RCNDE

UK RESEARCH CENTRE IN NDE

20 years of excellence with impact: 2003–2023

The Research Centre in Non-Destructive Evaluation (RCNDE)

Introduction and background

2023 marks 20 years since the inception of the Research Centre in Non-Destructive Evaluation (RCNDE). This brochure celebrates the impact of RCNDE, reflects on key milestones and imagines the future for both the Centre and NDE.

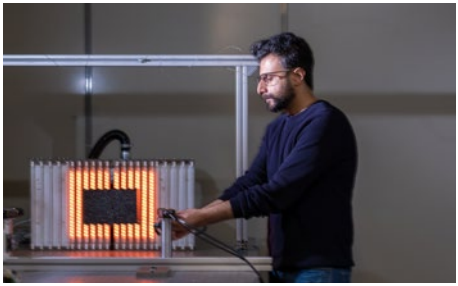


Image credit: University of Liverpool

The Research Centre in Non-Destructive Evaluation (RCNDE)

RCNDE is a collaboration between industry and UK universities to coordinate the latest research on Non-Destructive Evaluation (NDE) technologies.

We match this research to the needs of industry, both now and in the future. Founded in 2003 and co-funded by the UK Engineering and Physical Sciences Research Council (EPSRC), we have grown from an original 5 industrial members to 14 full industrial members and 45 associate members.

Founded on the guiding principles of world-class scientific research and industrial application, we are uniquely placed to help industry face ever more challenging requirements for integrity and safety, including adopting new approaches to inspection, monitoring, and quality control.

What is Non-destructive Evaluation (NDE)?

NDE utilises a wide array of technologies aimed at evaluating the condition of a component, system, or asset without changing its physical condition. It is used to provide information on the integrity of assets to inform decisions about their operational suitability and longevity.

It includes:

- sensor and imaging technologies to assess and monitor the structural health and condition of components, plant and engineering structures during manufacture and in-service
- methods such as radiography, ultrasound, magnetic, dye penetrant, eddy current, thermal and visual, and other physics-based methods and associated analysis techniques
- an essential underpinning capability for a diverse range of sectors from high-value manufacturing and power generation to defence and aerospace

Vision, Mission, and Key Facts

Vision:

To be the world-leading research centre of excellence in NDE research through active partnership with the industrial user community.

Mission:

To continue playing a leading role in the UK and global innovation landscape by:

- Supporting world-class scientific research by funding and co-funding cutting-edge research in the area of non-destructive evaluation.
- Delivering industrial benefit by liaising and collaborating with our wide and well-established industrial membership.
- Developing the NDE professionals of the future by supporting doctoral level teaching and training, and contributing to the UK's education environment.
- Supporting the RCNDE community and wider stakeholders through requirements capture, articulation of future needs, and horizon scanning.

RCNDE - at a glance

Current Members and Associate Members:

14 Members **45** Associates

Total funding secured to date:

£37.4 million

(core and targeted research grants)

Centre for Doctoral Training (CDT) research graduates (2005-2022, incorporated*):

89 EngDs **73** PhDs

*figures include Industrial CASE students (aligned to the RCNDE CDT)

Current universities:

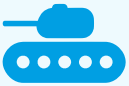
University of Bristol
Imperial College London
University of Liverpool
The University of Manchester
University of Southampton
University of Nottingham UK | CHINA | MALAYSIA
University of Strathclyde Glasgow
The University of Warwick

Industrial sectors that have directly benefited from RCNDE research and technologies:


Power generation


Oil & gas


Aerospace


Defence


Nuclear


High-value manufacturing

20 years of **RCNDE**

2003
RCNDE launches

- In recognition of a need for a champion of the NDE community, industry partners lobbied for a formal entity to provide a vital link between research and the end user.
- Founding universities: Imperial College London, Bristol, Strathclyde, Bath, Nottingham, Warwick
- First industrial members: Airbus, Rolls-Royce, DSTL, RWE nPower and NNL (formerly BNFL)

2003-2008
RCNDE 1

- £4.5m funding
- 5 Members and 6 Universities
- Introduction of the Associate Member category for industry and launch of the RCNDE Centre for Doctoral Training (CDT)

2008-2014
RCNDE 2

- £9.5m funding
- 14 Members and 9 Associate Members
- RCNDE and EPSRC strategic partnership

2014-2020
RCNDE 3

- 10.5m funding
- University of Manchester joins and University of Bath leaves
- 15 Members and 29 Associate Members

2020
RCNDE Funding model changes

- RCNDE moves away from EPSRC-only funding structure to a model based on contributions from industrial membership fees and a varied portfolio of publicly-funded grants aimed at different Technology Readiness Levels (TRLs).

