some root strain sensing for control purposes
- Tower top accelerometers for control and safety
- Some vibration measurements
- Some acoustic measurements

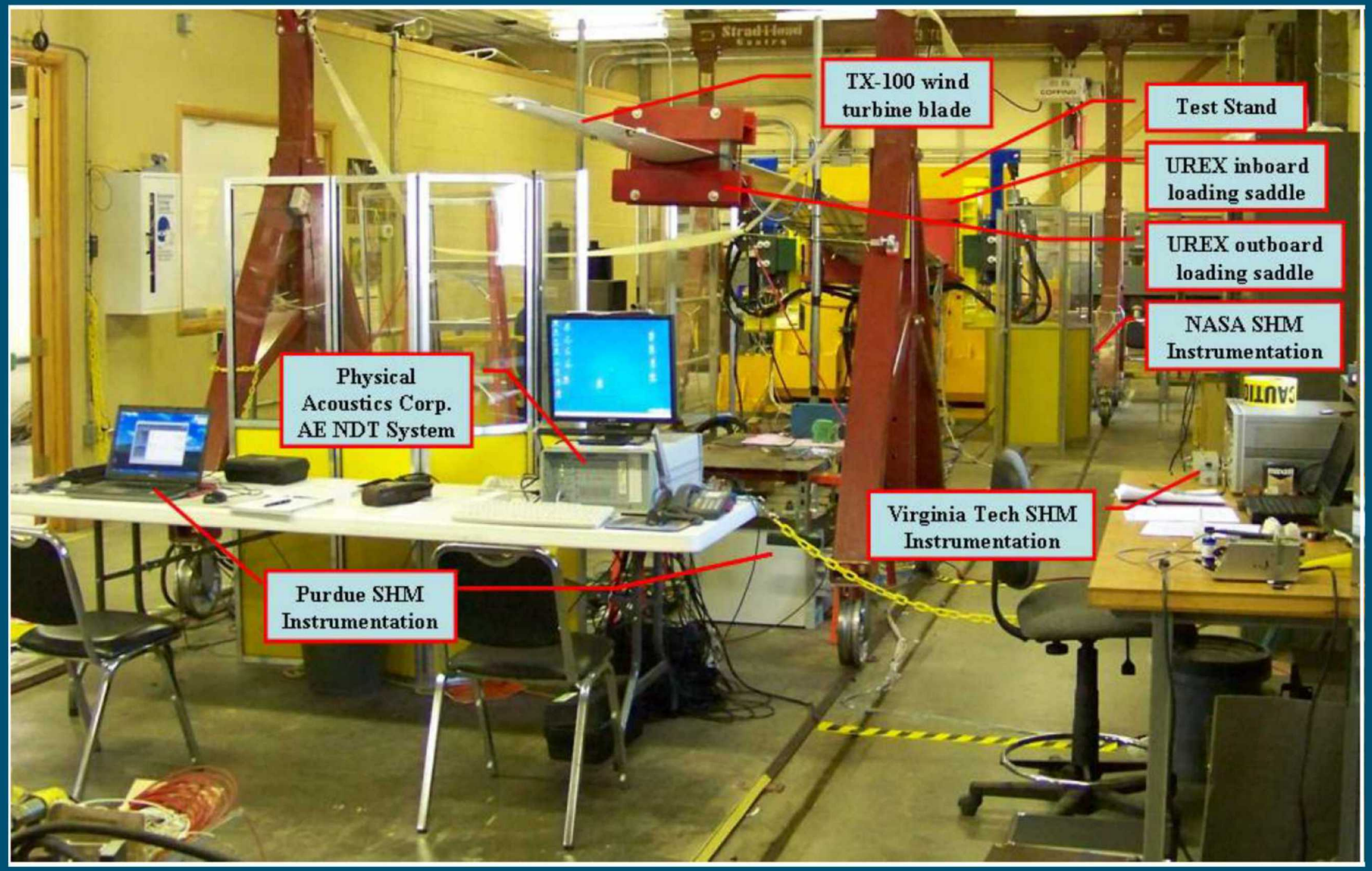
Damage is local and blades are attenuative

