



**London
South Bank**
University

**London
South Bank
Innovation
Centre**

Non-Destructive Testing Robot

Applications in Hazardous Environments

Professor Tariq Sattar

TWI Chair and Director London South Bank
Innovation Centre for Automation of NDT,
Cambridge, UK

INTRODUCTION

Capital Assets in safety critical industries have the following characteristics:

1. Expensive assets require regular monitoring
2. Large structures with test sites at remote locations
3. Located in extreme and hazardous environments
4. Inspection requires an outage with pressure to reduce turn-around time

Oil and gas industries-

- Petrochemical storage tanks
- FPSO's – Floating platform storage of oil
- Flexible risers
- Mooring chains and lines
- Oil and gas platforms
- Pipelines

Nuclear power plants & decommissioning

- Nozzle welds on pressure vessels and in primary circuit
- Radiation reprocessing cells
- Aerial stacks
- Concrete buildings

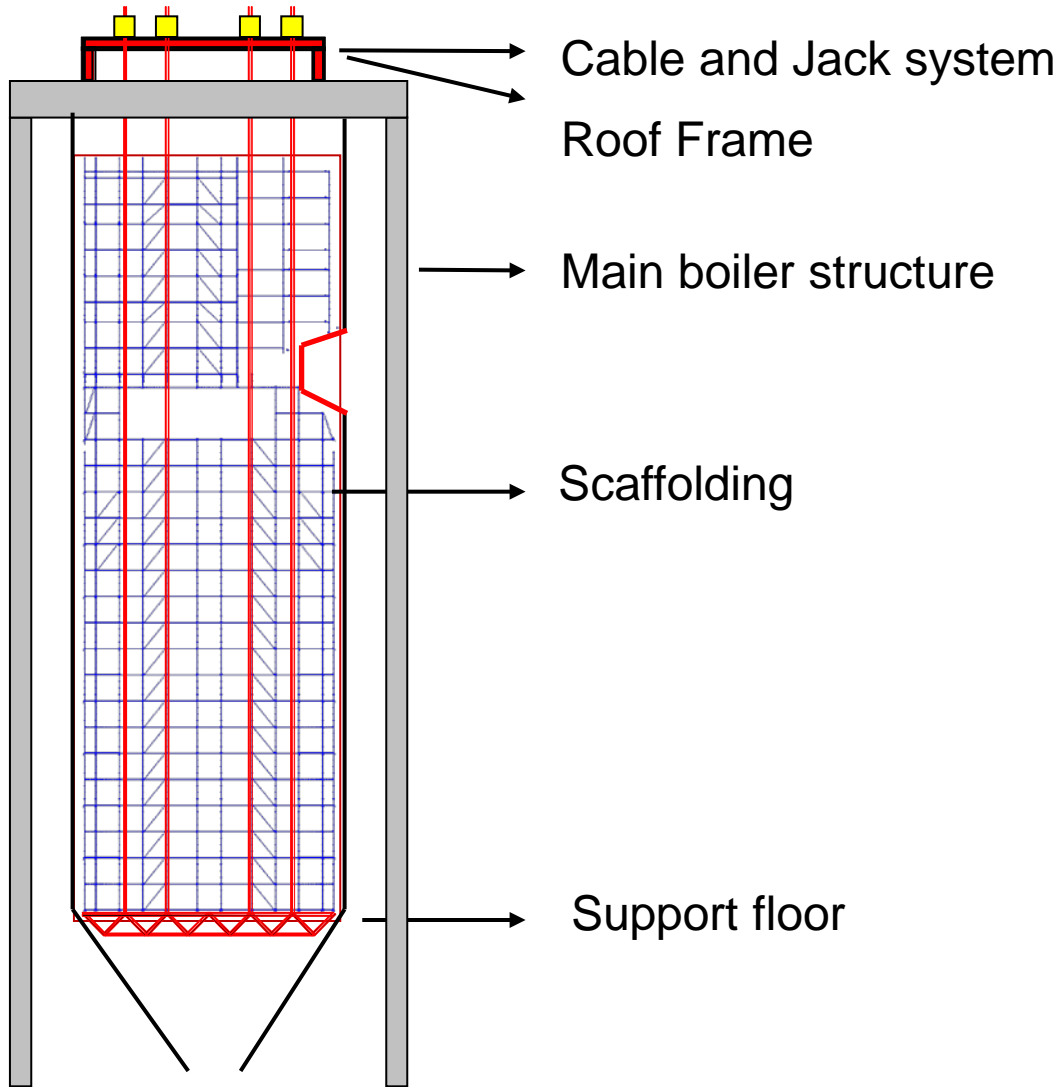
Renewable energy –

- Wind turbine towers and blades
- Tidal generator blades
- Off-shore monopiles for WTG's
- Dam walls in air and underwater

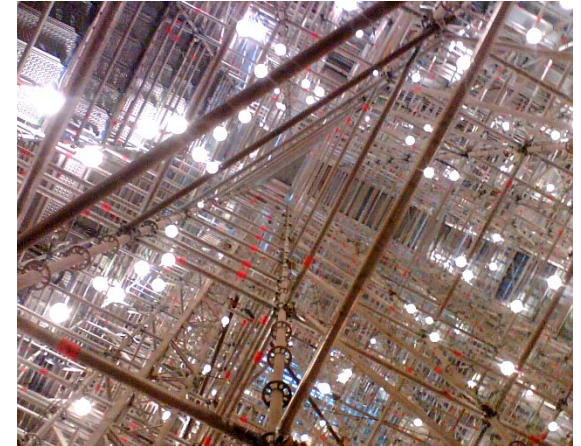
Transportation -

- Railway lines - cracks
- Aircraft - rivets, composite impact damage
- Ships – welds and corrosion

Inspection of 90 m tall gas boiler



Portaalframe strand Jack system



Five recent deaths due to scaffold collapse

Internal inspection of gas boiler using suspended platforms



Robotic Non Destructive Testing (NDT)

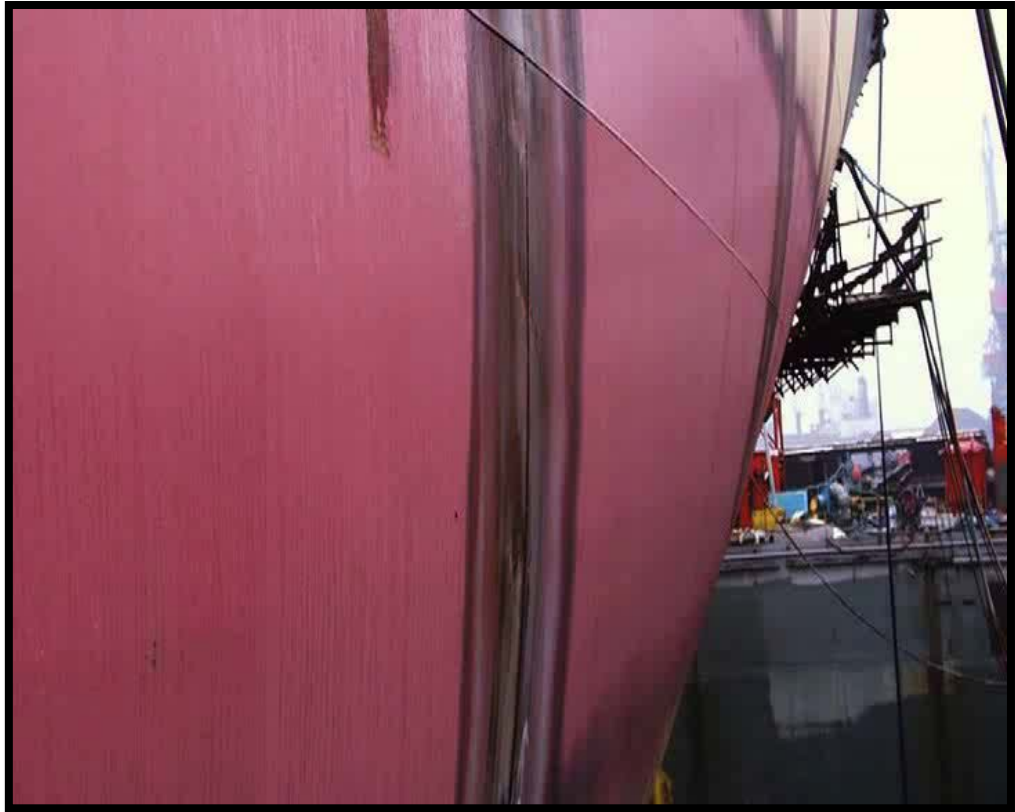
Ultrasound NDT
of horizontal and
vertical welds on a
new build cargo
container ship –
Odense Shipyard

Dimensions:

30m height

30m width

300m length

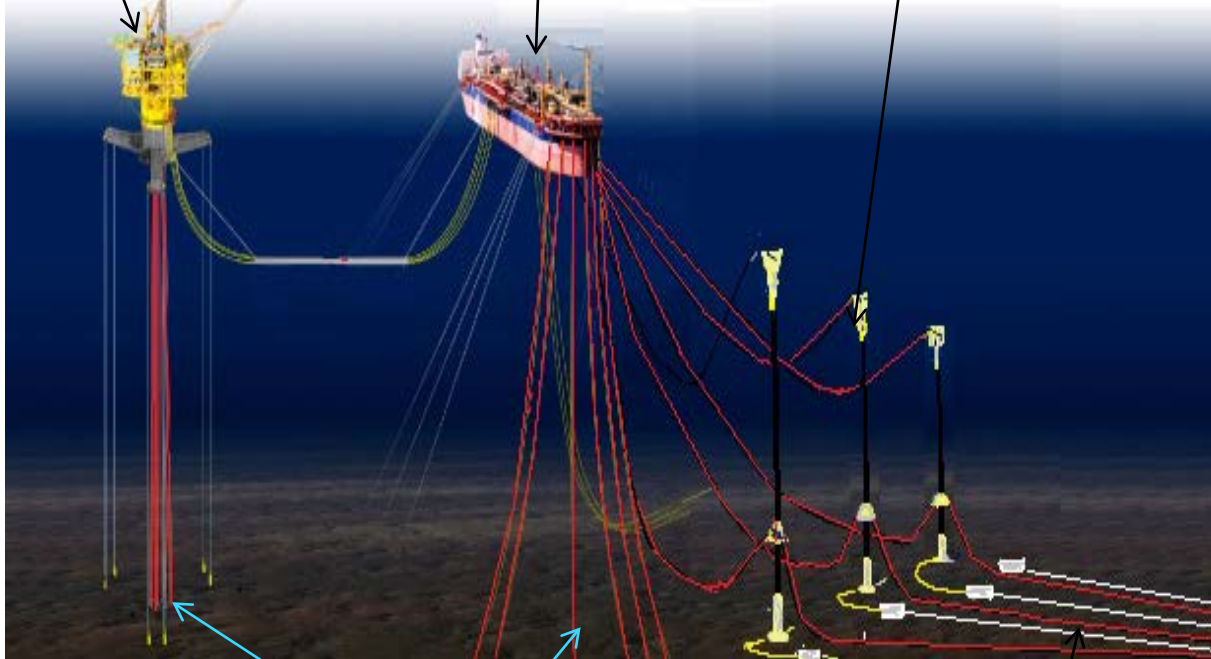


The floating platform, mooring chain, oil & gas flexible riser, flow-line, tie-back and tidal generator environment

Oil platform with pre-tensioned risers

FPSO

Tie-back Risers



Risers from oil wells

Pipelines from minor fields



DAM FAILURES

2005-2009 - 132 dam failures in the US with \$54.3M in repair and downstream costs.

Reported diver deaths in 2014



Robotic Non Destructive Testing (NDT)

R&D of Mobile robots to provide access and perform NDT of

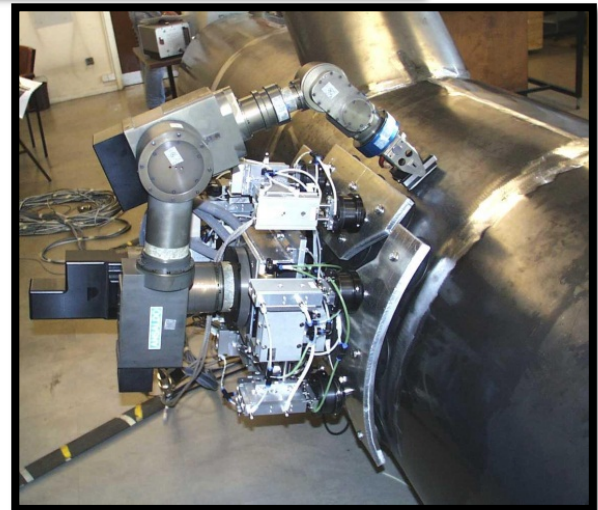
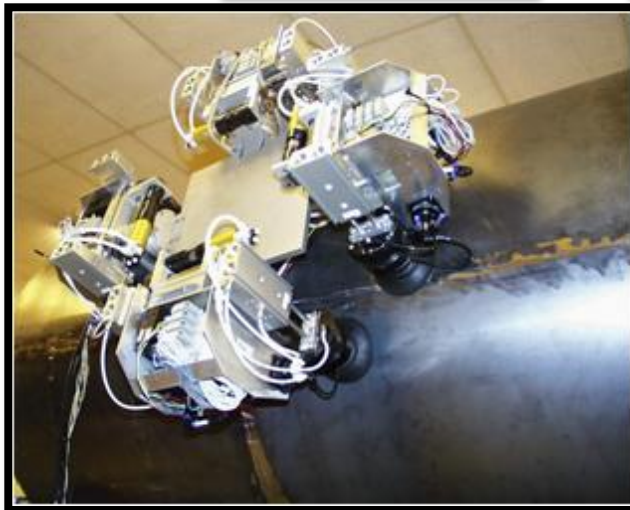
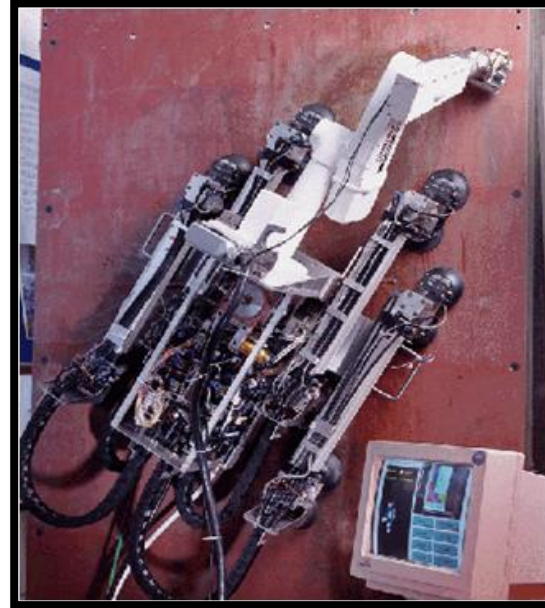
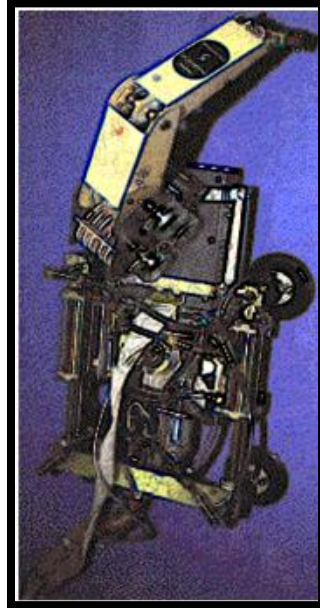
- very large structures
- test sites located in dangerous and hazardous environments

The aim is to

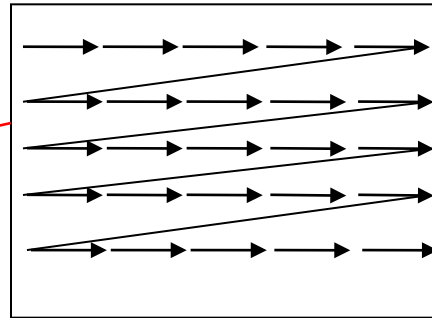
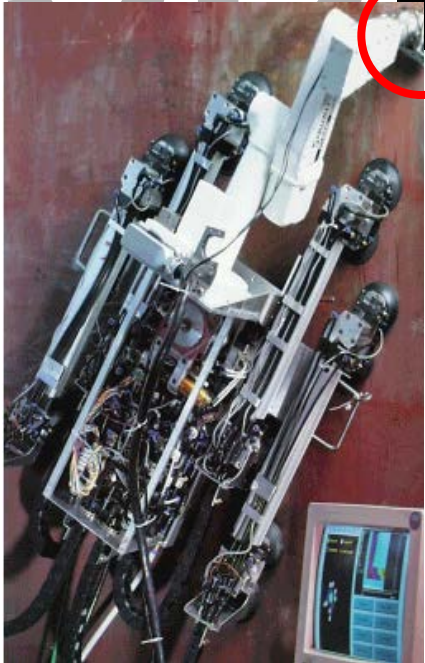
- reduce inspection costs, outage times during planned outages
- Provide in-service inspection where possible to eliminate outages

