Offshore Wind Technology Transfer Project

Nick Elbourn

Technology Transfer

TWI

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Where is TWI?

four UK technical centres

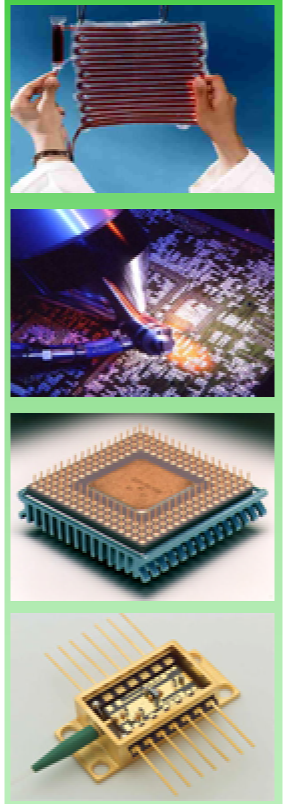
14 international training centres

members in 3500 locations worldwide

800+ staff

TWI Headquarters, Cambridge UK

TWI

Construction & Engineering	Aerospace & Automotive	Energy & Environment	Electronics, Photonics & Medical	Oil, Gas & Chemical	Equipment, Consumables & Materials
					

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Technology transfer in practice

Awareness and making contact

Access to expert know-how *(helpdesk, events, www.twi.co.uk)*

Identify issues

Deliver technical support

Implementation of best practice and innovation

Impact: Jobs created and safeguarded

Technology Transfer – Business Impacts

<table>
<tr><th>Region</th><th>jobs created</th><th>jobs safeguarded</th><th>t/o created £M</th><th>t/o safeguarded £M</th></tr>
<tr><td>North East</td><td>355</td><td>1249</td><td>30.3</td><td>74.8</td></tr>
<tr><td>Wales</td><td>190</td><td>1029</td><td colspan="2">83.5</td></tr>
<tr><td>North West</td><td>76</td><td>248</td><td>5.4</td><td>15.3</td></tr>
<tr><td>Scotland</td><td>44</td><td>95</td><td>2.9</td><td>5.1</td></tr>
<tr><td>Yorkshire</td><td colspan="2">1420</td><td colspan="2">62.4</td></tr>
</table>

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OSW Technology Transfer

For companies which are:

- **already in the OSW supply chain or who are interested in moving into this sector**
- **Growing and able to make use of high quality technical support**

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OSW-TT

- 18 month project, started in October 2012

- outreach/technology transfer: assist 100 companies, aiming to create/safeguard 650 jobs

- events programme

Project Key Facts

- **Funded by Regional Growth Fund via NAREC**
- **All TWI technologies covered:**
  fabrication, surfacing, cutting, inspection and NDT, processes, materials, quality
- **Large and small companies in North East, North West, Yorks & Humber**
- **Events**
- **Technical support – up to 12 FREE days!!** ***but***
- **Aims to create and safeguard jobs**

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OSW-TT technical support

- Initial 2 days scoping then, <u>subject to budget availability</u>:
- Up to 5 days Feasibility Study
- Up to a further 5 days

Innovation Support

<u>All free of charge</u>

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Technical Support

- Process/material change/innovation
- Procedure development
- Trouble shooting
- Design improvement
- Workshop practice
- Complying with standards
- Materials/consumables selection
- Health & safety issues
- Carbon footprint
- Skills development
- Quality systems
- Cost reduction

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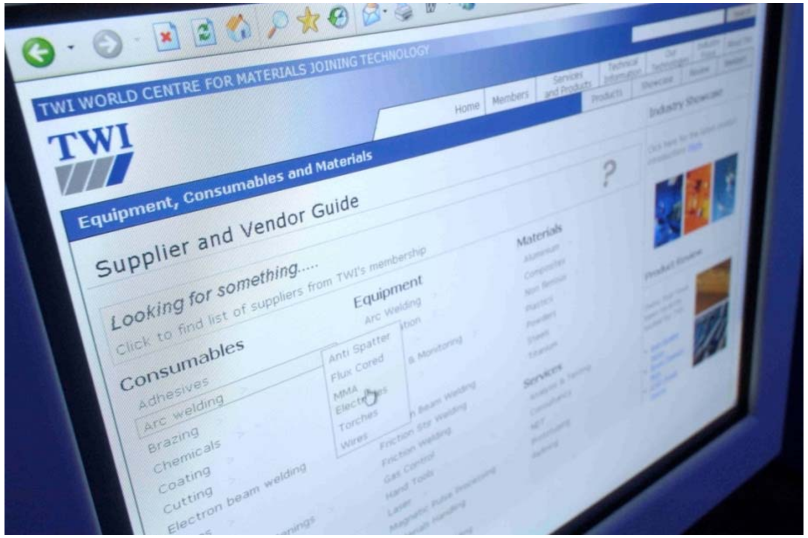
TWI Website Content

- Best practice guides
- Software toolkits
- Frequently Asked Questions (>1000)
- Knowledge summaries
- Corporate information
- Members reports (since 1995)
- Staff papers
- Technology briefings
- Weldasearch™
- MI-21 Consumables database
- Photographic images



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Visual appearance

Hydrogen cracks can be usually be distinguished due to the following characteristics:

- In C-Mn steels, the crack will normally originate in the heat affected zone (HAZ) but may extend into the weld metal *(Fig 1)*.
- Cracks can also occur in the weld bead, normally transverse to the welding direction at an angle of 45° to the weld surface. They are essentially straight, follow a jagged path but may be non-branching.
- In low alloy steels, the cracks can be transverse to the weld, perpendicular to the weld surface, but are non-branching and essentially planar.

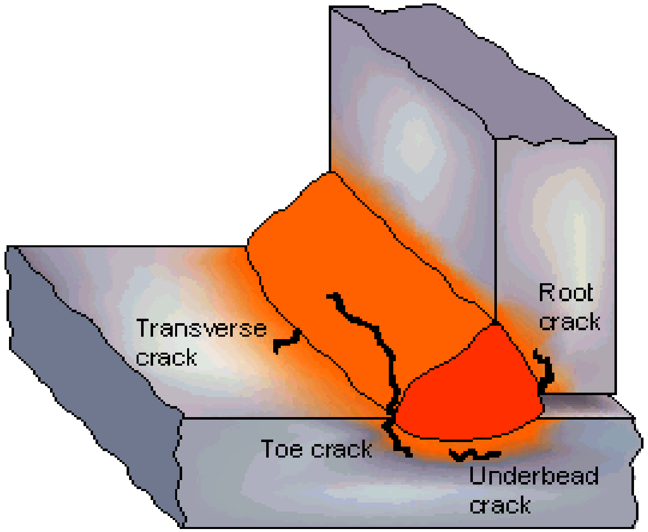

Fig. 1 Hydrogen cracks originating in the HAZ (note, the type of cracks shown would not be expected to form in the same weldment)

On breaking open the weld (prior to any heat treatment), the surface of the cracks will normally not be oxidised, even if they are surface breaking, indicating they were formed when the weld was at or near ambient

Cutting Selector Interactive Software Toolkit

Cutting Selector — Feasibility

Material	Edge type	Bevel angle (°)	Thickness (mm)
Stainless Steel	Square		4

Help

Production considerations

Number of heads	1	Plate size (m²)	20
Number of components	1	Cut length/comp. (m)	12
Number of starts/component	2	Total length of cut (m)	12.0

Sub-processes

Oxy-Fuel process	Laser C02 process	Plasma process
Standard Nozzle	1kW 02 assist	40A - Air
	Laser Nd:YAG process	HT Plasma process
	Pulsed <500W 02 assist	15A - Air

Approximate costs Help

	Suitable	Cutting speed (m/min)	Running cost (£/hour)	Cost per m of cut (£)	Duty cycle (%)	Cost per component (£)	Batch time (hour)
Oxy-propane	No	n/a	n/a	n/a	60	n/a	n/a
Oxy-acetylene	No	n/a	n/a	n/a	60	n/a	n/a
Laser C02	Yes	1.38	60.0	1.21	60	14.52	0.24
Laser Nd:YAG	Yes	0.21	58.8	7.67	60	92.0	1.56
Plasma arc	Yes	1.03	63.48	1.72	60	20.59	0.32
HT plasma arc	No	n/a	n/a	n/a	60	n/a	n/a
Abrasive waterjet	Yes	0.1	57.6	16.0	60	192.0	3.33

Stainless Steels

As their name suggests, stainless steels were developed to resist corrosion. Oxidation is prevented by the chromium present initially reacting with oxygen to produce a surface layer of chromium oxide (Cr_2O_3) which forms an impermeable seal over the underlying material. There are four main groups of stainless steels : Austenitic (grades 304, 309, 316), Ferritic (grades 405, 409), Duplex and Martensitic (grades 410, 420). These four types of steels are differentiated by their alloy content and the uses to which they are put as follows.

- *Austenitic Stainless Steels* : steels in this group are undoubtedly the most important members of the stainless steel family and are the most commonly used and laser cut. They possess a high resistance to corrosion, good weldability, toughness at subzero temperatures and excellent ductility. They are widely used in brewery , dairy

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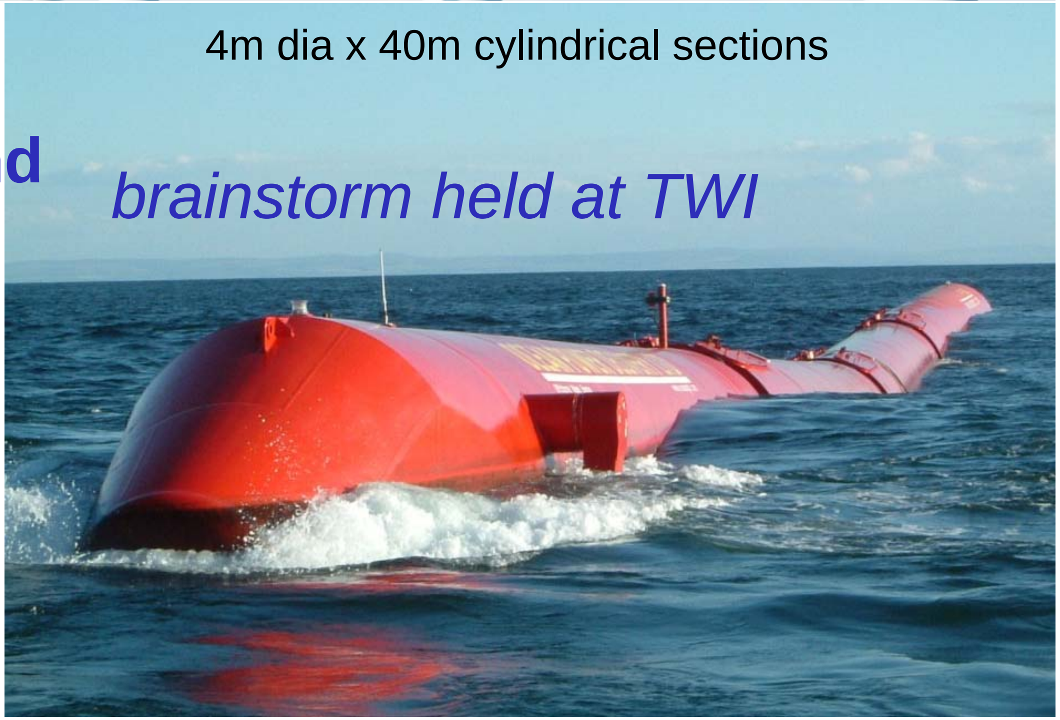
Case study: Pelamis Wave Power

Design review: maximising manufacturing efficiency and fatigue strength



TWI examined ways of achieving cost-effective volume production. Recommended cylindrical sections be designed for automated, multi-wire subarc welding

Pelamis Structural Engineering Manager: "*Joining Forces* Scotland is an excellent mechanism for accessing TWI's professional technical support, this will directly benefit our design and manufacturing processes"

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AARYAN

Case Study: Alnmaritec

- Innovative aluminium boat builder Alnmaritec has supplied operators from the Arctic to the Antarctic
- Customised work boats for oil and gas industries, fire and rescue, fishing, ferries and offshore
- Support vessels for OSW tower maintenance became central
- Boats 10 to 15m long single or twin hull vessels made from 5083 and 6082 grade aluminium alloy plate of between 4-6mm thickness
- Design and fabrication to Lloyds Rules involved MIG butt welding in the flat, horizontal, vertical and overhead
- Success rate was already high, x-ray examination revealed that a 100% pass rate was achievable
- Surface appearance was excellent and advice given on sidewall fusion and porosity, both of which were not perceptible visually
- TWI highlighted importance of operating gas-shielded process in a draught-free environment and emphasis on completing welding within four hours of degreasing

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Summary

- **TWI World Centre for Technology Transfer & Training - meeting the needs of Industry**

- **OSW-TT: free technical assistance and supply chain support, technology demonstration and trials**

- **Practical assistance and support provided to achieve real business benefits**

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OSW-TT project support

For more information contact:

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Application of NDT During Wind Turbine Manufactue

Ivan Pinson

TWI IMG Group

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Industrial Need

- Fast growing
  - >20% pa since 1994
- Huge market
  - €340bn investment in wind energy in EU 2008 – 2030
  - Global installed capacity: 194 GW (2010)
  - EU installed capacity: 86 GW (2010)
  - Installed capacity of wind power in the United Kingdom was 8,445 megawatts (MW), with 362 operational wind farms and 4,158 wind turbines
  - Rounds 1 and 2 allocated 8 GW of sites, while Round 3 alone could identify up to 32 GW

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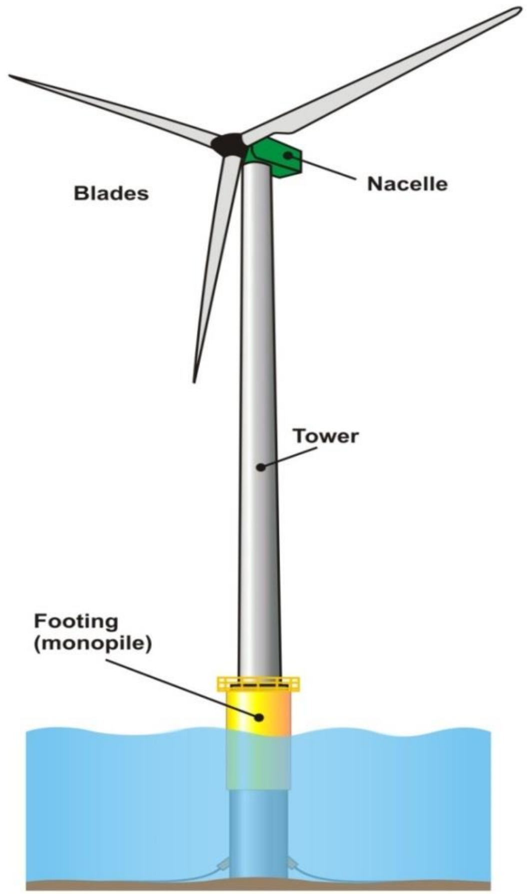
Wind Turbine Components



- VT: gearbox, generators, hub
- PT: tower welds, gearbox
- MT: tower welds, gearbox
- ET: tower welds, gearbox
- UT: tower, blades
- RT: tower welds, blades

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NDT Challenges

- Highly visible
- Mass production
  - Fairly new (lack of standards)
  - Speed
- Push for large, lighter, more productive units
- Many materials
  - Metals, composites (eg GRFP), wood
- Access/Design
- Confidentiality

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Advanced NDT methods

- Time of Flight Diffraction (tower welds)
- Phased Array Ultrasonics (tower welds, blades)
- Thermographic Testing (blades, generator)
- Laser Shearography (blades)
- Acoustic Emission (gearbox, generator, blades)
- Computed Radiography (various items)
- Computer Tomography (blades)

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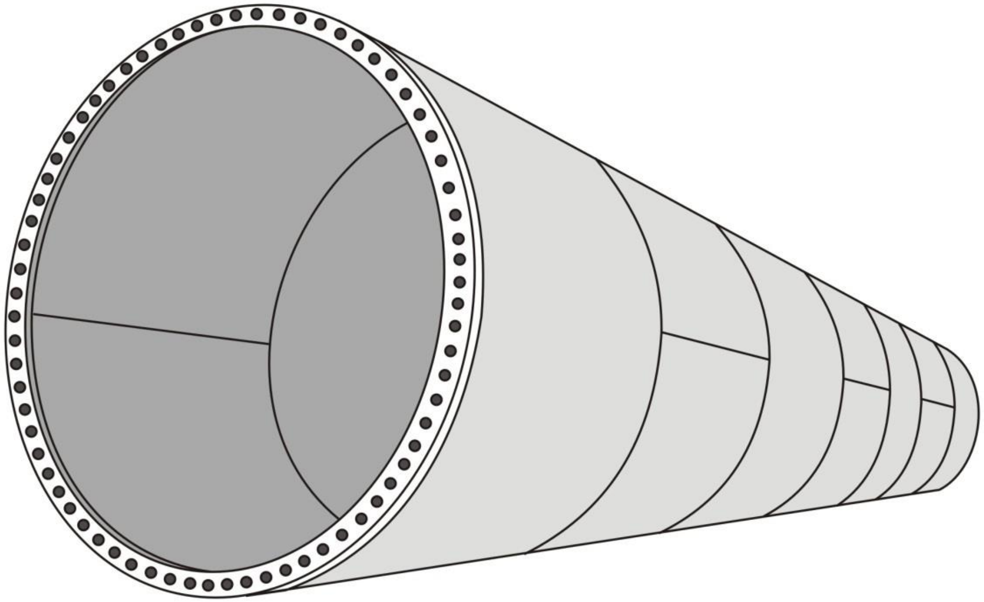
Wind Turbine – Tower

- Cans joined with SAW girth weld.
- Joining rings added internal or external.
- Multiple sections used to complete tower.



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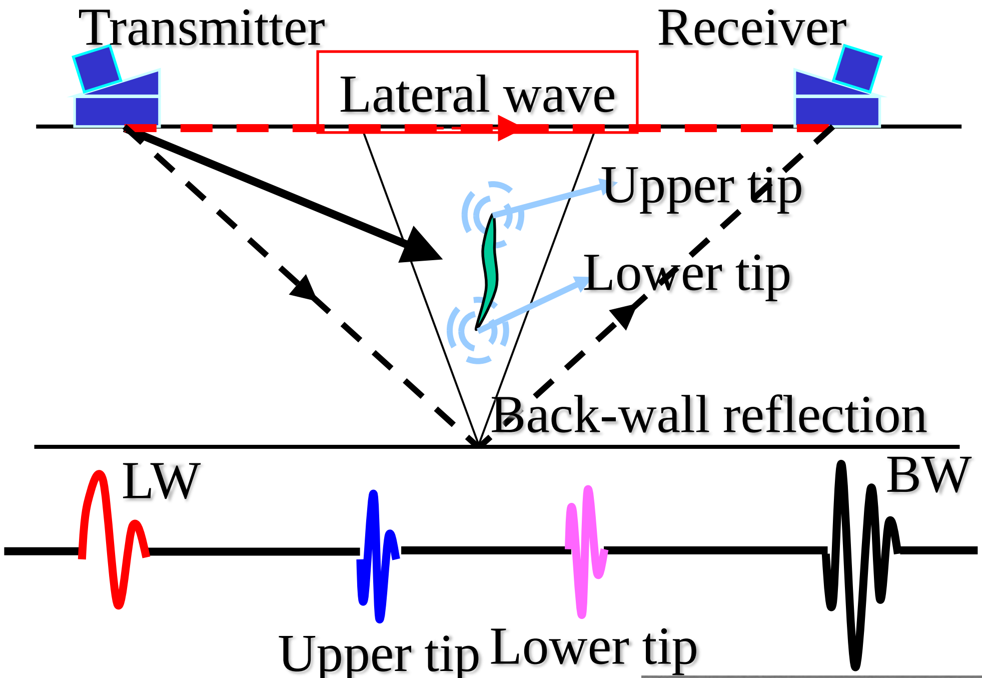
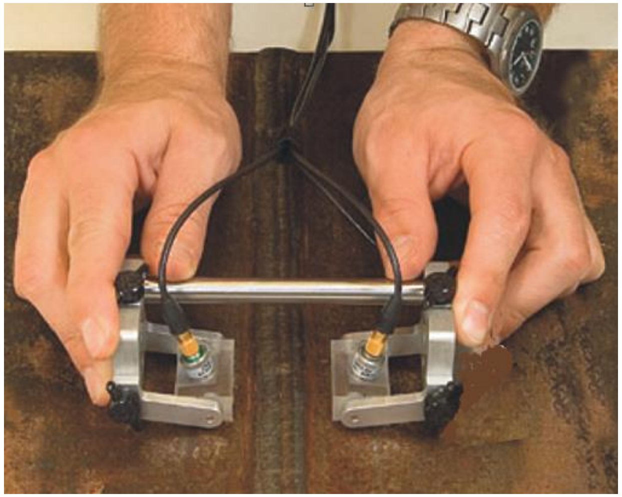
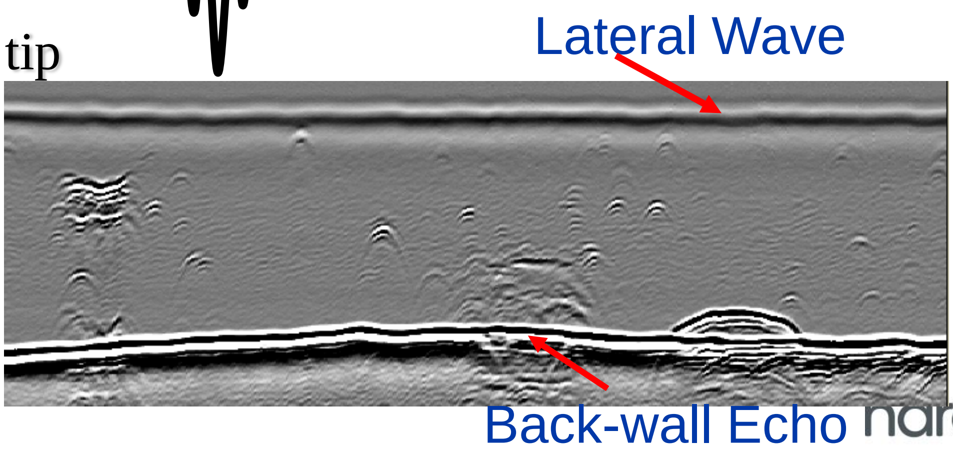
TOFD







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TOFD

Advantages

- Does not depend on defect orientation
- Defect height can be exactly determined
- Inspection results immediately available
- Permanent print is available
- Higher test speed means costs are less

Disadvantages

- Reasonable access from both sides
- Dead zone for defect detection close to the surfaces
- Is more a sizing tool than a detecting tool
- Interpretation of defects

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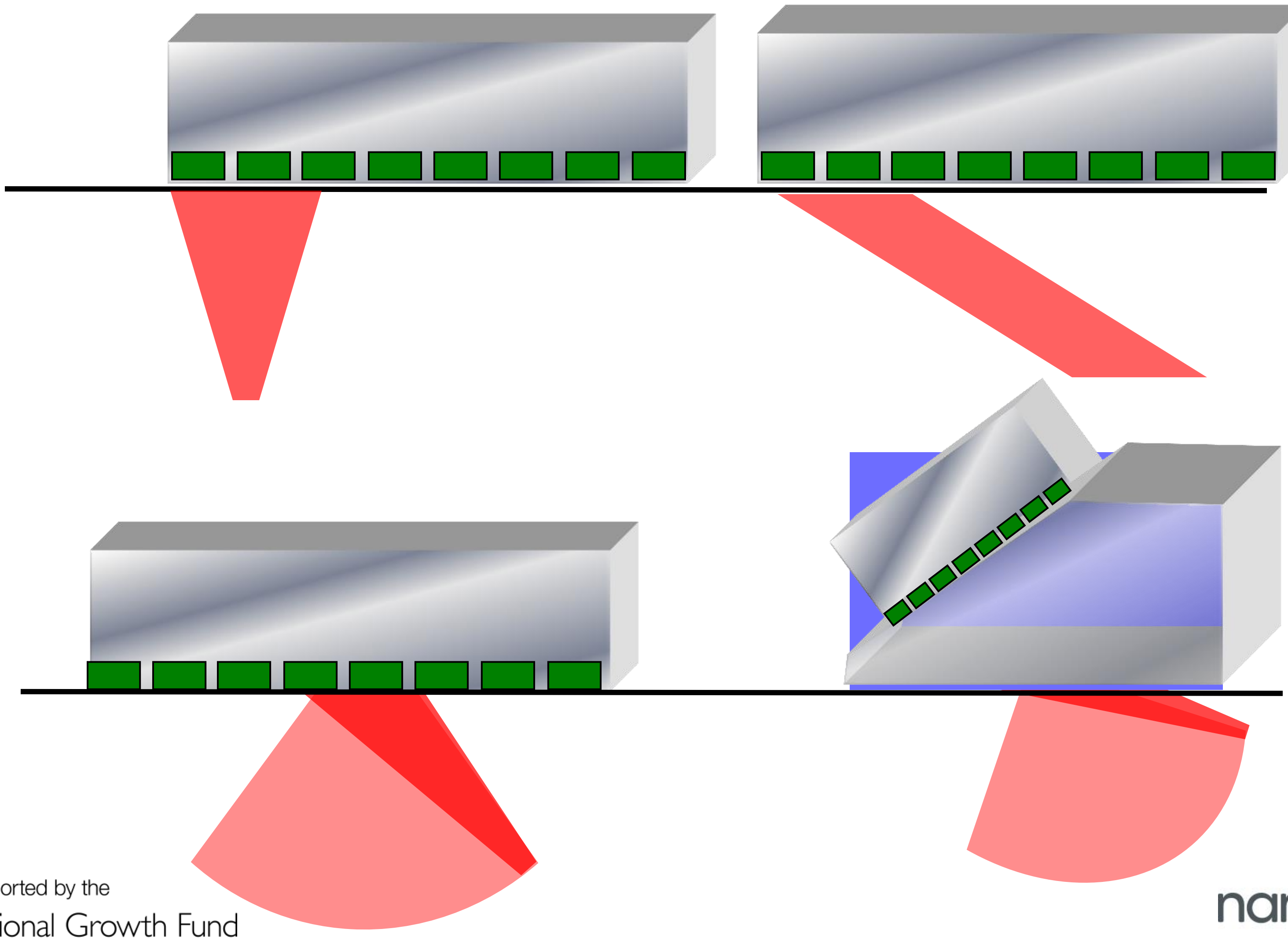
Phased Array – beam steering



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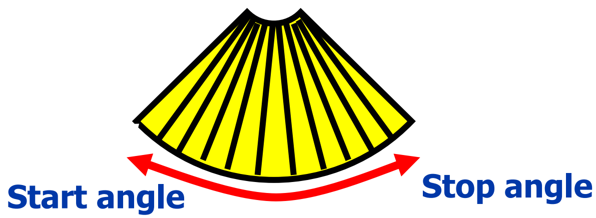
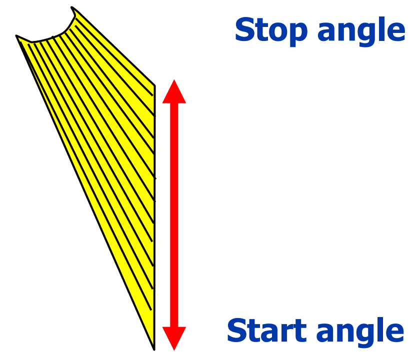
Phased Array – beam focus point

