

Robotic Non Destructive Testing

Centre for Automated and
Robotic Non Destructive Testing

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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

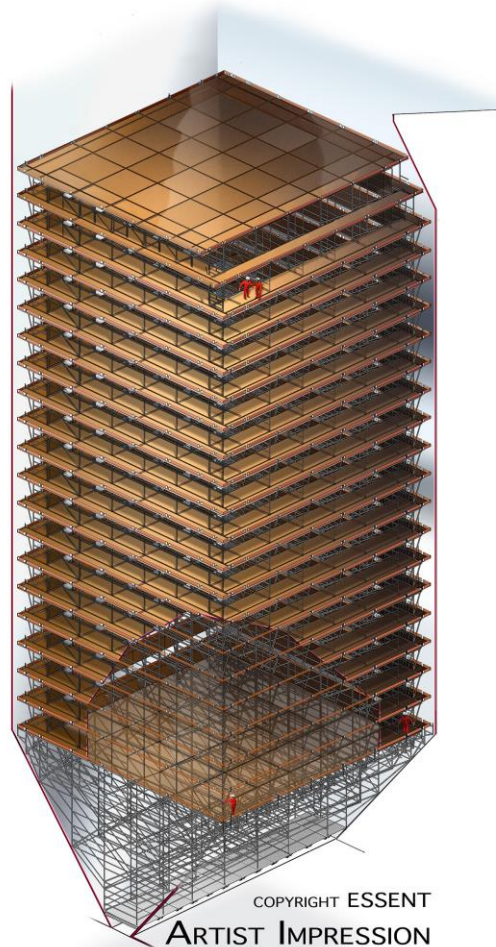
- reduce inspection costs, outage times during planned outages
- Provide in-service inspection where possible to eliminate outages



Example where Robotic NDT would save time and cost and improve Health & Safety

Internal inspection of Gas Boiler in Power Plant

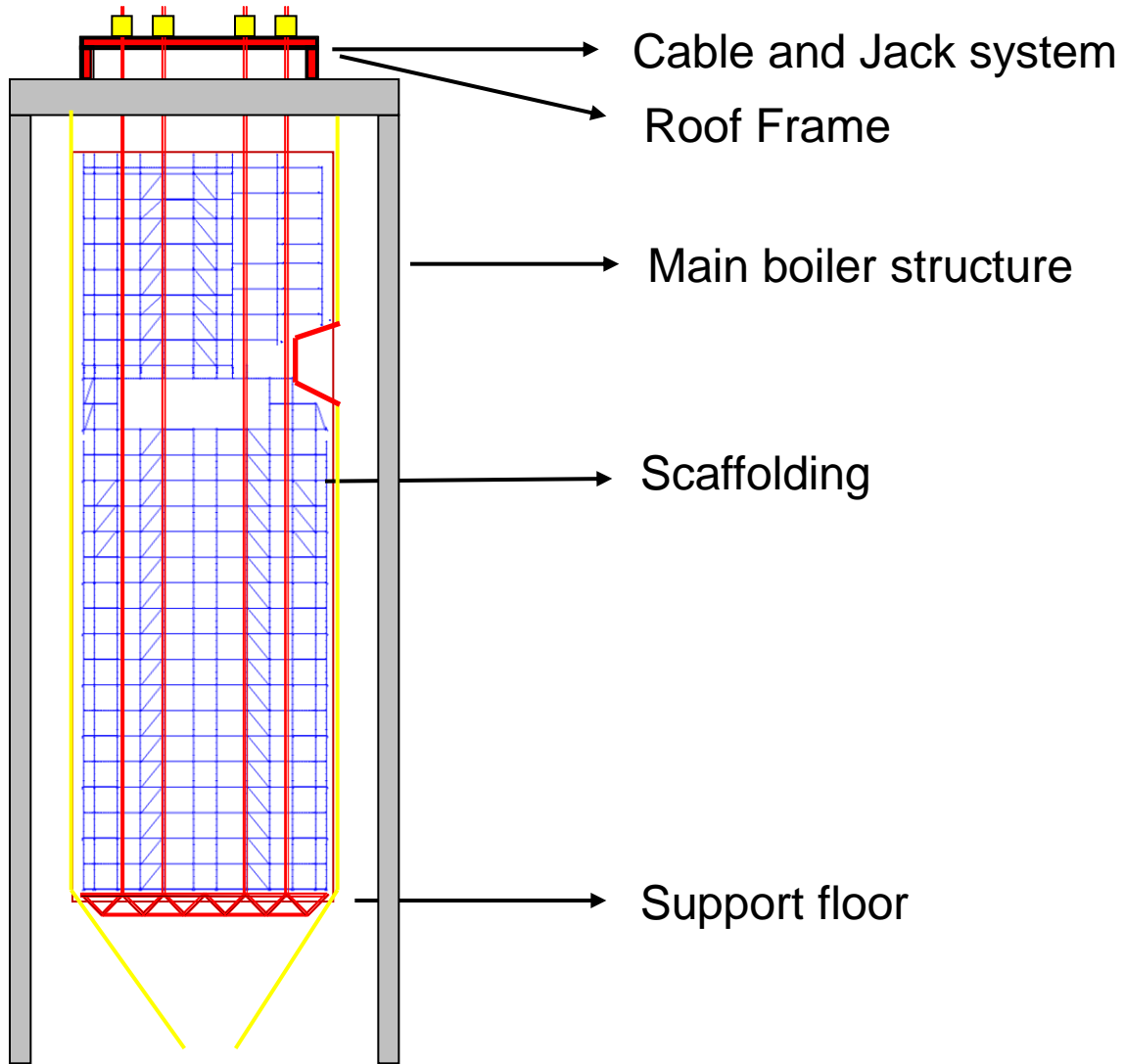
90m tall boiler, tapered at the bottom



Internal inspection of gas boiler using platforms



Inspection after erecting scaffold



Five recent deaths due to scaffold collapse

Robotic Non Destructive Testing (NDT)

R&D of Mobile robots to perform ultrasound NDT of horizontal and vertical welds

Dimensions:

30m height

30m width

300m length



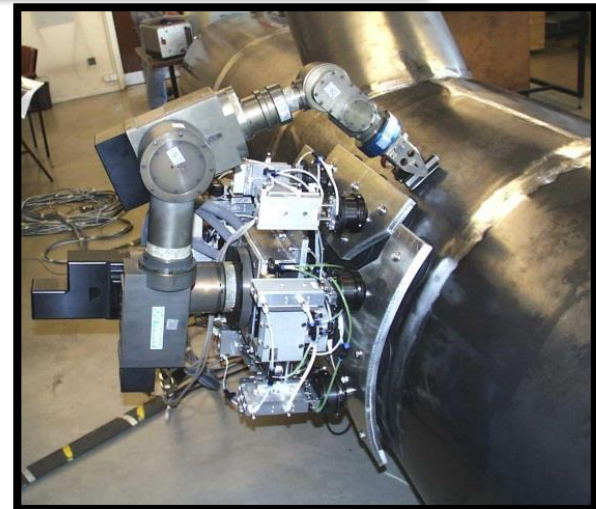
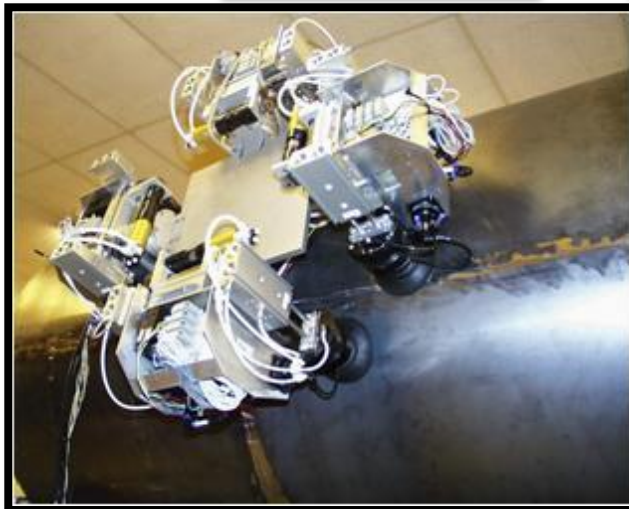
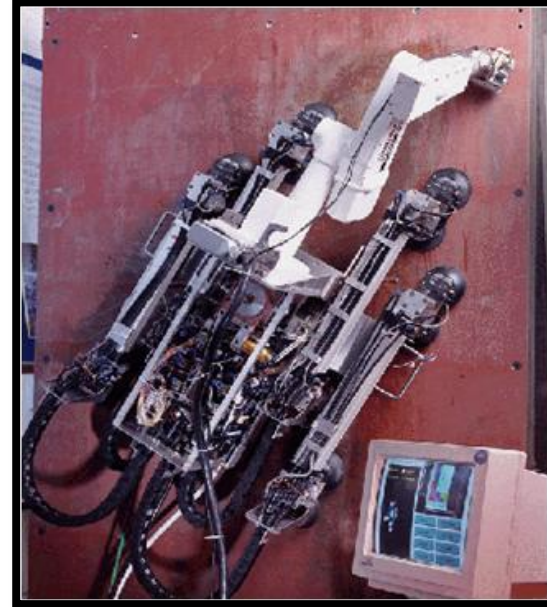
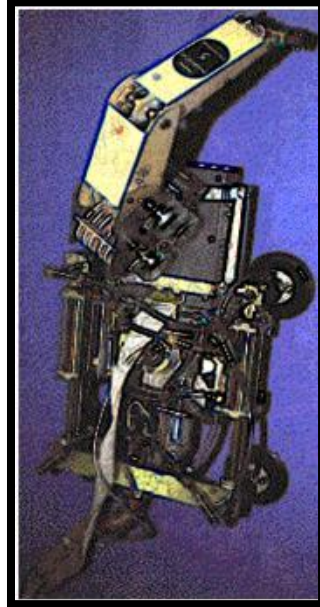
Mobile robots to access large vertical structures and perform NDT

Hulls of ships, bridges, dams, tank walls, buildings, etc.



