Nuclear News

June 2021

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INSTRUMENTATION & CONTROLS AND HUMAN FACTORS


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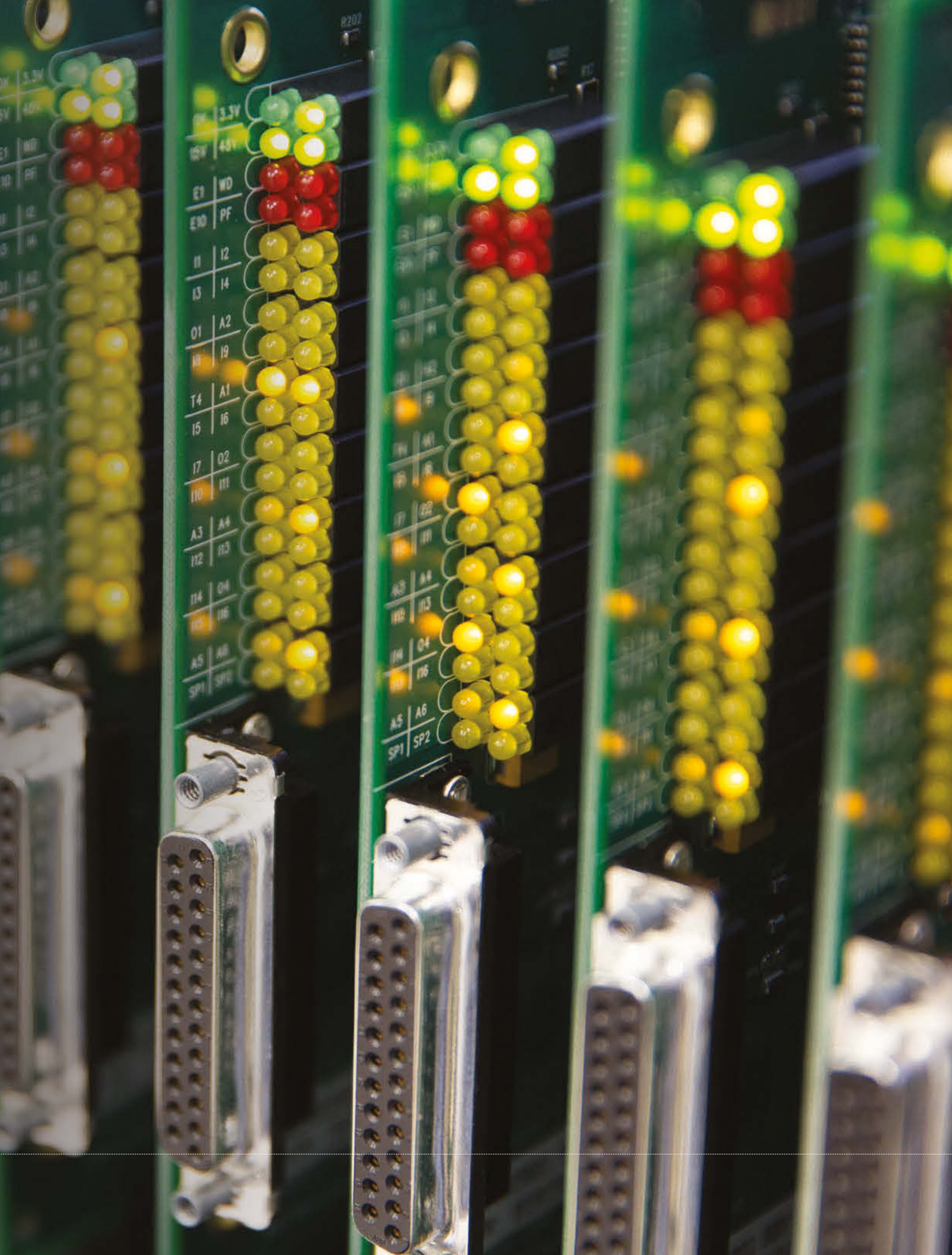

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An Idaho National Laboratory simulation lab with panels that can be reconfigured for U.S. nuclear plant control room training and modernization.

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A challenge for HFIC work

It's June and it's time for the 12th Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies meeting (NPIC&HMIT 2021), taking place in conjunction with the 2021 ANS Virtual Annual Meeting.

Professionals from all sectors of the nuclear community—utilities; national laboratories; government agencies; universities; and manufacturing, supply, and consulting companies—are involved with I&C and human factors.

The ANS Human Factors, Instrumentation & Controls Division has essentially been a part of ANS since 1979, when its predecessor—the Technical Group for Human Factors—was formed. That group became a division in 1985, and in 2008 it was renamed to reflect its involvement in instrumentation and controls. Today, the HFICD has more than 800 members.

Currently chaired by Mehdi Tadjalli, chief engineering director for Enercon, the HFICD focuses on the human component of nuclear technology, along with the underlying instrumentation, control, and human-machine interface technologies that support the safe operation of nuclear facilities. These technologies include sensors that transduce physical processes into signals; monitoring, control, and communications systems that process data into information; the interfaces that display plant operational information; and the human cognitive capabilities that enable perception and interpretation of information.

An ongoing challenge for HFIC professionals is personalizing control rooms for small modular reactors. According to Jamie Coble, associate professor of nuclear engineering at the University of Tennessee–Knoxville and the program chair for NPIC&HMIT 2021, a question that needs to be answered is how to operate an SMR control room that does not need the same number of operators as a large nuclear plant.

"From the human factors perspective, that's a really big deal," Coble said. "It's a function of how to make sure that the right information is being presented to operators at the right time so that they can monitor and make decisions and have a global plant view instead of focusing on a single unit." Coble noted that Ryan Flamand of NuScale Power is demonstrating NuScale's proposed control room design as part of NPIC&HMIT's technical program.

Work on control room design is ongoing at Idaho National Laboratory and Argonne National Laboratory, where investigations are being conducted into operator alert and support systems.

Ronald Boring, human factors manager at INL, gave an example of recent human factors research centered on computerized operator support systems, or COSS. "They are basically operator aids," he said. "We are trying to marry operator aids with some form of artificial intelligence to help operators look ahead."

Working in conjunction with Richard Vilim, manager of the Plant Analysis and Control and Sensors Department at Argonne, Boring said that a prognostic technology called PRO-AID was developed that detects deviations in plant performance. The idea behind PRO-AID is to give operators an overview of what is happening at the plant, where a typical control room can have about 800 alarms. "We're introducing technology that looks ahead and predicts what might go wrong," he said. "One of the challenges from an operator perspective is that they're already dealing with the realistic possibility that when a problem happens, there are multiple alarms going off, which we call floods or avalanches."

The new technology will allow operators to anticipate problems. "It's almost like the collision avoidance system in an automobile," Boring said. "It's an early warning system concept."

Such is the challenging work of HFIC. I hope you enjoy this issue of *Nuclear News* with the theme of HFIC and that you find the 2021 ANS Virtual Annual Meeting and NPIC&HMIT rewarding. —*Rick Michal, Editor-in-Chief (rmichal@ans.org)*

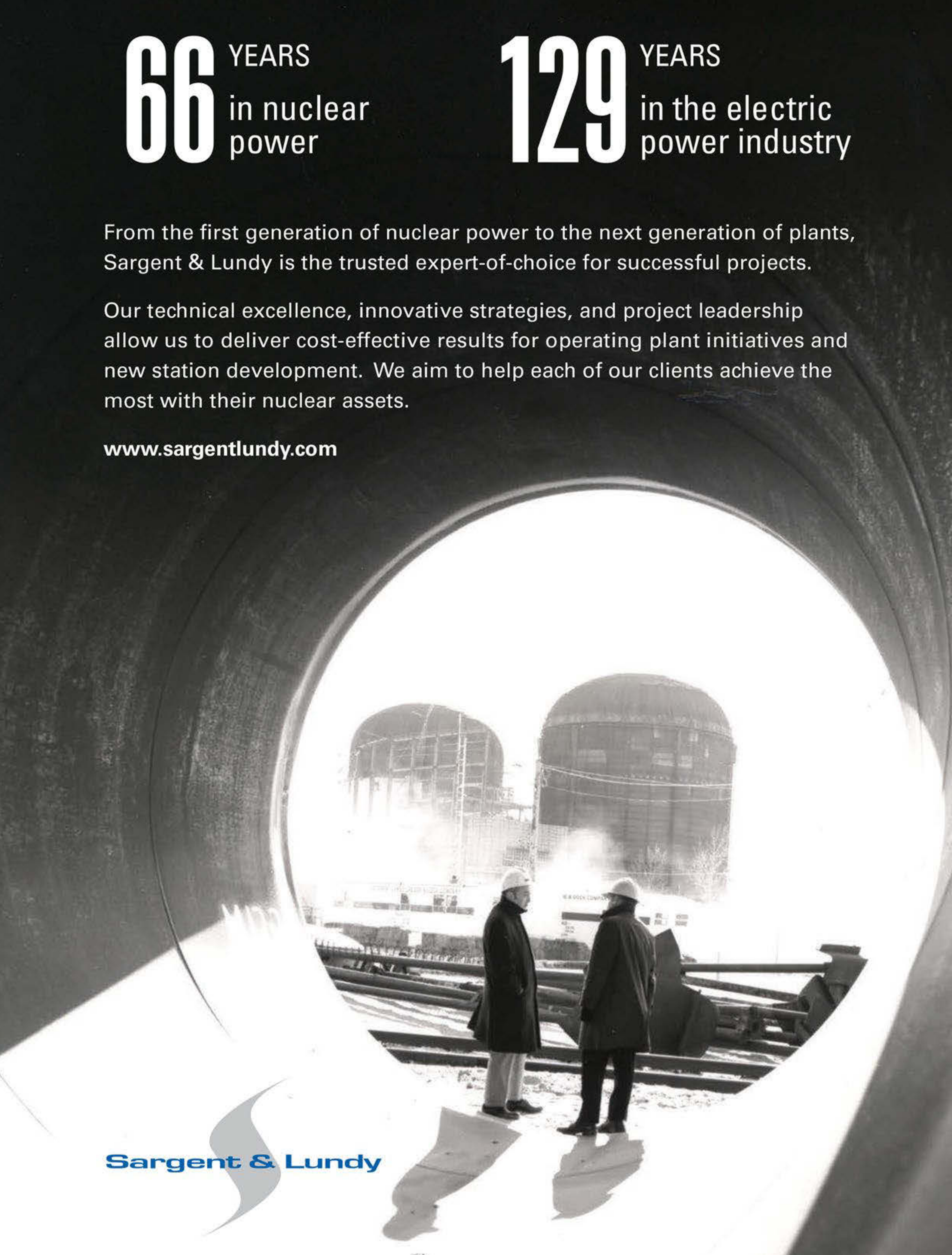
Readers Write is a new section of Nuclear News *that allows readers to comment more fully on a subject than in a letter to the editor. If you have comments on an issue at length, please send them to rmichal@ans.org.*

Fukushima: 10 years on and more

Much has been written on lessons learned from the Fukushima accident. In my opinion, however, the most important lesson learned is the one reported in Lake Barrett's article, "Fukushima Daiichi: 10 years on," in the March 2021 issue of *Nuclear News* (page 26). Barrett wrote: "Early evacuations prior to these [radioactive] releases protected the public. Extensive Japanese and World Health Organization studies have concluded that there were no radiation fatalities, and no observable increases in cancer above the natural variation in baseline rates are anticipated. Unfortunately, the psychosocial effects of the initial evacuation of approximately 160,000 people have been significant."

The unprecedented, powerful tsunami destroyed the Fukushima Daiichi nuclear power reactors, causing the greatest possible damage. What this means is that the worst possible U.S.-type (water-moderated) nuclear power reactor accident did not endanger the public, and the fear of nuclear is unjustified. This is important because nuclear power is an essential component of mitigating global warming. Of importance is the effect that natural gas has on global warming. Natural gas burns clean but produces 50 percent as much CO_2 as coal. In addition, natural gas is approximately 26 times more powerful in causing global warming than CO_2 and, therefore, is a super-potent global warming gas. Natural gas is released into the atmosphere wherever it is produced: when gas pipes break, when there are leaks in the thousands of miles of pipes transporting the gas, in agriculture, and from the ground and sea floor at the North Pole. The large amount of methane (natural gas) leaking at the North Pole may be the reason that it is heating up faster than the rest of the earth.

Readers Write continues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The United States is planning to spend hundreds of billions of dollars building renewable energy electric generators (solar and wind), while at the same time, we are closing nuclear plants and replacing them with natural gas plants. Nuclear power provides baseload electric energy free of global warming gases, whereas renewables are intermittent. The United States accounts for about 12 percent of the world's global warming. As Germany's renewable energy program shows, nature limits our ability to produce more than about 42 percent of our energy with renewables without incurring unacceptably large costs. Thus, the maximum that the United States can do is to reduce the world's global warming by about 5 percent. Spending hundreds of billions of dollars for renewable energy while shutting down nuclear power plants is resulting in economic waste that is draining our economy.

There needs to be support for the Nuclear Energy Institute's position that it is time to revisit regulations and remove roadblocks in order to improve and streamline the operations of our nuclear fleet. For example, the Fukushima tsunami has been used as a reason to add regulations, even though there will never be such an event in the U.S. While we are closing nuclear power plants, China is aggressively committed to a nuclear future.

In 1986, I had the honor of being the first International Atomic Energy Agency expert invited to China to teach the country's nuclear engineers the science of designing nuclear power reactors. At that time, China had no nuclear power plants, just some contours dug into the earth for the two French nuclear power plants that it was planning to build. Today, China is building the strongest nuclear power program in the world, operating 49 large nuclear power plants with plans to get to 76 plants in the near future.

China is also recycling all of its spent fuel (95 percent is reusable), which dramatically reduces the cost of subsequent core reload cycles and waste disposal. At the same time, it is working on plans to build future reactors to use this recycled waste. It should be noted that China is the world's largest producer of CO_2, so any significant reduction of CO_2 will be in the distant future.

While the cleanup costs of the Fukushima accident are enormous, this type of accident could not happen in the United States. Instead, while very unlikely, a U.S. incident would be similar to the Three Mile Island-2 accident wherein no radiation leaked from the containment. The melted fuel in the TMI-2 accident remained in the pressure vessel, preventing extremely large cleanup costs.

During that time, I was appointed by the Nuclear Regulatory Commission to relicense the TMI-2 operators to remove the damaged fuel safely from the pressure vessel. When the operators arrived at Penn State's Breazeale research reactor for relicensing, they were confused by the media's reporting of terrifying death stories. These operators had been only 20 feet from the reactor throughout the accident, and nothing had happened to them. The media and antinukes continue to spread dangerous misinformation, which has had major consequences, including psychosocial effects.

The way to solve the earth's global warming problem is to include nuclear power plants that produce electric energy as cheaply as fossil fuel plants. This is possible if we can get beyond the fear of and misinformation about nuclear power that has been promoted since the TMI-2 accident. The decisions we make today are consequential and will determine how the warming of the earth will proceed.

Samuel H. Levine
Professor emeritus, Nuclear Engineering Department, Penn State University
Director, Breazeale nuclear research reactor, 1968–1986


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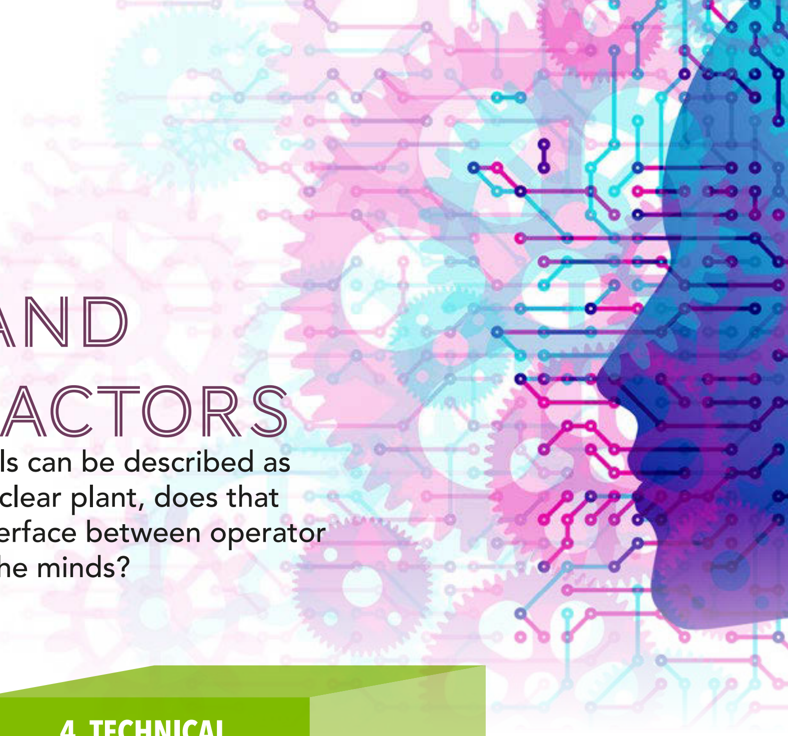


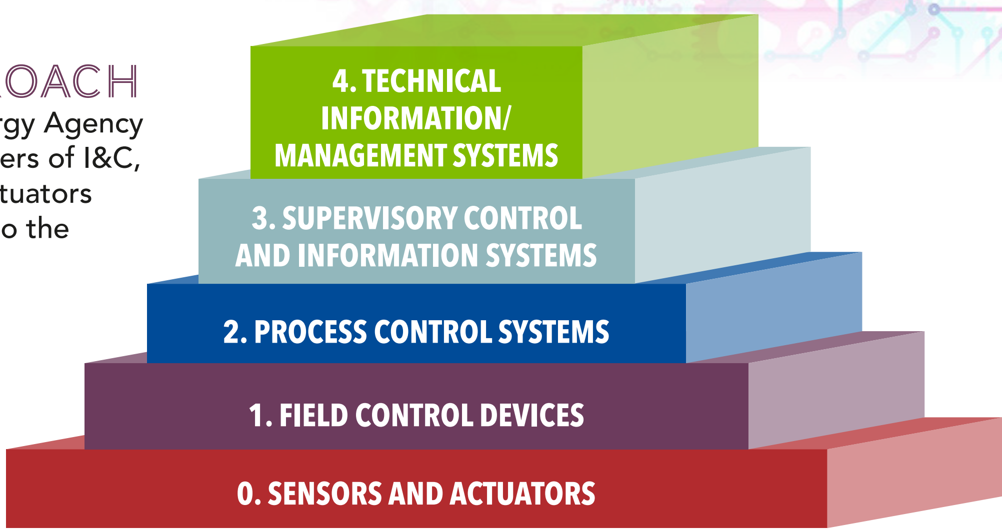
I&C AND HUMAN FACTORS

If instrumentation and controls can be described as the "nervous system" of a nuclear plant, does that make human factors—the interface between operator and machine—a meeting of the minds?