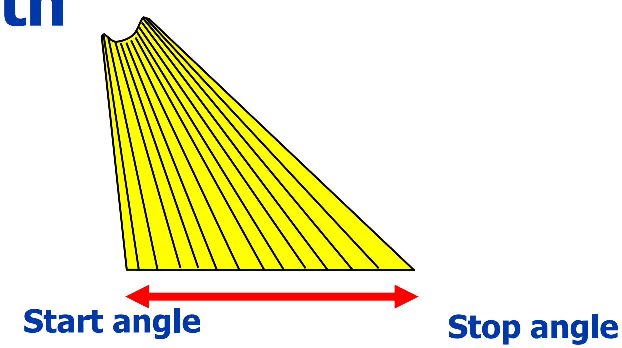
- **Various Modes**

Constant path

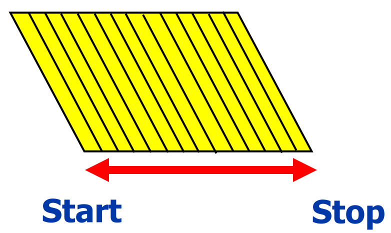




Constant depth

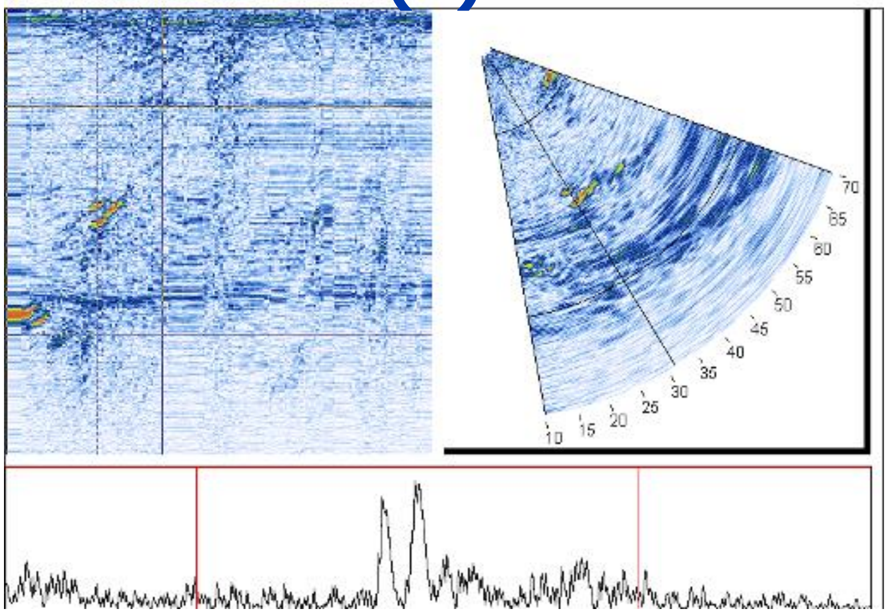


Linear scan



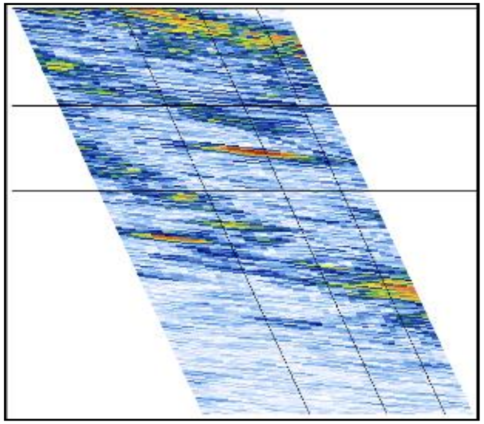
Phased Array

D-scan and (S)ectoral scan

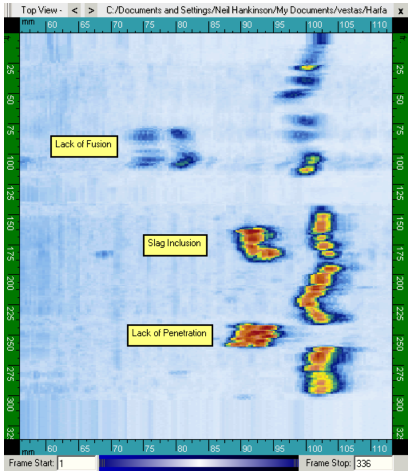


A-scan

Linear scan



C-Scan display



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Phased Array Technology

Advantages

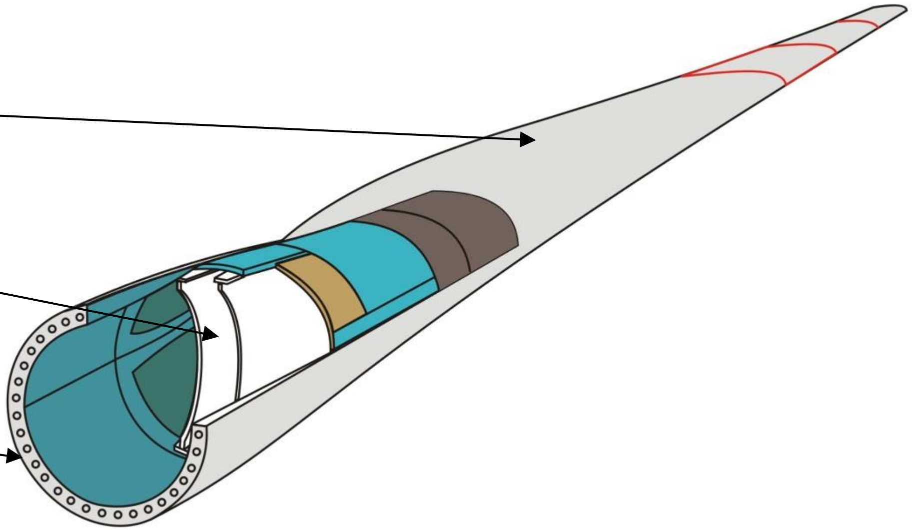
- No radiation hazard
- Flaw sizing capability
- Improved flaw evaluation by Engineering Critical Assessment (ECA)
- Rapid interpretation

Disadvantages

- Large probe size
- Operator and procedure dependant
- Geometry

Wind Turbine – Blades

- Main components
  - Aerofoil sandwich section
  - Spar beam or shear web
  - Root and fixings



There are design and material differences between each of the manufactures blades, and inspection selection will be affected by these differences.

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Wind Turbine – Blades

Materials used

- eGlass
- Balsa Wood
- Foam (Rohacell, etc)
- Continuous Strand Matting (CSM)
- Gelcoat
- Adhesives
- Carbon and/or Aramid fibres for future use

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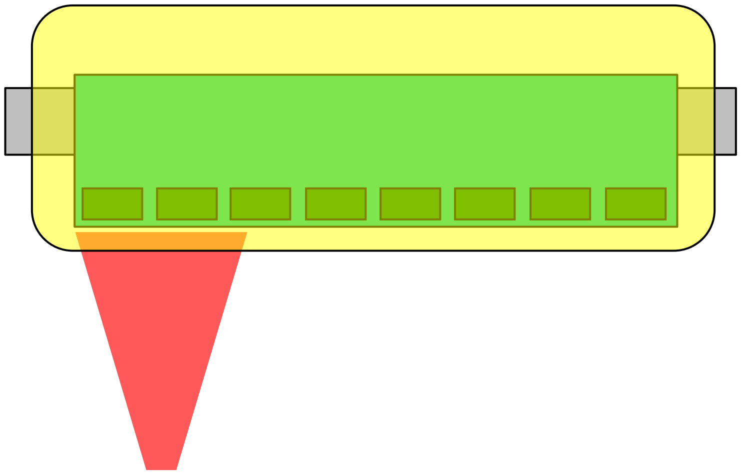
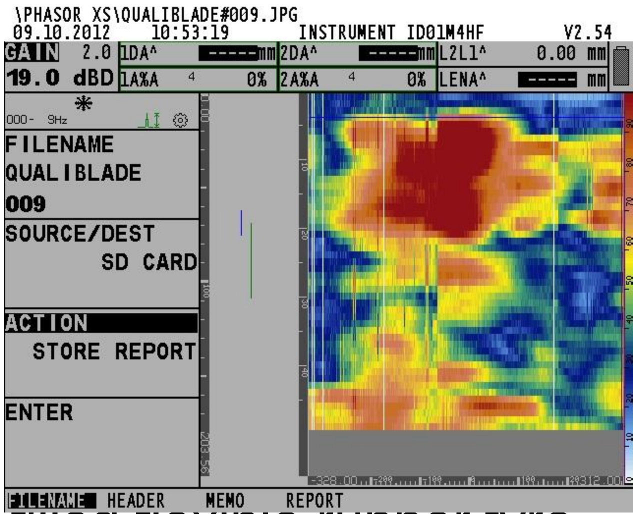
Wheel probe PAUT technique





- Multiple channel PAUT in wheel probe using liquid filled flexible rubber tyre A, B, C, D scan mode
- Mainly detects laminar defects but can be used on metals to detect corrosion (hidden, inter-laminar and exfoliation) and to detect cracks.
- Additionally can be used to assess Adhesive bonding and on composites to assess impact damage and de-laminations.

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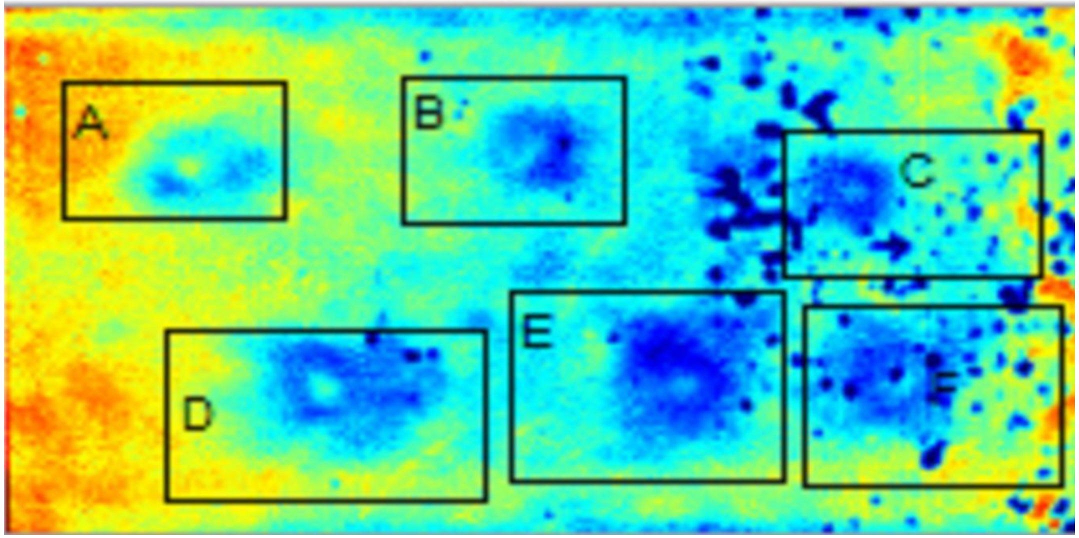
Thermography

- All objects above absolute zero temperature will emit infrared radiation.
- Use a camera containing large numbers of sensors sensitive to infrared radiation, which produces an infrared image and can detect and measure small temperature differences.
- There are two basic types of thermography - PASSIVE and ACTIVE.



Disbonds in wind turbine blade detected by thermography

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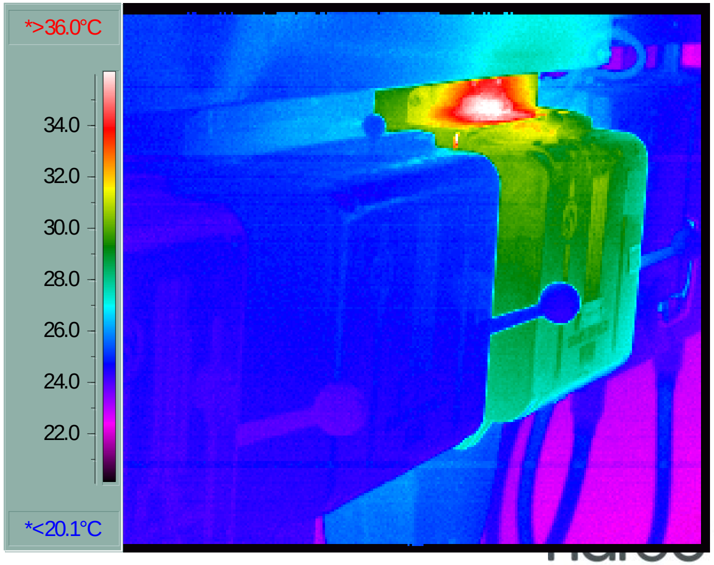
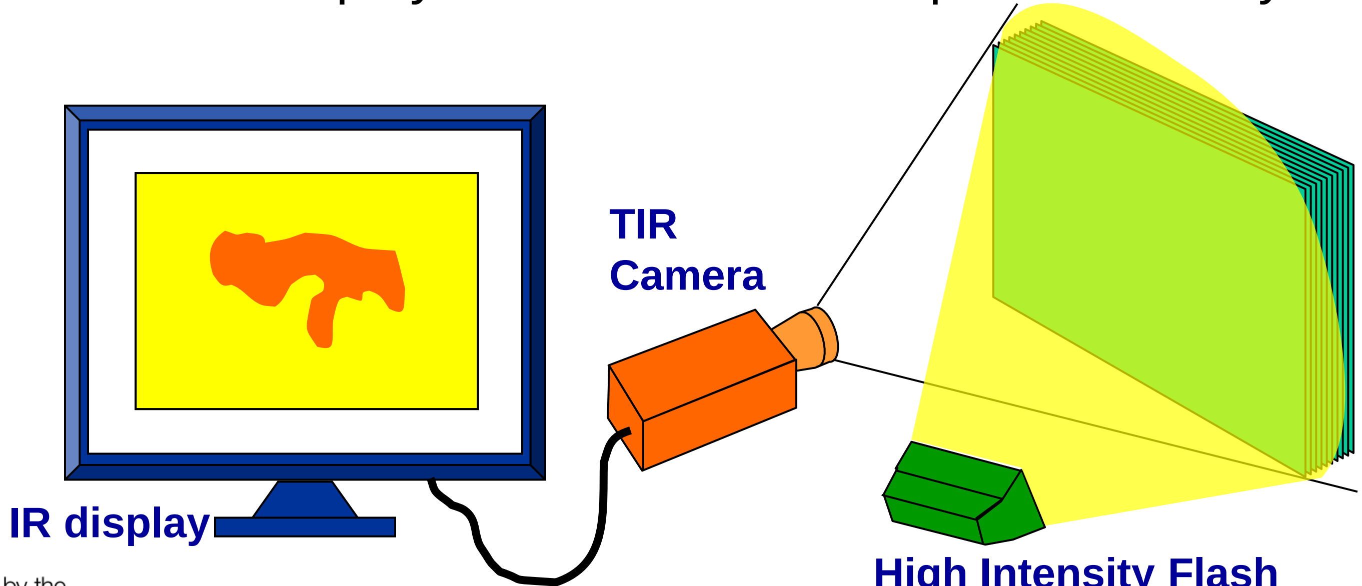
Passive Thermography

- Camera simply pointed at test piece and a temperature map constructed.
- Features of interest are naturally at a higher or lower temperature than the background.
- Abnormal temperature profiles at the surface of an object are an indication of a potential problem.
- Applications such as surveillance of people on a scene, medical diagnosis, electrical system checks.



Active Thermography

- Energy source required to produce a thermal contrast between the feature of interest and the background.
- Necessary in many cases given that the inspected parts are usually in equilibrium with the surroundings.
- Involves heating the surface of the object rapidly using an external heat source and observing how the temperature decays with time. Flaws in the material show up by variations in the temperature decay rate.



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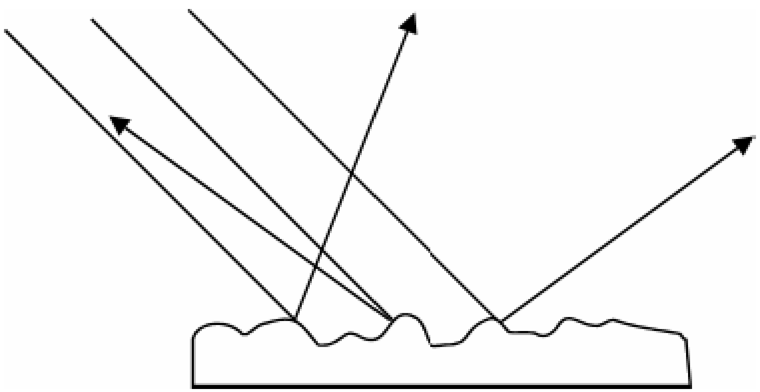
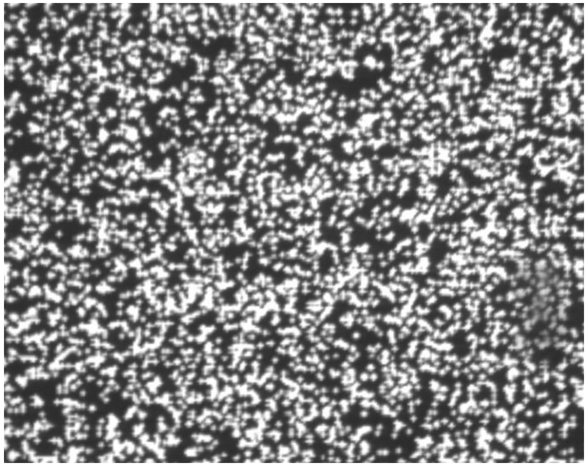
Laser Shearography (ESPSI)

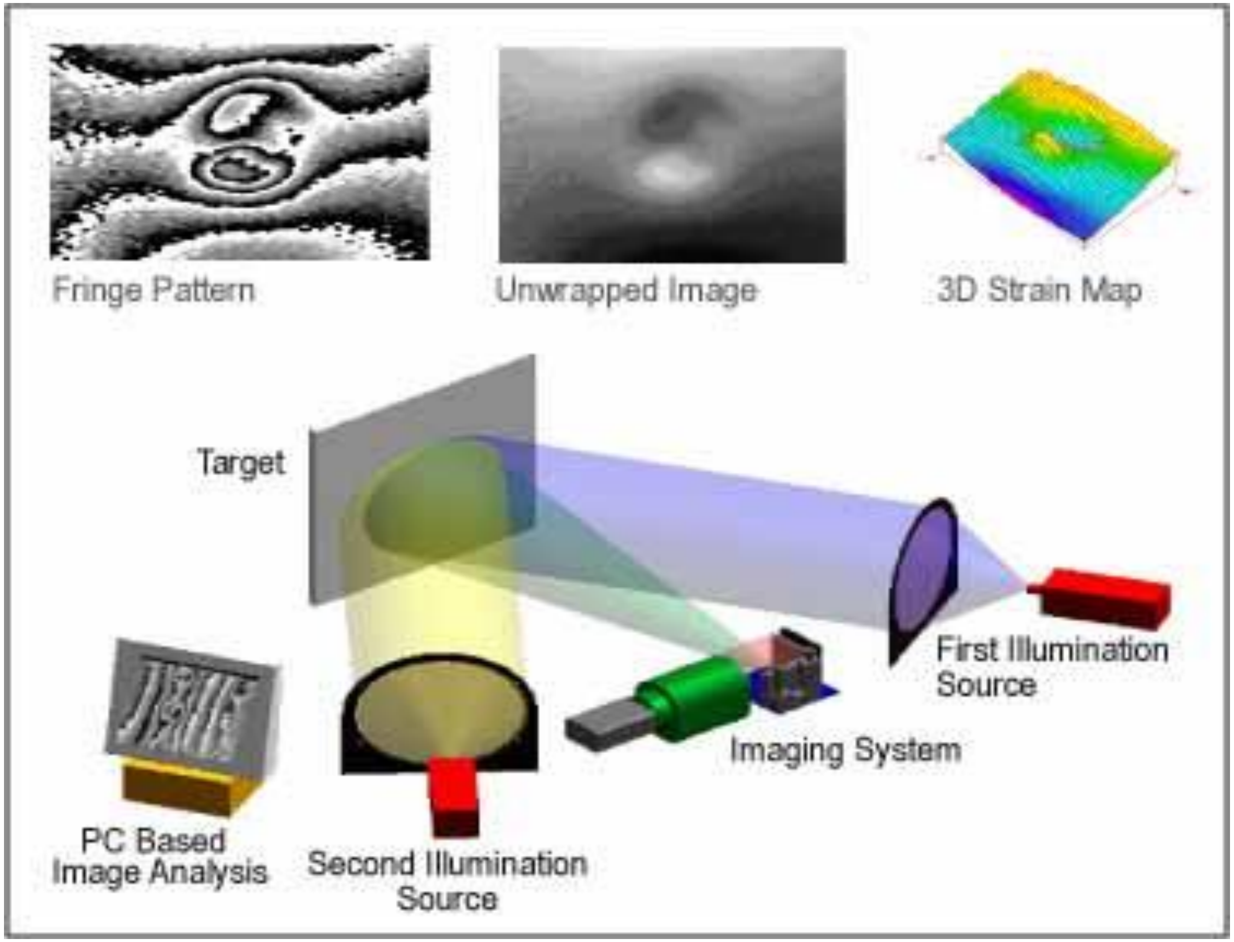
ESPSI – Electronic Speckle Pattern Shearing Interferometry

- Uses coherent, monochromatic properties of laser light to generate speckle patterns.
- Speckles appear when an optically rough surface is illuminated by a coherent light
- Optically rough surface: surface height deviation is greater than the wavelength of the illuminating light





Laser Shearography (ESPSI)



Stress Excitation Methods

- Defect is revealed from the defect-induced deformation excited by external stressing
- Stressing methods:
  - Mechanical:
    - Contact load, pressure, partial vacuum
  - Thermal:
    - Heating, flash/shock
  - Acoustic:
    - Vibration loading
  - Electromagnetic:
    - Induction

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Summary

- Non-contact inspection technique
- Detect subsurface defects: void, crack, disbond, delamination, impact damage etc.
- Quicker than most of the NDI methods,
- Working on all type of materials and structures
- Appropriate stressing is essential
- Phase shifting improves the capability
- Requirement for working condition is still rigorous

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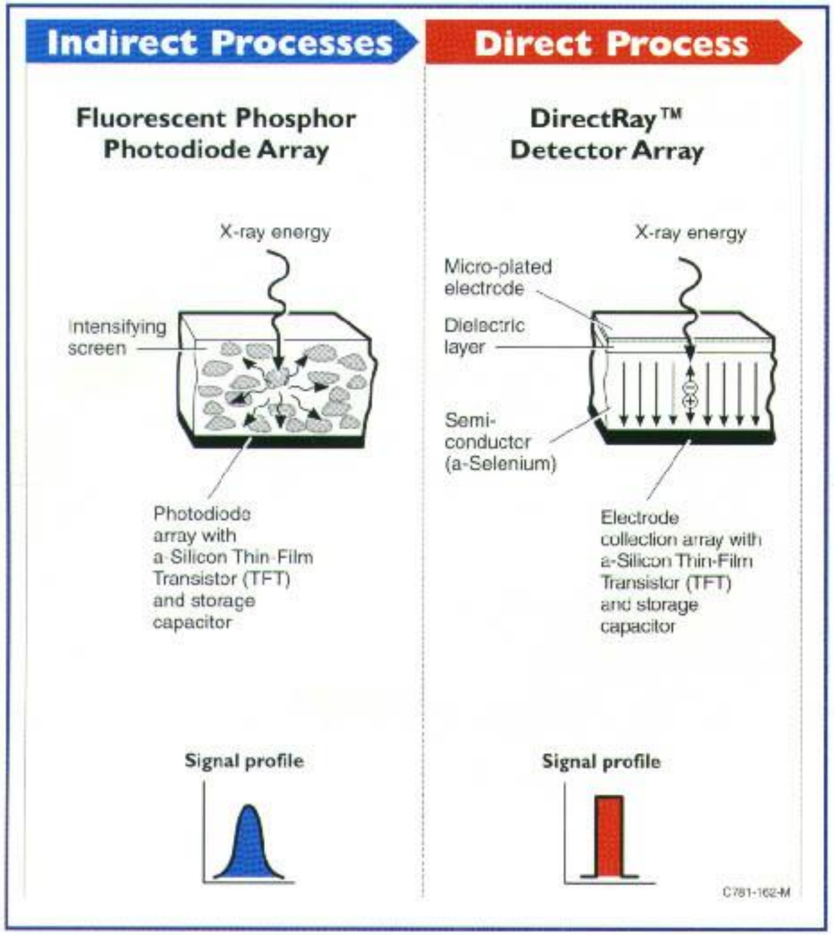
Indirect / Direct Digital Radiography



Computed Radiography – Benefits

- Exposure times typically range from 2 to 20 time less than film, depending on the image quality required
- Exposure latitude is over 1,000 times more than film
- Re-usable screens eliminate the need for film, processing chemicals, and disposal fees
- No darkroom requirement
- Reduce under and/or over exposures
- Phosphor plates are flexible and can be bent
- D8/D7 film type image quality

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Problems to be Addressed

- **Design**
- **Inspection Methods**
- **Man power**

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In-service Condition Based Maintenance using Acoustic Emission and Vibration Analysis

Dr Slim Soua - CSM section manager
Graham Edwards – CSM consultant

IM Group, TWI Ltd, Granta Park, Great Abington, Cambridge CB21 6AL, UK

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CM project funded by the RGF

TWI narec Newcastle University TBG SOLUTIONS www.tbg-solutions.com C·M·R GROUP

Applied Inspection Limited
non-destructive testing, materials testing, consultancy, training and welding

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NEED FOR CONDITION MONITORING SYSTEM

- Manual inspection
    - Very costly
    - Labour intensive
    - Can be unreliable
    - Small area inspection (a few square cm of blade)
- Inspection and maintenance costs can be as high as 40% of operating costs
- Costs increase with the age of the turbine
- Requires exposed work at dangerous heights.

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Condition and Structural Health monitoring

Machinery Vibration (CM)

AE SHM (for static structures)

Combined AE/GW /Vibration CM/SHM (for static / moving structures/ parts)

CBM: Strategy Combining CM /SHM

CBM

Implementation

- Structural Health Monitoring

- Condition Monitoring

- Operation monitoring

Identify requirements for a specific strategy

- Implementation of techniques and hardware provision

- Adapt NDT technique for an operation as part of a Monitoring approach

Vibration analysis

- Standing wave

Guided waves

- Ultrasonic wave propagation and interaction with defected area and corrosion.
- Inspection using LRUT, SRUT.

Acoustic Emission

- Load, stress, strain and material
- Crack growth in Metals and associated AE
- AE Sources in Non-Metals and Composite Materials
- AE application, software, data processing and location

Generic Requirements for CM/SHM

- To evaluate the complexity of multi-disciplinary industrial problem
- To gather signatures and take away environmental features
- To evaluate a process that detects damage (fatigue and corrosion cracking) before it becomes critical
- To be able to monitor the damage/crack
- To increase confidence in the monitoring process (feedback warnings)

CSM/SHM features

- Vibration analysis
- AE overall evaluation
- AE waveform localisation
- Ultrasonic wave transmission and focussing
- Operational process acquisition
- Acquire signature/ baseline
- Evaluate Deviation (similarity) analysis
- Trend evaluation/presentation
- Correlation to operational parameters

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Capabilities

- Real-time operating system
- Web based platform
- Data storage (networking)
- Flexible software
- Warranty / conformity
- Equipment validation
- Cost model

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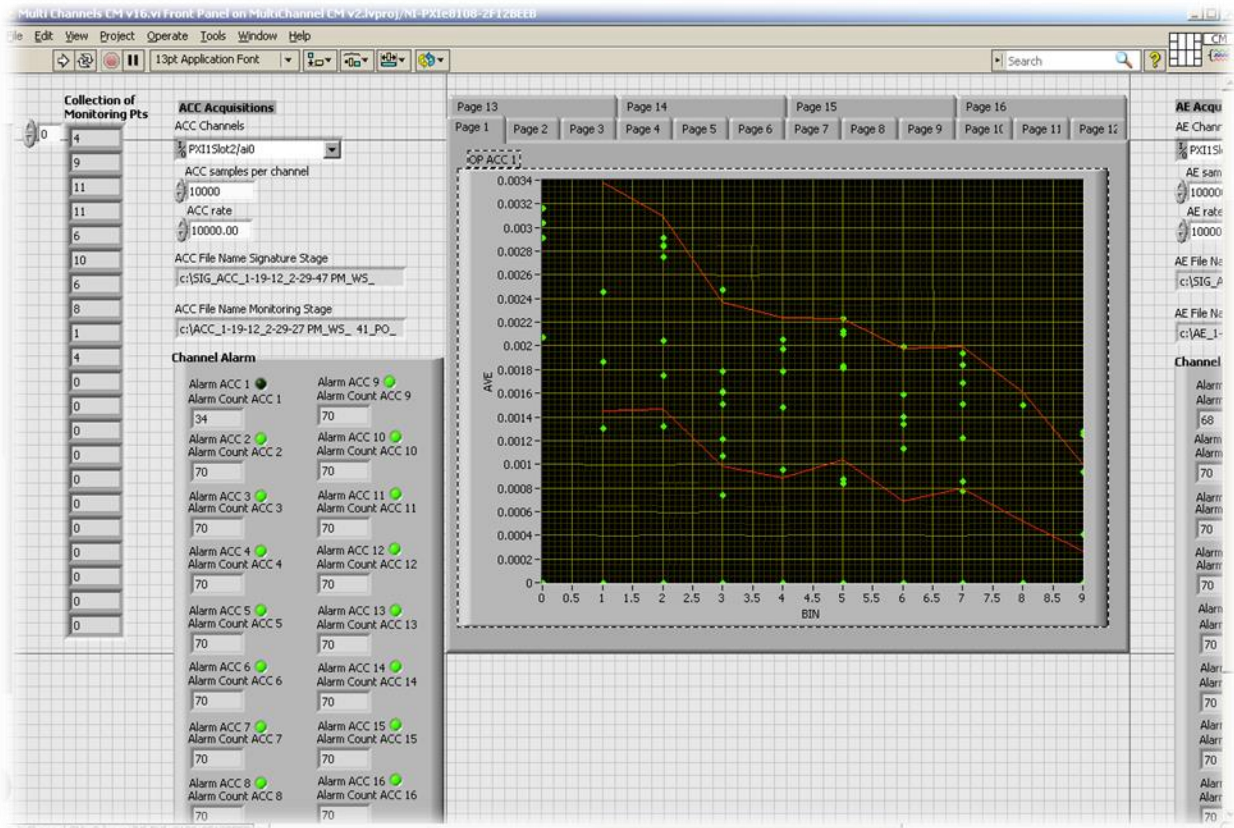
CMS Operation for Rotating Parts

- Automated signature acquisition
- Continuous on line monitoring
- Real-time operation hardware (National Instrument)
- Operation criteria setup and update (software)
- Operational Alarm
- Correlation with parametric inputs.



