

Nuclear Future

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Professionalism: Rising stars

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Academy Nuclear
Awards - What
happened next?**

**Big Bang 2018 -
Opening young
minds to nuclear**

DEFENCE SPECIAL

- ♦ Reactor simulators and Reduced Order Modelling
- ♦ Reactor operator dynamics in manual control of reactivity transients

Community news and more

- ♦ **WiN CUMBRIA**
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- ♦ **ARTIFICIAL INTELLIGENCE**
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Contents

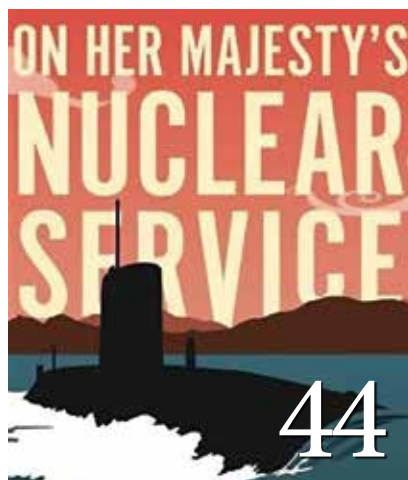
6

UK NUCLEAR SKILLS AWARDS

19



30



44

4 PRESIDENT'S PERSPECTIVE

John Clarke on the importance of being connected

6-7 EURATOM UPDATE

Where next on Euratom and the GDF consultations?

NEWS

8 UK news

10 International new build news

12 International news

14 US news focus

15 Nuclear law webinar update

16-17 Energy and climate policy news

18 YGN Spain trip report

COMMUNITY NEWS & MORE

COVER STORY

19-21 NSAN rising stars – What happened next?

23 How to mythbust with YGN

24-25 WiN Cumbria launches

26-27 NNL on why innovation

through collaboration matters

28-29 Emergency preparedness –

NEA "milestone" report

30-31 PERSONAL JOURNEY

NI Western Branch's

Viktorija Zaksaitė

YOUR NI

Contribute, connect, learn

34-36 ARTIFICIAL INTELLIGENCE

Can AI drive nuclear forward?

37-39 NATIONAL BIG BANG FAIR 2018

Inspiring the future of nuclear

40-43 ONR GUIDANCE

'Enabling regulation' in practice

44-46 BOOK SPECIAL

On Her Majesty's Nuclear Service

TECHNICAL FEATURES

49 Reactor Simulators and
Reduced Order Modelling

55 Reactor operator dynamics in manual
control of reactivity transients

REGULARS

9 BY THE NUMBERS

GDF and willing communities

11 THE BIG PICTURE

UAE'S Barakah nuclear
energy plant complete

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PRESIDENT'S PERSPECTIVE

The importance of being connected

NI President John Clarke on why networking at home and overseas matters



John Clarke

By the time this edition of *Nuclear Future* goes to press we should have had a successful conference in Cumbria on Integrated Waste Management. The conference has been a long time in the planning phase with great input from the Institute and a wide spectrum of key players

across the industry. Very many thanks to those who put in so much effort.

For me, the value of these events is twofold. First, they are an opportunity for people to hear, first-hand from experts in their field, of the latest developments in a particular area of our industry - across policy setting, planning, technical development and implementation issues. Second, and perhaps almost of as much value, they provide a great forum for people to meet others from different parts of the industry - to refresh old acquaintances, to establish new contacts and to exchange views.

Another example of networking opportunities provided by the Institute is the branch annual dinners. I had the pleasure of attending and the honour of speaking at the Cumbria branch dinner earlier this year. While I shouldn't be

surprised, it always impresses me just how many members turn out to these events and how many distinguished guests are so willing to attend. At the Cumbria dinner, we were joined by several MPs, the Chief Executive of the ONR, representatives from academia and senior industry representatives from throughout the supply chain. It was also great to see so many "younger faces" present. They are the nuclear future!

Looking a little further afield, a couple of years ago I would have bet a reasonable sum against The Euratom Treaty appearing as a significant discussion point across the mainstream media. But how wrong I was! With the UK's departure from the EU now less than a year away, the importance of making sure that we retain our vital international linkages and obligations in areas such as nuclear material supply and safeguards has been recognised. (*Please see pages 6-7 for an update on Euratom and page 12 for details of our recent nuclear law webinar which includes a focus on where next for Euratom.*) Perhaps more so than most other industries, our industry is only able to operate with strong international arrangements. Let's hope the necessary new arrangements are quickly put in place to ensure our ability to continue our activities across research, defence, energy supply and medical isotope production, all of which are so vital to us all.

"Perhaps more so than most industries, our industry is only able to operate with strong international arrangements"

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Government responds to report on Brexit impact

Report had urged the Government to agree “as close a relationship as possible” with Euratom

news@nuclearinst.com

The UK must be able to operate as an “independent and responsible nuclear state” as soon as it leaves the European Union in March 2019, the Government has said in its response to a parliamentary report about the impact of Brexit on the country’s nuclear industry.

The Business, Energy and Industrial Strategy Committee is appointed by the House of Commons to examine the expenditure, administration and policy of the Department for Business, Energy and Industrial Strategy (BEIS). The BEIS Committee published its second report of Session 2017-19 – Leaving the EU: Implications for the civil nuclear sector – on 13 Dec ember. That report had urged the Government to agree “as close a relationship as possible” with Euratom to minimise unnecessary expenditure and provide greater certainty for the nuclear industry. The Government’s response was received on 2 March and in late April.

“ALL NECESSARY MEASURES”

“The report and its recommendations are a valuable contribution to the overall programme of work that the Government is delivering in respect of its departure from the EU and Euratom, covering negotiations and domestic preparations,” the Government said in its response.

Whilst negotiations continue on the UK’s exit from the EU and Euratom,



and its subsequent relationship with it, the Government said it is “putting in place all the necessary measures to ensure that the UK can operate as an independent and responsible nuclear state from day one”.

The Government said it has “made good progress on Euratom separation issues in the last few months” during its negotiations with the European Commission. These negotiations have covered a set of legal and technical issues related to nuclear material and waste, and safeguards obligations and equipment. The next phase of discussions will focus on the UK’s future relationship with Euratom.

“We believe that it is of mutual benefit for both the UK and the EU to have a close association with Euratom,” the Government noted.

It added, “Whatever the outcome of the negotiations with the European Commission, it is vital that Government pursues all options for providing certainty for the civil nuclear industry that it will be able to continue its operations.”

CLOSE WORKING WITH ONR

The Government said it is working closely with the Office for Nuclear Regulation (ONR) to ensure that it will be in a position to take on the role and responsibilities required to ensure the UK’s future domestic civil nuclear safeguards regime meets international



David Davis MP

standards and nuclear non-proliferation standards when Euratom safeguards arrangements no longer apply in the UK.

It said it is confident the UK will be in a position to deliver a domestic regime to international standards by March 2019. However, it is committed “to going further, supporting the ONR to achieve standards equivalent to those delivered by Euratom in effectiveness and coverage as soon as possible”.

Meanwhile, UK officials are in negotiations with the USA, Canada, Japan and Australia to have bilateral Nuclear Cooperation Agreements (NCAs) in place so that cooperation and trade can continue uninterrupted when the UK leaves the EU and Euratom.

The Government expects that drafting the NCAs will be finalised this summer and that ratification in all four countries will be completed by the end of this year.

“The ratification procedures vary between countries and will finish at different times; however, we are confident that we will be in a position to exchange notes from the beginning of 2019 and for the agreements to be able to enter into force in March 2019,” it said.

KEY STRATEGIC IMPORTANCE OF NUCLEAR

The nuclear industry remains of “key strategic importance” to the UK, the

Government defeat in House of Lords over post Brexit plans on Euratom

Peers look to insist the UK should not withdraw from Euratom until a replacement deal is established.

The Government has been defeated twice in the House of Lords over its plans for nuclear cooperation after it leaves the European Union next year. They also backed a plan requiring the UK to report to Parliament regularly on its future arrangements with Euratom.

The Government has said it wants to establish a new domestic nuclear regime as well as negotiate a nuclear agreement with the EU once the UK leaves on 29 March 2019. Peers in the upper House of Parliament voted by 265 to 194 to insist the UK should not withdraw from the Euratom, until a replacement deal is in place.

Members of Parliament are likely to try and overturn the changes to the Nuclear Safeguards Bill when it returns to the lower chamber, the House of Commons, according to the BBC.

The Government has always said triggering of the formal two-year proceedings for quitting the EU in March 2017 had also started the process of leaving Euratom.

Lord (John) Hutton, chairman of the Nuclear Industry Association, said remaining in Euratom should be a “back-up” option in case direct arrangements with individual countries, including the USA, cannot be negotiated in time.

“I don’t think any of us should take a gamble or a risk with the energy security of our country,” he was quoted as saying.

The Government, which does not have a majority in the House of Lords, was defeated after cross-benchers joined forces with Labour and Liberal Democrat peers to insist on specific assurances over research and development collaboration and the movement of qualifying nuclear material.

—Researched and written by World Nuclear News

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Government said, adding, “We want to ensure that projects and investment, like Hinkley Point C, are not adversely affected by the UK’s withdrawal from Euratom. The UK remains open to accessing the talent we need from Europe and the rest of the world in the nuclear industry, but this needs to be managed so that our immigration system serves the national interest.”

The Government also said the UK’s withdrawal from Euratom “in no way diminishes our nuclear research and development ambitions”. Maintaining and building on the country’s “world-leading” fusion expertise and finding new paths into international fusion R&D projects is a “key objective” in respect of the UK’s future relationship strategy with Euratom.

“There is a clear common interest for the UK and the EU27 in maintaining close and effective cooperation on nuclear issues and the Government is confident that it will reach the right agreement with our European partners,” it said.

INDUSTRY WELCOMES RESPONSE

The Government’s response to the report was welcomed by the UK’s nuclear industry.

Tom Greatrex, Chief Executive of the Nuclear Industry Association, said: “The UK Government’s decision to leave Euratom has been consistently

contested by the industry, since it was announced in early 2017. It has already proved a time-consuming and unpredictable process, and we are still at the early stages. The key milestones outlined by the Government are welcome, indicating the progress made towards a successful relationship post-March 2019, and those areas yet to be resolved.”

However, he noted that the UK must still conclude its negotiations with the International Atomic Energy Agency on a Voluntary Offer Agreement and Additional Protocol, as well as conclude negotiations and ratify new bilateral NCAs with the USA, Canada, Australia, Japan and others. In addition, the UK must reach agreement on a comprehensive and new funding agreement for the country to continue its participation in Euratom’s fusion R&D activities.

“This must all be agreed on and implemented by the time we leave Euratom,” Greatrex said. “It is therefore essential, as part of the overall Brexit negotiations, Euratom remains a priority for the Government in seeking a comprehensive transitional agreement with the European Union. Successful and timely conclusion to these negotiations is vital, to prevent significant disruption to the UK’s nuclear industry.”

—Researched and written by World Nuclear News

“There is a clear common interest for the UK and the EU27 in keeping close and effective cooperation on nuclear issues...”



CGI rendering of proposed Hinkley Point C development

EDF Energy boss issues warning: "Sizewell C may not be feasible"

Assurances sought that a viable funding model exists

news@nuclearinst.com

The proposed Sizewell C nuclear power station in Suffolk, England, may not be feasible, although discussions are continuing with the UK government about possible funding options, EDF Energy's UK Chief Executive told *The Times*.

Simone Rossi told the newspaper that the company needs assurances from the government this year that a "viable funding model exists" for the construction of two EPR units at Sizewell C. If EDF Energy believes the project is not feasible, it may stop its involvement in the project, he said.

EDF Energy is in talks with the government over a funding model for the Suffolk nuclear power plant which would reduce costs for consumers.

Earlier this year Mr Rossi said there

had been strong appetite from pension funds interested in taking a stake in the Sizewell C project.

Mr Rossi told *The Times*: "This is the year where we need to understand whether this whole thing is really feasible or not."

He added: "If we were to conclude that maybe it's not feasible, then at that point maybe we say we are not in a position to continue the project."

COST SAVINGS COULD "DISAPPEAR"

Mr Rossi said expected cost savings for Sizewell C could disappear if there is a "significant delay" between work on it and Hinkley Point C.

EDF Energy has said it expects construction costs for Sizewell C to be roughly 20% less than for the Hinkley Point C station, which is costing almost £20bn. This is because the new plant would almost be a replica of Hinkley Point C, and because electricity grid connections are already in place at the Sizewell C site.



Simone Rossi

EDF is building two EPR units at Hinkley Point C by putting forward its construction costs upfront before later earning £92.50 for every megawatt-hour of electricity it produces once it starts running.

The price will be paid by consumers through their energy bills. It was set via a contract agreed between government ministers and EDF bosses.

Sizewell C would be north of its sister plant Sizewell B on the Suffolk coast. EDF estimates the two Sizewell C units would take 10 to 12 years to build once it has planning permission.

In July 2017 EDF revealed costs for Hinkley Point C had risen by £1.5bn to reach £19.6bn, while delays in delivering its reactors could add millions more. The announcement came weeks after public spending watchdog the National Audit Office said Hinkley was "risky and expensive".

—*Researched and written by NucNet*

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Measuring the true cost of power production

New OECD Nuclear Energy report aims to support better policies and more sustainable electricity mixes

news@nuclearinst.com

The social and environmental impacts of electricity provision affects individuals, economies and countries in ways that are not captured in market prices, but yet are too important to be neglected, according to a report issued recently by the OECD Nuclear Energy Agency (NEA). Despite their importance, full accounting for these costs remains difficult, it says.

The report – *The Full Costs of Electricity Provision* – is a collaborative effort by the NEA Division of Nuclear Technology Development and Economics, under the oversight of the Working Party of Nuclear Energy Economics.

“Market prices and production costs are important measures of the economics of electricity. However, over at least the past two decades, there has been a growing recognition that these values do not represent the whole story,” the report says.

The document analyses plant-level production costs, grid-level system costs, climate change impacts, air pollution, the costs of major accidents, land-use change and natural resource depletion, and the security of energy and electricity supply. It also gives an overview assessment of security of energy supply indicators and considers employment generated in the electricity sector as well as the impact of energy innovation on economic performance and growth.

The report concludes: “Disseminating and synthesising knowledge on some of the most salient features of the full costs of electricity provision is part of the process of arriving, through the progressive internalisation of social costs, at better policies and more sustainable electricity mixes.”

—A longer version of this piece, researched and written by World Nuclear News, first appeared on WNN

Nuclear regulations laid out

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The Government has laid out the Nuclear Security (Secretary of State Security Directions) Regulations 2018 in Parliament.

These regulations enable the Secretary of State to issue directions directly to industry in the case of an immediate security threat to the civil nuclear sector. Guidance is now being developed by the Office for Nuclear Regulation with the Department for Business Energy and Industrial Strategy to support these regulations, which are expected to come into force on 1 October 2018.

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By the numbers

Geological Disposal Facility (GDF) and willing communities

The Government's commitment to communities interested in hosting the GDF site includes*:



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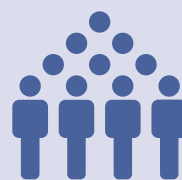
who enter the siting process

*Nuclear Institute's consultation responses for GDF are available to read on our website: www.nuclearinst.com/News/Consultations

Up to **£2.5 million** per year invested in communities



where deep borehole investigations take place



Employ **550 people**, on average, each

year through the operational lifetime of the project

15 to 20 years process to find a site



Construction start for first Turkish nuclear power plant

Russian-Turkish project expected to provide around one tenth of Turkey's electricity

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Immediately following a construction licence from the Turkish Atomic Energy Authority, first concrete was poured for the first of four Russian VVER-1200 reactors at Akkuyu, on Turkey's eastern Mediterranean coast. The presidents of both Russia and Turkey participated in the ceremony by video link from Ankara, with Russian President Vladimir Putin stressing that "the successful implementation



Vladimir Putin



of this project will be a symbol of the dynamic, progressive development of Russian-Turkish

interaction and partnership, Russian-Turkish friendship". The \$25 billion project is expected to provide about one tenth of Turkey's electricity and reduce reliance on imports. The first unit is due on line in 2023 on the 100th anniversary of

founding the Republic of Turkey.

Site works at Akkuyu have been underway since about 2014. Russia's Novovoronezh II is the reference design, with its first unit grid-connected 18 months ago. The project company, JSC Akkuyu Nuklear, is a subsidiary of Rosatom, and this is its first foreign nuclear plant on a build-own-operate (BOO) basis. Turkey's state power company

will buy 70% of the power from the first unit at US\$123.50 per MWh for 15 years. A consortium of three Turkish companies which were set to take a 49% share in the project pulled out early this year. Rosatom says that 35-40% of construction work will be localised.

—Researched and written by
World Nuclear News

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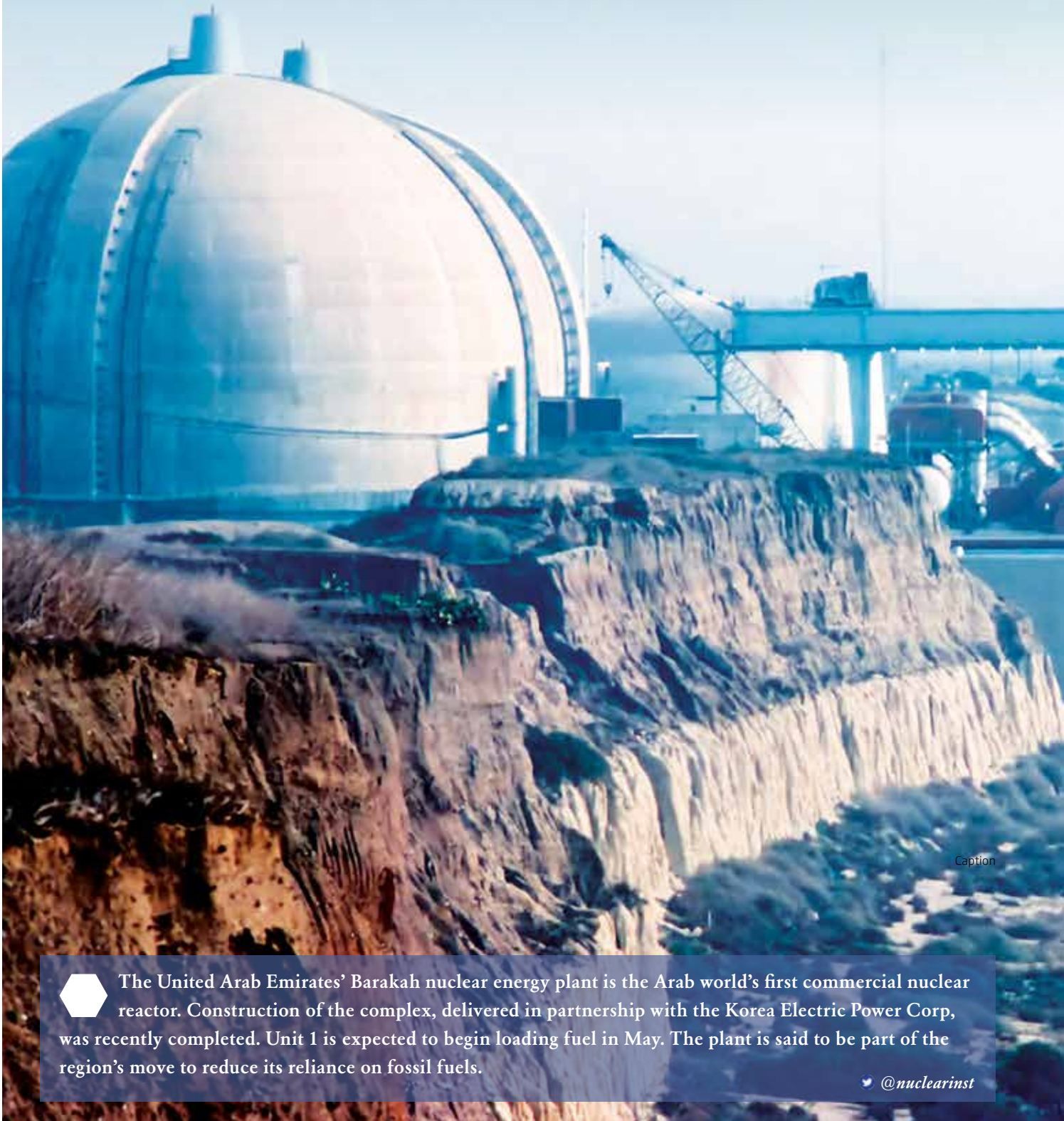
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UAE'S BARAKAH NUCLEAR ENERGY PLANT COMPLETE



Caption



The United Arab Emirates' Barakah nuclear energy plant is the Arab world's first commercial nuclear reactor. Construction of the complex, delivered in partnership with the Korea Electric Power Corp, was recently completed. Unit 1 is expected to begin loading fuel in May. The plant is said to be part of the region's move to reduce its reliance on fossil fuels.

