PRISM
Processing Routes for Integrated Structural Monitoring

Technology Dissemination

21st January 2009

Introduction: Julian Ellis OBE

Ellis Developments Ltd

Collaborators

BVT Group

Deep Sea Engineering and Management Ltd

Ellis Developments Ltd

QinetiQ Ltd

Sigmatex (UK) Ltd

The Strengths of the Consortium

- A ‘pan industrial’ group comprised of a multidisciplinary team
- Integrated supply chain approach
- Active problem solving personnel with a ‘can do’ attitude
- Short cycle times with often a short turn-around of a couple of weeks.

Potential of the Process

- Quick process from conception to scoping
- Both new products and a retrofit process
- Short timescales possible from pre-form to product testing

An example of making a demonstrator

Example boat hull timetable

20' MILITARY RIB BUILD

Design	20 days
Tooling	10 days
Hull and Deck Construction	20 days
Machinery Fit Out	28 days
Trials	5 days
Customer sea trial	2 days
Clean up	3 days
Acceptance	1 day
Total	89 days

Project Objectives

- To develop manufacturing methods for the automated insertion of sensors into reinforcing fabrics and pre-forms.
- Demonstration of a robust integrated SHM system
- Develop guidelines for structures with SHM

Project Financing

- 40% Technology Strategy Board
- 60% Project Partners
- Total project funding £1.04 million

The Key Challenges

- Exiting the wiring from the composite
- Insulating the sensors
- Ensuring the sensors did not weaken the structure
- Connectivity
- Survivability in construction
- Losing the sensors in the composite!

What we have developed

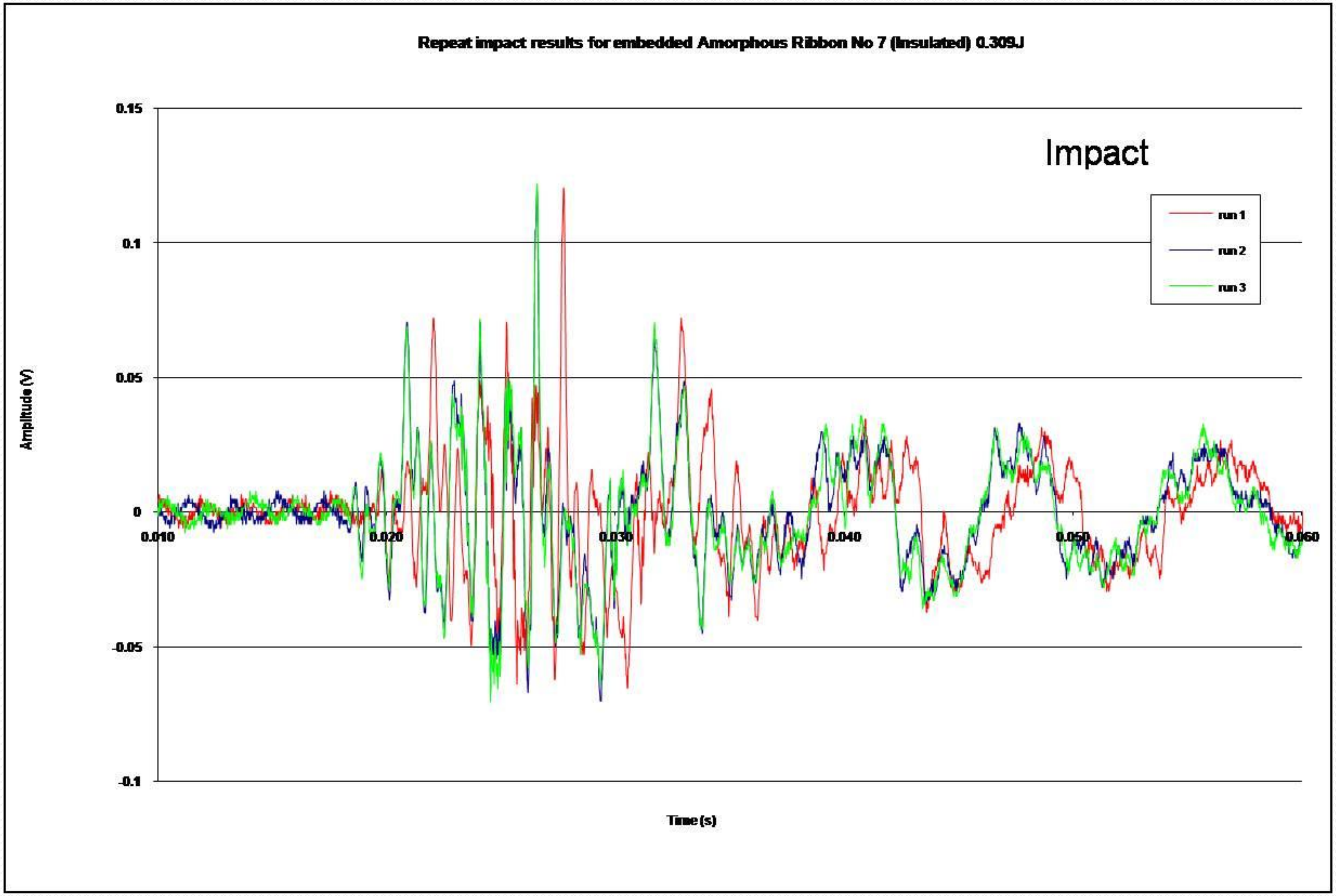
A new range of manufacturing techniques:-