A LAYERED APPROACH

The International Atomic Energy Agency identifies five architectural layers of I&C, from the basic sensors and actuators that interface with a process to the systems and subsystems used for automated processes or for operational and technical management of the plant.

Source: IAEA Nuclear Energy Series No. NR-T-3.31, 2020



WHAT ARE THE OPTIONS?

The Electric Power Research Institute (EPRI) identifies four basic options for nuclear plant I&C modernization while acknowledging that the full range of possible solutions defies easy categorization. EPRI describes the first two options below as "proactive and strategic" while the second two are "more tactical, reactive approaches."

IMPACTS OF I&C MODERNIZATION OPTIONS ON KEY PLANT FACTORS

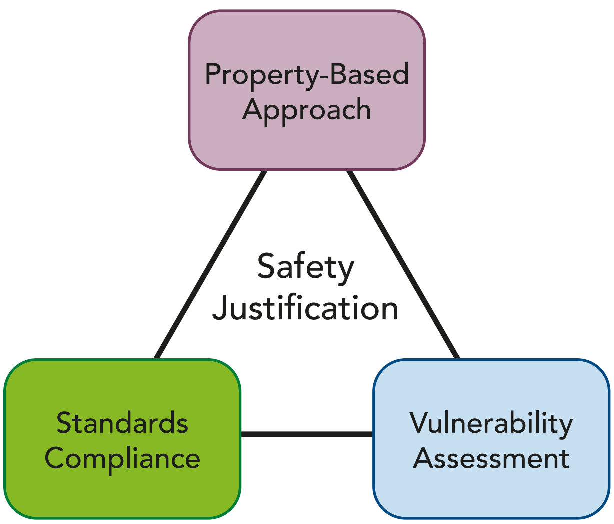
	PRODUCTIVITY IMPROVEMENT	INITIAL INVESTMENT	LONG-TERM MAINTENANCE	PLANT RISKS	PROJECT RISKS
Aggressive strategy	High	High	Low	Medium	High
Resource-constrained strategy	Medium	Medium	Medium	Low	Medium
Tactical upgrades	Low	Low	High	Medium	Medium
Maintain or replace legacy components	None	None	Very high	Very high	Very low

Source: EPRI, 2007 41.05.03 Instrumentation and Control Program, 1015087, Table 2-1

COLOR CODING

According to NUREG-0700, revised by the Nuclear Regulatory Commission in 2020, the number of colors used on nuclear plant control panels should be kept to the minimum needed to provide sufficient information, and once a color is assigned a specific use or meaning, no other color should be used for the same purpose.

Source: U.S. NRC NUREG-0700, Rev. 3, "Human-System Interface Design Review Guidelines"



STRATEGIC ASSESSMENT

How to know if a commercial, off-the-shelf device might suffice? The IAEA proposes a strategy triangle for safety justification that includes a vulnerability assessment (to spot potential weaknesses in hardware or software); a property-based approach (to assess a device's key attributes, including safety, reliability, accuracy, response time, functionality, and human factors/usability); and standards compliance (typically focused on the design, development, and manufacturing of a device).

Source: IAEA Nuclear Energy Series No. NR-T-3.31, 2020

Autonomous operation of small reactors: Economy of automation in lieu of economy of scale

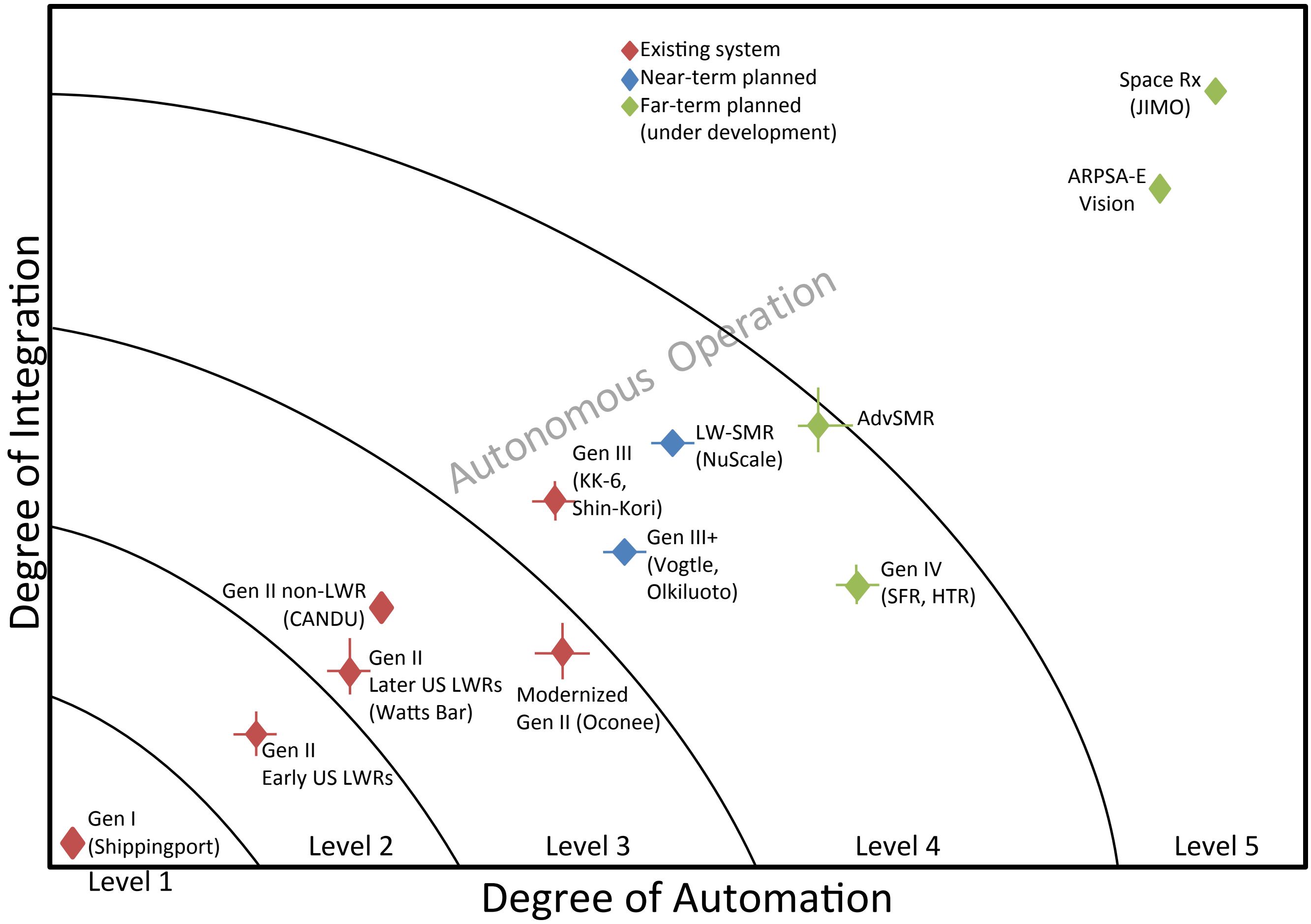
By Richard Wood

As indicated in the April issue of *Nuclear News*, development of advanced reactor concepts heavily emphasizes small modular reactors and microreactors. Promised features, such as capital cost savings, plant system simplification, implementation flexibility, and favorable operational responsiveness with passive safety behavior, all promote small reactors as desirable, non-carbon-emitting power sources to help satisfy future energy needs. In spite of the favorable up-front economics compared to large nuclear reactors, SMRs and microreactors do not provide the benefit of economy of scale that typically compensates for the high staffing demands associated with traditional, labor-intensive operations and maintenance (O&M) practices in the nuclear industry. To avoid the prospect that high staffing levels relative to unit power production will lead to unsustainable O&M costs for small reactors, a significantly higher degree of automation, to the point of near autonomy, is necessary. Essentially, the economy of automation is needed to offset the loss of economy of scale.

Richard Wood is a professor specializing in I&C architectures for advanced reactors in the Department of Nuclear Engineering at the University of Tennessee–Knoxville.

For remotely located small reactors, transportable microreactors, or space reactors, on-site or dedicated human resources may be minimal, intermittent, or even unavailable. Thus, the value proposition of greater autonomy for operation may be more essential for such applications. The nature of control necessary for autonomous or near-autonomous operation of a reactor involves more than automation of routine functions. It implies the detection of conditions and events, determination of appropriate response based on situational awareness, adaptation to unanticipated events or degraded/failed components, and even autonomous reevaluation of operational goals.

To clarify the distinction between automated control and autonomous control, the former involves self-action (*automatos*), while autonomous control involves independent action (*autonomos*). Therefore, autonomous control can be viewed in terms of a spectrum of capabilities, with manual control representing the lowest extreme or baseline of the continuum, automated control representing a range in the middle, and full autonomy (i.e., independent decision making based on embedded intelligence) as the highest endpoint of the continuum. The higher degrees of autonomy are characterized by greater fault management, more embedded planning and objective setting, and even self-healing or adaptation. The realization of full autonomy



involves learning, evolving, and strategizing independent of human interaction or supervision.

Drawing from long-standing involvement in research into autonomous operation of nuclear reactors, the University of Tennessee–Knoxville developed an autonomy chart (above) to illustrate the evolution of operational approaches in the nuclear power industry. The chart shows a scale of increasing automation against a scale of increasing integration (architectural, functional, and informational) to illustrate the progression toward autonomous operation. This chart relates to the impact of automation and integration on efficiency, dependability, and staffing demands arising from O&M activities. It does not address safety given an implicit assumption that protection functions remain independent in the form of automated, unchanging safety systems isolated from the operational systems. It is noted that there are other factors (e.g., passive/inherent dynamic response) that can contribute to the degree of autonomy that can be achieved.

Historically, the initial means of nuclear power plant operation were based on manual control with instrumentation and control architectures composed of point-to-point wiring to field equipment and control rooms consisting of rudimentary displays (strip charts and gauges) and interfaces (switches, knobs, and dials). Level 0 on the autonomy chart is represented by developmental reactors, such as the Graphite Reactor at Oak Ridge, through first-generation plants, such as the demonstration reactor at Shippingport.

Leaders continues

Main control room of the Shippingport Atomic Power Station in Beaver County, Pa. (Photo: Wikimedia Commons)

Level 1 addresses the incorporation of individual instrumentation loops aggregated into "stovepiped" systems. These systems implemented analog control logic for local automation with operational coordination from the control room. This level on the autonomy chart is represented by the early installations of Generation II commercial light water reactor plants.

Level 2 involves introduction of a greater degree of architectural integration to assign more responsibility for basic operational functionality to the machine/system and thereby extend automation to cover most aspects of normal plant operation. The increased automation results in a more supervisory role for operators, while the integration of data enables realization of more comprehensive operator support systems. The later installations of Generation II LWR plants and some non-LWR plants (e.g., CANDU plants) also included introduction of digital I&C technology for monitoring and control (as well as protection), through either initial design or modernization. For example, the Oconee Nuclear Power Station has modernized both its integrated control system and its independent redundant protection systems using digital technology. The transition to this technology facilitates greater integration of information and function while supporting increased automation.

Workers in the control room for Unit 1 of the Barakah nuclear plant, an APR-1400 representative of Level 3 on the autonomy chart. (Photo courtesy of the Embassy of the United Arab Emirates)

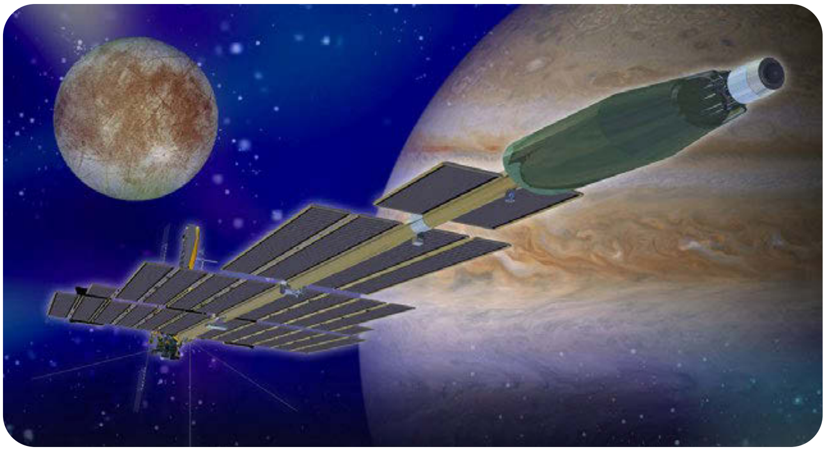
Level 3 on the autonomy chart addresses the current state of the art for I&C architectures, operational automation, and human factors engineering in the nuclear power industry. This level is characterized by a more fully digital I&C architecture, enhanced automation for operational efficiency and investment protection, and more extensive equipment health/condition determination and self-monitoring. Generation III (e.g., ABWR, APR-1400) and III+ (e.g., AP1000, ESBWR) represent Level 3. The extremes of Level 3 are expected to include light water SMRs as well as non-water-cooled advanced SMRs and Generation IV reactor concepts.

Level 4 on the autonomy chart represents the long-term target characterized by minimal, remote (off-site) human supervision. While this level of autonomy is valuable for expanding the applicability and geographical range of terrestrial nuclear power, it is an essential objective for space nuclear applications given the constraints on available human resources and opportunities for immediate intervention. Achieving this goal for nuclear plant operation will require a highly integrated digital I&C architecture that couples control, diagnostic (health and performance monitoring), and decision-making capabilities within a hierarchical functional framework.

So how close are we to realizing near autonomy for nuclear plant operation? Control systems with varying levels of autonomy have been employed in robotic, transportation, spacecraft, and manufacturing applications. However, autonomous control has not been implemented for an operating terrestrial nuclear power plant (or research reactor). The primary gap relates to decision capabilities (e.g., strategic, interpretive, adaptive, predictive). Over the past 30 years, concepts and capabilities for autonomous operation of nuclear power have been investigated through applied research. In the early 1990s, the concept of supervisory control for multiunit nuclear plants was developed under the Department of Energy's Advanced Liquid Metal Reactor program. The functional architecture and capability definition was further developed under the NASA Prometheus program to enable autonomous operation of the nuclear electric propulsion reactor for the unrealized mission of the Jupiter

Icy Moons Orbiter. The DOE has continued development of capabilities that can enable autonomous operation through projects under its Nuclear Energy Enabling Technologies program and its Advanced Reactor Technologies program.

Recently, the DOE has established two Advanced Research Projects Agency–Energy initiatives that involve investigations into autonomous control (MEITNER: Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration) and into digital twin application for transformative O&M enhancement (GEMINA: Generating Electricity Managed by Intelligent Assets). Finally, development of autonomous operation capabilities to support space reactor applications is continuing under the NASA Space Nuclear Propulsion program. It seems likely that space reactors and portable, isolated microreactors are the nuclear power applications that will drive the progression toward greater operational autonomy. Nevertheless, the continued development of autonomous features for control and health management can propagate into more traditional nuclear power applications with the attendant benefit of enhanced economy of automation.



Artist's rendition of NASA's Jupiter Icy Moons Orbiter, which was to be powered by an autonomous fission reactor. (Image: NASA)

Spotlight On . . .

The Utility Working Conference and Vendor Technology Expo

The Utility Working Conference, traditionally held on Amelia Island in Florida, has been an important draw for the nuclear community every year. A combination of plenary and panel sessions, vendor expo, and golf tournament (pairing vendors with utility personnel for a networking event before the work of the conference begins), the UWC has been a highlight for the past 27 years, attracting upwards of 700 attendees and nearly 80 exhibitors.