Wall climbing robots that use pneumatic suction cups

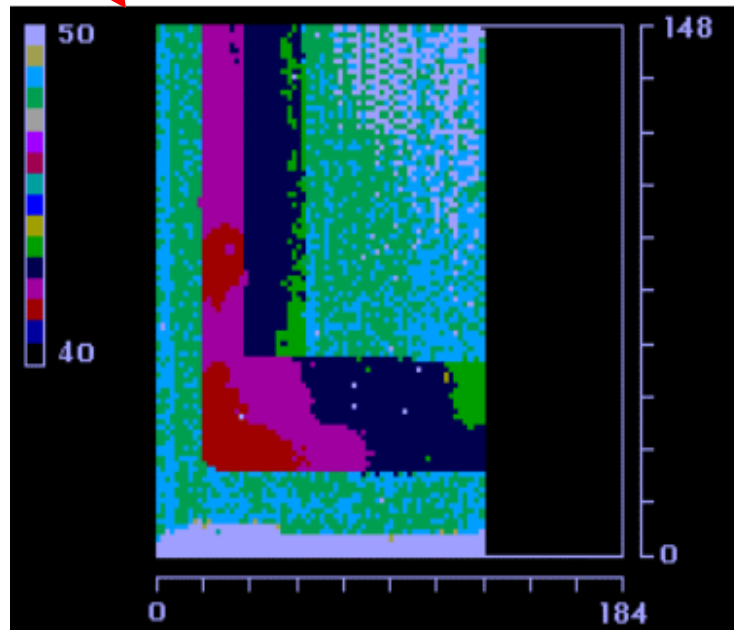
Worlds First
wall climber
1992



SBL

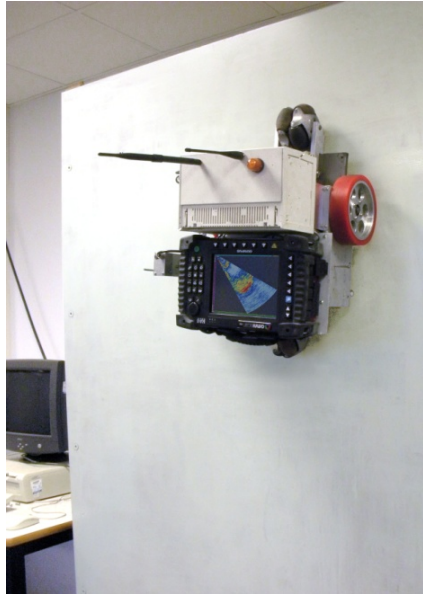


Raster-scan with UT probe

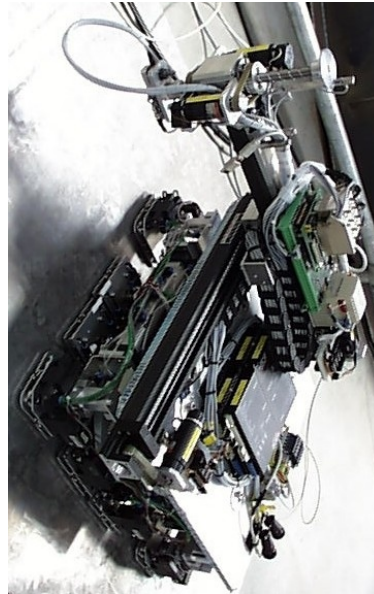


C-scan image of corrosion thinning (variable thickness 0 - 6 mm measured from the back wall) of a 10mm thick steel plate, adjacent colors corresponding to thickness steps of 0.375 mm. Data obtained with 5 MHz wet contact compression wave probe (8mm diameter)

Climbing NDT robots that use different adhesion techniques: permanent magnets, pneumatic suction cups and Vortex machines



CROCELLS



ROBAIR



VORTEX

Wall climbing robots for the NDT of welds on cargo containers ships

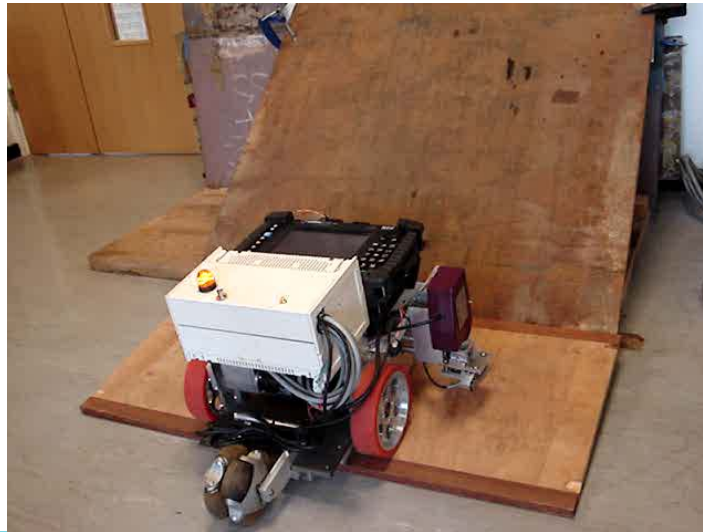
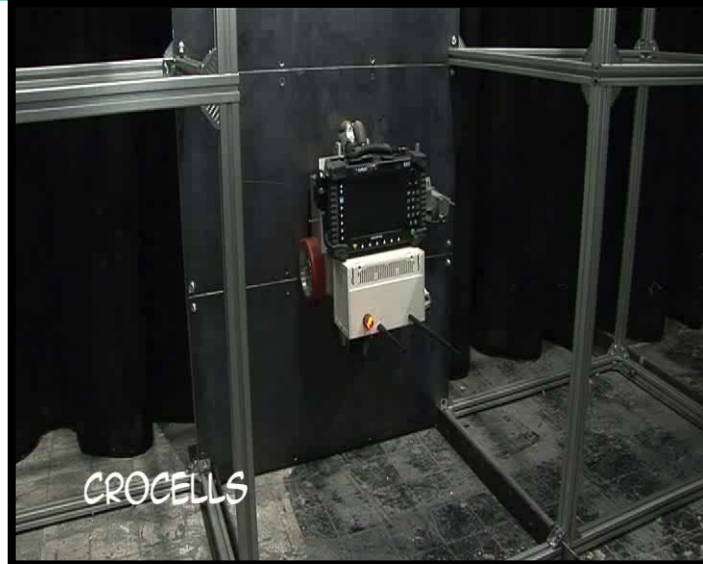
Permanent magnets

Wireless control and data acquisition

Ultrasonic phased array NDT

Laser weld profiling and tracking

Mass 35Kg



InnovateUK funded project AWI (Autonomous Weld Inspector) is currently developing a more advanced version of this robot

Magnetic adhesion climbing robots

Adapt to surface curvatures (concave or convex) or change surfaces



NDT robot
adapts to
Convex/Concave
structures

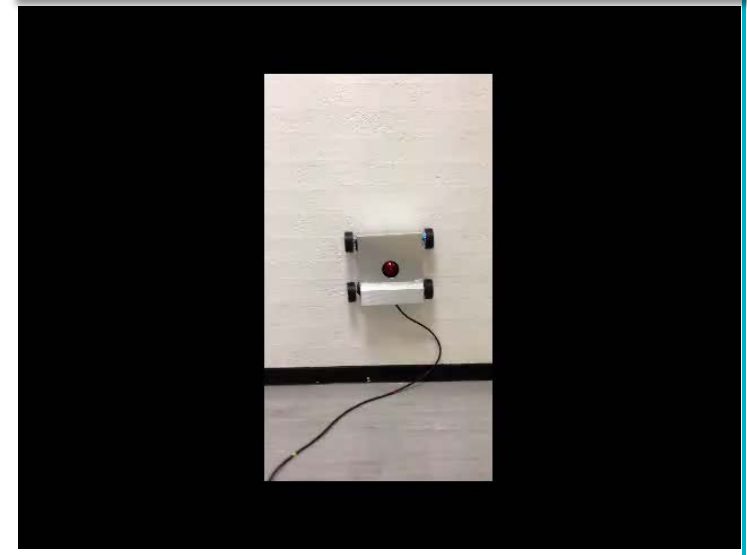
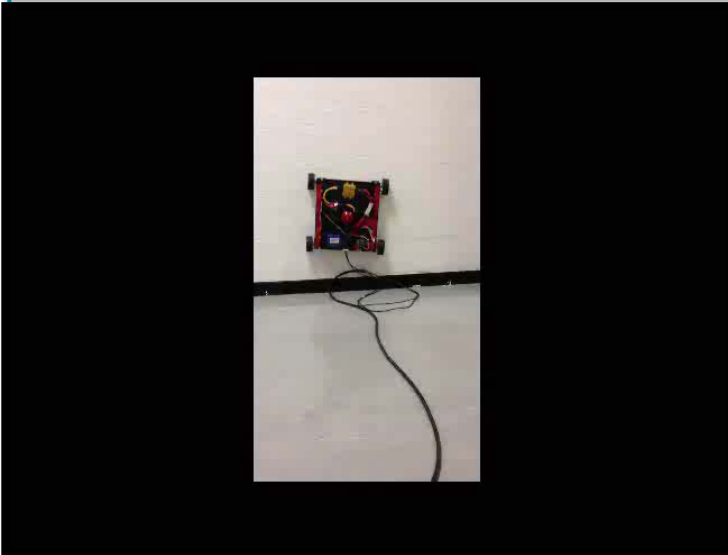


WALLEXPLOR

Wall climbing robots for NDT, inspection and surveillance on non-ferrous surfaces