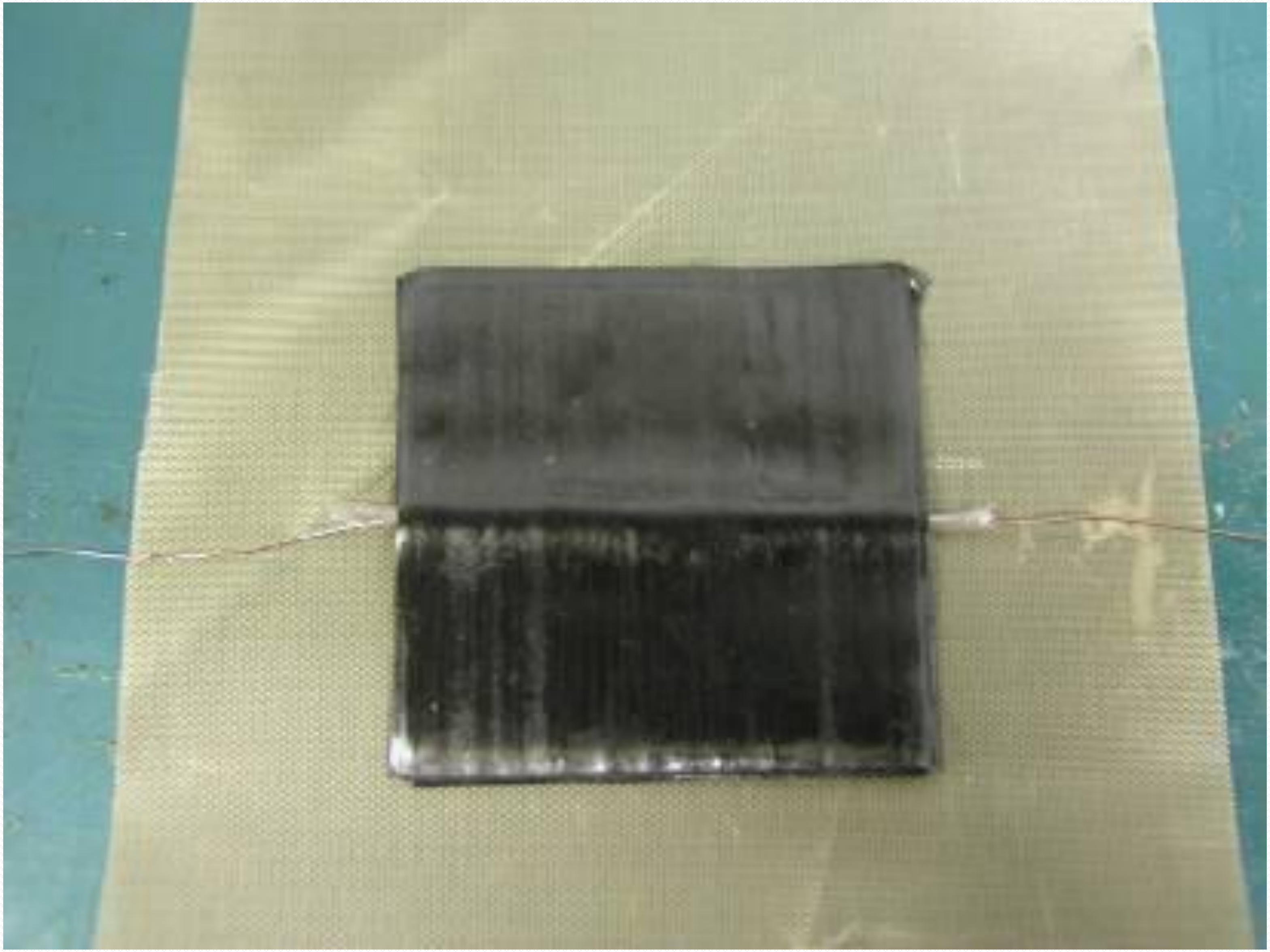
- Production focussed
- Some mass production methodologies
- Application oriented processes
- General production orientation

Because we are a ‘vertical’ group of people who think that way!

