RCNDE

UK Research Centre in NDE

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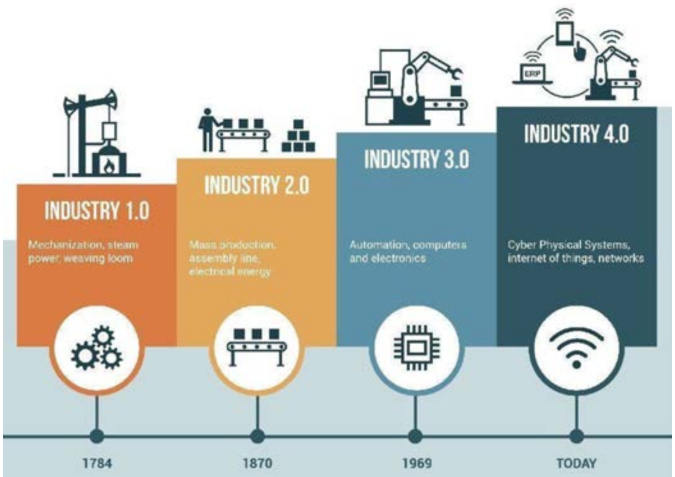
Unlocking Industry 4.0

The Fourth Industrial Revolution (4IR) is happening all around us, whether it is the emergence of self-driving vehicles, autonomous systems, or the transformation of industrial activities and infrastructure. Non-destructive Evaluation and permanent structural monitoring will both be impacted by 4IR, but crucially they will also be among the key enablers for the transition to 4IR, which is often also described as Industry 4.0.

The UK Research Centre in NDE (RCNDE) is established as a leading academic-industrial collaboration for undertaking industrially relevant research in the field of NDE and structural health monitoring. The industrial members of RCNDE produced their first 5, 10, and 20-year vision for NDE in 2011, and which was updated in 2016. This updated vision for their future NDE and monitoring needs anticipates the requirements for inspection technologies for a society embracing 4IR.

The first industrial revolution began in Britain in the late 18th century with the mechanisation of the textile industry. Tasks previously done laboriously by hand, as 'cottage industries', were brought together to form factories. The second industrial revolution came in the early 20th century with the moving assembly line and the age of mass production. The third industrial revolution in the latter half of the 20th century – the 'digital revolution' – saw the advent of microprocessors and high levels of automation. The 4IR reflects the coming together of digital and physical networks to create opportunities for the fusion of multiple technologies and new autonomous systems. It is



characterised by recent and anticipated breakthroughs in fields such as machine learning, artificial intelligence (AI), automated robotics and advanced manufacturing, pervasive digital networking ("Internet of Things"), autonomous vehicles, processes, plant and infrastructure, and additive manufacturing, "Big Data" analytics, material science and nanotechnology, among other things. Future manufacturing and infrastructure will involve self-optimisation, self-configuration, self-diagnosis and resource efficiency. Inspection and monitoring technologies have a key role in the transition to the 4IR.

The next 5 years will see the inexorable upgrading and replacing of current NDE with better NDE performance. This will be achieved with increased automation of data collection, processing and interpretation, together with the application of emerging material measurement capabilities supported by more powerful, realistic modelling. This will include coping with lossy or noisy materials for improved range and sensitivity, and reliably detecting and characterising smaller defects, and defects in difficult to access regions. The rollout of infrastructure monitoring will continue, including higher fidelity structural health monitoring of localised, high-impact regions of plant and structures. Over these five years, manufacturing NDE will help to enable the evolution of manufacturing technology advances envisioned for the 4IR, such as wider use of additive manufacturing and adoption of advanced materials and component designs. Manufacturing industries will be closer to the goal of in-process monitoring with high-precision, high-speed robotic NDE, and high-temperature and non-contact inspection.