2021
RCNDE 4

- £1.7m funding
- 14 Members and 45 Associate Members
- Universities of Liverpool and Southampton join
- Introduction of the Non-profit Member category
- Expansion of activities, including strategic leadership activities and increasing presence in new sectors

2023
RCNDE Strategy launched

- RCNDE 2023-2028 Strategy

Key technology developments

There have been many advancements of key technologies across the NDE industry over the last 20 years. Some examples of these are explained below.

Ultrasonic arrays - Reducing inspection costs in the naval, aerospace, nuclear, and power generation sectors

The University of Bristol's Ultrasonics & Non-Destructive Testing (U&NDT) group, led by Professor Bruce Drinkwater, has developed new methods in ultrasonic measuring to improve the efficiency of structural integrity testing. Since 2003, the group's research has led to the development of methodological breakthroughs including Full Matrix Capture (FMC), a process designed by the team to fire multiple array elements separately rather than in parallel (the historic method), record all data, and perform processing off-line.

This resulted in improved imaging and the conception of the Total Focusing Method (TFM) – a term coined jointly by the University of Bristol and Rolls-Royce – that leads to image resolution very close to the theoretical diffraction-limit.

U&NDT's work has resulted in significant improvements in ultrasonic inspection capability. It has enabled new technologies to be developed and exploited by end-user members in the naval, aerospace, nuclear, and power generation sectors, which have reduced inspection times and costs.

Image credit: Bruce Drinkwater and Adam Bowler

The importance and prevalence of FMC and TFM applications has led to both methods being included in the international standards for ultrasonic testing (ISO-23864 and ISO-23865, 2021).

Over the last decade, the U&NDT group has published over 50 journal papers on array usage and FMC in NDT. This research has led to real-world improvements in the effectiveness of ultrasonic detection across a range of industries.

Robotics, sensors, and automated deployment

The robotics research team at the University of Strathclyde has been researching the use of robotics in NDE since 2003. Subsequent work on small mobile robot platforms for delivering ultrasonic and magnetic flux leakage measurements was matured with the National Nuclear Laboratory (NNL) into an on-site inspection at Sellafield Ltd, supporting Magnox reactor reprocessing life extension in 2012.

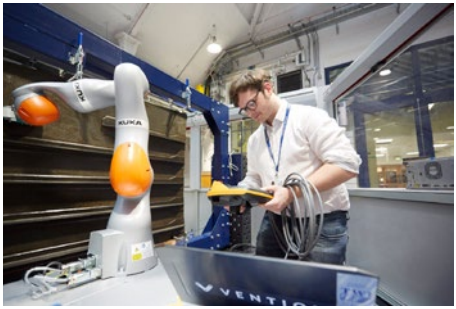


Image credit: University of Strathclyde

More recent work on mobile robotics concentrated on bringing classical robotic path planning and location systems (such as SLAM – simultaneous location and mapping) together with novel approaches using ultrasound to provide both NDE and path planning data. Working with supply chain partners such as Silverwing (now part of Eddyfi), and the commercial Scorpion platform, the team has developed and licensed technology for improved robot path planning and ultrasonic data capture.

Other key areas of research into the application of robotics to NDE are being led by the team at Imperial College London—specifically, the creation of sensor systems, signal processing and deployment strategies in robotic systems to retrieve valuable data in the field.

Modelling, simulation, and analysis of big data

The Fourth Industrial Revolution, or Industry 4.0, is rapidly changing technologies, processes, industries and societal patterns due to increasing interconnectivity and smart automation. With respect to the challenges and opportunities identified for NDE in Industry 4.0, there have been exciting advances made by RCNDE partners that show our ability to meet the anticipated digital demands.

Pogo is a powerful, GPU-based commercial finite element (FE) software package developed by Imperial College London that simulates waves in acoustic and elastic media. It is used by research groups across the world for multiple applications, including guided wave tomography and analysing complex multi-grained materials. The ability of FE to mesh arbitrary geometries makes Pogo well-suited to NDE applications, where the complexity of both components and defects must be considered for accurate results.

Pogo began as a simple tool capable of solving basic 2D models, written by Imperial's Dr Peter Huthwaite, as part of work carried out under his EPSRC Fellowship. The Pogo software can now run parametric studies quickly and handle significant data sets in 3D. It can run models with over 3 billion degrees of freedom. The work was helped by the RCNDE network given Pogo's numerous applications to other research projects supported by the Centre. The software is being increasingly used across the petrochemical and nuclear sectors and has generated a gross income of £300,000 to date.