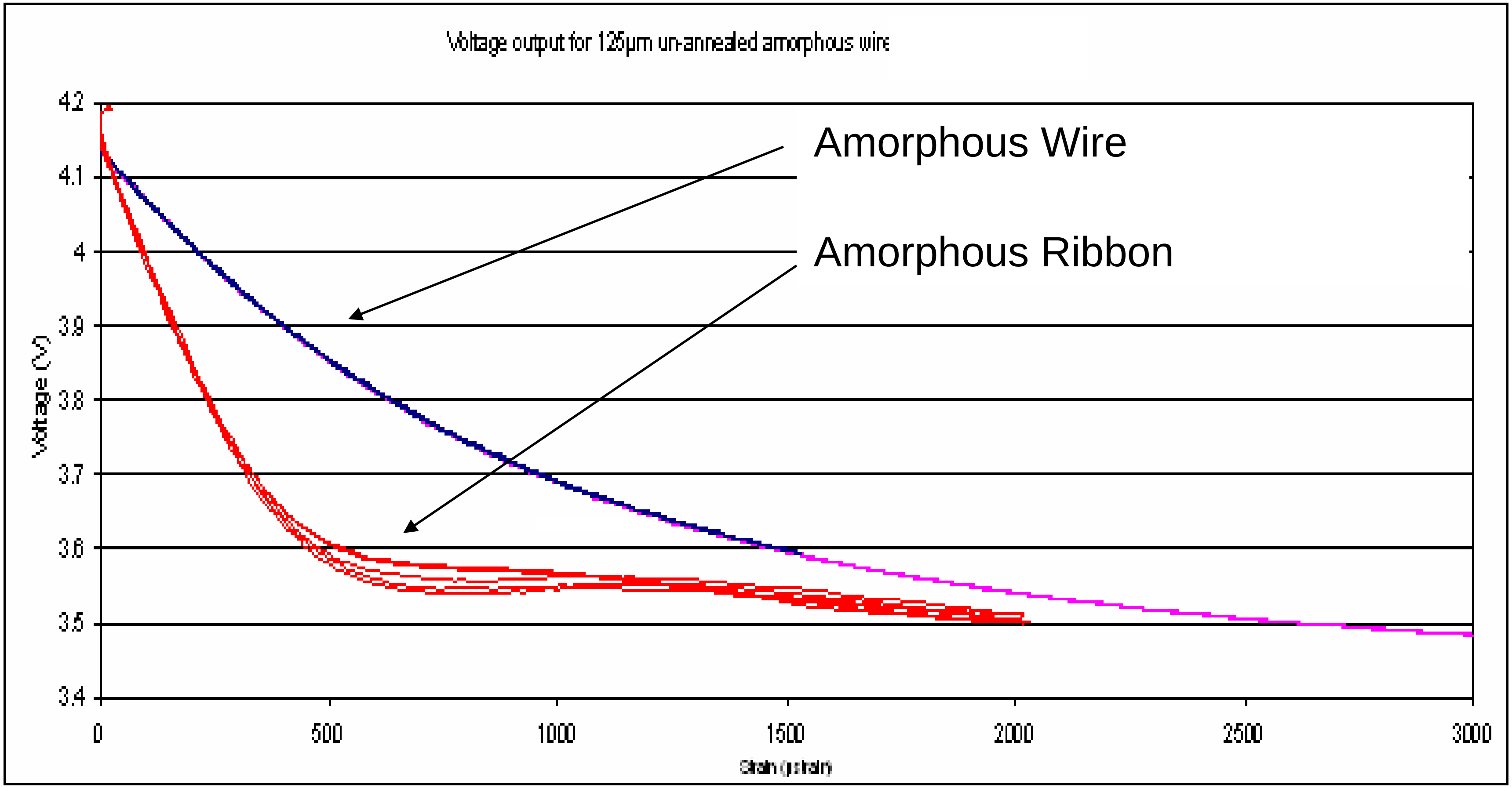
Sensor Development

Amorphous Sensor

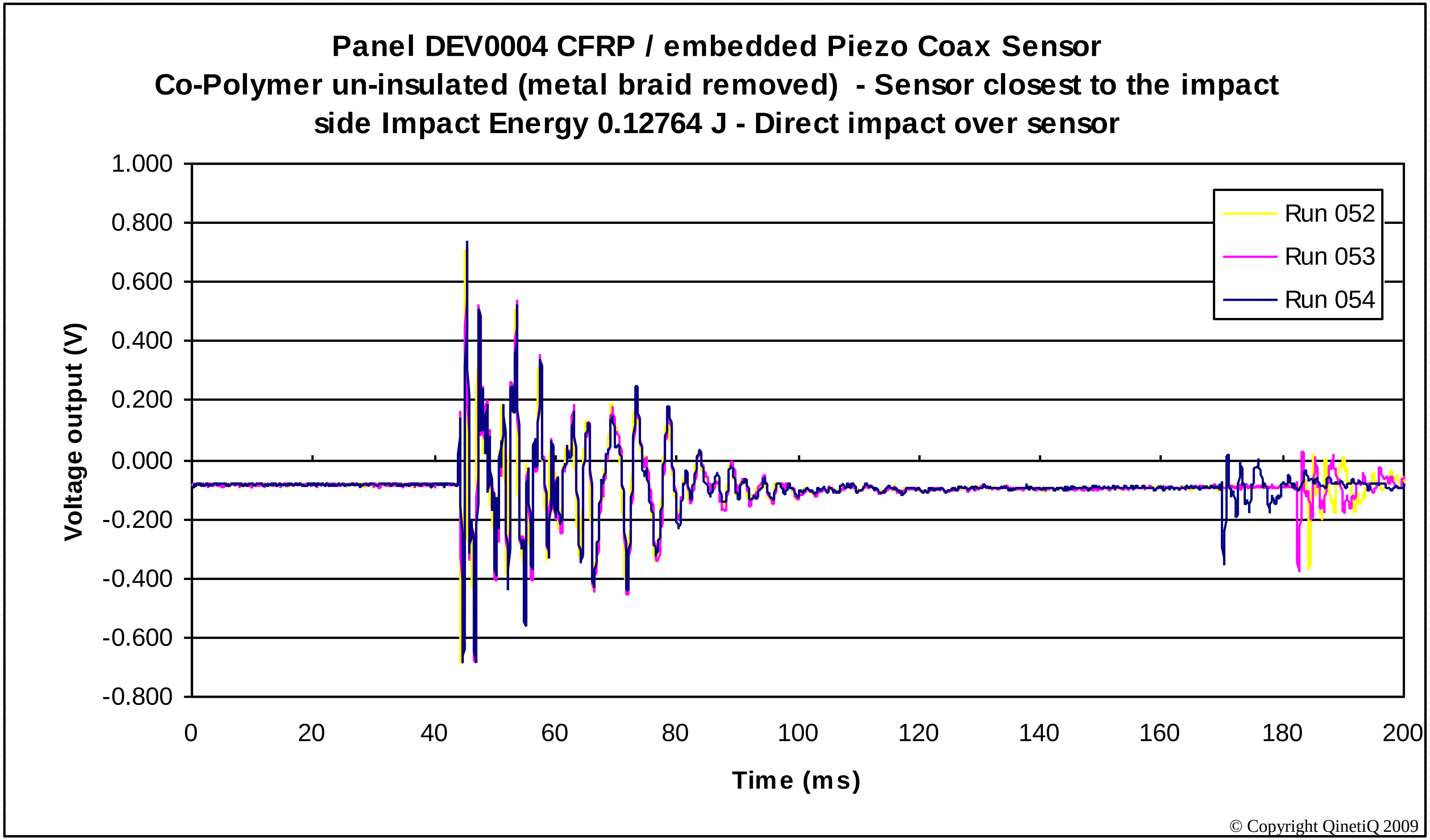




Voltage Output



Piezo Coax sensors



Process Route

1. Conception
2. Design
3. Application engineering
4. Weaving and/or stitching
5. Lay up
6. Infuse
7. Manufacture simple ‘black box’ for electronics
8. Deliver