Every sensor put on a blade is something that has to be maintained

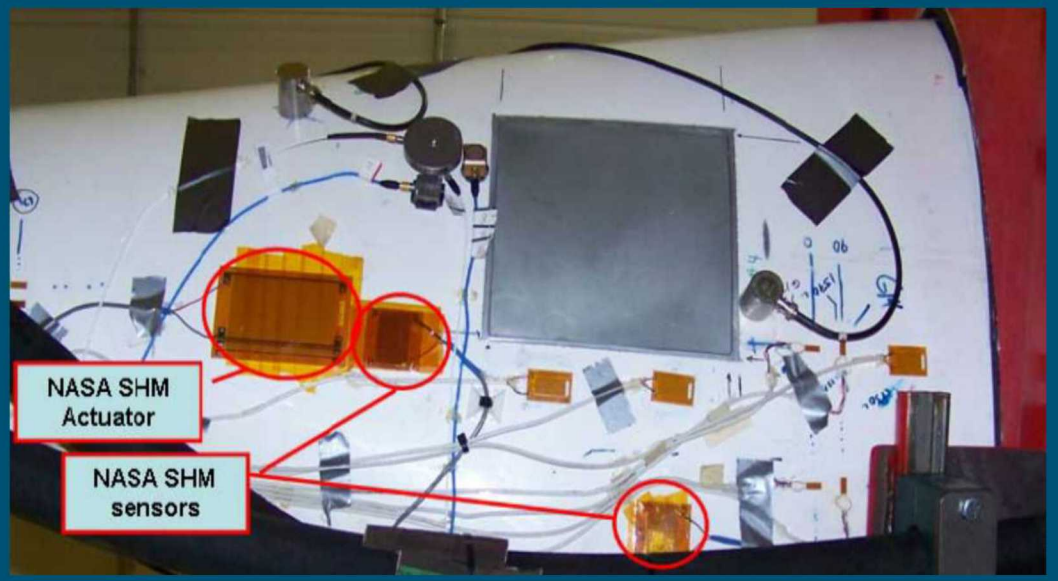
Continuum of Inspection

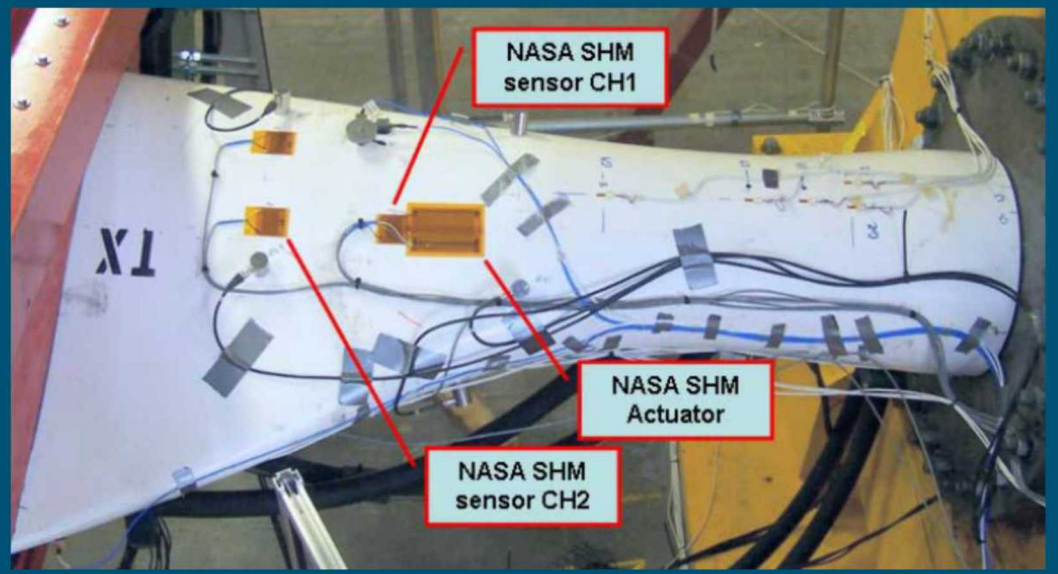


SHM Experimental Blade

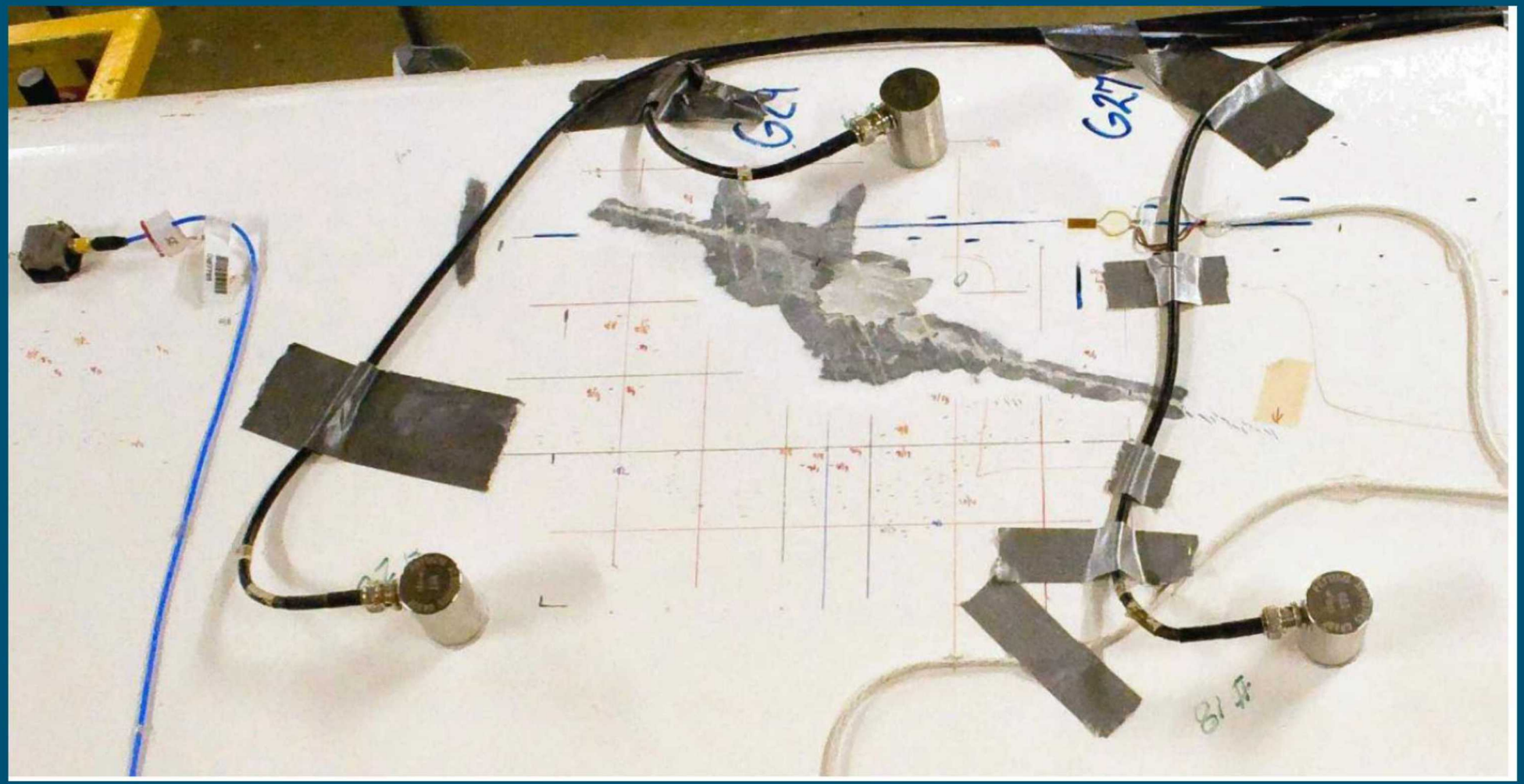


Massively Instrumented

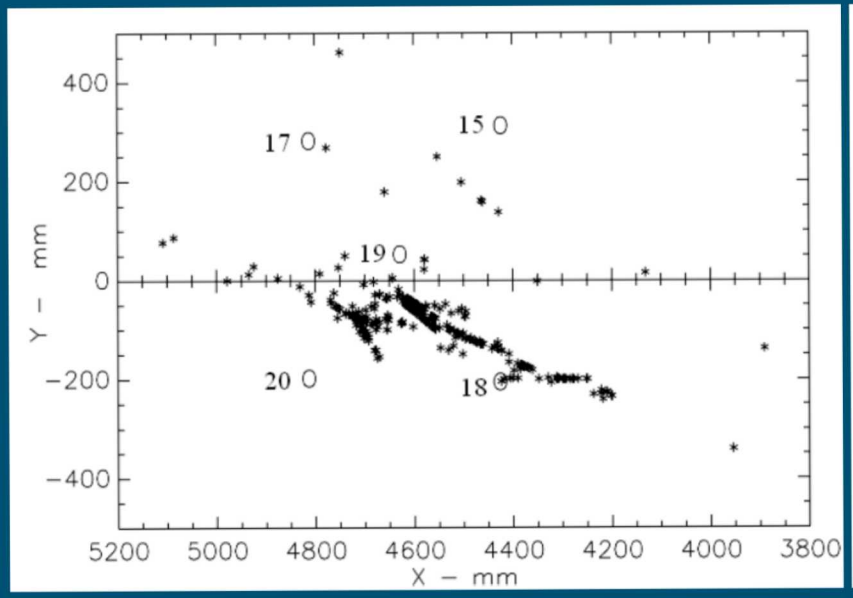


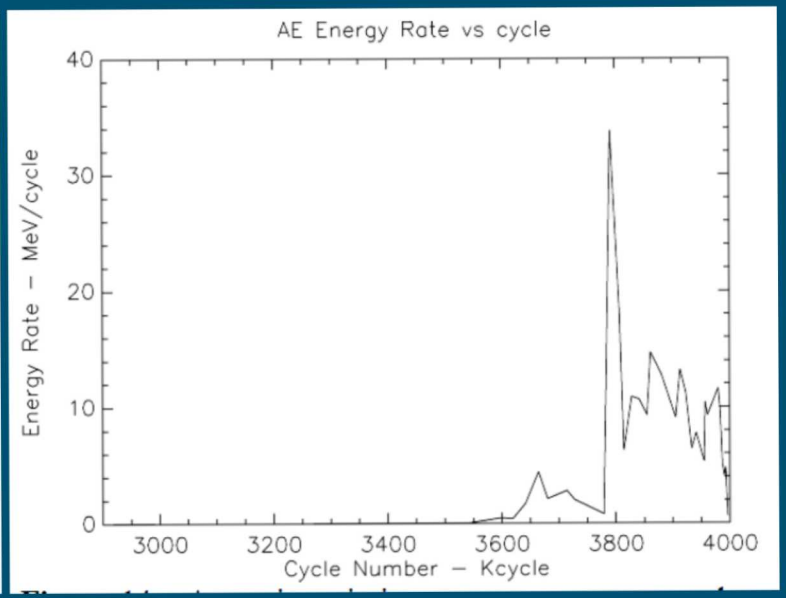