Wall climbing robots that use pneumatic suction cups

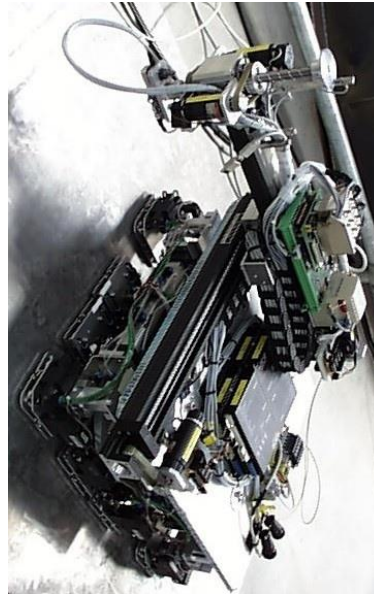
Worlds First
wall climber
1992



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



CROCELLS



ROBAIR



VORTEX

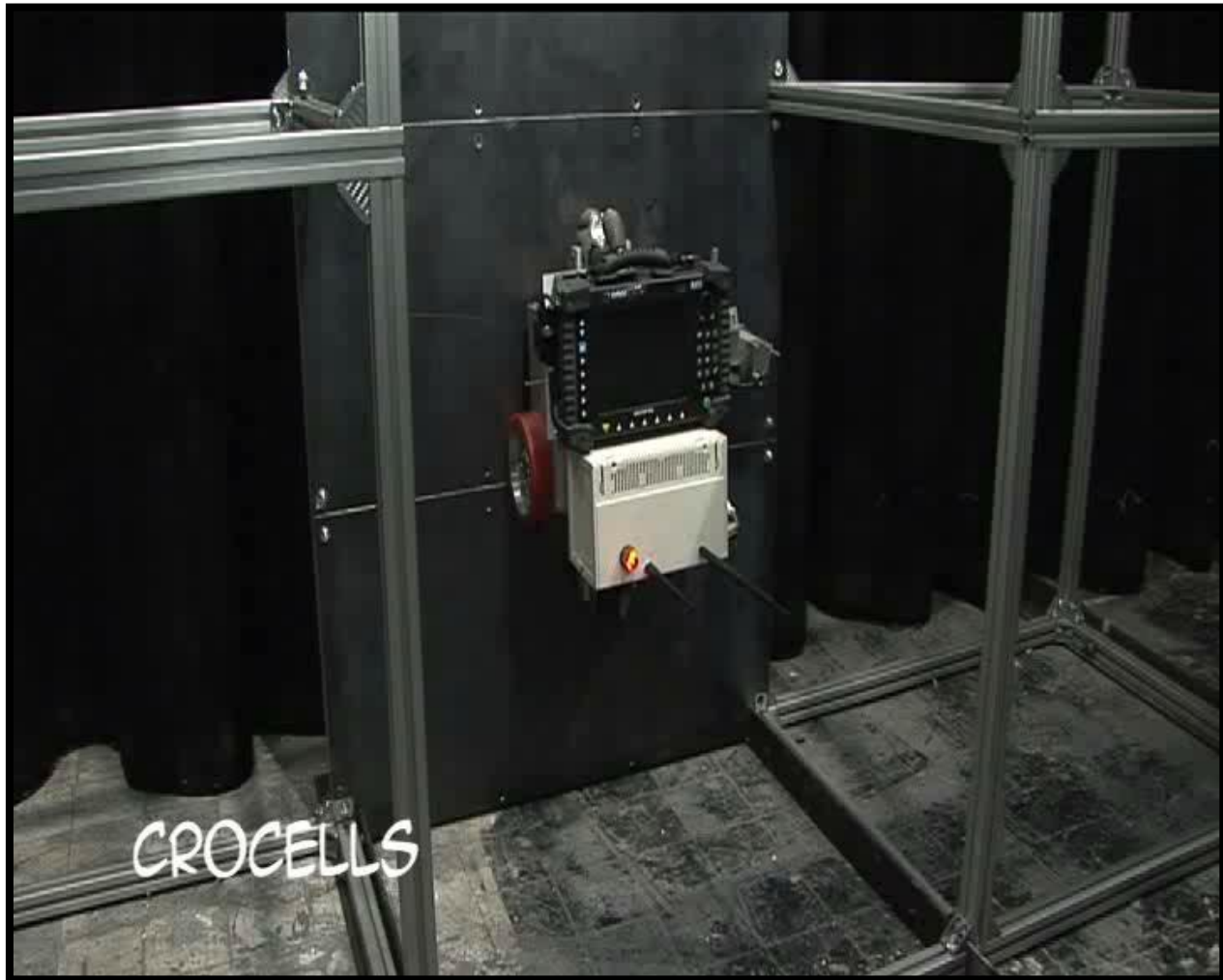
Advanced Wall climbing robot for the inspection of welds on cargo containers ships

Permanent magnets

Wireless control and data acquisition

Ultrasonic phased array NDT

Mass 35Kg



**Ultrasound NDT Climbing Robot – adapts to surface curvatures
(concave or convex)**



STRONGMAN Permanent magnet adhesion wall climber carries additional payloads of up to 50 kg



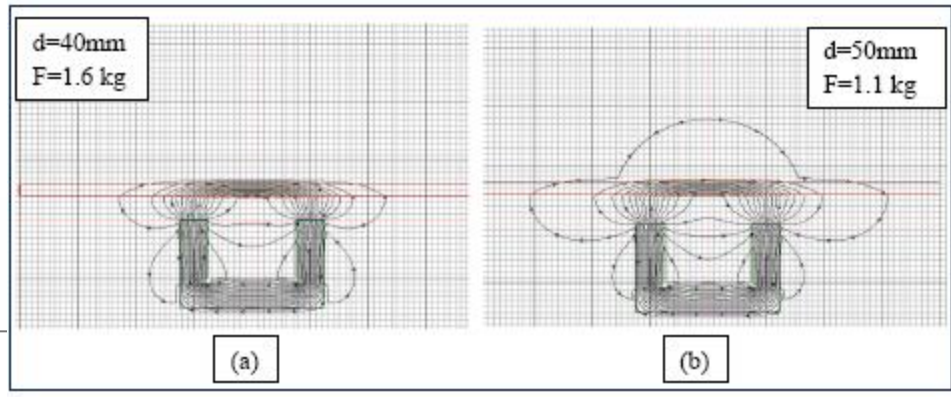


Figure 7-9 Magnetic field lines inside steel reinforced concrete when concrete cover (d) is (a) 40mm (b) 50mm



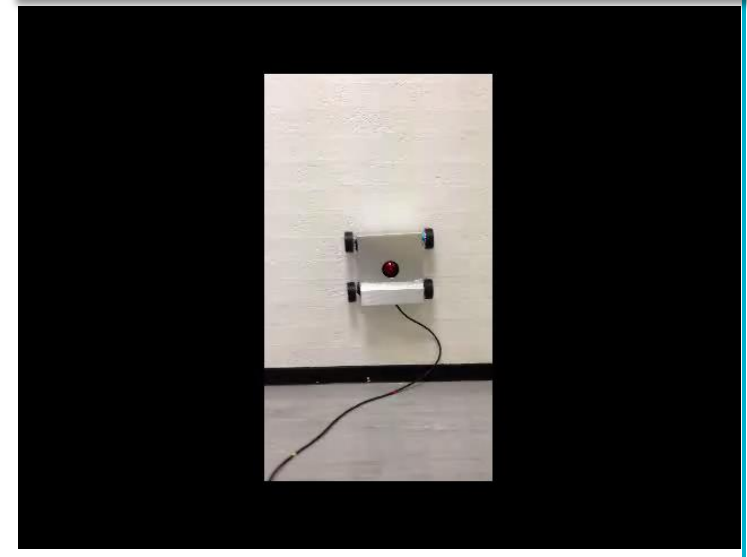
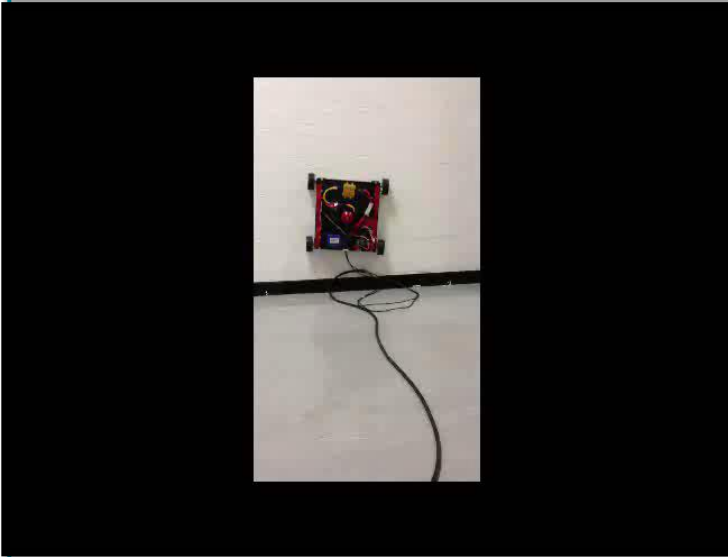
Maximizing magnetic adhesion over large air gaps (Concrete climbing using permanent magnets)



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



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 €70000

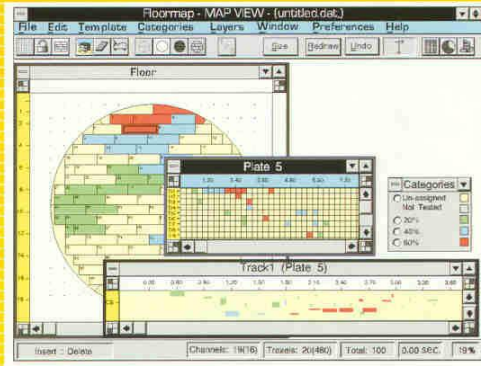
80% of cost is opening and closing the tank

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.