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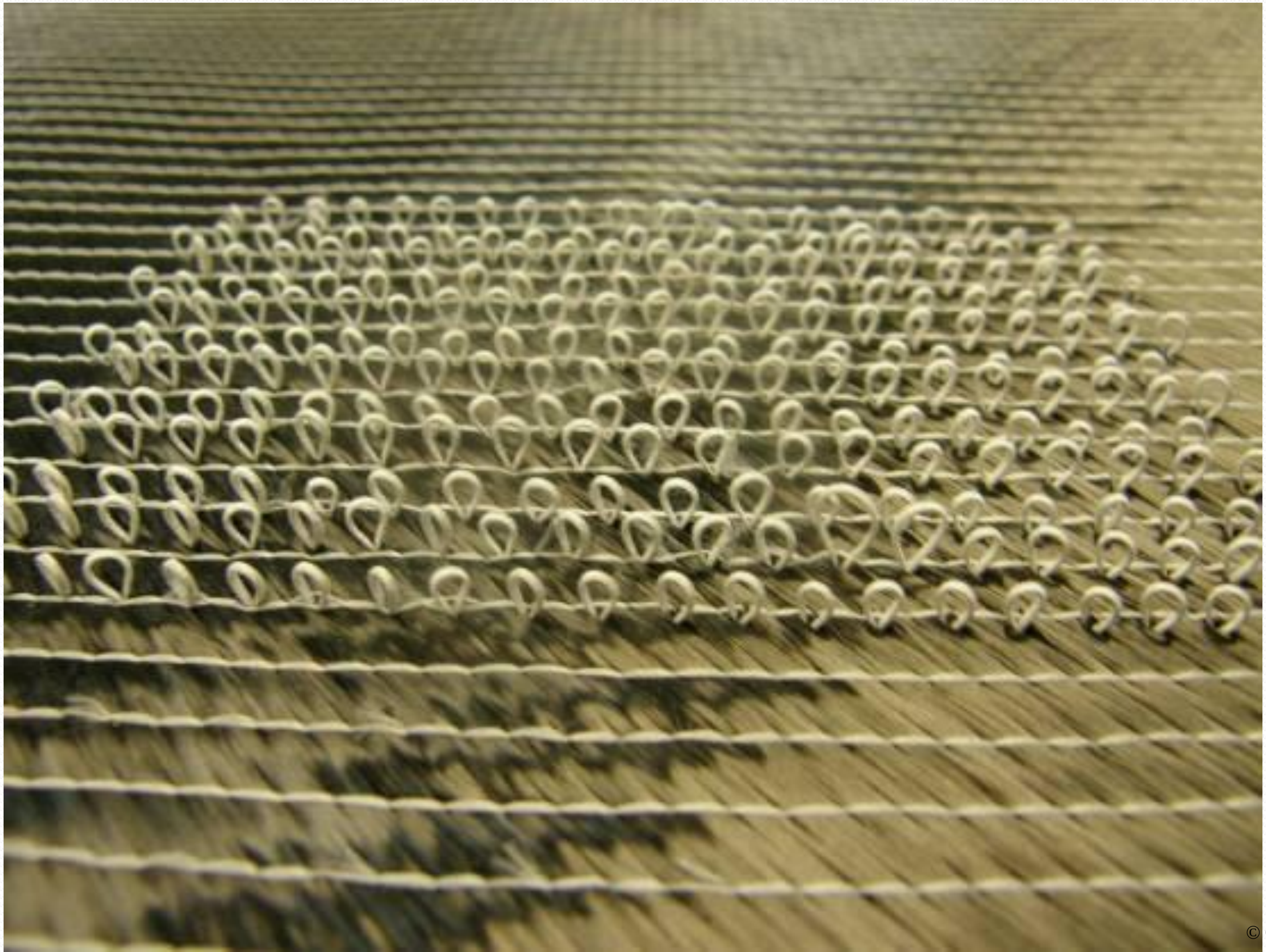
Tufting with Sensor



Tufting with Sensor

Sensor in Stitched Pocket

Stitching for the Demonstrator

Filament wound tube with sensors

A Short Introduction to Structural Health Monitoring

Lisa Fixter
QinetiQ, Farnborough

Why consider SHM?