The 10-year vision draws heavily on 'next generation' technologies. Defining business needs in NDE terms requires an understanding of where the individual businesses expect to be in 10 years' time, and involves

Unlocking Industry 4.0 (continued)

consultation with colleagues within members' organisations regarding the use of NDE data and any perceived limitations. The scoping of technologies potentially able to meet these future needs is somewhat more speculative, although there is usually already the kernel of knowledge and understanding to justify candidate technologies. Indeed, for 10 years' time, the vision generally relates to current or planned research activities, including those presently at TRL1-2. Therefore, the necessary development paths are broadly apparent today, albeit with some imagination and goal setting is specific where possible as well as including some conceptual goals. Inspection technologies in 10 years' time are expected to depend significantly on wide-area, connected permanent and embedded sensor networks for screening structures to detect emerging degradation, including high-sensitivity measurement of defect growth rates. These will require extended-life, auto-calibrating sensors. In-situ NDE targeted at critical regions will be delivered by remote operation using universal automated NDE platforms. Increasing automation will include measuring, and then adapting to, material properties for improved defect detection and characterisation sensitivity, automatic data processing, and model-assisted decision support. Human factors affecting inspection quality and data sentencing and interpretation will be greatly reduced. Improvements in inspection of materials will include progress with the sizing of very small defects (i.e. few tens of microns) in thick sections, and assessment of mechanical properties and material condition (such as hardness, residual stress, stress depth profiling). Important steps towards the digital ubiquity for the 4IR will include advances in data handling and common data formats. The manufacturing industries will employ in-process inspection matching the performance of post-manufacturing inspection, and on-line inspection of 3D-printed components will have been implemented, with validated acceptance criteria.

Looking to 20 years ahead, the industrial vision for NDE is much more speculative. It is important that new ideas are explored without hindrance from current knowledge of capability. Therefore, the industrial sectors were asked to consider the 'can't do' areas of NDE, including tasks where NDE is not currently used or envisaged, for example where the prevailing alternative is to scrap, strip or replace. The 20-year visions assume advances in all supportive technologies such as computer processing speeds, data storage capacity, etc. They also envisage that the required understanding will

exist for all facets of the engineering problems for which an NDE detection or measurement capability might be relevant. Nevertheless, the NDE and monitoring community will still need to reach out to other engineering disciplines to identify opportunities for new engineering practice, for example through closer understanding between the fields of NDE and Structural Integrity. These opportunities will arise from advances in inspection technologies and capabilities to enable better engineering integrity judgements and decisions, and the potential for new or improved approaches to engineering integrity. This is a distant horizon, and some goals are specific and others conceptual. The prospects for 20 years from now include high-sensitivity, full volumetric inspection, independent of material, with fully automated analysis decision-making and built-in artificial intelligence integrated with comprehensive material and integrity engineering models – the 'digital twin' replica of physical assets and how they are performing. Inspection capabilities will include ultrafast, long-range and wide-area sensing with extensive distributed systems spanning tens to hundreds of kilometres, with built-in self-monitoring and condition diagnosis. Defect characterisation will extend to fatigue and other damage precursors as well as characterisation of material changes and condition in wider areas, and bond integrity. These capabilities will be possible in challenging plant conditions and hazardous environments (e.g. raised temperature, ageing plant, deep water, high radiation environments). Where applicable, structural monitoring approaches will be based on defect growth rates (rather than absolute defect size) which should provide improved sensitivity and better predictions of future structural integrity. Manufacturing in the late 2030s will deploy inspection for assuring the performance of tailored materials, with product quality referenced to predicted in-service duty performance. Inspection processes will not affect manufacturing cycle times.

Not only does this updated industrial vision for NDE identifies how NDE and monitoring technologies will need to adapt, it also highlights the role that NDE and structural monitoring has as an important key to unlocking the potential of the Fourth Industrial Revolution

[Based on an article published in BINDT Insight journal, Sept 2017]

Wind energy NDE and monitoring requirements

As described in the earlier article in this newsletter, the RCNDE industrial members have collectively documented their long-term requirements for NDE in their 5, 10 and 20-year vision. RCNDE is also keen to identify the inspection and monitoring requirements of industrial sectors not currently well represented within its industrial membership. This desire recognises the broad applicability of NDE research across multiple sectors, and also the value in identifying opportunities for other sectors to maximise the benefits of the RCNDE research.