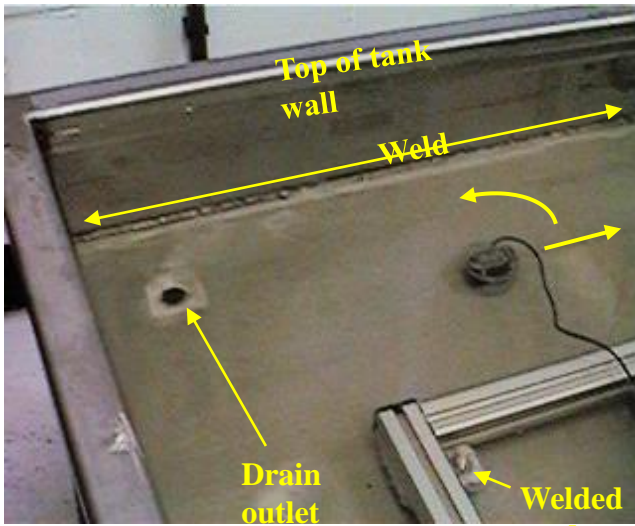


Manual tank floor inspection, underside corrosion defects

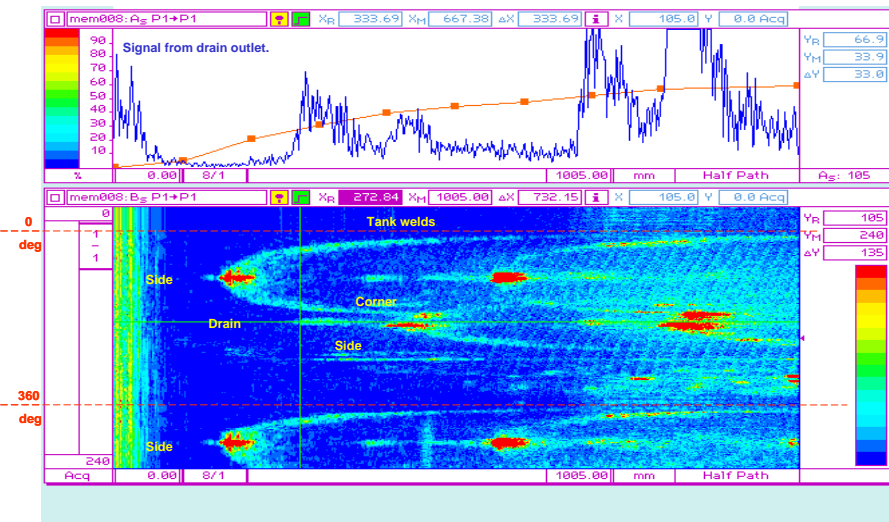
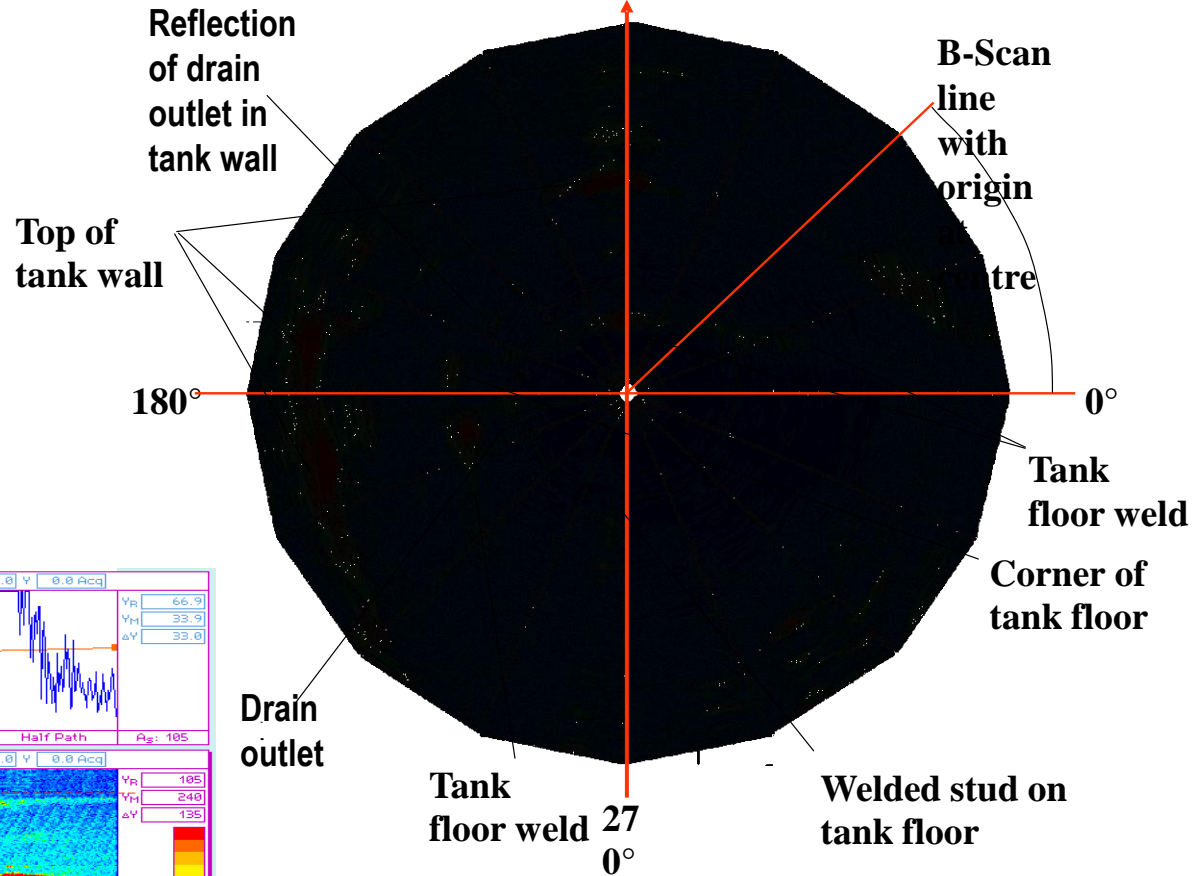
ROBTANK: Mobile wall climbing robot enters through manholes on the floating or fixed roof of a tank to inspect tank floor and internal walls



Mapping of floor defects using rotating bulk wave ultrasonic technique



0
deg



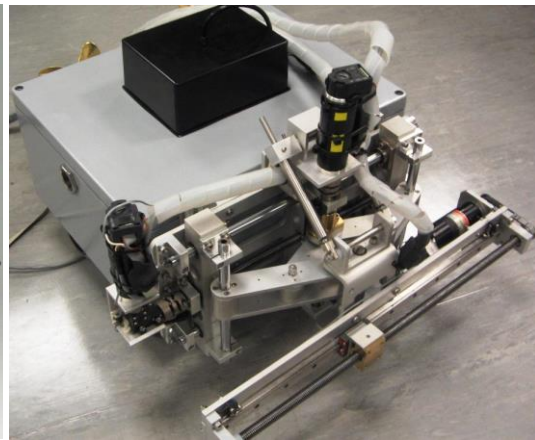
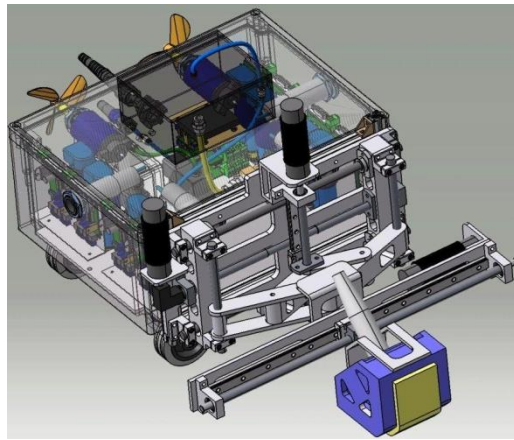
Floating Production Storage of Oil (FPSO)

Task: Inspect welds between strengthening plates and tank floor

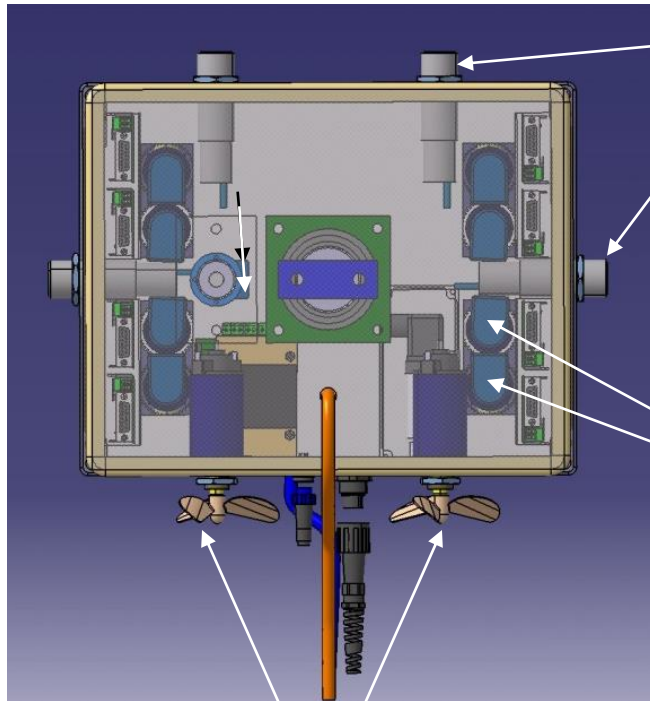
- Outage required with cleaning of tank before inspectors can enter tank – problem of disposal of cleaning medium
- Eliminate outage by performing in-service inspection with mobile swimming robots or empty without cleaning and use amphibious robot

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





Scanning Arm mounted on this face



Ultrasonic range finders for detecting walls and strengthening plates

Two motors, one for wheel motion, the other to change direction of wheel

Thrusters

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



SENSOR PAYLOAD

ACFM probes

- **Weld inspection**
 - 5 kHz
 - 8 sensors in 2 modules
- **corrosion sizing**
 - 50 kHz
 - 2 Bz coils