- Advanced materials are being used – Polymeric Composites
  - Stronger and lighter materials being used for structures
  - Ever increasing performance requirements
  - Damage mechanisms of newer composite structures differ from metallic structures
  - Requirement for more reliable structures

Requirements of a SHM system

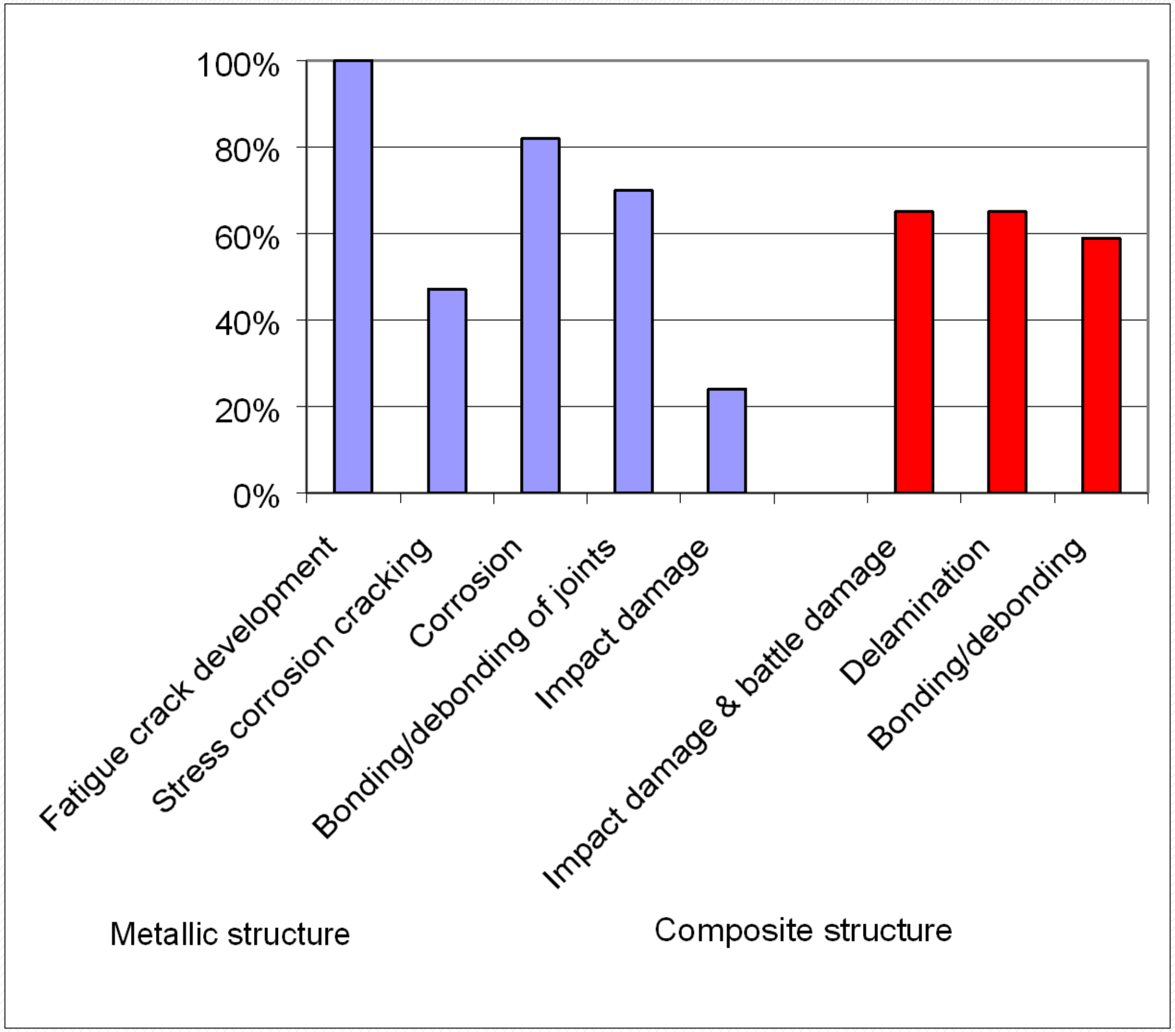
- Reliable damage detection
  - Must not miss events
  - Without false alarms
- Measurement of defect size and location
- Accurate load measurements
- Real-time or baseline systems must provide simple feedback to operator as to status of structure
  - Traffic light system often quoted

Requirements of an SHM system

- Combined with understanding of the material/structural behaviour
  - Knowledge of the significance of defects
  - Knowledge of load cases for structures
  - Understanding of the frequency of occurrence of events
  - Knowledge of uncertainty at each stage
  - Sensor application / embedding must not degrade mechanical properties
- Temperature compensation may be required
- Wireless systems desirable

SHM of Structures

- Defect types of interest
- European Framework IV MONITOR project questionnaire results