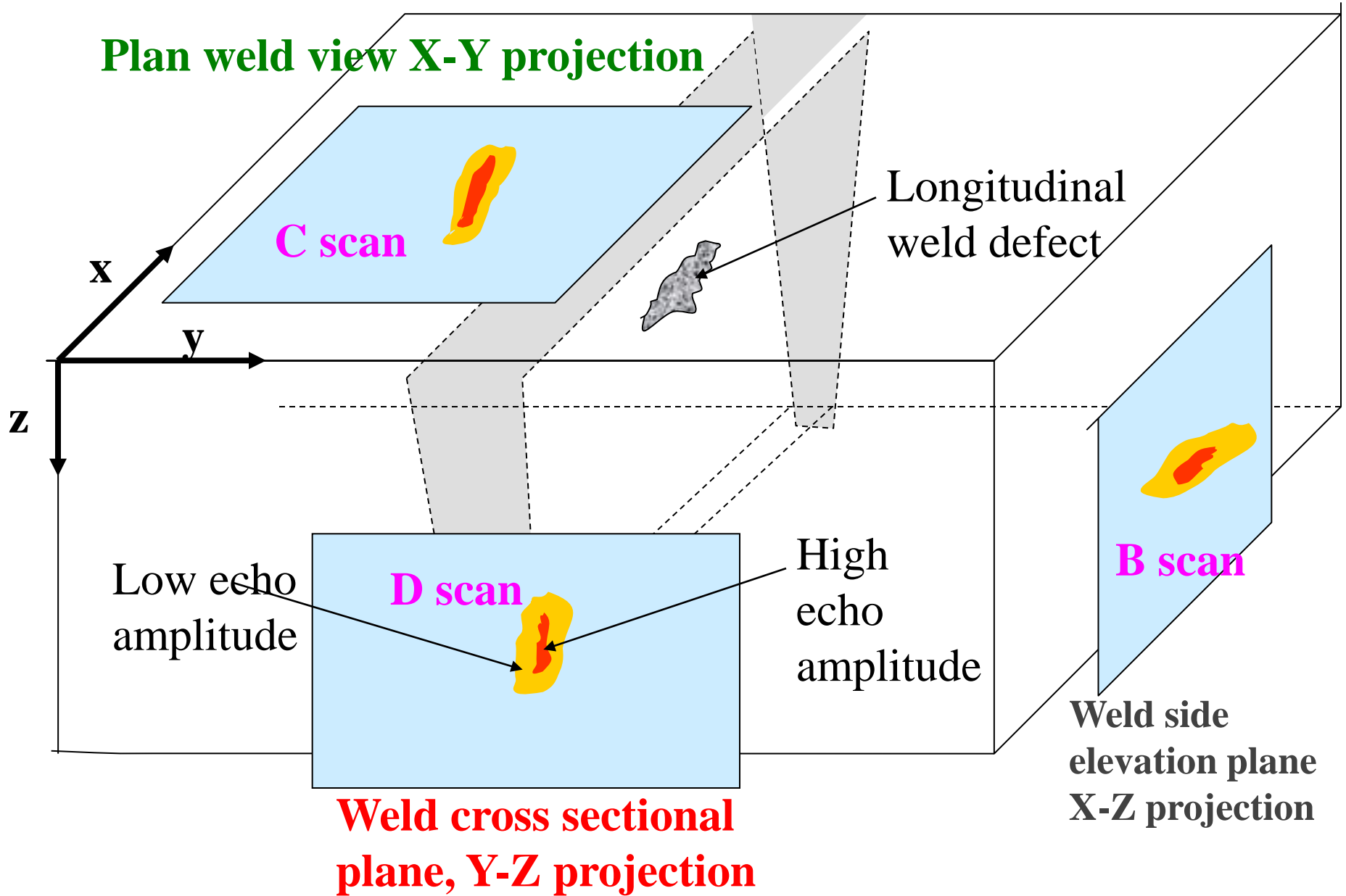


VORTEX MACHINES: Wall climbing robots for NDT, inspection and surveillance on non-ferrous surfaces



Measurement

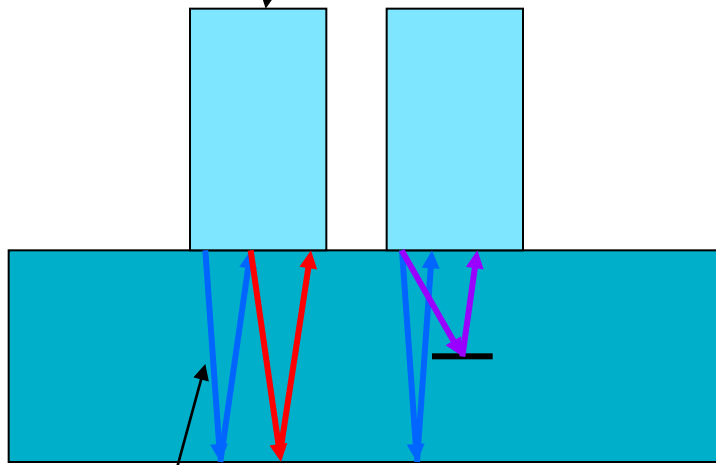
Non-destructive testing (NDT)
techniques



Display of weld defect on orthogonal planes related to the weld.