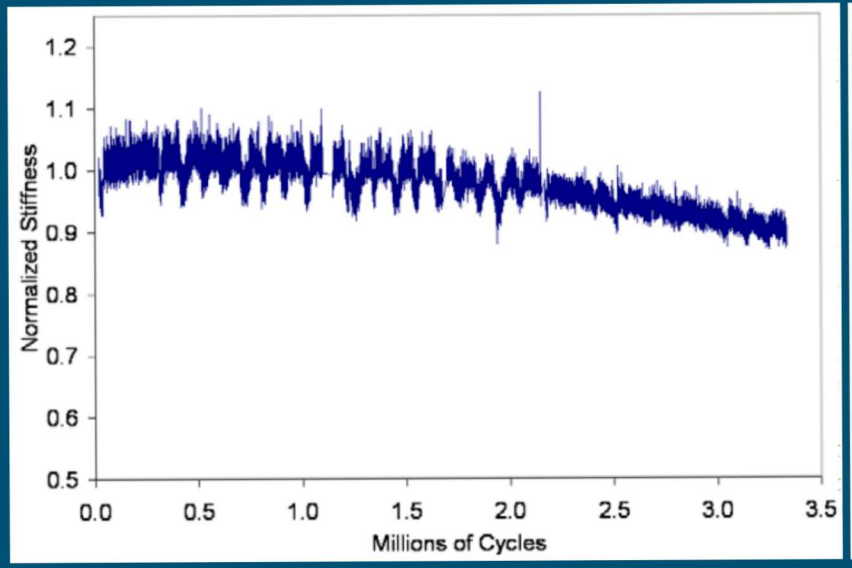
Nice Extensive Damage

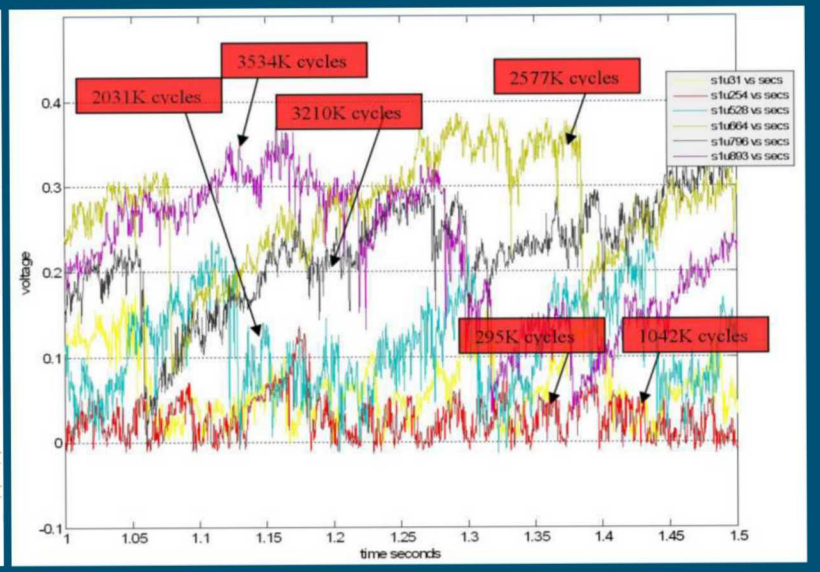


Results


17 0
15 0
19 0
20 0
18
Y – mm
X – mm


AE Energy Rate vs cycle
Energy Rate – MeV/cycle
Cycle Number – Kcycle

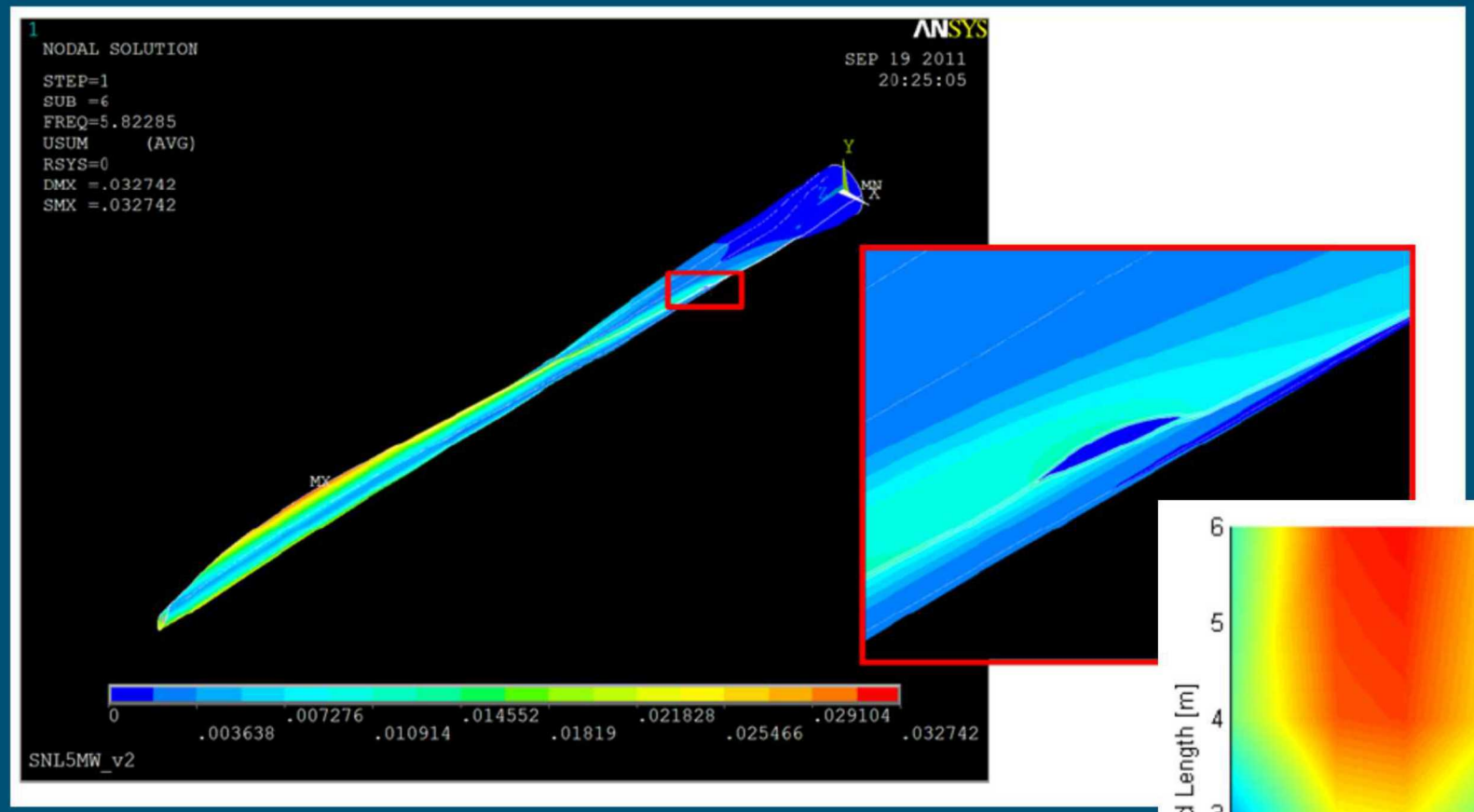

Normalized Stiffness
Millions of Cycles

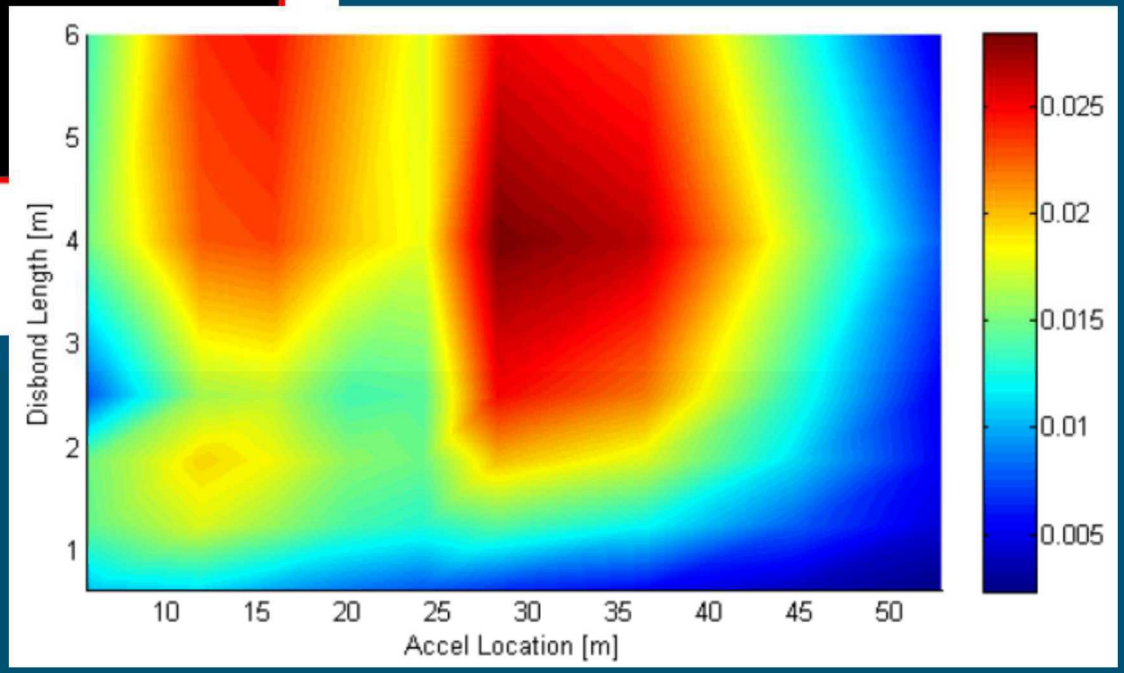

3534K cycles