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Weld issues at Flamanville EPR

Doubts over unit's start-up

news@nuclearinst.com

Quality deviations have been detected on certain welds of the main secondary system in the EPR reactor under construction at Flamanville, northern France, EDF has announced. The utility has informed the French regulator of the discovery, but at the time of writing was yet to determine whether the unit's start-up, expected at the end of this year, will be delayed.

Following the detection of deviations, EDF decided to carry out additional checks on the 150 welds in question in order to identify exactly which ones are subject to quality deviations. It has also ordered



a report into the causes and nature of the deviations, in order to define the necessary corrective actions and methods to be proposed to the French nuclear safety regulator, the Autorité

Flamanville EPR

[IMAGE: Alexis Morin and Antoine-Soubigou/EDF]

de Sûreté Nucléaire (ASN), so as to meet safety requirements. EDF said it expects to complete the checks and the report by the end of May.

EDF said it today notified the ASN of "a significant event relating to the detection of deviations in the performance checks of the welds".

"Following the current checks and the licensing process by ASN, EDF will be able to specify whether the project requires an adjustment to its timetable and its costs," EDF said.

EDF's roadmap for the Flamanville 3 project, drawn up in September 2015, sees fuel loading and start-up of the reactor at the end of the fourth quarter of 2018.

—A longer version of this piece, researched and written by World Nuclear News, first appeared on WNN

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Rooppur 1 hits build milestone

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Russia's Rosatom has completed concreting the foundation of unit 1 of the Rooppur nuclear power plant in Bangladesh. ASE Group, a subsidiary of the Russian state nuclear corporation, said the project to build the Asian country's first nuclear power unit was on schedule.

Shawkat Akbar, project director for the Bangladeshi side, said similar work would start soon on the second unit. He added that, in accordance with a tripartite memorandum on cooperation in the implementation of the project to build Rooppur NPP, 50 young specialists from Bangladesh will be sent to India for training.

The memorandum was signed on 1 March in Moscow

by Rosatom's deputy director general for international relations, Nikolay Spassky, Bangladesh's ambassador in Russia, S M Saiful Hoque, and the ambassador of India in Russia, Pankaj Saran.

Construction of Rooppur 1 officially began in November last year.

Two 1200 MWe VVER units are to be built at Rooppur, which is on the eastern bank of the River Ganges, 160 km from Dhaka. The VVER-1200 reactor design has already been implemented at Novovoronezh II in Russia, where the first unit of that design – an evolutionary development from the VVER-1000 – entered commercial operation in February.

Rosatom in February 2011 signed an agreement for two 1000 MWe-class reactors to be

built at Rooppur for the Bangladesh Atomic Energy Commission. The initial contract for the project, worth US\$12.65 billion, was signed in December 2015. The Bangladesh Atomic Regulatory Authority issued the first site licence for the Rooppur plant in June 2016, allowing preliminary site works, including geological surveys, to begin. The regulator issued a design and construction licence to the BAEC last month, enabling the plant to move to the construction phase.

A ceremony was held on 30 November to mark the pouring of the first concrete for the basement of Rooppur unit 1. First concrete is seen as the start of the main construction phase of a nuclear reactor.

*—Researched and written
by World Nuclear News*

NEW EM-1 confirmed

news@nuclearinst.com

After a year of being led by two different “acting” directors, the US Senate confirmed Anne Marie White as the assistant secretary of energy for environmental management, also known as EM-1.

White earned a B.S. in Mathematics at the University of Kansas in 1991 and an M.S. in Nuclear Engineering with an emphasis in Health Physics at the University of Missouri-Columbia in 1992.



Anne Marie White

According to the White House, White has more than 25 years of experience in the nuclear field, working primarily on projects with

complex technical, regulatory, and stakeholder issues. She has worked at a number of contaminated DOE sites, and since June 2017 has been decommissioning lead at Atkins Global in Oak Ridge, Tennessee.

White has worked on planning and preparation of a cost estimate for the decontamination and decommissioning of the California Public Utilities Commission reactor at Diablo Canyon.

INDIA AND USA COLLABORATE ON NEUTRINO SCIENCE

India and the USA have signed an agreement enabling their scientists to collaborate on the development and construction of different types of neutrino detectors. It opens the way to jointly advancing cutting-edge neutrino science projects under way in both countries: the Long-Baseline Neutrino Facility with the international Deep Underground Neutrino Experiment hosted at the US Department of Energy's Fermilab, and the India-based Neutrino Observatory. LBNF/DUNE brings together scientists from around the world to discover the role that subatomic particles known as neutrinos play in the universe.

—World Nuclear News

Contract provides continuing support for storage, transportation, possible reprocessing and ultimate geological disposal of used nuclear fuel and high-level radioactive wastes

NRC renews contract for waste support centre

news@nuclearinst.com

The US Nuclear Regulatory Commission (NRC) has renewed its contract with Southwest Research Institute (SwRI) to operate the Center for Nuclear Waste Regulatory Analyses (CNWRA). The five-year contract is valued at up to US\$52 million.

The contract – which includes a one-year base period and four one-year option periods – provides continuing technical assistance and research support to NRC activities related to storage, transportation, possible reprocessing and ultimate geological disposal of used nuclear fuel and high-level radioactive wastes.

The CNWRA is a federally-funded research and development centre that was established in 1987 by the NRC. The initial purpose of the CNWRA was to support licensing and regulatory oversight of the potential high-level radioactive waste repository at Yucca Mountain, Nevada. Over the past 30 years, the scope of the CNWRA support has grown to provide technical and programmatic assistance to the NRC staff and their agency's mission to protect public health and safety, and the environment.

SwRI President and CEO Adam Hamilton said: “SwRI is proud that our CNWRA operations support the NRC in its mission to protect public health and safety. Our staff members have expertise spanning the environmental, geological and materials sciences, as well as the engineering disciplines needed to evaluate safety and environmental compliance of nuclear facilities.”

The US Nuclear Waste Policy Act of 1982 established federal responsibility for all civil used nuclear fuel and obliged the government to begin removing used fuel from nuclear



The underground Exploratory Studies Facility at Yucca Mountain in Nevada built by the US Department of Energy to determine if the location was suitable as a deep geological nuclear waste repository

facilities by 1998 for disposal in a federal facility. Yucca Mountain, in Nevada, was in 1987 designated as the sole site for the repository.

The Department of Energy submitted a construction licence application for the Yucca Mountain repository to the NRC in 2008, but following 2009's presidential elections the Obama administration subsequently decided to abort the project, appointing a high-level Blue Ribbon Commission to come up with alternative strategies. The NRC terminated licensing activities for Yucca Mountain in 2011, but in August 2013 was ordered to resume work on its technical and environmental reviews of the application by the US Court of Appeals.

—A longer version of this piece, researched and written by World Nuclear News, first appeared on WNN



Adam Hamilton

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WEBINAR DOWNLOAD: Changes in the law on nuclear liability

The recent NI webinar with Roger Clayson, previous Head of Legal for the NDA and currently Senior Solicitor at Glaisyers Solicitors LLP, considers the effects of withdrawing from Euratom, providing expert insights around the potential transitional

arrangements, safeguards and cooperation agreements in light of potential changes post-Brexit. Roger also takes a closer look at the impact on insuring nuclear operations and the supply chain in light of changes in the law on nuclear liability. If you'd like to

present a webinar, or have an idea for one, get in touch at webinars@nuclearinst.com

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- ♦ **To submit news and comment pieces, get in touch at Nleditor@centuryonepublishing.uk**

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Interested in helping to write a book about the nuclear industry?

The Institution of Engineering and Technology (IET) is currently updating its publication about the nuclear industry – first produced 10 years ago. The desired outcome is to add more technical content alongside

the current broader overview of how the industry works. The book will include the work of several authors under the oversight of an editor. If you think there is a chapter or two you could contribute then please

get in touch. Previous writing experience is helpful, but not essential. We expect most contributors will be a Chartered Engineer or Scientist or have a similar background.

Please send a cv to ceo@nuclearinst.com

International Energy Agency flags increased emissions

news@nuclearinst.com

The OECD's International Energy Agency (IEA) has reported for 2017 the first real increase in carbon dioxide emissions for four years, a 1.4% increase to reach 32.5 billion tonnes.

It attributed this to "robust global economic growth of 3.7%, lower fossil fuel prices and weaker energy efficiency efforts".

Energy demand worldwide increased by 2.1% in 2017, according to IEA preliminary estimates, compared with 0.9% for several years prior. Fossil fuels met 70% of the growth in demand.

"The growth in energy-related carbon dioxide emissions in 2017 is a strong warning for global efforts to combat climate change and demonstrates that current efforts are insufficient to meet the objectives of the Paris

Agreement," the IEA said. World electricity demand grew by 3.1% to 25,570 TWh last year, significantly higher than the overall increase in energy demand. China and India accounted for 70% of this increase. Nuclear generation accounted for 10% of global power production last year, up 3% relative to 2016.

—Researched and written
by World Nuclear News

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Rising: Asia needs nuclear for clean and reliable electricity

40 of the 56 reactors under construction globally are being built in Asian countries

news@nuclearinst.com

Asia needs nuclear energy to meet its economic, energy and environmental goals, but such plans are still in the development phase in the South East region of the continent, Agneta Rising, director general of World Nuclear Association, has said. Addressing delegates at the Sustainable Energy Technology Asia 2018 conference in Bangkok, Thailand, Rising noted that nuclear power generation is growing rapidly in Asia, having increased by 35% over the last five years.

Asia is a focus of new nuclear build, with 40 of the 56 reactors under construction globally being built in Asian countries. New countries are planning to start using nuclear generation, with construction of



Agneta Rising

Bangladesh's first reactor under way and preparations progressing in countries such as Jordan, Saudi Arabia and Turkey.

South East Asia has become reliant on fossil fuels for electricity supplies, however, with coal-fired generation increasing dramatically, quadrupling since 2000. Electricity demand has risen sharply in the region and is expected to double over the next 20 years.

"Countries in South East Asia can be part of a global clean energy future by committing to use nuclear energy. This will help reduce pollution, improve air quality and deliver better public health," Rising said.

International vendors and supply chain companies are ready to work with businesses in the region to bring

investment and help develop a highly skilled workforce, she said. To enable this, governments need to establish clear energy policies and develop nuclear energy infrastructure, training and education.

"Nuclear energy will provide a clean and reliable 24/7 supply of electricity at a competitive price," Rising said.

London-headquartered World Nuclear Association's mission is to promote a wider understanding of nuclear energy among key international influencers by producing authoritative information, developing common industry positions, and contributing to the energy debate, as well as to pave the way for expanding nuclear business.

—Researched and written
by World Nuclear News

Seventh Japanese reactor restarted

Kyushu Electric Power Company has begun the process of restarting operation of unit 3 at its Genkai nuclear power plant in Japan's Saga prefecture ahead of resuming commercial operations.

The utility said the process of extracting the control rods from the 1180 MWe pressurised water reactor (PWR) has been restarted. Kyushu said it plans to resume electricity

generation at Genkai 3 on 25 March but noted that this date could change "due to turbine adjustment, etc."

"After restarting generating electricity, we will conduct the adjustment operation as output is gradually increased," Kyushu said. "Accordingly, the plant is expected to undergo the integrated performance test and return to commercial operation."

Kyushu submitted applications to Japan's Nuclear Regulation Authority (NRA) in July 2013 to restart Genkai 3 and 4, which

have been offline since December 2010 and December 2011, respectively. In January 2017, the NRA confirmed the two 1180 MWe PWRs meet new regulatory standards.

The Saga prefectural governor gave his approval for the restart of the units, following the prefectural assembly's adoption of a resolution permitting their restart.

—Researched and written
by World Nuclear News

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Belgium maintains nuclear phase-out

New strategy maintains the country's plan to shut down its seven operating nuclear reactors by 2025

news@nuclearinst.com

The Belgian government has approved a new “energy pact” that maintains the previous policy to phase out nuclear energy in the country by 2025. A draft bill on the new federal energy strategy will be submitted to the cabinet by the end of May. The energy pact was agreed last December by Belgium’s four energy ministers, at federal, Brussels, Walloon and Flemish level.

The new strategy maintains the country's plan to shut down its seven operating nuclear reactors by 2025. It also calls for investments in gas and renewables, particularly off-shore wind turbines, to replace the capacity that will be lost through the nuclear phase-out. The Council of Ministers approved the new energy strategy on 30 March. Belgium's seven operating nuclear reactors – four at Doel and three at Tihange – produce about half of the country's electricity.

—Researched and written by World Nuclear News

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“Belgium’s seven nuclear reactors - four at Doel and three at Tihange - produce about half of the country’s electricity”

Pickering supports Ontario’s economy, report says

Power plant accounts for 14% of Ontario’s electricity supply and directly employs over 4,000 Ontarians

news@nuclearinst.com

The Ontario Chamber of Commerce (OCC) says the continued operation of the Pickering nuclear power plant until 2024 would be a benefit to Ontario’s economy, its local communities, its climate change goals and the stability of its energy system. The OCC made its comment in a report released yesterday in partnership with the Canadian Centre for Economic Analysis (CANCEA).

There are three nuclear generating stations within the province’s borders - Bruce, Darlington and Pickering. In 2016, these three stations generated 91.7 TWh of electricity, constituting 61% of the total electricity produced in the province. In January 2016, the province announced that it had endorsed Ontario Power Generation’s (OPG’s) plan to pursue the continued operations of Pickering until 2024. Any plan to extend Pickering’s life would require approval from the Canadian Nuclear Safety Commission (CNSC).

Ten Candu nuclear power units are to be refurbished between 2016 and 2033 - four at Darlington and six at Bruce. In continuing to operate until 2024, the Pickering plant will provide baseload electricity during the refurbishment of the Darlington and Bruce nuclear power units.

Minister of Energy, Glenn Thibeault, provided comment on the OCC and CANCEA analysis: “The OCC and the CANCEA have confirmed the overwhelming benefits to Ontarians from the continued operation of Ontario Power Generation’s Pickering Nuclear



Generating Station. Operating the Pickering station to 2024 would ensure that Ontario families and businesses have an affordable and reliable source of emissions-free power during the Darlington and initial Bruce refurbishments, generate billions of dollars in economic activity and support thousands of jobs per year. This is part of our government’s plan to support care and opportunity, while producing affordable, reliable and clean energy for the people of Ontario.”

The Pickering Station, which is owned and operated by OPG, accounts for 14% of Ontario’s electricity supply and directly employs over 4,000 Ontarians.

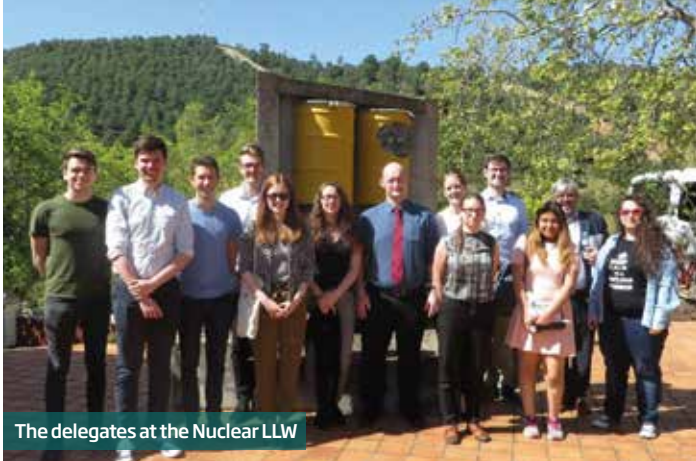
The report *Pickering Continued Operations: An Impact Analysis on Ontario’s Economy* finds that continued operation of the Pickering plant would have a positive economic impact not merely on Durham Region, but on the province as a whole; and not merely to the utilities sector, but to nearly all sectors operating across Ontario.

—Researched and written by World Nuclear News

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LILW handling and storage unit at EL Cabril



The delegates at the Nuclear LLW

What did YGN members from across the UK learn on their Iberian adventure?

Building networks – YGN Spain trip

DAY 1 – Meet up in Cordoba

Introductory drink in Cordoba, where the Nuclear Spanish Tour began. Delegates from different age groups, companies, backgrounds and personal life journeys explored their evening through Cordoba's Game of Thrones/Arabic picturesque narrows and enjoyed the beauties of the southern Spanish architecture overnight over drinks in a plaza.

DAY 2 – Site Visit to El Cabril

The narrow mountain paths of Cordoba's mountain side led to El Cabril, the Low-Level Waste (LLW) Repository run by Empresa Nacional de Residuos Radioactivos (ENRESA), which hosts LLW and Very low level Waste (VLLW). Delegates were amazed by the surrounding beauty of the site, hidden amongst green sunny valleys.

The tour initiated with an informative presentation detailing the organisational structure around how nuclear is handled in Spain, introducing the Spanish regulator, duties, responsibilities.

The presentation also introduced the site itself, with a time-lapse on the activities, legalities and authorities that Spanish regulator the ENRESA has over the LLW/VLLW, along with the methods and processes it uses to handle, store and monitor waste.

The delegates had the chance to enter the control room where the waste is monitored, the Low and Intermediate Level Waste (LILW) packaging unit is housed and visualise the mass and volume of this process.

We then visited the underground monitoring 'bankers' lying beneath the LILW units, after they are assembled and closed off.

Any liquid that might happen to be concentrated into the watertight banker, is captured and analysed for its radioactivity. In the event where there is an overflow, the tube directs the radioactive water right into

another LILW container and if the overflow happens to be clear water, the tubes redirect it onto the water storage facility. Both water mixes are kept to be incorporated onto the filling mortar to seal off the LILW containers and hence obtain sustainability.

The tour then continued onto reportedly one the largest spanning container building for the VLLW, at 150m long. This contains a variety of waste, such as decommissioning/ground debris (white), metal scraps and tools (green), organic matter (clothing, gloves etc), cylinders from decommissioning, hospitals, or research sites. The waste would be then topped up with clay and gravel under a waterproof design and be monitored for about 30 years before the release of the site.

After the tour of El Cabril, the delegates headed towards Madrid, passing through the world famous Extremadura region of Spain where the black pigs for Jamon Iberico de Bellota are bred, with some wonderful green and flowery scenery.

Reaching Madrid, the delegates indulged in the gastronomical magic of Mercado de San Miguel, in the city centre where they had the opportunity to experience the taste of Spain and forge new friendships.

DAY 3 – Site Visit at Jose Cabrera decommissioned NPP

Arriving at Jose Cabrera on the final day of the tour, after a very early start the delegates reflected on a nuclear experience that would never be possible to have on any respective site in the UK (or perhaps somewhere else in the world!).

The delegates were given an exceptionally visual presentation and were given a thorough explanation on how each compartment of Spain's first NPP was decommissioned by ENRESA.

The tour continued with the delegates

suiting and booted, ready to enter the NPP building and visit the reactor and spent fuel locations! The group was astounded by the in depth detailed tour. The presentation of how the reactor pressure vessel was decommissioned continued inside the reactor building itself, on a video projected on the reactor dome, right beneath where the video was taken, giving the delegates an exceptional understanding.

The tour continued onto the adjacent building formerly containing the spent fuel, which has been turned into a 'mini nuclear waste assembling unit'. To their surprise, the delegates experienced a Virtual Reality (VR) presentation of the actual process that took place on those very premises by large VR Codes at various locations along the building.

The visualisation of the process immersed tour members into a different level of detail and gave the tour an exceptional highlight to remember, along with valuable key information on the decommissioning process.

The tour then proceeded around the site and onto the spent fuel storage area, where they had the process explained to them before discussing nuclear waste political concepts.

Tour concludes

As the tour ended, the delegates bonded and enjoyed their overnight in one of the hottest European capitals. For some this was their very first experience of the Spanish culture, land, food, drinks and timeframes. They had the opportunity to learn and observe how cultural habits were implemented onto the common 'to-do' decommissioning practices, for example, working hours end before 3pm, and explore the Spanish grounds.

—Find out more about YGN at www.nuclearinst.com/Communities

COVER STORY: FUTURE OF PROFESSIONALISM

Emerging talent – UK Nuclear Skills Awards perspectives

Insight and advice from winning Nuclear Institute members

THE WINNERS OF THE 10TH UK NUCLEAR SKILLS Awards were recently announced at an event organised by the National Skills Academy Nuclear (NSAN) and Cogent Skills, the UK's strategic body for skills in the science industries.

As well as the prestige of winning, the Nuclear Institute offers a year's free membership to all the shortlisted entries at this and previous years' awards.

The UK Nuclear Skills Awards aims to showcase the exceptional quality of people of all levels, who are committed to careers in the nuclear sector. The dinner also celebrates the vital work done by the training and education professionals working in and with the nuclear industry across the UK.

We caught up with some of last year's winners to get their take on the impact of being recognised at last year's awards, as well as their subsequent NI membership.



Francesca Brandford-Adams

Risk Consultant,
Corporate Risk
Associates Limited
Nuclear Skills
Awards 2017
Runner-up

FRANCESCA BRANDFORD-ADAMS

WHAT WAS THE IMPACT OF BEING SHORTLISTED?