0° compression wave

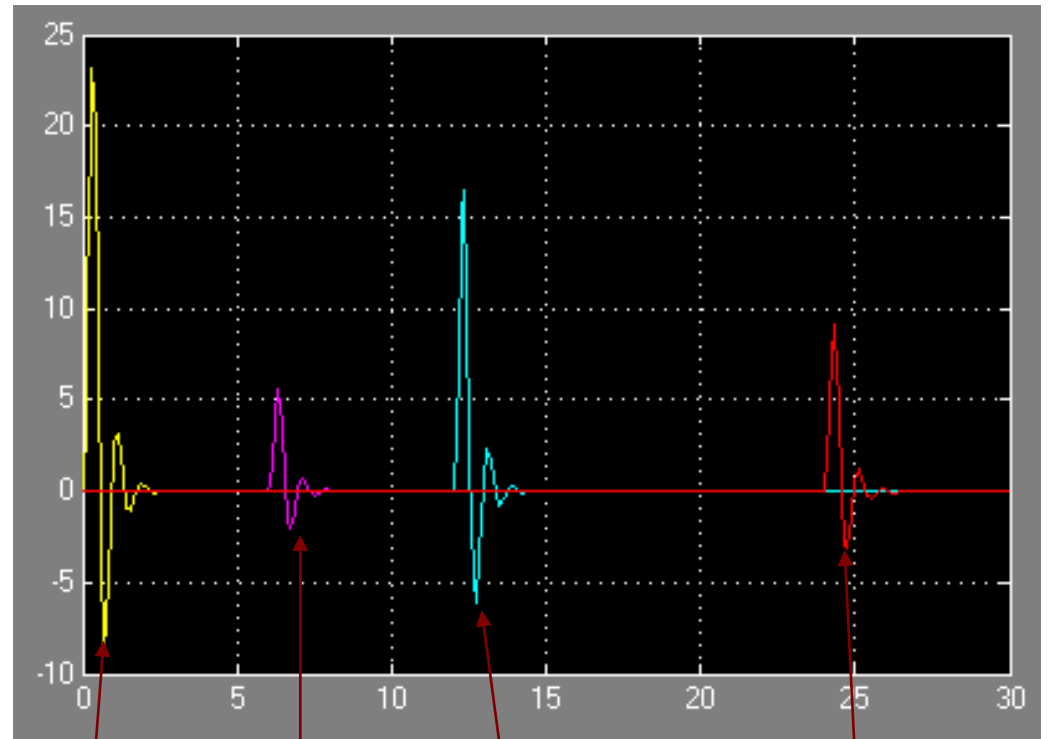
Ultrasonic probe



Back wall

longitudinal waves

A-Scan



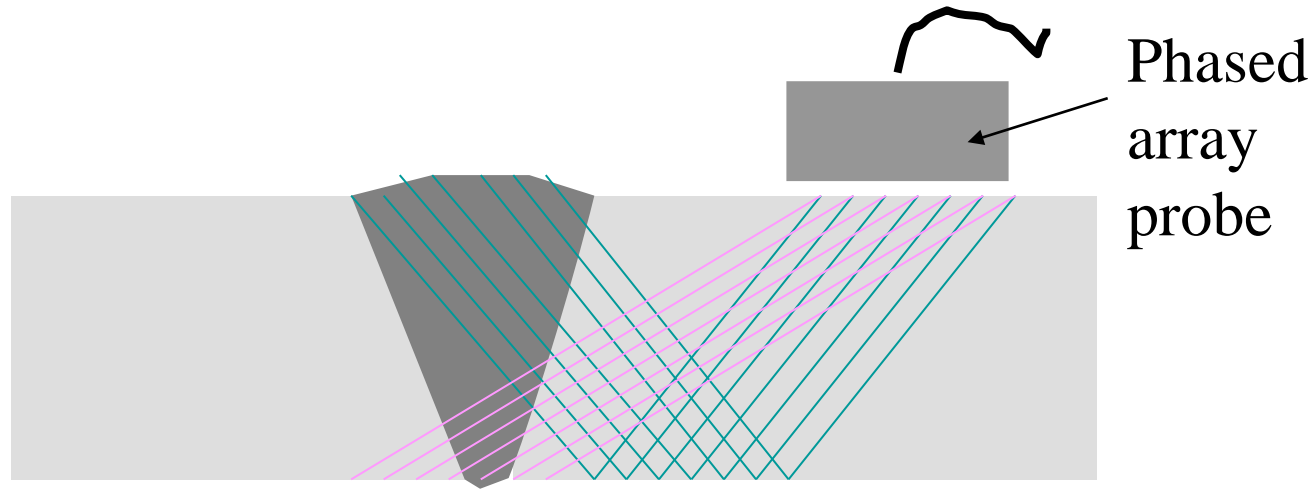
Transmitted
ultrasonic
pulse

Defect
echo

Back-
wall echo

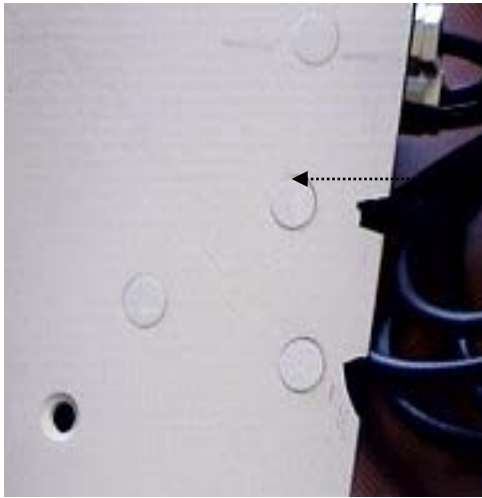
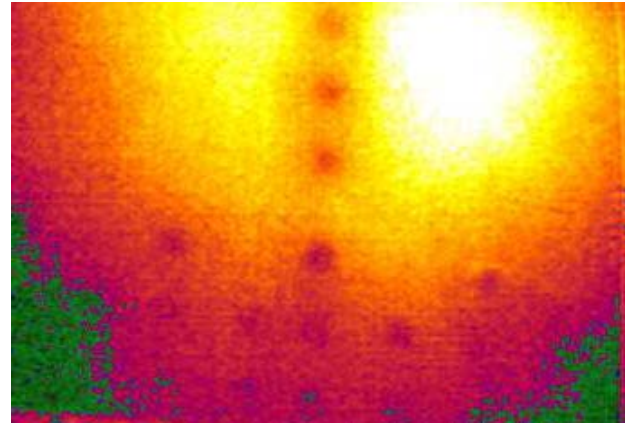
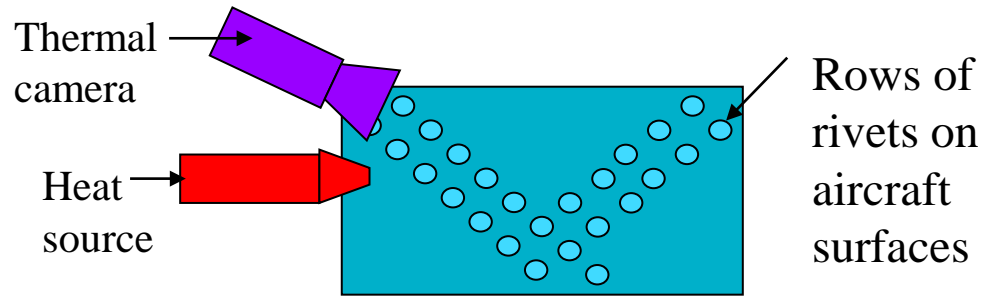
SecondBack
-wall echo

Phased array ultrasonics



- Array of elements, all individually wired, pulsed and time shifted.
- Each element generates a beam when pulsed; these beams constructively and destructively interfere to form a wavefront.
- Electronic beam steering reduces the number of scanning axes required to examine a defect

Thermographic NDT



Loose rivet on an aircraft wing



Thermal image of loose rivet

In-service inspection of petro-chemical storage tanks with mobile robots – RobTank project

Worldwide, over 218,000 petrochemical storage tanks and 53,000 large storage tanks with diameter > 50m are mostly inspected with outages. A large 100m diameter crude oil tank can be out of service for up to 9 months



Existing tank floor inspection activities

Preparing recipient tank

Moving contents to the recipient tank

Opening the tank under inspection

De-gassing the tank

Cleaning the tank – Sludge removal

Manual Inspection conducted by personnel

Closing the tank after inspection

Refilling the tank

Checking seals, vents, hoses etc.

Average Total Cost €90000

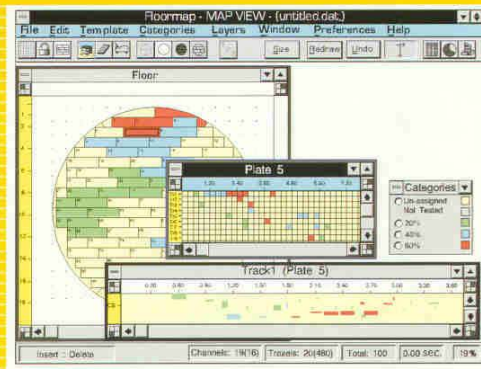
80% of cost is opening and closing the tank

CLEAN TANKS
Diameter 2 to 20 metres, fixed roof.
Visual inspection,
a few ultrasonic
thickness
measurements.

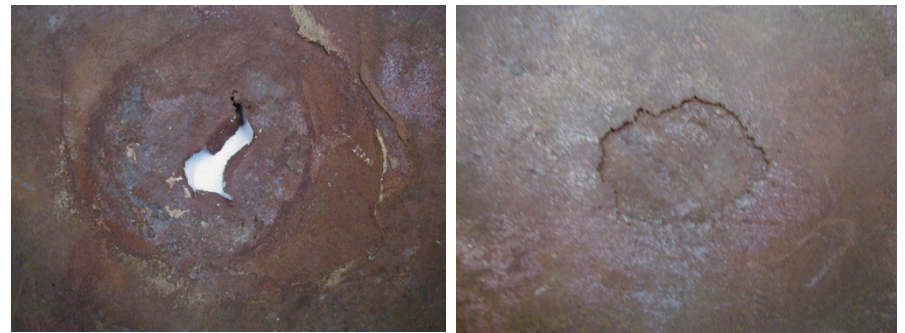


Crude oil tanks
floating roofs, dia
20 - 100 metres,
carbon steel. Floor
thickness of 6-
12.5mm,
Preparation: 6-9
months .Another 3-
6 months to clean .

Visual inspection
followed by MFL.
UT final method to
validate the
problem areas.

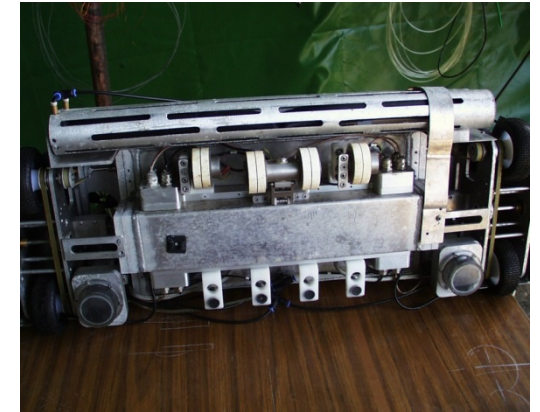
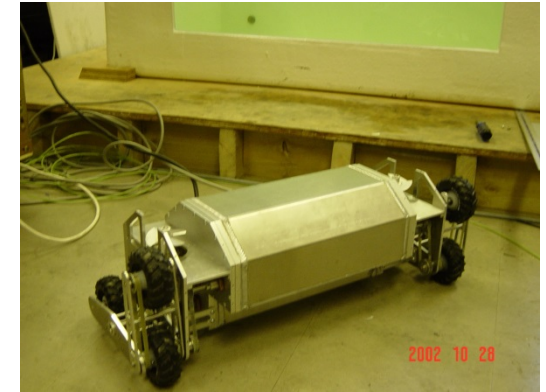


- ◆ Advanced Magnetic Flux Leakage Technology.
- ◆ Automated Data Acquisition and Analysis on line.
- ◆ Offline integrated reporting package.