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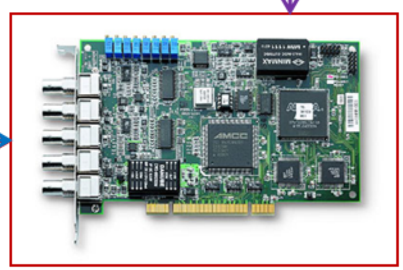
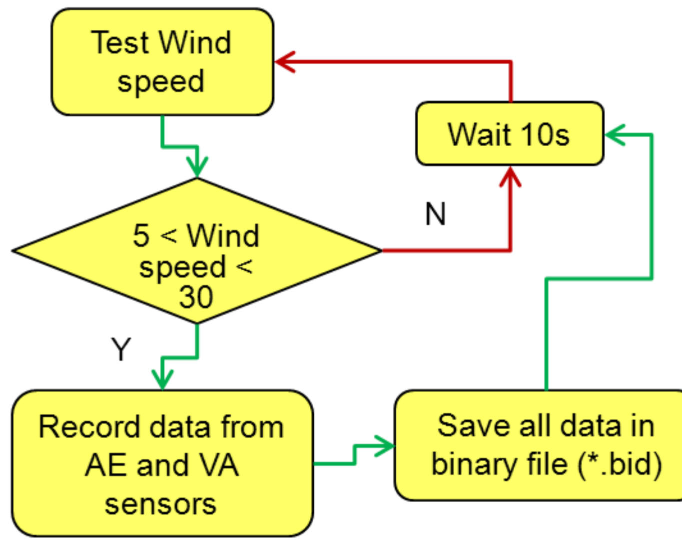
Process configuration

Accelerometers: 0.2Hz – 11kHz (100mv/g)

Acoustic Emission Sensors: 90kHz – 1MHz (VS 900RIC)

Wind Speed & Power output





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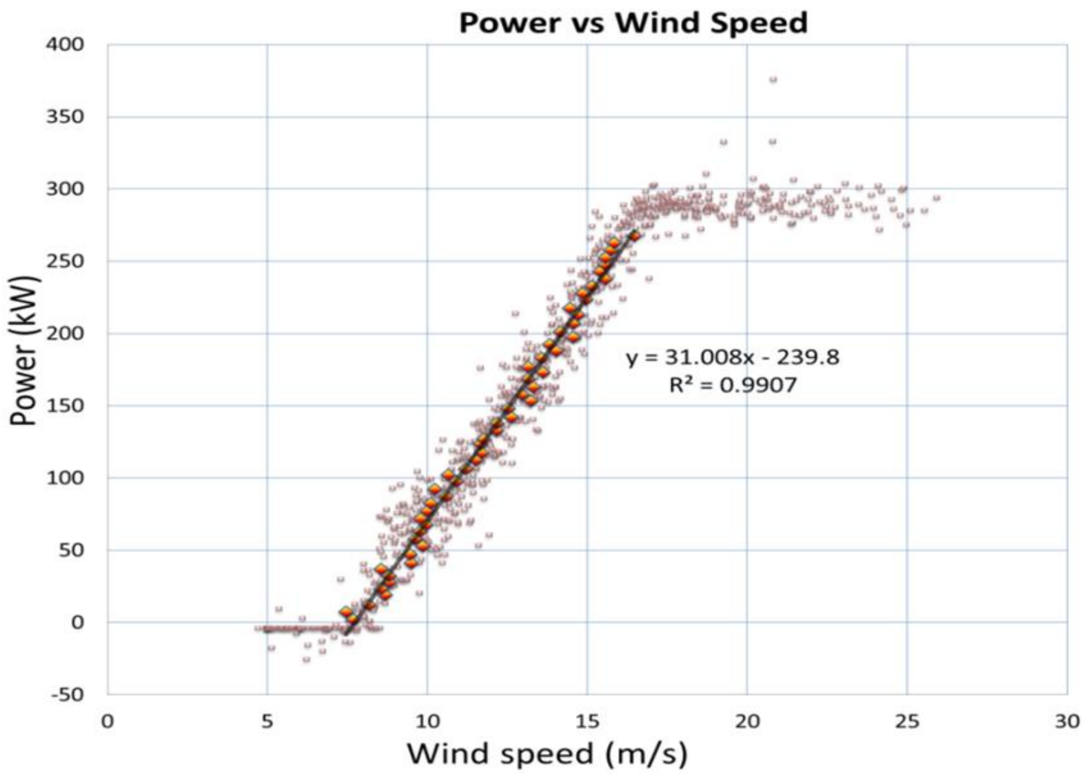
In service CMS operation for 350kW in service wind turbine

- Use of the power dependent signature and signal analysis of a healthy - in service -wind turbine drive train as a prerequisite for condition monitoring



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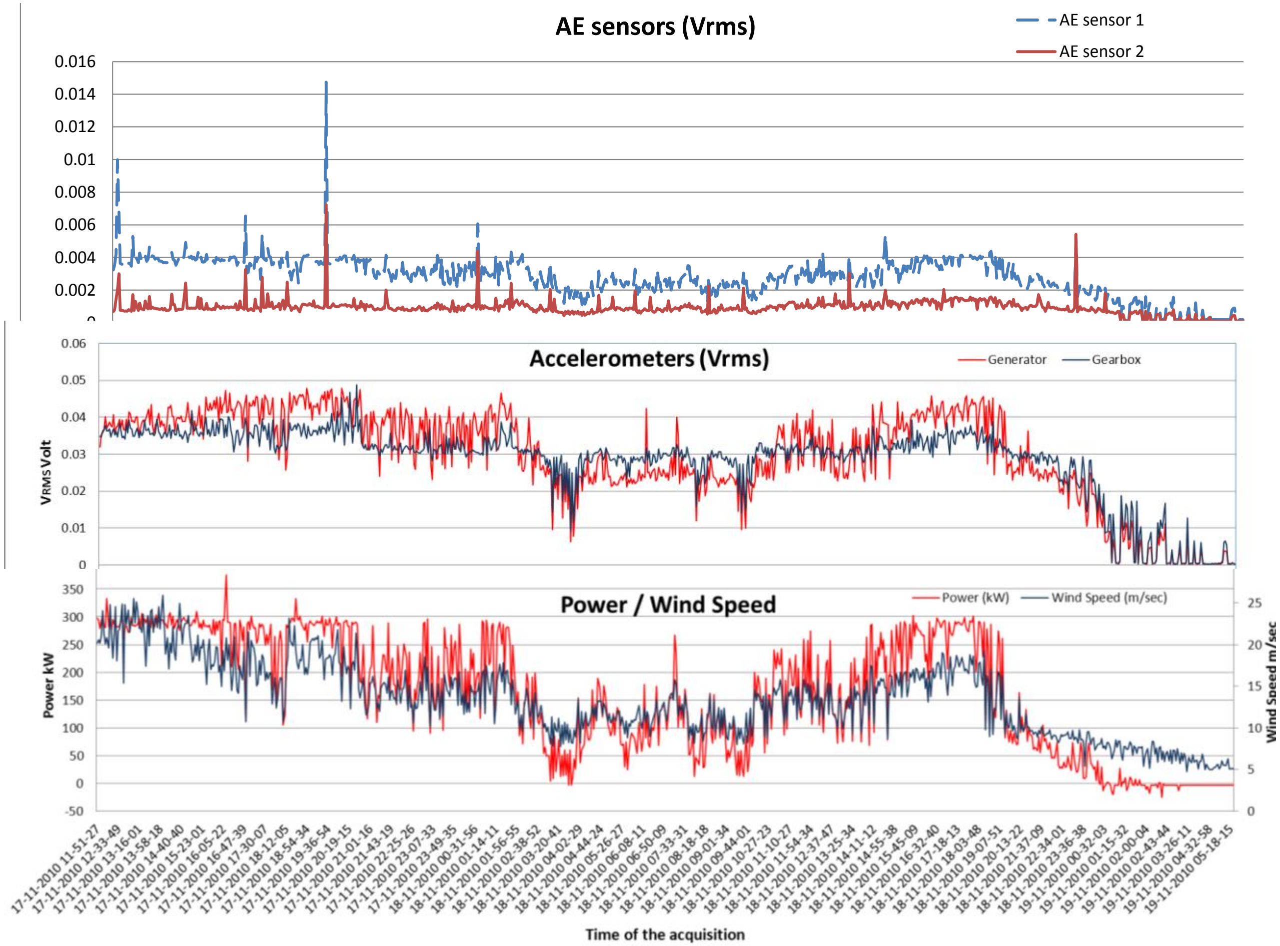
AE/ACC Vs Power/WS time domain data



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In service CMS operation for 350kW in service wind turbine

Gear meshing (Hz) to the generator = 1515 RPM	
	1st harmonic
High Speed	808
Intermediate Speed	194
Low Speed	60
Shaft Rotational (Hz)	
High Speed	25
Intermediate Speed 1	10.8
Intermediate Speed 2	3.3
Low Speed	0.85
Passage of blades	**3*0.84=2.54 Hz**

0.84Hz (51RPM) - Frequency of the rotor

10.8Hz - Frequency of the 3rd shaft rotation

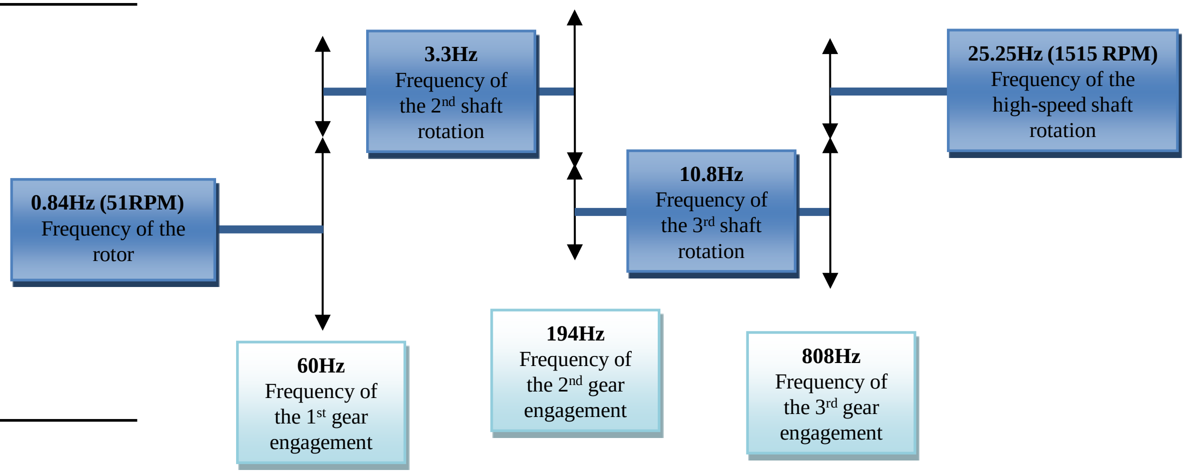
3.3Hz - Frequency of the 2nd shaft rotation

25.25Hz (1515 RPM) - Frequency of the high-speed shaft rotation

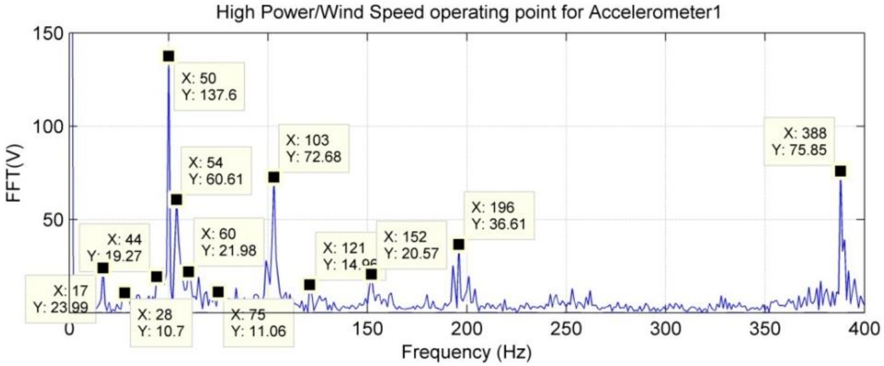
60Hz - Frequency of the 1st gear engagement

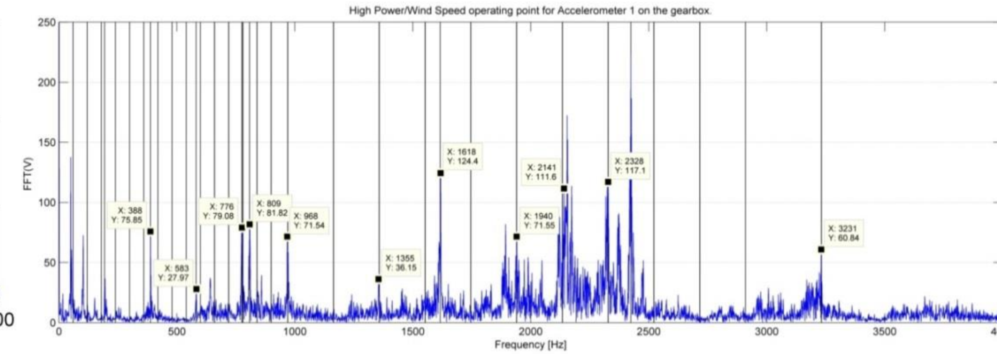
194Hz - Frequency of the 2nd gear engagement

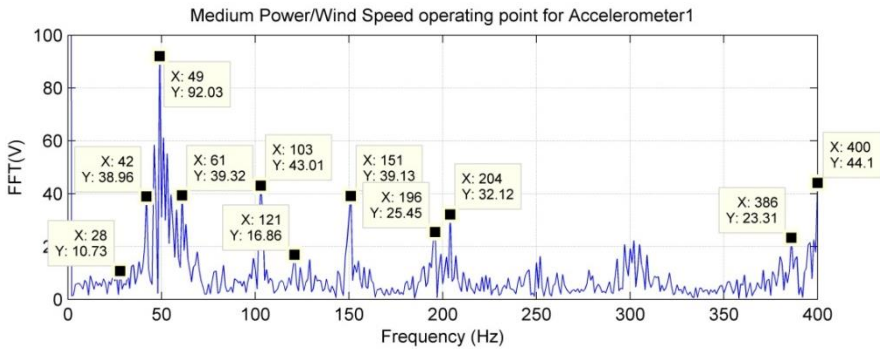
808Hz - Frequency of the 3rd gear engagement

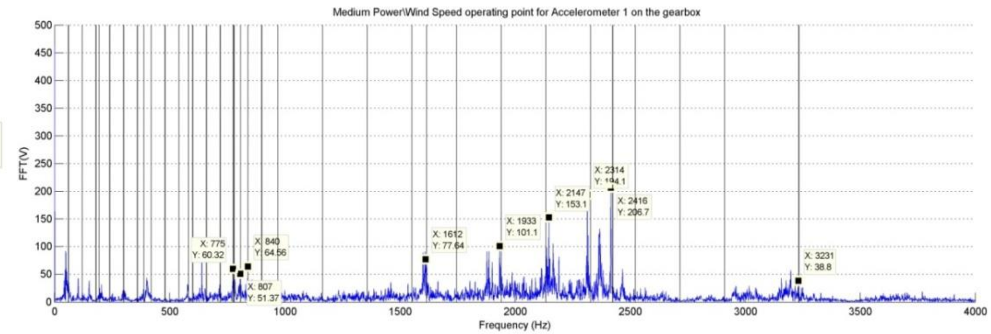


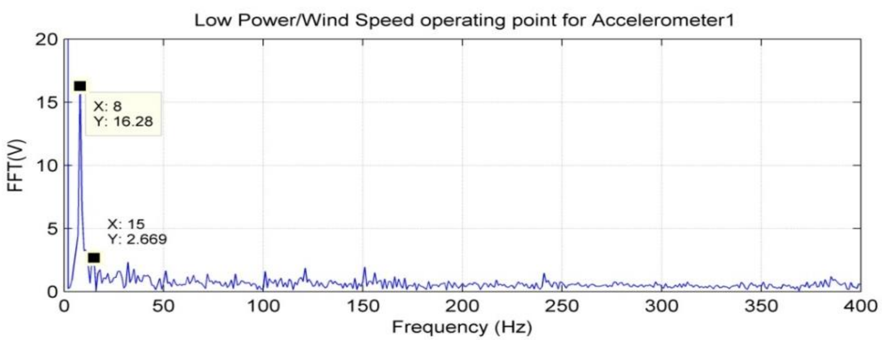
ACC data in frequency domain

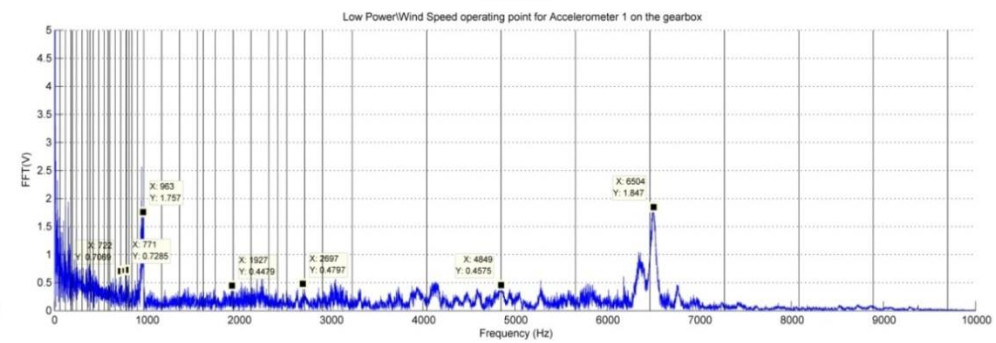












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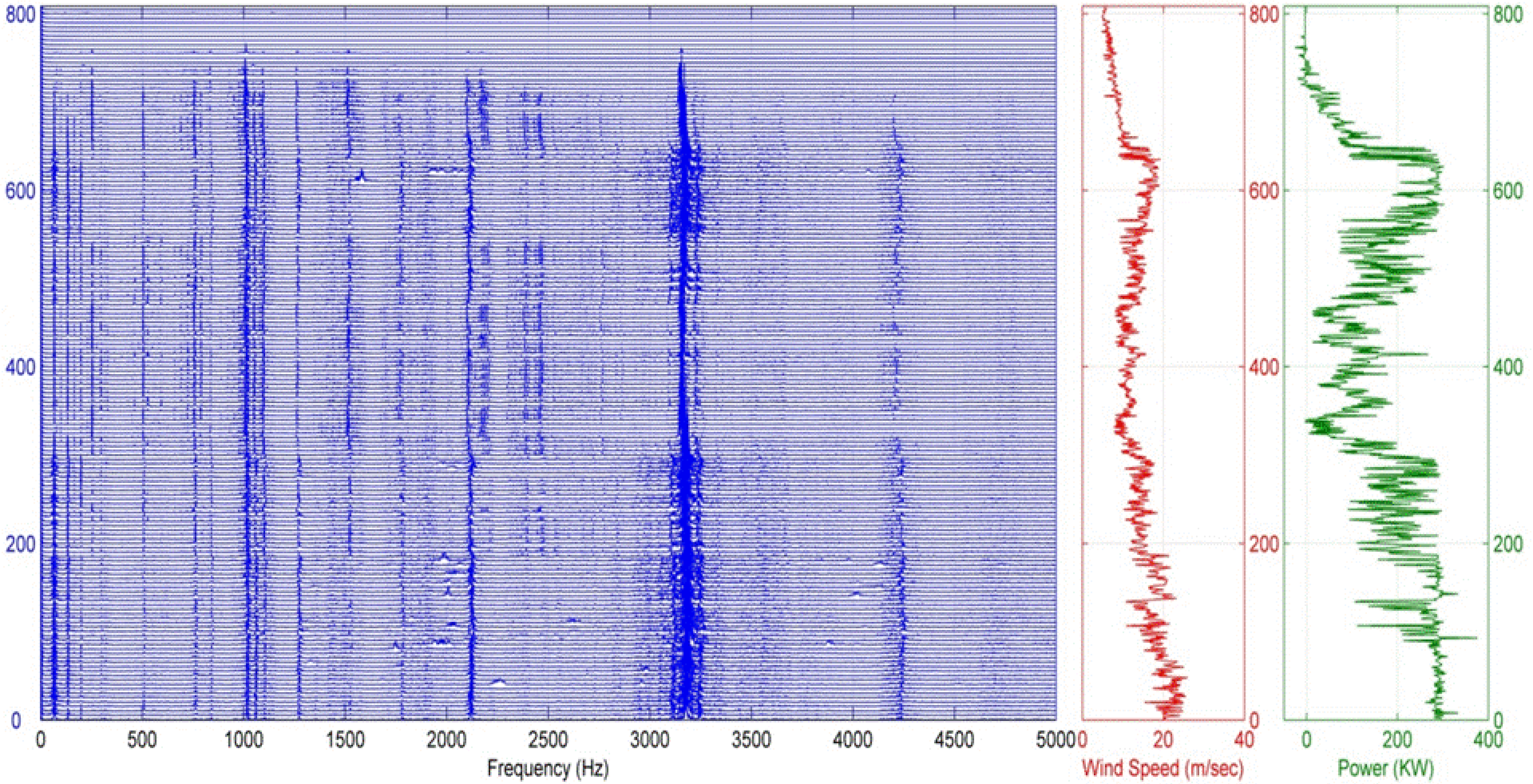
All ACC data in frequency domain



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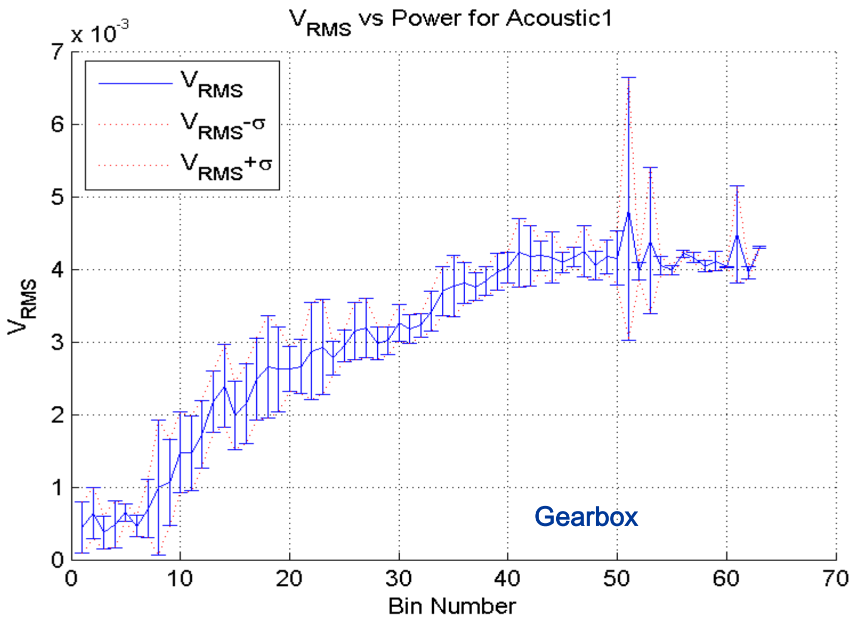
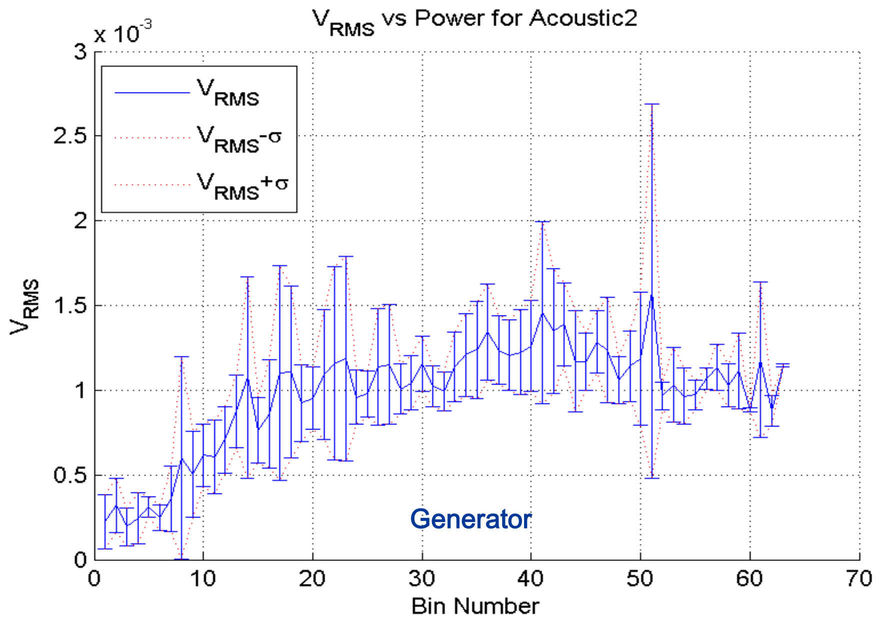
AE Signature Identification

- **The signature defined - for each sensor - taking into account a safety range offset of ±Std-Dev**





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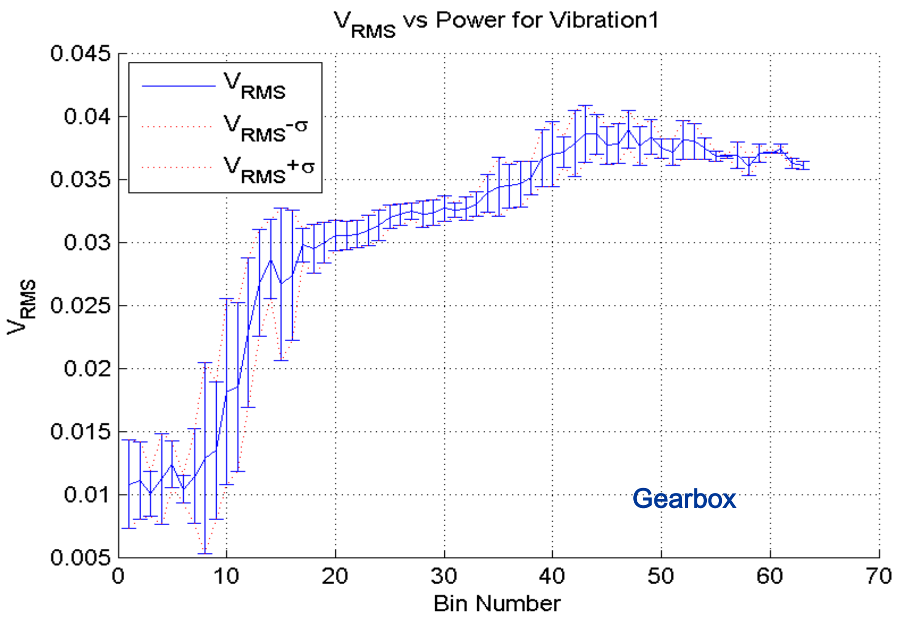
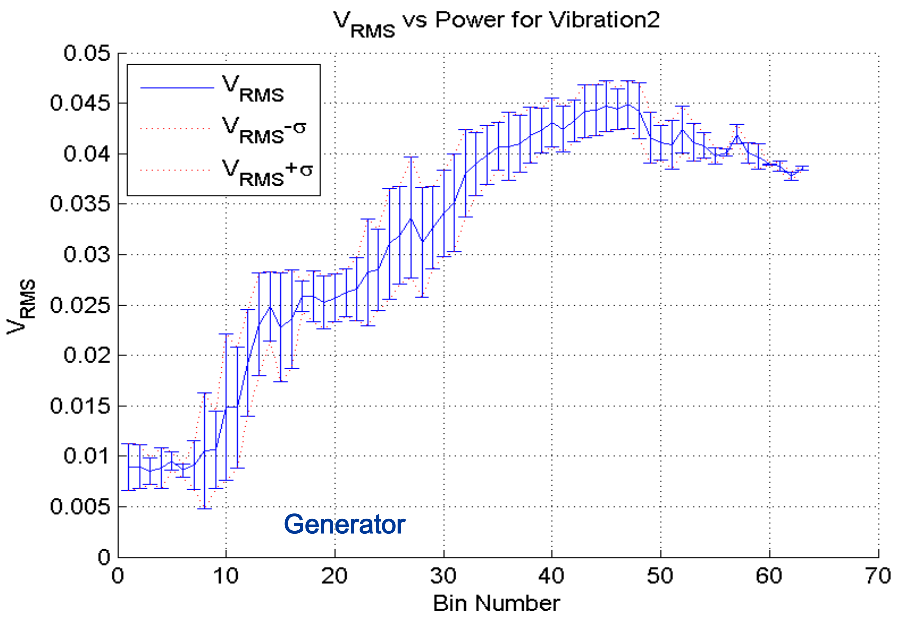
Vibration Signature Identification

