Data-Centric Engineering Approach in New Nuclear

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A SINDRI REPORT

Evaluation and recommendations for the adoption of data-centric engineering in new nuclear

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Introduction

The UK is committed to ensuring and expanding the role of nuclear power in achieving net zero by 2050 and in contributing to ensuring energy supply sustainability and security. The industry is engaged and ready for this national effort, as evidenced by the development of Hinkley Point C and Sizewell C, Small Modular Reactor (SMR) technologies, and, in the long term, Advanced Modular Reactors (AMRs) and fusion technology.

However, these efforts could be hindered by two key issues: cost and pace of development. Nuclear is typically perceived to have significantly higher costs compared to other low-carbon energy sources and there is a need for considerable upfront investment. This ultimately goes hand in hand with a historically slow pace of deployment. Consequentially, it is essential that a pathway to reducing cost and time is developed and implemented, ensuring value for money on both public and private investment and strengthening the future of nuclear in the UK.

CHALLENGES TO NUCLEAR INNOVATION

Hinkley Point C is the first new UK nuclear power plant in a generation, and with its development has come a need for innovation and realignment of the nuclear supply chain. This creates major challenges throughout the nuclear sector – from research through to construction.

1. Some innovations are time sensitive; new industry challenges require solutions be planned, validated and implemented at, for example, the design and construction stages. This means the chance to adopt and utilise new innovations may be overlooked or missed.

2. A second key challenge to implement innovations is the perceived willingness of the regulator to consider them. Whilst it is recognised that regulators are making efforts to enable innovation to be introduced in nuclear (where it is in the interest of society and consistent with safety, security and safeguards expectations) there remains a perception in the broader nuclear sector that innovation is difficult or, in extreme cases, not possible.

3. Finally, adaptation of research from low to medium Technology Readiness Levels (e.g. academia, national laboratories, catapults, small-medium enterprises, and innovation start-ups) across the supply chain (e.g. large-scale design consultancies, manufacturing, and construction) all the way through to the provider (e.g. EDF, Rolls Royce, UKAEA). Critically, recognising and adapting innovations from different fields is key. Utilising pre-existing technologies and innovations builds resilience in the supply chain and reduces costs, all while opening up the nuclear sector to wider manufacturing and engineering groups which may enable adaptation of previously established approaches.

Moving Towards Digital Innovation

The UK is world leading across a range of digital innovation. Key areas related to nuclear (such as net zero capabilities) are addressed in the UK's Digital Strategy published in October 2022, but nuclear itself is not featured. While some industries have been agile enough to integrate digital innovations, the nuclear sector has been slow in adopting digital innovation in the full-life cycle of assets. As well as the challenges mentioned previously, historically nuclear has been met with a lack of investment stemming from a lack of available cost-benefit evidence due to the long time-scales involved.

Now there is ample evidence – not just from the nuclear sector but in many safety-sensitive industries – that a data-centric engineering approach to development of a nuclear power plant at all stages (construction, operation, and decommissioning) is almost a prerequisite for further improving safety and driving down costs. It is clear that to build safer plants economically in the future, the field must adopt a blend of material and in-silico methods which, when combined, will facilitate more rigorous interrogation. More specifically, these methods will underwrite a paradigm shift in design which will allow a whole system route to probabilistic design from the material level up and connect processes across design, manufacture, operation and decommissioning.

CAN NUCLEAR ADOPT DIGITAL?

To explore the readiness of the nuclear industry for adoption of a digital-centric engineering approach, a joint event initiated by SINDRI (a large-scale Prosperity Partnership programme funded by EDF and EPSRC), The Jean Golding Institute, The Southwest Nuclear Hub, and The Henry Royce Institute was organised. The aim was to bring together representatives from a large range of relevant sectors (academia, regulators, supply chain, and operators) to assess the need, willingness, and preparedness of the nuclear industry for application of data-centric engineering.

The event was attended by experts from leading nuclear institutions (see Appendix). Following presentations by The Office of Nuclear Regulation (ONR), Jacobs, CEA, Rolls Royce, The Henry Royce Institute for Advanced Materials and The University of Bristol, a discussion ensued in which the following conclusions were drawn:

CONSOLIDATION OF HISTORIC EXAMPLES

There is value in pulling together examples where a data-centric engineering approach has been successful in the nuclear industry. One such example is the probabilistic assessment of the integrity of a graphite core in Advanced Gas-cooled Reactors (AGRs), which has contributed to the continued safe operation of AGRs. This was a unique and concerted effort by the operator EDF and its supply chain (Frazer Nash Consultancy, Atkins and Jacobs).