2031K cycles
3210K cycles
2577K cycles
295K cycles
1042K cycles
voltage
time seconds

Summary

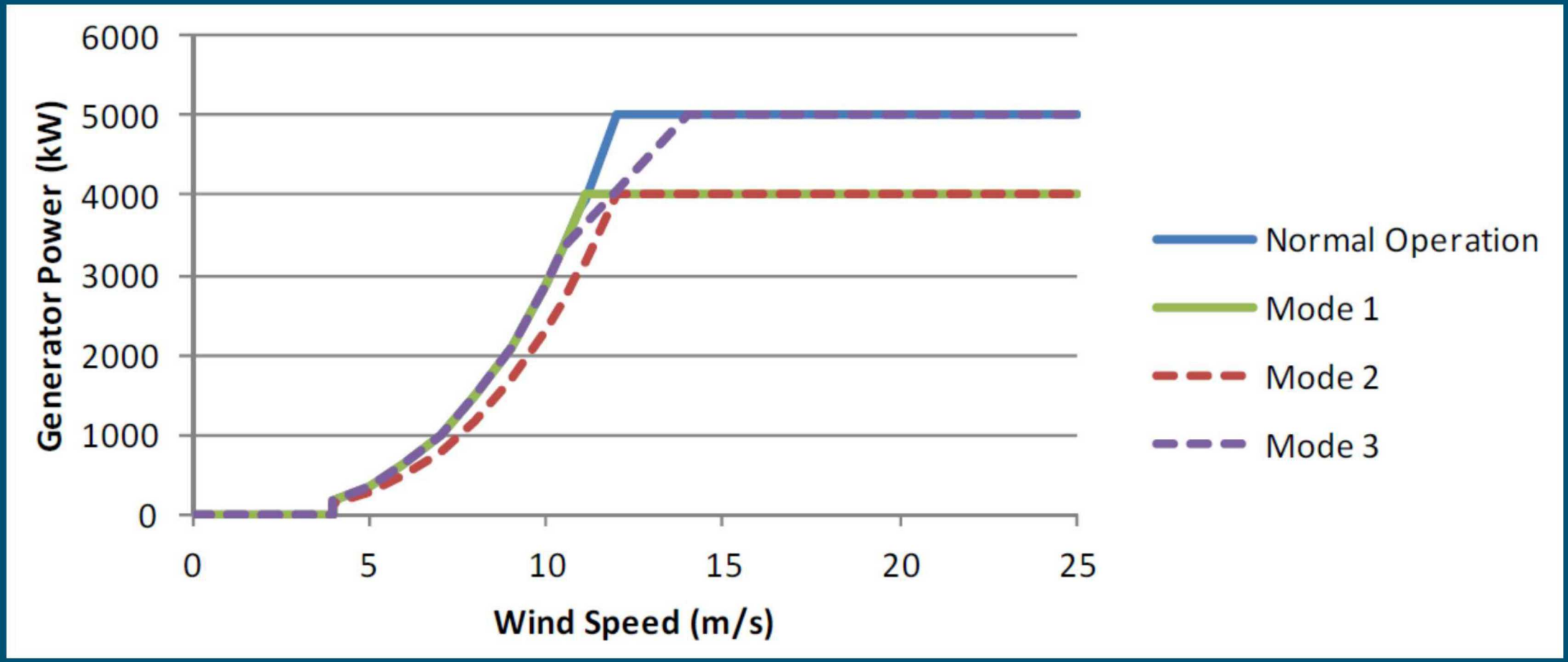
Technology	Pros	Cons
Acceleration	• Cheap and reliable • Can be used for rotor displacement	• Doesn't directly measure damage • Difficult to measure higher order modes which best indicate damage • Large sensor set required to locate damage
Strain	• Already implemented at blade roots for control • Measures loads effectively	• Doesn't directly measure damage • Reliability questions • Large sensor set required to locate damage
Acoustics	• Good indicator of certain flaws • Overall indicator of "problems"	• Doesn't directly measure damage • Large sensor set required to locate damage