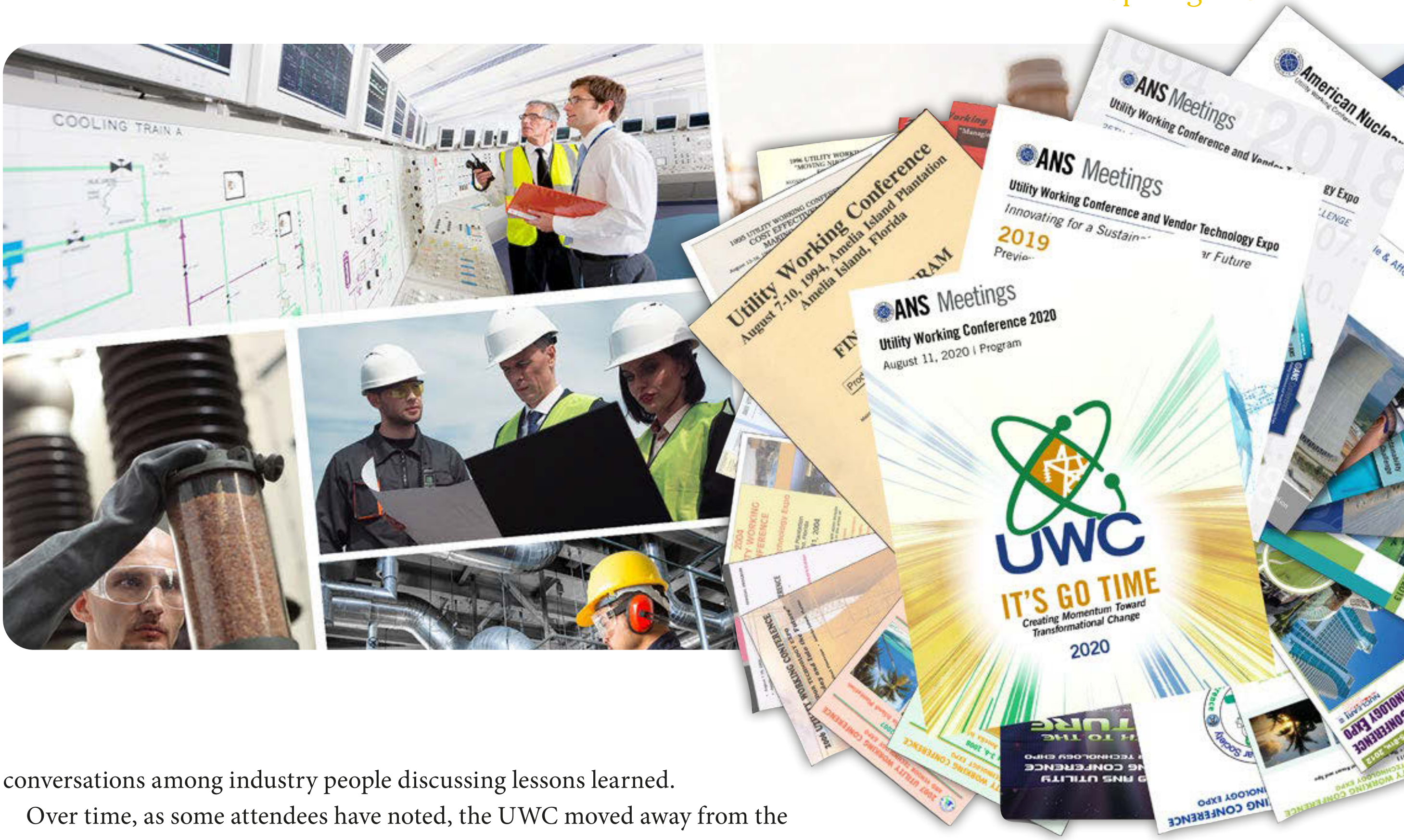
Daniel Churchman, the 2021 UWC technical program cochair, said that over the years the UWC has had excellent plenary session speakers from industry and beyond, including Nuclear Regulatory Commission commissioners who have presented at the last three conferences, as well as senior executives from the Institute of Nuclear Power Operations and the Department of Energy. In addition, speakers from outside the industry have included a retired admiral of the U.S. nuclear navy, a Delta Airlines reliability manager, and motivational/leadership speakers such as David Marquet, author of *Turn the Ship Around*. Churchman noted, "In a technical session, I heard one senior operator say that the conference was the best benchmarking trip he has ever been on."

The first UWC took place in 1994 when the predecessors of ANS's current Operations and Power Division (the Reactor Operations Division and the Power Division) joined forces to launch the inaugural conference. As described in the November 1994 issue of *Nuclear News*, at the time, nuclear power in the United States encompassed 47 utilities operating 109 reactors across the country in four different NRC regions. One issue then facing the industry was the different operating principles among the many utilities, which often meant that there was little in common from one plant to another.

These differences and the lack of knowledge sharing in the industry led to inefficiencies at the individual plants, reflected to a degree by the industry's capacity factor—as discussed in the article "U.S. nuclear capacity factors: Reliable and looking for respect" (*NN*, May 2021, pp. 28–36)—which was around 70 percent in the late 1980s and early 1990s. That general reliability was much lower than what the industry has come to expect in the new millennium, where the U.S. fleet has averaged a capacity factor of around 90 percent since 2000. The current fleet is now so reliable that it produced more carbon-free electricity in 2020 with 94 operating reactors than it did in 1990 with 112 reactors.

As noted in the article "The nexus between safety and operational performance" by Doug True and John Butler of the Nuclear Energy Institute (*NN*, May 2020, pp. 28–36), "Many factors have influenced this performance improvement, including the cultivation of a strong safety and reliability culture by utilities, a strong independent nuclear regulator in the Nuclear Regulatory Commission, an independent industry excellence organization in the Institute of Nuclear Power Operations, and the development and application of risk-informed programs." The UWC, then, is meant to be a forum for industry leaders to discuss best practices and lessons learned in the spirit of these industry-led initiatives.

The very first UWC, in August 1994, was described as "offering more than the traditional meeting format of featured speakers talking from a dais; audience participation through roundtable discussion was encouraged." There were 20 workshops that tended to be interactive sessions with impromptu



conversations among industry people discussing lessons learned.

Over time, as some attendees have noted, the UWC moved away from the interactive format and became more of a traditional meeting, with plenty of PowerPoint presentations in 50 to 70 technical sessions organized into nearly a dozen tracks. While this format has worked well for traditional ANS meetings that include many technical tracks, the spirit of the UWC is to foster discussion among utility members to help work through issues facing the entire U.S. fleet.

The organizers of the 2021 UWC—the first ANS in-person meeting since before the COVID-19 pandemic—have committed to moving back to the original focus of the conference. The refreshed UWC will provide sessions that are open and collaborative, allowing leaders to share experiences and insights and encouraging attendees to bring new perspectives and actionable items back to their work teams. Churchman said that this year's UWC will have five main topics instead of technical tracks. The current topical areas are Supply Chain Challenges and Opportunities, Cost Reduction Opportunities, Alternate Revenue Streams, Workforce Development, and Maintenance/Work Management Challenges and Opportunities.

"The idea is instead of 'death by PowerPoint' to have panels, facilitated discussions, and breakout sessions to address the issues we're facing," Churchman said. "The ultimate goal of the UWC is to allow for utility, supplier, and regulatory leaders to come together across disciplines to network, benchmark, and solve problems."

The UWC has long been held on Amelia Island—with a three-year break along the way when it was held in Hollywood, Fla.—but this year, the conference is being moved farther south to Marco Island. It will still include the popular vendor expo and golf tournament.

"The UWC is a great networking opportunity," Churchman said. "Unlike other conferences, it brings everyone together—utilities, vendors, the NRC, INPO, the DOE, EPRI, and others—from across all functional areas. I've established contacts and made friends that I've called on many times. There is no other conference like it."

Make plans to attend the 2021 ANS UWC. For more information and updates to the program, visit the official UWC web page at www.ans.org/meetings/uwc2021.

Rewriting the script: The real story of advanced reactors

By Susan Gallier

At the box office or streaming at home, it's fear, not truth, that sells. The laws of physics are swept aside, apocalypse is inevitable, and superpowered heroes wait until the last possible second to save the universe. It can make for great entertainment, but in the real world we need to stick with science over science fiction and be wowed by engineering, not special effects.

The truth is, science and innovation are incredible in their own right. From communications and machine learning to space travel and medical advances, technology is evolving in hyperdrive to solve real problems. With climate change and global warming here on earth, we don't have to go looking for trouble in a galaxy far, far away.

New momentum

People who are serious about fighting climate change know that the status quo is not enough. They acknowledge that low-carbon nuclear energy is necessary to reach climate goals and ensure the sustainability, reliability, and security of the world's energy supply.

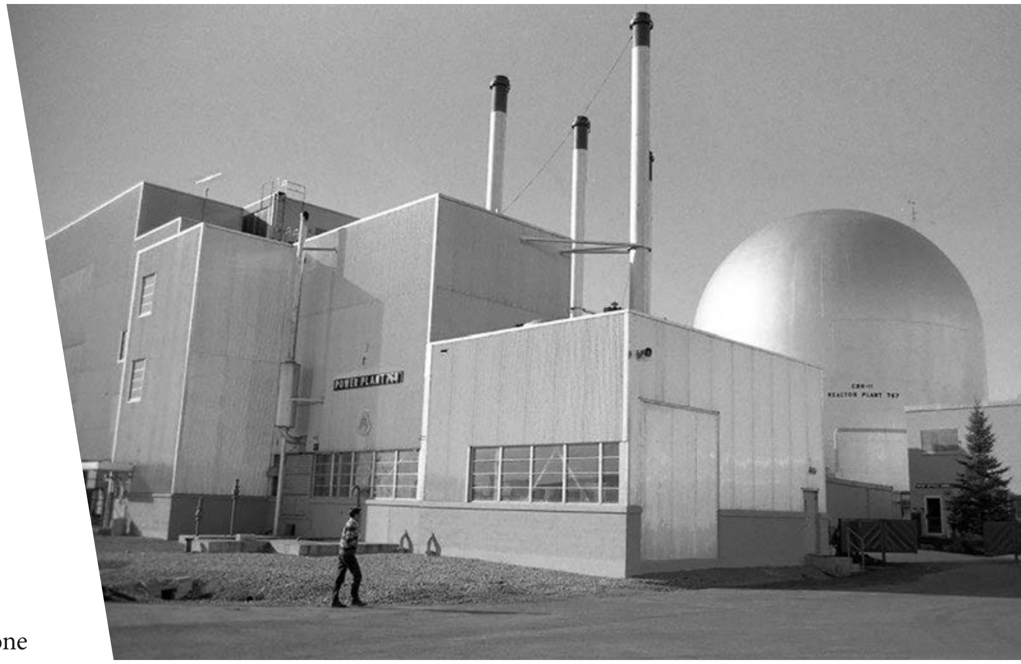
There is momentum to deploy advanced non-light water reactors alongside operating reactors and planned small modular reactors. Today, a phone has more computing power than a 1980s mainframe, and advanced nuclear technology can pack more power into a smaller reactor, potentially yielding advantages in cost, sustainability, and reliability. Policymakers have taken bold bipartisan steps to empower the United States to build advanced reactors—and not watch as other countries lead the way.

Given this rapid progress, many people have questions. Those looking for reliable information may instead find sensationalism masquerading as objectivity. Subtle misinformation, designed to encourage doubt and delay, can tap into our natural fear of the unknown. Advanced reactors, some have claimed, are at risk of taking the scriptwriter's cue by melting down, exploding, or throwing open the door to weapons proliferation. Should we be concerned? Are advanced reactors about to doom or save the world? Or could they simply be a savvy piece of engineering designed to address one of the planet's most pressing problems?

Proven performance

The best advocates for advanced reactors may be today's reactors. The United States currently has the largest nuclear power fleet in the world—93 light water reactors that provide about 20 percent of the nation's electricity and more than 50 percent of its low-carbon generation. In fact, nuclear plants generated more electricity than coal-fired plants in 2020, becoming the second-largest source of electricity in the United States after gas-fired plants. These reactors are not only safe—they are saving us from greenhouse gas emissions, including more than 50 million metric tons of CO_2 emissions each year.

LWRs are backed by decades of testing and operating experience, but there is a growing appreciation for the potential of other reactor technologies to address the challenges of the 21st century. Both LWRs and non-LWRs are benefiting from advances in materials science, computational modeling, real-time online instrumentation, digital twins, and denser, more efficient high-assay low-enriched uranium (HALEU) fuels. Uranium enriched to the HALEU level, between 5 and 20 percent uranium-235, packs more fissile material in a smaller volume of fuel than low-enriched uranium of less than 5 percent enrichment. That can mean less used fuel for each megawatt of electricity generated.



The EBR-II sodium fast reactor at Idaho National Laboratory began operations in 1964 and generated electricity for decades. Soon it will serve as a National Reactor Innovation Center test bed for future advanced reactor demonstrations. (Source: ANL)

Advantages by design

Many, but not all, non-LWRs fall into one of three categories: liquid metal fast reactors, high-temperature gas reactors, and molten salt reactors. While no two designs are alike, many advanced reactors offer similar advantages, which may include:

- Improved heat transfer efficiency from the use of coolants other than water.
- Scalability to different sizes, including modular, factory-built construction.
- Higher enrichment, which means increased fuel efficiency.
- Operations at or near atmospheric pressure that don't require a high-pressure containment, so structures can be smaller.
- Passive safety systems that rely on thermal expansion and other fundamental properties of physics and chemistry and don't require a backup power supply or human intervention to work.
- On line refueling to avoid the need for refueling outages.
- Higher operating temperatures well-suited to process heat applications, including low-carbon manufacturing of hydrogen, steel, and cement.
- Flexibility to adapt to rapid changes in energy demand on the electricity grid.
- Safeguards incorporated into the reactor at the design stage.

Sodium fast reactors

Most liquid metal fast reactors employ sodium, the sixth most abundant element on the planet, as a coolant. Sodium is 100 times more effective at transferring heat than water. As a noncorrosive liquid metal at operating temperatures of about 500°C and atmospheric pressure, sodium is used both in a sodium fast reactor (SFR) core and in a sealed coolant system. The temperature of the sodium pairs well with molten salt heat storage systems, which can give operators flexibility to meet grid demands.

Fast reactors don't slow down neutrons with moderators, so each fission reaction can release more high-energy neutrons that can be employed to break down waste products into elements with shorter half-lives. This means that fast reactors can be used to recycle used fuel, limiting or reducing waste.

Advances in materials science are guiding the selection of fuels, cladding, and structural materials to improve on the demonstrated safety of the Experimental Breeder Reactor-II (EBR-II), an SFR that operated for more than three decades. Research has focused on both active and passive safety systems that shut down a reactor if temperatures rise and that remove residual heat from the decay of short-lived radioisotopes.

A Critical Look continues

High-temperature gas reactors

Gas-cooled reactors have operated successfully in the United Kingdom for decades, and several high-temperature gas-cooled reactors (HTGRs) have been operated worldwide. Advanced HTGRs are thermal reactors that use TRISO (TRIstructural ISOtropic) coated fuel particles embedded in a graphite moderator, which does not melt and retains its strength at temperatures far above the highest postulated HTGR operating or transient temperatures. TRISO can be used in fuel manufactured in different shapes and sizes—including spheres the size of golf balls or tennis balls. Together, the TRISO particles and the graphite that surrounds them serve to contain fission products.

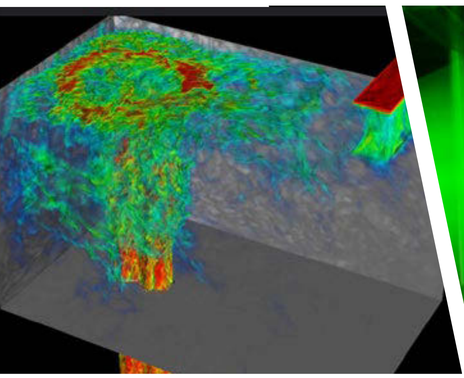
Circulating through an HTGR is nonreactive helium gas at temperatures of about 750–900°C. HTGRs can produce and maintain high-quality steam for commercial and industrial end users, and at higher temperatures than fossil-fired plants.

Molten salt reactors

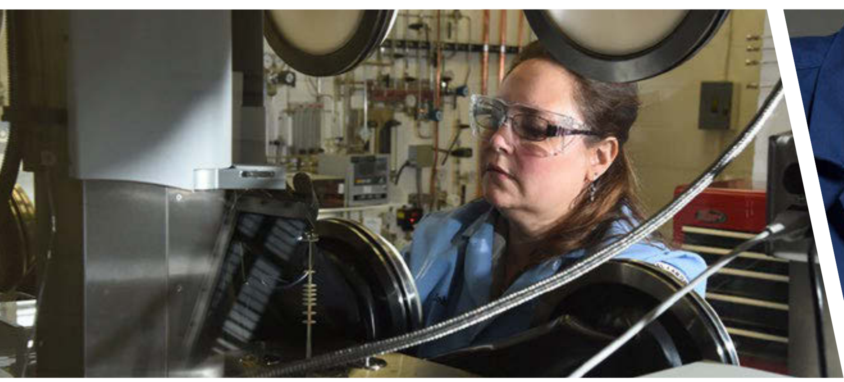
Chloride and fluoride salts become transparent liquids at the operating temperatures of molten salt reactors (MSRs) and, in some cases, serve as both the coolant and the fuel carrier. The fuel—which could include a mix of thorium and uranium or reactor-grade plutonium recycled from LWR fuel—can be dissolved in the circulating molten salt. Like SFRs, MSRs can operate in the fast spectrum to potentially reduce waste stores and allow for more efficient fuel use than LWRs.