- **The signature defined - for each sensor - taking into account a safety range offset of ±Std-Dev**





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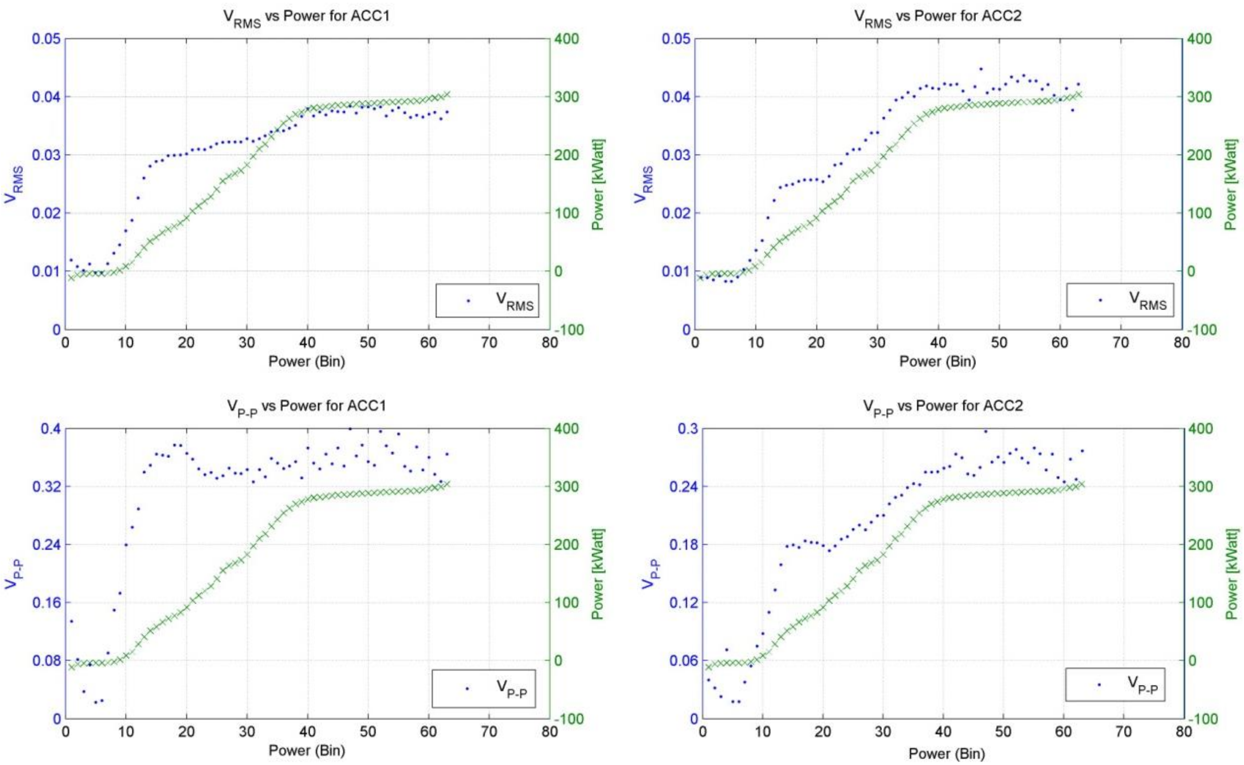
Correlation with Power data

- RMS and peak-to-peak data plotted for the whole operation power range bins



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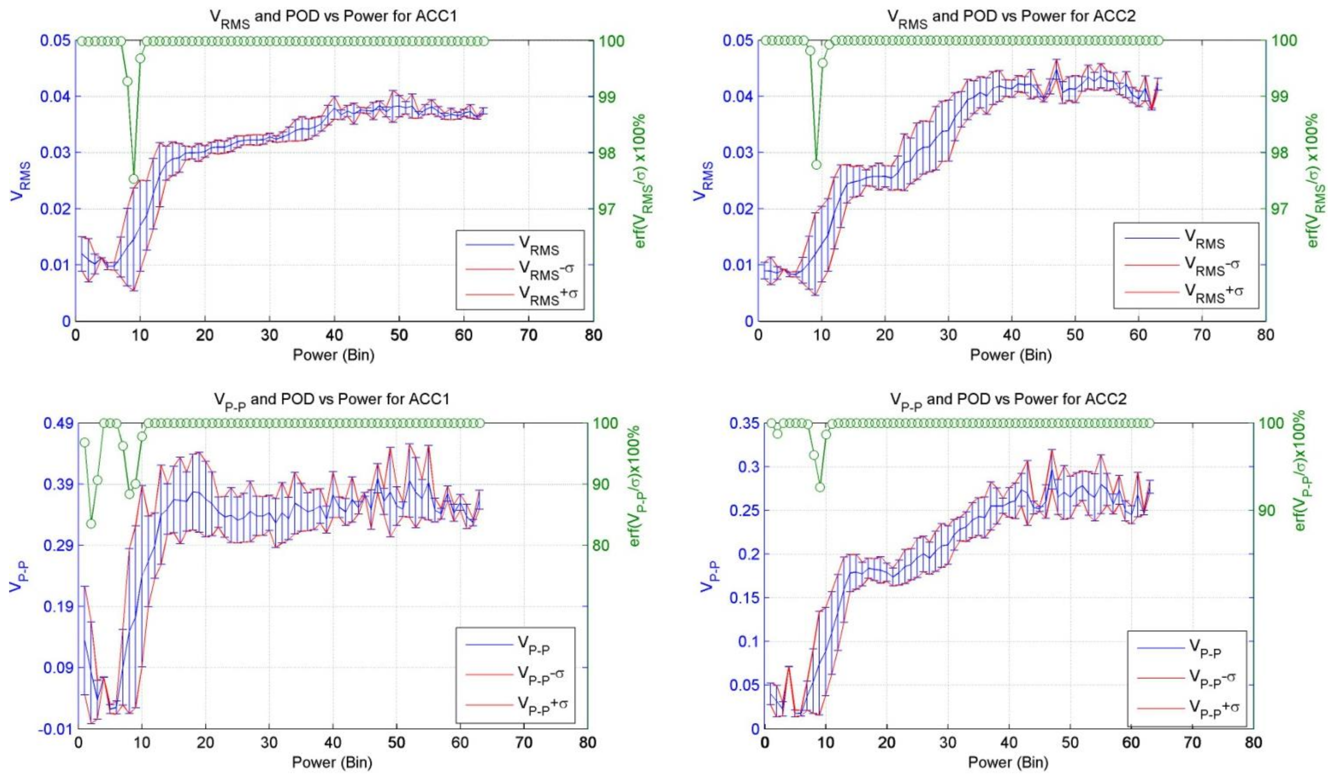
Standard Deviation and POD

- The signatures for safety range offset of $\pm\sigma\{V_{RMS}\}$ and of $\pm\sigma\{V_{P\text{-}P}\}$.



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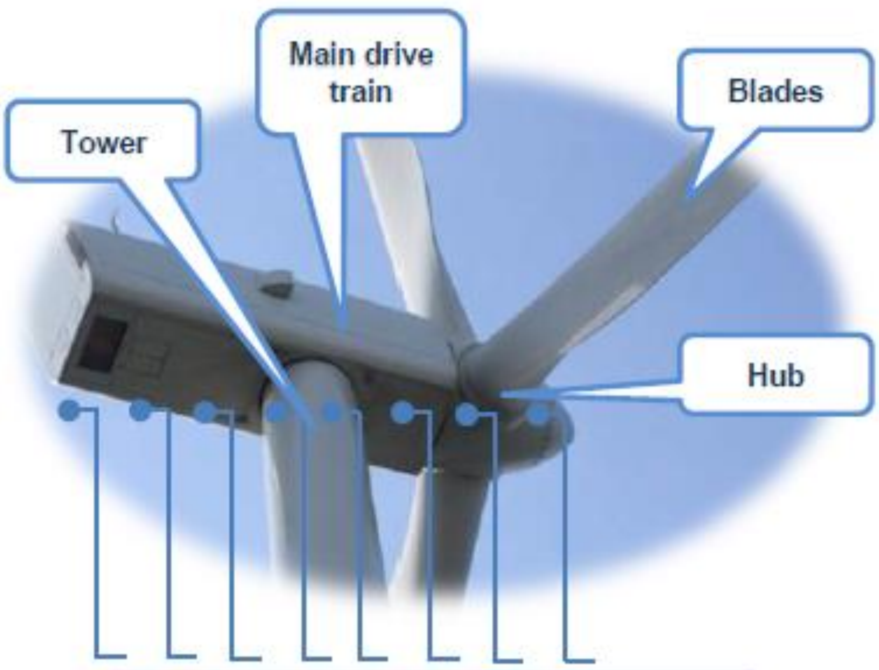
CM/SHM at TWI

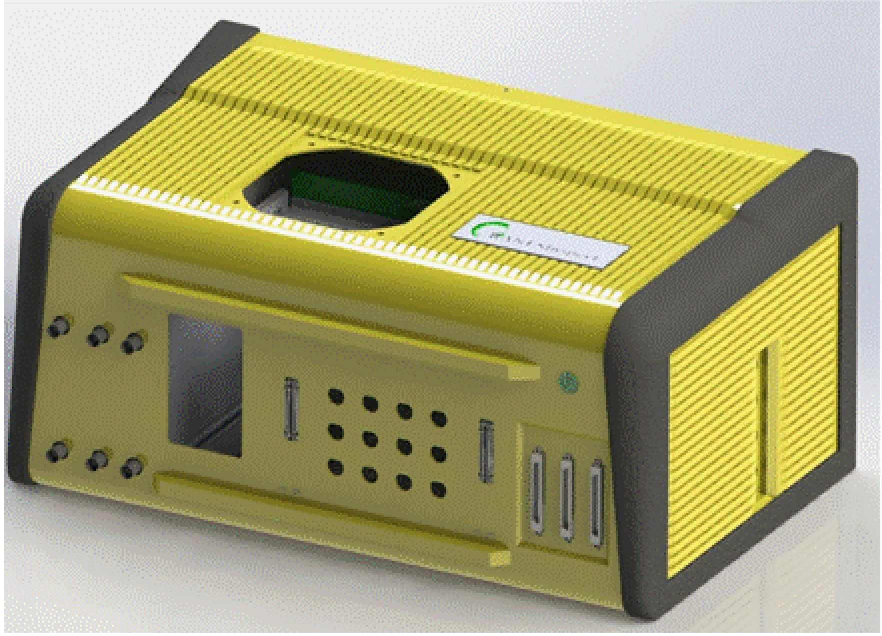
Benefits

- Optimise maintenance and inspection interventions
- Minimise risk of failure (advance warning)
- Real time remote data acquisition and analysis

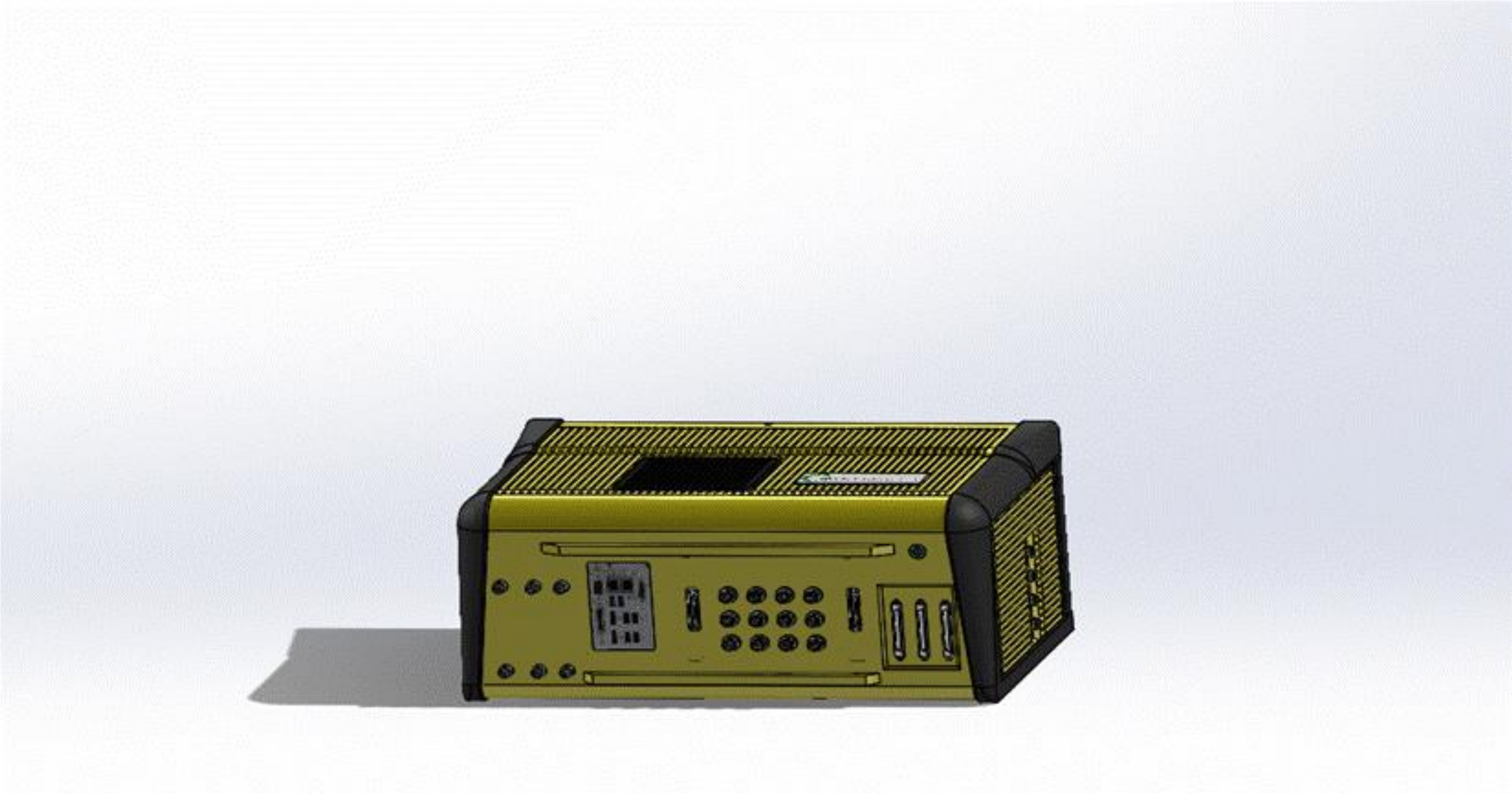


Sensors distribution

16 inputs @ 2MSam/Sec for AE SHM
16 inputs @ 250KSam/Sec for CM
16 parametric inputs



CM/SHM system



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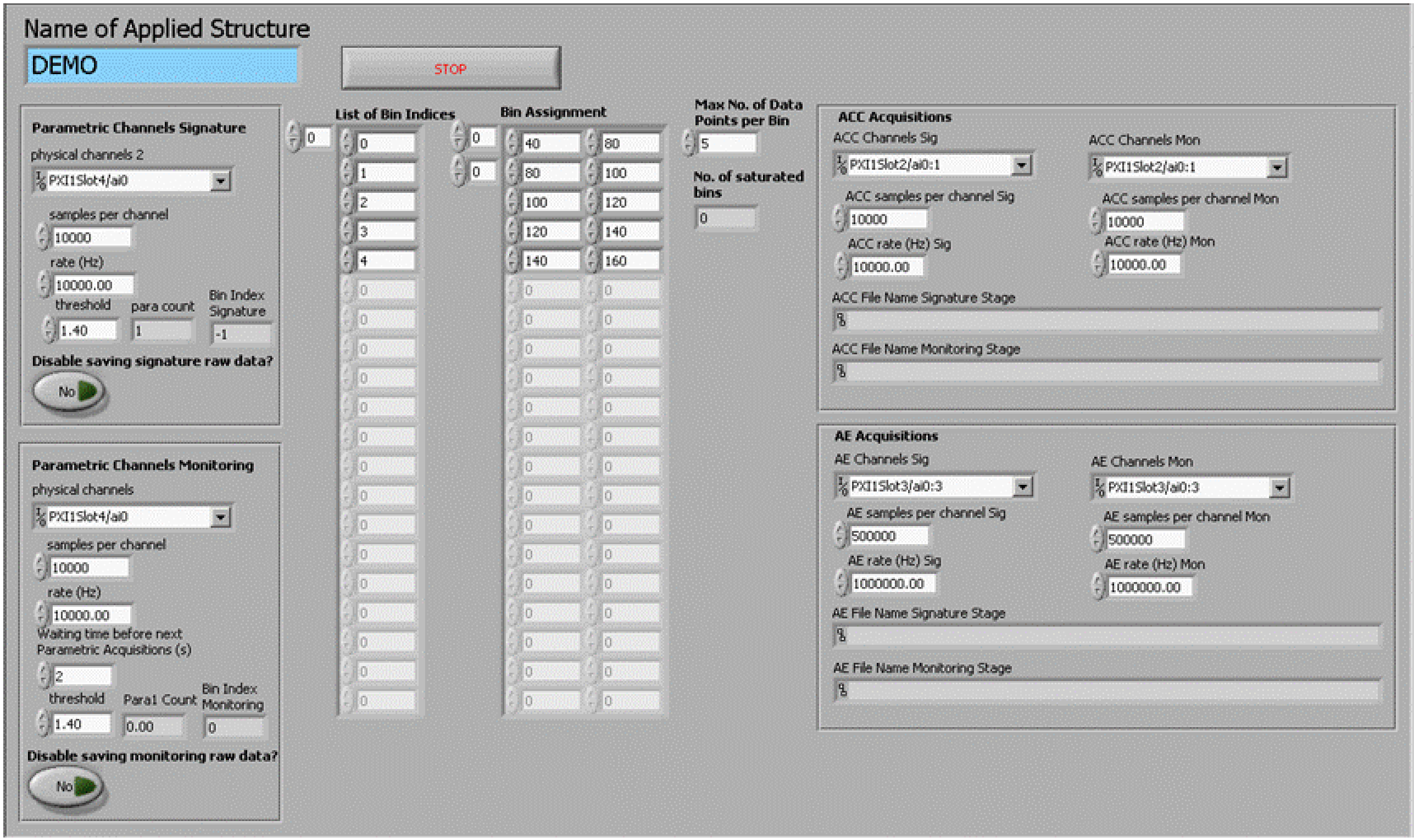
Demonstration



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Conclusions

- AE: Advancement to market
- AE: Wind market for CM/SHM
- Variable speed operation.
- Business plan for CM/SHM.

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In-Service Inspection of Wind Turbine blade roots

Giorgos Asfis, Project Leader, NDT Section
Fredrik Hagglund, Senior Project Leader, NDT Section
Ivan Pinson, Section Manager, NDT Section

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Background

- TWI was approached by member company with a component failure.
- Phased array ultrasonic inspection by the manufacturer did not provide exact flaw details.
- TWI was asked to replicate manufacturer's inspection and determine crack locations.

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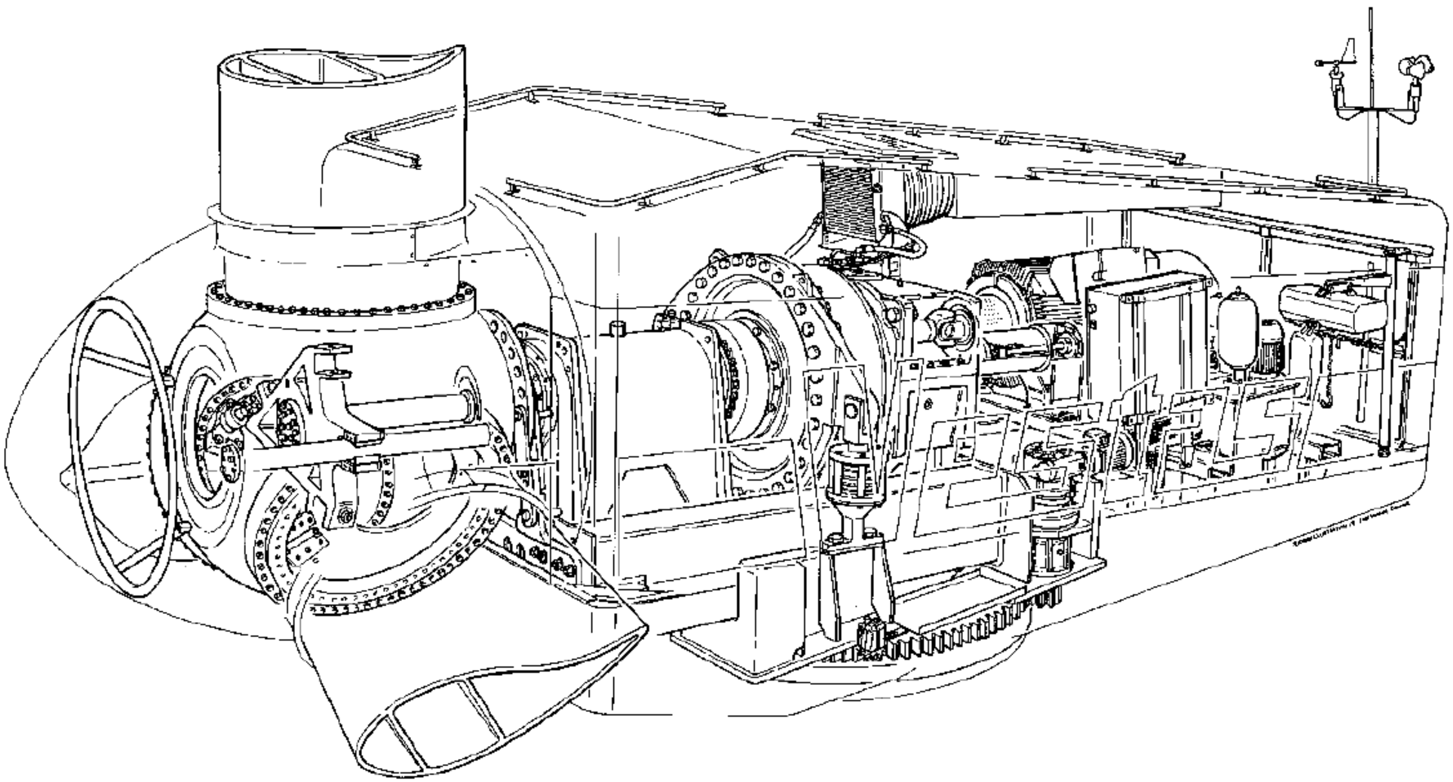
Turbine models

Vestas V42-600kW & V47-660kW



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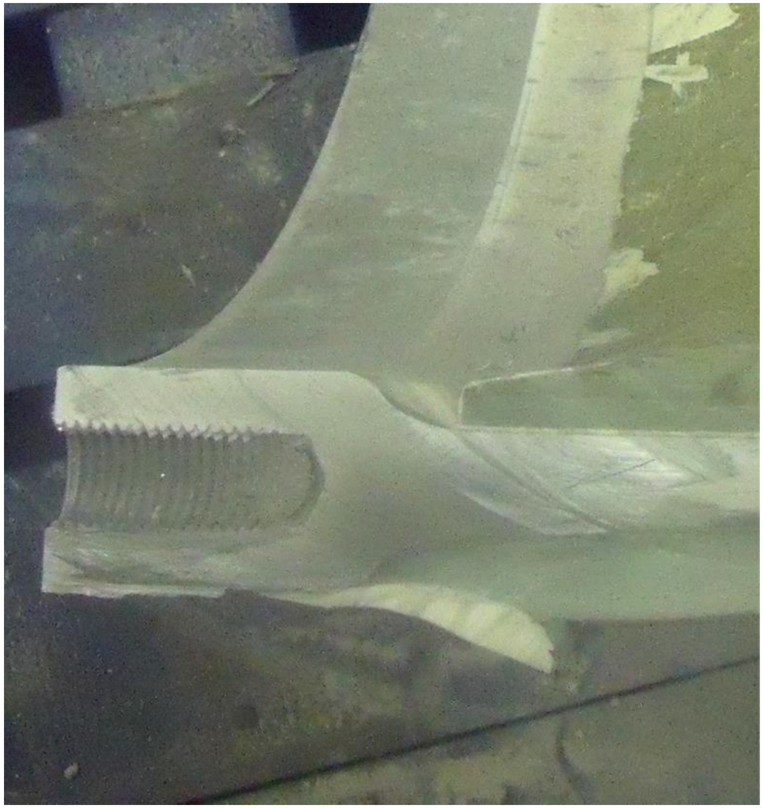
Turbine component

Bolthole of blade root



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Component Details

- Continuous aluminium construction

- 60 boltholes, 1m diameter, approximately 3m external circumference

- M20 bolts with depth of roughly 50mm

- Composite material is covering the root suspect area

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Workscope

- Development of a suitable technique to inspect the blade roots
- Report any cracks in the aluminium ring main body
- Validate results provided by the manufacturer’s personnel

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Results

- Several visits on wind turbine farms were needed before a technique could be developed. The best insight was gathered from the failed component.

- Cracks can be detected within the ring

- Data correlates with manufacturer’s previous inspections.

