Gas turbines in a carbon-neutral society
10th International Gas Turbine Conference
11-15 October 2021

Paper ID Number: 63-IGTC21

NON-DESTRUCTIVE EVALUATION FOR INDUSTRY 4.0

Pete Loftus, RCNDE and Evalu8ion Ltd; Paul Wilcox, RCNDE and University of Bristol

University Walk Bristol BS8 1TR
+44 7718990870
pete.loftus@ndevr.org.uk

ABSTRACT

Non-Destructive Evaluation is well established in Gas Turbine life cycle management. However, it is a stand-alone, labour-intensive activity that adds costs and delays throughout life-cycle operations. In this extended abstract, we consider a vision for the future of NDE, "NDE 4.0" and the opportunities it presents. We outline the journey required to achieve this vision and the part played in that journey by the activities of the UK Research Centre for NDE (RCNDE). NDE 4.0 requires changes to skill sets, process, and equipment, and requires integration with enterprise systems and methodology at multiple levels There are also opportunities for technology to transform the performance of NDE and facilitate its integration with the life-cycle management processes and systems. RCNDE is championing a suite of technology developments to deliver this capability across multiple high integrity engineering sectors.

INTRODUCTION

The UK Research Centre in NDE www.rcnde.ac.uk links university research with industrial NDE users to create a world-leading centre of excellence in NDE research. It combines innovative science with industrial applicability. As part of its mission, it holds regular consultations with its Industrial members and others to inform the vision of the future for NDE. It then works with the University sector to develop research programmes to advance the state of the art in key areas which are typically funded through the support of the industrial members and the UK funding body the Engineering and Physical Sciences Research Council subject to successful bids. The strong industrial guidance, and academic excellence make this attractive for all the stakeholders and results in extremely attractive financial gearing for the end users.

The journey of digitalisation often referred to as the fourth industrial revolution is well documented and it would be easy to dismiss NDE as playing little part in this, given its origins as a manually intensive inspection approach. However, to take that view would be to miss opportunities on several levels. The industry itself has been articulating these opportunities under the term "NDE 4.0" but engagement with the structural integrity community and enterprise system developers is key to exploiting the opportunity.

NOMENCATURE

There is no mathematical nomenclature used in the paper

THE NDE 4.0 CONCEPT

The concept and definition of NDE 4.0 is still developing but the British Institute of NDT (BINDT) defines it thus (Brierley, N and Loftus, P 2021) "The Industry-4.0-driven transformation of the non-destructive evaluation (NDE) domain. For the purposes of the BINDT Group it is considered to span two (Fig1) facets: the enhancement of NDE to serve, or enable, Industry 4.0 ("NDE for I4.0") and enhancement of NDE by adopting Industry 4.0 technologies ("I4.0 for NDE").

The first facet is based on connectivity *to other* domains, resulting in a cross-domain cyber-physical system as would be the case if for example exposing full outputs of a production line's NDE inspection to production planning. The second facet is based on connectivity *within* the domain, resulting in a domain-specific cyber-physical system, as would occur if using a digital twin of the inspection for adaptive inspection planning. Both facets are expected to be adopted and exist in parallel for most applications.

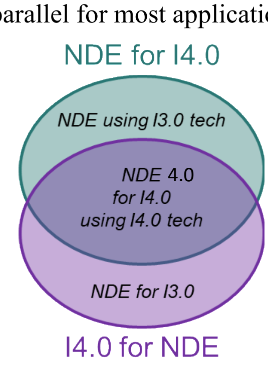


Fig 1 NDE 4.0

Whilst it is useful to recognise this terminology in collaborating with the NDE community, the NDE 4.0 definition need not constrain the exploration of wider ways in which technologies developed for NDE can support I 4.0 developments by gas-turbine manufacturers and users.

NDE TODAY

NDE today is heavily reliant on human intervention as illustrated in Fig 2

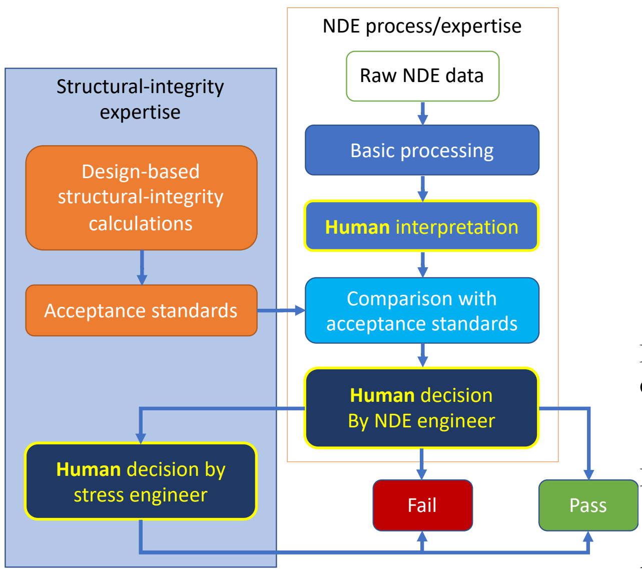


Fig 2 NDE today (from RCNDE private communication)