Manual tank floor inspection, underside corrosion defects

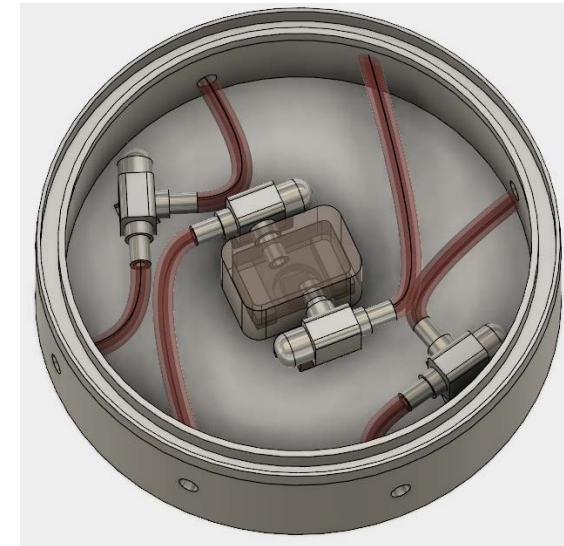
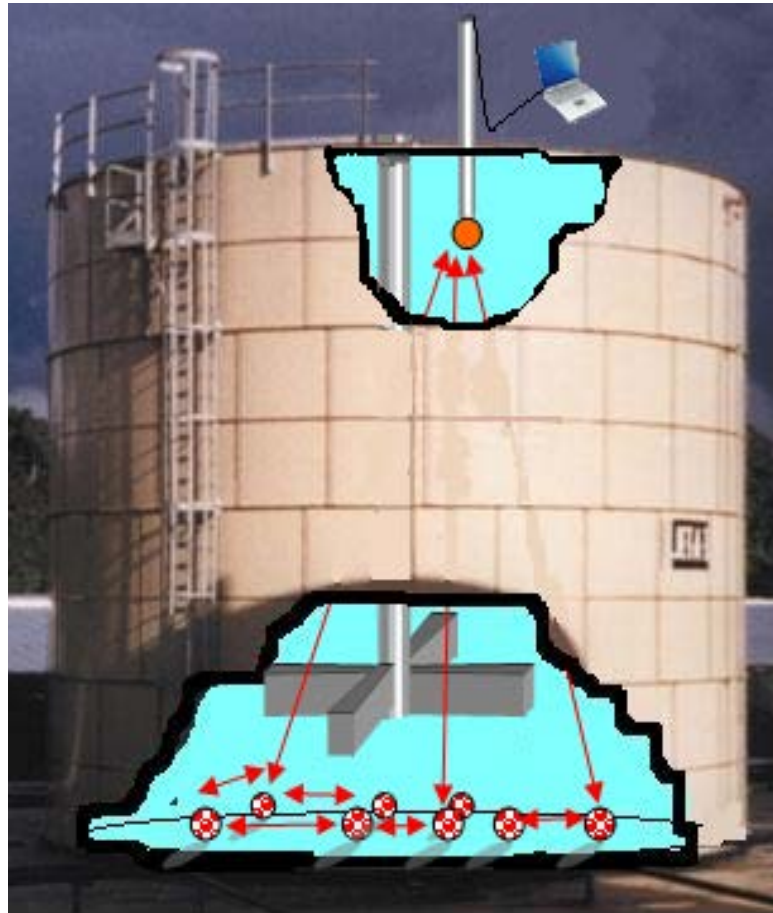
EU FP5 ROBTANK: Mobile wall climbing robot enters through manholes on the floating or fixed roof of a tank to inspect tank floor and internal walls



H2020 FTI TANKROB: Mobile robot to NDT tank floors with Phased Array Ultrasound – ATEX certification for Zone 1 operation

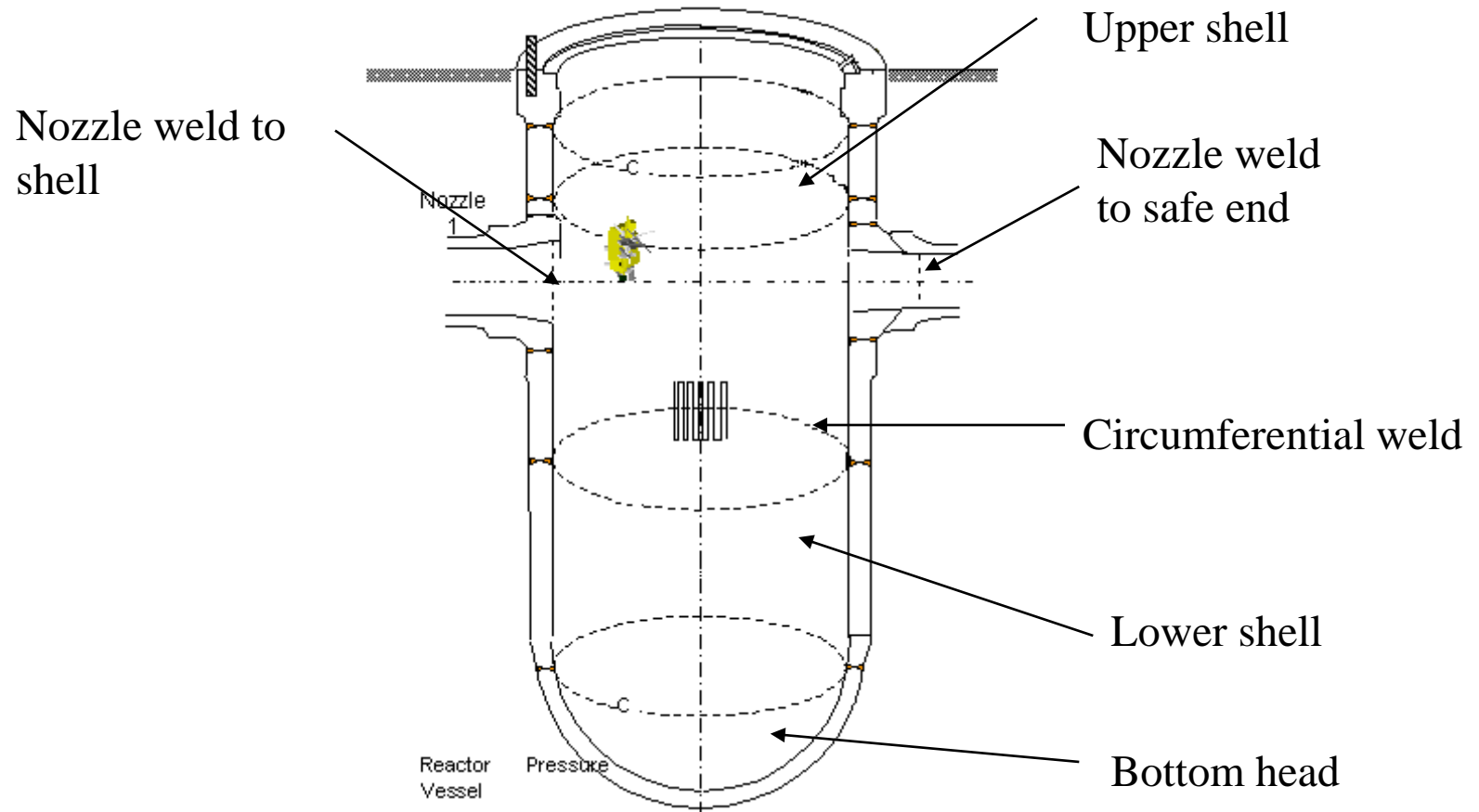
New InnovateUK funded project NAUTILUS: Bathyscaphic Robotic Floor Thickness Monitoring of Hazardous Liquid Storage Tanks