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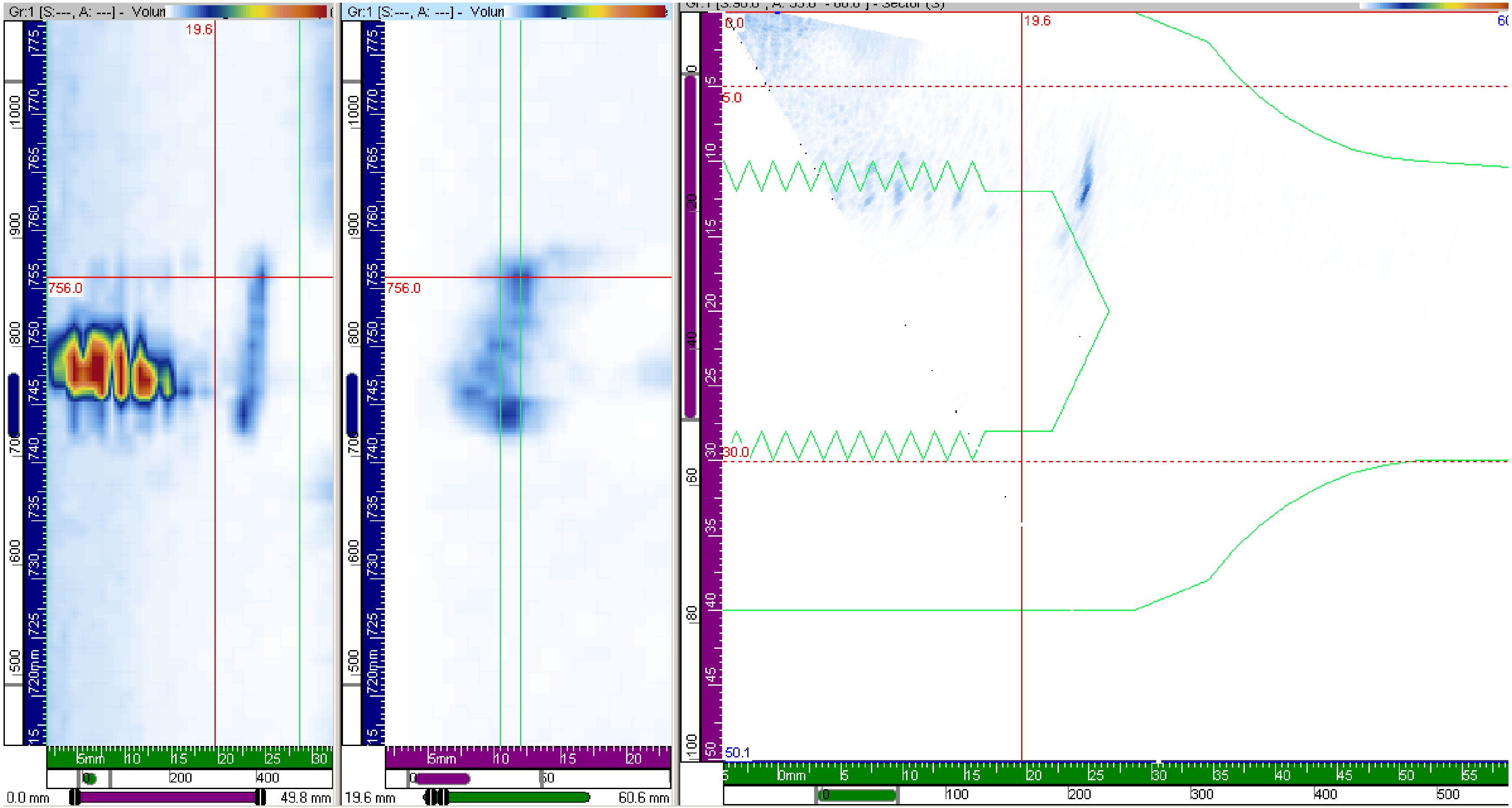
Example results



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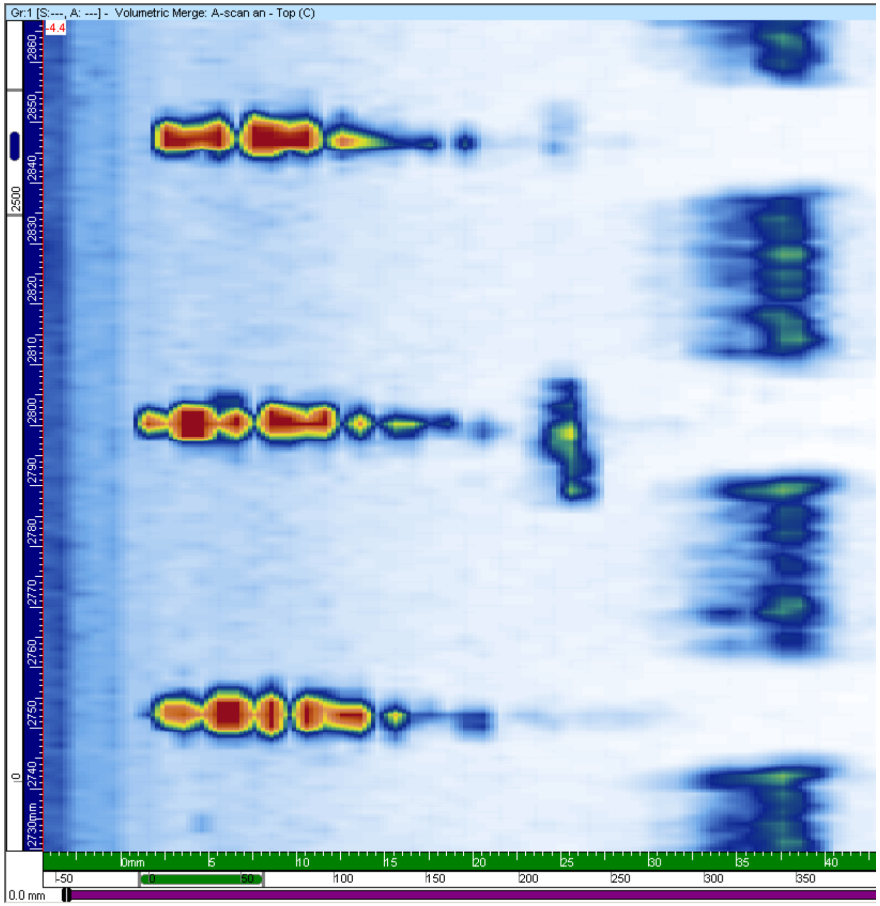
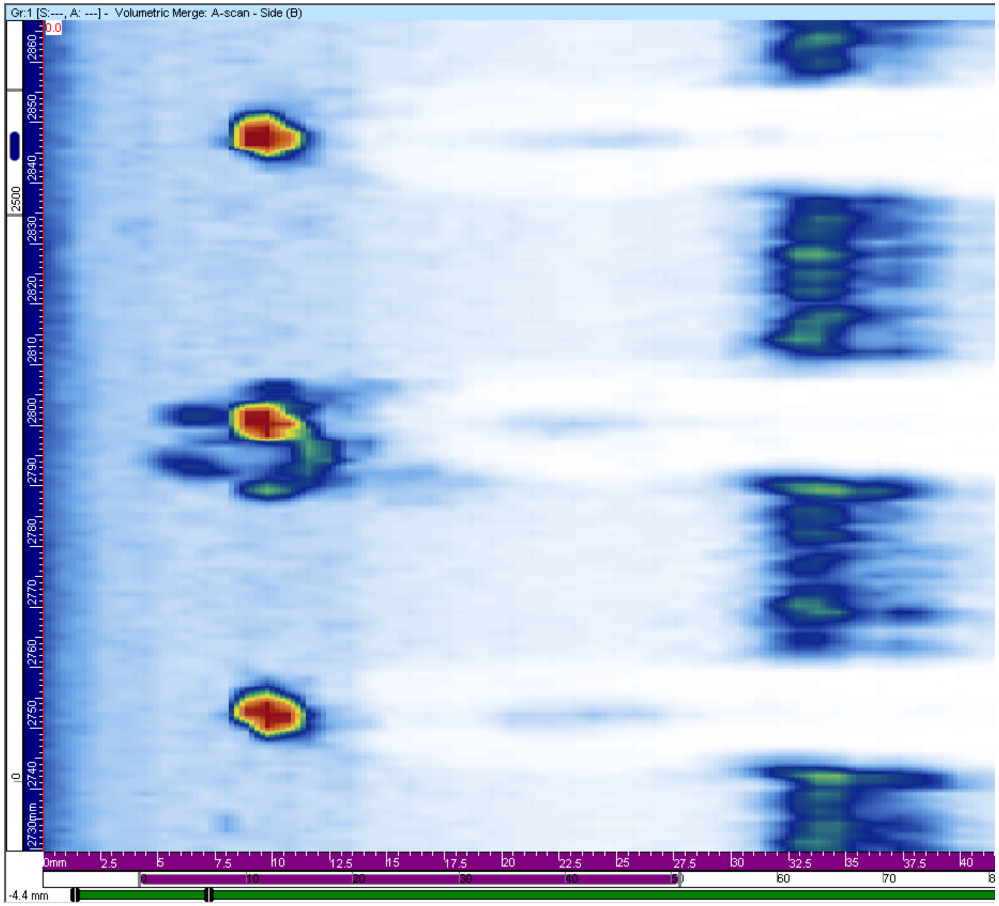
Example Results





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Acceptance Criteria

- These inspections appear to be outside the scope of current codes

- Current advice is based on total circumferential length of cracks

- Circumferential length is easily proven inadequate as in several cases individual cracks are suspected to have reached the outer surface.

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Engineering Critical Assessment

- With over 40 years experience, TWI considers it more appropriate to adopt ECA.
- NDT results can be used to classify the blade root in terms of safe remaining life. (e.g. Unfit, 1year remaining, 2 years)
- The ECA approach will use size (length and height), position and orientation of flaws.

Future Potential

- V42s and V47s are widely sold and most of them are reaching 15+ of age.
- Similar designs most likely will have the same condition (V44, G42, G44, G47 by Gamesa).
- Larger V66s are coming to age.

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Thank you,

Any Questions?

Contact:
Ivan Pinson
ivan.pinson@twi.co.uk

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Condition Monitoring of Wind Turbine Components

Vichaar Dimlaye
Graham Edwards
TWI Ltd,
16/07/2013

Outline to Presentation

- Tower Monitoring
  - INSIGHT Project/ Onshore Tower Monitoring
  - TowerPower Project/ Offshore Tower and Supporting Structure Monitoring

- Blades Monitoring
  - WinTur Project
  - WinTurDemo

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Objectives of INSIGHT Project

- To develop novel technology for the continuous monitoring of the tower structures using Non Destructive Testing (NDT) methods such as Guided Wave Testing (GWT) .
- To provide remote access to the monitoring system
- Demonstrate the application of this system on an actual Wind Turbine

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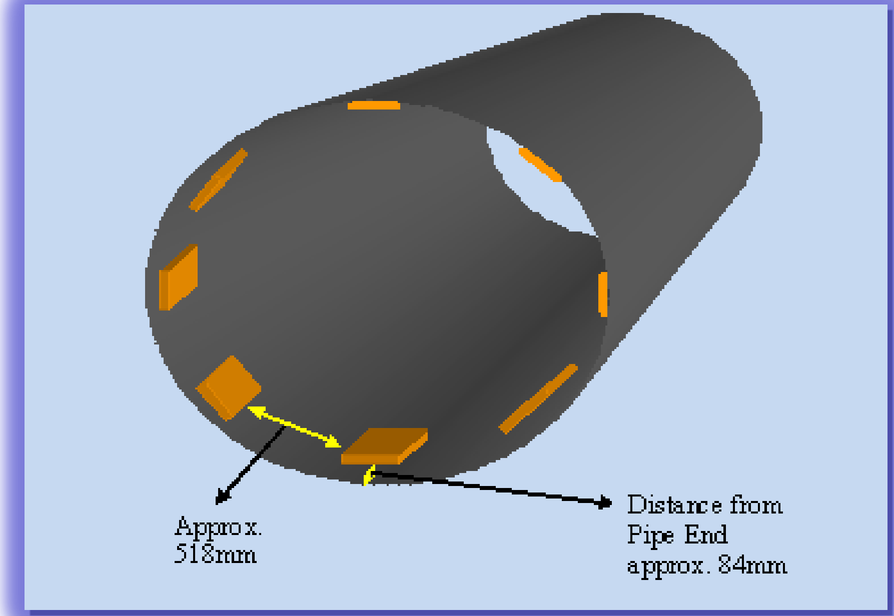
Experimental Set-Up

48” Pipe

Transducers Network



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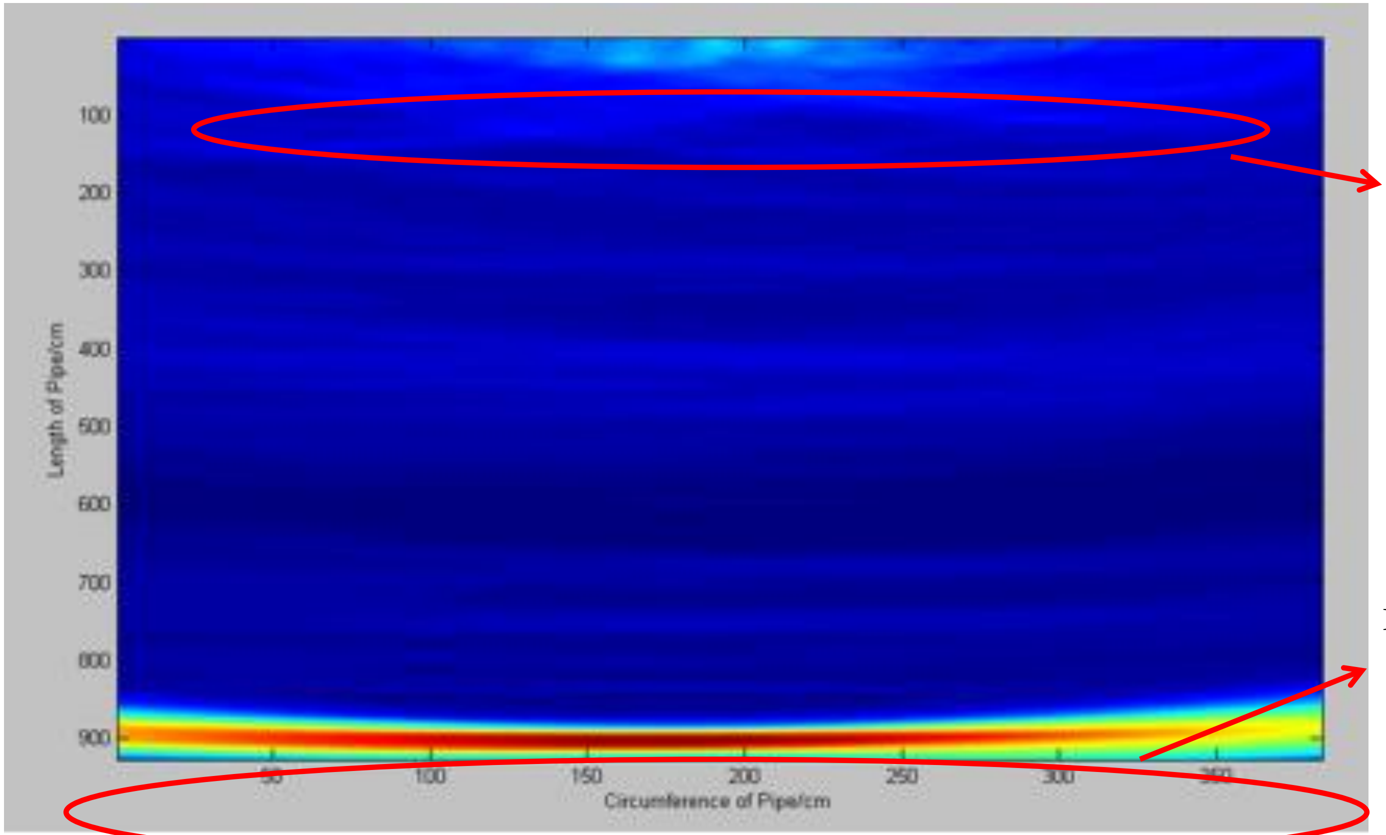
Baseline Pipe Image



Energy from Transducers Network

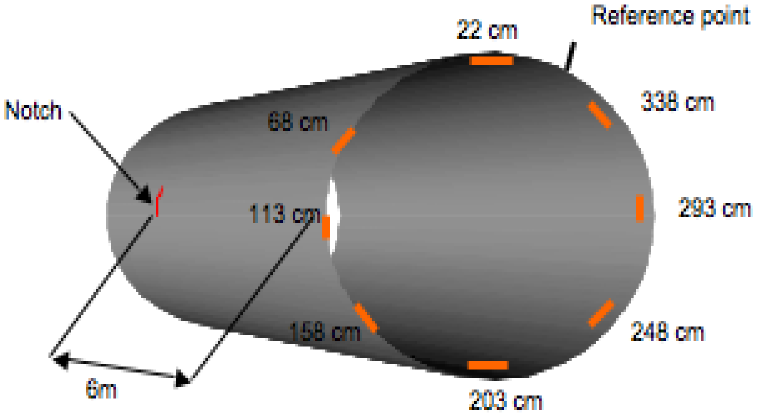
Energy from Pipe En

Length of Pipe

Circumference of Pipe

Defect Detection

- A notch cut of length 220mm and max depth of 8mm, hence 3% cross-sectional area loss was introduced on the pipe.



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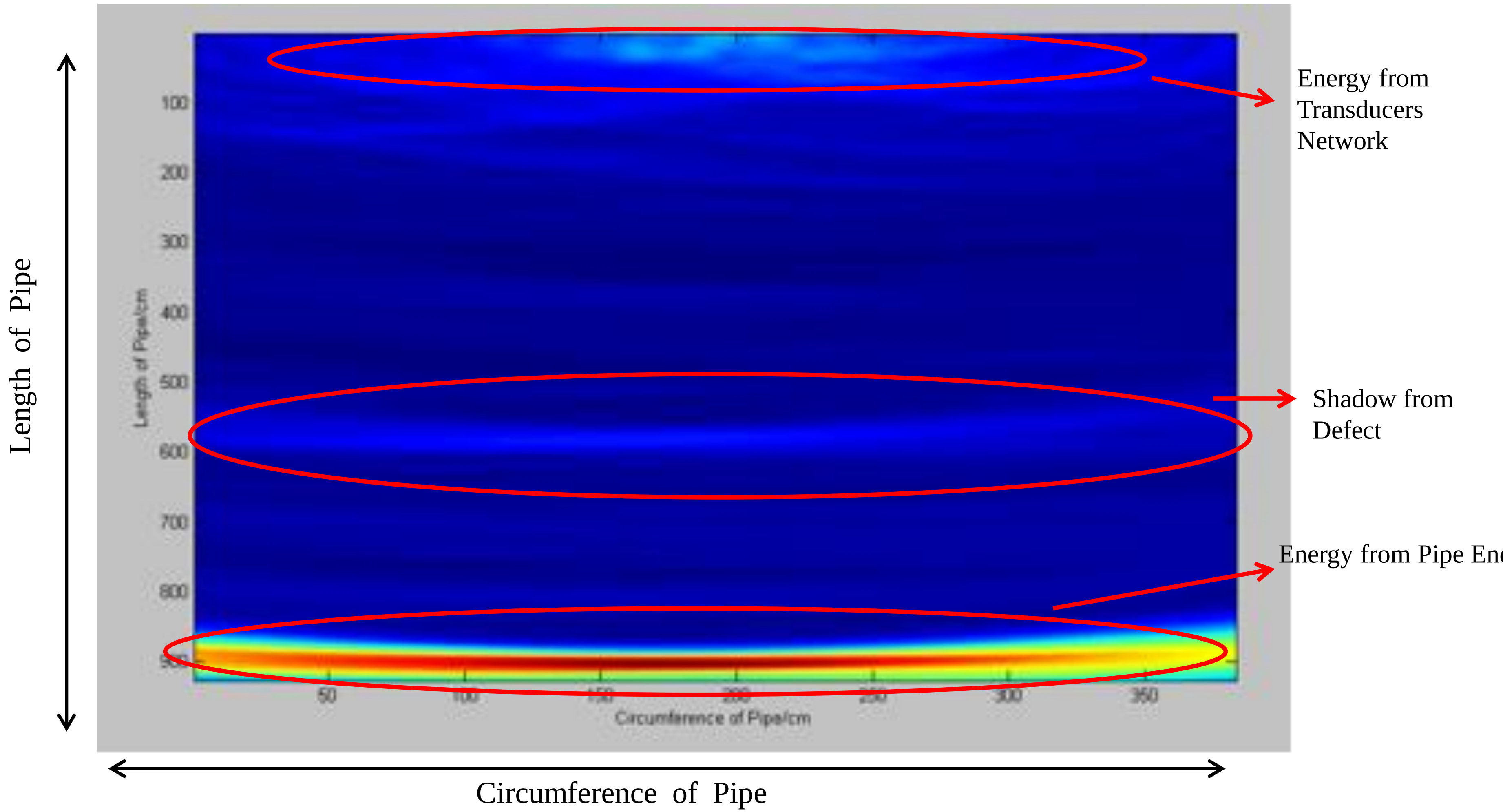
Post-Defect Pipe Imaging



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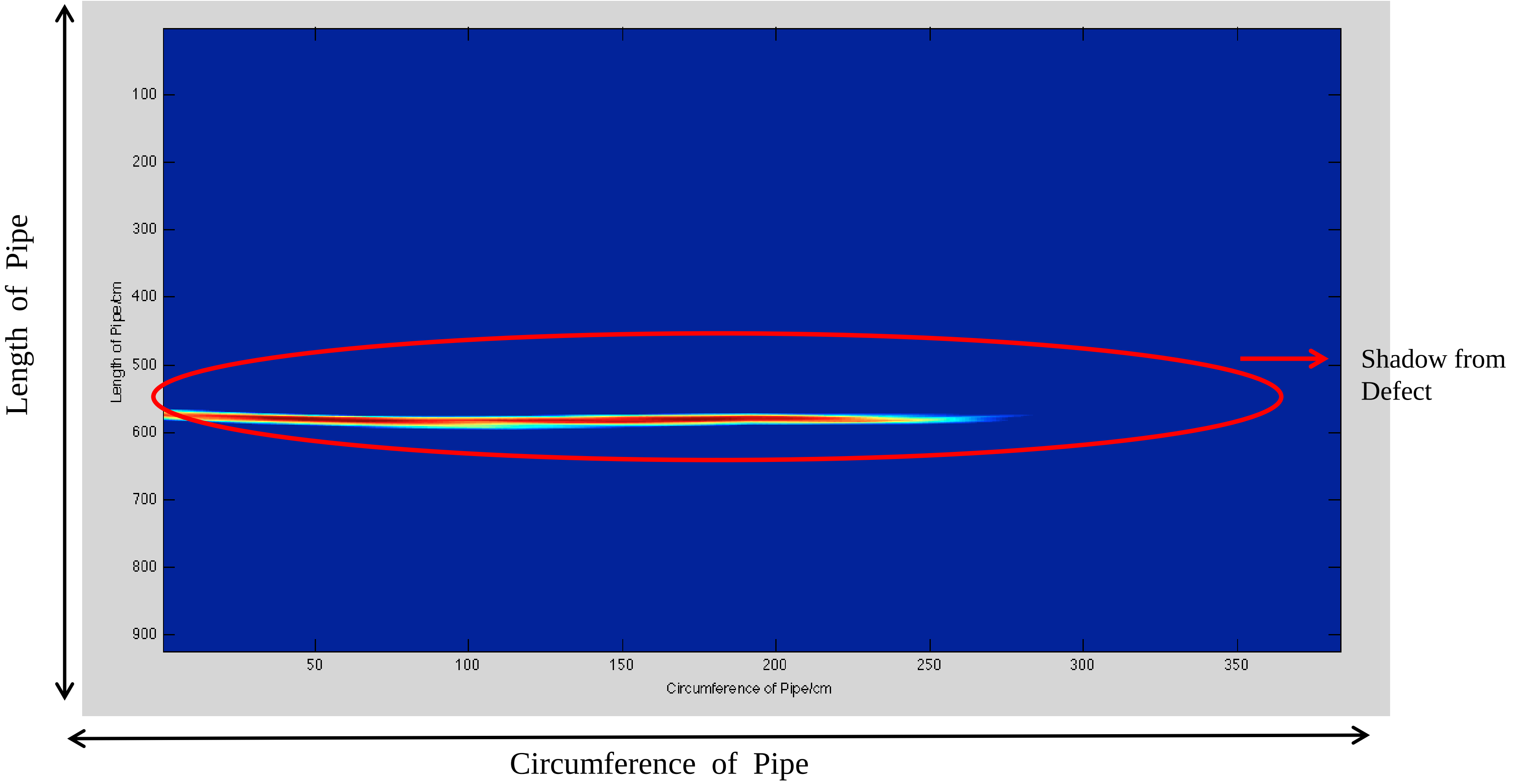
Baseline Subtraction Pipe Imaging



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Onshore Demonstration System, December 2010

1MW NEG Micon Wind Turbine,
Myres Hill,
Glasgow
TUV NEL

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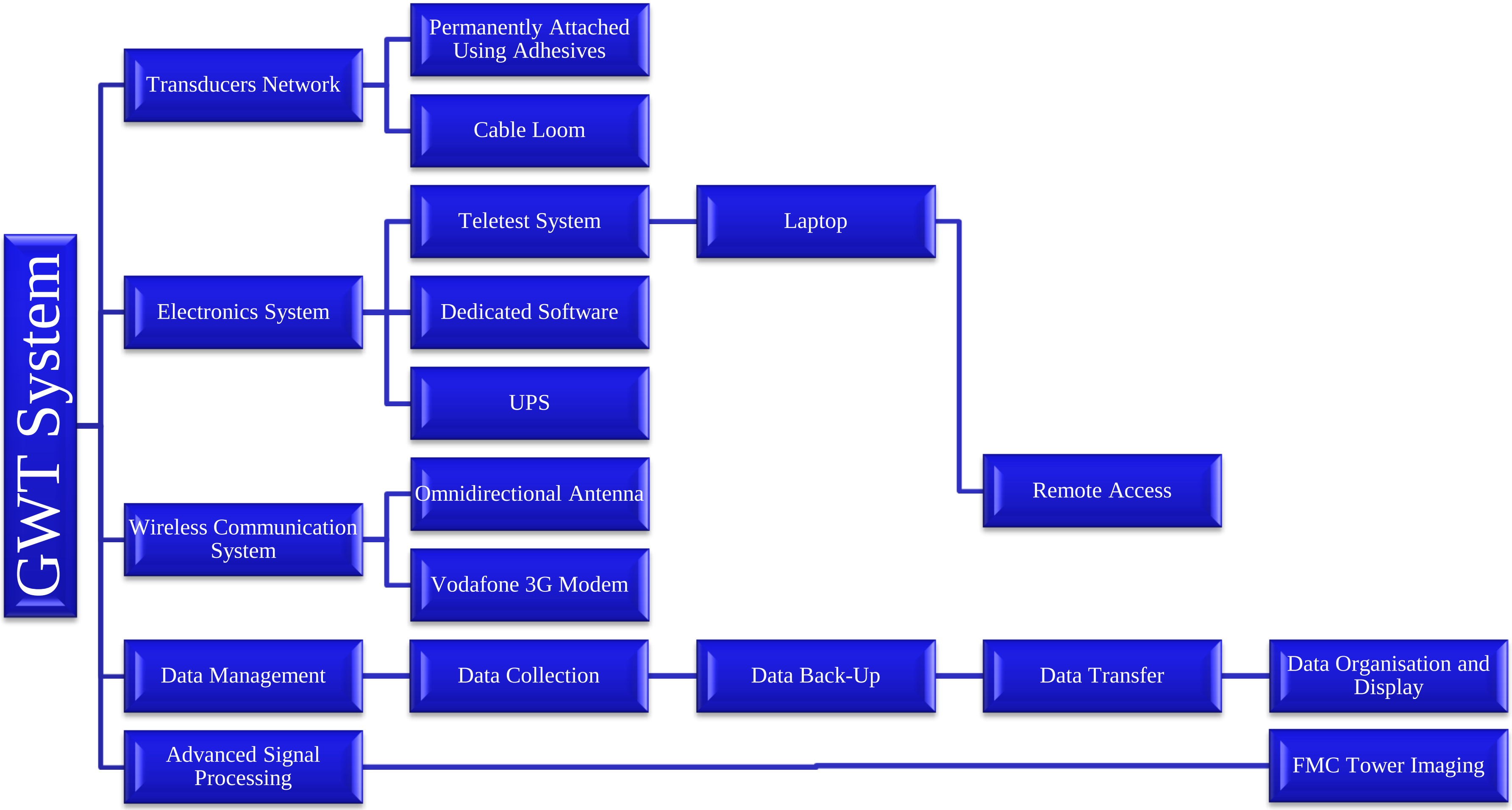
Taxonomy of GWT



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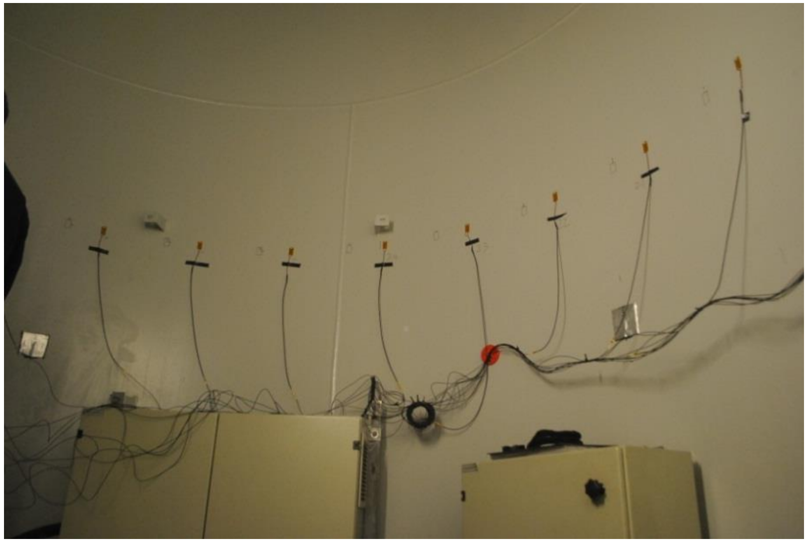
Transducers Network

- 24 transducers are permanently attached at regular spacing around the inside circumference of the tower. The network is approx. 7m from ground level.



Electronics System

- A modified Teletest Focus system is used to provide a 24 channel pulser-receiver.
- Power Failure Management –UPS
- Laptop with dedicated Software

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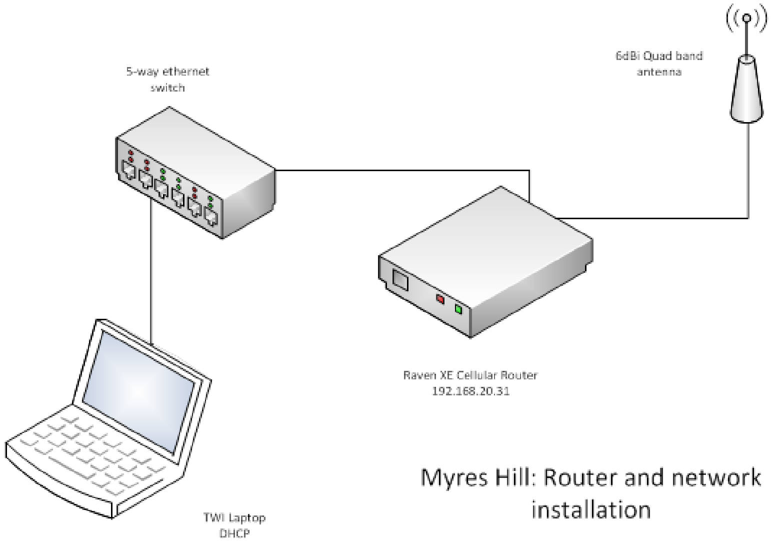
Wireless Communication

- RFI CD2195 Quad band, marine grade antenna
- Provides 6.5dBi gain on 3G/GSM at 900MHz and 3dBi gain on 3G/GSM at 1800 and 2100 MHz.