Plate wave sensor: Sonatron S54008

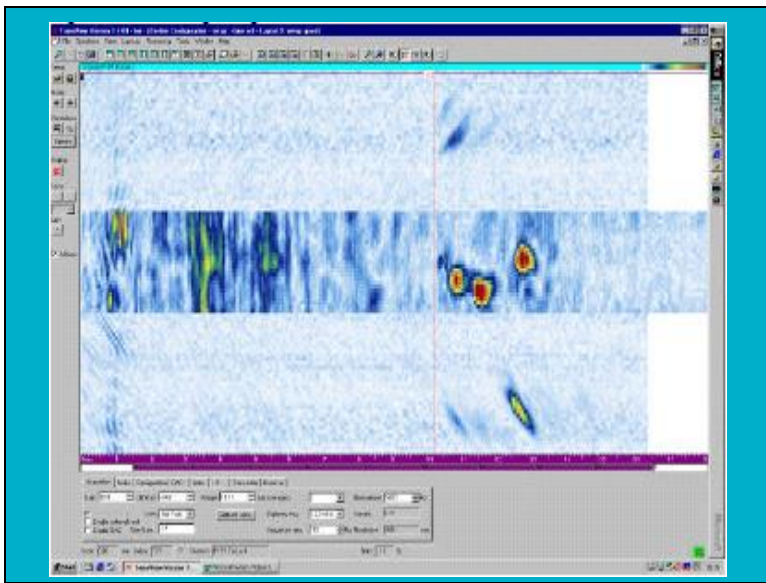
- **2 MHz**
- **65° refracted angle**

Dual creep wave sensor: RTD Crst4

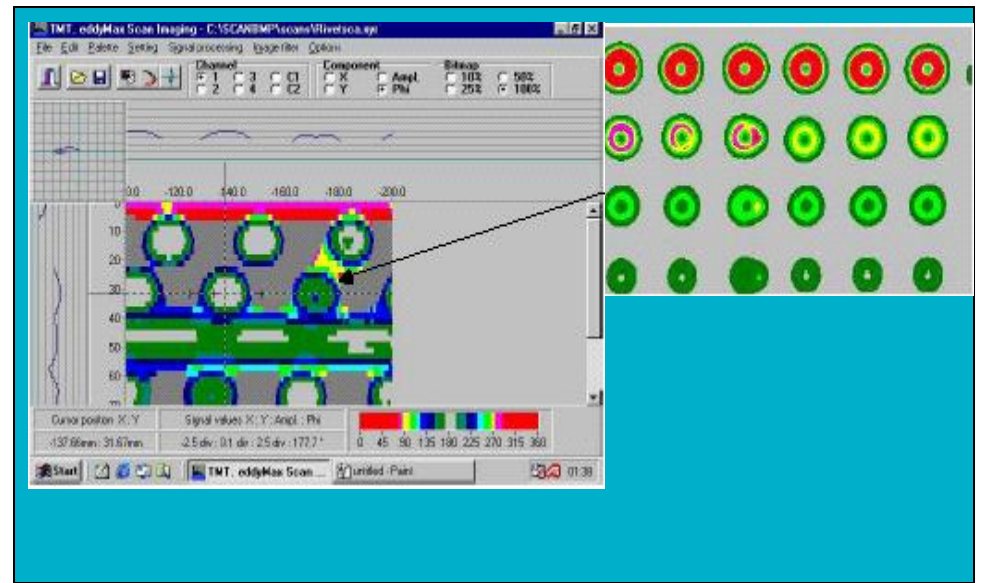
- **4 MHz**
- **Dual element**
- **80° refracted angle**

Inspection of rows of rivets on aircraft wings and fuselage with a climbing robot

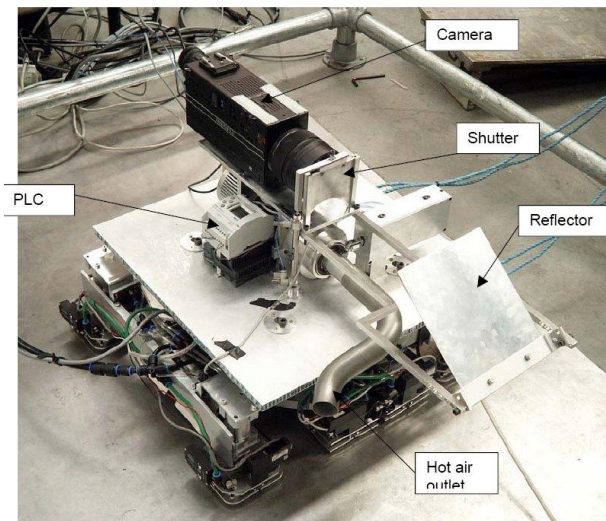




ULTRASONIC PHASED ARRAYS to inspect rivets on aircraft, ROBAIR project

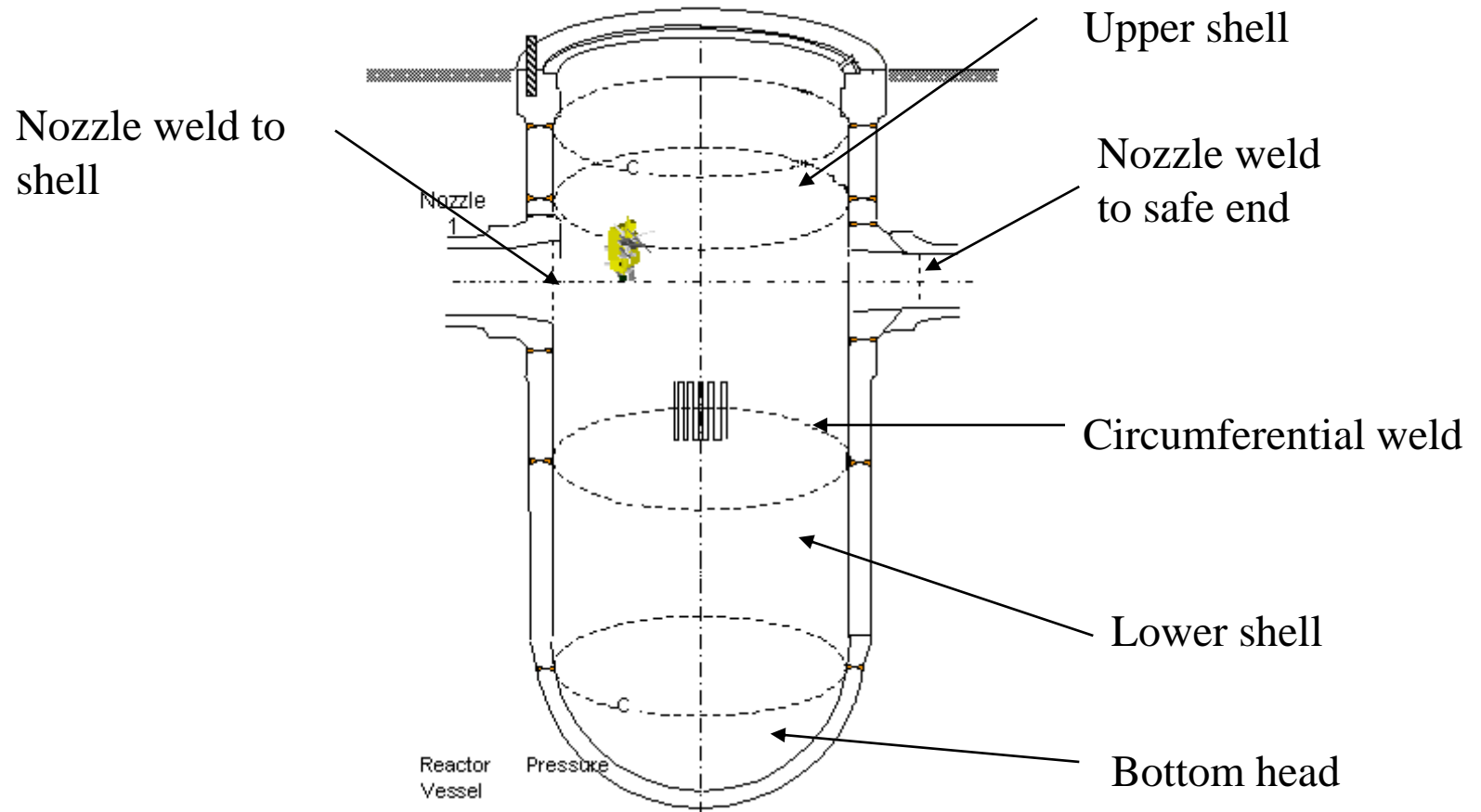


EDDY CURRENTS inspection of rows of rivets on the wings and fuselage of aircraft, ROBAIR project