More information on Pogo can be found at www.pogo.software.

Developing future leaders in NDE

> It is the people in our industry that matter. We are proud to continue to support and train the next generation of experts and leaders in NDE through our related Centres for Doctoral Training (CDT).

The following testimonies demonstrate the personal value and industrial benefits for those pursuing a career in NDE in partnership with RCNDE.

Dr Naomi Shipway

‘Automated defect detection for fluorescent penetrant inspection using machine learning’

My EngD considered automated defect detection for Fluorescent Penetrant Inspection (FPI) using machine learning. FPI is a well-established NDT method used widely in the aerospace industry. The nature of FPI inspection, particularly in new manufacture, can lead to variable results influenced by human factors. This has led to a need within the industry for an automated inspection system which can improve reliability.

I was a member of the 2015–2019 cohort and studied at Imperial College London, with Rolls-Royce as my project sponsor. My doctoral project gave me the opportunity to explore improving Machine Learning (ML) algorithms to benefit FPI by using two types, Random Forest and ResNet50. By feeding these algorithms with gathered real-world test and training datasets, I was able to use methods to improve the accuracy of detection in both algorithms, with the most accurate detection achieved using the deep-learning ResNet50.

“The doctoral programme provided a great platform from which to launch my career. The combination of taught courses as well as the individual research projects provided a broader base and wider appreciation for the field, whilst developing the deep technical and analytical skills required to complete a doctorate.”

In addition to the technical skills, the CDT provided many opportunities to present at conferences, helping me network with academics and industry experts. These relationships were pivotal for my career. Following completion of my EngD, I took up employment with Rolls-Royce where I continued to work in the field of automation for NDT and other image-based applications. My research was awarded the Dr Ashraf Ben El-Shanawany Memorial Prize from Imperial College London in 2019, for outstanding achievement by a PhD or EngD student to include research, public outreach, innovation, and entrepreneurial achievement.

Dr James Watson

Industrial CASE Studentship (15220135) 'Novel Quantum Well Hall Effect (QWHE) 2D arrays sensor for surface flaw inspection'

My ICASE experience allowed me to take what I was learning at university and apply it to industry via my sponsor company, BAE Systems (Submarines). This gave me a much broader understanding of my research within the wider industrial contexts of manufacturing and inspection. The approach gave me experience and transferable skills that significantly enhanced my employability when I sought work in industry on completion of my doctorate.

As part of my ICASE I conducted a comparative study of a novel specific surface flaw inspection technology against commercially available systems and supported the development of its technology readiness level via optimisation of inspection parameters. Developments were presented annually at the British Institute of Non-Destructive Testing (BINDT) Conference as well as various RCNDE related events throughout the studentship. In 2019, the research was the recipient of the William Gardner Award by BINDT.

To support my work, I took extended site visits to BAE Systems to understand their industrial challenges and context and to acquire experimental data. BAE Systems benefitted from the research by using it as a platform to assess the capabilities of their own legacy inspection technologies. They invested in new advanced eddy current array technologies with a view to eventually replace their legacy inspections. This new technology enables better quantification of the manufacturing process, evaluation capabilities of defects, and inspection data that can be stored digitally for future use.

"The ICASE was an extremely positive experience. Throughout my doctorate I had the opportunity to interact with peers across the CDT as well as engage with the wider NDE community. As a direct consequence, I am now a member of BINDT (MInstNDT), serve on their Technical Committee, and am employed by an RCNDE industrial member as an NDT consultant for the nuclear/defence industries."

The impact of spin-outs: creative innovators

> Reducing the inspection costs of key petrochemical and nuclear infrastructure worldwide

Inductosense

A University of Bristol spinout, Inductosense, has developed a wireless ultrasonic sensor that improves the accuracy and cost-effectiveness of NDT in industrial plants in a range of sectors including oil and gas, chemical, marine, nuclear, and renewables.

The start-up was co-founded by Bristol researchers Dr Chenghuan Zhong, Professor Anthony Croxford, and Professor Paul Wilcox from the Ultrasonics and Non-Destructive Testing (U&NDT) Group at the University of Bristol. The team were working to find solutions to the challenges of in-service inspection in industrial settings, a human and financially resource-heavy activity.

Inductosense have developed innovative wireless sensors that can be used in these environments for measuring thickness loss due to corrosion or erosion. The maintenance-free sensors can be installed permanently and are inductively coupled to inspection hardware resulting in an inspection process that is faster, less labour intensive, more accurate, and significantly more cost-efficient.

Image credit: Sonobotics and Imperial College London.