Dissolved MSR fuel has no solid structure and cannot sustain structural damage. As fission heat increases the temperature of the reactor, it also causes the salt mixture to expand, moving the fissile fuel nuclei farther apart and passively slowing the fission chain reaction.

As coolant flows through an MSR, it is routed through a processing system to filter out gaseous byproducts of the fission reaction. Current research is focused on structural materials, the thermophysical and thermochemical properties of fuel salts, corrosion mitigation strategies, and modeling tools for radionuclide tracking.



Clockwise from top left: model of reactor coolant flow in an advanced reactor; fluid dynamics research at Argonne National Laboratory; high-temperature thermocouple research at Idaho National Laboratory; post-irradiation examination of advanced fuels at INL. (Sources: ANL, ANL, INL, INL)



Preparing for deployment

The U.S. Nuclear Regulatory Commission is the gold standard for nuclear regulation worldwide and is committed to ensuring the safety of any nuclear reactor undergoing licensing in the United States. Other countries will be looking to the United States as a model while the NRC, backed by years of preparation, new experimental data, and a congressional mandate, determines what information is necessary to license advanced reactors. Demonstrating the overall safety case for a reactor through modeling, testing, and operating experience is the license applicant's responsibility, and it is in the applicant's best interest to submit a thorough application that stands up to the NRC's review and helps make the financing case for the reactor.

The NRC is taking a technology-neutral, risk-informed, and performance-based approach to building a licensing framework that will provide effective and efficient regulation of advanced reactor designs. As part of a rigorous application review, the NRC staff will review probabilistic risk assessments, pose questions, gather public feedback, and post documents for public review. Public meetings give members of the public a chance not only to get information, but also to question the NRC's approach. Some have suggested, for example, that the lack of a clear determination on whether prototype testing will be required before a reactor is licensed constitutes a serious safety issue.

What is to be made of such ominous but credible-sounding concerns? It is important to acknowledge that the NRC cannot make determinations on prototyping for a specific design until a license application is submitted for review. Existing regulations clearly state that special testing and protective provisions may be required for the initial unit of a new reactor type for a limited period, which gives the NRC the

A Critical Look continues

authority it needs to require special provisions for the operation of first-of-a-kind demonstrations, according to the needs of a particular design or license application. That is consistent not only with past deployments of new types of LWRs, but also with good engineering practice.

Fuel cycle security

Some worry that advanced reactors, or the technologies that support them, could lead to proliferation—the potential spread of sensitive material or technology to groups seeking to obtain nuclear weapons. If sensational action dramas are any guide, power plants are sitting targets for plunder by terrorists. But there's a reason they make it look so easy. If TV terrorists had to deal with the actual security and safeguards in place at nuclear facilities, the plot would grind to a halt.

Questions about proliferation and advanced reactors generally involve either HALEU or reprocessing. While it is a great fuel, HALEU is impractical for direct use in nuclear weapons. Even if a group seeking a nuclear weapon were to obtain HALEU, it would need to go through a series of technically challenging steps to construct a nuclear weapon—the same steps that would be required if starting with natural uranium or LEU.

Reprocessing involves separating used nuclear fuel into its constituent materials—including plutonium—for reuse as fuel while concentrating radioactive by-products for efficient disposal. Other countries have safely operated reprocessing facilities for decades under International Atomic Energy Agency safeguards without any instances of theft or diversion of nuclear material.

Making realistic assessments of potential proliferation pathways and addressing those concerns during the design phase—a process called safeguards by design—will improve the fundamental proliferation resistance of any reactor.

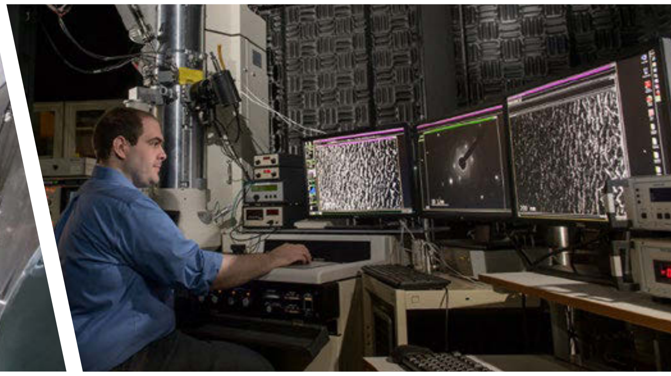
Engineering the grid

No low-carbon technology that may help us reach our climate goals should be lightly dismissed. All positive and negative aspects of every energy source should be assessed so that end users are empowered to select the energy technology that will best meet a given situation. Reducing carbon emissions will be difficult, but giving up in the face of a challenge is not a path to success. Instead, any challenge is an open invitation to engineer a solution.

The sun grows crops, water quenches thirst, wind fills a sail, and all can be used to generate electricity, too, thanks to engineering. The natural energy of the atom can be used to diagnose and treat cancers and to generate electricity around the clock. Thanks to engineers, technologies are available to safely store, transport, recycle, and dispose of nuclear waste. Engineering will no doubt also be used to mitigate the significant life cycle impacts of the manufacture and disposal of wind turbine blades, solar panels, and the utility-scale batteries that may be deployed nearby.

All low-carbon technologies are needed, but solar and wind installations are weather and time dependent, and they simply cannot generate electricity 24/7. Nuclear fission knows no season. The inherent energy density of nuclear power means that nuclear plants have not only a small carbon footprint, but also a smaller land footprint. According to the Nuclear Energy Institute, to generate the same amount of electricity as a 1-gigawatt LWR sited on one square mile of land, a wind installation would require 360 times as much land, and a solar photovoltaic installation would require 75 times as much. Both would also require a massive grid infrastructure buildout to deliver electricity to populous areas.

Advanced nuclear plants—in sizes that range from the footprint of a fast-food restaurant to an industrial factory—could be located close to the people they serve, often on the site of an old coal or gas plant, where they could connect to the grid using existing transmission lines and could even offer employment to former fossil-plant workers.



Clockwise from top left: advanced reactor passive safety research at Argonne National Laboratory; advanced fuels research at ANL; Idaho National Laboratory's Human Systems Simulation lab. (Sources: ANL, ANL, INL)

Ready to build

The two companies chosen to build cost-shared reactor demonstrations by 2027 through the Department of Energy's Advanced Reactor Demonstration Program (ARDP)—TerraPower and X-energy—are working with Energy Northwest, an experienced nuclear operator in Washington state. By state law, Washington must reach 100 percent carbon-free electricity by 2045. Energy Northwest signed on to the ARDP projects after commissioning a study that showed decarbonization through renewables alone would be prohibitively expensive.

The ARDP teams are responsible for preparing license applications, determining the best construction methods, and demonstrating a safety case to the NRC, but they are not alone. They are backed by decades of ongoing research at national laboratories and universities and by DOE programs such as the Gateway for Accelerated Innovation in Nuclear and the National Reactor Innovation Center.

Other nuclear technology companies are drawing on many of the same resources as they develop their own advanced reactor designs for deployment in this decade or the next. Some designs will not prove to be viable in the future energy marketplace, but innovation and competition can point the way to success.

Into the future

Unless someone can figure out how to build a plutonium-powered time machine from a DeLorean, there will not be a second chance to tackle carbon emissions in this decade. That's why it is critical that advanced reactors receive consistent support, now and into the future.

The epic battle we need to be fighting is for a sustainable, reliable, and secure long-term energy supply. The people of the nuclear community are real-life heroes in that fight to build a clean energy future for generations to come. That's a happy ending we can all get behind.

Susan Gallier is a Nuclear News *staff writer focusing on nuclear technology research and applications.*

Nuclear *Trending*

Kadambi presents ANS comments on advanced reactors rulemaking to NRC/ACRS


Kadambi

N. Prasad Kadambi, ANS member since 1972 and principal of Kadambi Engineering Consultants, recently presented comments on behalf of ANS to the Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards (ACRS). Kadambi spoke regarding the proposed 10 CFR Part 53, which addresses rulemaking for a technology-inclusive, risk-informed, performance-based regulatory framework for advanced reactors. Kadambi's presentation reiterated what ANS leadership included in a March 3 letter to the NRC on the subject.

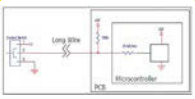
"ANS members have a great deal of interest in advanced reactors," Kadambi said. "It is important for ANS to offer [members] opportunities to participate in formulating the 'rules of the road' in this vital rulemaking."

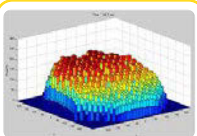
In addition to wanting a seat at the table, Kadambi stated four other main points:

- ANS has a special interest in promoting and modernizing its consensus standards addressing safety topics supporting advanced reactors.
- ANS supports a holistic formulation of safety moving away from the existing fragmented consideration of technical topics, disjointed treatment of major phases of a project, and inefficient management of safety margins.
- ANS wants to see the NRC learning from the experiences with 10 CFR Parts 50 and 52 in structuring requirements within Part 53.
- ANS is leading in the effort to move away from prescription of safety criteria toward performance-based approaches that offer more flexibility for innovation and incentives for improved outcomes. Part 53 should reflect this work.

Nuclear Notables—A human factors and I&C timeline


March/April 1979
Noise analysis is used to monitor the dispersion of a hydrogen bubble in the TMI-2 core.

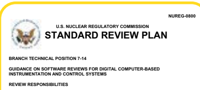

1984
Digital technology for safety systems–SPIN (Système de Protection Intégré Numérique, or Integrated Digital Protection System) is first put into service in France. SPIN has been deployed in 20 units.


June 1984
10 CFR 50.62 formalizes requirements for reduction of risk from anticipated transient without scram (ATWS) events for light water reactors, incorporating diversity in reactor trip systems.

NPIC HMIT

April 1993
First ANS International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies (NPIC&HMIT) is held in Oak Ridge, Tenn.

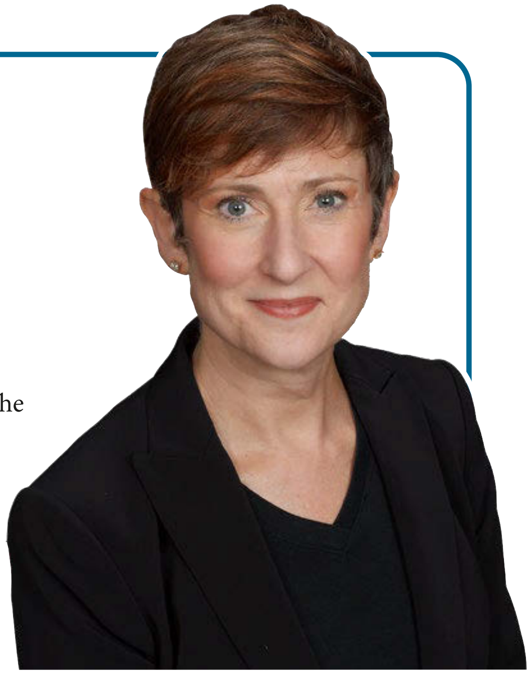

July 1993
Common-cause failure/diversity and defense-in-depth guidance (SECY-93-087) is established.



1997
Guidance on software quality assurance (Standard Review Plan, chapter 7, Branch Technical Position 7-14, and Regulatory Guides 1.168–1.172) is developed.

1980 1990 2000

The criminalization of nuclear



Mary Lou Dunzik-Gougar
president@ans.org

Nuclear energy is the cleanest, safest, densest, and most reliable energy source. The value proposition for nuclear energy is unparalleled. It is the only commercially proven, "dispatchable" clean energy technology that can be scaled up fast enough to meet the demand for electricity in a decarbonizing scenario. It is the answer for governments and nongovernmental organizations worldwide that are clamoring for a reduction in human-generated CO_2 emissions. Humans flourish when they have access to plentiful, safe, and reliable energy. Nuclear excels at all of these.

Unfortunately, nuclear energy is also the most regulated source, thanks, in part, to an unfounded fear of radiation and resulting regulation based on the linear no-threshold (LNT) hypothesis. It is time to end the war on nuclear energy, starting with how we think about radiation. Crafted in the early days of the Cold War, the outdated LNT model supposes that all radiation poses a deadly risk, and thus, any radiation dose is harmful. This claim, however, is scientifically unsubstantiated at all but very high doses.

Under the LNT, the regulated dose limit to the public from nuclear power must be less than 100 millirem per year. According to the National Council on Radiation Protection and Measurements, however, the average American receives a radiation dose of 620 mrem/year. The natural environment and medical procedures contribute 98 percent of this annual dosage. Nuclear power contributes less than 0.1 percent. Under the LNT, significant resources go into getting doses lower than the surrounding natural background. This adds considerable expense to nuclear operations without any added benefit.

Much of the LNT's regulatory burden is due to a misinterpretation of the ALARA principle, which urges us to make doses "as low as reasonably achievable." Rather than optimizing safety, as originally intended by ALARA, LNT-based regulation focuses on minimizing exposure. Nuclear energy has had a far less negative impact on the environment than any other energy source while at the same time enabling more humans to flourish within in a limited space. A typical 1,000-MWe nuclear plant requires roughly a square mile of land. Wind turbines would require 360 times more land to produce the same amount of electricity.

Finally, nuclear produces less waste than any other energy source. Nuclear generation is emissions free, avoiding more pollution per megawatt-hour than other sources, thanks to its energy density and superior capacity factor. Nuclear energy also has the lowest life cycle emissions among all energy sources, including renewables, which require more energy usage for mining, component production, and transport.

According to Danish economist Bjørn Lomborg, atmospheric CO_2 concentrations increased from about 305 parts per million to more than 400 ppm from 1920 to 2017, while global average temperatures increased by about 1°C. Yet, worldwide, the individual risk of dying from climate-related disasters declined by 99 percent, mostly in countries with increasingly adequate supplies of electricity, much of which is nuclear generated.

So, rather than focusing on a proxy goal of eliminating CO_2 emissions with the hope of eliminating variations in a geophysically dynamic climate, perhaps the focus should be on decriminalizing nuclear and getting sufficient power to those who need it.

MLDG

Nuclear Trending continues

The New Republican podcast features ANS policy guru John Starkey


Starkey

ANS government relations director John Starkey was a recent guest on the podcast *The New Republican*. Starkey discussed a range of topics with podcast host Lincoln Wallis in the 30-minute episode, "All Things Nuclear."

"In 2020, nuclear energy became the second-largest source of electricity in the United States," Starkey said in response to Wallis's first question, adding, "That would entail nearly 20 percent of electric generation in the U.S. Nuclear energy has also operated at 90 percent capacity rate for the past 20 years or so. No other source of electricity can touch those [capacity] numbers. . . . I really see [nuclear energy] being a leader in decarbonization in the country and the world."

Wallis and Starkey packed a lot into a relatively short time. Much of the conversation dealt with topics surrounding waste management and radiation—a pair of nuclear's biggest obstacles in winning over the general public. The two also discussed nuclear's role in the Biden administration, including its inclusion in a section of the Build Back Better initiative. In addition, Starkey mentioned the CLEAN Future Act, a provision of which includes the Department of Energy entering at least one long-term power purchase agreement with an advanced nuclear reactor.

To listen to the full interview, find *The New Republican* wherever you get your podcasts and search for the March 31, 2021, episode.

LETTER FROM THE CEO

Is nuclear finally getting the credit it deserves?

Craig Piercy
cpiercy@ans.org

“Prejudice” is a word we hear often these days. The dictionary defines it as a “preconceived opinion that is not based on reason or actual experience.” In our current public discourse on race and gender, prejudice hangs in the air like a persistent fog that obscures the path to real progress. But prejudice is also a much broader societal phenomenon—our caveman brains are constantly looking for quick shortcuts (which psychologists call heuristics) to make sense of the world, which often leads us to conclusions that are outdated, unfair, or just plain wrong.

Nuclear technology has been subjected to more than its share of prejudiced thinking over the years. If you are a member of the nuclear community, you know what it feels like. Sometimes it can be a palpable experience, say, when confronting opponents of nuclear technology in a public forum. Other times, it can be more nuanced—a quizzical look at a cocktail party when you respond to the question, “What do you do?”

Subtle or not, this kind of thinking eventually gets baked into our public policies. Nuclear plants are consistently held to a much higher public health and safety standard than any other form of energy generation, even while studies have consistently shown that on a strict “deaths per megawatt-hour generated” basis, nuclear is the safest form of energy available. Or in medicine, consider the gamma knife, a type of stereotactic radiosurgery. It is unparalleled in its accuracy to target very small tumors and malformations in the brain without damaging surrounding gray matter; however, this technology often finds itself at a market-based disadvantage against less precise linear accelerator systems, which are not regulated by the Nuclear Regulatory Commission.