Myres Hill: Router and network installation

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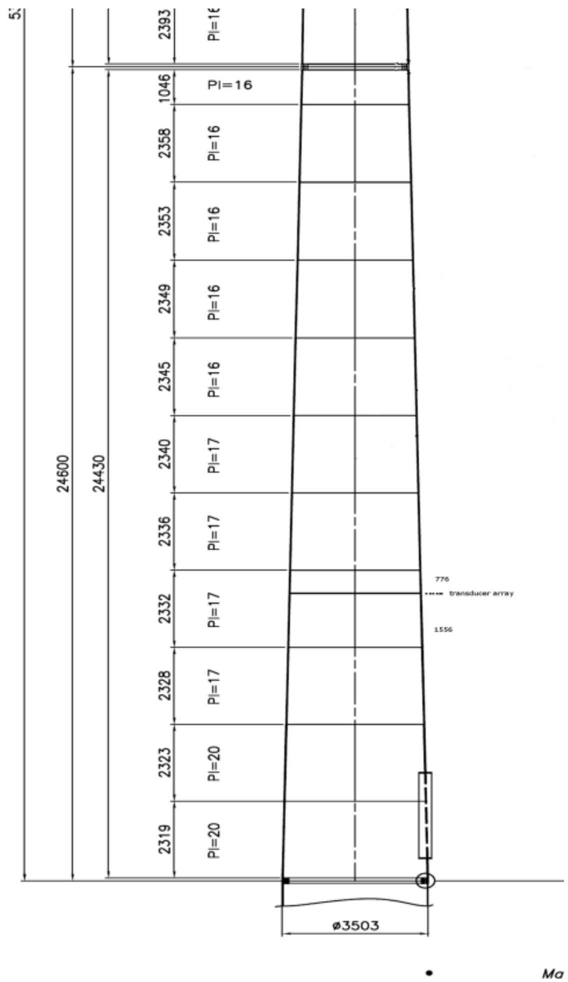
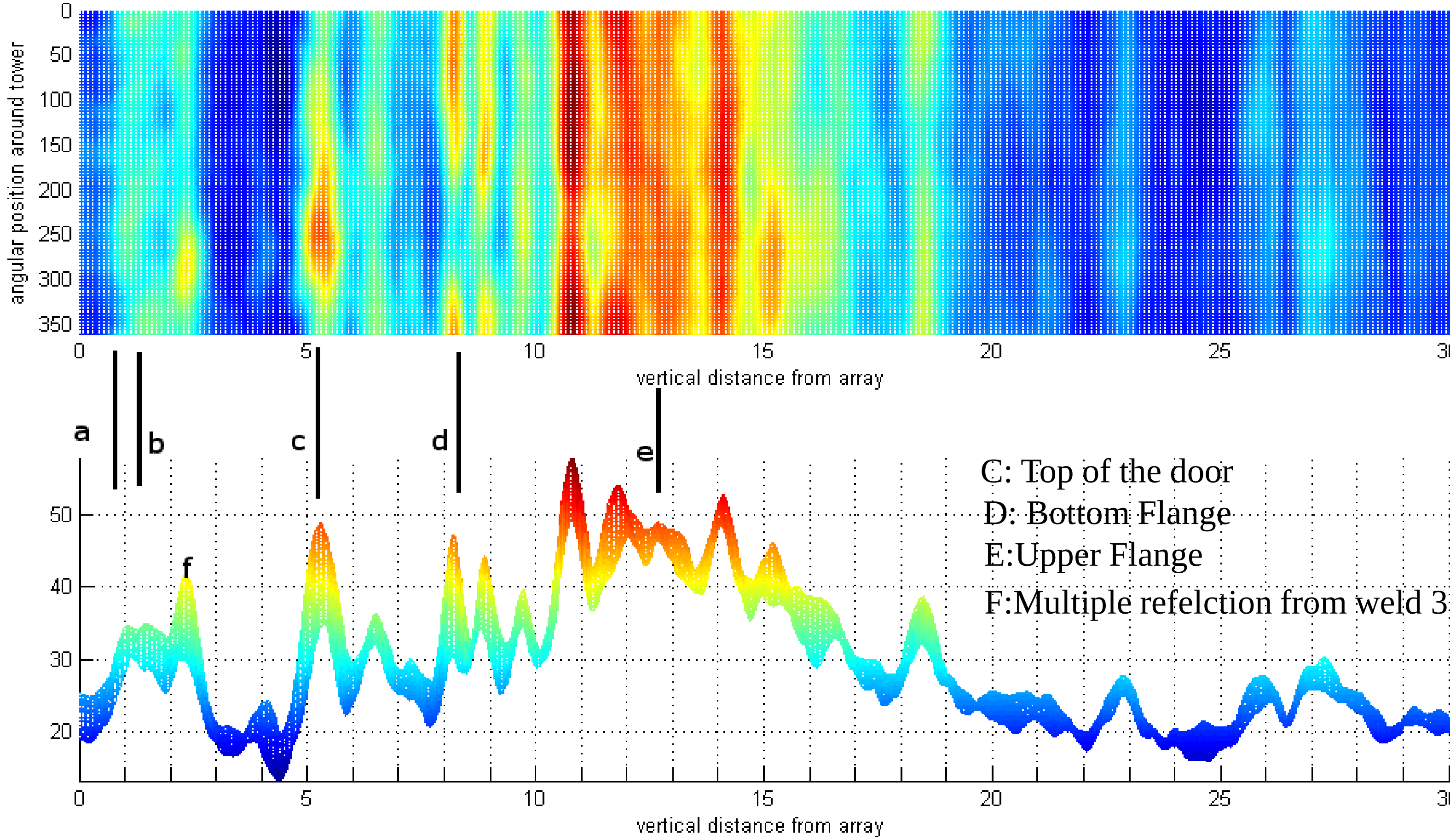
FMC Imaging of Tower



feature	distance to next feature (mm)	distance from array (mm)
flange	1048	13560
weld 9	2358	12512
weld 8	2353	10154
weld 7	2349	7801
weld 6	2340	5452
weld 5	2336	3112
weld 4	776	776
Transducers		
weld 3	1556	1556
weld 2	2328	3884
top of door	1442	5326
weld 1	881	6207
flange	2319	8526

FMC Imaging of Tower



1st weld above and below the array is at a and b resp.

C: Top of the door
D: Bottom Flange
E:Upper Flange
F:Multiple refelction from weld 3 and 4

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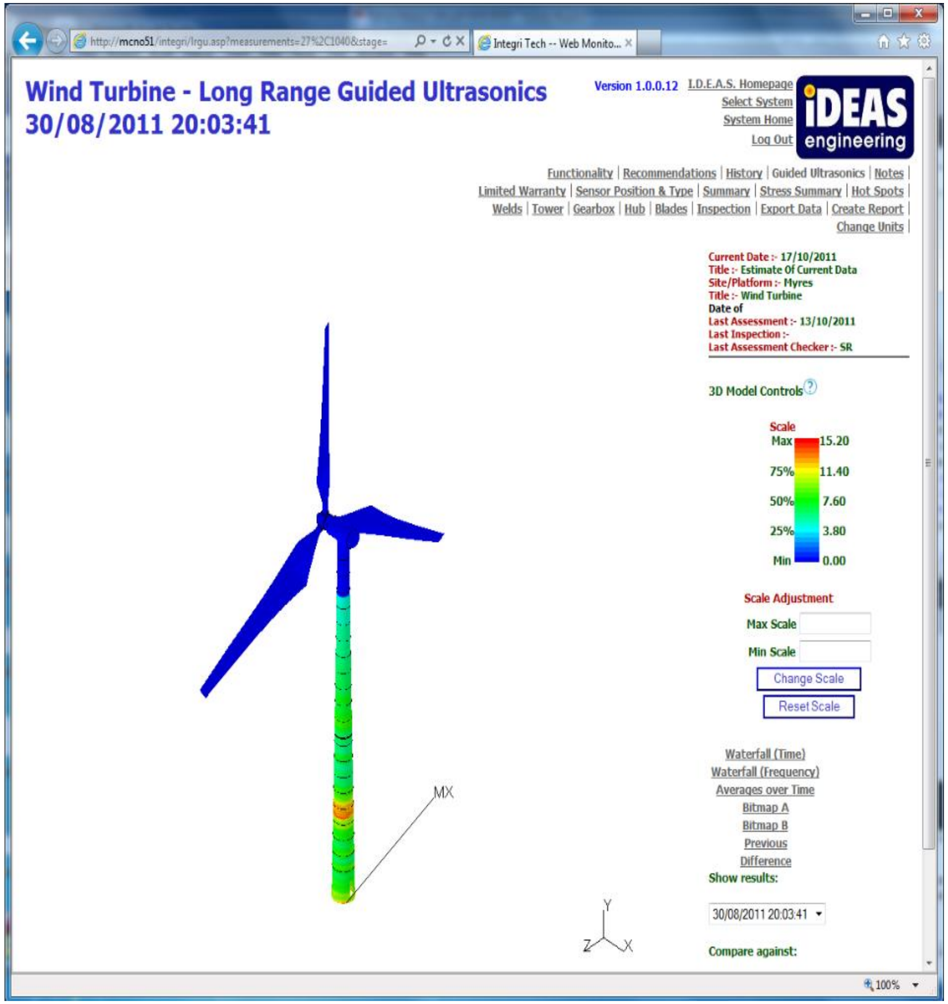
Online Monitoring Software

- Automated transfer of data to online monitoring software.
- Display of tower imaging.
- Historical time domain and frequency domain data.



System Capabilities

- Stable performance of the permanent transducers since installation.
- Teletest System providing a stable pulser-receiver electronics performance, with no downtime.
- Uninterrupted automated data collection on timely schedule, 4 times every 24 hours.
- Ability to dial into system for manual data collection or system check up through remote access to Teletest System
- Automated data transfer to server , for post-data processing and display of data.
- Tower imaging by using FMC technique providing pictorial view of the “healthiness” of the tower over time

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Continuous monitoring of the structural condition of the tower and supporting structure of floating and static offshore wind turbines

‘TowerPower’ 3 year FP7 project

To start Nov. 2013

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TowerPower Consortium

Beneficiary name	Beneficiary type	Country	Date enter project	Date exit project
Capenergies	SME-AG	France	1	36
Hub North	SME-AG	Denmark	1	36
AGRUPACION PYME PARA LA SINERGIA EN I MAS D SL	SME-AG	Spain	1	36
Associazione Italiana Prove Non Distruttive	SME-AG	Italy	1	36
Kingston Computer Consultancy Limited	OTH	UK	1	36
Smithers Purslow Property Services	OTH	UK	1	36
Teknisk Data AS	OTH	Norway	1	36
WLB Limited	OTH	Cyprus	1	36
Centre Technique des Industries Mecaniques	RTDP	France	1	36
Innora Proigmena Technologika Systimata Kai Ypiresies Anonymi Etaireia (AE)	RTDP	Greece	1	36
TWI Limited	RTDP	UK	1	36

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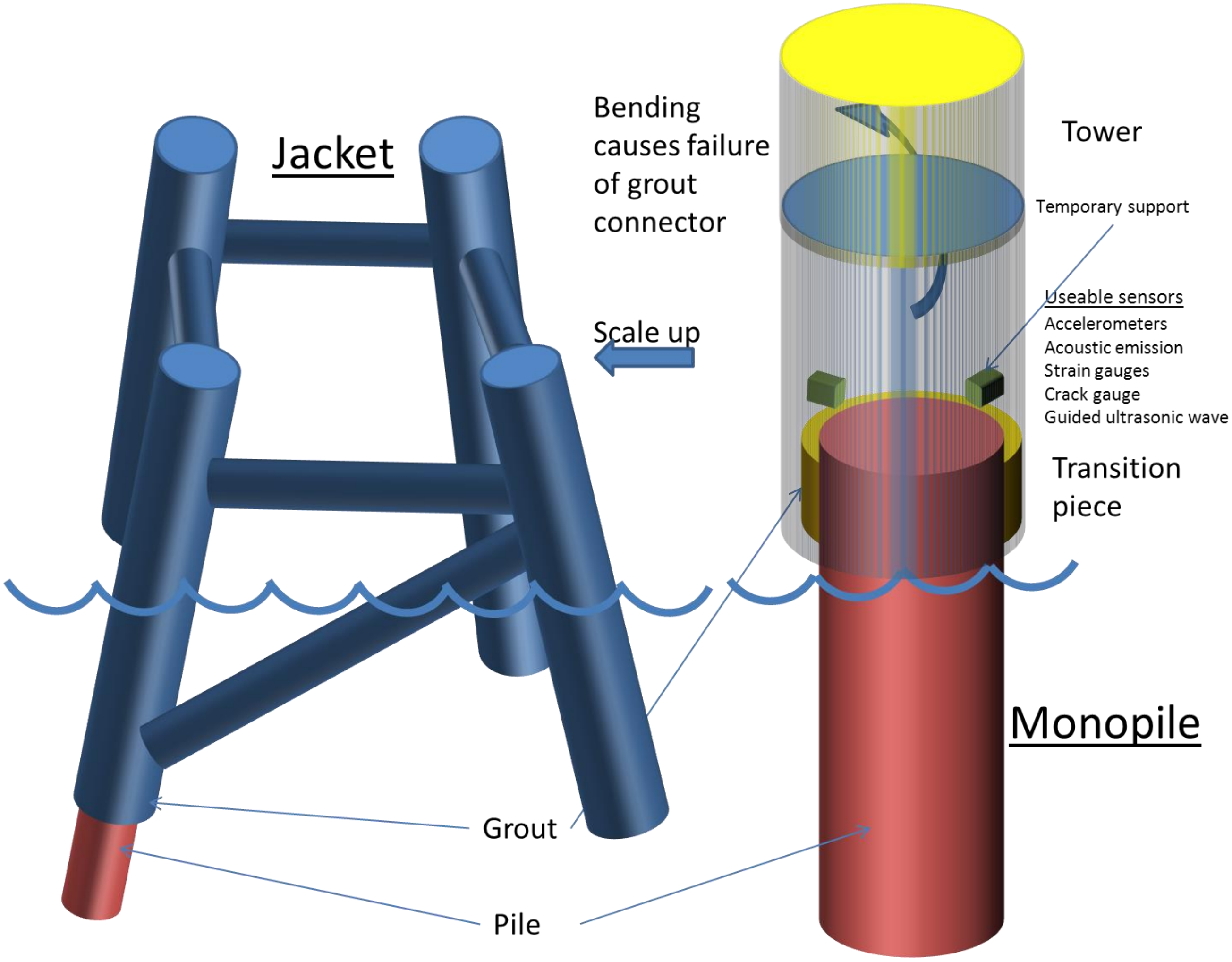
The principal problem



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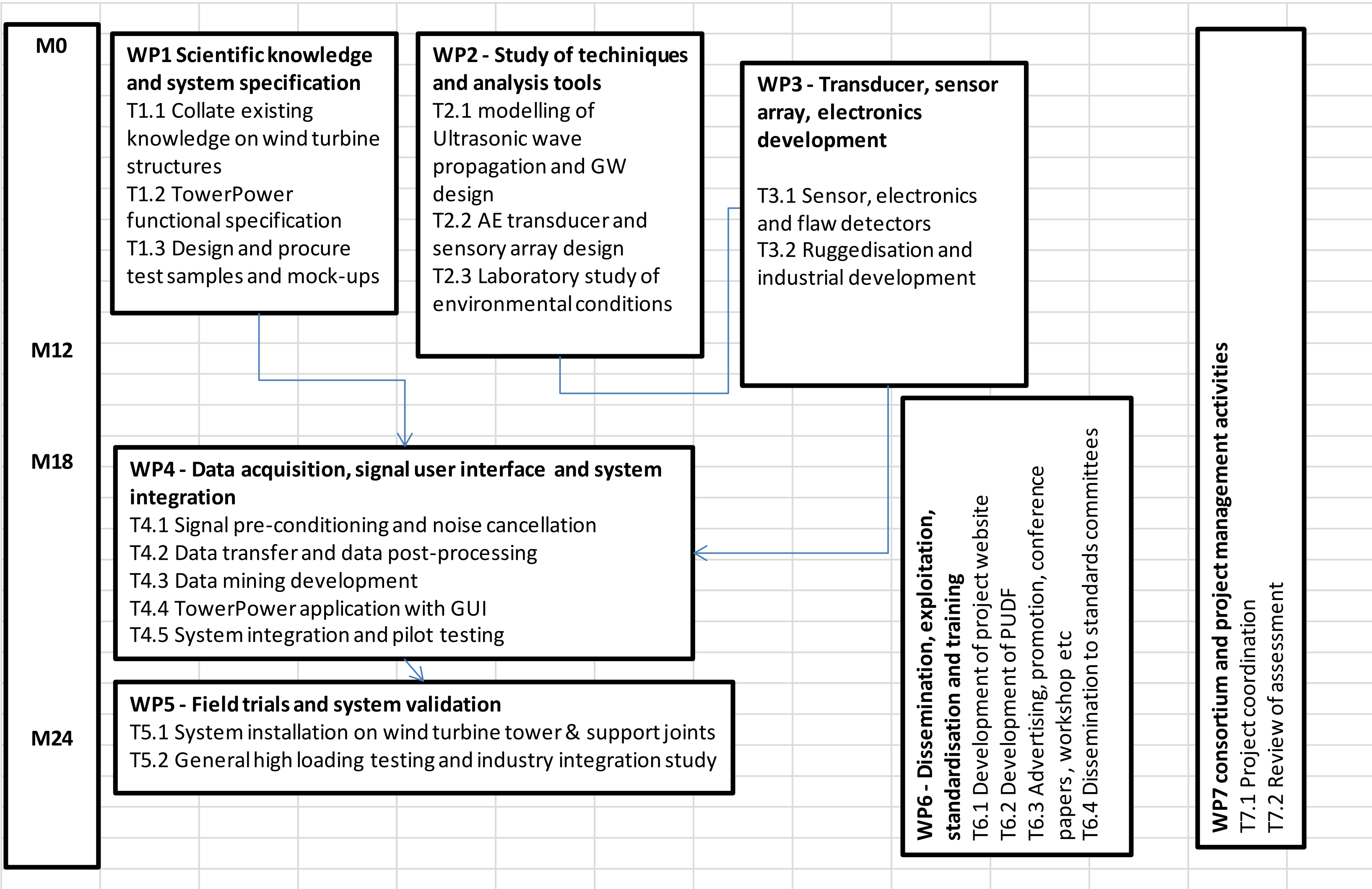
The work programme



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Expected results

- An integrated acoustic emission and vibration analysis system.
- An guided wave ultrasonic add-on for monitoring known crack or corrosion growth.
- A technology transfer roll-out for SME associations in Denmark, France, Spain and UK

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In-situ wireless monitoring of on- and offshore wind turbine blades using energy harvesting technology

www.wintur-project.com

Project Budget: £1.1m

End User:

• Scottish and Southern Energy (UK)

The project aims at developing novel wireless and self-powered technology to monitor wind turbine blades continuously using combined passive (acoustic emission) and active (guided ultrasonic wave) methods

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Wind-turbine tower failures

Collapsed wind turbine tower due to combined fatigue failure and wind loading

Catastrophic delamination of blades

Fractured tower caused by blade shaft bearing flaws.

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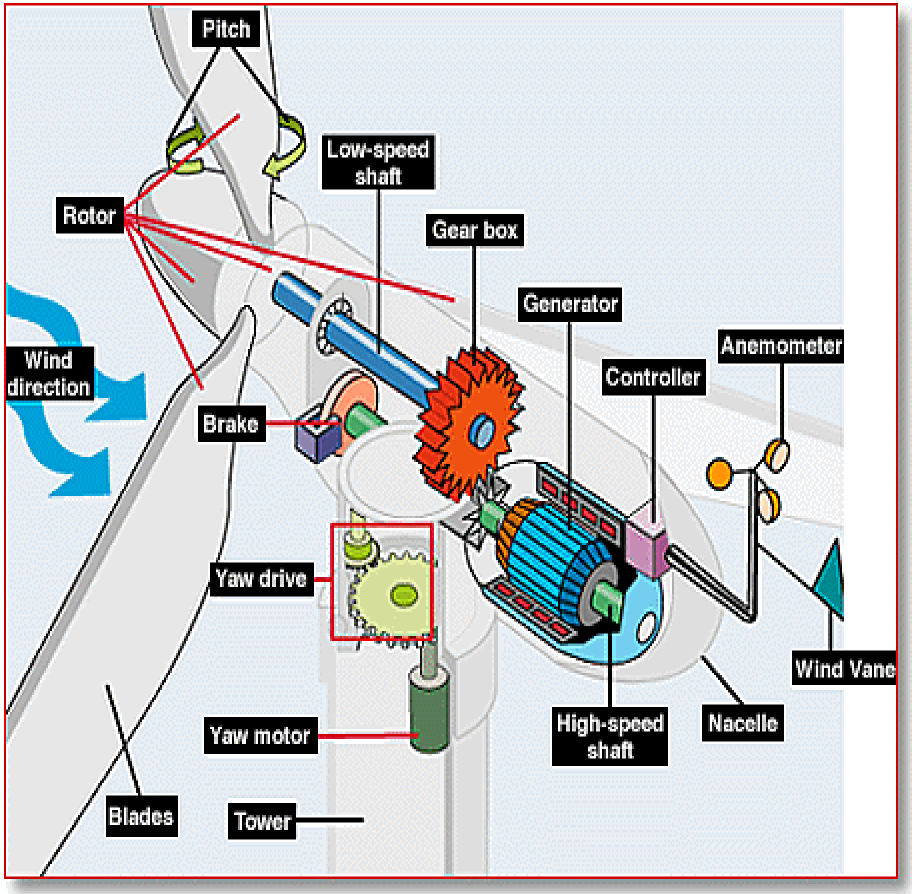
Non destructive technique issues

- Current inspection methods can only be:
  - performed offline
  - through human intervention
  - with limited volume coverage
  - time consuming
  - hazardous and expensive

- More R&D activities are required to solve problems linked to wind energy



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Project objectives

TWI

- The project will develop an advanced integrate system for real time monitoring of on- and offshore wind turbine BLADES

- The system, providing 100% volume coverage of the wind turbine blade , will reduce inspection costs

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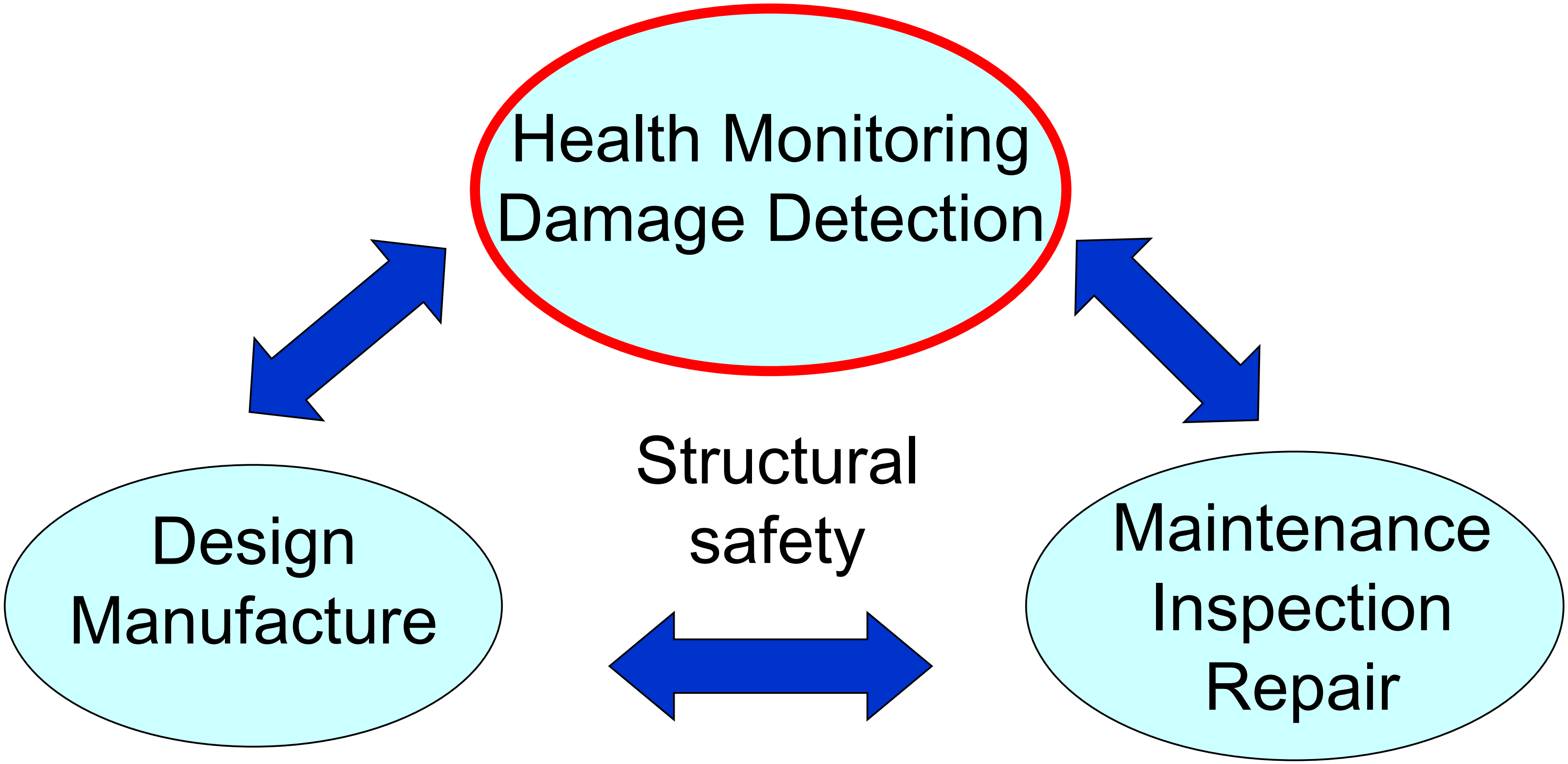
How to Improve Blade Reliability?