Example: Trailing Edge Disbond

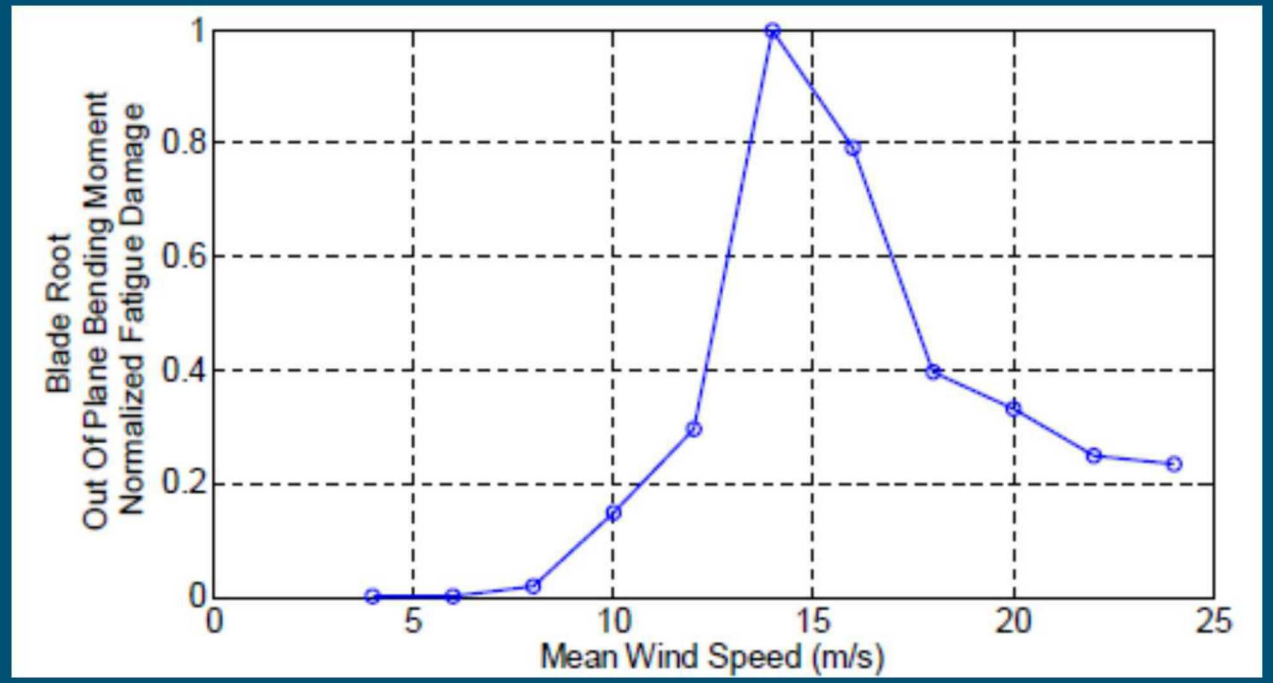


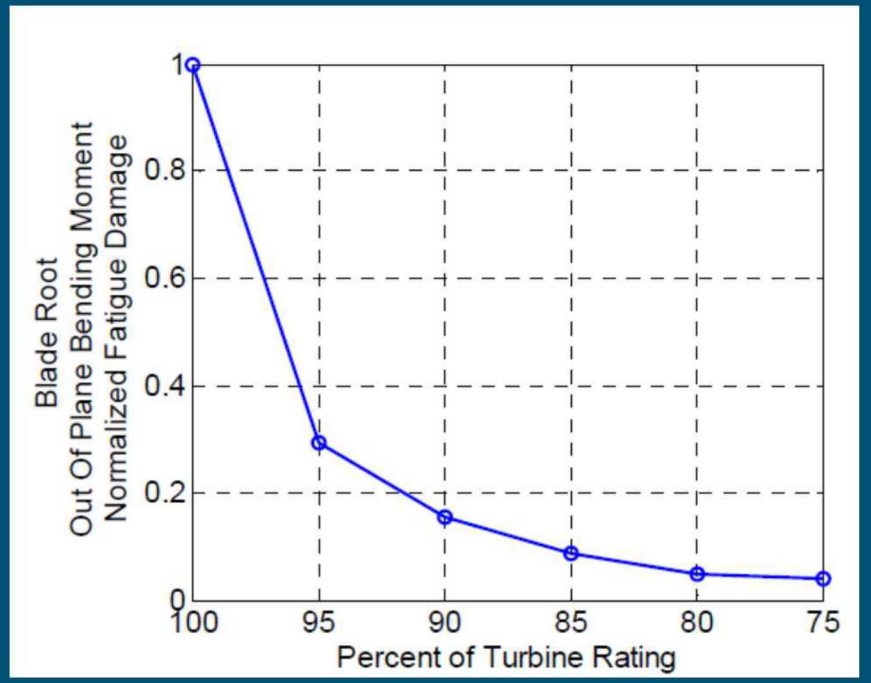


Operational Modifications

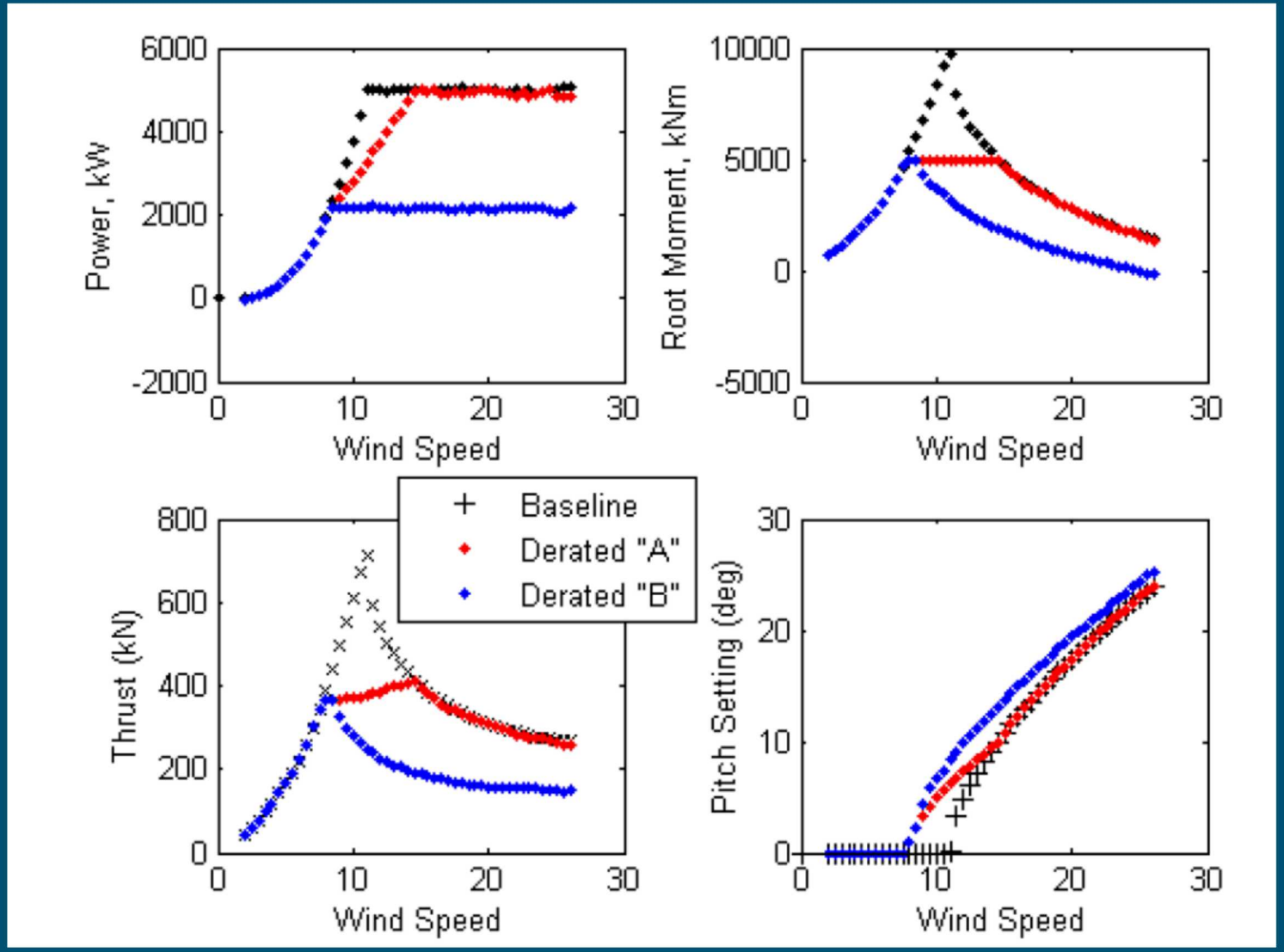


Impact on Fatigue Damage Accumulation

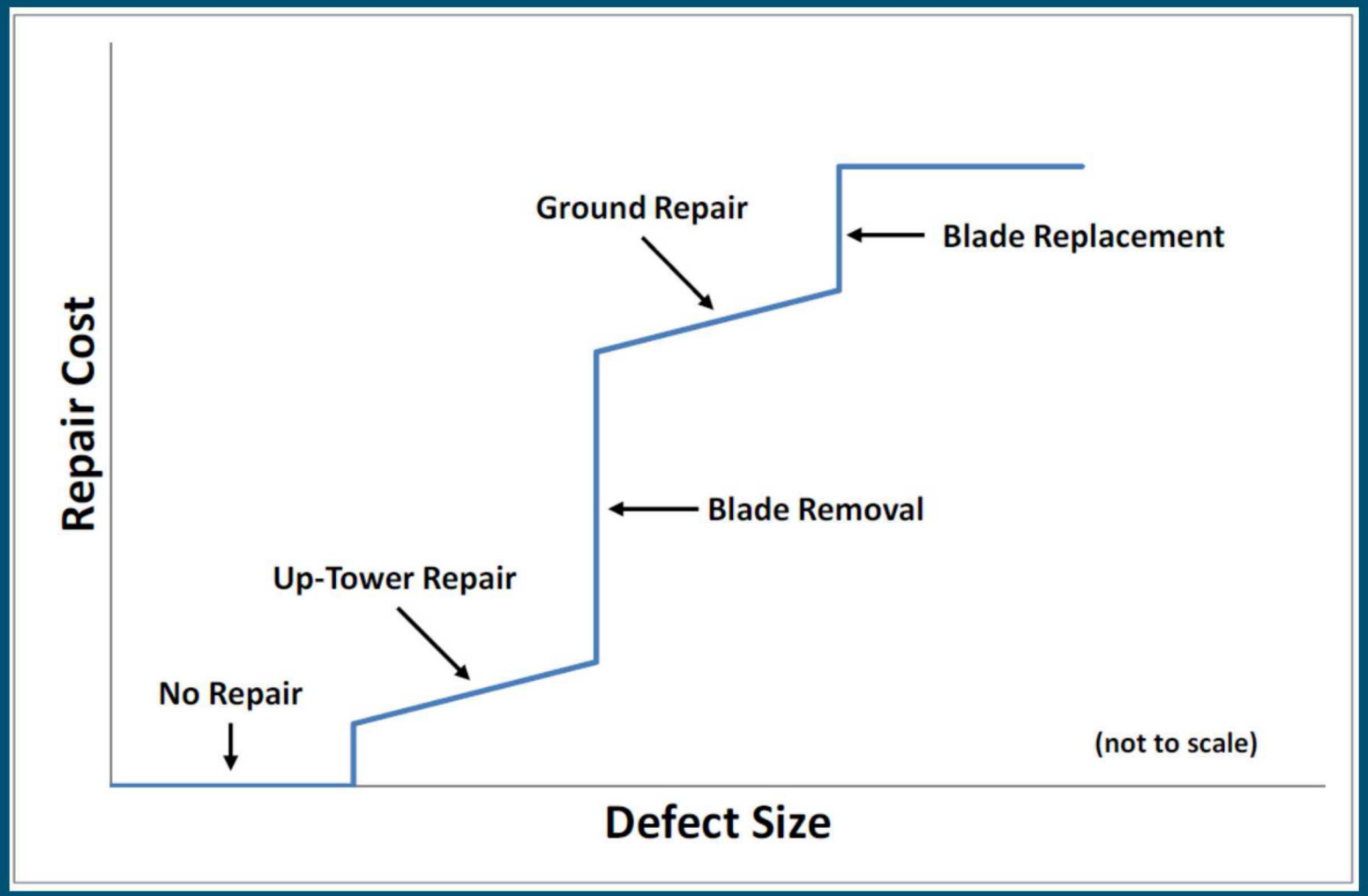




Impact on Power and Loads



Monitoring of Damage and Scheduling of Repairs