Perhaps the most impactful instance of prejudicial thinking about nuclear exists in policies that determine the sustainability, or “green-ness” of particular energy sources. These classifications are critically important for the future of nuclear, because they will guide trillions of dollars of public and private investment in clean energy over the next 20 to 30 years. We’ve seen some promising developments as of late. Last June, the U.S. International Development Finance Corporation agreed to change its Environmental and Social Policy and Procedures to enable the support of nuclear power projects. This will help U.S. nuclear vendors get the financial assurances they need to engage in overseas projects.

The European Union seems to have taken a step forward with acknowledging that nuclear is sustainable under its energy Taxonomy on Sustainable Finance. Of course, the EU being the EU, the process is complicated. Initially, the inclusion of nuclear was subjected to so much political wrangling among member nations that the European Commission appointed the Joint Research Centre (JRC), its in-house technical body, to make an independent determination as to whether nuclear energy is sustainable. The JRC did exactly that in March, noting that its “analyses did not reveal any science-based evidence that nuclear energy does more harm to human health or to the environment than other electricity production technologies already included in the Taxonomy as activities supporting climate change mitigation.” However, two other expert groups must first review the JRC report before it goes back to the Commission, likely in the second half of 2021. Whatever decision the Commission makes, its impacts will be felt far beyond Europe, as it will set the tone of for the 26th UN Climate Change Conference of the Parties (COP26), which is scheduled to convene in Glasgow, Scotland, on November 1.

We still have a lot of prejudiced thinking to overcome, both in the United States and abroad, if we want to be successful in applying this wonderful technology for the maximum benefit of humanity. With recent momentum in Europe and domestically, however, nuclear may just be starting to get the credit it deserves.

Nuclear I&C Modernization: The Future is Digital

Robert Ammon, Technical Director of Digital Safety Systems at Curtiss-Wright Nuclear Division

As the U.S. nuclear industry moves into plant life extension and subsequent license renewals, the modernization of safety instrumentation and control (I&C) systems holds significant potential to transform plant operations. Automated system diagnostics, equipment health monitoring, and performance indications reduce the need for manual surveillance activities and enable condition-based maintenance, resulting in improved system reliability and reduced maintenance costs. Despite these benefits, adoption of digital I&C systems for safety-related applications across the domestic nuclear fleet has been slow. U.S. nuclear power plants that do choose to embrace the transition from analog to digital are in good company; international plants have successfully implemented digital safety systems for more than a decade. Furthermore, digital safety systems are also the first choice of the growing small modular reactor (SMR) and advanced reactor (AR) communities.

Why digital I&C?

The benefits of this digital transition are numerous. The flexibility of digital I&C technology – coupled with the higher capacity of its modular equipment – allows plants to implement enhanced digital I&C architectures that can increase reliability and availability, simplify maintenance and testing, eliminate failure vulnerabilities in the current system designs, and reduce the number of hardware components in existing I&C systems by up to 80%. Further, replacing analog with digital also supports long-term plant modernization objectives by resolving numerous parts obsolescence issues – an industry-wide challenge.

Digital I&C functionality provides plant operators with the ability to automate operations and reduce maintenance, ultimately resulting in lower maintenance costs. Self-testing, diagnostic, and monitoring features enable early detection of problems, simpler troubleshooting, and shorter repair times; these improvements lead to a corresponding increase in I&C system availability. By reducing direct maintenance efforts dedicated to I&C systems, plant personnel can focus on other critical tasks – improving the plant's overall workforce utilization.

By implementing digital I&C technology, nuclear power plants can improve system reliability and streamline operations while lowering maintenance costs and supporting industry modernization and plant life extension initiatives. Simply put, digital I&C can enable the transformation and modernization of plant operations.

Digital I&C Modernization in Operating Reactors

Safety-related I&C design for existing nuclear power plants is complex. The plants' non-passive designs require numerous redundant safety systems, equipment, and operating procedures; all incorporated into the plant's design basis. As a result, upgrading an existing plant's I&C systems is complex, time-consuming, and expensive. Consequently, Safety I&C modernization projects have evolved to varied scope and scale depending on a plant's individual needs and existing challenges.

• *Tactical I&C System Replacement:* These projects focus on replacement of a single protection or control system with digital I&C technology, typically to address maintenance and/or obsolescence concerns.

• *Limited-Scope I&C System Modernization:* This type of project expands upon Tactical I&C System Replacement by addressing obsolescence in multiple systems. This approach involves increased utilization of the digital platform to improve plant monitoring and diagnostic capabilities.

• *Large-Scope Modernization:* This broad-reaching modernization approach extends beyond Limited-Scope I&C System Modernization to implement a control system architecture that enables the transformation of the plant's operations and supports the workforce of tomorrow.

Tactical I&C System Replacement and Limited-Scope I&C System Modernization projects address obsolescence in single or multiple systems and provide synergy to aggregate data collection and provide integrated system monitoring and diagnostic displays. Large-Scope Modernization projects take a comprehensive approach to digital I&C implementation and establish a broader framework for automation that reduces human error, increases visibility of plant activity, and leverages digital technology to simplify plant operations for the next generation of the nuclear workforce. Early involvement and collaboration with stakeholders from across the plant's operations – including operations, engineering, maintenance, and licensing – is critical for Large-Scope Modernization projects to ensure that upgraded I&C technology is not only compatible with existing systems, but also supports plant-wide strategies and objectives.

For existing plants to operate long into the future, they must become digital. Existing systems are expensive and lack the features needed to transform operations. The good news is that the solutions are available, and the industry is poised to move forward.

Digital I&C in New Reactor Designs

There are currently dozens of small modular reactor and advanced reactor designs in development. For these plants, the future is now; they will be digital from day one. SMRs and ARs differ significantly from existing nuclear power plants and will require different digital I&C platform designs. These plants have passive safety features that open the door to more flexible I&C platforms with larger safety margins and simpler designs. The passive safety designs of SMRs and ARs require fewer automatic actuation functions with no automatic control or required operator actions. There is no need for active monitoring of critical plant safety functions to support near-term operator actions or emergency planning decisions. New reactor designs may have fewer regulatory requirements for safety-related support systems for I&C equipment used

to mitigate design basis events, as mission times for these safety-related functions may be short and require no long-term occupancy to perform safety functions.

Despite their differences from operating reactors, the current work in SMR and AR development will benefit the digital I&C modernization of the existing nuclear power plant fleet. These new designs will encourage the development and adoption of new digital I&C platforms and applications. They will increase industry experience and comfort with digital I&C solutions. They will improve workforce knowledge and expand the number of workers with the needed skills and knowledge. Ultimately, this will reduce the risks and costs associated with modernization projects.

For Nuclear I&C Modernization, the future is digital and the future is now.

About Curtiss-Wright

As a systems integrator, Curtiss-Wright brings together the best available hardware and software components for each project. Curtiss-Wright has partnered with Radics, LLC—an international nuclear engineering company specializing in advanced, customized safety I&C solutions—to bring the RadICS digital instrumentation platform to the U.S. nuclear power market. The RadICS I&C technology is currently deployed in more than 100 safety systems in nuclear power plants in Europe and South America.

The RadICS platform forms the basis of Curtiss-Wright's NRC-approved Digital Safety System, a functionally and technologically diverse replacement for analog and digital safety-related systems at nuclear power plants throughout the United States. The July 31, 2019 U.S. Nuclear Regulatory Commission approval of the RadICS I&C platform for use in safety-related systems in nuclear power plants paves the way for this technology at U.S. nuclear power plants.

Pandemic-delayed ANS Student Conference goes virtual

North Carolina State University hosted the 2021 ANS Student Conference, April 8–10. After the 2020 event was canceled due to the coronavirus pandemic, the 2021 conference was held virtually for the first time. Nearly 600 attended the event, which featured more than 100 papers, 35 career fair booths, and some very popular virtual socials such as Trivia Night. All of the conference's plenary and technical sessions are available for registered attendees to view online (ans.org/meetings).

Trivedi

"It was truly a delight seeing this event come together after two years of planning," said Ishita Trivedi, the general chair and a Ph.D. candidate in nuclear engineering at NCSU. "I am very proud of my team, who put in a lot of hard work toward this event. Overall, it was an excellent conference experience."

The organizers' efforts were noted and appreciated by ANS leaders. "Obviously, we all hoped we could be meeting in person, but the virtual agenda that was created is very impressive," ANS President Mary Lou Dunzik-Gougar said in her opening remarks on April 8.

With the theme of "Enlighten, Embrace, Empower," the conference began with an opening plenary session that focused on the current outlook for nuclear energy. The keynote speakers were Heather Feldman, director of nuclear innovation at the Electric Power Research Institute (EPRI); Tanya Hamilton, senior vice president of nuclear corporate for Duke Energy; and Tatiana Ivanova, deputy head of the Division of Nuclear Science at the OECD Nuclear Energy Agency (NEA).

Dunzik-Gougar told attendees to find—and tell—their unique stories so they can act as nuclear science ambassadors whenever the topic comes up. "I just want you to never underestimate the power of your voices," she said. "Even in everyday conversations, recognize that who you are and what you do tells a story. It's through stories that people get impressions about things. When we talk to people outside our nuclear echo chamber, we can tell stories rather than cite statistics. I encourage you all to find your own story. Your everyday interactions with friends and coworkers and families are opportunities to share your enthusiasm about nuclear science and technology."

North Carolina State University was the host of the 2021 ANS Virtual Student Conference.

Additional introductory remarks were provided by Kostadin Ivanov, head of the Engineering Department at NCSU, and John Gilligan, executive associate dean of the College of Engineering at NCSU.


Hamilton

Hamilton spoke about the bright future she believes nuclear energy has in the United States and beyond. She referred to Duke's commitment to nuclear energy well into the future, especially as new technologies, such as small modular reactors and advanced reactors, come to market. And Hamilton thinks that time is coming soon. During the Q&A portion later in the session, she said that advanced reactors and SMRs will be available for commercial deployment before 2030. "That probably sounds like a long time for some students, but for me it feels like tomorrow. It's really just right around the corner. It has taken a while to get started, but now that it's started, it seems to be moving very, very quickly."


Feldman

EPRI's Feldman followed Hamilton with a presentation that highlighted not only nuclear's role in clean energy but also how nuclear plants can evolve beyond electricity production. Feldman said that EPRI has been conducting research over the past five to seven years to understand the implications of taking a baseload nuclear plant and transitioning it to operate flexibly. "If there is less demand for electricity on the grid, the nuclear power plant could stay online and produce hydrogen, or it could be used to desalinate water in regions of the world where fresh water is limited, or it could be used to store energy when that demand is low," Feldman said. "We've got some research going on to understand what that means for the nuclear power plant."


Ivanova

Ivanova spoke about the NEA's efforts to pass knowledge on to a new generation of experts. "As experts retire and few young people rise to replace them, the nuclear expertise is on the decline," she said. "At the NEA, we are doing our best to help this situation." Among its efforts, the NEA has collected evaluated experiments into accessible databases; has created the Nuclear Education Skills and Technology (NEST) Framework; has begun the NEA Global Forum on Nuclear Education, Science, Technology and Policy; and has held various training opportunities, including a mentoring workshop for young women, whom Ivanova said are significantly underrepresented in the nuclear sector. The NEST Framework, launched in 2019, enables students from around the world to work together to solve real-world challenges in areas such as decommissioning, SMRs, radioprotection, and nuclear medicine.

The second day of the conference opened with the plenary session, "Student Opportunities within the Nuclear Community." The session featured three panelists, each representing a different sector of the nuclear community. Leslie Dewan, founder of Criticality Capital; Jonathan Coburn, a senior researcher at Sandia National Laboratories; and John Wagner, director of Idaho National Laboratory, provided insight into potential career paths and job opportunities for students. ANS executive director/CEO Craig Piercy delivered introductory remarks.


Dewan

Dewan offered the perspective of venture capitalists and their role in financing advanced technologies for nuclear's future. But before that, she provided a quick rundown of nuclear energy's origins to illustrate how that can be used to inform today's decisions. She pointed to early successes in communicating the benefits of nuclear technology with the general public, giving as examples the "Atoms for Peace" trucks used by the Atomic Energy Commission to spread public awareness following President Eisenhower's

Special Report continues

famous speech in 1953, and Disney's 1957 short film *Our Friend the Atom*, which was also turned into a children's book.

"One of the best ways to build a better nuclear future is by looking backward and learning from the past and by examining nuclear's rich history," Dewan said. "It's something that has always been inspiring to me, and we can gain a lot of insight by digging into it a little more."

Coburn followed with a two-part presentation designed to give a scientist's perspective on career opportunities. He started by explaining his career path, from earning his bachelor's degree in nuclear engineering to his current role as a materials scientist at Sandia. He closed with advice to students looking to discover their own career path. He recommended attending nuclear engineering conferences, utilizing university resources such as job postings and interview prep, seeking out career fairs and internships, and joining professional societies such as ANS.

Coburn

The final speaker, INL's Wagner, discussed job opportunities within the national laboratory community and the pathways that lead to them. Wagner sees a bright future ahead for nuclear technology and the labs' roles in achieving that with advanced reactors. That future includes an increasing number of jobs being created. Wagner said INL is nearing 5,300 staff members, which is an increase of 1,000 over the past five years. He expects the staff to increase by another 1,000 members in the next five years. "At no point in my career have I ever been more excited by the opportunities to demonstrate advanced reactors," he said. "There have been decades where we were shutting reactors down, where we were cleaning up nuclear facilities and were really stuck in what I call 'paper reactor' time, talking about reactors but not building anything. One of the things I'm passionate about now is that we're on the cusp of demonstrating new reactors."

Wagner

The future of nuclear technology is bright and affords ample opportunities for today's students to make an impact. That was the message given by the three plenary panelists during the final plenary on April 10. The "Future for Nuclear Technology" session featured Julie Ezold, head of the Radioisotope Production and Operations Section at Oak Ridge National Laboratory; Avneet Sood, senior scientist at Los Alamos National Laboratory; and William E. Russell, chief scientist at BWXT Nuclear Operations Group.

Ezold opened the session with a presentation focusing on the Department of Energy's Isotope Development and Production for Research and Applications program. She described many of the medical applications for reactor and accelerator production of a variety of isotopes, including radium-223 and thorium-227 used in targeted alpha therapy. She also mentioned the industrial applications for certain isotopes, including californium-252, which is used in fuel rod scanning, new reactor startup, and more.

Ezold

"All of those things you've been learning in your classes about neutron capture and cross sections, there is a bigger application for those with respect to isotope production," Ezold said. "You can apply some of the principles we've learned as nuclear engineers for accelerator production."

Sood followed Ezold with some background on LANL, where he focuses his work on nuclear security. But he pointed out that LANL also does research in the life sciences and that some of his colleagues were working on COVID

Sood

modeling that helped researchers elsewhere create the vaccines. Sood then turned to discuss microreactors and the unique challenges they offer scientists. He said LANL has gone from modeling and simulation to creating specialized fuel to small-scale testing and using their capabilities to partner with other organizations to move forward.

"It's an area where, if I were a student, this would be one of the exciting areas because it's quite novel," Sood said. "From my seat now, after 20 years in the business, I see how we bring all those capabilities to this kind of a mission."

Of the three speakers, Russell offered the most enthusiastic outlook for nuclear's future, especially in finding solutions for climate change, nuclear medicine, nuclear defense and security, and space travel. "We live in an exciting time for nuclear," he said. "All of you should be so proud of your

Russell

chosen field. I strongly believe that all of the most important issues facing the world will require an innovation of nuclear to solve."

Russell advised the students to continually think outside the box for solutions, but don't be too quick about sharing their ideas. He estimated that only about 10 percent of ideas are solid enough to pursue, so it's best to do some legwork to see how viable the solution is before letting others know about it.

"The people of this conference will be the individuals to make the nuclear future happen," he said. "I challenge all of you to be the innovative leaders of our industry."

—Paul LaTour

How the NRC modernized infrastructure and where it

its digital I&C goes from here

By Eric J. Benner and Steven A. Arndt

The Nuclear Regulatory Commission[a] first formally developed infrastructure for the review of digital instrumentation and control (I&C) systems in the 1990s. Although the current fleet of nuclear power plants in the United States was originally designed and constructed with analog systems, the U.S. nuclear industry has for more than 30 years been working to upgrade these older systems with modern digital equipment.

Digital systems have many advantages over analog systems, but they also pose different engineering challenges and need to be reviewed by the NRC in a different way. Because of these differences, the NRC started looking at its regulatory infrastructure to see if changes needed to be made to support the expanded use of digital systems in nuclear power plants. Several efforts in the 1990s included a review by the National Academies' National Research Council, a review by the NRC staff of the impact of potential new digital systems resulting from advanced reactor designs, and the NRC staff's update to the I&C section of the Standard Review Plan (SRP).[1]

In the review of the impact of new digital systems arising from the evaluation of potential issues associated with advanced nuclear power plants—the NRC at the time was reviewing the early "advanced" reactors, such as the AP600—several I&C issues were evaluated, but the key issue that came to the forefront was the potential concern with software common cause (then referred to as common mode) failure. Common cause failures had always been evaluated as environmental or manufacturing issues and had been generally excluded from design reviews. With software not having a material presence, however, the "manufacturing" was really in the coding that would be replicated in all the redundant channels of a software-based safety system. At the time, several software professionals were looking at this challenge and had proposed potential solutions, but these potential solutions were not generally accepted for several reasons, including cost and dependence on the underlining requirements specifications.[2]

[a]Hereinafter referred to as the NRC—not to be confused with the National Research Council, which is not abbreviated.