Acceptance standards are developed by structural integrity specialists; Inspections are performed, often manually, by human operators. Interpretation of inspection data is usually manual, as is the resulting decision making which may invoke structural integrity expertise in marginal cases.

NDE – A VISION

There are many ways to articulate a future vision. Clearly, it is desirable to remove the human intervention where possible. Many elements of the NDE processes could be automated individually and the NDE sensing modalities could be deployed in on-line structural health monitoring or re-purposed for other forms of condition monitoring beyond the parameters of interest for structural health.

However, it is in integrating NDE fully into life-cycle management that the biggest gains are foreseen in reduced life-cycle costs, operator safety, and product performance. Fig 2 (based on Brierley et al 2020) shows one such description of a possible future centred on a digital twin of the inspection target and drawing on integrated design definition that includes the life-cycle management based on NDE 4.0 sensors, analysis exploiting machine learning, and decision making encoded algorithmically with continuous feedback to support continued operations and future designs.

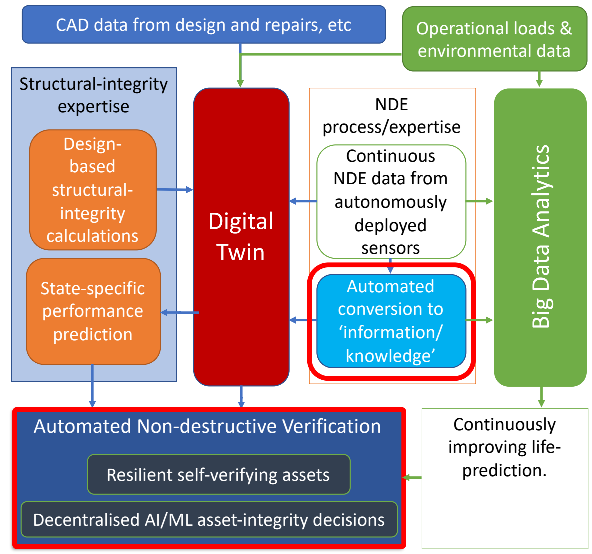


Fig 3 a vision for NDE 4.0 (from RCNDE private communication)