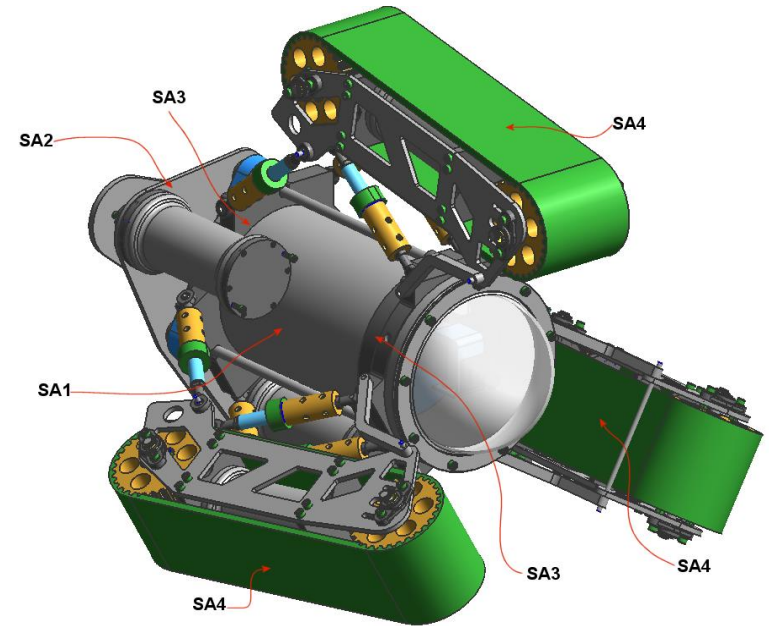


Thermographic detection of loose rivets

Inspection of RPV Circumferential and Nozzle welds

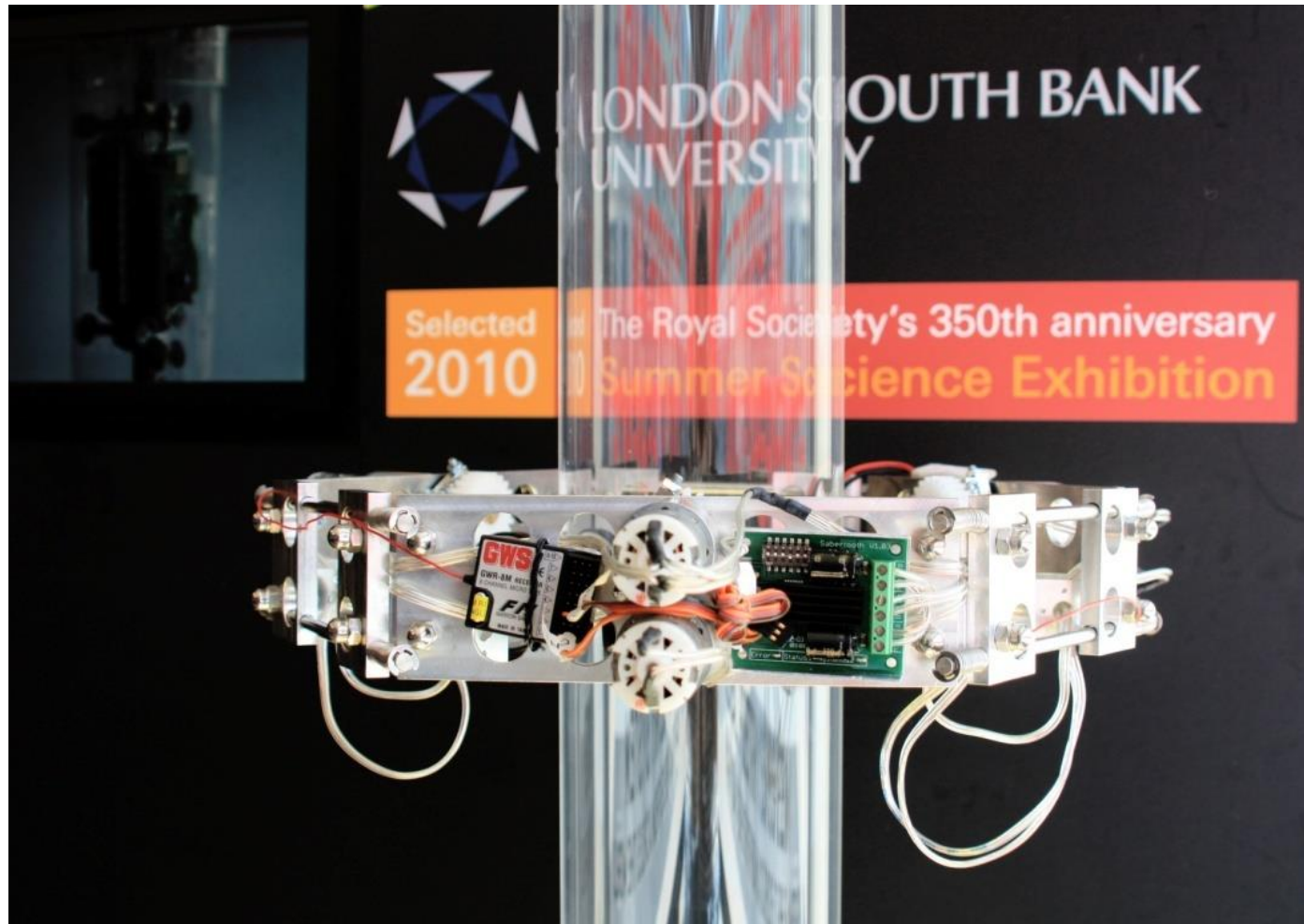


Nozzle inspection robot



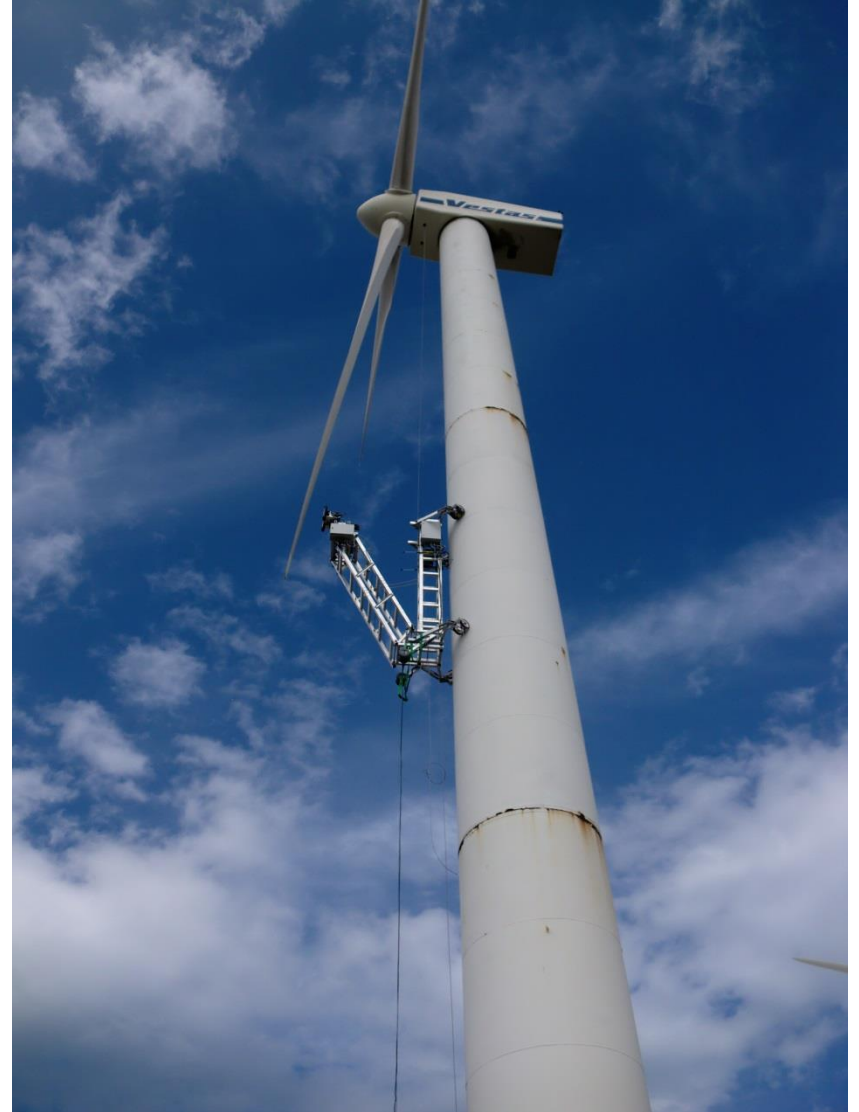
Climbing ring robot for wind turbine tower and pipe inspection