◆ As a result of being shortlisted for an award, I have been designated as CRA's relationship manager for NSAN. Alongside attending NSAN meetings, I now work directly with NSAN's Managing Director, Jo Tipa, to develop a strategy for awareness of diversity which can be applied in organisations in the nuclear industry. In particular, our focus is to promote the benefits that diversity can bring to organisations of differing sizes whether they are licensees or smaller companies and enterprises. The work encompasses all levels, from apprentices, to supply chain and board directors. As part of this work, we have discussed the importance of attracting young minds into the work place such as graduates and interns, recognising that they can bring a diverse mind-set and new and interesting ideas.

HOW HAS YOUR JOB CHANGED SINCE THEN?

◆ Since the awards, I have had the opportunity to visit Heysham 1 Nuclear Power Station as part of a project I'm working on. I have gained a better logistical understanding of their systems and buildings which has a direct and positive effect on the work I do. I have also delivered a tutorial in PSA and fault-based modelling at Imperial College, London to undergraduate Engineering students.

YOUR CAREER HIGHLIGHTS SINCE THE 2017 AWARDS?

◆ A particular highlight of my work at CRA is that as part of a separate project I've worked with a client abroad. I enjoyed this as the experience of working within a different culture is interesting and quite beneficial at this stage of my career.

WHAT VALUE HAVE YOU GAINED FROM YOUR NI MEMBERSHIP?

◆ I have gained particular value in my NI membership. One example is that as part of a research and development project that I manage on cyber security concerns in the nuclear industry, the NI's Special Interest Group (SIG) in security has agreed to work with us at the data gathering stage. This will involve support from the NI security SIG to run a workshop where experts, made up of NI security SIG members, will be invited to contribute to the project.

NEXT STEPS FOR YOUR CAREER?

◆ I intend to continue to grow my knowledge as a consultant and commit to further study to expand my skillset.

ADVICE TO OTHER APPRENTICES IN THE NUCLEAR INDUSTRY?

◆ Work hard, look for opportunities and have fun.

"We have discussed the importance of attracting young minds into the work place"

UK NUCLEAR SKILLS AWARDS

LOUISE LEACH

WHAT WAS THE IMPACT OF BEING SHORTLISTED?

◆ The good news spread quickly around the Jacobs community and I was being recognised by people from all over the business for the nomination. As a direct result, I also established new connections that strengthened my network, including our President of Aerospace, Technology, Environmental and Nuclear, who I can go to for advice and support when I need it. I also received two job offers within Jacobs shortly after the awards which presented me with a very tough decision, but I chose to move into the Quality Department and personally feel this was the right move for me – I've never looked back!

HOW HAS YOUR JOB CHANGED SINCE THEN?

◆ I have now gone from the administration side of the business to training to become a Quality Engineer. Jacobs is also sponsoring me through a CQI Diploma in Quality Management, a degree in Project Management and an NVQ in Project Controls. Juggling three qualifications alongside a full-time job has its challenges as expected, and will require three years of working extra hard and making some sacrifices in my personal life, but the rewards will be far greater at the other side. Jacobs have been incredibly supportive throughout this process, particularly my line manager who has done everything in his power to ensure I am not overwhelmed by the workload.

YOUR CAREER HIGHLIGHTS SINCE THE 2017 AWARDS?

◆ The main highlight for me has been starting my



Louise Leach

Quality Engineer,
Jacobs Shortlisted
at Nuclear Skills
Awards 2017

new role and new qualifications, which have given me a real insight into a different part of the business, which I didn't previously know much about. I have also enjoyed meeting a wide range of new people I wouldn't usually have come across, and the networking opportunities this has provided.

NEXT STEPS FOR YOUR CAREER?

◆ I am currently developing a formal Learning from Experience system, so in the medium-term, I am working towards getting the system ready to launch across Jacobs, and then in the long-term managing its process and developing its capabilities, and hopefully in the future recruiting a small team to help manage it.

WHAT VALUE HAVE YOU GAINED FROM YOUR NI MEMBERSHIP?

◆ Being a member of the NI, you get to hear about a wide range of events that you wouldn't otherwise get to hear about, these can benefit both professional and personal development and the amount of support available within the Nuclear Institute community is amazing. There are also the added benefits of being a member of a widely-recognised and respected professional body.

ADVICE TO OTHER APPRENTICES IN THE NUCLEAR INDUSTRY?

◆ Take every opportunity that comes your way, no matter how scary it seems, and don't be afraid to step out of your comfort zone – it will be well worth it! And remember, the harder you work and the more you network, the more opportunities will come your way.

“The good news spread quickly around Jacobs”



Jason Savage

Sellafield Ltd
Winner Nuclear
Skills Awards 2017
- Business Support
Apprentice of the
Year 2017

JASON SAVAGE

WHAT WAS THE IMPACT OF BEING SHORTLISTED?

◆ It was fantastic to be shortlisted, especially after seeing what all the other apprentices had done, and to win was completely unexpected, but I'm very proud of what I have achieved.

HOW HAS YOUR JOB CHANGED SINCE THEN?

◆ Although I am in the same team, I am given much more responsibility in delivering our strategy. Winning the award motivated me to do more, achieve more and as a result I know I am working to a level far greater than that which is expected of me at this stage in my career – and I don't intend to stop!

NEXT STEPS FOR YOUR CAREER?

◆ I started a HNC in Business Management in September which I plan to progress on into a degree. With that further education I want to move into a team leader/management role supporting individuals and driving the business forward.

YOUR CAREER HIGHLIGHTS SINCE THE 2017 AWARDS?

◆ I've enjoyed all of the networking and the further reach I have had since winning the award but the highlight has to be speaking at the Department for International Trade's Civil Nuclear Showcase, an event attended by over 400 delegates from the UK and overseas – it was nerve-racking but exciting and a fantastic opportunity.

WHAT VALUE HAVE YOU GAINED FROM YOUR NI MEMBERSHIP?

◆ The NI send updates on a regular basis which include the hot topics in the nuclear industry which I have found useful for applying to my work. I have also attended a number of webinars on a variety of topics which have supported my development. It was well worth getting involved.

ADVICE TO OTHER APPRENTICES IN THE NUCLEAR INDUSTRY?

◆ Being an apprentice is the one time you will be able to explore a much wider view of your own business and the industry, take all the opportunities available to you and look for ones yourself. Yes, apprenticeships are about getting qualifications while working, earning a wage, but they are also about developing you into a well-rounded skilled individual for the future of the industry.

"I know I am working to a level far greater than that which is expected of me at this stage in my career"



Calum Murdoch

Chemical Engineer,
DSRL Shortlisted
at Nuclear Skills
Awards 2017

CALUM MURDOCH

WHAT WAS THE IMPACT OF BEING SHORTLISTED?

◆ Since being shortlisted and attending the NSAN awards, I have an increased confidence and pride in the delivery of my work as a chemical engineer for DSRL. Being shortlisted for the award has positively affected my career as since then, I have been promoted from my Graduate Engineering to a Professional Engineering role.

HOW HAS YOUR JOB CHANGED SINCE THEN?

◆ The national recognition of achievement the shortlisting represents has led to increased opportunities in my work where I have been given more responsibility for the delivery of engineering work packages.

NEXT STEPS FOR YOUR CAREER?

◆ I am currently enjoying my role as a Process Engineer for DSRL and my short-term goal is to become a Chartered Engineer. My next career step is to move into a senior engineering role at DSRL where I aim to manage the delivery of packages of work.

YOUR CAREER HIGHLIGHTS SINCE THE 2017 AWARDS?

◆ Since the awards I have continued to remain involved in the nuclear community through managing a workshop at the European Nuclear Young Generation Forum (ENYGF) which was held in Manchester last year. This week-long conference was an excellent opportunity to see the impressive work throughout the nuclear industry, as well as network with other young professionals.

WHAT VALUE HAVE YOU GAINED FROM YOUR NI MEMBERSHIP?

◆ Through my membership of the NI I was able to reduce the cost of attending this ENYGF conference which factored into the business case that was presented to attend the conference. I have also begun liaising with my branch in order to help make activities such as webinars to be available for other young professionals.

ADVICE TO OTHER APPRENTICES IN THE NUCLEAR INDUSTRY?

◆ Embrace the unique opportunities that the nuclear industry offers and get involved. The nuclear industry promotes knowledge sharing which provides excellent opportunities for apprentices and graduates to attend events such as NI courses and conferences which increases your knowledge network vastly.

"My next career step is to move into a senior role at DSRL"

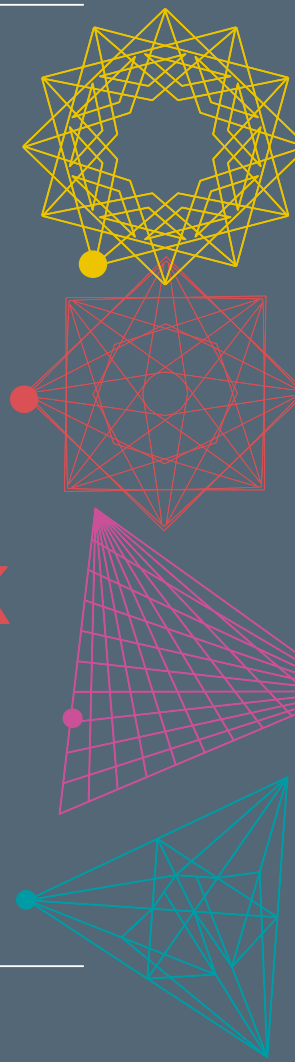
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FACT CHECK

How to myth bust on nuclear energy

Young Generation Network (YGN) *Nuclear Future* Co-ordinator **Reuben Holmes** gives his perspective on how to change perceptions on public opinion around nuclear

Have you ever been asked a question about nuclear or had a nuclear-related discussion and wondered about the other person, “Why on earth would you think that?” Since the birth of the nuclear industry, numerous unfounded claims and incorrect statements have been made about the sector, which have led to common misconceptions among civil society. We plan to regularly highlight the common myths around nuclear and provide some supporting information that can be used in every-day conversations. In this article, we tackle the received wisdom on public opinion.

MYTH: “THE UK PUBLIC DOES NOT SUPPORT THE USE OF NUCLEAR ENERGY”

Public opinion of nuclear energy in the UK has changed over time. When the nuclear sector started out in the 1950s, public support was generally high. There was the promise of electricity being “too cheap to meter,” coupled with a post-war feeling that defence of the nation should be a priority. However, as issues around environmental discharges, nuclear waste storage and The Cold War became prominent through the 1970s and 1980s, public opinion plummeted to unprecedented lows. The UK has since experienced a steady increase in public support, and over the past decade or so has been relatively stable, with ~40% support vs ~20% opposition for the building of new nuclear reactors in the UK [1] [2]. The UK public also strongly supports the use of nuclear energy as part of a low carbon energy mix, recognising the role nuclear energy can play in our fight against climate change (figure 1, [3]).



Reuben Holmes

“Public opinion of nuclear energy in the UK has changed over time. In the 1950s, public support was high. There was the promise of electricity being “too cheap to meter...” ”

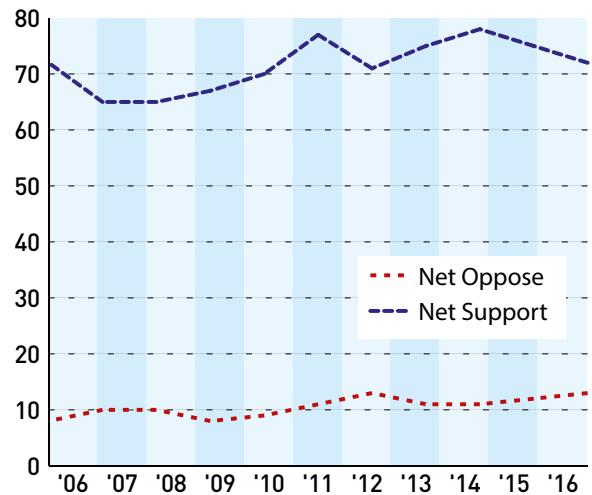


Figure 1: Results from the NIA’s opinion polling conducted in 2016 [3]

The NIA’s research demonstrates that while UK public opinion of nuclear has changed over time and there was a time when the majority of the UK public opposed nuclear, the majority of UK citizens support the continued use of nuclear power. ●

✉ news@nuclearinst.com
 @nuclearinst

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- [2] Public say, nuclear must play a role in reducing emissions, [online], Available: <https://www.niauk.org/media-centre/press-releases/public-say-nuclear-must-play-a-role-in-reducing-emissions/>, Nuclear Industry Association, 03 December 2015
- [3] Nuclear Energy Facts, [online], Available: https://www.niauk.org/nia_facts_170809web/, Nuclear Industry Association, 09 August 2017

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WIN CUMBRIA COMMITTEE: [FROM LEFT]
 Sheena Taylor, Ruth Hutchison, Angie Dean,
 Cathie Hunter, Miranda Kirschell, Claire Gallery-
 Strong (Chair of Cumbria WiN), Donna Connor,
 Karen Dickens, Tracey Hutchison and Nikolaos
 Adamidis. (*Caitlin Johnson, not pictured*)



Creating 'sticky commitments'



Speaker, Ruth Hutchison

Sticky commitments to equality

Regional Chair for WiN Cumbria **Claire Gallery-Strong** reports on inspiration and action at the recent WiN Cumbria launch event

news@nuclearinst.com

Nuclear is one of the major industries for Cumbria, with Sellafield, the National Nuclear Laboratory (NNL), as well as the Low Level Waste Repository all based in our region, along with as potential plans for new nuclear build. Cumbria has its own regional issues and it is one of the worst performing regions in the UK for pay gap at 22%, according the Office of National Statistics, October 2017. Our industry echoes the national picture with a top-heavy gender imbalance in senior roles.

On 8 March, International Women's Day, we came together at the National College for Nuclear to take action by launching our own Women in Nuclear (WiN) local network in Cumbria.

APPETITE FOR CHANGE

There was clearly a huge appetite for the event and our agenda. With a week to go, the launch was a sell-out and the requests for spaces kept coming in from a diverse range of companies and people, and not just the usual "familiar faces". From CEOs and industry executives, to apprentices, more than 45 companies were represented at the event, with male and female delegates giving voice to addressing the diversity issues.

Many of those executives attending shared the sentiment echoed by NNL CEO Paul Howarth, who posted on LinkedIn at the event, "I'm delighted to be at the Women in Nuclear UK Cumbria Regional

team launch today...At present, only 22% of employees in the sector are female. As the industry grows, it's essential this changes. Diverse businesses are more successful businesses and, in our line of work, diversity means better innovation. This is something I'm personally committed to and something that NNL is also committed to as signatories of the WiN UK industry charter as well as enabling our people to get involved with WiN and their activities."

INSPIRATION INTO ACTION

We set out to inspire and did so from the outset, starting with an early morning BBC Cumbria live interview with our keynote speaker Dorothy Gradden OBE, one of my own inspirational leaders.

Dorothy has an established career as a successful nuclear leader, decommissioning one of the most complex hazardous nuclear facilities in the UK.

She shared her personal story, including being the only female on her all-male engineering degree course and how she looked to her own inspirational role models to drive her career.

Setting us up for our workshops was our speaker Alison McDermott, an expert in the field of diversity. She set out an action plan for inclusivity which energised us all as we broke off for workshops to explore what we needed to do in our own region.

Alison shared some feedback from one male delegate: "It's the

first time I have ever felt included rather than targeted as the potential cause of the problem."

After lunch came the rollercoaster ride that was our other guest speaker, entrepreneurial role model Sarah Purdham. You could have heard a pin drop as she shared her experiences from selling hamsters as a child, to her first failed venture to where she is today, Cumbrian business person of the year and MD of the fastest-growing SME in Cumbria, Prima Uno, a specialist project and controls consultancy.

ACHIEVABLE GOALS

Together, delegates generated more than 200 "Sticky commitments". These are our calls to action for the event, setting out what we could do to make a change. Rooms, people, skills, capability and funds were just some of the positive contributions that people pledged on the day. Angie Dean, our launch lead said: "I have just been blown away by the output from

the Sticky commitments! What a range and variety of things to think about now."

Our committee stood up to set out our programme for the year. Feedback after the event came from WiN executive Gareth Thomas who said, "The programme of activities WiN UK Cumbria Regional Team shared – covering all aspects of WiN's remit (attraction, retention, dialogue and industry guidance) – looks thorough and challenging but ultimately achievable. It will make a real difference to the gender diversity agenda in Cumbria and beyond."

BE PART OF THE MOVEMENT

But it doesn't end there. Our local MPs Sue Hayman and Trudy Harrison joined our call for action and have pledged their support to address this at a strategic level for the region. It's not just those who were there on the day who can take action, it needs all of us to engage and address the issues. There are so many ways to get involved. Check out the WiN charter signatory logos to see if your company has signed up to the WiN charter. If it hasn't, ask why not?

We can help too. We have materials, tools and ambassadors who are ready and willing to work with you to get your local company involved in addressing diversity issues.

Follow us on twitter @WiNuclear. Come to one of our events, offer to be one of our inspirational role models or act as a mentor. Contact us at WINCumbria@nuclearinst.com.

"Check out the WiN charter signatory logos to see if your company has signed up to the WiN charter. If it hasn't, ask why not?"

NNL'S SCITEC CONFERENCE

Why promoting innovation through collaboration matters

In light of National Nuclear Laboratory's (NNL's) recent SciTec conference, we look at the big technology themes on the agenda and why open-mindedness could be key to solving the sector's greatest challenges

NNL's SciTec conference welcomed some of the leading players in the global nuclear industry to the ACC in Liverpool under the concept "Innovation through collaboration".

This theme reflects NNL's belief that the future of the UK nuclear industry can be secured through better collaboration, and a willingness to embrace disruption and innovation. The organisation believes it is imperative the nuclear sector challenges the status quo and finds new ways of reducing costs.

To achieve the vision for a better future, NNL and others also believe a collective effort is required. This endeavour begins with nuclear specialists reaching a consensus on the need for fresh thinking, with a continued push for new approaches and a commitment to things like rethinking supply chains and exploring what can be achieved by working with other industries not traditionally associated with the nuclear sector.

There is huge potential for the sector to work with complementary industries such as oil and gas, aerospace and pharmaceuticals, as well as encouraging innovative SMEs and digital start-ups to work with the nuclear industry.

BROADENING THE SUPPLY CHAIN

For example, can some of the persistent challenges facing nuclear be tackled by reconsidering the industry's supply chain, and including smaller companies?

NNL says it can: "We want to build relationships with a wide range of organisations to harness innovation. The Innovation Zone at SciTec featured a number of our partners presenting their technology solutions and how they could translate to the nuclear sector, including ceramics manufacturer Cryoroc. It has developed a

"To achieve the vision for a better future, NNL and others also believe a collective effort is required"



technique for mixing waste with ceramic paste and cooling it with liquid nitrogen to produce a solid mass. This could have huge implications for nuclear waste storage.

INDUSTRY 4.0

Industry 4.0 is the term used to describe the next industrial revolution and emphasises the push towards greater automation and data exchange. It's expected these developments will be a huge enabler of collaboration, with digital technologies being the key driver. Some of the topics on the agenda at SciTec included how digital technologies deployed elsewhere could be harnessed within nuclear. This includes the use of things like gamification – which



Diversity driving innovation

Zara Hodgson, NNL University Strategy Lead, looks at embracing equality and diversity at this year's SciTec



refers to applying game-playing elements to other environments which can provide benefits such as improved knowledge retention – and blockchain – which originated as the foundation for cryptocurrencies like Bitcoin but today has much broader implications on the structure, storage and security of data – plus other tools that could help to improve processes and efficiency in nuclear.

SOLVING CHALLENGES

How can we connect new technologies to solve nuclear problems? This was one of the other issues in question at SciTec where experiential challenges were designed to promote open-mindedness and the power of the collective over the singular.

This year's conference was designed to reflect the breadth of talent within our industry, in recognition of how diversity can help to drive innovation. Arguably, there's never been a more exciting time to enter the nuclear industry, both in terms of scientific advancements and because of its inclusive and progressive nature as a career choice.

Looking back over my career, I was one of two girls to study physics A Level at my school. Fast forward to 2018 and the classroom looks very different. There's still work to

be done though. When I studied for my degree in Chemical Engineering there was a fairly balanced split between male/female students, but I'm not sure that's typical of all universities. And currently, only 23% of employees in the nuclear sector are female.

That's why it's so important that we go out into our local schools and colleges and engage in STEM outreach activities.

The collaboration projects, which are in their infancy now, will soon become the everyday technologies of the future and it's vital we support the next generation of scientists and engineers. Initiatives such as Women in Nuclear (WiN UK), which aims to promote gender diversity in the nuclear industry, are so important in helping to address some of our most immediate issues in terms of diversity. We're proud to be leading the agenda on this via the Nuclear Skills Strategy Group and are currently producing a report on promoting diversity in the sector.

At the recent Nuclear Industry Skills Awards it was also fantastic to see a much healthier mix of talented young men and women – from a broad range of social backgrounds – nominated for awards. It's our responsibility, as professionals already working in the sector, to continue to promote apprenticeships and other entry routes and to engage with young people about the many reasons to work in STEM.