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Portrait of E. Gail de Planque, NRC commissioner 12/16/91–06/30/95, during which the NRC contracted with the National Research Council to investigate how best to regulate the introduction of digital I&C systems into nuclear power plants.

This review led the NRC staff to recommend to the commission[3] that digital system common cause failure be treated as a possible but unlikely event and that the means to cope with it be required. The commission directed the NRC staff to treat digital system common cause failure as a beyond-design-basis event for the purpose of analyzing the adequacy of coping with proposed failures and provided guidance associated with how to develop acceptance criteria.

In parallel with the above review, in 1994, the NRC, at the urging of the Advisory Committee on Reactor Safeguards (ACRS), contracted with the National Research Council to investigate how best to regulate the introduction of digital I&C systems into nuclear power plants. The National Research Council appointed a committee that was charged to define the important safety and reliability issues that arise from the introduction of digital I&C technology in nuclear power plant operations.

The committee, in its 1997 report,[4] identified eight key issues associated with the use of digital I&C systems in existing and advanced nuclear power plants. The eight issues were:

1. Systems aspects of digital I&C technology.
2. Software quality assurance.
3. Common cause software failure potential.
4. Safety and reliability assessment methods.
5. Human factors and human-machine interfaces.
6. Dedication of commercial off-the-shelf hardware and software.
7. Case-by-case licensing processes.
8. Adequacy of the technical infrastructure.

In the area of systems aspects of digital I&C, the committee recommended that the NRC staff reach out to foreign nuclear power regulators and other industries, such as the chemical processing and aerospace industries, to compare their guidance documents with those being developed by the NRC and to develop staff knowledge and experience in digital I&C. In the area of software quality assurance, the committee recommended that the staff develop nuclear-specific software quality assurance guidance and focus on the early phases of the software development life cycle.

In the area of common cause software failure, the committee concluded that the NRC's position as stated in COM-SECY 93-087 was correct. However, it recommended that the NRC continue to revisit its guidance on how to assess whether adequate diversity exists. The committee also recommended that the NRC retain its position that common cause software failures are credible, and that its basic position regarding the need for diversity in digital I&C systems is appropriate.

In the area of safety and reliability assessment methods, the committee recommended that the influence of software failure in system reliability be included in probabilistic risk assessments (PRAs) for systems that include digital components. Although the ability to accurately model digital system (particularly software) reliability is still quite challenging, the most recent revision of Chapter 19 of the SRP provides guidance on how best to include digital components into PRA models based on research completed by the NRC[5] and others.

The recommendations in the areas of human factors and human-machine interfaces, dedication of commercial off-the-shelf hardware and software, case-by-case licensing process, and the adequacy of the technical infrastructure would also lead to updates to the SRP associated with human factors reviews, the development of guidance on the use of third-party certification for use in licensing commercial off-the-shelf products, guidance on how to amend a nuclear power plant license when upgrading I&C to digital, and new guidance on the use of 10 CRF 50.59 for digital systems.

Also, in parallel with these efforts, the NRC staff updated the SRP chapter associated with the review of I&C systems for both new licenses and amendments for existing licenses to accommodate the use of digital systems. In 1997, Revision 4 of Chapter 7 of the SRP was published and, for the first time, specifically provided for the challenges associated with the regulatory review of digital systems.

Because analog systems' performance can typically be predicted—using well-known engineering models that accurately predict their continuous performance based on physics principles—the review of analog I&C systems is similar to that for other reactor components. The system designers and the NRC staff could establish a reasonable expectation of continuous performance over substantial ranges of input conditions as part of the qualification of the system's design, which allowed reliance on the testing of a finite sample of input conditions and a review of models of the system to demonstrate acceptable performance with a high level of confidence.

The 1997 revision of the SRP acknowledged that digital I&C systems are fundamentally different from analog I&C systems in that minor errors in design and implementation can cause them to exhibit unexpected behavior. Consequently, the performance of digital systems could not generally be established using traditional design reviews and testing. Design reviews, inspections, type testing, and acceptance testing of digital systems and components do not alone accomplish design qualification to adequate confidence levels.

To address this issue, the NRC staff turned to an approach to the review of design systems that was the state-of-the-practice at the time for both military and civilian applications of digital systems. This approach focused to a greater extent on confirming that the applicant or licensee employed a high-quality development process that incorporated disciplined specification and implementation of design requirements. Inspection and testing are still used to verify correct implementation and to validate the desired functionality of the final product, and confidence that discontinuous failures will not occur comes from the discipline of the development process.

To implement this approach, the staff developed several branch technical positions (BTPs) and regulatory guides (RGs) that explained the requirements and endorsed the state-of-the-practice industry standards. This included BTP 7-14 for the development process; RG 1.152, which endorsed IEEE Std. 7-4.3.2-1993, for the general digital system design; and BTP 7-19 to provide staff with review guidance for the commission's position on common cause failures. These and other similar documents made up the NRC's first digital I&C infrastructure.

For the next 10 years, the NRC used this first digital infrastructure to support the licensing of a number of digital systems in the current nuclear fleet. This basic infrastructure was updated as new industry standards were developed and research supported updates. The NRC's digital research program was also established[6] along the lines of the National Research Council report's recommendations.

In January 2007, in response to a November 8, 2006, commission meeting and a staff requirements memorandum dated December 6, 2006 (available through the NRC's ADAMS document retrieval system with accession number ML063400033), the NRC staff initiated

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a project (the Digital I&C Project) to improve the regulatory efficacy and predictability of the licensing of digital I&C systems in new and existing power reactors. During that November 2006 commission meeting, an industry panel expressed concerns about utilities' ability to license digital I&C safety systems and to implement certain NRC policies regarding digital I&C. The Nuclear Energy Institute (NEI) stated that NRC guidance needed improvements to facilitate the nuclear industry's needed retrofits of aging analog systems in operating reactors and orders for new reactor simulators.

The Digital I&C Project, which ran from 2008 until 2011, was managed by a steering committee and organized around seven task working groups to accomplish specific objectives.[7] The industry established a parallel group of industry executives to coordinate industry efforts and interface with the NRC staff. The Digital I&C Steering Committee and the task working groups prepared interim staff guidance (ISG) documents for each of the key issues identified: cybersecurity, common cause failure, review of new-reactor digital I&C PRA, challenges associated with more highly integrated digital system communications, human factors, the licensing process, and fuel cycle facilities. The ISG on cybersecurity was superseded by updated guidance in support of the new rule on cybersecurity.

The ISG that supported the review of digital I&C PRA for new reactor applications was used in the update of Chapter 19 of the SRP and has been used successfully in several Part 52 reviews. The ISG on highly integrated digital system communications remains in effect as part of the digital I&C infrastructure but will be sunsetted when the NRC endorses the most recent version of IEEE 7-4.3.2 in an updated version of RG 1.152. The ISG on human factors was also integrated into an update to the SRP, as was the ISG on digital systems in fuel cycle facilities. (There is a separate SRP for fuel cycle facilities that contains the updated guidance on digital systems.) The ISG on common cause failures was integrated into an update of BTP 7-19.

At the conclusion of the Digital I&C Project, the NRC staff committed to working with the nuclear power industry and other stakeholders to continue to enhance communications on technical issues in this area through a series of periodic public meetings to address issues of common concern. One of the key issues identified during these meetings, and subsequently through inspection findings, was the need to improve guidance on the use of 10 CFR 50.59 for digital systems upgrades. In November 2013, the NRC sent a letter (ML13298A787) to NEI, summarizing the NRC's concerns about NEI 01-01, Revision 1 to EPRI TR-102348, *Guideline on Licensing Digital Upgrades*, the industry guidance on the use of 10 CFR 50.59, "Changes, Tests, and Experiments," for digital safety systems at the time.

Subsequently, in 2014, the NRC held four public meetings to clarify these concerns, including that the technical guidance in NEI 01-01 had become outdated. In parallel with this work, the NRC staff was developing additional updates to the digital I&C infrastructure, but many in the industry stated to the commission that they were hesitant to pursue the deployment of digital I&C through license amendments, new applications, or changes under the 10 CFR 50.59 process unless regulatory efficiency and predictability could be improved. In response, the commission directed the staff to develop an integrated strategy to further modernize the NRC's digital I&C infrastructure.

In 2016, the NRC staff developed an integrated action plan (IAP) (ML17102B296) and submitted it to the commission for approval in SECY-16-0070. Although significant improvements were made to the digital systems licensing infrastructure associated with the previous project, that project's focus was primarily on resolving specific technical issues that were anticipated to be challenges for the licensing of new reactors rather than improvements to the licensing infrastructure.

The NRC's objective for digital I&C has always been to have a clear regulatory structure with reduced regulatory uncertainty that enables the expanded use of digital I&C in commercial nuclear reactors. When developing and implementing the IAP, the NRC staff aimed to address, more broadly, the regulatory challenges for operating reactors, as well as those for new and advanced reactors. The IAP was based on NRC licensing and inspection experience, as well as extensive stakeholder engagement, to reach a common understanding of the regulatory challenges and priorities associated with digital I&C and potential solutions to address them.

This new infrastructure improvement project focused on four areas:

1. Protection against common cause failure.
2. Digital upgrades using the 10 CFR 50.59 "changes, tests, and experiments" rule.
3. Commercial-grade dedication of digital equipment.
4. Additional perceived impediments of the licensing process.[8]

In again looking at the challenge of protection against common cause failure, this new effort focused on developing technical guidance for low risk-significant safety systems and auxiliary and/or support systems that would typically use the 10 CFR 50.59 process.

The NRC staff was able to improve guidance (using qualitative assessment) for evaluating and documenting the proposed use of design attributes, quality measures, operating history, and appropriate coping and bounding analysis to address common cause failure when replacing or modifying lower risk-significant safety systems and auxiliary and/or support digital I&C systems under 10 CFR 50.59. In May 2018, the NRC staff clarified how licensees could perform digital I&C modifications without NRC approval in Regulatory Information Summary (RIS) 2002-22, Supplement 1, *Clarification on Endorsement of Nuclear Energy Institute Guidance in Designing Digital Upgrades in Instrumentation and Control Systems* (ML181430633).

Industry feedback indicates that this guidance has been vital in supporting licensees in addressing real-time equipment obsolescence challenges and improving system and component performance. In addition to providing this new guidance for low safety-significant systems, the NRC staff has also reevaluated the more general position on common cause failure in digital systems. After reviewing both the original position and key issues raised by industry, the NRC staff proposed a strategy for updating BTP 7-19 that would incorporate the five guiding principles in SECY-18-0090 and introduce an approach to grading the level of review based on safety significance. In this way, the NRC staff was able to modernize the common cause failure implementation, including providing more flexibility in the analysis, while at the same time maintaining the commission's policy on common cause failure that has served the NRC well since the inception of the digital I&C infrastructure. The NRC staff actively engaged industry through public meetings throughout 2019 and published a new revision of BTP 7-19 in 2020.

The second major focus of the new improvement effort was to further clarify the use of 10 CFR 50.59 for digital I&C modifications.

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Portrait of NRC commissioner Christopher T. Hanson, sworn in 6/8/2020, designated chairman effective 1/20/21.

The general guidance in this area is NEI 96-07, which is endorsed by an NRC RG. The industry requested this additional information on how to complete the required screening and evaluation of modifications made under 10 CFR 50.59 because of the concerns that the NRC raised with the guidance that was available at the time (NEI 01-01) and the negative experiences that some plants had with the process.

To resolve these concerns, the industry and the NRC staff agreed that the best path to a long-term solution would be to update NEI 96-07 and the RG endorsing it (RG 1.187) to incorporate everything the NRC had learned and to be more consistent with RIS 2002-22, Supplement 1. NEI submitted NEI 96-07, Appendix D, *Supplemental Guidance for Application of 10 CFR 50.59 to Digital Modifications*, in November 2018. This document provides insight on the application of the 10 CFR 50.59 guidance contained in NEI 96-07, Revision 1, to activities involving digital I&C modifications. It also provides screening guidance for digital I&C modifications that is not contained in RIS 2002-22, Supplement 1. The NRC staff endorsed Appendix D through a revision to RG 1.187 in July 2020.

Another area that has been a challenge to the digital I&C infrastructure is the use of the commercial-grade dedication process for qualifying digital equipment. Because of the relatively low demand for nuclear-specific digital equipment, it has always been a challenge to get equipment vendors to go through the extensive process of qualifying their equipment specifically for nuclear applications. One way to address this challenge is to use the commercial-grade dedication process.

Although the process of qualifying commercial products varies from country to country,[9] in most cases, this process provides a means by which commercial-grade equipment can be used in nuclear safety systems. The industry requested that the NRC look at relaxing specific requirements in its approval process for these systems by substituting a third-party certification of a commercial product for certain equivalent steps in the U.S. process. In February 2020, NEI submitted NEI 17-06, *Supplemental Guidance for Acceptance of Digital Equipment using 3rd Party Certification*, for NRC endorsement through the issuance of an RG.

Perhaps the most significant area of work in this new update to the infrastructure is the NRC staff's effort to improve efficiency in conducting licensing reviews. In the first infrastructure improvement program, the NRC staff issued ISG-06, *Licensing Process*. This document provided additional guidance to the NRC staff and licensees on what documentation needed to be provided and how to sequence the submission and review of the needed information most effectively for the NRC staff to reach its safety finding. Although this guidance was successfully piloted as part of the Diablo Canyon nuclear plant's reactor protection system (RPS) review, there was a concern that more needed to be done to increase the predictability and efficiency of the review process for major digital upgrades and shift the regulatory decision to earlier in the design process. Unlike most components used in nuclear power plants, the regulatory review of digital I&C systems is done during the design of the system, not after it is complete. In December 2018, the NRC staff issued a revision to ISG-06 (ML18269A259).

The revised ISG contains an alternate review process that would have the NRC start the review at a more mature point in the licensee's design process, would call for only one submittal rather than two, and would allow for the final licensing decision to be made earlier in the design process. This alternate review process is also more performance-based because it leverages vendor and regional inspections for confirmatory checks during the implementation stages if the NRC approves the amendment request. The staff expects this alternate review process to result in faster NRC decisions than the traditional process, which remains available. Although not expected to be an issue, the alternate review process does present the possibility that if the design changes significantly between the time of licensing and completion of the design, it will need to be rereviewed.

Concurrent with these most recent infrastructure modernization activities, the NRC staff has also completed digital I&C licensing activities in an efficient and effective manner. Recent licensing successes include a license amendment for the Purdue University research reactor for a complete digital replacement of the reactor protection and control system, completion of the staff review of the design certification for the APR1400, a license amendment for Hope Creek Generating Station's power range neutron monitoring system, and approvals of generic topical reports for digital I&C platforms from Lockheed Martin (nuclear protection and control), Mitsubishi Heavy Industries, and Radiy.

The staff also successfully evaluated the highly integrated I&C systems for the NuScale small modular reactor using the approach of a design-specific review standard (DSRS) for digital I&C that is based on adherence to fundamental safety principles, with a focus on risk importance and safety significance. This was the first time an applicant and the NRC staff used a DSRS approach to prepare and evaluate a highly integrated digital I&C design.

While more improvements can always be made, the NRC modernization efforts and the digital I&C licensing infrastructure have enabled the expanded use of digital I&C in commercial nuclear reactors. This is evidenced by the widespread use of RIS 2002-22, Supplement 1, and by licensees planning for more complex digital I&C projects to be submitted as license amendment requests using the alternate review process contained in ISG-06.

Specifically, Entergy submitted a license amendment request in August 2020 for digital equipment modifications regarding the core protection calculator and control element assembly calculator at the Waterford nuclear plant; NextEra is planning to submit a license amendment request for digital replacement of the RPS and the engineered safety features actuation system (ESFAS) in May 2021; and Exelon plans to submit a license amendment request for digital replacement of the RPS, ESFAS, and other safety systems in the third quarter of 2022. At a workshop held by the NRC in February 2021, Dominion and Southern Nuclear Corporation also indicated plans for future license amendment requests using ISG-06. Because of this interest, the NRC staff is now preparing for this licensing work, including undertaking pre-application activities.

The NRC staff also plans to continue upgrading and modernizing the new infrastructure through efforts to expand the use of risk-informed approaches to the regulatory infrastructure, enhanced evaluation of data provided by stakeholders on the likelihood of digital common cause failures, and assessing the use of emergent digital technologies. Examples of this ongoing effort include continuing research on the expanded use of modern hazard analysis and the impact of embedded digital devices. Through proactive research and continued improvements to the infrastructure, the NRC staff will continue to support the expanded use of digital technology in the nuclear industry.