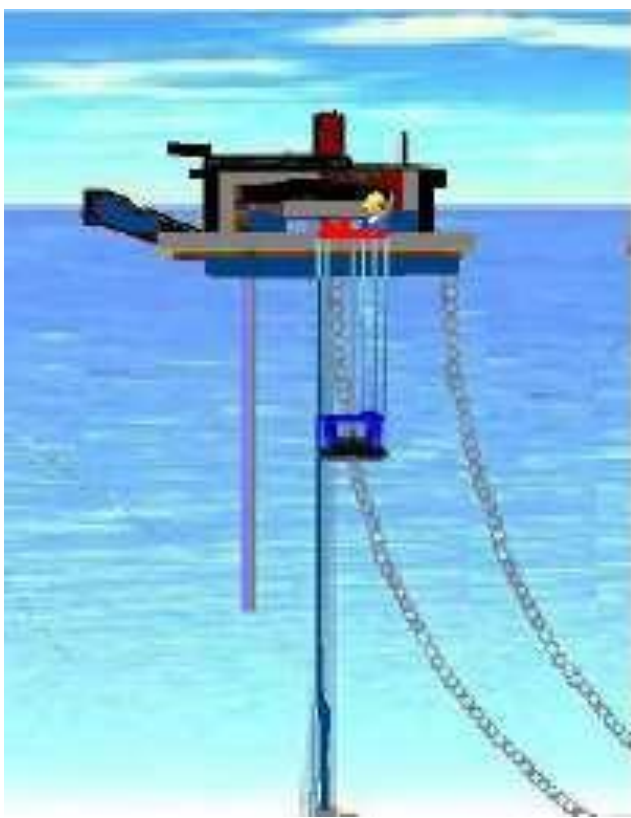
The Ring Pipe Climbing Robot

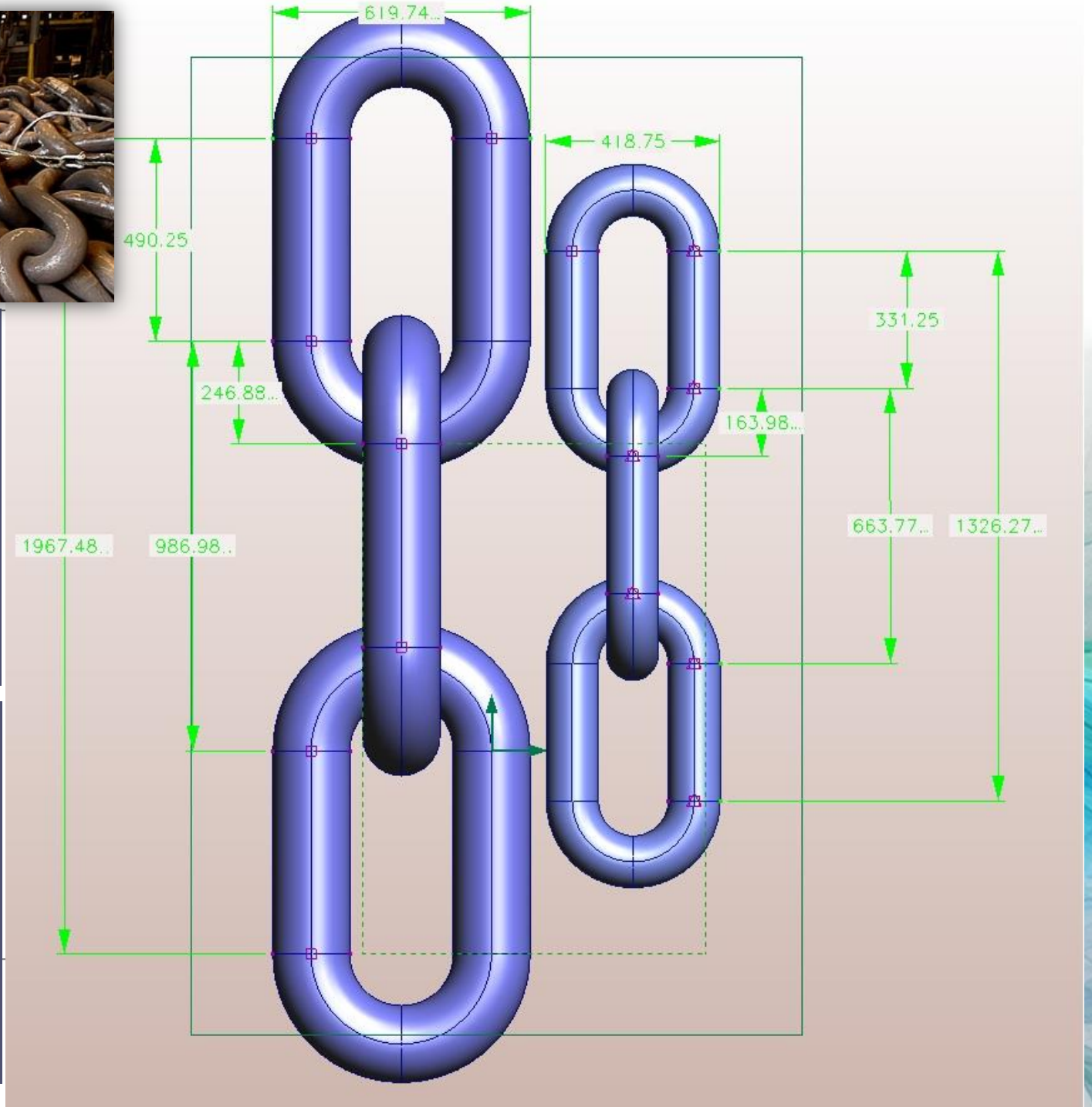
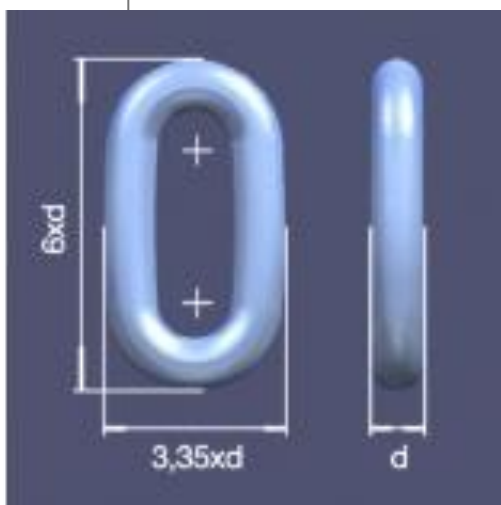
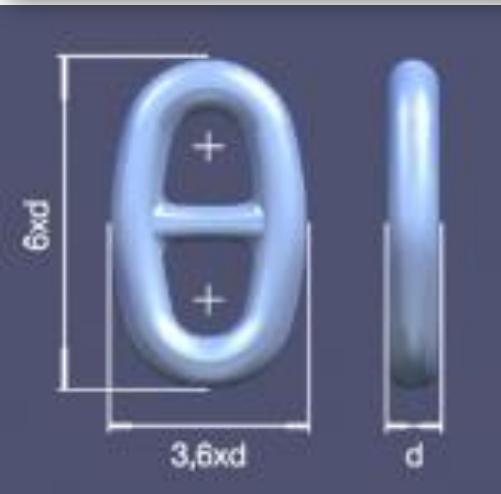
The DASHWIN European project : Climbing robot and 4 DOF arm



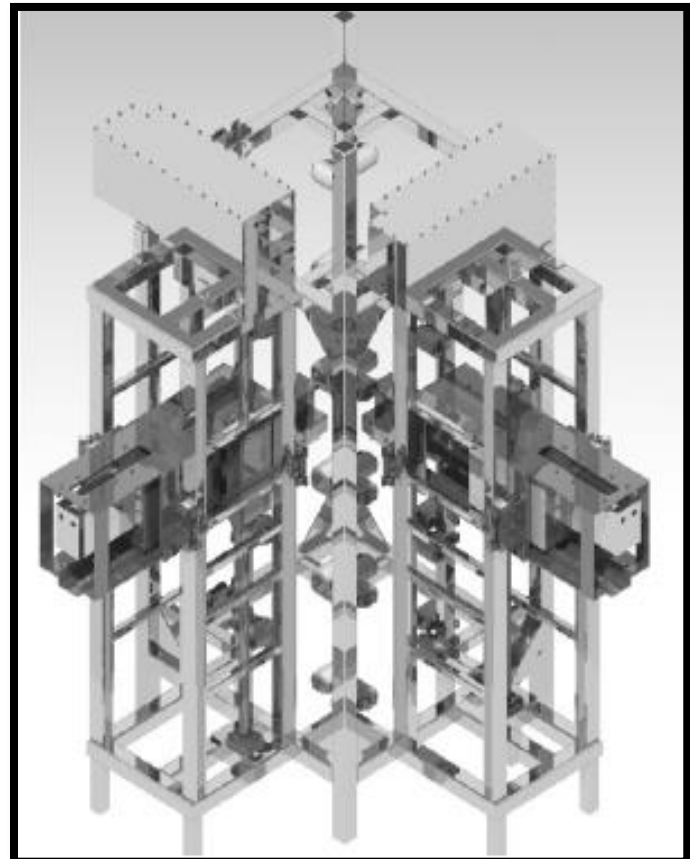
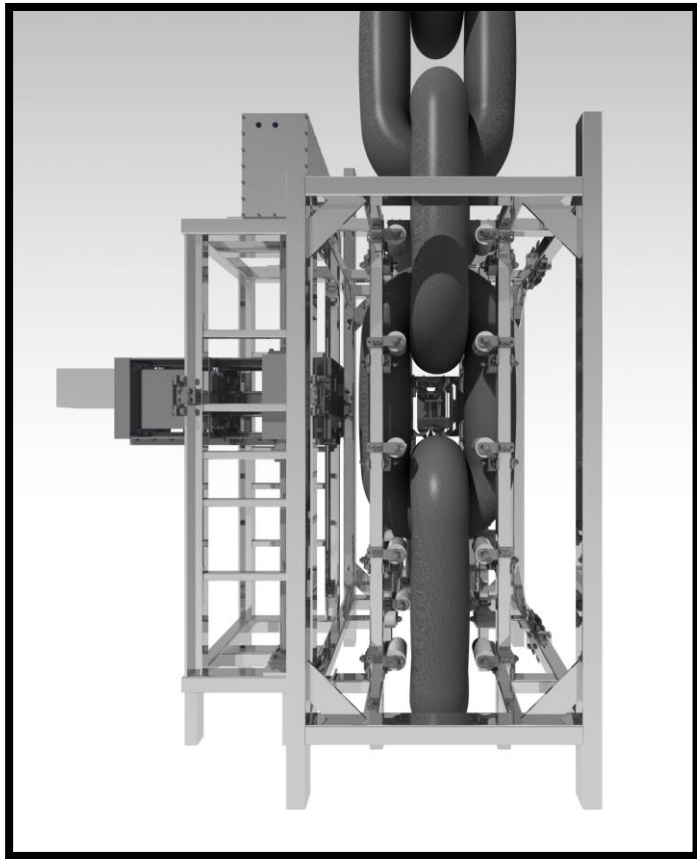
Mooring chain climbing robot