I'm extremely proud that all four of this year's SciTec innovation zones were led by female scientists and engineers. As well as showcasing some of the ground-breaking research being done by NNL and beyond, they are also a fantastic advert for women to choose a career in nuclear.

With 2018 marking the 10th anniversary of NNL, it's also a good time to reflect on some of its achievements over the past decade, which includes innovations that have achieved billions of pounds in savings. It is also a great time to consider the fundamental role nuclear has to play in the UK's energy future. NNL SciTec was a fantastic opportunity for us all to come together to discuss the objectives of the industry and how we can all work together to achieve our goals.



RISK MANAGEMENT

Towards an all-hazards approach to emergency preparedness and response

NEA "milestone" report brings together global lessons learnt and looks to further collaboration on 'all-hazards' approach to emergency management

Emergency preparedness and response (EPR) in the nuclear sector is more than ever being seen as part of a broader framework, according to the Nuclear Energy Agency (NEA).

In order to achieve an all-hazards approach to emergency management, a major step in the process will be to consider experiences from the emergency management of hazards emanating from a variety of sectors.

The NEA has recently joined forces with the OECD and the European Commission's Joint Research Centre (JRC) to collaborate on a new report, *Towards an All-Hazards Approach to Emergency Preparedness and Response: Mitigation Safety Preparedness Guidance Response Emergency Recovery Lessons Learnt from Non-Nuclear Events*. The NEA says the report represents a major milestone towards building an all-hazards approach, as well as towards the strategic goal of working more closely with the OECD family and other international organisations.

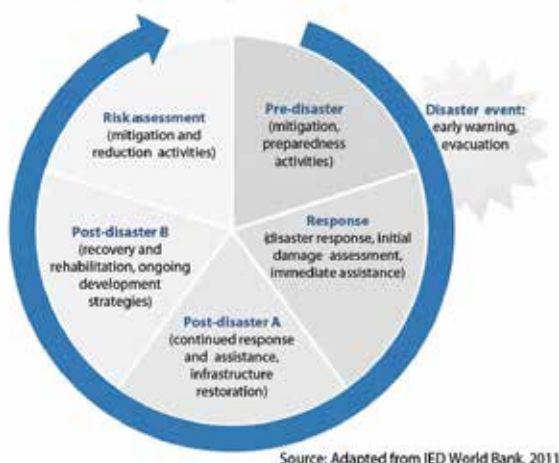
Experts from outside of nuclear and radiological fields participated, analysing databases and drawing

"The report represents a major milestone towards building an all-hazards approach"

from published works in an effort to assist the nuclear and radiological response community.

The NEA's intention is to demonstrate a similarity in emergency planning and preparedness across sectors and identify lessons learnt and good practices. These lessons, originating from the multidisciplinary perspectives of fields outside of the nuclear sector, can then be used to enhance

The risk management cycle

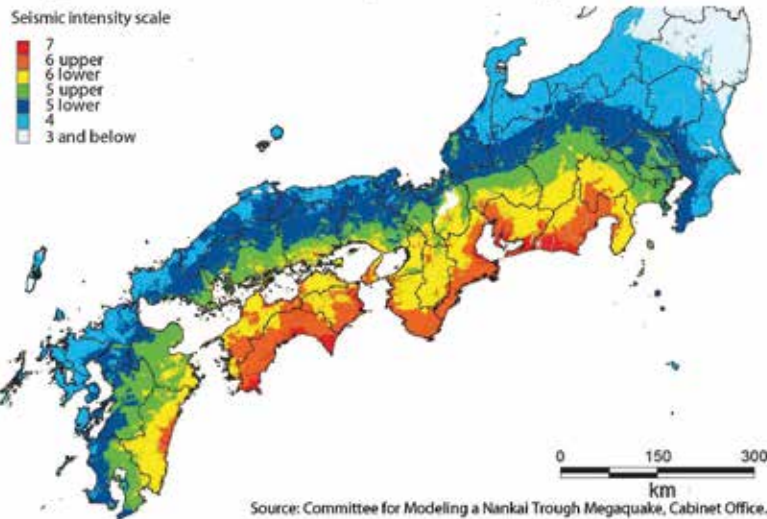


Source: Adapted from IED World Bank, 2011

[LEFT] In evaluating risk exposure, countries should consider evolving risk patterns, including demographic, economic, technological and environmental drivers



Map of maximum seismic intensity distribution in Japan



already existing, robust nuclear emergency preparedness and response systems. It's expected countries implementing the OECD Council Recommendation on the Governance of Critical Risk may also benefit from such lessons.

The overall aim is to join forces across sectors and agencies around the world in order to continue improving already robust nuclear emergency management systems and contribute to building an all-hazards approach in OECD and NEA member countries.

Over the years, member countries from the OECD Nuclear Energy Agency (NEA) have developed effective EPR arrangements for nuclear facilities and off-site response organisations. These arrangements have usually been tested through exercises involving the facility and off-site response organisations.

The NEA says EPR arrangements have been enhanced as necessary to include lessons learnt from nuclear emergency exercises, nuclear power plant accidents and changes to international guidance. While nuclear power plant accidents are very rare, industrial non-nuclear events and natural disasters occur more frequently and can have a potentially large impact on populations and on widespread geographical areas. As a result of these events, populations may be required to take part in protective actions such as sheltering, evacuation and the restriction of food supplies. Research on these types of non-nuclear events and natural disasters has been extensive and has led to an understanding of factors that have supported the effectiveness of response activities, as well as those factors that may have degraded the response. This type of information can be used to enhance existing preparedness efforts for nuclear power plants, for other industrial facilities and for

"Research on these types of non-nuclear events and natural disasters has been extensive"

[LEFT] Japan is prone to virtually every type of natural disaster, located on the Circum-Pacific Mobile Belt where seismic and volcanic activities occur constantly. Also, because of geographical, topographical and meteorological conditions, the country is subject to other forms of natural disaster – such as typhoons, wind and rainstorm and heavy snowfalls, sediment disasters and tsunami

natural disasters in an "all-hazards" framework.

The report concludes that while there are unique aspects to radiological/nuclear EPR, most of the aspects of planning are very similar to planning in an all-hazards framework. For example, protective actions need to be taken for NPP accidents as well as chemical accidents and natural disasters. These can be the same types of protective actions (i.e. evacuation).

Review of evacuations in many non-nuclear events can reveal lessons learnt that can enhance the effectiveness of similar protective actions around NPPs. The need for rapid and accurate information is similar for both nuclear and non-nuclear events. Analysis of communication strategies employed during non-nuclear events enables NPP EPR planners to employ up-to-date communications strategies that can result in more effective messaging to the public or between response organisations. This report shows the similarity in EPR planning across all sectors, and identifies lessons learnt and good practices. Incorporation of these lessons learnt and good practices into the nuclear field builds strong emergency preparedness and response, as well as national resiliency. The IAEA and the OECD recognise the importance of a strong and unified response and urge the inclusion of radiological emergency preparedness to the event possible in greater comprehensive all-hazards emergency planning. The contributions to this report support the value of such an all-hazards approach to EPR. Lessons from a multidisciplinary perspective in fields other than nuclear energy can be used by countries, as appropriate,

The NEA says the next steps in this process will be to organise an international joint workshop bringing together EPR experts from different sectors addressing different types of hazards – either natural or human-made – to share experiences, identify best practices and issue recommendations to further move towards an all-hazards approach to emergency preparedness and response. Involving the public, the media (traditional and social media) and other relevant stakeholders will be an important part of this process.

◆ Download the report at oe.cd/nea-all-hazards-pub-2018 or www.oecd-nea.org/rp/pubs/2018/7308-all-hazards-epr.pdf

PERSONAL JOURNEY

Nuclear career success stories

Nuclear Institute Western Branch and CRA Graduate Consultant **Viktorija Zaksaitė** gives her personal perspective on realising a career in nuclear was the right path for her and how volunteering for the NI helped her on her way

graduated with an MPhys in Physics from the University of Sussex in 2011. I struggled to get a job related to my degree for years. I had filled out countless applications and attended several interviews, but it was not enough. I thought that having a physics degree would open many doors for me, but not having any relevant experience and not knowing which industry sector to prioritise made it hard to get a job.

I spent some time trying to understand what I wanted and what I am interested in. I wish there was an equation where you could plot each X and Y to find the answer on the career path you should take. I did my own research and realised that the nuclear sector was something I had been interested in before but never pursued. By the time I realised this, 3-4 years had passed since my graduation. I found it even harder to get any job and jump through the application hoops to secure an interview. I had no contacts in this field, but with some help from Google I came across the Nuclear Institute (NI). The NI Western Branch was looking for volunteers to join, so I did not hesitate and sent an email straight away. Soon after I received a phone call from Anna Ellis, NIWB Chair, asking me to join the next committee meeting.

I joined the Nuclear Institute Western Branch (NIWB) in 2015 and straight away I got involved in committee activities as Communications Lead. I have attended and helped to organise various NIWB events through the past three years. This enabled me to expand my professional network and to get a feel for the industry and its people.

During a seminar run by South West Nuclear Hub, on the subject of Advanced Boiling Water Reactors (ABWRs) in 2016, I found out about a new master's course in Nuclear Science and Engineering at the University of Bristol. I knew I wanted to get a career in the nuclear sector, and I was finding it challenging to compete for job positions with all the fresh graduates and experienced candidates as my technical experience was limited at the time.



Viktorija Zaksaitė



"I kept in touch with some of the employers I had met through NIWB events"

So, I registered for the MSc program in 2016 and by the spring of 2017 I was selected as one of three students from the UK for a Hitachi-GE summer internship in Japan. This was an unforgettable experience.

When my graduation was approaching I told my fellow NIWB committee members that I was actively looking for a job. All of them were extremely supportive and provided invaluable tips and guidance for applying for roles in the nuclear sector. I also kept in touch with some of the employers I had met through NIWB events and was alerted to vacancies via this part of my network. Via the NIWB committee members and my network, I received introductions to potential employers, including my current employer CRA, and supporting recommendations.

When CRA offered me a job they said: "We like you for who you are, not just your credentials," – so I knew straight away that this is a company I want to work with. I currently work as a Graduate Consultant

“Gaining a master’s degree and experience strengthened my CV. Consulting appealed to me as it involves communicating with clients to help solve challenging problems”

[BELOW] University of Bristol, Department of Engineering



at the CRA and I could not be happier.

Gaining a master’s degree and experience strengthened my CV and enabled me to forge my path. Consulting appealed to me as it involves communicating with clients, helping to solve challenging problems, expanding both my knowledge and that of my organisation, engaging in a variety of topics, and getting involved in research and development.

My world was transformed when I figured out what I want and pursued it proactively.

About NI Western Branch

This branch area is active in one of the key centres of the nuclear industry in the UK and one where activity is growing. In response to this, Western branch is constantly building on its already impressive line-up of activities and events, to respond to the demands of the blossoming community.

It aims to provide members with forums for education and networking, while furthering our charitable objectives, in particular through its work promoting energy in educational establishments and publications.

◆ For more information on how you can get involved, please read Volunteering with NI Western Branch page at nuclearinst.com

The volunteering win-win

Viktorija’s story shows the value of volunteering

Get new skills

Discover something you are really good at and develop new skills.

Volunteering is a great way to gain experience in your field. Some roles provide the chance to gain career enhancing skills such as influencing, negotiating, chairing meetings, project management, and guiding others so you can grow your experience outside the scope of your current job role. Training undertaken as part of your volunteer role can also contribute towards your continuing professional development (CPD).

Meet new people

Volunteering allows you to make new contacts and build your network, particularly if you are just starting work or are new to an area, or even if you just fancy a change. Some will become lasting contacts but all could be informal mentors to help your career.

Networking with peers in your industry will not only expand your knowledge, but can allow you to benchmark yourself and your organisation; bringing new understanding to your work.

You will broaden your support network, be exposed to people with similar interests, and learn and in turn inspire others. Volunteering with the Nuclear Institute also gives you the kudos of being an active member of an internationally recognised professional association.

Make a difference

Volunteering can help you build upon competences you already have and use them to benefit the wider community. For instance, offering to speak at a careers event about your experiences would not only benefit those thinking about their career choices but will also help you in developing and improving your public speaking and communication skills. Mentoring is another key way you can help others.

Give something back to the community

Share your knowledge and experience with others, and ensure that they are exposed to activities and learning to support the sector. Volunteering for the Nuclear Institute is helping to build our community, to preserve and extend knowledge and keep our shared experience alive. Together we can also help to advance public understanding of nuclear energy and related topics. We can also help others in really practical ways through outreach activities.

Volunteering does not need to be time consuming but it is always rewarding.

Feel valued as part of a team

Volunteering is about working with and supporting others as part of a team. This is an invaluable life as well as professional skill.

◆ Go to www.nuclearinst.com/Volunteering-Opportunities for more details

TAKING PART

Could you be a Topic Champion for *Nuclear Future*?

Share expertise and broaden your network by joining our Editorial Committee

***Nuclear Future* provides an expert forum to share the latest insights on the most important topics in nuclear. We're now calling for NI members to join the *Nuclear Future* Editorial Committee which shapes and reviews the technical content of the journal.**

In particular, we're searching for Topic Champions for specific themes, including the nuclear fuel cycle, nuclear law, skills and human resources and radiation safety. Also, if you have an alternative specialist area and would like to bring this to the Editorial Committee, get in touch as we will also be considering other topics for representation.

We're also currently looking for a guest Topic Champion for our 2019 issues where we'll be focusing on radiation safety and protection.

As a Topic Champion or guest Topic Champion, you'll be responsible for:

- ◆ identifying upcoming and important themes within your topic area
- ◆ identifying approximately five other experts in their areas from amongst the Nuclear Institute membership and the wider community to act as peer reviewers for this topic area and introducing these experts to the technical editor
- ◆ taking responsibility for issues focused on your topic area, identifying authors and commissioning articles (typically one issue every 18 months)
- ◆ attending Editorial Committee meetings (four per year) and contributing to the wider editorial strategy of the *Nuclear Future* journal.

Topic Champions are asked to commit to a three-year term on the Editorial Committee. Each Committee member will serve a maximum of two terms.

We are looking for Members or Fellows who have the time and commitment to the development of *Nuclear Future* and to help us maintain the flow of high quality scientific, engineering and technical papers.

If you're ready to get involved, network and help direct the technical content of *Nuclear Future*, the first step is to submit your CV to the Technical Editor at TechnicalEditor@nuclearinst.com with a brief covering message. Your application will then be considered by the Editorial Committee.

We look forward to hearing from you.

CALL FOR TECHNICAL PAPERS

How to submit a paper to *Nuclear Future*

1. Take a look at the upcoming themes for issues or be ready to suggest another technical topic worth exploring in *Nuclear Future*.
2. Submit a 200-300-word abstract with some brief details on your professional background to the Technical Editor at technicaleditor@nuclearinst.com
3. Your proposal will be considered by the Editorial Committee and the Technical Editor.
4. Before drafting, you'll take on board the guidance for authors from the Technical Editor and Creative Editor. Bear in mind, your article should be informative, rather than promotional, and your piece may be edited for style and length ahead of publication.
5. Post-editing you'll review and approve your article on-page and ahead of publication.
6. Your paper will be published in the journal and may also be posted on the website, making it easy for you to share on LinkedIn, Twitter and other forums.

UPCOMING ISSUES & DEADLINES

14.6 NOV/DEC 2018

- ◆ **Workforce education and training.** (SQEP compliance, managing supply chain competencies, skills gap, transfer of skills, diverse and inclusive workforce). Submit abstracts by 4 June, submit full papers by 16 July.

15.1 JAN/FEB 2019

- ◆ **Advanced manufacturing.** (Development of advanced manufacturing processes, advanced tooling and fixturing design, additive manufacturing, virtual reality to aid design and review). Submit abstracts by 2 Aug, submit full papers 20 Sept, 2018.

15.2 MAR/APR 2019

- ◆ **Fuel cycle.** (Fuel manufacture, enrichment, fuel management, radioactive waste). Submit abstract 19 Sept, submit full papers 7 Nov, 2018.

15.3 MAY/JUN 2019

- ◆ **Nuclear reactors.** (New build, plant life extension, small modular reactors, next generation reactor design, and reactor operations) Submit abstracts by 21 Nov, 2018, submit full papers by 22 Jan, 2019.

15.4 JUL/AUG 2019

- ◆ **Licensing and regulation.** ('Safety, security and safe-guards', regulating for safety, environmental monitoring, EU directives, international standard and guidance, public consultation) Submit abstracts by 23 Jan, submit full papers by 13 Mar 2019.

15.5 SEP/OCT 2019

- ◆ **Radiation safety and protection.** ('Safety, security and safeguards', accident prevention and emergency planning, nuclear medicine, isotope production) Submit abstracts by 27 Mar, submit full papers by 21 May, 2019.

connect with confidence

F4N
Fit For Nuclear

F4N Connect is your new gateway to UK suppliers you can trust to meet your specific needs for nuclear manufacturing.



F4N Connect is an interactive showcase for companies which have demonstrated their ability to meet nuclear industry requirements through the Fit For Nuclear (F4N) programme.

Delivered by the Nuclear Advanced Manufacturing Research Centre, F4N is the UK's independent benchmark for nuclear-ready manufacturers.

The fully searchable database lets you identify companies you can trust to solve your manufacturing needs – from suppliers of nuclear-grade steels and forgings, to precision machinists, fabricators and specialist service providers.



connect.f4n.namrc.co.uk



NUCLEAR AMRC
namrc.co.uk

CATAPULT
High Value Manufacturing



The
University
Of
Sheffield.

Supported by the
 Regional Growth Fund

RESEARCH & DEVELOPMENT

Will artificial intelligence drive forward the nuclear sector?

Mark Greatrix, Associate Director and Head of Research and Development at Waldeck Consulting, discusses the opportunities that developing technological advances such as artificial intelligence offer the nuclear industry

Artificial intelligence (AI) has been widely recognised as one of the most influential and disruptive technology-based game-changers of our time, with its ability to create simulated intelligence in machines that have the capability to teach themselves.

These “machines” have been programmed to mimic human action and rational thought, which is transforming the way we go about our everyday life and even how we do business across the globe.

As Andrew Ng, former chief scientist at Chinese multinational technology company, Baidu, observed: “I have a hard time thinking of an industry we cannot transform with AI.”

Year on year we’re also witnessing the evolution and integration of digital technology into domestic and industrial life through the Internet of Things (IoT) – which refers to everyday objects, enabled by the internet to send and receive data. IoT has and continues to disrupt all aspects of life. This includes on a domestic level, with more homes featuring internet-enabled objects, through to the industrial level where machine learning and AI advancements see operational assets now communicating their servicing requirements, transmitting operational data for efficiency-based analysis and, in some cases, automatically navigating their environment.

READYED FOR DISRUPTION

AI has been more defined as a form of non-human intelligence which is then measured on its ability to replicate human mental skills. These skills comprise of understanding natural language, pattern recognition, strategising, case-based and rule-based reasoning, as well as being able to adaptively learn from its own experiences.

As technology progresses, we’re starting to see a number of sectors ready for the disruption and transformation to create more efficiency, certainty, reduced cost, improved quality and time in getting assets into operational performance. We believe the nuclear sector represents a



Mark Greatrix

stand-out opportunity for a positive disruption.

Within our nuclear sector projects and wider construction industry projects alike, we are already seeing the influence that AI and digital technology can have at the very coal face of project delivery.

Working in these sectors, Waldeck now leverages machine learning and AI to automate rule-based design and coordination routines, support object and defect recognition as well as pre-planning and automating the flights for our

Unmanned Aerial Vehicles (UAV) as they undertake detailed surveying and surveillance tasks.