In February 2019, RCNDE held a workshop in collaboration with the British Institute in NDT (BINDT) and the Offshore Renewable Energy (ORE) Catapult on the NDE and structural health monitoring requirements of the wind energy sector.

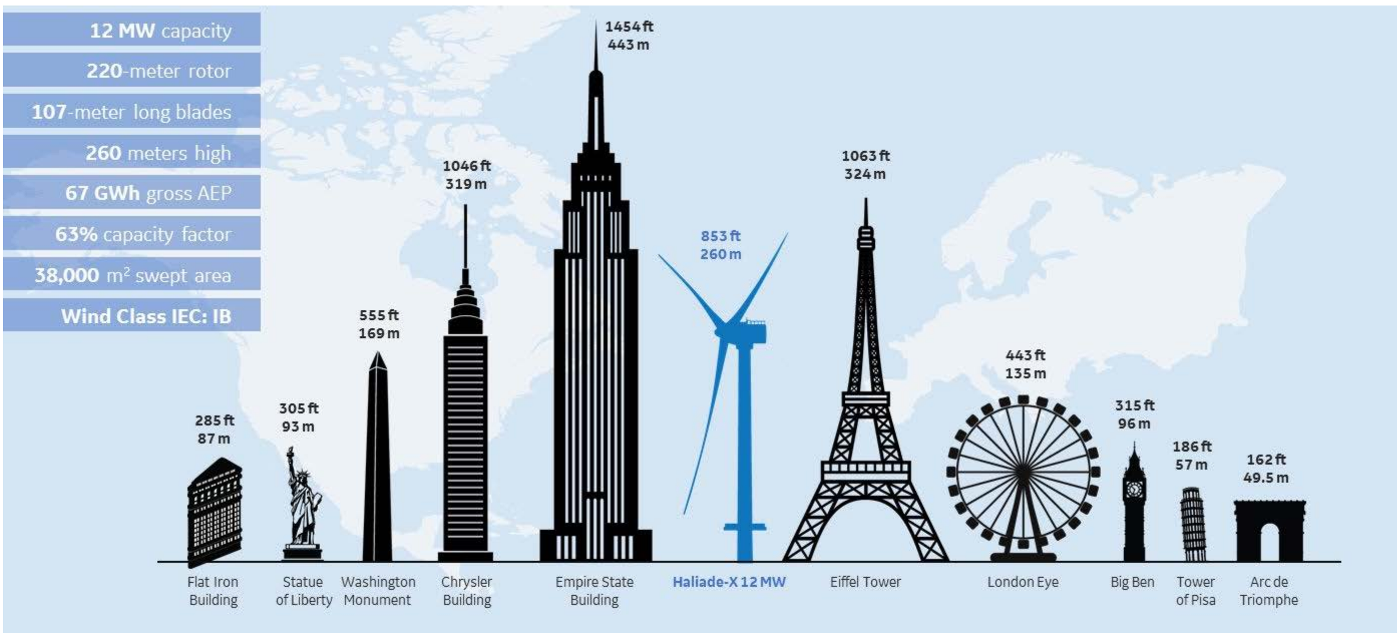
The manufacturers, owners and operators of renewable energy systems seek cost-effective and reliable operation of their installed facilities. Inspection and structural health monitoring technologies are struggling to adapt to the increasing size and hazardous environment of offshore wind turbines in particular. In order to develop and apply improved solutions, it is essential to identify and define the requirements for the inspection and monitoring of both structural components and systems.