Moorinspect

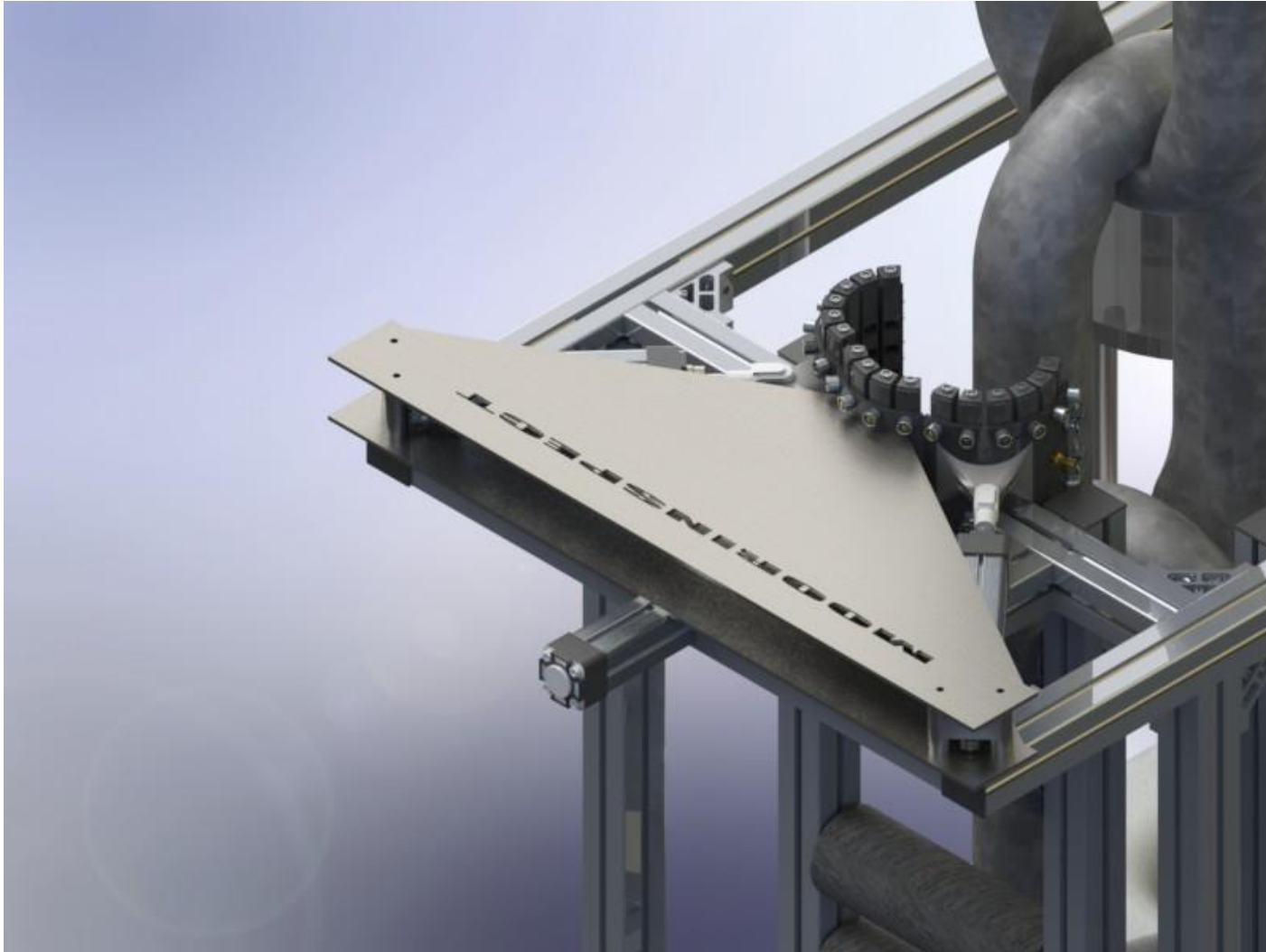




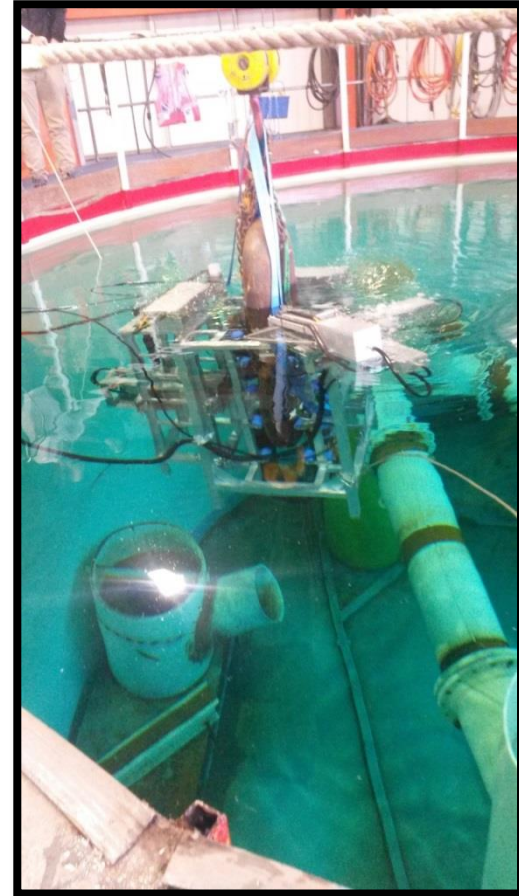
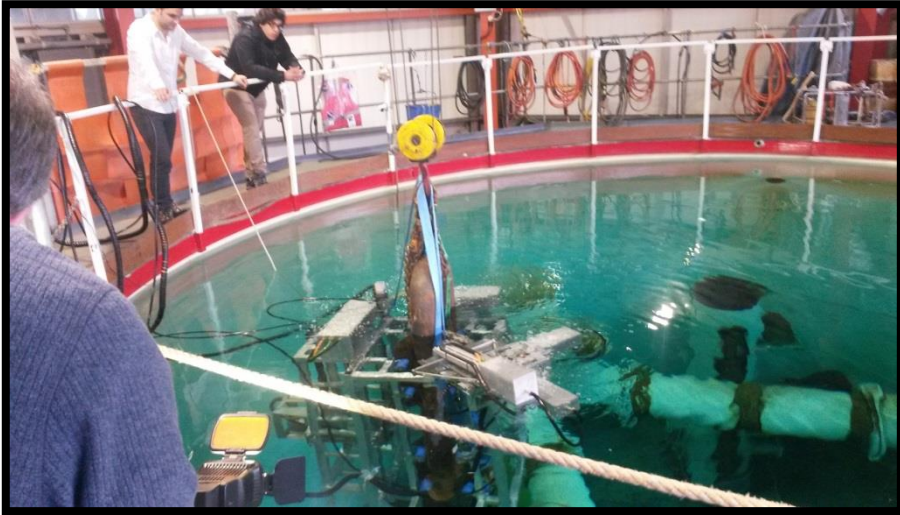
Moorinspect Robot Design



NDT with Long Range Ultrasound Guided wave collar



Trials: Underwater tests

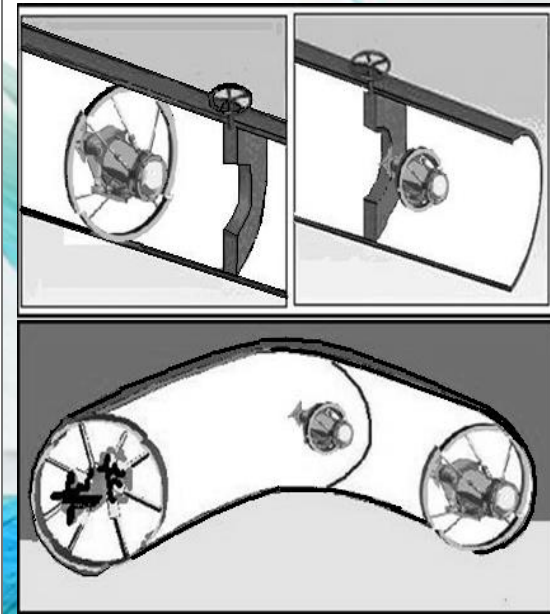


**FASTER INSPECTION OF CURRENTLY
UNPIGGABLE OIL PIPELINES**

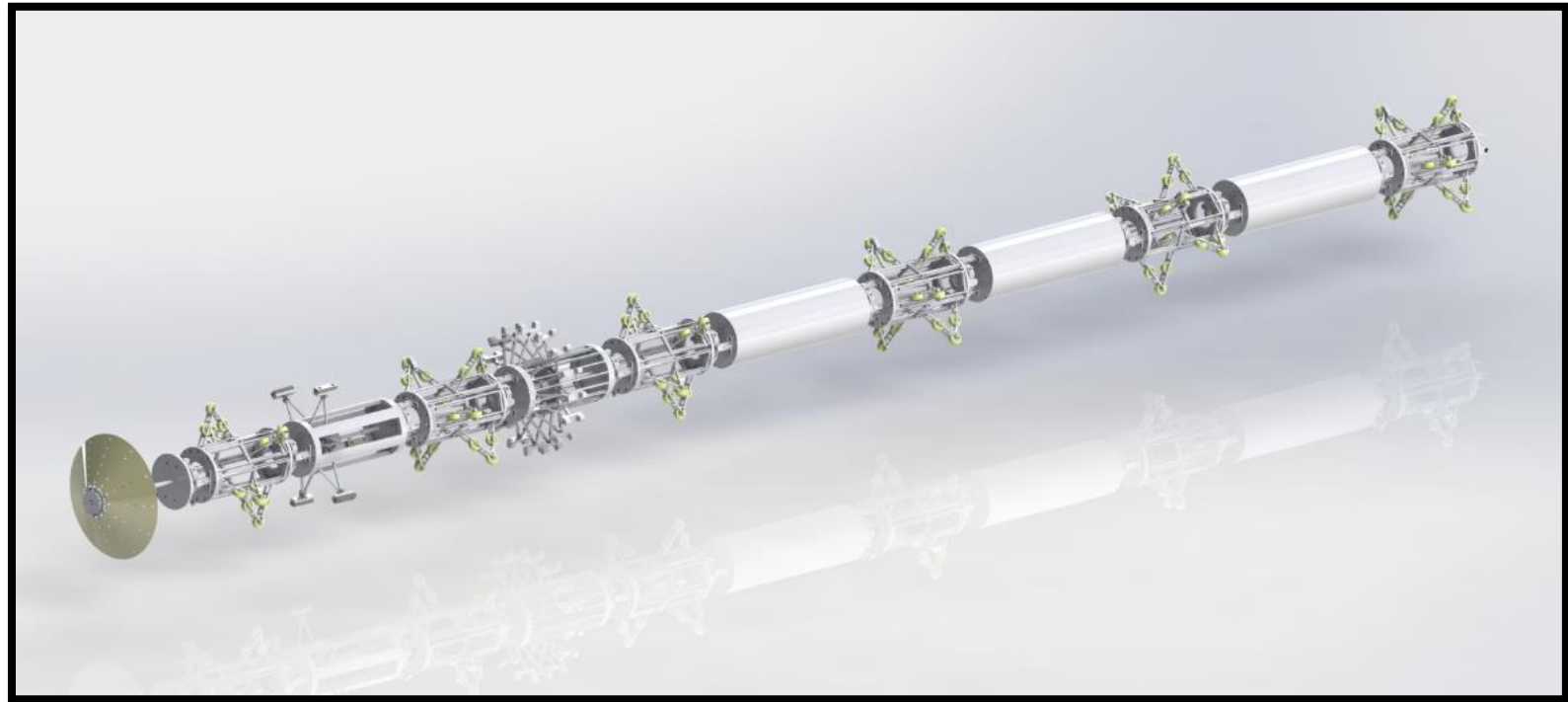
PigWaves project

The PIGWaves solution

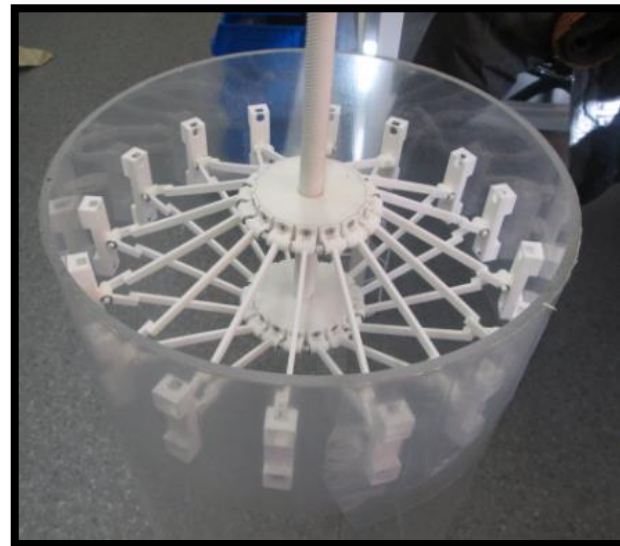
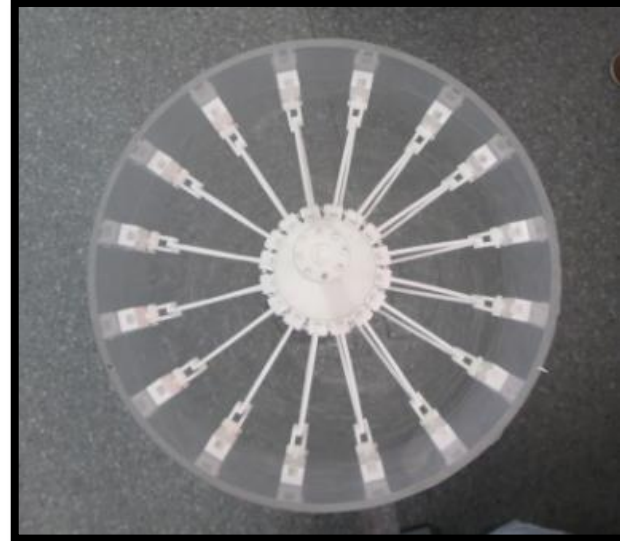
- Small-sized, umbilical-free neutrally buoyant robot able to swim/ float in oil pipelines with internal diameter ranging from 150-350mm.
- LRUG collar uses ultrasonic guided waves and time reversal focusing to identify circumferential and axial pipe corrosion and cracks
- Robot communicates with base station at entry point to send NDT data and **locate position of robot.**