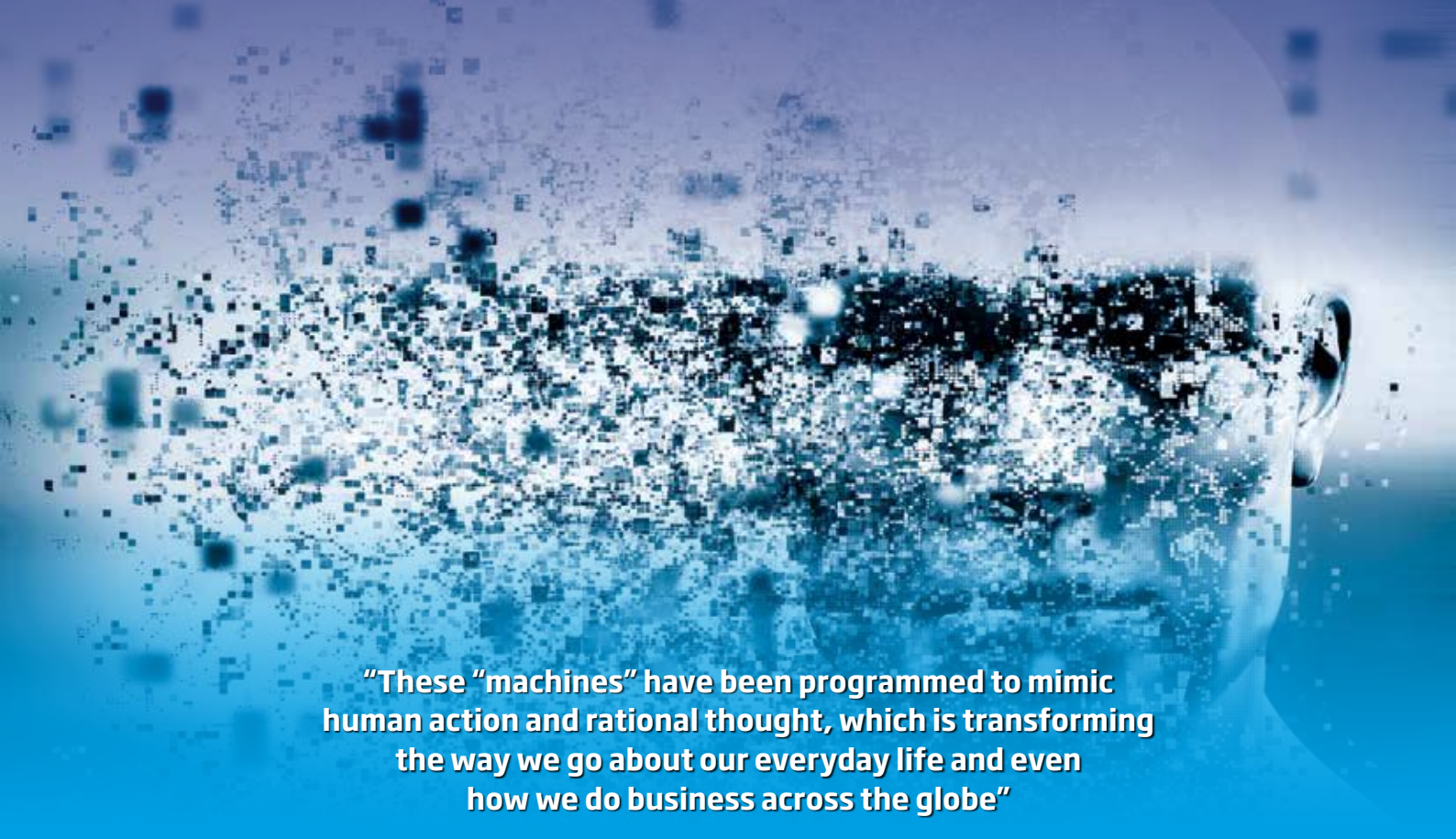
We now see incorporating cutting-edge AI technologies as key to supporting the competitiveness of many professions and sectors facing a paradigm shift in AI-supported means of working including nuclear, defence and security.

LEVERAGING UAV BENEFITS

Regularly deploying UAVs Waldeck has leveraged key project benefits, supporting accuracy, efficiency and health and safety improvements. The increased autonomy of UAVs and ground-based technologies has provided a step change and has been hugely influential in their utilisation on an industrial scale, and as such are certain to be key enablers to future nuclear and defence sector-based progressions.

Reducing or, better still, eliminating human presence in high risk nuclear environments and any area of conflict will be the driver for future unmanned systems deployed within these sectors. These devices will rely heavily on machine learning and AI to strengthen their current operational limitations.

The range of AI solutions which can potentially benefit the nuclear and defence sectors are vast, however neural networks which are inspired by the way the biological nervous system such as the brain processes information stand out as providing huge potential. Neural networks have the ability to extract meaning from imprecise and



"These "machines" have been programmed to mimic human action and rational thought, which is transforming the way we go about our everyday life and even how we do business across the globe"

complex data sources, detecting patterns and trends which go undetected by other computer-based solutions and humans alike, enabling them to simulate projections and determine what if scenarios providing a step change in how AI can be leveraged to support the future of these sectors.

CYBERSECURITY CHALLENGE

The IoT has inevitably presented itself as somewhat of a double-edged sword which has enabled huge innovation-based progression, whilst also presenting cybersecurity-based minefields for all those that adopt and integrate IoT technologies, by its very nature allowing more potential for cyber and digital data-based attacks.

With cybersecurity posing huge implications for nuclear and defence projects, the nuclear energy industry has had a cybersecurity program running since 2002, protecting digital assets and the sensitive information they contain.

Currently, and more importantly moving forward to support IoT adoption, machine learning and AI will be leveraged to supplement the nuclear and defence sectors' security in both the physical and cyber-based environments whereby this technology will be a key enabler and intuitive analysis tool.

As a business working on nuclear projects, we see first-hand the importance of handling and securing digital data, and with the current boom of digital data and the physical world's predicted progression curve for data production, its associated storage and transmission requirements, the defence sector will leverage AI technology in its native environment – cyberspace to tackle the increasingly sophisticated cyber-attacks which are becoming

commonplace in the modern era, facing the ongoing threats of keeping data secure.

UNTAPPED POTENTIAL

Both private and public organisations are certain to be impacted dramatically with revolutionary changes certain to take place over the coming years.

AI will be more and more commonly leveraged to automate repetitive tasks, simplify tedious manual processes and streamline stressful and expensive tasks, all of which will improve productivity and efficiency across the professions and indeed walks of life.

For sectors such as nuclear and defence there still remains huge untapped potential whereby AI can be utilised to lessen and mitigate risks humans would have traditionally been exposed to, this by far has to be one of the biggest advantages AI can present for humanity more broadly.

About the author

Mark is a digitally and technology focused professional with a Master of Science (MSc) in Building Information Modelling Management from Middlesex University, having over 20 years' experience working closely with project teams delivering innovative and technology focused solutions for blue chip clients from within specialist multi-disciplinary design organisations in the AEC industry

■ TWITTER: @macaman46
■ LINKEDIN: Mark Greatrix

University of Bolton



Philip Isgar

Digital leaders from nuclear share insights on latest technologies

Following two KTN workshops on *The Role of BIM in the Nuclear Industry* in 2016, the Nuclear Institute set up the Digital Special Interest Group (Digital SIG) to provide a forum for industry-leading debate and to promote and drive cohesive digital development across all aspects of the industry.

The group, comprising digital leaders from across the nuclear industry, held its third workshop in Bristol on 30 January at the offices of Waldeck Consulting. Over 30 members attended and the group discussed a range of issues. Paul Waldeck (CEO and Founder, Waldeck) welcomed the group and went on to describe several areas where Waldeck is engaging with digital technologies, including the use of drones, photogrammetry techniques and retrospective manufacturing.

Philip Isgar then gave an overview of the NI SIG programme and interfaces with the Digital SIG activities, an update on the journey of BIM in nuclear, touching upon how nobody is using the term “BIM” anymore, it’s known more widely as “digital” or “Information Management”. This was followed by industry updates from EDF Energy, NuGen, Horizon, Sellafield, RWM, UKAEA who all gave updates on their projects and the future of technology in their field,

followed by an update on skills from the University of Bolton.

The group then held an open session to discuss several issues, including what the key outputs from the group should be, how to disseminate best practice, the possible use of focus groups, how to work alongside other NI SIGs and how to engage with other communities in this area such as professional institutions, OGDs (other government departments) and other industry groups such as the Construction Industry Council, Construction Excellence and the Knowledge Transfer Network (KTN). There was a big focus on asset management, validation and verification, and the use of “futuristic” tools, such as: machine learning and artificial intelligence.

■ For further information on the Digital SIG go to www.nuclearinst.com/Digital-SIG

About Waldeck Consulting

Waldeck Consulting is a technology-based engineering consultancy who work on nuclear projects including Hinkley Point C.

■ TWITTER: @waldeckconsult
 ■ LINKEDIN: Waldeck
 ■ INSTAGRAM: Waldeckconsulting

Focus



NATIONAL BIG BANG FAIR 2018

Inspiring the future of nuclear

Volunteers and staff from the Nuclear Institute and the Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC) spent four successful days at the National Big Bang Fair in Birmingham in March, inspiring the next generation of nuclear workers

Interactive games to pique young delegates' interest



More than 70,000 students aged between 7 and 19 attended this year's event, with thousands of young people visiting the NI stand each day where they were encouraged to engage with technical and mental challenges and learn more about the exciting prospects of a career in nuclear.

LEARNING THROUGH PLAY

The stand featured a variety of nuclear-themed activities which aimed to represent some of the challenges faced by the industry. Activities included an infra-red camera to identify heat generating "radioactive" waste containers, toy hydraulic arms to remotely pick up and categorise waste blocks, and an obstacle course for robotic vehicles. Students had the opportunity to win prizes by completing the activities or by successfully answering a nuclear related quiz.

This year the stand space was shared with the Nuclear AMRC, who brought along a virtual reality headset, the HTC Vive, to demonstrate how this emerging technology could be used for the benefit of the industry. Nuclear AMRC volunteer Evan Bolle-Jones, said: "We used the HTC Vive to show the capabilities of how the technology can be used in both decommissioning and new build, using a point cloud to demonstrate how robots can go in and determine the orientation and shape of objects which can then be used for decommissioning planning. I talked with all ages from 5 years old to a few retired individuals on topics from new build to decommissioning and final disposal. Attending the Big Bang Fair was really enjoyable and there was great engagement from all

participants." Volunteer Henry Lamb, who also attended the event, added: "The Big Bang Fair was buzzing with activity especially around our VR and AR equipment. We showed kids 8-14 years old and adults alike the power and use of the virtual space. Using VR can be a solitary experience, but displaying what the user was seeing onto a screen allowed their friends to engage. The models that were shown were of the Nuclear AMRC's shop floor and a generic PWR, and both were received very well."

VOLUNTEER ENERGY

Mark Gardiner, NI volunteer and lead organiser for the NI stand, was really pleased with the success of this year's stand: "This was our fifth year at Big Bang, and the best one yet! The stand was designed to be as interactive and as educational as possible, and our newly developed activities proved to be a great success. It was excellent to be able to team up with the Nuclear AMRC, who brought along a really cool VR headset to show the next generation of scientists and engineers the exciting new developments within the industry. A big thanks is in order for all our volunteers, who represented many different areas of the nuclear industry, and worked incredibly hard during the event with never-ending energy and enthusiasm."

ABOUT THE BIG BANG

The Big Bang UK is the largest celebration of science, technology, engineering and maths (STEM) for school children in the UK. The Big Bang is an award-winning programme of national and regional events, consisting of

"Nuclear AMRC brought along a really cool VR headset"



The team of hard-working volunteers were key to a successful event



Highly concentrated - children get deeply involved in learning games



Volunteers on hand to open young minds to nuclear

engaging STEM exhibits, interactive workshops and careers information, which aims to engage young people in STEM subjects through fun hands-on activities, and increase awareness of the multitude of career options available in industry.

Educating young people about nuclear technology and providing information, advice and guidance on careers in the nuclear sector are central to the

“Educating young people about nuclear”

role of the NI and important in meeting our charitable objectives. Supported by our members’ contributions and the extraordinary efforts and enthusiasm of our volunteers, the NI attends The Big Bang Fair annually to inspire the next generation of nuclear scientists, technologists, engineers and mathematicians.

REGULATION

ONR issues guidance on “enabling regulation” in practice

Guidance aims to improve safety and security while holding sector to account

The Office for Nuclear Regulation (ONR) has published guidance on how it can work with dutyholders to improve safety and security activity in the nuclear industry. The document, **Holding to Account and Influencing Improvements – Enabling Regulation in Practice**, features a definition of “enabling regulation”, the principles and behaviours that support it, plus a number of case studies of enabling regulation in practice.

The document does not represent formal policy or guidance, but instead is intended to provide helpful information to support better understanding, discussion and development by demonstrating compliance with the regulatory code and providing practical examples of where an enabling approach has worked well.

The ONR is clear nothing in this approach alters the obligations on industry to comply with the law. As the foreword of the guidance by Chief Nuclear Inspector Mark Foy states: “We will continue to use our enforcement tools appropriately, proportionately and independently. Both industry and government have a vital part to play in creating and sustaining the conditions where an enabling approach can continue to be successful, and we are working with the Safety Directors’ Forum to develop approaches further.”

One potential example provided of this development is opportunities for the industry to take an enabling approach in developing more robust internal regulation, as well as improving the quality of dutyholder submissions to articulate more clearly why a specific activity will be safe and/or secure.



Mark Foy

- ◆ Building on regulatory good practices and successes.
- ◆ Ensuring priorities are established, understood and agreed.
- ◆ Being clear on legal duties and what is needed for compliance.
- ◆ Focusing on outcomes rather than process.
- ◆ Constructive, committed, open and early engagement to avoid surprises and build trust.
- ◆ Ensuring solutions are fit for purpose in meeting the requirements of the law efficiently and effectively.
- ◆ A willingness to address blockers, distractions and unnecessary bureaucracy.

An enabling approach also:

- ◆ Includes consideration of strategic factors in regulatory decision making; sometimes colloquially referred to as “programme or holistic ALARP”. Although ALARP (the legal duty to reduce risks to “as low as reasonably practicable”) usually features strongly in safety cases, the scope of the arguments can prove too narrow, particularly in complex cases, and “bigger picture” factors also need to be considered in the regulatory decision.
- ◆ Recognises the speed at which improvements can be realised is often a key aspect in the risk balance and a pivotal factor in identifying the best safety or security outcome. ONR recognises that there cannot be a “one size fits all” approach to applying an enabling style of regulation to the range of dutyholders and safety and security challenges that are present across the industry. Instead, it needs to ensure it consistently applies the regulatory principles that underpin its activities as set out in its Enforcement Policy Statement.

ONR should be:

- ◆ proportionate in dealing with compliance gaps and securing compliance
- ◆ consistent in its approach
- ◆ targeted on the most serious risks or those least well controlled

DEFINITIONS

The given definition of enabling regulation is: “A constructive approach with dutyholders and other relevant stakeholders to enable effective delivery against clear and prioritised safety and security outcomes.”

The ONR says the features of a successful enabling approach are enshrined in the regulatory principles and can be summarised as:

MARK FOY

Chief Nuclear Inspector on Enabling Regulation

“To be an efficient and effective regulator that is fit for the future, we need to ensure that we identify and learn lessons from our activities and consistently employ practices and behaviours that have been proven to deliver successful safety and security outcomes. I am seeking to build on good regulatory practices, encourage innovation and lead an organisation which regulates in a manner that enables the best safety and security outcomes to be routinely achieved. In so doing I highlight the growing need to improve confidence in compliance through greater transparency and certainty; to better understand and minimise undue negative economic impacts; and to engender increasing recognition that the speed at which improvements can be realised is often a key aspect in the risk balance. Enabling regulation is a term we have been using increasingly over recent years. Put simply, it means that we will take a constructive approach with dutyholders and other relevant stakeholders to enable effective delivery against clear and prioritised safety and security outcomes. We can adopt enabling approaches most readily where the dutyholder is compliant with the law. Enabling is not new for ONR and there are many examples of how an enabling approach has been successful in the past.”

Extract from Holding industry to account and influencing improvements – A guide to enabling regulation in practice. © Office for Nuclear Regulation, 2018

- ◆ transparent about how it operates, its decision-making and what dutyholders may expect
- ◆ accountable for its actions.

IN PRINCIPLE

The principles as set out by ONR are:

- 1.** We focus on clear priorities for safety and nuclear security, and communicate these to our dutyholders and key stakeholders.
 - i. We agree strategic safety and security priorities with dutyholders, at an ONR Division level, taking cognisance of dutyholders’ strategic business context.
 - ii. We regulate in a manner that is aligned with these priorities, and avoid creating undue distractions from achieving them.
 - iii. When improvements are needed, we are clear about what precisely is required for legal compliance, formalising this in a Regulatory Issue.
 - iv. Wherever appropriate, we work with key stakeholders to identify common priorities and remove barriers to improving safety and security outcomes.
 - v. To support continued compliance with the UK Regulators’ Code, we carry out our regulatory activities in a way that supports growth for legally compliant dutyholders.
- 2.** We are constructive in the resolution of agreed safety and nuclear security priorities.
 - i. We work constructively with stakeholders to agreed common priorities where possible.
 - ii. We focus on outcomes rather than processes.
 - iii. Where we have raised a regulatory issue, we agree reasonable timescales for achieving compliance and are proportionate in our subsequent regulation of the Issue.
 - iv. We maintain our independence whilst seeking opportunities for early engagement to maximise the likelihood of achieving our goals.
 - v. We will take into account well understood and managed risks when making decisions in the pursuit of strategic safety and security goals.
- 3.** We aim for efficient, proportionate and consistent approaches to safety and nuclear security – without compromise of intent to achieve the required safety performance.
 - i. We require solutions that are legally compliant while being fit for purpose within their context.
 - ii. We encourage and facilitate the removal of undue bureaucracy and will challenge outdated practices.
- 4.** We maintain public trust by targeted, transparent, risk-informed oversight of safety and nuclear security, and use our legal powers appropriately in the public interest.
 - i. We undertake our inspections and other interventions in a targeted, risk-informed manner.
 - ii. We only require what the law requires and we seek this in a non-prescriptive manner where possible.
 - iii. We publish guidance for inspectors, which set out the assessment and inspection processes and standards



- that we use to judge dutyholders' performance.
- iv. Our presumption is that we publish information describing our activities and explaining our enforcement decisions. We also publish guidance documents such as our Enforcement Policy Statement and our guidance for inspectors, which set out the assessment and inspection processes and standards that we use to judge dutyholders' performance.
 - v. Where appropriate, we will take enforcement action in accordance with our Enforcement Policy Statement through the application of our Enforcement Management Model. An enabling regulatory approach does not prevent or curtail use of our enforcement powers to restore compliance or hold to account.
5. We actively promote the mature self-regulation of day-to-day safety and nuclear security by dutyholders.
- i. We recognise that the industry has an important part to play in maintaining the conditions where enabling regulation can be used effectively. We therefore set

clear expectations for self regulation by dutyholders, including governance, leadership, effective internal oversight, and culture.

- ii. We are clear and open about our expectation of right first-time safety cases and security plans, and effective management of the supply chain.
- iii. We target our discretionary permissioning decisions to where they add value or where the risks are most significant or not well controlled.
- iv. Where we find repeat or significant non-compliance, we expect dutyholders to address the root causes and identify potential failures of their self-regulation, not just the non-compliance itself.

WORK SMART

To apply a consistent enabling approach, both industry and ONR recognise the behavioural attributes that support or possibly detract from effective delivery of safe and secure outcomes. Whilst not exhaustive, the following table illustrates both effective and ineffective enabling behaviours and ways of working, summarised below:

Effective behaviours and ways of working	Ineffective behaviours and ways of working
Establish strategic, long-term, risk-based priorities and ensure these are well founded and properly understood within the wider business context.	Adopt a short-term reactive approach to activities, with little thought to overall priorities or longer-term outcomes.
Engage openly with stakeholders to agree priorities, provide guidance and advice, to establish a 'no surprises' culture.	Adopt a closed approach with stakeholders, sharing little or no information.
Regulate to secure the solution that maximises the safety and/or security benefit.	Take an overly cautious approach to regulation that focuses on the reputational risks to ONR rather than the risks to society and/or workers.
Proactively identify shortfalls in a proposed approach at the earliest opportunity and provide advice.	Passively wait for problems to be encountered.
Work with dutyholders to agree Regulatory Issues and associated Action Plan timetables and be proactive in regulating to achieve timely compliance.	Impose Issues and compliance timescales without seeking to understand dutyholders' perspectives, reasonable constraints and safety or security priorities.
Focus on outcomes.	Focus on tasks/projects without giving due regard for the sought outcome.
Consider risk factors in a wide context as part of our decision making, ensuring strategic factors are considered, as well as ALARP and other legal requirements.	Assess risks on a case-by-case basis without consideration of interactions between faults or placing the risk in the wider context.
Encourage development of fit for purpose solutions which meet legal obligations and represent relevant good practice appropriate to the prevailing circumstances.	Seek unrealistic or disproportionate design standards, over complex designs or push for gold-plated solutions.
Recognise and accept that increases in the short-term risk profile may be necessary in order to reduce long-term risks and hazards.	Take a rigid or short-term approach to risk reduction, seeking to reduce risks without consideration of the overall picture.
Conduct regulatory oversight in a way that provides sufficient control, but avoids unnecessary diversions or distractions.	Give undue attention to details which have no meaningful impact on the outcome.