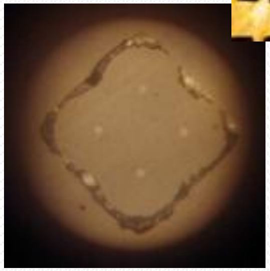
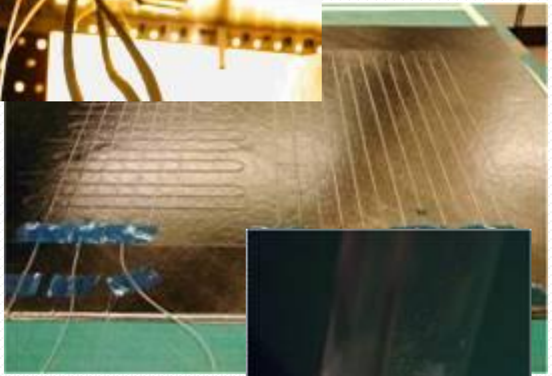
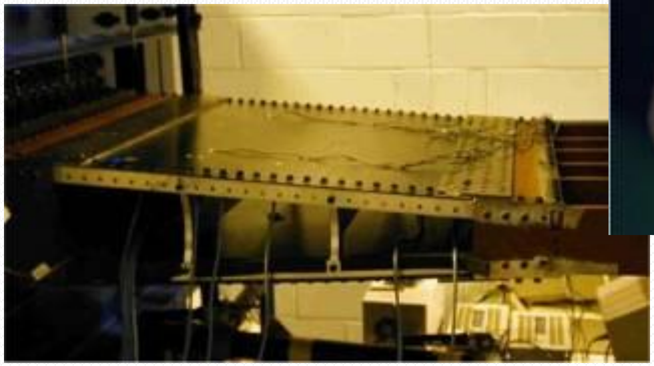
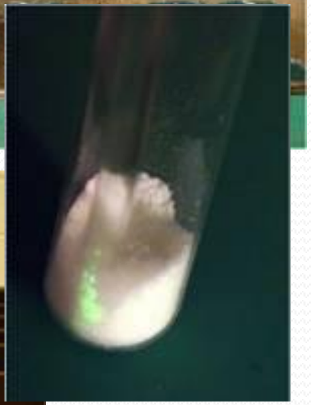


Smart Sensors used for SHM

Sensor type	Advantages	Disadvantages
Optical Fibre	Dielectric - immune to EMR Sensors such as FBGs do not suffer zero shift Sensors can be multiplexed Size of optical fibre makes it suitable for embedding into composite materials	Fragile – accidental damage Need to design for redundancy Connections to embedded composites difficult Temperature compensation often required Instrumentation can be complex
Electrical	Mature technology Rest of array is not affected when one sensor goes down Grids can be used for larger coverage Printed circuitry and MEMS miniaturising devices	Weight penalty with individually wired sensors Susceptible to EMR Insulation problems with regard to CFRP Protection from corrosion required Temperature compensation often required

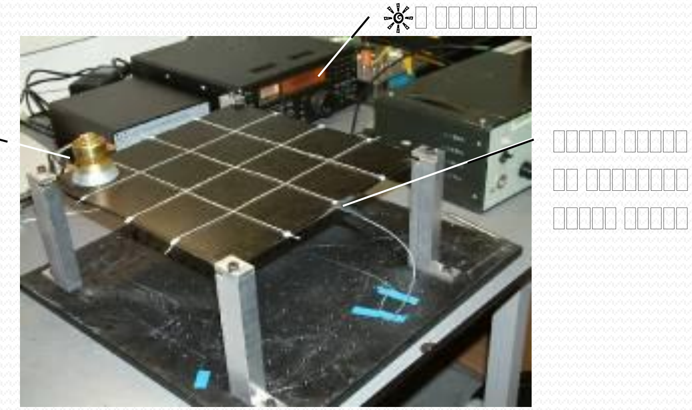
Optical Fibre Sensors

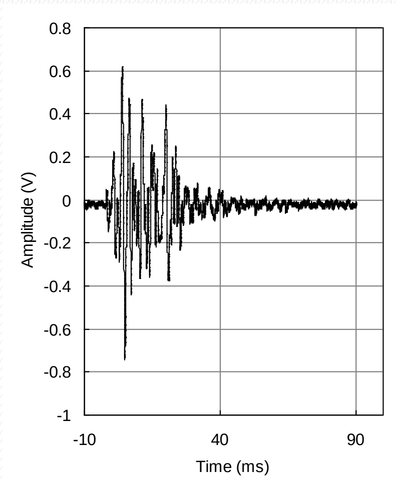
- Multi-core fibre sensors
  - Bending
- Tribroluminescent sensors
  - Light is emitted by crystals when fractured/stressed
  - Used as impact damage sensors

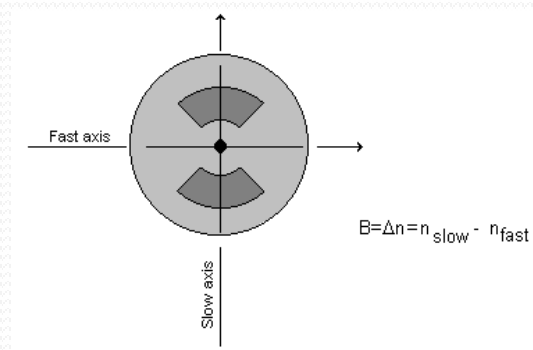
Optical Fibre Sensors

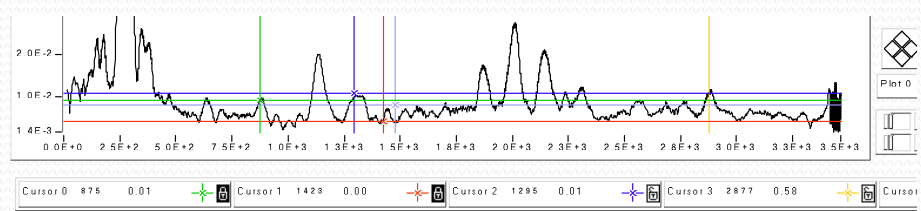
- Fibre Laser sensors
  - Very sensitive strain sensor
  - Acoustic emission