1. Active buoyancy control
2. Ultrasound NDT
3. Under liquid data communications
4. Zone 0 certification



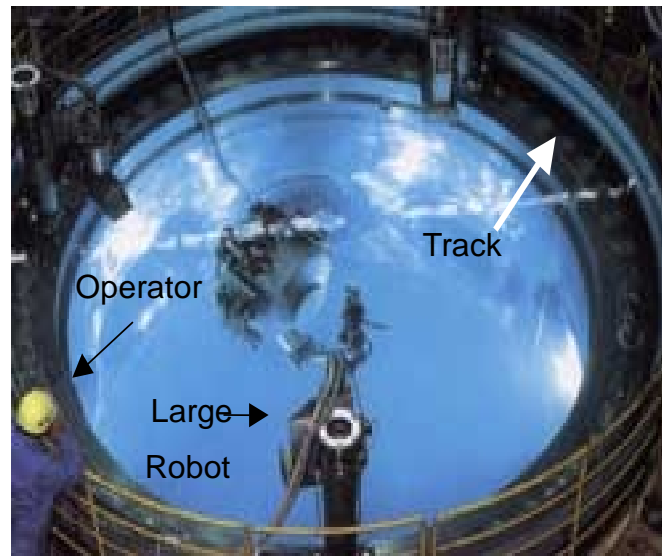
Nuclear power plant

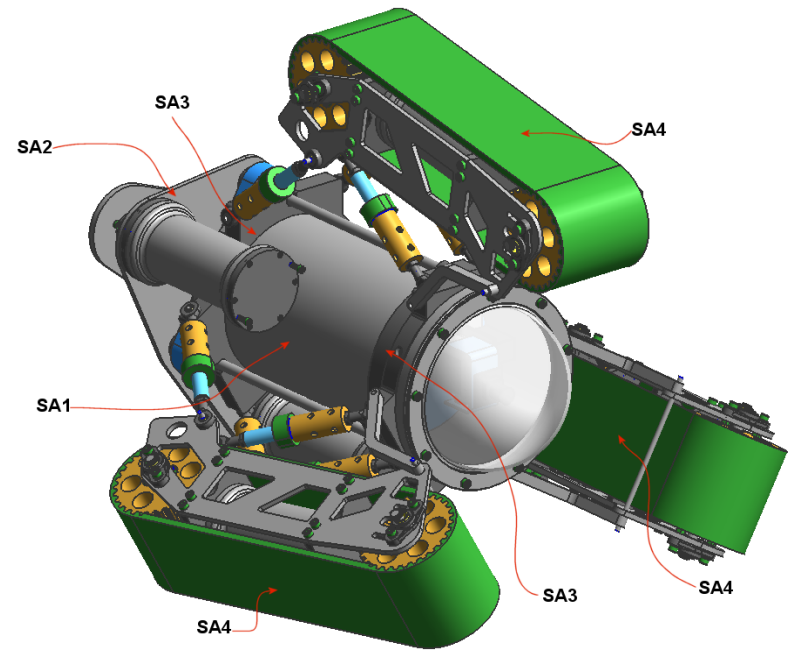
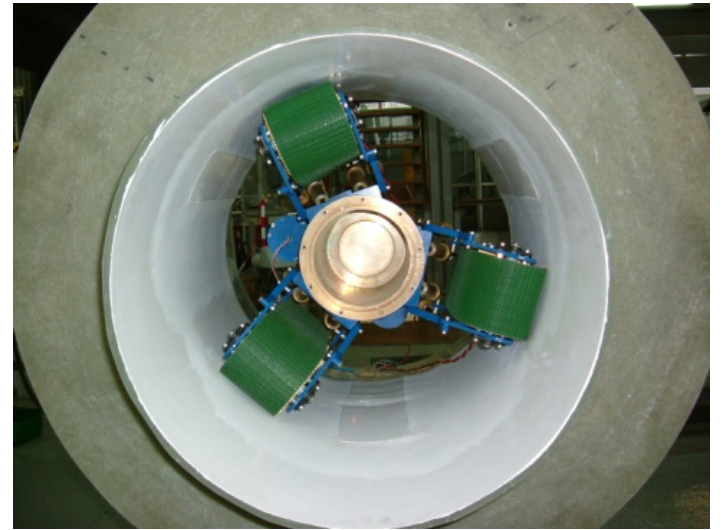
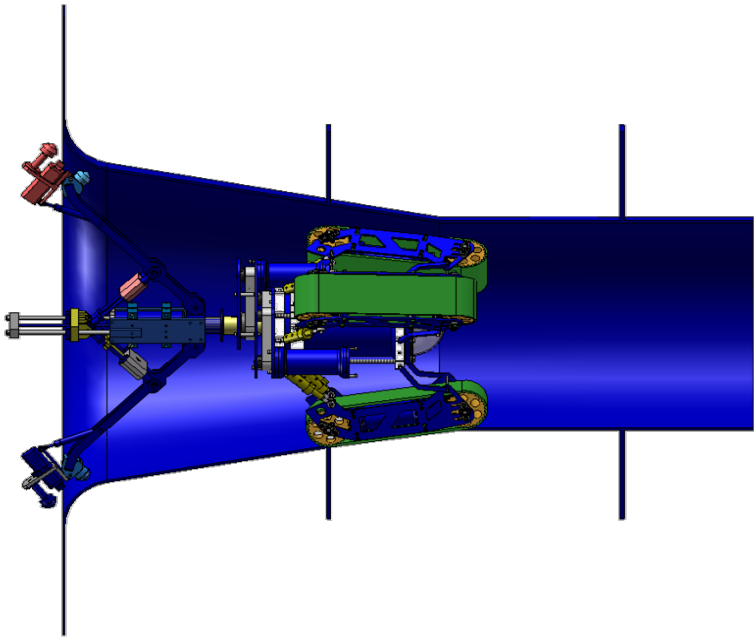
- RPV Circumferential and Nozzle welds
- Nuclear decommissioning



Current method of inspection uses large robots to do inspection – robot transported and assembled on site before immersion in RPV

- Require large and heavy robots with a central mast costing millions, manual set up time, tying up of polar crane needed for other tasks





Decommissioning of the Sellafield nuclear reprocessing site

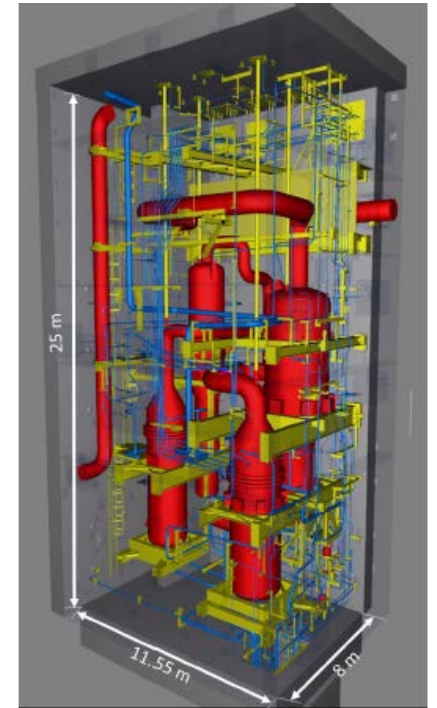


- 120 concrete buildings housing reprocessing cells, nuclear waste
- £80 billion to be spent in next 5 years to decommission
- 120 years to decommission site

Inspection (1) – Large Structures and Buildings

Inspection (2) – Aerial Stacks

Inspection (3) – Radiation Contaminated Reprocessing Cells



Climbing Robot for inspection of large concrete structures e.g.

- Stacks
- Radiation Cells
- Buildings
- Civil engineering structures



Demonstration of STRONGMAN carrying TWI laser cutting tool for nuclear decommissioning – 21 September 2016



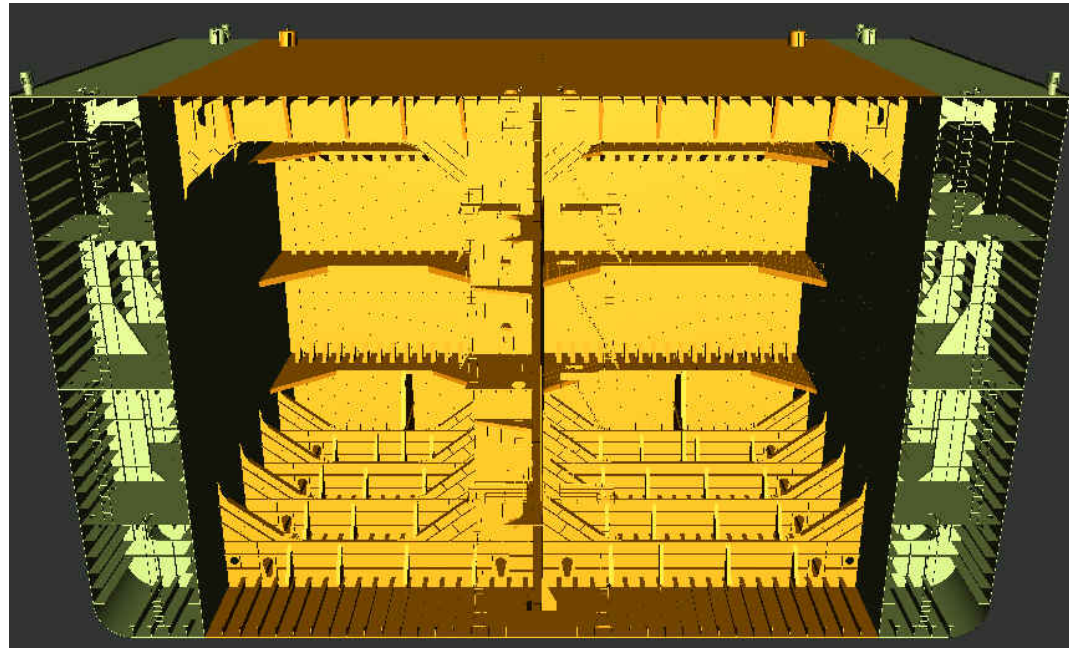
The Lasersnake2 R&D project funded by the UK Technology Strategy Board, the Department for Energy and Climate Change, and the Nuclear Decommissioning Authority is using snake arms to deploy laser cutting heads

Floating Production Storage of Oil (FPSO)

Task: Inspect welds between strengthening plates and tank floor

Two tanks are emptied, cleaned and inspected in 3-4 weeks with 60-70 man-days work and costs between £30-40k.

- Outage required with cleaning of tank before inspectors can enter tank – problem of disposal of cleaning medium
- Eliminate outage by performing in-service inspection with mobile swimming robots or empty without cleaning and use amphibious robot