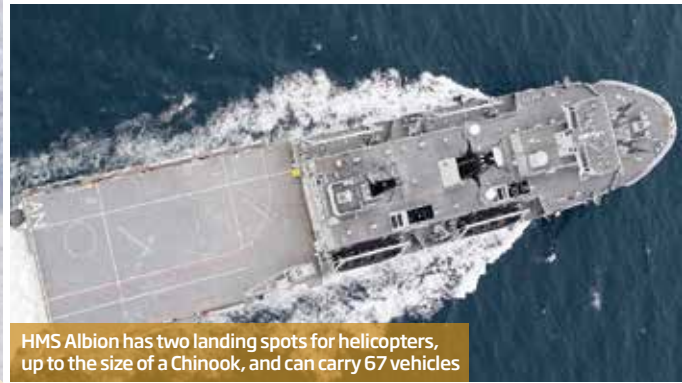
Taken from *Holding industry to account and influencing improvements – A guide to enabling regulation in practice.*
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HMS Albion: A Royal Navy amphibious transport dock



HMNB Devonport



HMS Albion has two landing spots for helicopters, up to the size of a Chinook, and can carry 67 vehicles

Enabling regulation in practice

Undocking of HMS Albion during HMS Vanguard's deep maintenance project at Devonport

What outcome was sought?

Enabling the timely undocking of HMS Albion (amphibious transport dock) to be conducted safely and on time so that the Ministry of Defence could maintain its strategic priorities.

What was the issue preventing this outcome?

During the docking of HMS Vanguard in 9 Dock at Devonport, HMS Albion was docked in the neighbouring 10 Dock facility. Following completion of HMS Albion's maintenance period, it was identified that multiple mobile cranes would be required to support her exit from dry dock. This included a mobile crane positioned on the 10 Dock East which has the potential to interact with the 9 Dock cranes, as well as other nuclear support facilities.

Fault sequences initiated by mobile cranes outside the 9 Dock boundary had not been considered within the plant safety case by the site licence company, Devonport Royal Dockyard Ltd, and were not within the control of 9 dock management.

Delaying the undocking of HMS Albion to update the safety case would mean the reduction of a major naval

asset to support defence requirements.

What was done differently to enable the solution to be reached?

Devonport Royal Dockyard Ltd produced a Category A safety submission to enable the use of mobile cranes on the neighbouring docksides, which allowed 9 Dock management to control the use of mobile cranes in the vicinity of the nuclear hazard.

ONR recognised the strategic importance of undocking of HMS Albion and the timescales this was required within. As such we undertook a proportionate review of the licensee's safety submission and considered existing intelligence of safety operations on the site. Inspectors engaged with the site to consider the licensee's arrangements for controlling the potential hazard to 9 Dock operations. These arrangements included 9 Dock management controlling vehicle access keys for 8 and 10 Docks and a 9 Dock duly authorised person required to sign off all lifting plans in 10 Dock East and 8 Dock West.

We also considered the safety analysis already produced to justify the mobile crane that was to be used to perform the operation, along with previous human factors inspections associated with mobile cranes on the site. The use of existing

regulatory intelligence in this area minimised the assessment required for this permission.

Our targeted interventions enabled us to determine that risks from mobile crane operations in adjacent facilities are suitably low and would be appropriately controlled. This resulted in a timely, balanced and informed regulatory decision, granting permission to allow the use of mobile cranes in the vicinity of 9 Dock and enable the undocking of HMS Albion in a timely manner.

What were the outcomes and benefits?

By modifying our approach and taking previous regulatory intelligence into account, ONR avoided delays to national strategic priorities, and ensured nuclear safety was maintained.

Taken from *Holding industry to account and influencing improvements – A guide to enabling regulation in practice*.

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◆ To read the full guidance including further case studies and all references, get the full report at www.onr.org.uk. What's your take on "enabling regulation"? email us at NIEditor@centurionepublishing.uk to share your views in the next issue of NUCLEAR FUTURE.

@nuclearinst

On Her Majesty's Nuclear Service

—by *Commodore Eric Thompson*

Dr Nigel Buttery reviews a fascinating chronicle of a life in the Royal Navy including duties on nuclear boats deployed to deter and patrol

It seemed appropriate that, for the 'Defence Issue' of *Nuclear Future*, we should include a review of *On Her Majesty's Nuclear Service* by Commodore Eric Thompson. The author has supplied us with a brief summary, which is appended in this issue, since it provides a useful introduction, particularly to one of the key themes: the role of the nuclear deterrent. However, there is much more to the book than this.

What is presented is a personal memoir of a working life spent in the Royal Navy. The first thing that has to be said is that it is very readable. If I was expecting a rather dry "military dispatches" style, I soon realised that this was not the case.

STARTING WITH A BANG

The book starts with a bang or rather, a very loud roar, with the description of the handling of the incident occurring on the *Revenge* mentioned in the summary. Having grabbed our interest he continues with a more or less chronological account of his career, starting with winning a scholarship to Britannia Royal Navy College, Dartmouth and ending as Commodore of *Faslane*, which was close to where he grew up. He joined the submarine service as an engineer and qualified as an Electrical Engineer, but with an abiding interest in acoustics. He served on both diesel and nuclear boats and his career had its high and low points. The latter, he decided, correlated with growing a beard, so remained largely clean shaven.

OFFICIAL SECRETS, HUMAN TALES

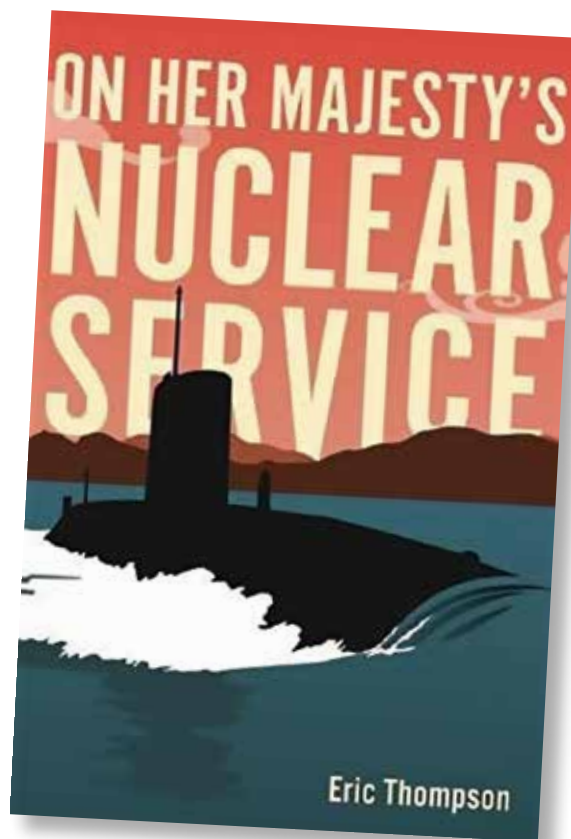
The account has obviously had to steer around the strictures of official secrets,

but there are also many human tales to be told and Eric Thompson comes over very much as a person with a concern for his comrades as well as a respect for others. He also has a penchant for practical jokes, which he reluctantly gave up when promoted to a more senior position. There are also tales of tussles with the bureaucracy, when he felt it was needed.

There is plenty that is familiar to someone on the civil nuclear side, as well as intriguing differences. The commitment to nuclear safety is the same and I was already familiar with the strengths of the PAG (Procedural Authorisation Group) having worked with an ex-submariner who regarded the nuclear operations review system we were running as a somewhat limp affair by comparison. However, the context is somewhat different and the commitment to duty, and to your comrades comes over, as does a respect for fellow submariners. The book also briefly discusses some of the issues behind nuclear deterrence and the public perception of nuclear risk.

FROM DIESEL BOATS TO FASLANE

His involvement in homing torpedo development and acoustics I found particularly interesting, with plenty of bells ringing concerning the joys and frustrations of development and testing. Because the book covers a working life, which spanned service on both diesel and nuclear boats, involving deterrent and a range of other patrols as well as service with HQ and MoD units and finally the running of *Faslane*, there is plenty to interest the reader. It also is written in a style which makes it very readable and on occasions had me laughing out loud.



Overall, I would thoroughly recommend the book. It was an interesting, sometimes thought provoking, but above all an entertaining read.

On Her Majesty's Nuclear Service

By ERIC THOMPSON

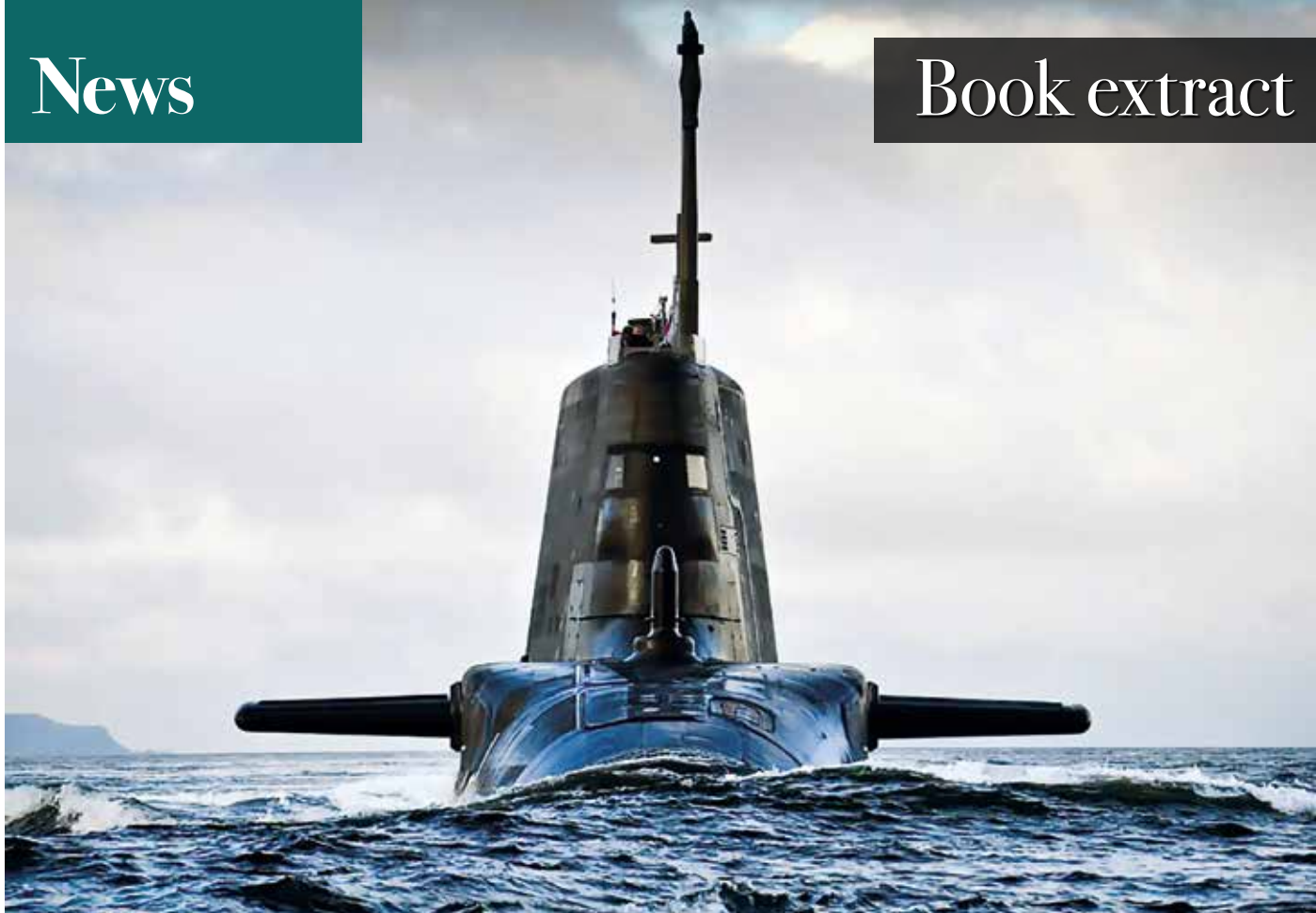
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**An introduction by Commodore
Eric Thompson MBE MSc,
CEng, FIEE, MNucl, RN (rtd), DL**

In the first half of the twentieth century, there were two world wars. In the second-half, there were none. This was not because the human race had become more amicable. It was because, in 1945, the world entered the Nuclear Age.

At the end of the Second World War, Churchill said: 'It must never happen again.' To ensure it did not, the victors equipped themselves with nuclear weapons, weapons so devastating that they were viewed as the ultimate deterrent to a third world war. The principle was called Mutually Assured Destruction (MAD).

Thus, the world entered a nuclear-powered peace and all citizens born after 1945 have lived under a nuclear umbrella though few ever express gratitude. Quite the reverse, thanks to anti-nuclear activists, ownership of nuclear weapons has been depicted as a 'crime against humanity', nuclear disarmament being promoted as the true route to peace, a complete inversion of reality.

The First World War was christened 'The War to End All Wars'. Twenty-one years later, the even bloodier Second World War happened. There were no nuclear weapons then, not until Hiroshima and Nagasaki brought an abrupt end

**HMS Ambush
returning to
HMNB Clyde,
Faslane, Scotland**

to hostilities. The point missed by the anti-nuclear brigade is that mankind does not require nuclear weapons to create megadeath. More than sixty million people died in the Second World War, less than 0.5% as a result of nuclear weapons. The fact is that the rifle has killed far more people than nuclear weapons – and so has the motorcar.

The advent of the Nuclear Age ushered in the Cold War, in which world superpowers confronted each other with vast arsenals of nuclear weapons, some capable of being delivered by intercontinental ballistic missiles launched from undetectable nuclear-powered submarines. Nuclear Armageddon was on the cards, but the principle of MAD held firm. The Cuba missile crisis in 1962 is proof of that; it was the nearest the world has come to nuclear war. The Soviet Union understood the consequences and had the wisdom to back down.

Further proof of the nuclear deterrence principle is that, after forty-five years of nuclear stalemate, the Cold War ended peacefully in 1989. It did not, as anti-nuclear protesters had prophesied, descend into a third world war.

I joined the Royal Navy in 1961, volunteered

for submarines, became a Nuclear Engineer and served On Her Majesty's Nuclear Service for much of the Cold War. My career spanned thirty-seven years and led to my becoming Chief Engineer and ultimately Commodore in charge at Faslane, the operating base for our nuclear submarines.

En route, I served in five submarines, two being nuclear-powered of which HMS Revenge was a Polaris missile submarine. I was but

**"In the Cold War,
[the] superpowers
confronted each
other with vast
arsenals of nuclear
weapons..."**

one of thousands of men engaged in this peacekeeping mission in which the role of the Naval Nuclear Engineer was pivotal.

Submariners live in a closed and secret world. Engineers, for different cultural reasons, also tend to

avoid the limelight, their exploits and heroism rarely being brought to public attention.

The world knows that during the Falklands War, HMS Conqueror sank the Argentine cruiser Belgrano but few appreciate that she was on a three month, thirty-thousand-mile war patrol. For such a technically complex machine as a nuclear-powered submarine to have operated entirely independently on a three-month patrol at the opposite end of the world was a tour de force



HMNB Clyde,
Faslane, Scotland

by her engineers – but that was no more than the norm in the Submarine Service. Five other Attack boats conducted similar patrols in the Falklands' war zone whilst another was conducting surveillance on the Soviet Navy and our Polaris boats were maintaining continuous deterrent patrols, all of similar duration and without external support.

When *Conqueror* returned to Faslane, she was flying the Jolly Roger, a long-established submarine tradition begun in the First World War – but *Conqueror*'s Jolly Roger was unique. It bore the symbols of an atom.

Submarine patrols are not without technical challenges, in some case fairly extreme. When I was Engineer Officer of the Watch on patrol in *Revenge*, there was a sudden explosive roar. It sounded like a jumbo jet taking off. 'Steam leak in the TG room!' a voice shrieked over the intercom. This was serious. I was in the tail end of a nuclear submarine, locked-in behind the massive steel doors of the reactor compartment and my space was filling with steam.

I knew the emergency drill by heart: Shut both Main Steam Stops. That would instantly shut off all steam to the engine rooms but would also scram the reactor and take the plant into Emergency Cooling from which there was no recovery at sea. We would be reduced virtually to a dead ship and would have to surface and signal for a tug and escort. Unthinkable. We were in our top-secret patrol position. Surfacing would mean breaching one of the country's most tightly guarded secrets: our location. The credibility of the British Nuclear Deterrent was at stake.

If I got it wrong, the political ramifications would be incalculable. Jim Callaghan's Government was riven by anti-nuclear sentiment. Many of his Labour MPs were proud to flaunt CND badges in public, none more so than Michael Foot, the left wing leader-in-waiting. This could be their golden opportunity. If the Deterrent were seen to fail, British nuclear strategy would be holed below the waterline. Britain could lose its place in the UN Security Council. The Americans could end our Special Relationship. Such lofty anxieties flashed through my mind as I prepared to be poached alive.

I hit the starboard Main Steam Stop first; then a split-second thought occurred. There was a fifty-fifty chance I'd got it right first time. 'Which side?' I screamed into the intercom. 'Starboard,' came a strangled reply.

Thank God! I had not hit the port Stop. We could survive on half power. But the roar had not stopped. The leak was from upstream of the stop valve! One massive, nuclear-

powered steam generator was discharging its contents into my airspace and could not be stopped. We were now in a race against time. The boiler had to be emptied before it killed us, but emptying an operational boiler whilst dived on patrol had never been done before.

There were eight of us on watch. Should I order evacuation now while we could still get out and leave the Prime Minister to deal with the politics? If I did, I would be court-martialled and hung out to dry. The submarine nuclear programme had zero tolerance for failure; a scapegoat would be required. The roaring continued. The smell of wild steam was spreading fast.

The rest of the saga is beyond the scope of this article; suffice it to say that patrol aims were maintained and one young Mechanic gained a Queen's Gallantry Medal. The public remain largely unaware of such nuclear heroics.

When the adjective 'nuclear' is introduced, objectivity goes overboard and journalists sensationalise disaster. When did the popular media last report a 'good news' nuclear story? In this respect, the anti-nuclear propagandists have been successful. They have turned 'nuclear' into a toxic word yet, in the sixty-five years between 1952 and 2017, only three nuclear accidents, serious enough to include core damage, have occurred (Three Mile Island, Chernobyl and Fukushima).

By my count, only sixty-one nuclear-related fatalities have been recorded in the history of the global nuclear industry. It is virtually impossible to know the numbers of consequential cancer-related or incidental deaths but if one takes a blind guess at 50,000, this should be set in perspective against the 1.25 million road traffic deaths worldwide in just one year (2015). Automobiles also pump out atmosphere-changing greenhouse gases yet there is no popular demand for an end to the automobile industry. Why not? Because automobiles have societal benefit. And so has nuclear-generated electricity.

The *Herald of Free Enterprise* sailed with her bow doors open and sank before she had even left Zeebrugge harbour. One hundred and ninety-three passengers perished. That was equivalent to a submarine diving with its conning tower hatch open. Such utter disregard for basic safety measures is incomprehensible to me as a submariner and nuclear engineer.

The nuclear industry is probably the world's safest industry. It provides a non-greenhouse-gas emitting source of power and has been successful in preventing world war for the last seventy-five years? This deserves huge public approval. So why is there such antipathy towards all things nuclear?

TECHNICAL FEATURES

Nuclear defence

49 Reactor simulators and Reduced Order Modelling

Claire E. Heaney,
Andrew G. Buchan,
Christopher C. Pain
and Simon Jewer

55 Reactor operator dynamics in manual control of reactivity transients – theory, experiments and models at the VR-1 Reactor

A.M. Darbyshire and
K.D. Atkinson

Nuclear Professionalism



All people working in the nuclear sector, irrespective of their level or grade of employment, can be characterised as nuclear professionals. All require specialist education and training to develop the skills and expertise needed to perform their jobs safely, securely and effectively in a nuclear context.

In addition to role-specific technical skills, all nuclear professionals demonstrate something extra – what we call in the United Kingdom the **Nuclear Delta®**. This is the understanding of nuclear specific standards and requirements, especially the importance of nuclear **safety** culture, nuclear **security** culture and nuclear **technology**.

Employer responsibility

Promoting nuclear professionalism brings together the responsibilities of the employee and the employer to create an environment and culture in which nuclear professional practice is highly valued and expected as the norm.

Continuous professional development

In most professional disciplines it is normal practice for individuals to maintain and record their professional status independently of their employment through the appropriate professional body. Professional status is maintained by reporting continuing professional development, accumulated experience and on-going commitment to uphold the profession's standards and codes of conduct.

As the professional membership body for the UK's nuclear industry, the Nuclear Institute has developed the **Nuclear Delta®** to support professionals in meeting and maintaining the specific attitudinal, competence and behavioural requirements of the nuclear industry. Achieving the requirements of the Nuclear Delta® is central to professional membership and accreditation by the Nuclear Institute.

For more information visit:- Nuclearinst.com

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Reactor Simulators and Reduced Order Modelling

SUMMARY

- ◆ The high quality real-time solutions offered by Reduced Order Modelling (ROM) could greatly improve the resolution of the solution available in training simulators and would add significantly to a student's understanding.
- ◆ ROM will be a key component of the modelling of reactor simulators, the operational modelling of reactors and accident analysis.
- ◆ The computational speed of this unique framework will enable real-time interactive use, uncertainty analysis, rapid data assimilation and better-informed reactor management.
- ◆ The goal of a real-time response has been realised in the reduced-order model of a fuel assembly presented here.