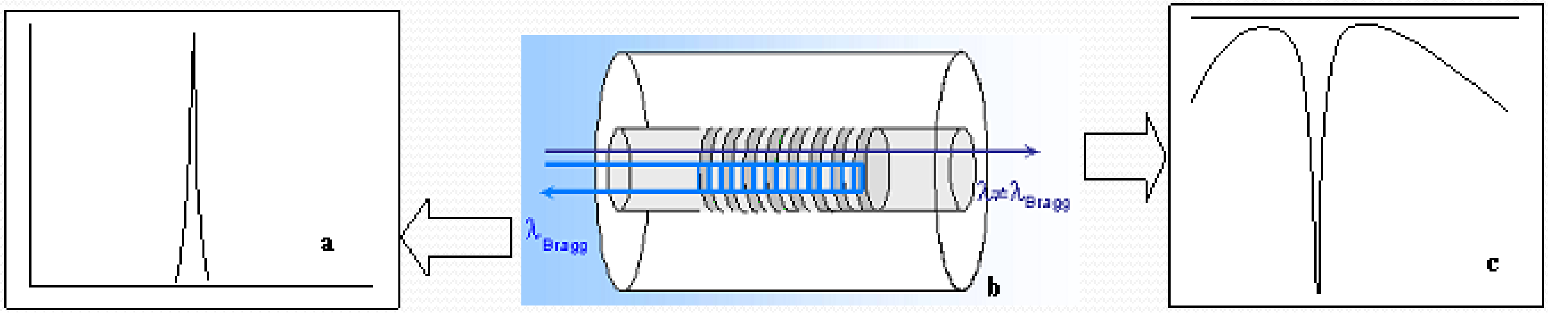


- High Birefringent Damage Detection Technique
  - Transverse stress
  - Impact and damage





Optical Fibre Sensors



Fibre Bragg gratings

Wavelength shifts with strain and temperature

Multiplexed along one fibre length

Wavelength or time domain multiplexing

Can be used to measure

Strain & temperature

Crack detection

Damage detection

Disbond detection

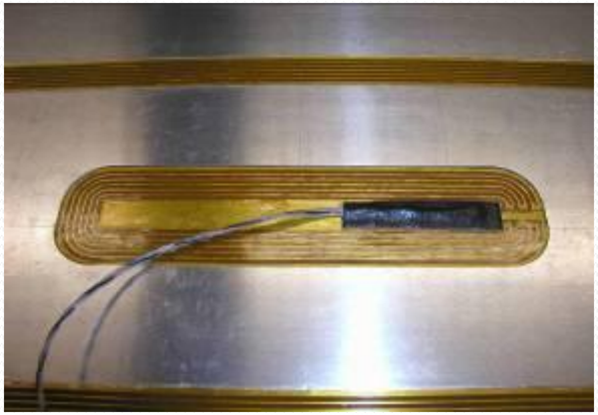
Impact detection

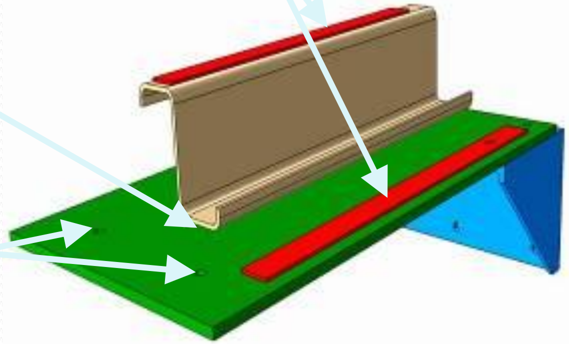
Acoustic emission

Cure monitoring

Electrical sensors

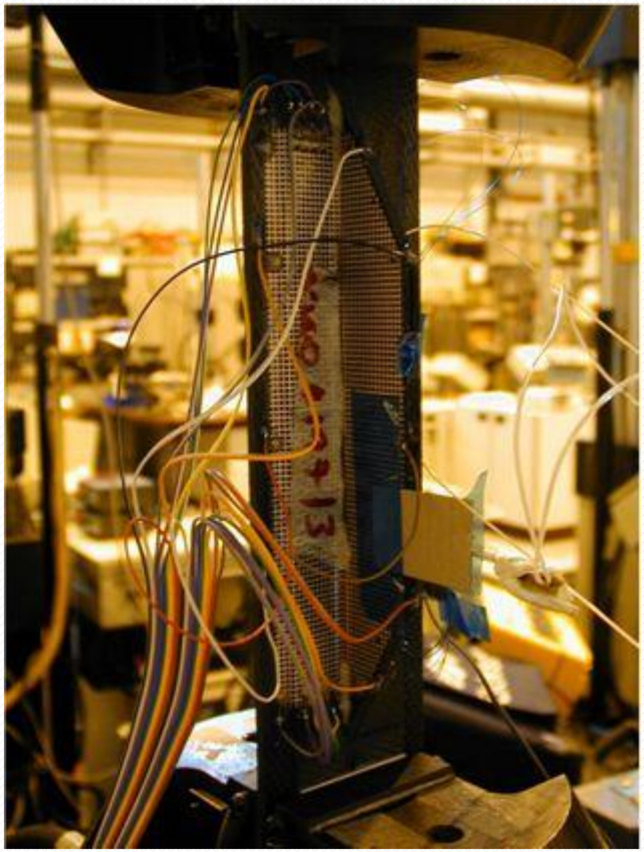
- Magnetostrictive sensors
  - Amorphous wires and ribbons
  - Strain and impact events
- Piezoelectric sensors
  - 0-3 piezoelectric composites
  - Lamb waves
  - Acoustic emission
  - Damage detection / disbonds
- Strain memory alloys
  - Peak strain
- Shape memory alloys
  - Typically used actively – resistance can be measured for SHM purposes





Electrical Sensors

- Self sensing
  - Change in resistance of carbon-fibre reinforced plastics
- Electrical resistance
  - Strain gauges or embedded resistive wires
  - Electrical Resistive Patch
- Amorphous Sensors
- Comparative Vacuum Monitoring



What can SHM provide?