- Set up a structural safety system



Technology specifications

- Do not interrupt the power generation
- Transducers sufficiently light, flexible and do not interfere with the blade aerodynamics
- Advanced NDT techniques
- Energy powering adapted solution
- Data transmission system
- Data analysis and defect recognition

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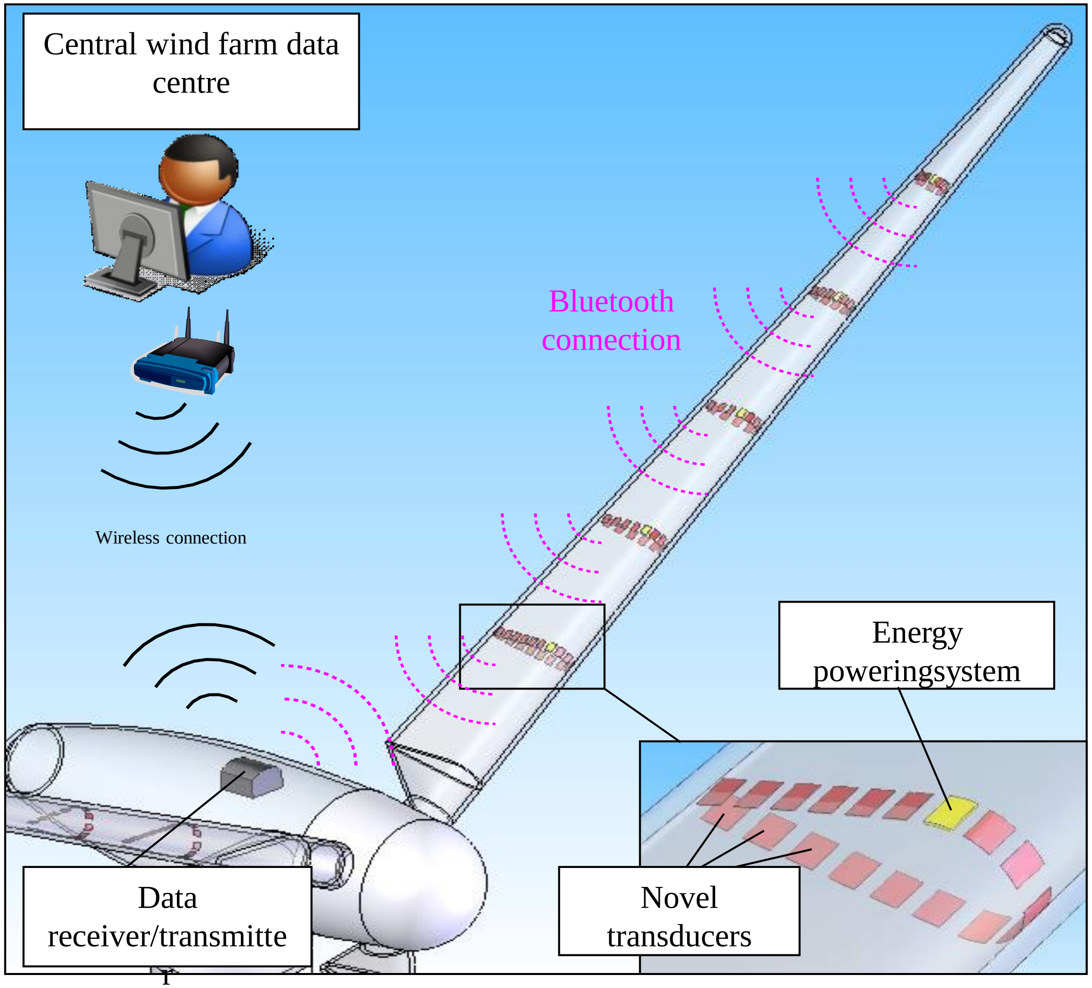
Project scientific & technical objectives

- Novel transducers
- Develop advanced NDT techniques
- Energy sourcing
- Communication system
- Software development
- Advanced signal processing
- Final trials



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Blade Monitoring

Acoustic emission detected from eventual sources

Yes

The AE data analysis:

- Locates the source
- Filters false calls

Acoustic emission data classification and indication identification

No

False call

Potential flaw

LRUT

No activation of LRUT

Activation of LRUT by focusing on the AE source.
Flaw sizing & assessment

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Laboratory Trials

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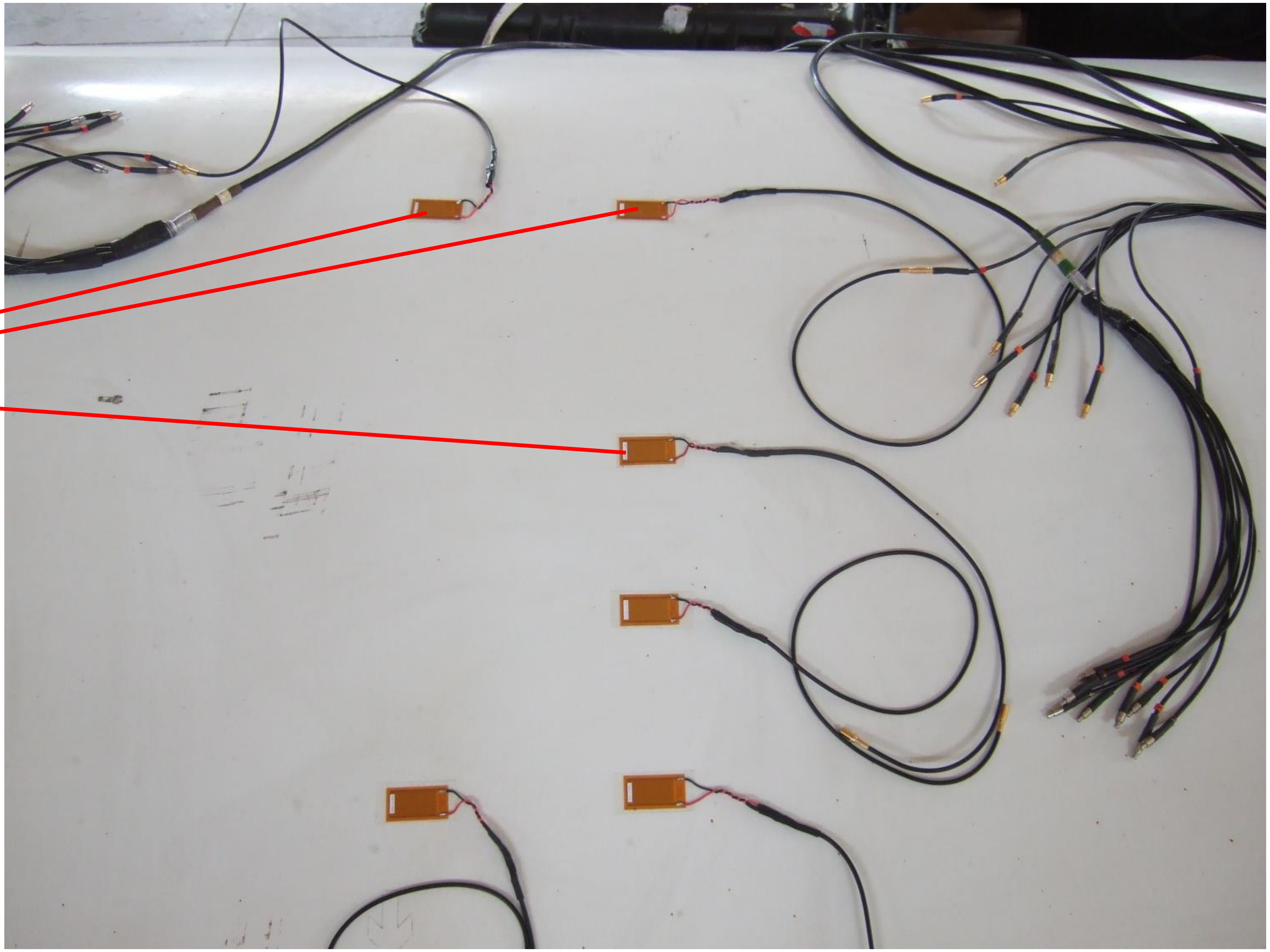
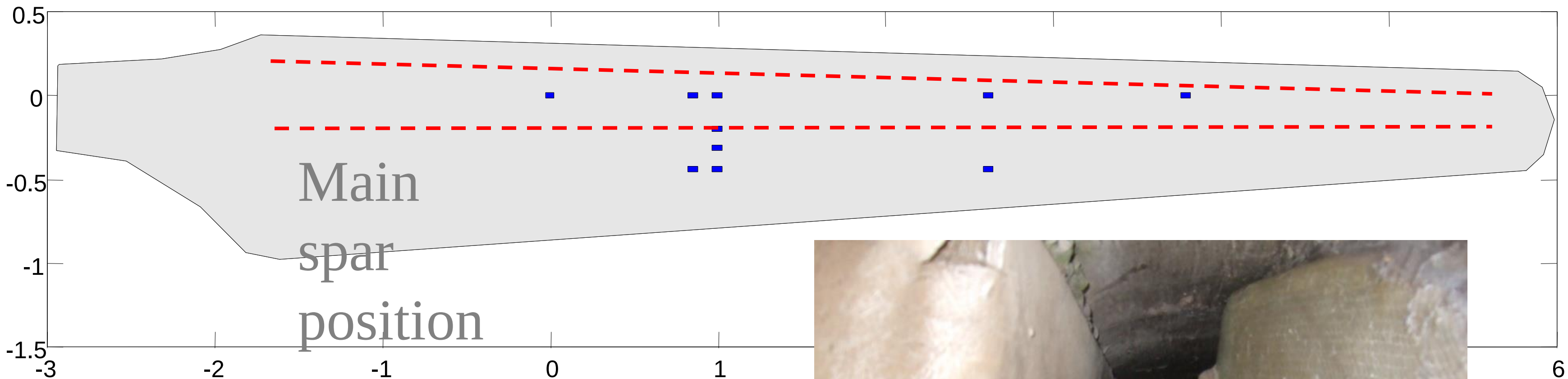
Experiment set - up

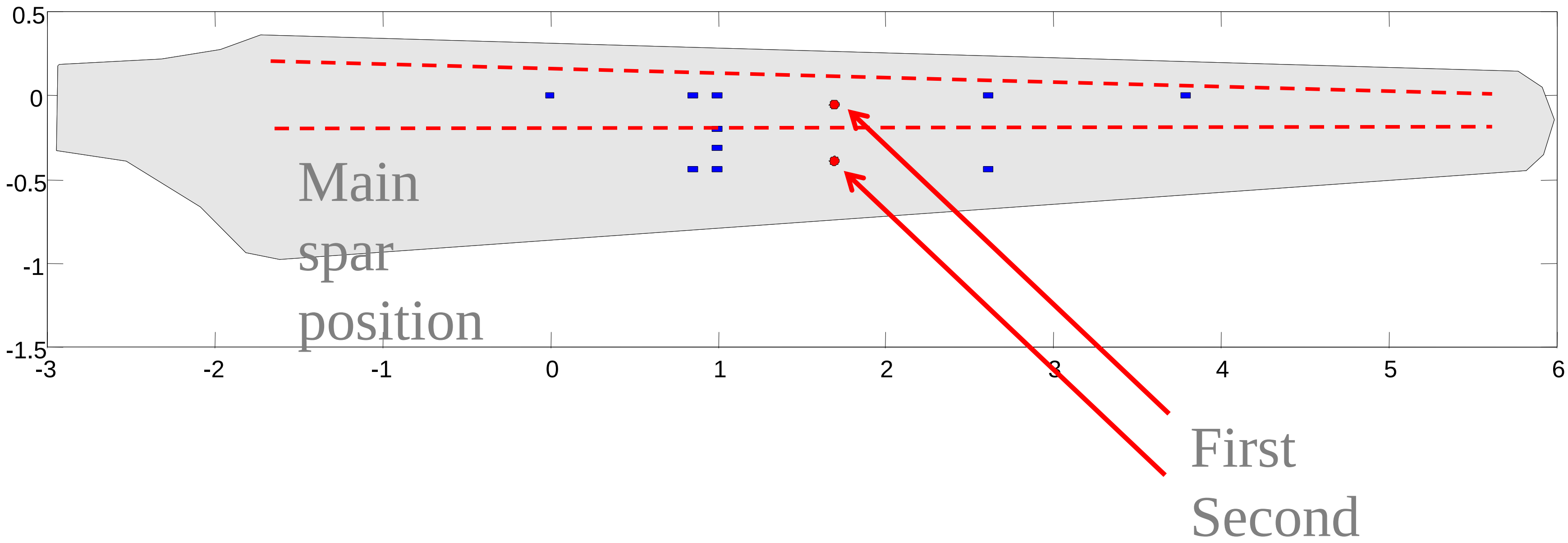
MFC transducers



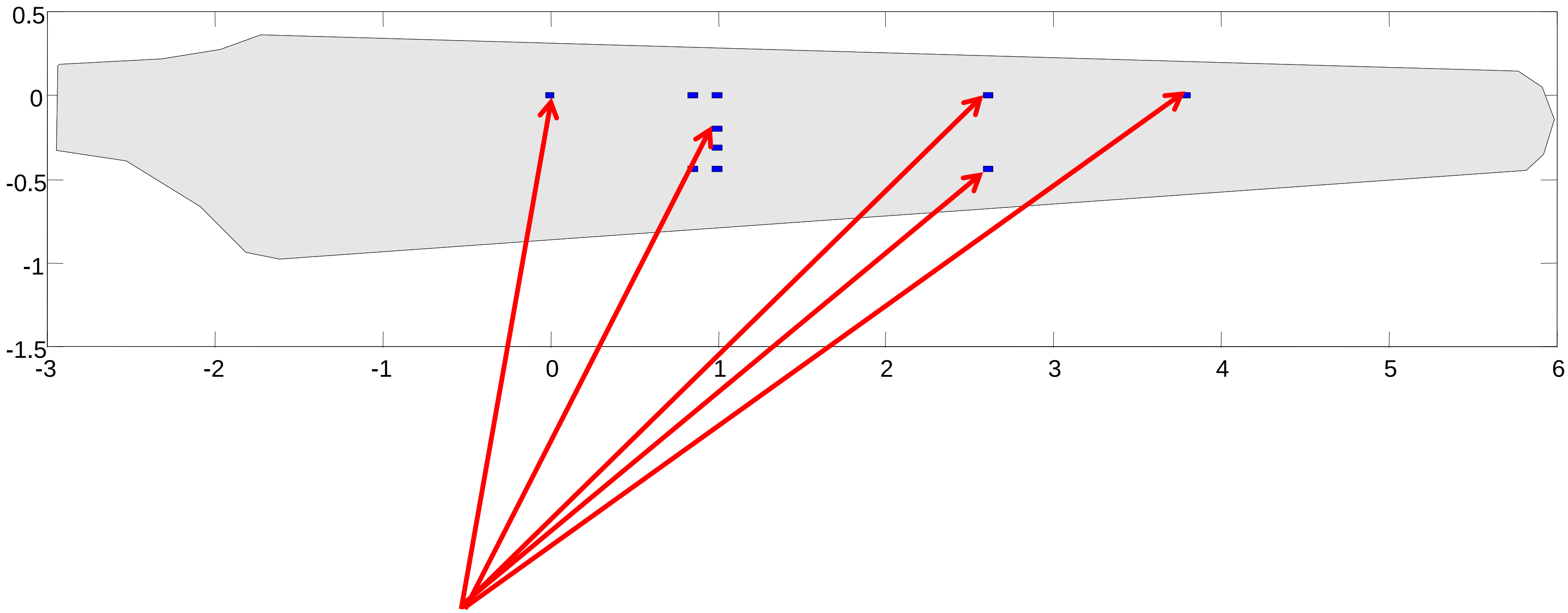
Experiment set - up



Drilled holes positions



Sequence of data acquisition



Transmitter, all other receivers

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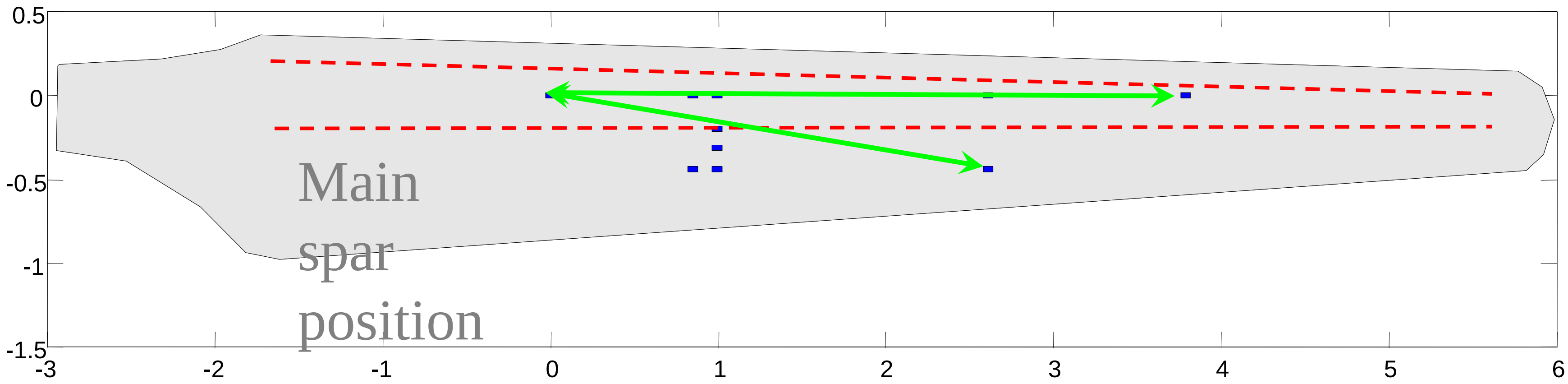
Estimation of measurement possibilities



- Is it propagates maximal distance 3.79m ?
- Is it propagates outside main spar?

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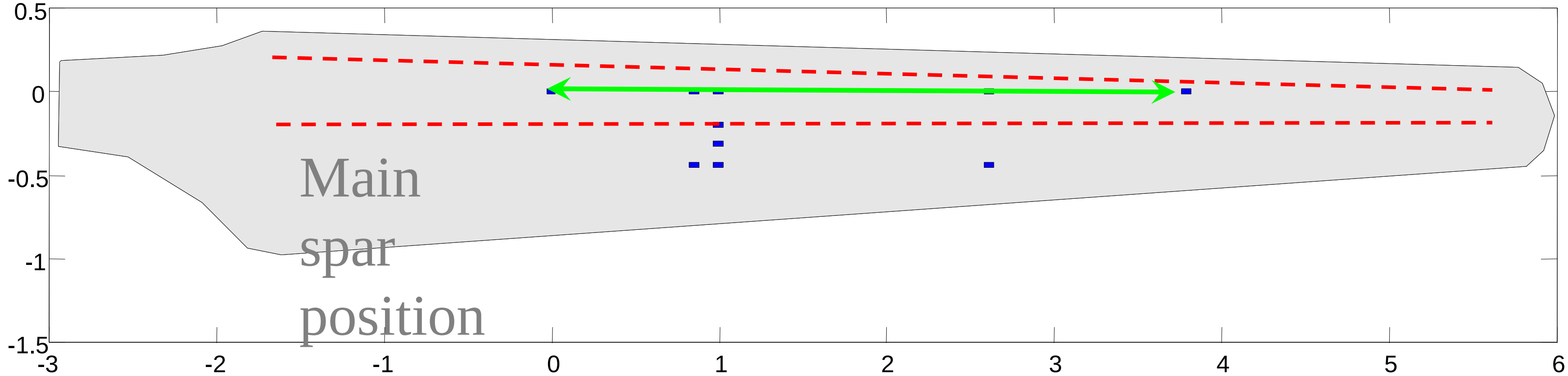
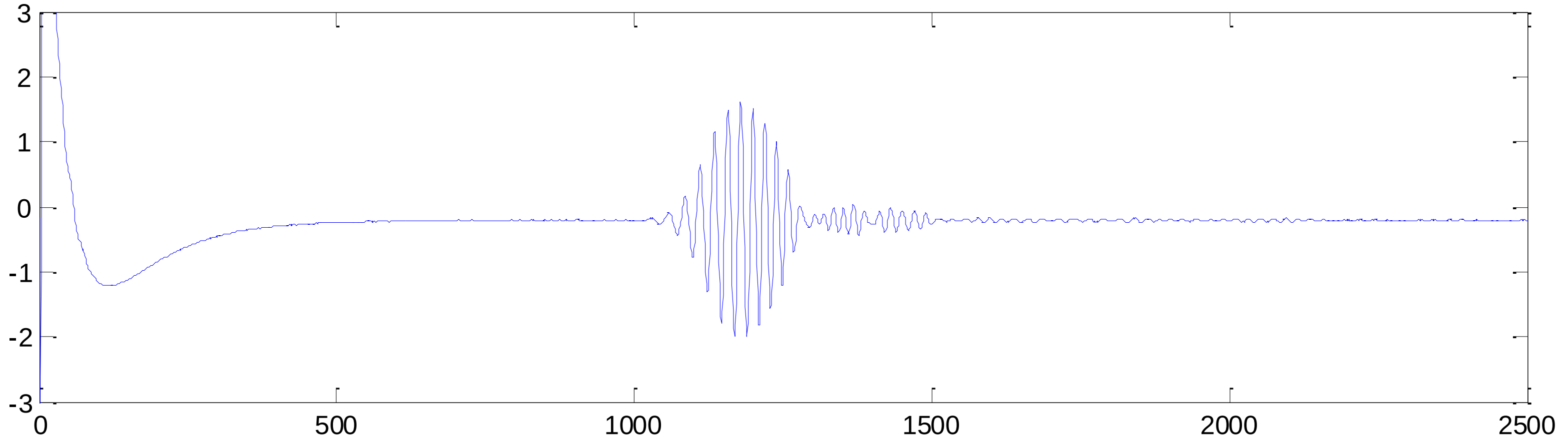
Propagation 3.79 m





- Estimated group velocity is about 3700m/s

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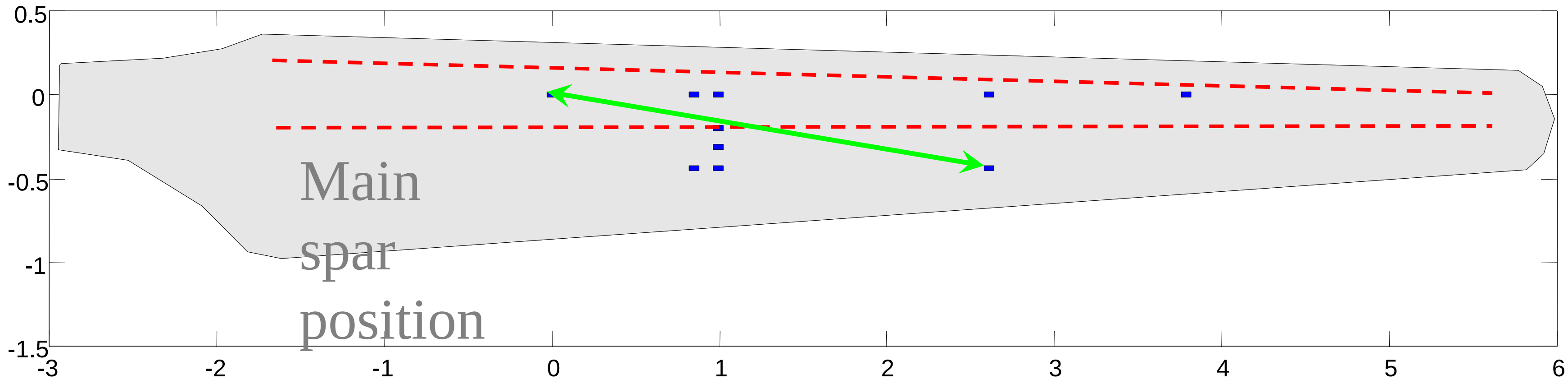
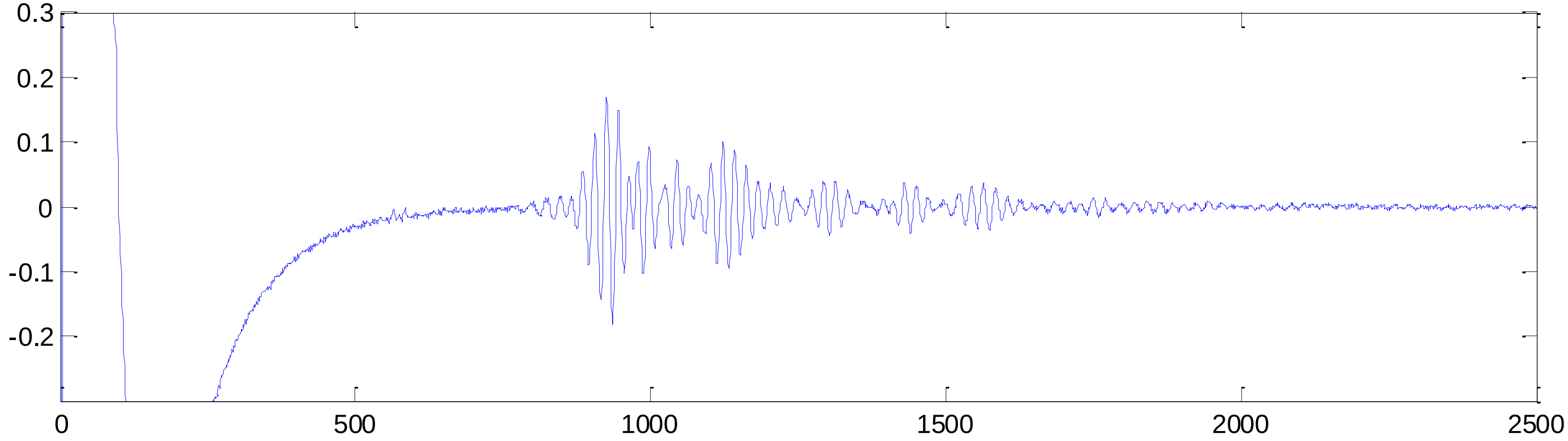
Propagation out of main spar





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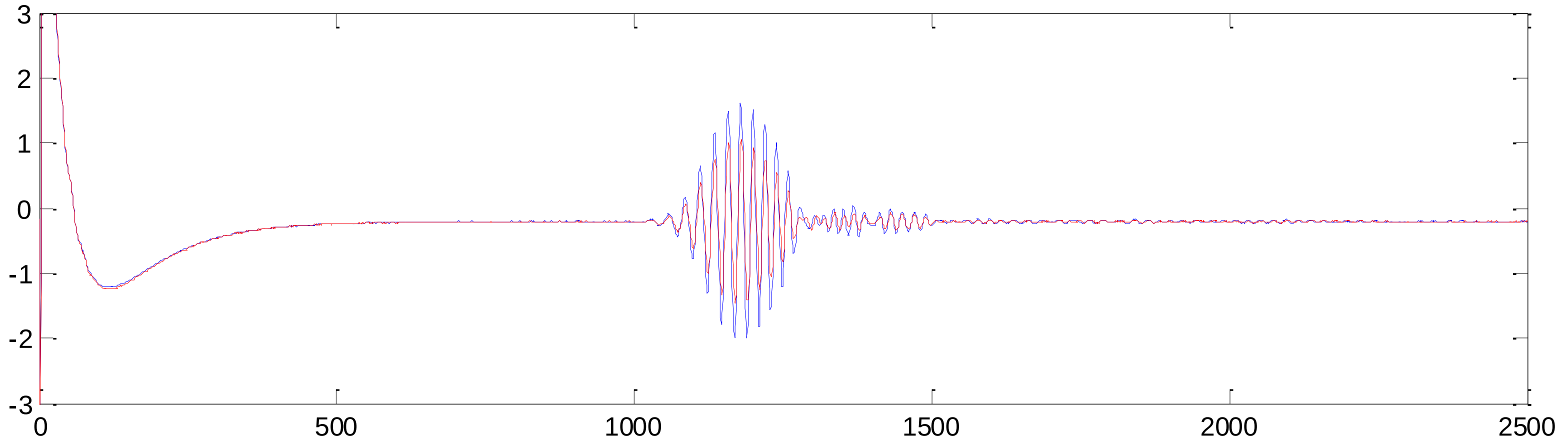
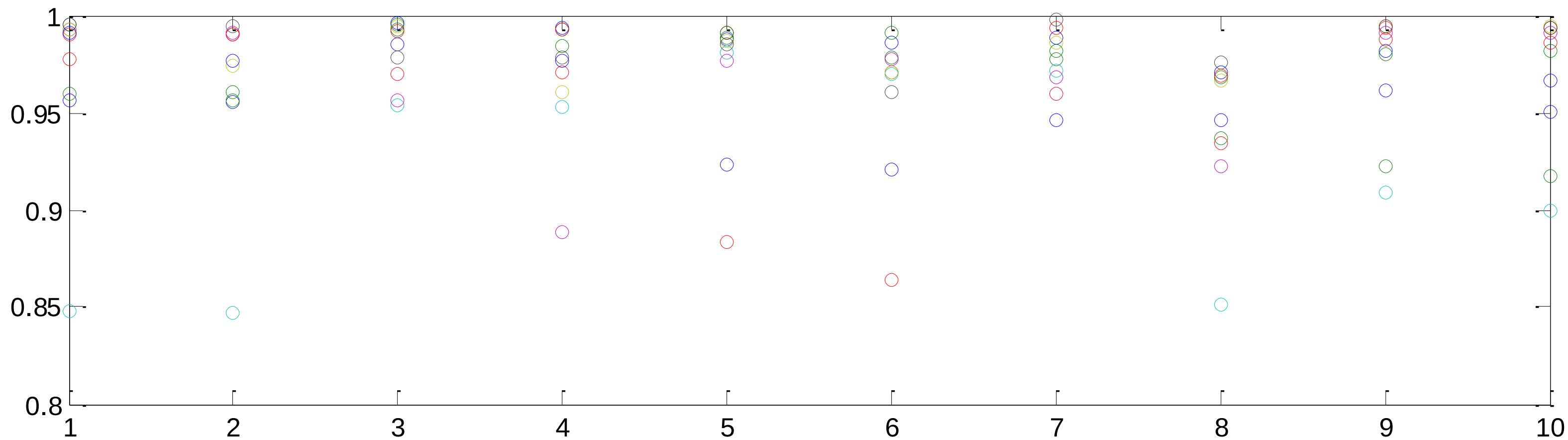
The differences after drilling first hole

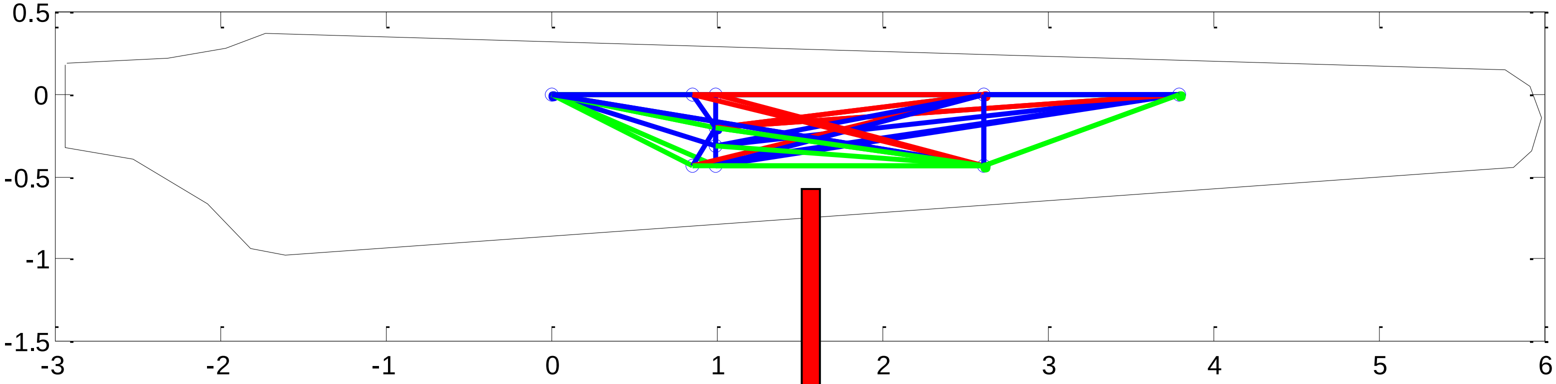
The signal at longest distance (the hole on the path)