EVALUATING THE ROLE OF THE REGULATOR

The ONR recognises the need for digital innovation in supporting timely and inexpensive growth of the nuclear sector. It considers digital tools (including AI) as aligned with their renewed mission to support innovation in nuclear. It was also concluded that the ONR will continue to follow its non-prescriptive philosophy which underpins its independence; it cannot, therefore, insist on digital-centric design or make specific requirements (for example integration of data storage plans in proposals). This position encourages two-way dialogue over top-down prescription of innovation, demonstrating a pro-active approach from all parties; a key factor in successful innovation.

COST REDUCTION

Energy generators identified data-centric engineering as a successful means of increasing efficiency and cost-effectiveness of deploying new products which are aligned with customer needs. In-silico iterations of design and operations of assets have been evidenced by Rolls Royce initiatives in data-centric engineering as well as in EDF's efforts in digital twin development of their plants in the UK and in France.

USE OF ARTIFICIAL INTELLIGENCE

While the suitability and value of applying artificial intelligence (AI) in nuclear operations is currently unproven, its value in analysing supporting data has been demonstrated (see: UKAEA's success stories). There are also ad hoc examples of government and industry investment in the use of AI in analysing large amounts of data in support of the safe operation of plants (e.g. SINDRI). However, the omission of the nuclear industry in the UK Digital Strategy can be viewed as a disincentive to digital applications in nuclear.

EVALUATING THE ROLE OF THE SUPPLY CHAIN

The supply chain reports experience in AI and data analytics from previous ad hoc applications of digital tools within a nuclear setting and, more importantly, from applications lifted from other safety critical industries. One example from PA Consultants showed they prevented power outages using AI and helped San Diego Gas & Electric drastically reduce its operational and maintenance costs while minimising negative impacts of outages.

TIME CRITICAL

There was consensus that data-centric engineering that should reduce costs in the nuclear sector by demonstrating agility for design. This does mean that the clock is ticking however, and the opportunity to employ innovations which will make the nuclear industry safer, more cost effective, sustainable and more agile in deployment is being lost.

Recommendations for Adopting Digital-Centric Engineering in Nuclear

A list of recommendations to facilitate the application and adaptation of data-centric engineering in a nuclear setting was discussed and compiled:

a) **All stakeholders in the supply chain must work collaboratively.** This requires combining data from various reactor systems (e.g. microstructure in materials or non-destructive testing data). Of particular importance is the data transfer at interfaces between various elements of the supply chain. This means adopting compatible data collection policies and addressing the intellectual property and possible market conflicts.

b) **The industry needs more applied data scientists.** Historic lack of investment in the nuclear industry means that there is a deficit in nuclear-industry-aware data scientists. Career development and pathways into the industry must be prioritised.

c) **There needs to be a clear strategy for integrating digital-centric engineering.** A coordinated approach to funding, implementation and quantitative risk and benefit analysis is necessary. Disconnected efforts make cooperation with other national initiatives (e.g. data collection at Royce Institute and the National Nuclear User Facility) impossible. A framework through which data produced by various national and/or industrial initiatives facilitates accessibility and retrievability of data produced.

d) **An industrial digital roadmap is key.** A clear industry AI and digital strategy would include a roadmap that would underpin a governance strategy and make prioritised solutions clear.

e) **Accessibility of data should be paramount.** Ensuring quality data schema, data management systems and well curated databases are available and accessible across the industry will be key.

f) **Build momentum in bringing skills into the industry.** This would mean encouraging people with the required skills to consider moving into the nuclear industry, as well as targeting individuals who are early in their careers/research to match their skills to the required engineering expertise.

Appendix - List of Attending Institutions

Henry Royce Institute

Frazer-Nash Consultancy – A KBR Company

NPL – National Physical Laboratory

ONR – Office for Nuclear Regulation

National Nuclear Laboratory

Ada Mode

Rolls Royce

PA

Pixel Mill

cea – De la recherche à l'industrie

UK Atomic Energy Authority

Priestland Consulting

Jacobs

Prifysgol Bangor University

PolyChord

South West Nuclear Hub

eDF

Jean Golding Institute

SINDRI

A Prosperity Partnership Project

https://www.sindri-partnership.ac.uk/

sindri Prosperity Partnership

University of Bristol

UKRI Engineering and Physical Sciences Research Council