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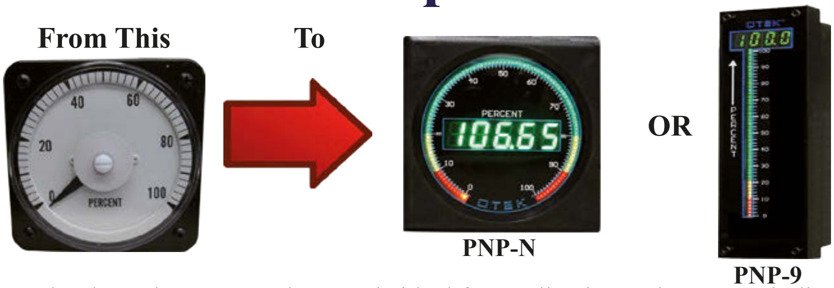

Without NRC approvals or any changes to your I&C room

The technology that powers the PNP is ideal for applications where HMI indication and/or control is necessary to combat the unreliability, inaccuracy, and inefficiency commonly found in obsolete analog and digital instrumentation. What separates PNP technology from other drop-in replacement instrumentation of its era is the ability to replace obsolete meters without any changes to the wiring and panel mounting, while also requiring no additional operator training. Unlike popular metering technology designed solely to take advantage of digitization or to conform to NRC mandates such as NEI 08-09, the PNP specifically addresses the economic side of maintaining a nuclear I&C room. Yet above all else, this new technology represents unprecedented versatility—not only can PNP instrumentation replace any obsolete analog or digital meter form, fit and function regardless of size or shape, it also eliminates the need for multiple spare units to back up a single meter. PNP technology can also be customized onsite via One Size Fits All adaptability, which allows for externally mounted "Stick-On" scale plates to feature any color or language the user wants, simply by applying a self-adhesive scale plate that sticks to the front of the meter without having to open the PNP.

With versatility at the core of its invention, the PNP meter revolves around a universal I/O module that is inserted into the back of any PNP—no matter, the size, shape, signal, or panel cut out—and without any changes to the surrounding panel, the wiring, or display. This universal I/O module can be manipulated into performing the various functions of instruments present in a typical I&C room simply by plugging signal conditioners into the module itself. These signal conditioners (up to four per I/O module) can accept over 50 input signals and either 100% signal power like analog meters (such as current loops [4-20 & 10-50 mA], VAC to 260V, VDC to 300V, AC Amps to 5Amps (AC & DC, Watts & Hertz). For units requiring external power (such as RTD, TD, S-G, pH, ORP, etc.) or even 4-20mA retransmission and alarm outputs, PNP technology uses universal power modules that are plugged, inside the hub, into the instrument, requiring no solder or otherwise alteration to the surrounding wiring and panel displays that might void certification. The module is then housed in a 3-inch-long tube (1.5" in diameter), known as the "HUB" that attaches to the back of any and all meters offered. In instances where the back panel needs to be modified, an adapter plate may be used to ensure cohesion between the modular tube and the back panel of the instrument. Once all PNP processes are understood by the technician or operator, this installation should take no longer than the average time required to replace a standard meter. Furthermore, PNP technology should require no soldering or other labor-intensive measures. From this one simple piece of hardware, the PNP can assume the full range of its versatility and perform the functions of nearly any meter in the I&C room—and most importantly, eliminates the need for multiple spares (in other words, "One Size Fits All). This means that if your panel has the space, you can replace any and all meters with the same PNP meter; all you need is the display that will fit the space available. All else is the same. This reduces spare units in inventory for emergency replacement down to only one per display size.

PNP technology represents the natural evolution of modernization in the nuclear I&C room. Improvements in accuracy, reliability, and efficiency have allowed digitization to overtake analog instrumentation in the twenty-first century control room, and it is now time to add cost effectiveness to that list. It is the belief of this author that PNP technology can not only improve the performance of I&C room instruments, but it can also efficiently, effectively, and exponentially address economic concerns over spare inventory by reducing the number of spares necessary, from multitudes down to a single spare instrument. Though there are numerous issues facing the nuclear industry twenty-one years in the new millennium, instrumentation obsolescence and the uneconomical overabundance of spare inventory are within technology's ability to solve. The conclusion of this article asserts that Plug & Play instrumentation is that very solution.

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ONLINE MONITORING TECHNOLOGY TO EXTEND CALIBRATION INTERVALS OF NUCLEAR PLANT PRESSURE TRANSMITTERS

BY H. M. HASHEMIAN

Online monitoring (OLM) technology can be used in nuclear power plants as an analytical tool to measure sensor drift during plant operation and thereby identify the sensors whose calibration must be checked physically during an outage. The technology involves a procedure to (1) retrieve redundant sensor measurements from the process computer or through a separate data acquisition system, (2) calculate the average of these measurements and the deviation of each sensor from the average, and (3) identify any sensor that has deviated beyond its predetermined monitoring limit.

OLM FUNDAMENTALS

OLM technology for transmitter drift monitoring involves a simple procedure that is passive and benign to plant operation and does not require any modification to the plant.[1–8] All that is needed to implement OLM is a means to retrieve the readings of r edundant transmitters, which can be accomplished using the plant computer or a separate data acquisition system, and a software package to validate and analyze the data. OLM is not a substitute for conventional calibrations. Rather, it is an analytical tool equivalent to using measuring and test equipment to check for drift of transmitters during plant operation to determine whether they must be scheduled for a physical calibration by plant personnel during an upcoming plant outage.

To perform OLM, readings of redundant sensors are tracked while the plant is operating to identify drift beyond acceptable limits. Figure 1 shows the readings of four redundant steam generator level transmitters at Unit 2 of the McGuire nuclear power plant over a period of about 30 months, representing nearly two full operating cycles. The work was done by Analysis and Measurement Services Corporation (AMS) in collaboration with Duke Power Company, the owner of the McGuire plant. The results of this research and development are documented in NUREG/CR-5903 (1993) and NUREG/CR-6343 (1995).[9, 10]

In arriving at the deviation plot in Fig. 1, an estimate of the true steam generator level was first obtained by averaging the four signals. Next, the process estimate was subtracted from the reading of each transmitter to yield the deviation of each transmitter from the average. The OLM limits for the steam generator level transmitters are also shown by the dotted lines in Fig. 1.

It is obvious from the four traces in Fig. 1 that the McGuire transmitters did not drift over the two operating cycles shown in the figure and, in fact, remained well within the plant's OLM limits. With this information, it is reasonable to claim that the calibrations of these transmitters are intact. However, it is important to note that this claim would be true only if the four transmitters did not all drift together in either the positive or negative direction (i.e., common-mode drift). If there is no common-mode drift, then their average value is a close representation of the true process.

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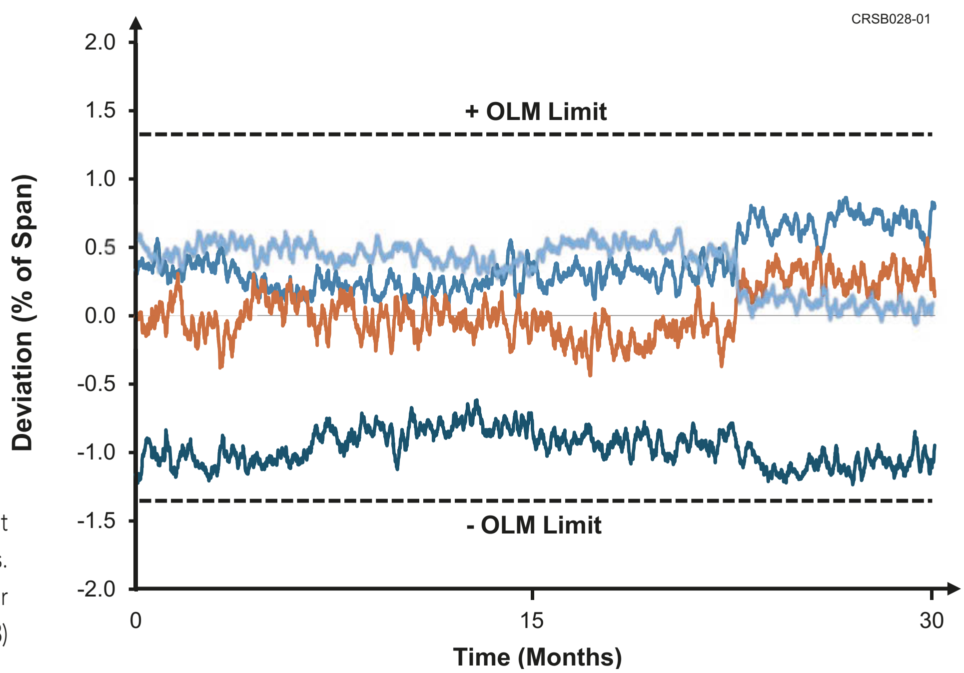

Fig. 1. OLM data for four redundant steam generator level transmitters. (Source: McGuire nuclear power plant Unit 2, NUREG/CR 6343)

Vogtle-1 and -2 (four-loop Westinghouse PWRs): transmitters monitored from October 2018 to the present as part of an ongoing commercial OLM implementation performed under a contract between AMS and Southern Nuclear Operating Company. (Photo: Southern Nuclear)

SOME HISTORY

Periodic calibrations and response time measurements have been performed during every fuel cycle on all safety system transmitters in nuclear power plants since the 1970s, providing a huge volume of data. These data were analyzed in the early 1990s by the Electric Power Research Institute (EPRI), which concluded that the performance of most nuclear-grade pressure, level, and flow transmitters is rather stable, and therefore they do not have to be calibrated or response time tested as often as once every operating cycle. This conclusion prompted EPRI to launch two efforts to accomplish the following objectives on behalf of the nuclear power industry: (1) eliminate periodic response time testing requirements for pressure, level, and flow transmitters; and (2) develop OLM technologies to extend the interval between calibrations of pressure, level, and flow transmitters.

The effort to eliminate transmitter response time testing requirements provided the foundation for pressurized water reactor and boiling water reactor plants to obtain the approval of the Nuclear Regulatory Commission to cease transmitter response time testing beginning in the mid-1990s. Of course, any replacement transmitter or new transmitter design for which adequate performance data are not available or analyzed must be response time tested before it is placed into service.

Although EPRI was successful in obtaining regulatory relief for the nuclear industry from response time testing of transmitters, results from its efforts to obtain relief from unnecessary calibrations have not yet materialized except for the Sizewell B nuclear plant in the United Kingdom. This despite the fact that in the late 1990s, EPRI submitted a topical report to the NRC leading to a safety evaluation report (SER) in September 2000 authorizing the use of OLM for transmitter drift monitoring subject to 14 requirements for plant-specific implementation.[1]

Subsequently, the nuclear industry addressed many of these plant-specific action items, and the utility operating the Summer nuclear power plant applied to the NRC for approval to implement OLM to extend the calibration interval of its transmitters.[11] Following a short period of interaction between the utility and the NRC and before any NRC ruling, however, Summer's application to implement OLM was withdrawn by the utility, and no further attempts were made by this or any other U.S. plant to seek

NRC approval to implement OLM. Presumably, the nuclear industry found a few of the NRC's plant-specific action items in the SER to be too restrictive and costly to resolve and therefore abandoned its efforts to take advantage of the SER to extend the calibration intervals of transmitters.

Today, nearly 20 years have passed since the NRC issued the first SER on OLM, and in that time, the following has taken place:

- Additional operating experience demonstrating that the current generation of nuclear-grade pressure, level, and flow transmitters do not normally drift enough to need a calibration at each refueling outage.
- Continued research by the nuclear industry and academia to advance the state of the art in OLM and address the known technical questions and regulatory concerns, such as the potential for common-mode drift.
- AMS's implementation of OLM at more than 10 U.S. PWRs and one U.S. BWR on a demonstration basis, with grants or collaboration agreements provided to AMS by the Department of Energy, the NRC, EPRI, or utilities.
- OLM implementation with the approval of DOE regulators to extend sensor calibration intervals at the Advanced Test Reactor, a 250-MW plant located at Idaho National Laboratory.
- Successful OLM implementation at the United Kingdom's Sizewell B nuclear power plant with the approval of British regulators.
- Probabilistic risk assessment (PRA) work by EPRI and others showing the negligible risk of extending transmitter calibration intervals using OLM.

These developments support the technical justification for the widespread implementation of OLM to extend the calibration intervals of pressure, level, and flow transmitters in nuclear power plants. A topical report (referred to as AMS-TR-0721R1) was been submitted by the author to the NRC for approval to switch from conventional calibration strategy to condition-based calibration strategy. The topical report was approved by the NRC in November 2020 for a formal review that is currently pending, with a safety evaluation expected from the NRC in late 2021 or early 2022. The production of the topical report was funded with a grant from the DOE.

OLM IMPLEMENTATION

Over the past 15 years, AMS has implemented OLM in the following U.S. nuclear power plants. These are in addition to AMS implementation of OLM at the McGuire nuclear power plant in the 1990s.

- Watts Bar-1 (four-loop Westinghouse PWR): transmitters monitored for one cycle from November 2006 to February 2008.[12]
- Farley-1 and -2 (three-loop Westinghouse PWRs): transmitters monitored over multiple cycles from April 2008 to July 2011.[13]
- North Anna-1 and -2 (three-loop Westinghouse PWRs): transmitters monitored over multiple cycles from January 2008 to April 2011.[13]
- Vogtle-1 and -2 (four-loop Westinghouse PWRs): transmitters monitored from October 2018 to the present as part of an ongoing commercial OLM implementation performed under a contract between AMS and Southern Nuclear Operating Company. [14–16]

The OLM data retrieval processes at each plant were straightforward and the data quality was good. For Watts Bar-1, OLM data were retrieved from the Tennessee Valley Authority's DatAWare historian in the form of text files for data at periods of startup, normal operation, and shutdown. At Farley and North Anna, the compression settings of the data historians could not be turned off for OLM data acquisition. Therefore, the plant personnel retrieved the data from the plant computer to avoid problems with compression settings. AMS also demonstrated OLM at the Perry nuclear power plant, a 1,250-MWe BWR, where OLM data were collected between January 2008 and September 2013 as a part of a feasibility study to demonstrate OLM.

For Vogtle, OLM data are accessed remotely from Southern Company's Maintenance and Diagnostic Center database and analyzed at AMS. The goal of the project is to provide full-cycle analysis using OLM data from all modes of plant operation, including startup, normal power operation, and shutdown. The OLM data at Vogtle are sampled at the rate of one sample every five minutes due to limitations of the plant historian. To compensate for this slow sample rate, an entire month of data is analyzed for each transmitter. OLM implementation at Vogtle is performed in support of the plant's TSTF-425 initiative to satisfy

Continued

Sizewell B

the performance-monitoring requirement of the industry guidance document NEI 04-10 to extend transmitter calibration intervals.[17]

To date, 343 transmitters have been tested at Watts Bar, Farley, North Anna, and Vogtle. Of these, only about 10 percent reached their OLM limits. This is comparable to the nuclear industry's experience that only about 10 percent of pressure, level, and flow transmitters lose their calibrations over an operating cycle.

Except for Vogtle, the OLM implementation projects performed by AMS at U.S. plants have all been experimental and have been performed primarily as R&D efforts to establish the feasibility of OLM for the detection of transmitter drift. Nevertheless, together with OLM implementation at Sizewell B and McGuire, these projects have provided the foundation for the development of a generic OLM methodology that can be applied to all nuclear power plants.

OLM AT SIZEWELL B

In 2001, Sizewell B began its effort to implement OLM by contracting AMS to develop and validate commercial software to extract data from the plant computer and analyze it to identify drifting transmitters. In the meantime, Sizewell B engineers obtained approval from British regulators in March 2005 to formally switch from time-based calibration of transmitters to condition-based calibrations using OLM.[18] For the next 10 years, Sizewell collected the OLM data in house and sent it to AMS to perform the analysis. After 2015, Sizewell began performing the analysis in house with the AMS OLM software.

In addition, near the end of each operating cycle, noise data are collected and analyzed by AMS to identify any sensing line blockage and verify the response time of the transmitters. For services with a history of sensing line blockage issues, noise data are collected quarterly at Sizewell to detect the onset of blockages that can occur at any time throughout the operating cycle.

OLM implementation at Sizewell and other related information has been documented in the following reports written by AMS for EPRI:

- EPRI-TR-1013486, *Plant Application of On-Line Monitoring for Calibration Interval Extension of Safety-Related Instruments,* vols. 1 and 2, 2006. This document was later updated in 2007 (TR-1015173), 2008 (TR-1016723), and 2009 (TR-1019188) as more OLM data were collected at Sizewell and analyzed to validate OLM.
- EPRI-TR-1016725, *Requirements for On-Line Monitoring in Nuclear Power Plants,* 2008.