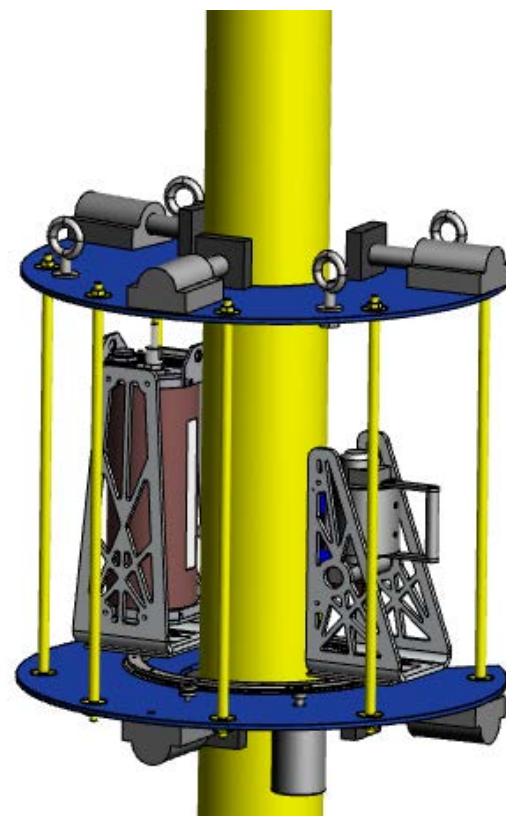
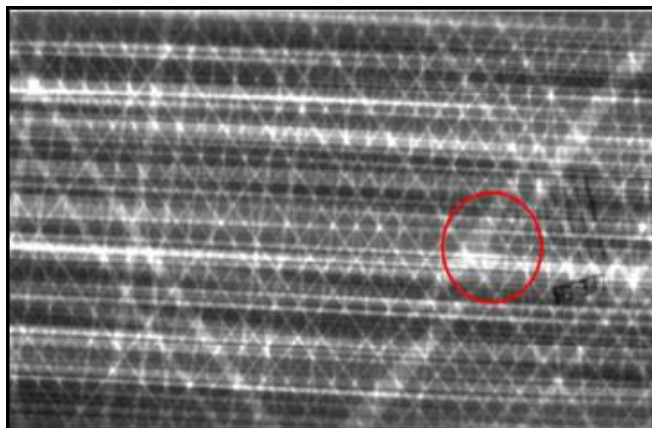
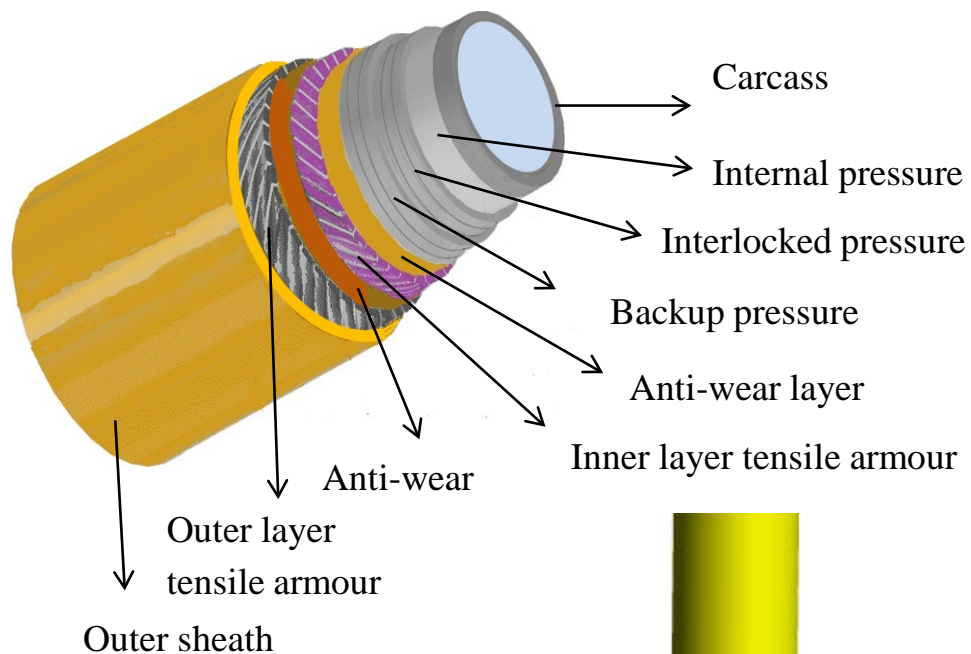
FPSO swimming and floor inspection robot to inspect tank floors and welds on strengthening plates

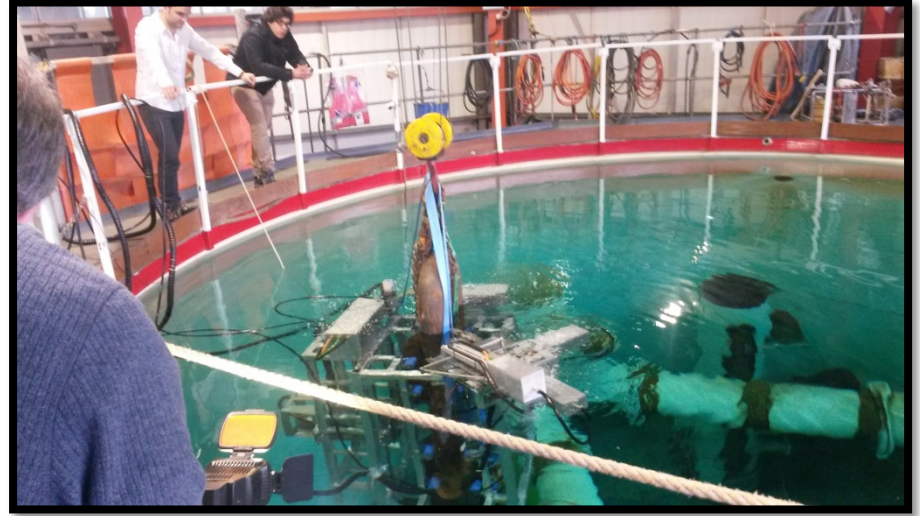


Horizon 2020-FTI Pilot-2015

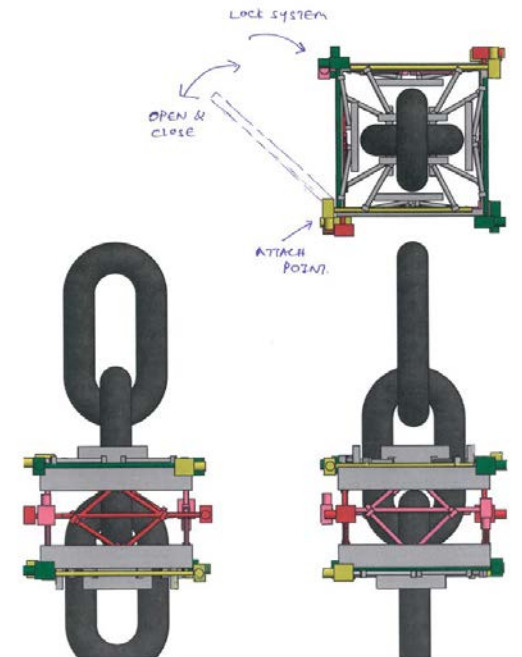
RiserSure

Rapid Integrity Assessment of Flexible Risers for Offshore Oil and Gas Installations with radiography

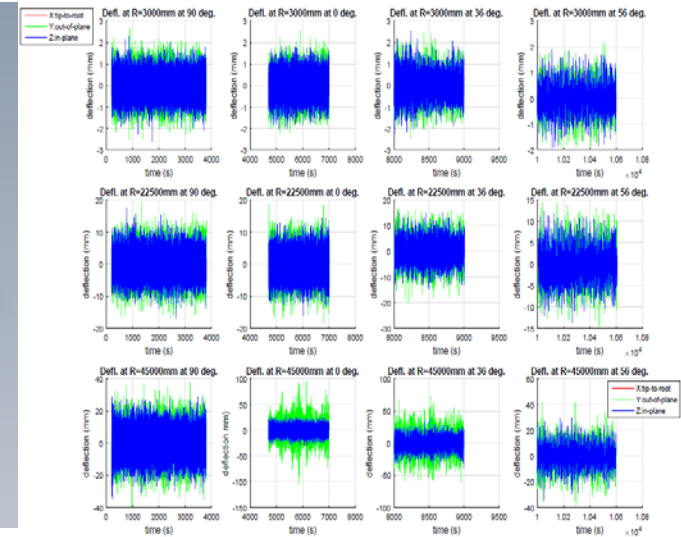
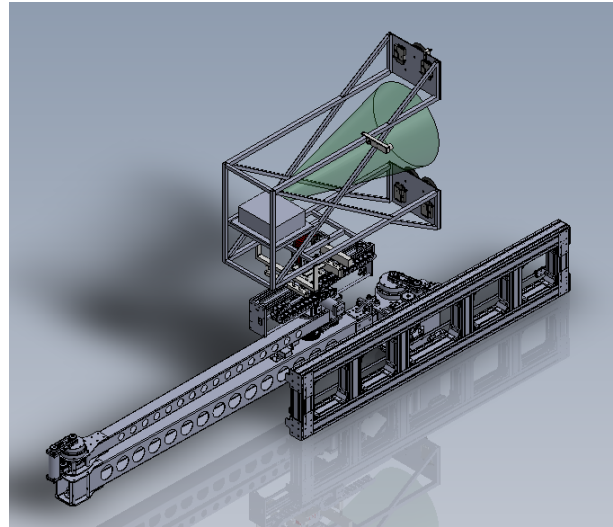




FP7-SME The MOORINSPECT PROJECT → InnovateUK/EPSRC project RIMCAW



Climbing robots for monopile, wind turbine tower and blade inspection



H2020 FTI project WINSPECTOR uses shearography to NDT blades

FP6 project to NDT blades uses X-ray computed tomography to NDT blades

New InnovateUK project RADBLAD X-ray radiography of NDT blades with robots



Conclusion

Mobile robots that can access safety critical infrastructure located in remote and extreme environments promise to

- Ensure the integrity of assets
- Reduce inspection and maintenance costs
- Reduce outage turn-around time/ perform in-service NDT
- Increase worker health and safety and reduce fatalities