By **Claire E. Heaney^a**, **Christopher C. Pain^a**, **Andrew G. Buchan^{b;a}** and **Simon Jewer^c**

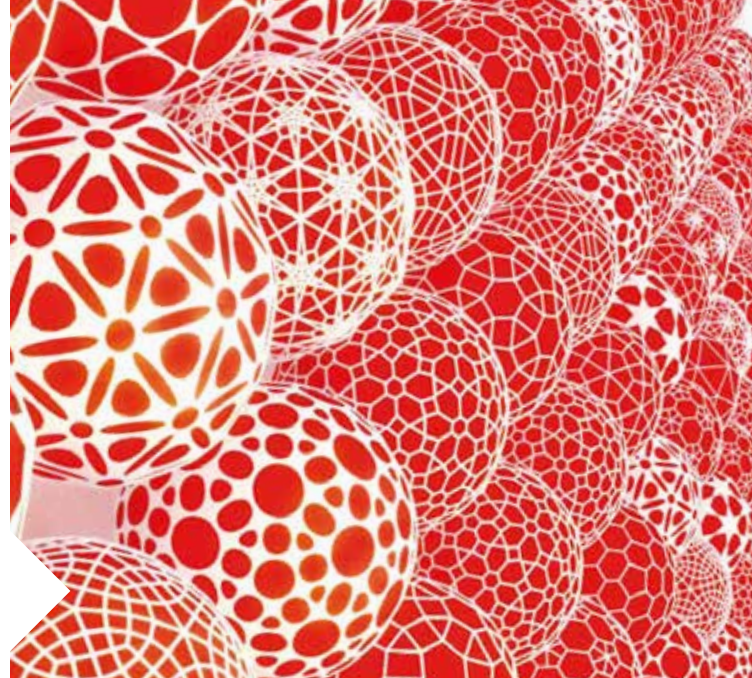
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INTRODUCTION

Imagine if a tool were able to predict, in great detail, the turbulent single or multi-phase flows within a light water reactor in faster than real time from a laptop or even a mobile phone. With access to a supercomputer, imagine being able to predict at unprecedented levels of detail. The combination of these two aspirations forms our long-term vision and we believe Reduced Order Modelling (ROM) will be a key component of the modelling of reactor simulators, the operational modelling of reactors and accident analysis. We expect the computational speed of this unique framework will enable real-time interactive use, uncertainty analysis, rapid



data assimilation (constraining models with measurements) and better-informed reactor management.

As part of its commitment to training, the MOD deploys simulators to emulate the response of a submarine to instructions delivered through a control panel. If incorporated into simulators, the high quality real-time solutions offered by ROM could greatly improve the resolution of the solution available in such interactive simulators and would add significantly to a student's understanding of the spatial variation of key variables, for example the neutron flux or temperature, within the reactor.

MOTIVATION FOR REDUCED ORDER MODELLING

To operate as realistically as possible, training simulators require a real-time response from a computational model, so that when a user makes a change to the controls, the response is felt immediately.

Historically, simulators have relied on models such as point kinetic models which simplify the physics considerably in order to return a solution in real time. In this article we highlight a technique that has the potential to introduce high-fidelity 3D numerical solutions to the simulator in real time. The technique, ROM, also known as Model Reduction [1, 2] is fast establishing itself as an invaluable tool for scientists who wish to solve a set of equations repeatedly, for a large number of parameter values, so-called 'multi-query problems'.

Such problems arise in data assimilation, optimisation, and uncertainty quantification, for example, where obtaining a model that runs in real time and that approximates (well) an associated high fidelity model (HFM) is deemed worth the initial outlay of forming the reduced order model.

The goal of reduced order modelling is, therefore, to approximate a high fidelity model (that is, a high dimensional model with many degrees of freedom) using a model of significantly lower dimension (the reduced order model) whilst retaining, as much as possible, the predicting capability of the former. Typically, a high fidelity model may have millions of degrees of freedom, whereas a reduced order model may have just hundreds, hence the potential for real-time simulation.

Figure 1 encapsulates this idea, where, on the left we have a high fidelity image of the Stanford bunny [3, 1 (front cover)] with physical features clearly defined using many degrees of freedom – our high fidelity solution of the neutronics inside a reactor, say. On the right we have a representation with many fewer degrees of freedom in

which only the broad features are visible, the detail having been lost – a point kinetics model, say. The success of reduced order modelling lies in its ability to produce high fidelity solutions (left) with compute times related to the degrees of freedom of the lower dimensional problem (right).



FIGURE 1:
Images of the Stanford bunny at different resolutions [3].

To date there has not been much work reported on applying ROM to nuclear applications. Notable exceptions are [4] which applies ROM to solving eigenvalue problems for reactor physics applications and [5] which presents a reduced order model for simulating control rod movement.

REDUCED ORDER MODELLING

The process of forming a reduced order model splits into two stages, a preparatory ‘off-line’ stage that is computationally expensive and an ‘on-line’ stage which executes rapidly. All assembling and solving of the high fidelity model is restricted to the off-line stage, to ensure that the on-line stage can be solved in real time. The aim of the off-line stage is to produce (1) a set of basis functions that capture the essential behaviour of the system and (2) a set of low dimensional matrices that will be used to generate the discretised reduced order model system. In the following, we refer to these matrices as (pre-calculated) reduced order matrices and the discretised system they represent as the reduced order system.

To calculate the basis functions, the high fidelity model is sampled at a number of parameter values thought to be representative of the system. For instance, to produce basis functions for a fuel assembly, the high fidelity model could be solved for a number of control rod heights and a number of temperature profiles.

The solutions are known as snapshots and are gathered together to form a matrix to which a singular value decomposition (SVD) is applied. The SVD distils the information contained within the snapshots into a relatively small number of global basis functions, providing that the problem is amenable to ROM, in which case, these basis functions are able to capture the fundamental behaviour of the system.

The SVD also returns a set of singular values whose magnitude allows the basis functions to be ranked in order of importance. In the case that some singular values are sufficiently small, their corresponding basis functions can be discarded, thereby further reducing the dimension of the reduced order model. The method of sampling the governing equations described above is known as the method of snapshots based on Proper Orthogonal Decomposition, see [1] for more details.

To complete the off-line stage, we must find the reduced order matrices that will be used to generate the reduced order system. They are found by projecting the matrices assembled in the high fidelity model onto the basis functions resulting in a number of

relatively small matrices, that is, low in dimension.

In fact, the dimension of these pre-calculated matrices is equal to the number of basis functions. As this reduced order system is much smaller in dimension than the high fidelity model, it can, therefore, be solved much faster. For instance, in the results we show, the high fidelity model has 39,528 degrees of freedom, whereas the reduced order system has 42 degrees of freedom.

In our discretisation of the neutron diffusion equation, the matrices are sparse, however, the reduced order system is dense due to the projection step, and therefore, for efficiency, a direct solver is used for the reduced order model. For a review of projection-based ROM see [6].

The use of projection means that this particular reduced order model comes under the category of ‘intrusive’, which indicates the code representing the high fidelity model must be modified in order to project the discretised governing equations from the high fidelity model onto the basis functions. This modification does not affect the standard code outputs in any way; what it will do is provide one more model output, that is, the reduced order matrices.

With access to the source code this can be done. When working with licensed codes, highly complex sources codes or legacy codes, modifying the source code might not be practical. In this case another type of reduced order model, ‘non-intrusive’, could be used, see [7] for example. Non-intrusive ROM relies solely upon the high fidelity model inputs and outputs, and builds the discretised reduced order system by fitting multi-dimensional surfaces to the snapshots.

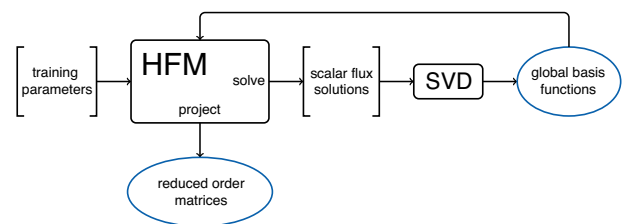


FIGURE 2:
The off-line stage of a reduced order model: the algorithm to generate the basis functions and the pre-calculated reduced order matrices

The off-line algorithm is illustrated in Figure 2. For each set of training parameters, the high fidelity model is solved once. The snapshots are passed to an SVD which returns the basis functions. The high fidelity model is called again in order to project the discretised governing equations onto the basis functions, producing the pre-calculated reduced order matrices from which the reduced order system will be constructed. The steps are given in Algorithm 1.

ALGORITHM 1: The off-line algorithm

Generate snapshots

- ◆ run the high fidelity model for all parameter combinations

Calculate basis functions

- ◆ for each energy group gather flux solutions into a matrix
 - take the SVD of the snapshots matrix to obtain the basis functions
 - decide how many basis functions to retain based on the singular values

Projection

- ◆ generate the matrices in the high fidelity model which represent the discretised governing equations for all parameter combinations
- ◆ project these onto the basis functions to give the reduced order matrices

In the on-line stage, we must first construct the reduced order system associated with the parameters we wish to solve for ('desired parameters'). The most accurate way to do this would be to assemble the matrices associated with the high fidelity model and then project them onto the basis functions. However, as previously mentioned, we wish to avoid this as it involves assembling the high fidelity model and would be too slow.

Instead we approximate the reduced order system by interpolating a subset of the pre-calculated reduced order matrices generated in the off-line stage. The pre-calculated matrices associated with parameter values that are closest to the desired values are found, see Figure 3, and then interpolated to approximate the reduced order system at the desired parameter values. The interpolation is linear in temperature but non-linear in control rod height. The on-line stage is summarised in Algorithm 2. For more details on the approach described in Algorithms 1 and 2, see [8].



FIGURE 3:

Parameter space. In the on-line stage, the desired parameters are specified, the closest training parameters to the desired parameters are identified, and, finally, the pre-calculated reduced order matrices corresponding to the closest training parameters are interpolated to give the matrices representing the reduced order system at the desired parameter values

ALGORITHM 2: The on-line algorithm

Assemble and solve the reduced order system

- ◆ choose the desired parameter values
- ◆ find the reduced order matrices associated with the parameter values closest to the desired values
- ◆ interpolate between these matrices to give the reduced order system
- ◆ solve the reduced order system

RESULTS

To demonstrate these ideas, we present results for a reduced order model of a PWR fuel assembly with 17 by 17 channels, 264 of which house fuel rods and the remaining 25 accommodate control rods, see Figure 4.

The material cross-sections were calculated with WIMS [9] and smeared so that there is one value for each cross-section per energy group. The high-fidelity simulations were run with FETCH [10]; a finite element code that solves the Boltzmann transport equations

for neutron population developed by the Applied Modelling and Computation Group at Imperial College London.

Here we use FETCH to solve the multi-group criticality diffusion equation for a two-energy group problem. Eight-noded hexahedral elements with 4 quadrature points were used in the finite element discretisation. The mesh had 17 by 17 by 60 elements over a domain of [0, 21.42] by [0, 21.42] by [0, 300] (cm), giving 39,528 degrees of freedom. The reduced order model was constructed and solved in Python using PETSc4py [11] and SLEPc4py [12].

The parameters chosen for this particular problem were control rod height and temperature. To generate the snapshots, we used 31 equally-spaced control rod heights ranging from fully inserted ($h=0$ cm) to fully withdrawn ($h=300$ cm) and two uniform temperature profiles of 291°C and 1398°C. Uniform temperature fields were used for simplicity, and, although unrealistic, they were able to capture the underlying temperature dependence giving good results as will be demonstrated. FETCH was run for each of the 62 parameter combinations generating 62 snapshots for each energy group.

After performing the SVD we kept 17 of a possible 62 basis functions for group 1 and 25 of a possible 62 for group 2, which corresponded to capturing 99.9995% of the energy of all 124 basis functions. (The energy of a basis function is the square of its associated singular value.)

The final part of the off-line process is to project the matrices associated with the discretised system onto the basis functions. We split up each matrix into sub-matrices which correspond to contributions associated with regions of the domain (layers in the vertical direction). This allows us to impose on the reduced order model temperature profiles which vary in height. In this particular example we used 10 layers, so we produced 620 matrices. These matrices are relatively small, and we used the PETSc file format to increase efficiency.

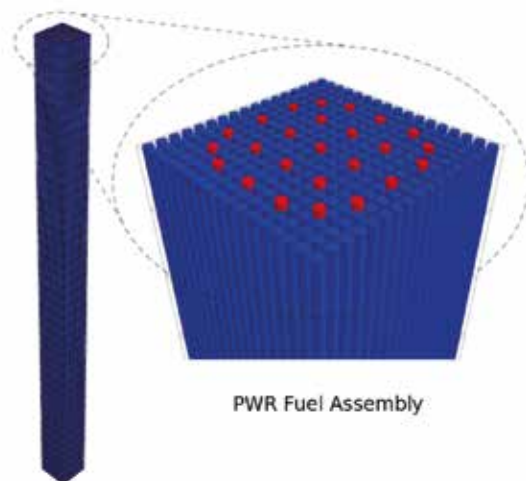


Figure 4:

A PWR fuel assembly (control rods in red, fuel rods in blue).

The next step is to run the reduced order model. First, we will demonstrate how well the model can reproduce the results for parameter values which were used to train it, so-called 'seen parameters'. Figure 5 shows a plot of neutron multiplication factor,

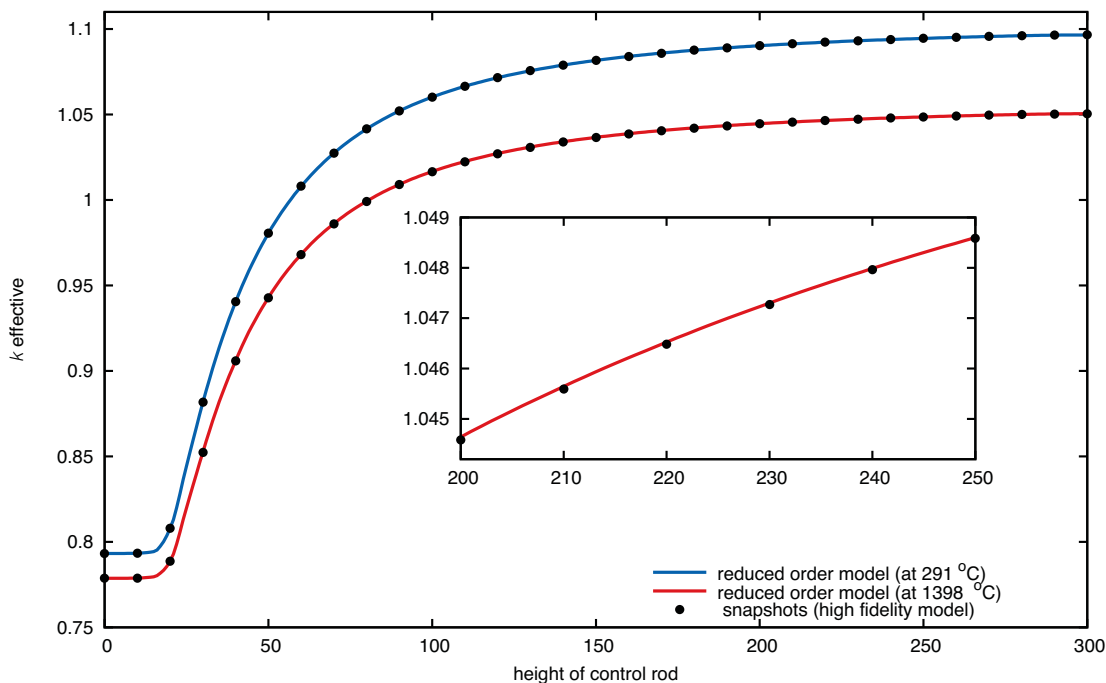


Figure 5: Comparing values of k effective from the high fidelity model and the reduced order model for the parameters used in training the latter

k effective, as predicted by the high fidelity model, FETCH, and the approximation from the reduced order model for seen parameter values. The agreement is excellent. Second, we test how well the model predicts behaviour for parameters that have not been used to train it, so-called ‘unseen parameters’. We choose a varying temperature profile

$$400+600\sin(\pi z / 300)$$

and for this profile we test control rod heights at 5 cm intervals. Once the reduced order model is coupled with a sub-channel model, the temperature profile will be calculated as part of the solution procedure of the sub-channel model. Figure 6 shows a comparison of k effective as predicted by FETCH and by the reduced order model.

The results from FETCH shown in this figure were not used in the training of the model; they were additional simulations that were run specifically for the comparison. The agreement is also very good. Despite the fact that the reduced order model was trained with uniform temperature profiles, the reduced order model is capable of capturing behaviour for vertically-varying temperature profiles. Finally, Figure 7 shows the scalar flux of group 2 as predicted by FETCH and by the reduced order model. The plots are virtually indistinguishable.

Table 1 compares the timings for the high fidelity model and the reduced order model, from which, we can see the speed up gained by using the latter is approximately 200,000.

Work could be done to improve the efficiency of the high fidelity model, perhaps gaining at most an order of magnitude reduction in time. Even so, the difference in calculation time between the two models is significant. Furthermore, the absolute time taken to run the reduced order model is comfortably in line with what would be required for real-time simulation.

TABLE 1:
Number of degrees of freedom and time taken to solve the high fidelity and the reduced order models

	DEGREES OF FREEDOM	TIME FOR ONE SOLVE (SECONDS)
HIGH FIDELITY MODEL	39,528	499
REDUCED ORDER MODEL	42	0.00254

When using reduced order models, ideally one would have an error measure to know how far away the solution is from the high fidelity model. In the absence of such a quantity we have calculated the infinity norm of the error between the reduced order model solutions and the high fidelity model solutions (snapshots) that are available. We have also run some high fidelity model simulations in order to calculate an error for the unseen results. The infinity norm is taken as the maximum absolute difference between k effective calculated by the two different models and the results are seen in Table 2.

TABLE 2:
Infinity norm of the error between the k effective for the high fidelity model and the reduced order model. The points seen in Figure 5 and Figure 6 are used to evaluate the norm

Error in k effective for the snapshot parameters	2.2×10^{-5}
Error in k effective for the unseen results	1.4×10^{-4}

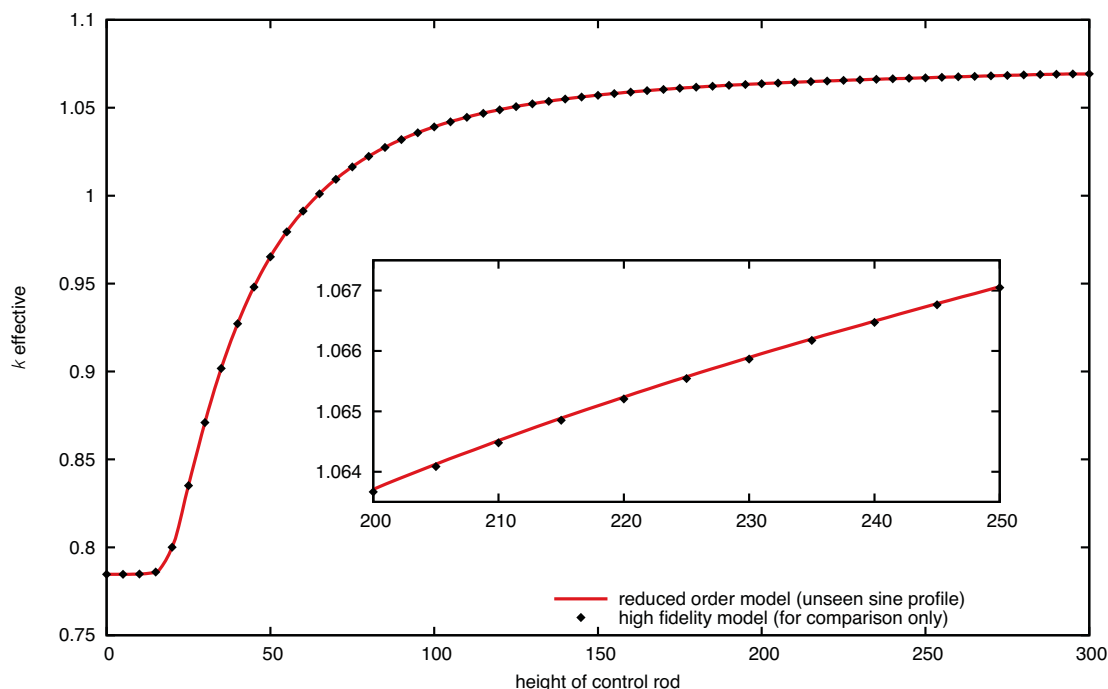


FIGURE 6:
A comparison of $k_{\text{effective}}$ from the high fidelity model and the reduced order model for unseen parameters. The temperature profile imposed was sinusoidal, taking values between 600°C and 1000°C

“This framework has the potential to provide an extremely powerful tool, not only for training and reactor analysis, but also for reactor management and control, fuel management, data assimilation and uncertainty quantification...”

CLOSING REMARKS

Applying ROM has led to a model of a fuel assembly, capable of providing a real-time response. The model is both fast, with one solve taking just 0.00254 seconds, and accurate, with 1.4×10^{-4} being the largest error detected in $k_{\text{effective}}$.