- Real time or Baseline comparisons of health of structure
- Active structures need feedback of position/shape change
- Whole life costs of a structure can be reduced
  - Reduced maintenance – NDE inspections
  - Real time monitoring
  - Greater confidence in structural performance of new materials

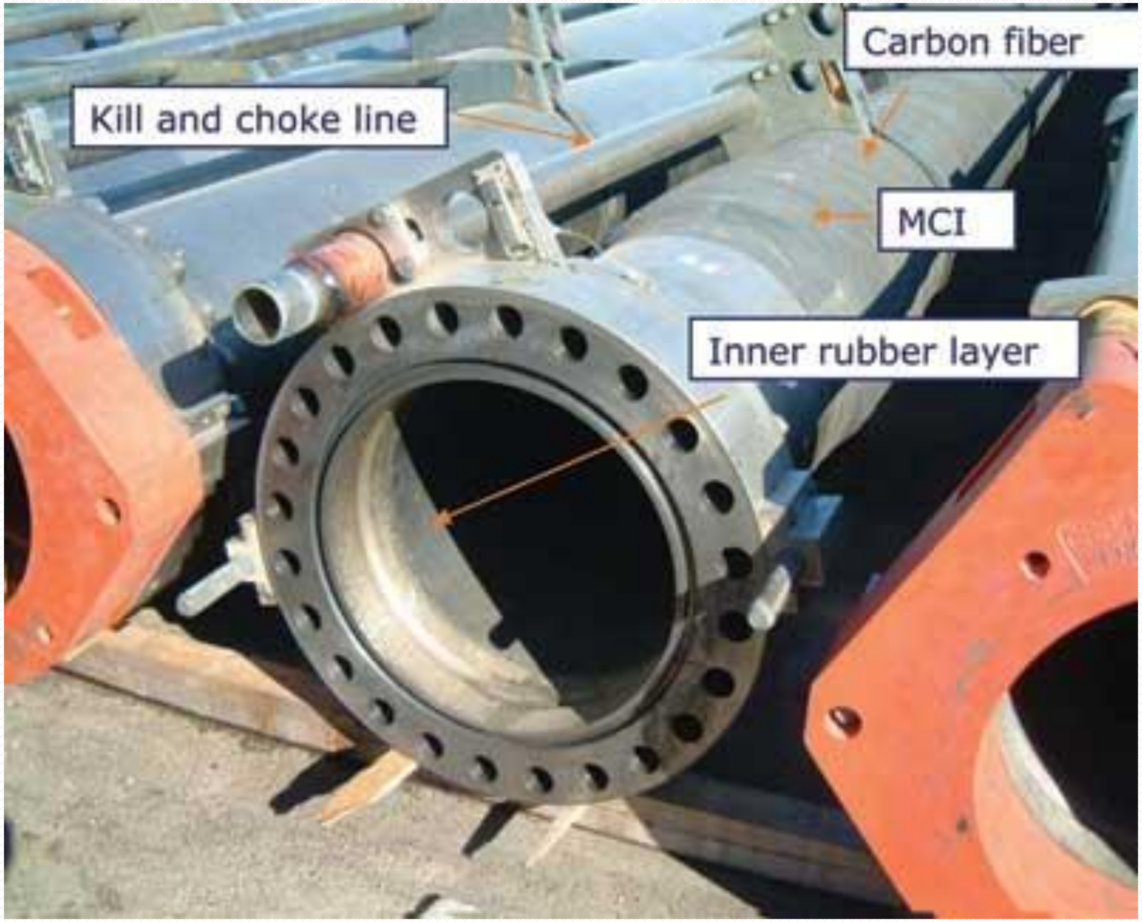
The PRISM DVD

Technology Applications

- Oil Industry

3 deaths from pipeline damage

Composite Risers



Technology Applications

- Oil Industry
- Marine

Lifeboat Damage

Ship and Boat Damage

Ship and Boat Damage

Technology Applications

- Oil Industry
- Marine
- Wind energy

Wind turbine blade damage

Fuselage Damage

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts


Mirabella V on the rocks

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails

Yacht sail stress monitoring

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail
- Deep sea

Deepwater Pressure Vessels

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail
- Deep sea
- Seals

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail
- Deep sea
- Seals
- Automotive


CREDIT SUISSE
MICHELIN

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail
- Deep sea
- Seals
- Automotive
- Civil Engineering

Bridge Strike

Technology Applications

- Oil Industry
- Marine
- Wind energy
- Air frames
- Marine Masts
- Sails
- Rail
- Deep sea
- Seals
- Automotive
- Civil Engineering
- Defence Applications

What is stopping you adopting SHM?

- Cost?
- Technology?
- Lack of Information?

How we might assist

- Provide know-how
- Provide components such as ready-to-use sensors
- Provide pre-forms
- Provide application engineering
- Provide structures

What do you need
that we could develop together
using our SHM expertise?

Who to talk to here

Steve Phillipson, Sigmatex

Who to talk to here

Andrew Ball, Sigmatex

Who to talk to here

Ed Findon, BVT

Who to talk to here

Mark Dixon, Deep Sea Engineering

Who to talk to here

Lisa Fixter, QinetiQ

Who to talk to here

Julian Ellis, Ellis Developments

Who to talk to here

Robert West, QinetiQ

Who to talk to here

Jonathan Gore, QinetiQ