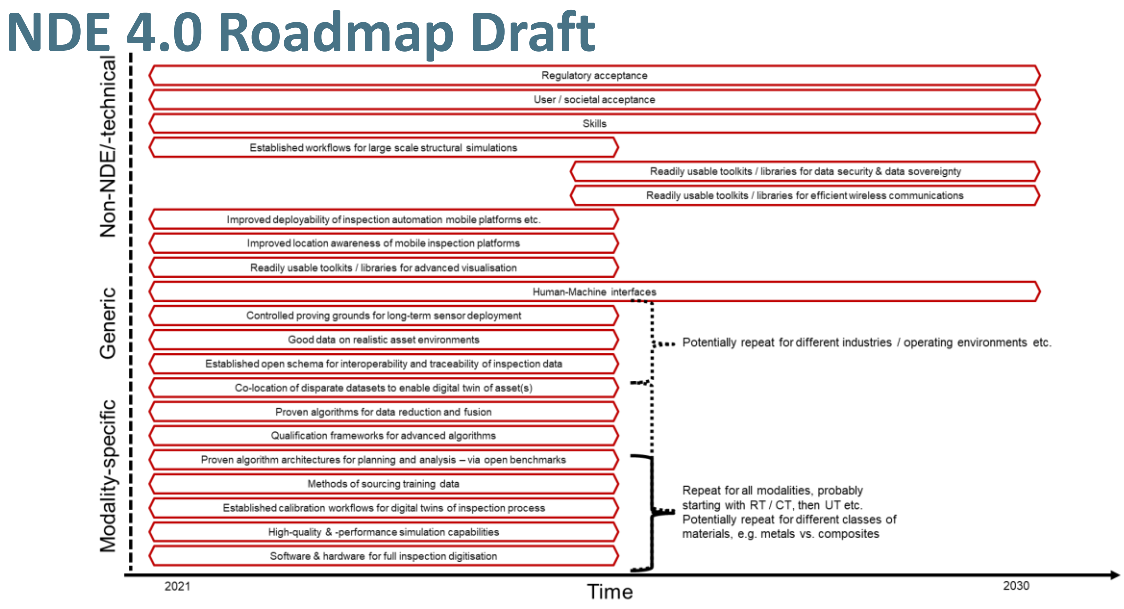
ROADMAPPING

RCNDE actively participates in national and international fora related to the future of NDE. It has supported the BINDT in the continuing efforts to develop a roadmap for NDE 4.0. This has involved extensive consultation based around views of the developments required, the technologies possible, specific technical objectives and a rationalised list of NDE 4.0 objectives. The mapping between all of these has been laid out and has resulted in an emerging view of the roadmap shown in fig 4

A limitation of the current state of development is that, whilst the areas where development is required are now identified, it has not yet been possible to develop a timeline with intermediate deliverables. The difficulty has primarily arisen because of the differing areas of focus across sectors and individual users. It may be that this level of planning will need to be done at sector level to bring the focus needed.

The key technical areas of focus are illustrated in fig 5 and these are backed up by a transformation in the skill sets of NDE practitioners and the business processes underpinning life-cycle management.

Further elaboration on key elements of NDE 4.0 may be found in Vrana, J 2021.



Courtesy of BINDT

Fig 4 BINDT Roadmap (after Brierley and Loftus 2021)

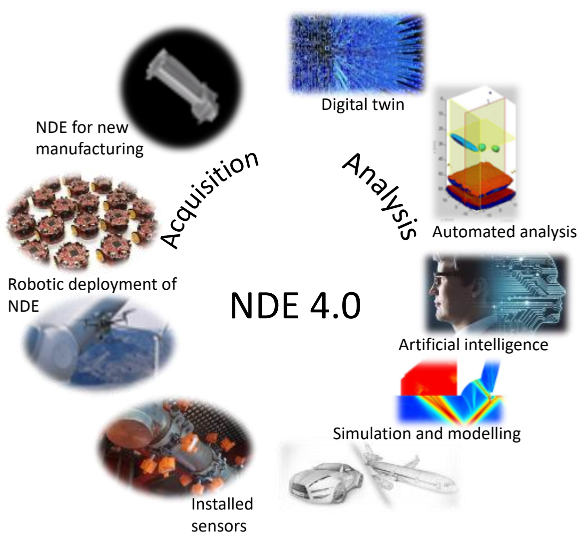


Fig 5 Graphic of technical scope of NDE 4.0 (RCNDE private correspondence)

EXAMPLES OF RCNDE PROGRESS

The RCNDE Website gives examples of recent past core projects and current themes https://www.rcnde.ac.uk/research/core-research/ .

Examples of deployed solutions arising from RCNDE research include:

1. Permanently deployed High Temperature ultrasonic thickness sensors marketed by Permasense Ltd which begins the transition from inspection to embedded monitoring for pipe corrosion.
2. Wireless ultrasonic SHM sensors interrogated by a non-contact antenna system marketed by Inductosense Ltd. Whilst this system is currently manually operated, the non-contact approach with minimal sensitivity to antenna alignment makes it well suited for robotic deployment in future.
3. Robotic delivery mechanisms developed by the University of Strathclyde
4. And machine learning applied to the creation of model based multi-frequency eddy current coating thickness measurement by the University of Bristol

CONCLUSIONS

We have attempted to show that there is an evolving consensus view of ways that NDE technology can develop to provide a more comprehensive input to future life-cycle management regimes. Technology pull will be vital to ensure that gas-turbine operators are able to capitalise on these opportunities. RCNDE has begun exploring the technology developments that can have the greatest impact and is already active in key areas such as embedded sensing, wireless connectivity, robotic delivery, and machine learning based analytics. RCNDE is keen to work with ETN and its members to refine and deliver on the vision.

ACKNOWLEDGEMENTS

The authors would like to acknowlede the support of RCNDE & BINDT in the visioning and roadmapping and the support of EPSRC and the Univarsity partners in delivering the technology cited here.

REFERENCES

N. Brierley, P Loftus, BINDT Insight journal November 2021

N. Brierley, R. A. Smith, N. Turner, R. Culver, T. Maw, A. Holloway, O. Jones & P. D. Wilcox (2020) Advances in the UK Toward NDE 4.0, Research in Nondestructive Evaluation, 31:5-6, 306-324, DOI: 10.1080/09349847.2020.1834657

N. Meyendorf, N. Ida, R. Singh, J. Vrana (2021) Handbook of Nondestructive Evaluation 4.0, 978-3-030-48200-8, https://doi.org/10.1007/978-3-030-48200-8