Modular Design of Pigwaves



Sensor collar: Long Range Ultrasonic Guided waves



SUBSEA and DEEP SEA: The new frontier

90% of undiscovered hydrocarbon reserves believed to be at depths of more than 1000m. Already Gulf of Mexico fields at 1844m and 2438m

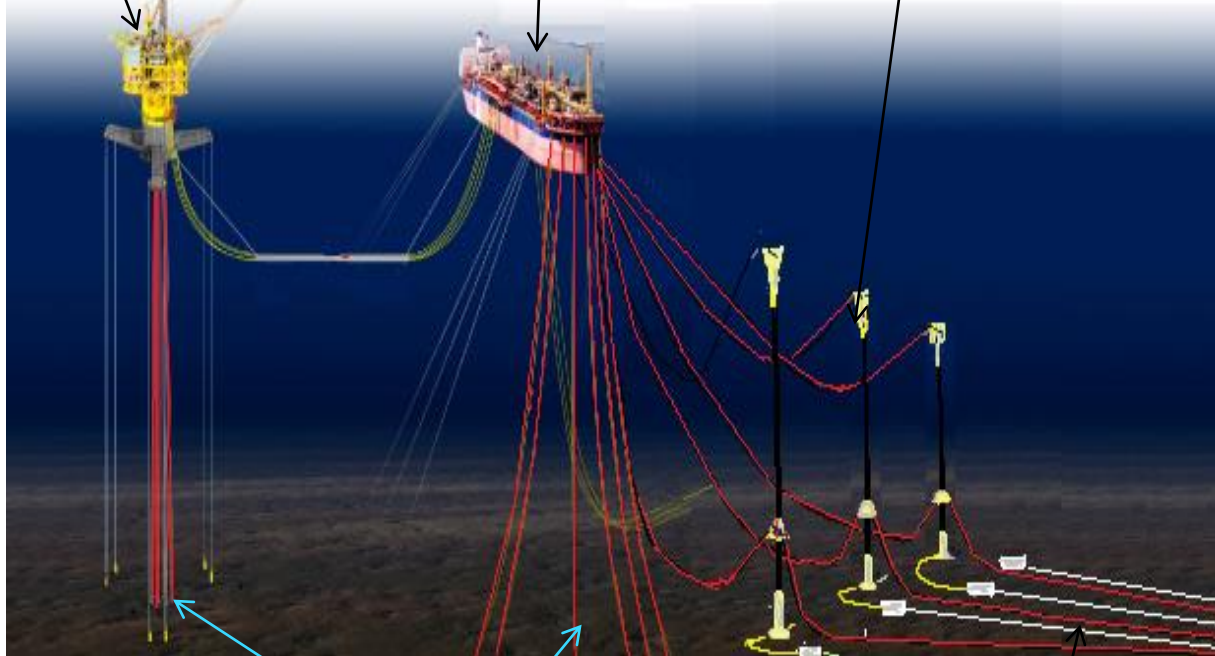
Diver inspection possible to max 150m without dry hyperbaric habitat.

New tools required for Field Integrity
Management of risers, moorings, seafloor support structures, FPSO's

Oil platform with
pre-tensioned
risers

FPSO

Tie-back Risers

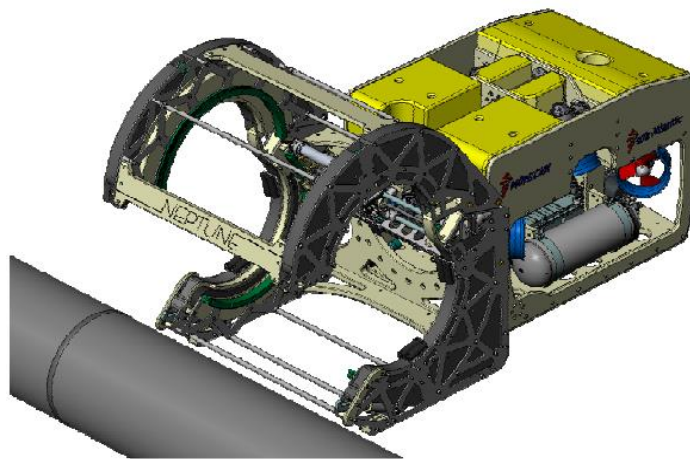
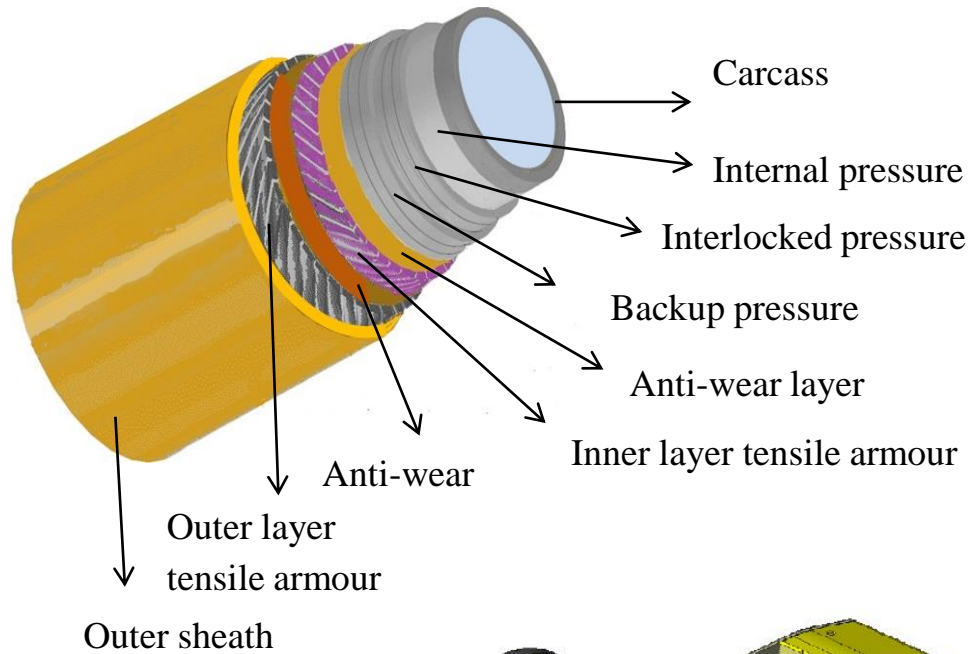


Risers from oil
wells

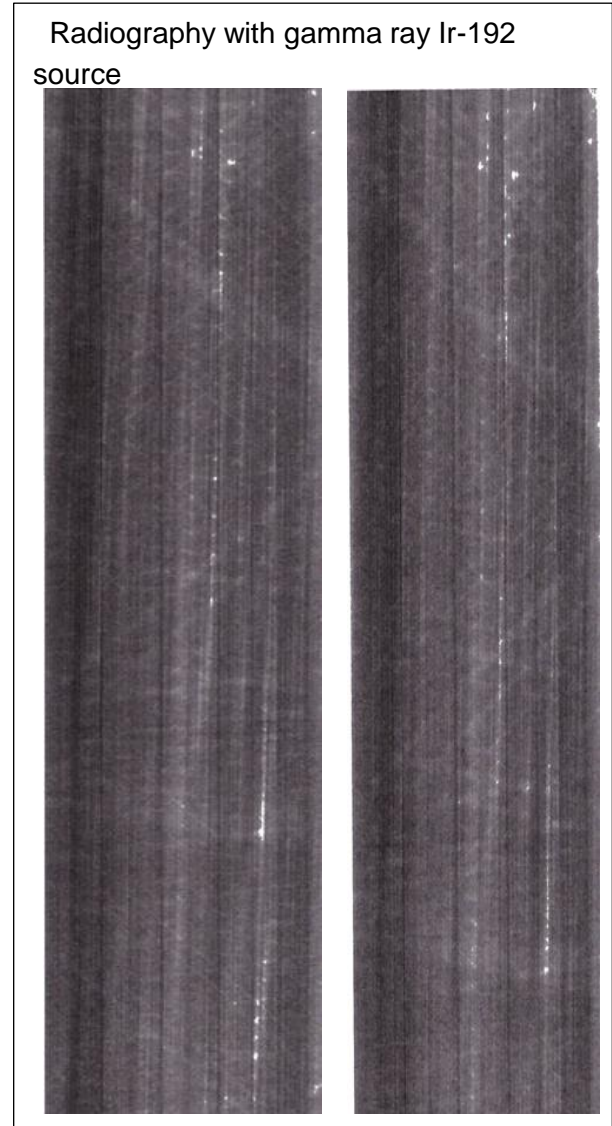
Pipelines from minor
fields

The floating platform, riser, flow-line and tie-back environment

SubSea and Deep sea infrastructure: New frontier for use of Robotic NDT



Neptune: Ultrasound NDT



Conclusion

Robotic NDT has the potential to REDUCE INSPECTION COSTS, improve the integrity management of many safety critical infrastructure.

While many prototypes demonstrate the feasibility of using mobile robots to perform NDT, very few have been commercialized.

Opportunity

However, inexpensive technology is becoming available to build smarter lightweight and compact robots that can self-localize, use wireless communications and control to eliminate cumbersome umbilicals, and acquire better NDT data. Could result in more widespread use.

Robot Detectives: Sherlock Holmes meets Spiderman exhibit for the Royal Society of science and the Royal Academy of Engineering



Thank you