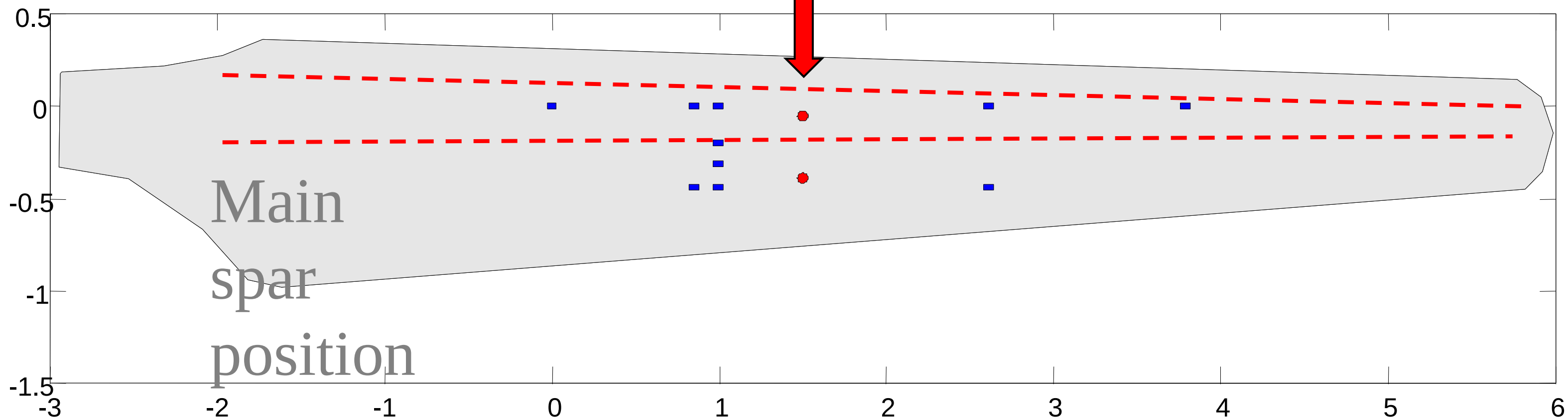


The normalize cross-correlation between different signals at longest distance (the hole on the path)



Damage Detection Result





Cross-correlation: green >0.98; blue >0.95; red <0.95

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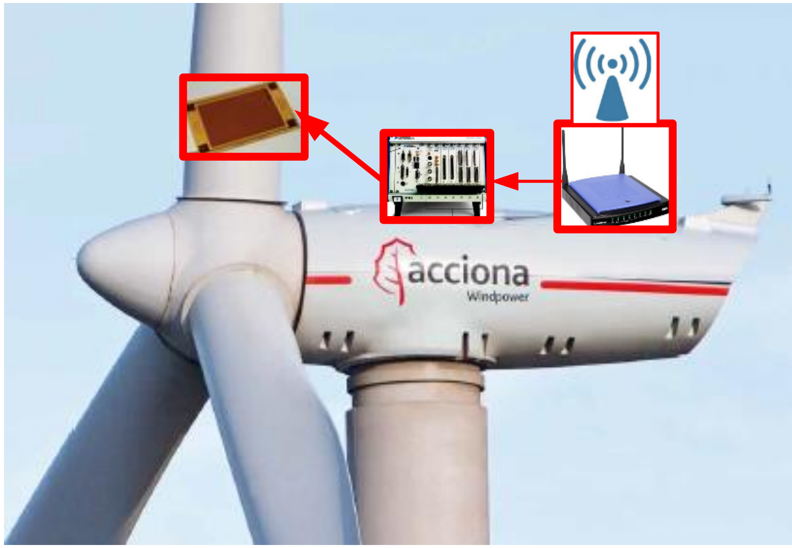
WinturDEMO

- Implementation of the technology demonstrated at the end of WinTur project,
- Use of Acoustic Emission (AE) and Ultrasonic Guided Waves (UGW) for damage detection,
- Aim of the demonstration project is to accelerate the pace of the technologies towards commercial maturity.



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System Development and Demonstration

- Sensors – 4 AE and 8 MFC will be installed around 1-2m from the blade root,
- System to be placed inside the hub,
- Industrial PC will be installed to control the electronics and data storage,
- WinTurDEMO software will be installed and TCP/IP comms protocol will be used,
- Wireless comms implmentation from hub to the base of the tower,
- WinTurDEMO system will be installed on NEG-MICON 750/48 at CRES in Greece

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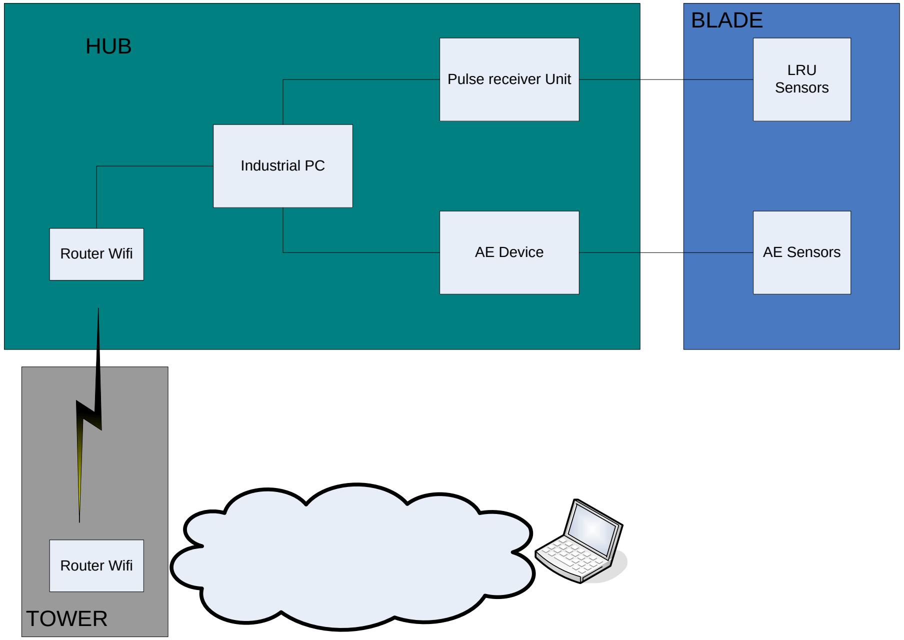
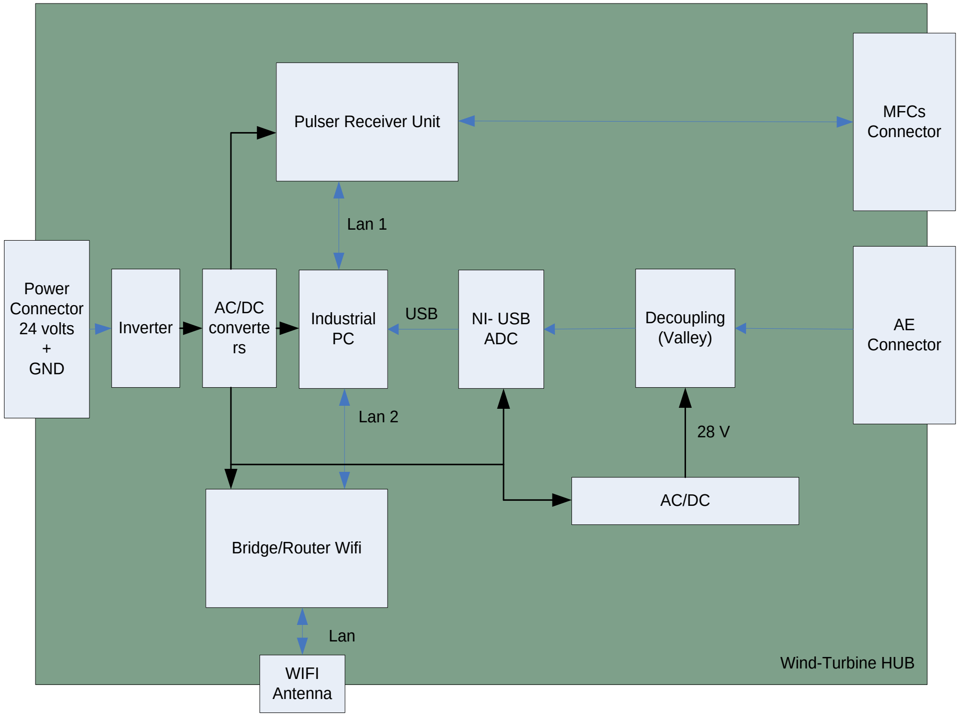
System Development





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Thank You!

Application of advanced NDT to wind turbine blade inspection

Offshore wind – Inspecting the Future

TWI Yorkshire – 15 July 2013

Dorothee Panggabean

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QUALIBALDE E!6213

- Eurostar project
- Semi-automated inspection and repair of in service Wind turbine Blades
  – Inspection by Phased Array UT
  – Inspection by Infrared
  – Repair of damaged composite material
  – Robotization

Consortium

- GMI: project leader
- INNORA: robot
- KCC: software integration
- TWI: inspection techniques

Evaluation of existing in situ inspection methods

- Rope Access technicians: visual inspection by video and photographic means, with conventional methods of NDT also available.
- Remote Operated Aerial Vehicles: carry out visual surveys with images transmitted to ground operators offering in-field inspection on live equipment.
- Climbing robots: GE IT robot but limited to visual inspection using HD video cameras (no contact inspection or repair methods).

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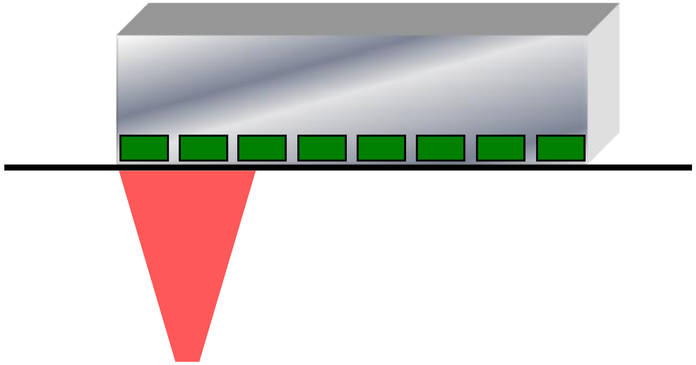
QUALIBLADE Robot

- Suitable reach to the blade along the entire length, with a payload appropriate to the task at hand.
- Freedom of movement in the vertical plane and resistance to horizontal deflection due to wind loading
- Use of personnel: safety measures including of a fall arrest system for the platform/cabin
- Accurate and repeatable positioning of NDT/repair tooling, with sufficient force to effect the inspection or repair

Phased Array UT

- The Phased Array (PA) ultrasonic probe used consists of 64 separate piezoelectric crystal elements.
  A computer fires each element in a finely controlled sequence so as to produce constructive interference at a chosen location.
  The PA probe can effectively produce a wide range of beam angles, be selectively focussed or scan across the probe length without moving the probe, as in this project.



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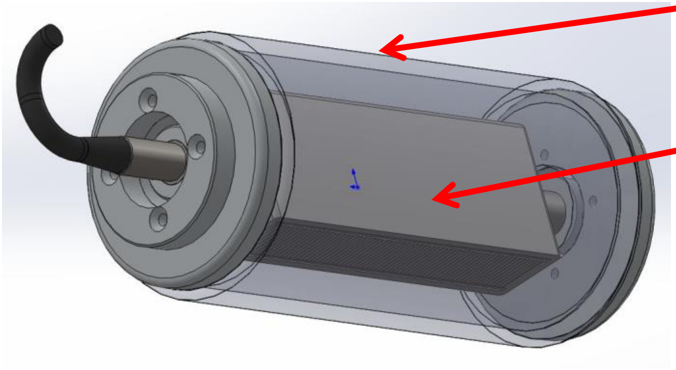
Main component in QUALIBLADE PAUT system

- To permit suitable coupling with the blade surface, without the need to apply a coupling medium or have the probe face fully irrigated, a wheel probe is used.
  The PA probe is housed in a flexible tire, filled with coupling fluid, and only a wetting film of water is required to provide good sound transmission through the blade surface.



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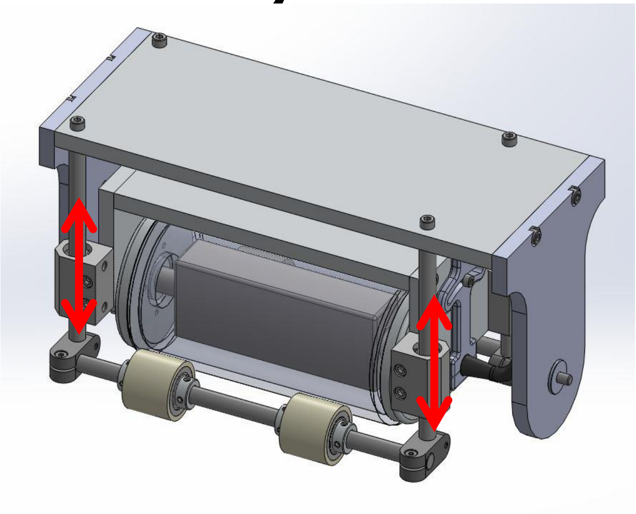
QUALIBLADE bespoke scanning assembly

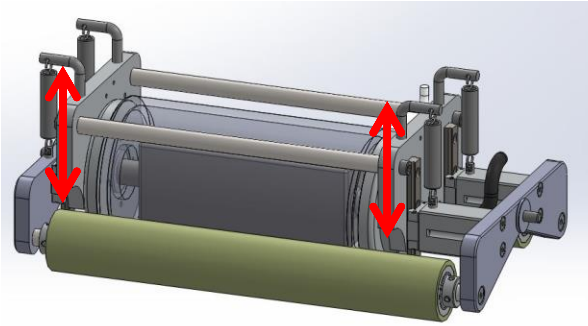
- The PA wheel must remain perpendicular to the blade surface and also follow changes in blade curvature.

  This is achieved by a spring loaded carriage within a frame. The robot arm keeps the frame rollers in active contact with the blade, and passive spring load on the carriage then keeps the wheel on the surface.

  Positional encoding takes place in the x-axis as the scanning assembly is moved across the blade face by the robot arm.

  (alternative design also shown)





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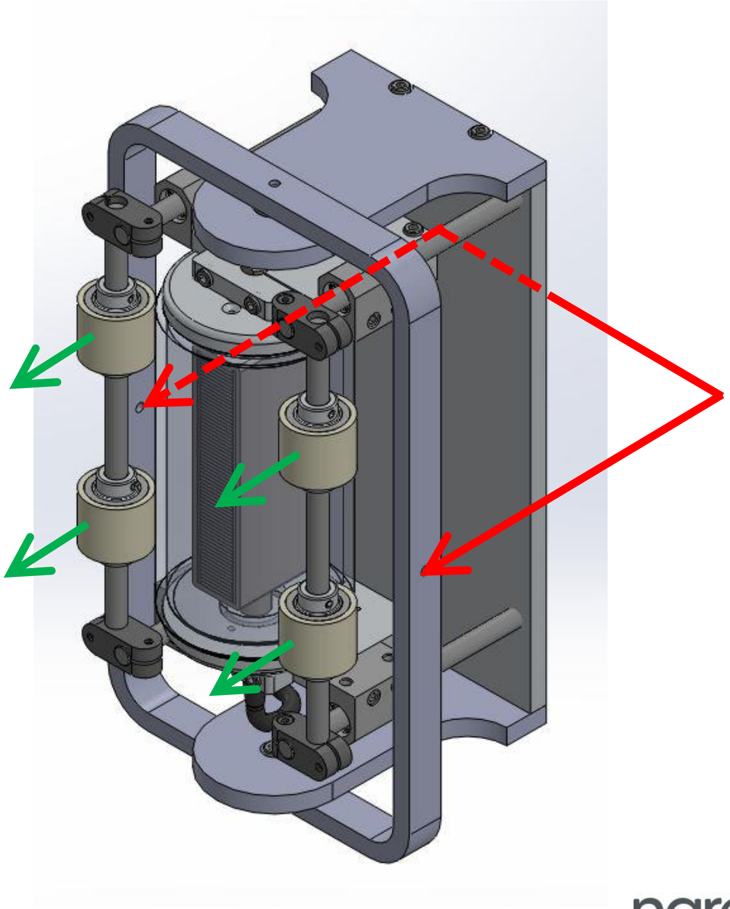
Scanning assembly in robot manipulator

- The robot arm connects to the scanning assembly via a gimbal ring. This is spring loaded to provide compliance for small deviations.
  A sensor in the robot end effector monitors the force on the scanning frame and ensures the arm maintains scanner contact with the blade surface.



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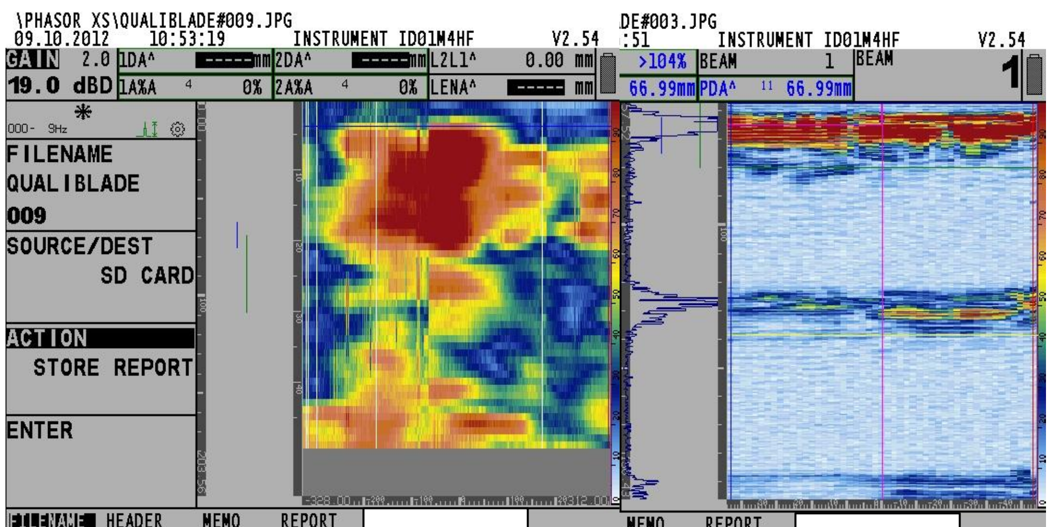
PAUT acquisition data

- C- and B-scan data is acquired during scanning.
  X-axis position is gathered via an encoder on the probe wheel carriage, with z-axis distance across the array width.
  The data from each scan will be matched with the global x- and z-axis position on the blade within the software.



C-scan B-scan

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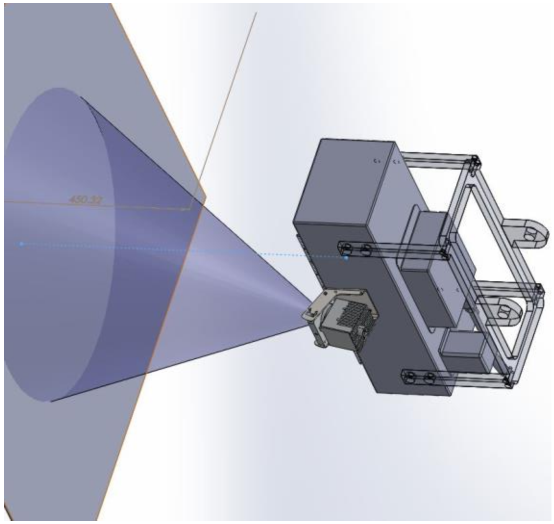
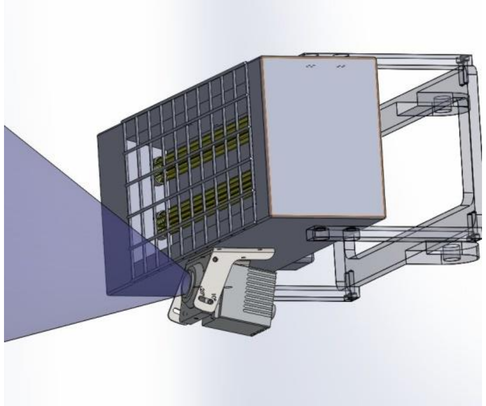
Thermal Imaging System

- The IR imaging system will enable to assess the damage of the inspected area by creating a ‘thermal’ map of the area and detecting thermal anomalies on the generated image.





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IR thermography for QUALIBLADE

IR thermography for QUALIBLADE:

- Inspection of GPRF and foam
- Different procedures of inspection for each part of the WT blade
- Necessary to use external heat source (active thermography)
- Use of infrared heating in order to have penetrating and uniform heating on the WT blade
- During heating and cooling down process, search of anomalous temperature gradient in specific location to detect potential defects

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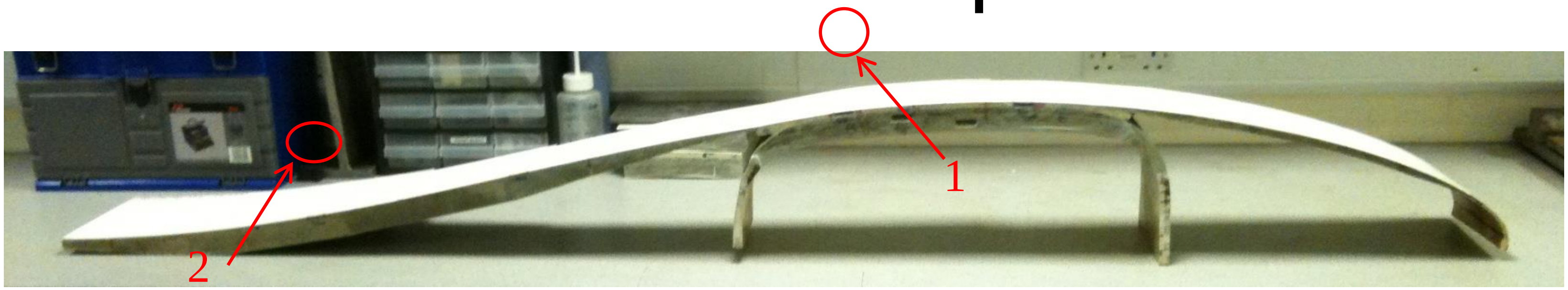
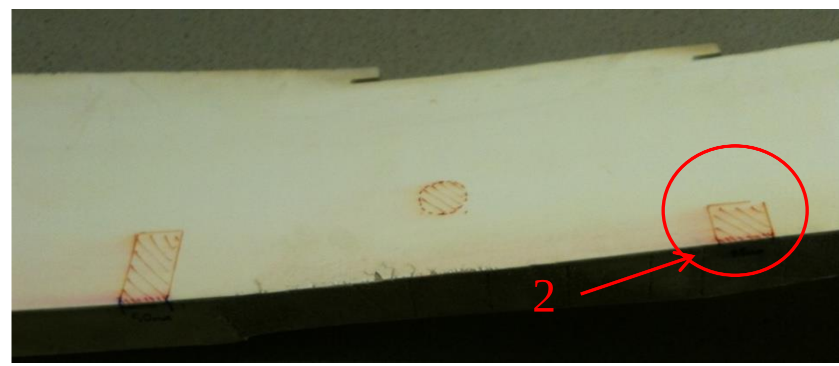
Test with IR thermography on WT blade sample



Section of Wind turbine Blade

Trial on defect 1 (25mmx50mmx5mm) in GPRF located under gel coat



Trial on defect 2 (25mmx25mmx1mm) in foam located 5mm under gel coat

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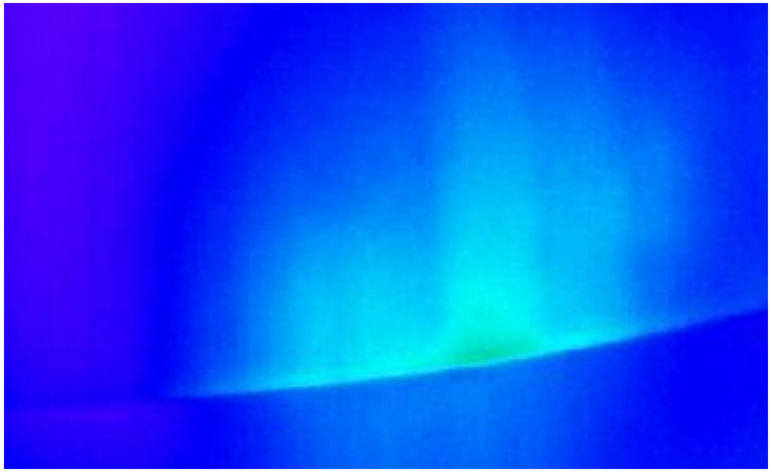
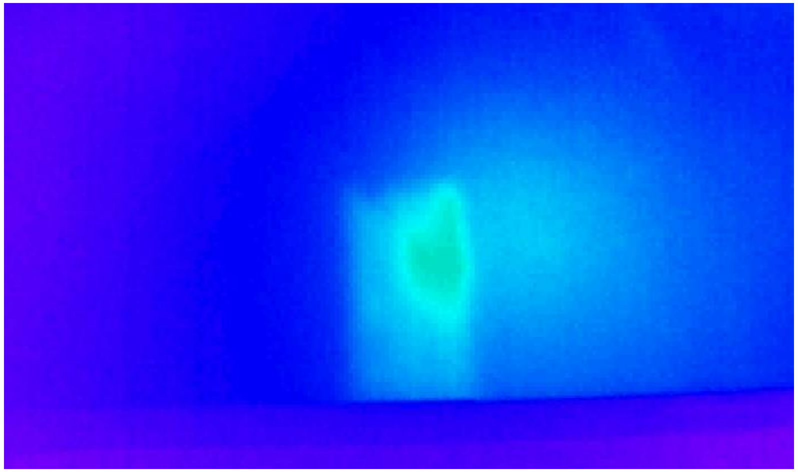
Results of initial trials



Trial on defect 2 (25mmx25mmx1mm) in foam located 5mm under gel coat



Trial on defect 1 (25mmx50mmx5mm) in GPRF located under gel coat

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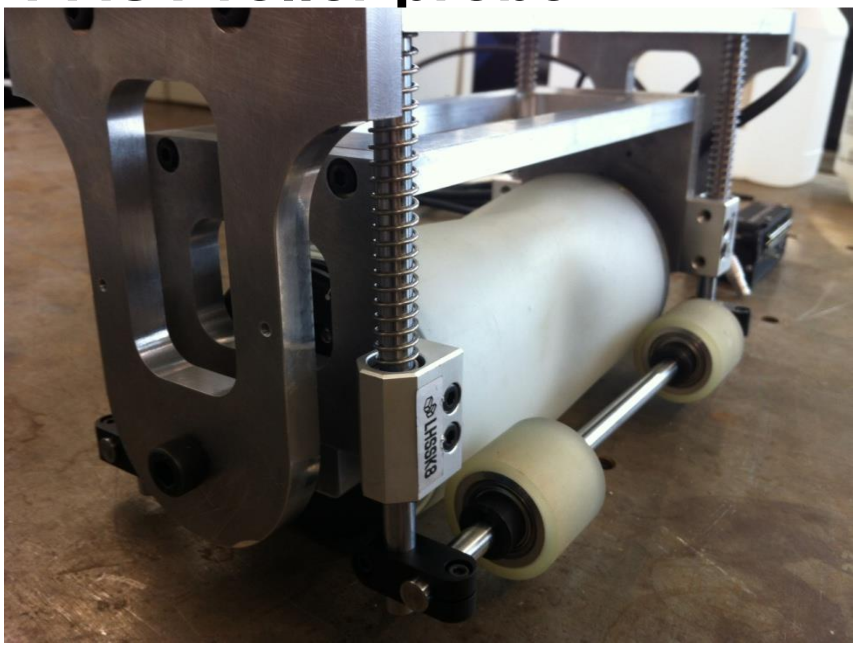
Assembly and Integration

IR Camera

PAUT roller probe



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Future work

- Full integration
- Software modifications
- Data acquisition
- On-site tests

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