The two-day workshop, held at the ORE site in Blyth, aimed to bring together stakeholders (regulators, insurers, manufacturers, owners, operators) and the NDE community, to understand the inspection problems faced by the manufacturers and operators of wind turbines, and establish the future NDE requirements, whether relating to thick-section large composite structures, or metallic components and systems. Finally, the workshop aimed to consider the application of emerging inspection tools and technologies.

Drone visual inspection

The two days involved a series of presentations covering the range of different industrial contributors in the sector. A breakout session sought input on four discussion topics, with everyone having an opportunity to contribute to each topic: *requirements for manufacturers; in-service requirements for composite blades; in-service requirements for non-blade structures;* and, *potential for new NDT, CM and SHM.* The workshop concluded with a tour of the ORE site and test facilities, and panel discussion from some key contributors covering some of the arising topics.

A report published by BINDT detailing the presentations and discussions summarises the requirements identified and what success will look like so that it will be clear whether or when the requirements have been met in the future. https://www.bindt.org/events/PastEvents/wind-turbines-workshop-2019/



Comparison of the GE Haliade-X 12 MW wind turbine with other well-known structures

Doctoral training with the new FIND-CDT

The UK Engineering and Physical Sciences Research Council, EPSRC, which funds university research and doctoral training, ran a competition in 2018 to award ~£450M public funding for a further tranche of Centres for Doctoral Training spanning the engineering and physical sciences. The Centre for Doctoral Training in Future Innovation in Non-Destructive Evaluation (FIND-CDT) bid was successful and was one of 75 new CDTs announced in February 2019.

The FIND-CDT had its first of five student intakes in October 2019. The Centre provides exciting opportunities for collaborative industry-university research in advanced sensor and imaging technology, and is designed to launch outstanding graduates into an engineering career.

Both PhD and EngD studies are offered, and the courses combine advanced knowledge and professional development training modules with industrially relevant research. PhD projects tend to be more fundamental research while EngD projects tend to be more applied.

With close links to RCNDE, the new Centre builds on the success of the previous CDT in Quantitative NDE, and involves the same consortium of six universities integrating research with industries: Bristol, Nottingham, Manchester, Imperial College London, Warwick and Strathclyde.

During the 4 years of either a PhD or EngD, each student completes a range of cohort-based advanced technical courses and courses on innovation and entrepreneurship, all delivered by world-leading experts. Students present their research at national and international conferences and at regular events to audiences from across industry. Networking workshops provide opportunities for collaboration across disciplines, reflecting the wide range of scientific skills needed within this area. Students are part of a large and vibrant RCNDE community of researchers, plus many industrial specialists from end users and the supply chain, and have access to a range of technical training courses delivered by world leading experts.

The structure of the FIND-CDT involves a project topic that matches the student's interests and career aspirations. The student embarks on the research project journey from the outset and is immersed in industry from day one, making it unique in its approach and preparing the student for their career immediately. The student maintains continuous contact with their academic and industrial supervisors throughout.

The training begins with a residential three-week course on the industrial context of NDE, including lectures, hands-on NDE activities, industrial visits, networking and a start to the mentoring programme.

New for FIND-CDT is the addition of a transferable skills programme. The programme will be delivered through a collaboration between the industrial partners and the team from the Bristol Centre for Innovation and Entrepreneurship. The training adopts a predominately practice-orientated educational approach based on collaborative team-work across disciplines, and built around the central themes of technology transfer, entre/intrapreneurship and responsible innovation.

The final year focuses on the research project and thesis write up. The past CDT's graduates have an excellent track record of timely completion with 38 of its 40 doctoral graduates now working in industry, nearly all related to NDE and several already in senior roles, plus the research outcomes benefiting the companies hosting their projects.

For more information please visit the website at www.find-cdt.ac.uk, and for any informal enquires please contact the FIND CDT Manager, Amy Harris, at find-cdt@bristol.ac.uk. Follow it on twitter @CdtFind.

FIND-CDT
EPSRC CDT in Future Innovation in NDE

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Or, Maria Arias, RCNDE Centre Manage, at: maria.arias@bristol.ac.uk

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