Conclusions

True structural health monitoring is likely to remain elusive for wind blades

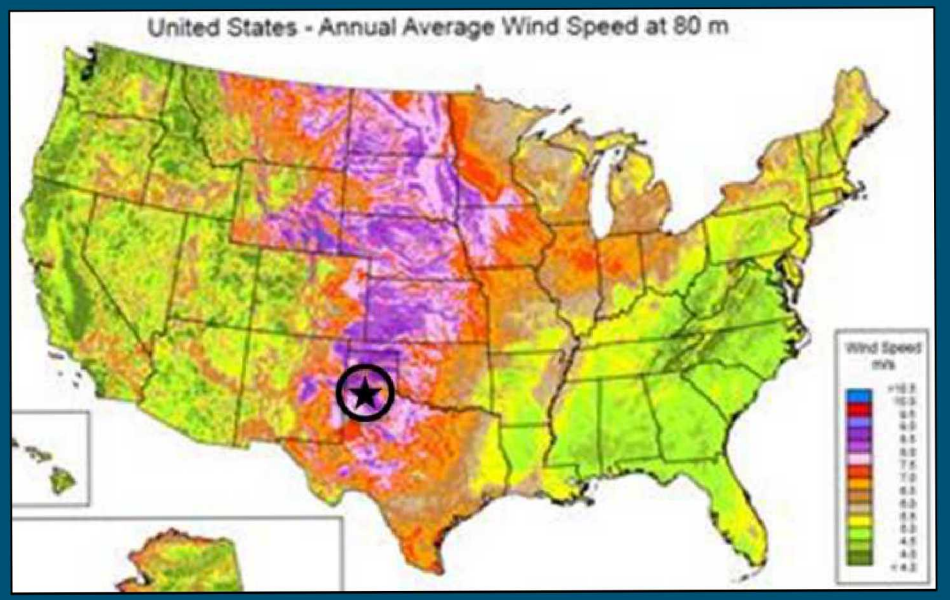
Would require large numbers of sensors, which would be a maintenance problem

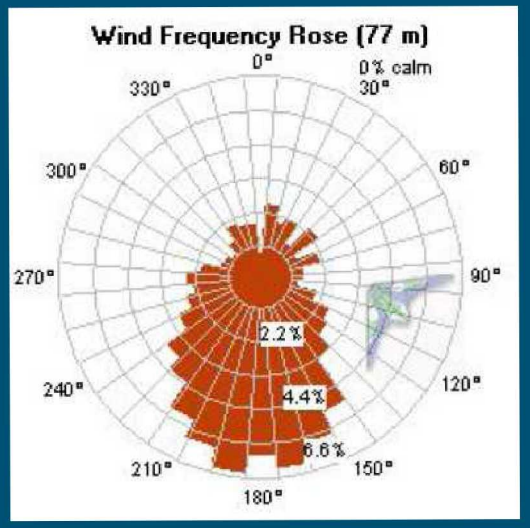
The most promising approach is to use limited sensors to indicate more detailed inspection