Inductosense benefits the local economy in Bristol and has an international market. As of 2023, the company had grown to 25 employees, achieved a turnover of ~£2 million and attracted £10 million of private investment and grant funding. It has sold thousands of sensors to more than 50 clients globally. It has also created a strong UK-based supply chain to manufacture its products, spending over £500,000 annually in the local economy.

More information on Inductosense can be found at www.inductosense.com

EMAT technology and robotic integration solutions

Sonobotics Ltd.

Sonobotics Ltd is a spin-out from the Imperial College London NDE group. The core technology nested within the products of the company has largely resulted from the research and use cases that were inspired by the EPSRC-funded ORCA robotics and AI hub for extreme environments (EP/ R026173/1).

The Sonobotics team identified the need for inspection technology that can be easily integrated onto robotic platforms, particularly in the offshore energy sector. They set out to develop the SONUS EVO platform for easy integration onto robots that utilise the robotic operating system (ROS). The system is a powerful lightweight Electro Magnetic Acoustic Transducer (EMAT) acquisition system and has been integrated onto numerous robotic technologies and platforms ranging from drones, wheeled and animal inspired robots, and augmented reality (AR) human assistive technologies.

Image credit: University of Strathclyde

Through the NDE Group at Imperial, Sonobotics has had in-depth interactions with the network of RCNDE universities and industrial partners, and Sonobotics itself has become a member of RCNDE. The RCNDE network has helped raise global awareness of Sonobotics technology and the company is currently trialling integration of its systems onto client platforms in Asia, Europe, and the Americas.

More information can be found at www.sonobotics.com

RCNDE Strategy 2023-28

The world has seen significant change in recent years, with Brexit, a global pandemic, and knock-on economic constraints creating widespread challenges across sectors. This has led to impacts on academic research and industry practices, including changes to funding models, remote working, and an increasing reliance on digital technologies.

This presented an opportunity to reconsider our strategic priorities to ensure we maximise the opportunities available to the NDE community, our partnerships, and the wider society.

The new RCNDE 2023-28 Strategy can be found on our website. The four strategic goals that define the ways we will realise RCNDE's Vision and Mission are outlined below.

Ensure the future sustainability of RCNDE

We are developing ways to ensure we can maintain and expand our membership base while continuing to deliver excellent value. We will champion EDI through our activities and our partnerships.

Support talent

We commit to continuing to support and develop the next generation of NDE specialists for academia and industry. We will do this through access to funding, technology transfer, knowledge dissemination and tailored training activities.

Deliver industrial benefit to RCNDE's membership and beyond

We have defined a robust set of processes which enable us to plan for the technical requirements and needs of our industrial members both now and in the future.

Strategic leadership and influence of the innovation landscape

Through our expertise and our networks, we will influence and advise, taking a leading role in developing and impacting the UK and global innovation space and providing strategic leadership to forums and activities.

The future of NDE and the role of RCNDE

Image credit: University of Strathclyde

In recent times, NDE has been focussed on high-criticality structures in industries such as transport, energy, or civil engineering. It is becoming increasingly clear that it will be key in driving transformational change in the way physical assets across an even wider range of sectors are designed, made, and used.

Improvements to the technology will develop in several areas. There are ongoing opportunities to refine the scale of defect detection and the application to advanced materials and new structural forms. Digitalisation is bringing new opportunities and challenges. Robotics offers to transform the deployment of inspection in a wide range of settings. Systems thinking is reopening questions about the relationship between NDE and topics such as structural health and condition monitoring and diagnostics, as well as enabling the circular economy through reuse and re-manufacture. Looking beyond the technology, regulation and legislation are being challenged to keep pace with the art of the possible and public expectations around safety and reliability are constantly evolving.

The impacts of digitalisation, robotics, and remote sensing on the people working in NDE are still being assessed. We know that there will be less hands-on inspection and more systems design, and we will need to merge existing expertise with new skills and roles as part of a progressive adaptation of the workforce.

The key research themes currently being studied will ultimately lead to a world in which, without human intervention, the state and remaining useful life of component parts of assets are continually assessed and their operation automatically optimised. However, the benefits do not end there. Everyday equipment, systems, and other transferable fields can derive similar benefits from the same technologies and methodologies. All of this leads to exciting times ahead and reaffirms the central role of RCNDE in taking forward a balanced, industry-led, research portfolio to realise the promise for the future.

Contact Details

The Centre operates across multiple locations in the UK, which reflects our operational structure.

You can read more about our work at: **www.rcnde.ac.uk**

To get in touch about the work of the Centre or for membership enquiries, please use **rcndeinfo@ndevr.org.uk**

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