Once coupled with a sub-channel model, the temperature feedback from the moderator to the neutrons can be investigated. With a hierarchical model to link reduced order models of individual fuel assemblies, this framework has the potential to provide an extremely powerful tool, not only for reactor analysis, but also for reactor management and control, fuel management, data assimilation and uncertainty analysis.

ABBREVIATIONS

MOD	Ministry of Defence	SVD	Singular value decomposition
ROM	Reduced order modelling	PWR	Pressurised water reactor
HFM	High fidelity model		

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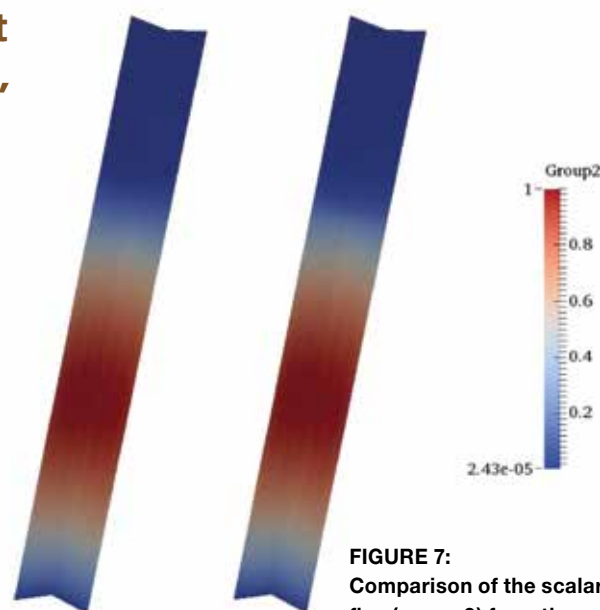
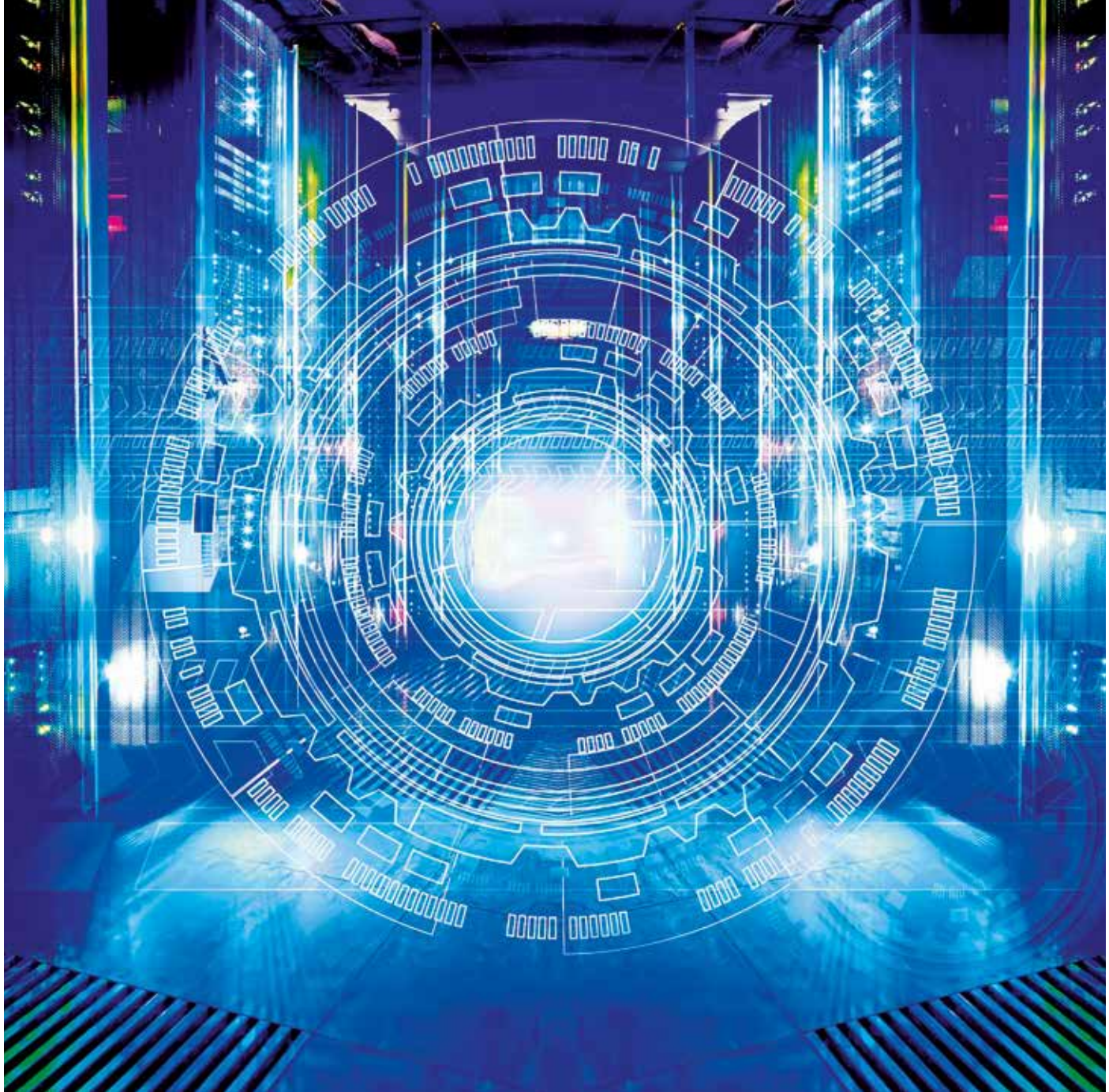


FIGURE 7:
Comparison of the scalar flux (group 2) from the reduced order model (left) and the high fidelity model (right). The base of the control rod is at a height of 205 cm and temperature of 291°C (rescaled vertically). The solution on the left took 0.00254 s to generate, the solution on the right, 499 s



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Reactor Operator Dynamics in Manual Control of Reactivity Transients

– Theory, Experiments and Models at the VR-1 Reactor

SUMMARY

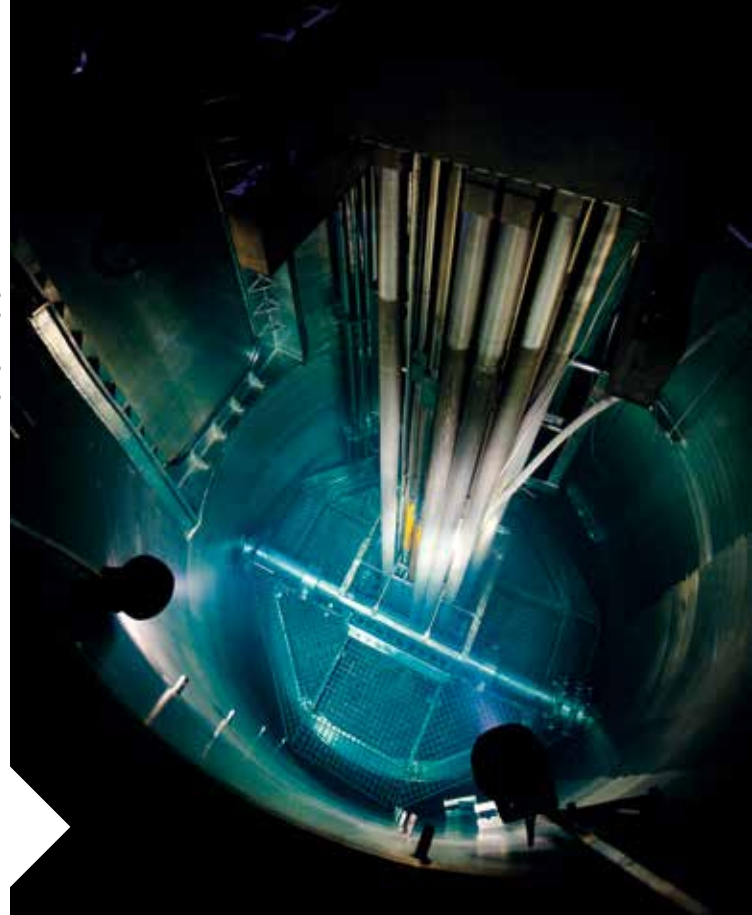
- ◆ Theory for mathematically modelling the human element of a control-loop was applied to the reactor operator.
- ◆ Operator-reactor dynamics experiments were performed at the VR-1 reactor for disturbance rejection tasks.
- ◆ Non-linear models were identified for three operators each responding to several reactivity disturbances.
- ◆ Data interpretation successfully showed that operator responses were in keeping with that expected of a good closed-loop system.
- ◆ Potential indicators of operator style, task learning, and the effect of increasing task complexity were seen.

By **A.M. Darbyshire** and **K.D. Atkinson** of the **Defence Academy of the United Kingdom**, and **T. Bily** of **CTU, Prague**

INTRODUCTION

Safe nuclear reactor operation requires effective operator control through interaction with plant dynamics, manipulators and displays. Since 2016 the Nuclear Department of the Defence Academy of the UK has been researching the concept of modelling human operator dynamics in compensatory nuclear reactor systems; and 2017 saw the first full analysis of experimental data from the VR-1 reactor in Prague [1]. The primary objective of the experimental and analytical research carried out by the Nuclear Department is to develop mathematical descriptions for operator response characteristics and to achieve reasonable descriptions of the operator as a component in an engineering system. Although it

VR1 REACTOR IMAGE: Czech Technical University in Prague – J. Ryszawy



is early days for this research, it is anticipated that the type of operator-reactor dynamic models under development may be used for:

1. Analysis of the overall effectiveness of operator training programmes and education.
2. Estimation of overall operator-reactor system dynamic response – with potential to aid selection of future automation strategies.
3. Determination of controllable reactor dynamics and manual controllability boundaries.
4. Indication of the type of additional system equalization (to be achieved via displays, manipulators (control rods), or by reactor modifications) desirable to achieve better operator control.

In this article we summarise our initial work towards construction, refinement and successful application of the mathematical theory.

OVERVIEW OF THE THEORY

Let us first briefly consider some important aspects in mathematically modelling the human operator. Operators in manual control systems exhibit a type of cause-and-effect behaviour which is analogous to the behaviour of equalising elements inserted into a servo-system to improve over-all dynamic performance. Essentially, there are three task variables that have a major effect on a nuclear reactor operator's dynamics – these are:

1. The forcing function characteristics; i.e the input reactivity perturbation,
2. the controlled-element dynamics; i.e. the reactor dynamics and its displays, and
3. the manipulator control; i.e the control rod drive mechanism and load.

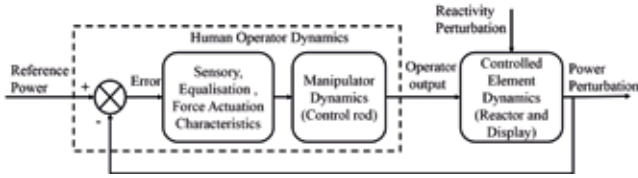


Figure 1: operator-reactor system [1]

Figure 1 shows a block diagram of the simplest operator-reactor control system indicating the relative positions of the above-mentioned variables and the human-in-the-loop. An analytical-verbal model has previously been used for humans in compensatory tracking tasks such as the ones that were carried out at the VR-1 reactor. The low frequency approximation of this model is given by equation 1 [2]:

$$Y_p = \frac{K_p e^{-j\omega\tau} (T_L j\omega + 1)}{(T_I j\omega + 1)(T_N j\omega + 1)}$$

Where Y_p is the operator describing function, K_p the human operator gain, T_L the general lead time constant, T_I the general lag time constant, T_N the first-order lag time constant approximation of the neuromuscular system, and τ the pure reaction time delay.

The term containing T_N is a first order neuromuscular lag term which is partially adjustable for the task.

The pure delay $e^{-j\omega\tau}$ term is due to sensor (retina) excitation, nerve conduction, computational lags, and other data processing activities in the central nervous system; it is taken to be a constant.

The equalising characteristics, of T_L and T_I , coupled with the gain K_p are the major elements in the adaptive capability of the human which allow the control of different dynamic devices.

The controlled element in our study is the VR-1 Training Reactor at the Czech Technical University in Prague. The VR-1 reactor is a pool-type light-water reactor based on low enriched uranium with maximum thermal power of 1 kW. The moderator is light demineralised water which is also used as a reflector, a biological shielding and a coolant [3]. A linear point reactor model captures the dominant dynamics of this controlled element and the appropriate zero-power transfer function is given by equation 2:

$$Y_c(s) = \frac{\delta n}{\delta \rho} = \frac{n_0(s + \lambda)}{\Lambda s(s + \frac{\beta}{\Lambda})}$$

The controlled element model (Y_c) contains parameter values for delayed neutron fraction β , neutron generation time Λ , decay rate of neutron precursors λ , neutron level n , initial neutron level n_0 , reactivity ρ and the Laplace transform operator s . In this approximation we have taken the initial reactivity to be zero, corresponding to equilibrium operation at an arbitrary power level.

To satisfy tracking requirements and rejection of low frequency disturbance it is preferable for the system to have large gain at low frequencies; while at high frequencies the gain would be kept low to filter out high frequency noise. The desired closed-loop response is that of a low-pass filter.

The region near the crossover frequency, ω_c where $|Y_p Y_c| = 1$ is of most importance. The operator's describing function, $Y_p(j\omega)$ must be adjusted so that exceeds the highest important frequency in the

input, ω_c . The shape of $Y_p Y_c$ at near crossover frequency determines the dynamics of the dominant modes of system response. For good feedback control, neutrally stable or unstable dominant modes should be avoided by adjusting the system so that there is a positive gain margin as given by equation 3

$$|Y_p Y_c| < 1 \quad \text{when} \quad \angle Y_p Y_c = -\pi$$

and a positive phase margin as given by equation 4.

$$\angle Y_p Y_c > -\pi \quad \text{when} \quad |Y_p Y_c| = 1$$

From theory, the operator is expected to adjust his describing function so that the open-loop function $Y_p Y_c$ in the vicinity of the gain crossover frequency, ω_c is closely approximated by equation 5.

$$Y_p Y_c = \frac{\omega_c e^{-j\omega_c \tau_e}}{j\omega}$$

The VR-1 reactor exhibited conditional stability for particular inputs and therefore can be difficult to control; this resulted in non-linear controller action which can be decomposed into three interconnected elements; a transport delay at the operator's input, linear dynamics represented by the describing function, and an output non-linearity.

EXPERIMENT TECHNIQUES

Previous knowledge of human operator behaviour has been focused on pilot-vehicle characteristics in compensatory tracking using data from simulators. As we were utilising live reactor data to analyse operator behaviour we were constrained, at least in this initial investigation, to the study of reactivity disturbance rejection tasks. In our experiments the operator responded to a visual stimulus of the reactor power displayed on the monitor indicated in figure 2. The operator manipulated one of the control rods using the buttons indicated in the figure. The three selected participants were skilled operators of the VR-1 reactor.



Figure 2: operator control desk [3]

The test situation involved the operator manipulating the control rod position to reject a power disturbance caused by the movement of a device known as the HOPIK. The operators were instructed to minimize the error as the power changed from a steady-state level. The reactor power and the rod position signals were recorded at a

sampling rate of 0.1 seconds; figure 3 shows an example of the data collected for one of the operators.

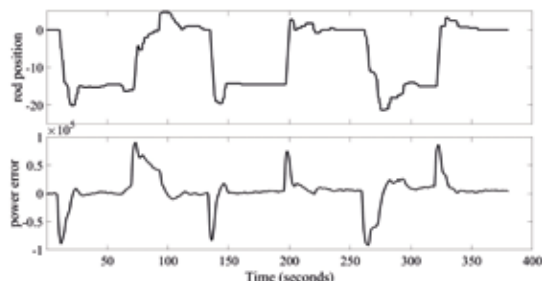


Figure 3: example test data for one operator [1]

MODEL ESTIMATION AND INTERPRETATION OF DATA

The computer aided control system design software package MATLAB was used to process, estimate and analyse the data for the three operators and six experiments. A non-linear Hammerstein model structure was fit to a total of eighteen datasets (six experiments for each of the three operators). Figure 4 shows the result of each estimation. The chosen non-linear model structure showed reasonably good fit to over 94 percent of the experiments.

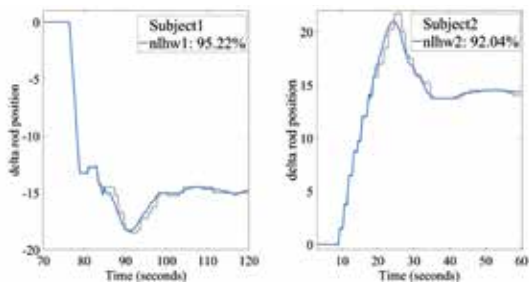


Figure 4: example of non-linear estimated model simulation [1] where grey line is the actual operator response and blue line is the model response

In order to investigate the variability of the operator's describing functions we may examine the frequency responses for all 6 experiments for the three operators shown in figure 5.

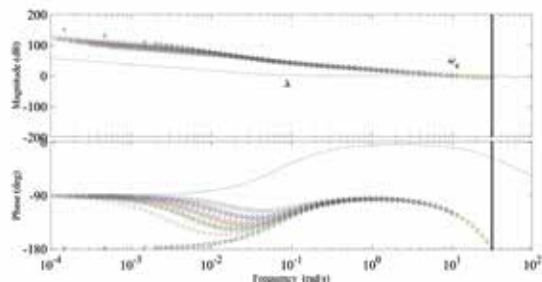


Figure 5: Frequency responses of the open-loop describing functions for all 6 experiments for the three operators

Figure 5 shows the describing functions, $Y_p(s)$, pass the lower frequencies and attenuate the higher frequencies more. The crossover frequency is $\omega_c \approx \lambda$ and located at 10 rad/sec. The phase

“As the reactor approaches critical the operators behave nearly identically under the constrained conditions. The shape of the open-loop function away from the gain crossover frequency is usually almost irrelevant...”

margin can be calculated at gain crossover as 60 degrees. The resulting frequency response is in keeping with what would be expected in a good closed-loop system.

Intra- and inter-operator variability

The first operator variability of interest is of a run-to-run nature – an operator compared with himself when he tracks the same input successively. On examining figure 5 we observe that all three operators indicate run-to-run variabilities at low frequency. There is less variation in the region of crossover; this behaviour is consistent with the demands of the closed-loop system. There is evidence of constrained behaviour through the entire measurement range. The impact of operators on the variability of the describing functions may be examined in figure 5. The same general trends as already observed for the run-to-run intra-operator changes. There is a wide variation in the phase for this critically difficult controlled element.

Output non-linearity

The linear describing function comprises one part of the quasi-linear system; the output non-linearity is an equally important component. The results of identification of the piecewise non-linearity are shown in figure 6. The three marker shapes represent individual operators and the different colours represent the six experiments. A positive power perturbation elicits the expected rod insertion movement from the operator; and a negative power perturbation results in a rod withdrawal.

The following features are of particular interest:

- Potential evidence of pulsing behaviour in the control of the reactor.
- Evidence of inappropriate variations in operator temporal action; this is reflected in the presence of larger response overshoots (a potential indicator of increasing task complexity).
- A general reduction in maximum magnitude of the input to non-linearity with successive individual operator tests (a potential indicator of operator task-learning).

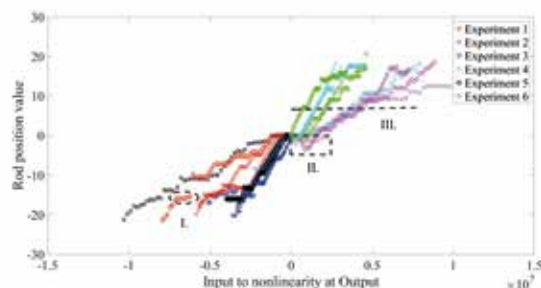


Figure 6: intra- and inter-operator non-linearities [1]



VR1 REACTOR IMAGE: Czech Technical University in Prague – J. Ryszawy

Each operator may have their own style of operation and this is reflected in changes in the describing function model in those regions away from crossover where the form of the model is not critical to good disturbance control. As the reactor approaches critical the operators behave nearly identically under the constrained conditions. The shape of the open-loop function away from the gain crossover frequency is usually almost irrelevant to the closed-loop performance.

CONCLUSIONS

This study has heightened the desire for, and increased the potential importance of, a more complete understanding of the mathematically describable aspects of human dynamics in reactor control systems. Extensions to the current research programme may include:

1. Broadening of the operator task types to include visual- and audio-input tracking.
2. Investigations into the effects on reactor handling of display and manipulator interface variations.
3. Investigations into the effects of reactor handling on operator training programmes and increased workloads.

If you are interested in learning more about Reactor Dynamics and Control or the VR-1 reactor and research please contact Alice Darbyshire.

DISCLAIMER:

Any views expressed are those of the author(s) and do not necessarily represent those of the Defence Academy/ HM Government

“This study has heightened the desire for a complete understanding of the mathematically describable aspects of human dynamics in reactor control...”

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