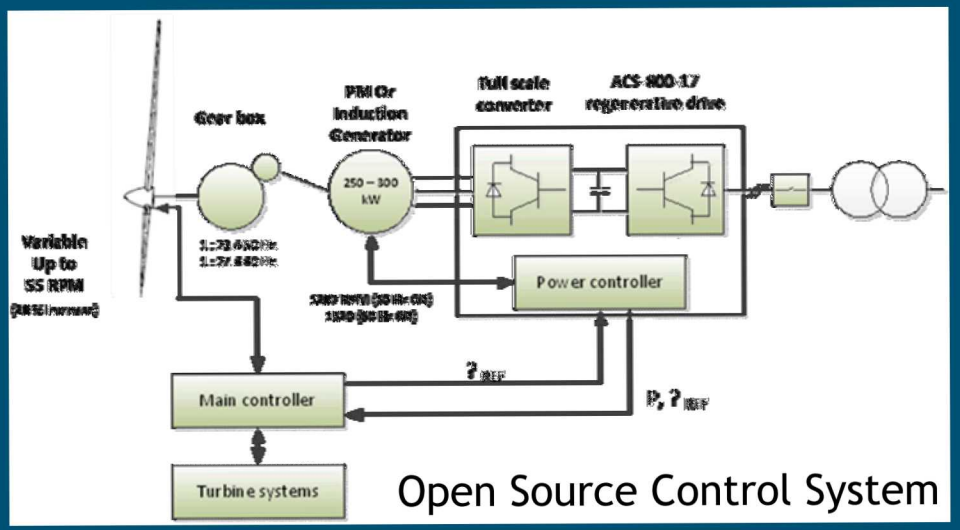
Implementation of loads monitoring should be relatively straightforward

Combined with digital twin, this could dictate maintenance schedules and/or lead to load leveling across a plant

SWiFT







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