Table 1. Agreement Between OLM and Manual Calibration for Sizewell Transmitters

OLM	Calibration	Number of Matches	Assessment
Good	Good	332	Perfect match
Bad	Bad	24	Perfect match
Bad	Good	77	Conservative mismatch
Good	Bad	2	Nonconservative mismatch

OLM RESULTS

OLM implementation at Sizewell B over the period 2005–2020 involved 197 transmitters producing a huge database of results. For example, there are 435 cases in the database involving 108 transmitters that were monitored over five operating cycles by OLM and subsequently calibrated, providing the opportunity to compare the OLM results with manual calibrations. A summary of this comparison is provided in Table 1, and its conclusions are as follows:

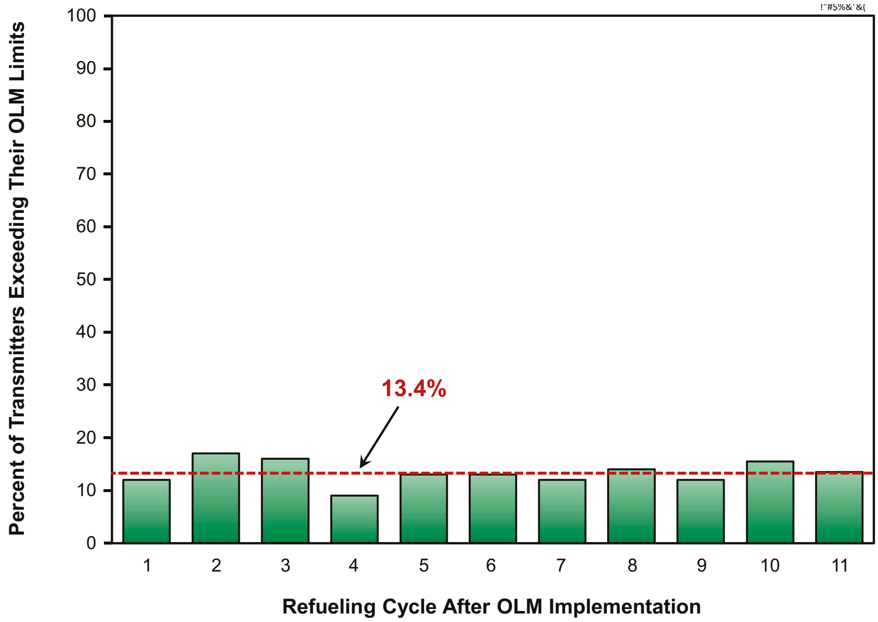

Fig. 2. Sizewell transmitters flagged for calibration checks at the end of each plant operating cycle.

1. The OLM and manual calibration results for 356 of 435 transmitters, or over 80 percent, matched perfectly. Although OLM and manual calibrations are not exactly the same due to the effect of process conditions and the different number of components that are involved in the two tests, this good agreement is nevertheless important, as it provides confidence in the validity of OLM technology.
2. For 77 transmitters, or nearly 18 percent, OLM found the transmitters to have drifted beyond their OLM limits, while manual calibrations showed no significant drift. Although the two methods did not produce comparable results, this outcome is readily acceptable because it is conservative.
3. OLM did not flag two transmitters that were found to be bad by manual calibrations. The cause of this discrepancy could not be found. On arriving at this outcome, which is not conservative, Sizewell B engineers compared this observation to their experience with discrepancies in manual calibrations over the years since 1996, when Sizewell B began operations. This effort showed that Sizewell has experienced an average of three discrepancies due to human error and miscalibrations during each operating cycle.[19] Sizewell engineers concluded that the two discrepancies seen here are readily acceptable because they are better than the conventional practice, where about 15 cases of human error and miscalibrations would have typically occurred over the same period.

With only two nonconservative results out of 435 cases, it is reasonable to conclude that OLM correctly or conservatively identified greater than 99 percent of the Sizewell transmitters that needed a calibration check. Furthermore, in a 2019 update, it became known that Sizewell is in possession of 921 cases, 11 of which are nonconservative. Again, this statistic confirms that OLM has correctly or conservatively identified about 99 percent of the transmitters that needed a calibration check.

SIZEWELL TRANSMITTERS

As of 2020, OLM has been used at Sizewell B for 11 operating cycles. Figure 2 shows the results in terms of the percentage of transmitters that OLM flagged for calibration checks at each of the 11 operating cycles. Based on these results, an average of 13.4 percent of the Sizewell B transmitters were flagged by OLM for calibration checks. This compares with about 10 percent that the analysis of "as found" data has shown for the calibration stability of nuclear-grade transmitters in the existing fleet of nuclear plants over the past 40 years. The extra 3.4 percent is most likely due to conservative OLM limits at Sizewell, as well as AMS's current practice of flagging any transmitter for which there is doubt about its OLM data or analysis results.

Continued

H. M. Hashemian is president and chief executive officer of Analysis and Measurement Services Corporation.

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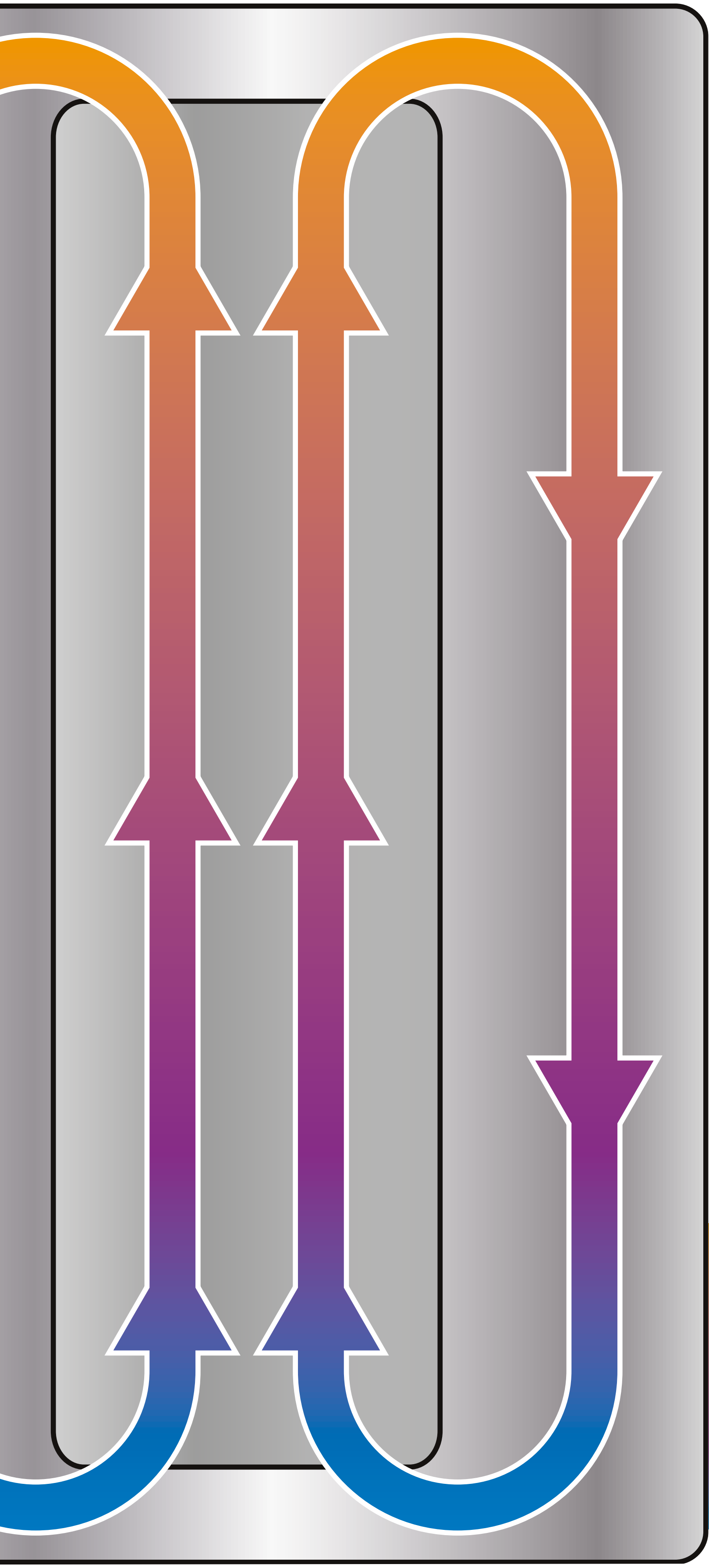

INTRODUCING THE MOLTEN SALT NUCLEAR BATTERY

Molten salt reactor technology first gained popularity in the 1960s, through the Molten Salt Reactor Experiment program at Oak Ridge National Laboratory. Now, decades later, a technology known as the molten salt nuclear battery (MsNB) is being developed to support the growing need for carbon-free, reliable, independent, and compact sources of small-scale heat and electrical power.

By Paul Marotta, Richard Christensen, and Piyush Sabharwall

Applications for the MsNB are numerous, and initial units are targeted to support locations such as sensitive Department of Defense bases or installations, which often require frequent shipments of fossil fuels to meet baseload energy demands. Other early applications include facilities that are not connected to a wide electrical grid, such as islands and off-grid industrial sites. A microreactor such as the MsNB can meet this energy demand with long-term reliable thermal and electric power. More specifically, the MsNB microreactor is currently designed to operate continuously for up to a decade.

The MsNB is a microscale nuclear fission heat source capable of providing heat to power a small commercial gas turbine on the order of 5–10 MWe. The MsNB is novel because it is a natural-circulation molten salt reactor that requires no pumps or valves. Natural-circulation power reactors have been already proven in other reactor designs. Feasibility analysis, scaled experiments, theoretical studies, and computational modeling have shown that the MsNB can provide power reliably, is radiologically safe, and as designed can provide 10 MWe of power for up to 10 years. The MsNB itself is small (a 3-meter-diameter by 3-meter-height right cylinder), transportable, and self-contained—all desirable parameters for remote and critical infrastructure use.

Development of a novel reactor design is a significant effort. The creative engineers working on the MsNB design, led by the authors and with the help of various student design projects and theses, have recently developed a new testing device that physically validates the MsNB as an improved, more reliable, and cost-effective molten salt reactor for its ability to naturally circulate liquid fuel. The device projects to save millions of dollars in testing costs and may cut up to two years off the MsNB's development timeline.

The testing device has a cylinder-within-a-cylinder configuration and uses ohmic heating to evenly heat liquid via an electric current and volumetric heating. It acts as a reactor surrogate, duplicating the internal heat generation that would occur within a reactor through fission of fuel dissolved within the molten salt. In the ohmically heated device, heat released during the ohmic heating testing process causes the salt solution within the battery surrogate to rise in the central cylinder. Once at the top, the fuel moves to a heat exchanger, where it is cooled and falls back down the space between the inner and outer cylinders. This natural circulation eliminates the need for valves and pumps, improving the reliability and simplicity of the reactor design.

Continued

Fig. 1. Fountain test.

Fig. 2. Loop test rig.

In a natural-circulation system, the flow is driven by the density difference resulting from the temperature variance between T_{hot} and T_{cold}. This “thermal driving head” is primarily a function of the temperature difference, not the specific temperature of the fluid. This provides the opportunity to physically validate computer simulations using low system temperatures in an environment that is not radiologically burdensome, eliminating the needs for high-temperature-alloy materials and high energy input, thus dramatically reducing overall testing cost. A patent is being filed on the concept’s application to natural circulation for nuclear power plants.

Several tests have been conducted using the ohmic heating concept in a phased approach, starting with the fountain test illustrated in Fig. 1. The purpose of this initial testing was to demonstrate the ohmic heating process using saturated salt water and a welder. This was not a flowing system and generated boiling-water conditions (creating a fountain) within 20 minutes.

The next phase of testing was focused on generating naturally circulating flow within an ohmically heated flow circuit with heat input and cooling. The loop test rig was designed, built, and tested to demonstrate flow as presented in Fig. 2. Note the similar electrodes for energy input into the system near the bottom of the test rig and the cooling loop at the top left. Natural circulation was directly observed in the pipe opening at the top right of the test rig.

The next two test rigs were designed as surrogates for the MsNB with the intended objective of validating the thermal hydraulics code calculations performed with molten salt for the MsNB. The ohmically heated full-height reactor surrogate was constructed by contractor Premier Technology Inc. The visible test reactor was constructed using clear PVC material, with testing for both being conducted at Premier Technology’s facility. Both units are shown in

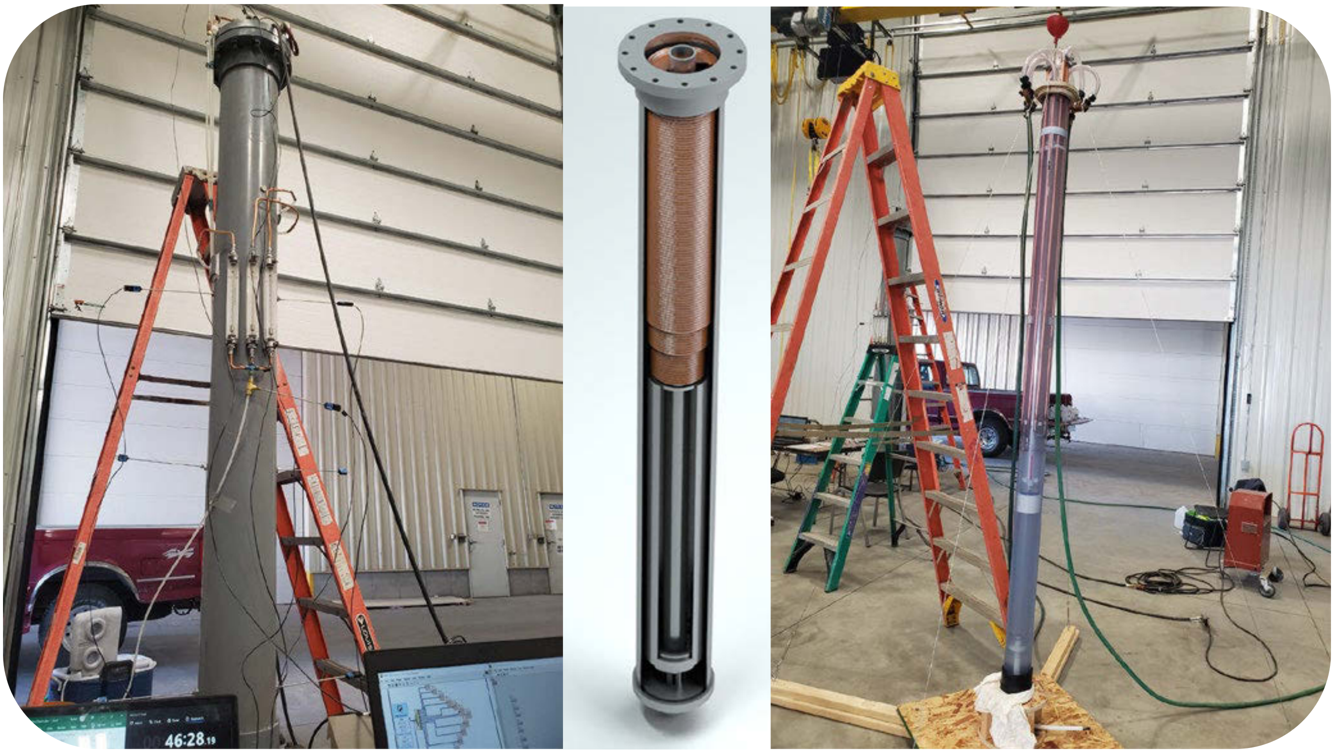

Fig. 3. Left: full-height reactor; center: a cutaway view of the full-height reactor; right: visible test reactor.

Fig. 3. All of the tests used a homogeneous, aqueous, 25 percent salt (NaCl) working fluid system and were built using the same general geometry used in several other systems designed as part of this overall program.

The temperature profiles from two sequential test runs of the full-height reactor simulator are illustrated in Fig. 4. In both plots, the T_{hot} and T_{cold} of the reactor are represented by the top two traces, and the coolant T_{in} and T_{out} are the lower two traces.

The startup case (Fig. 4, left) illustrates the development of the temperature difference across the core that, after an initial heat-up phase, decreases and becomes stable as steady-state natural-circulation flow is established. An increase in input power (Fig. 4, right) illustrates an increased temperature difference, as expected. Since natural circulation had already been established, steady state at the higher power level was established very quickly. The test system provides the opportunity to gather required data and validate both steady-state and transient modeling solutions.

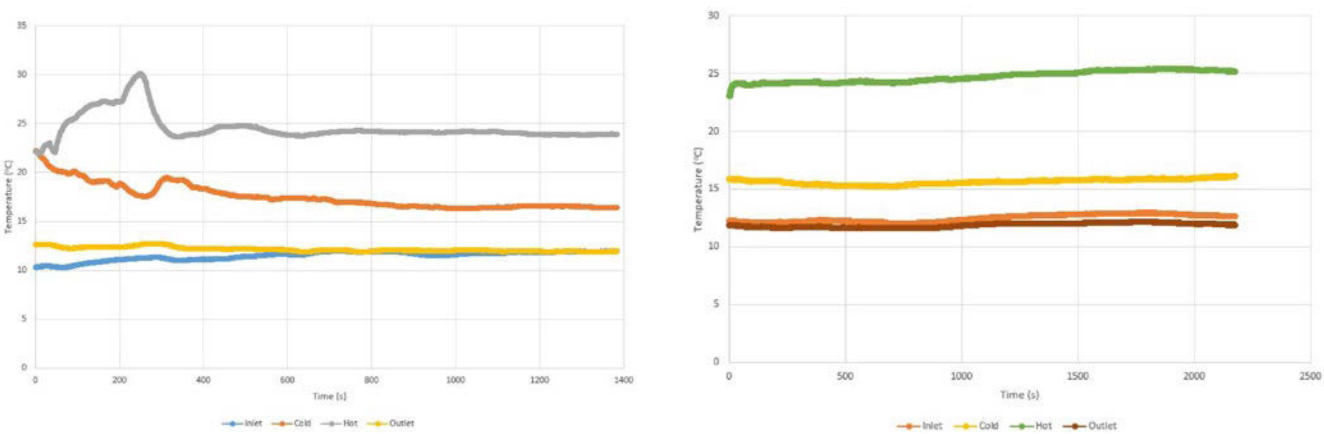

Fig. 4. Left: 40-amp-power run from startup; right: 75-amp-power run.

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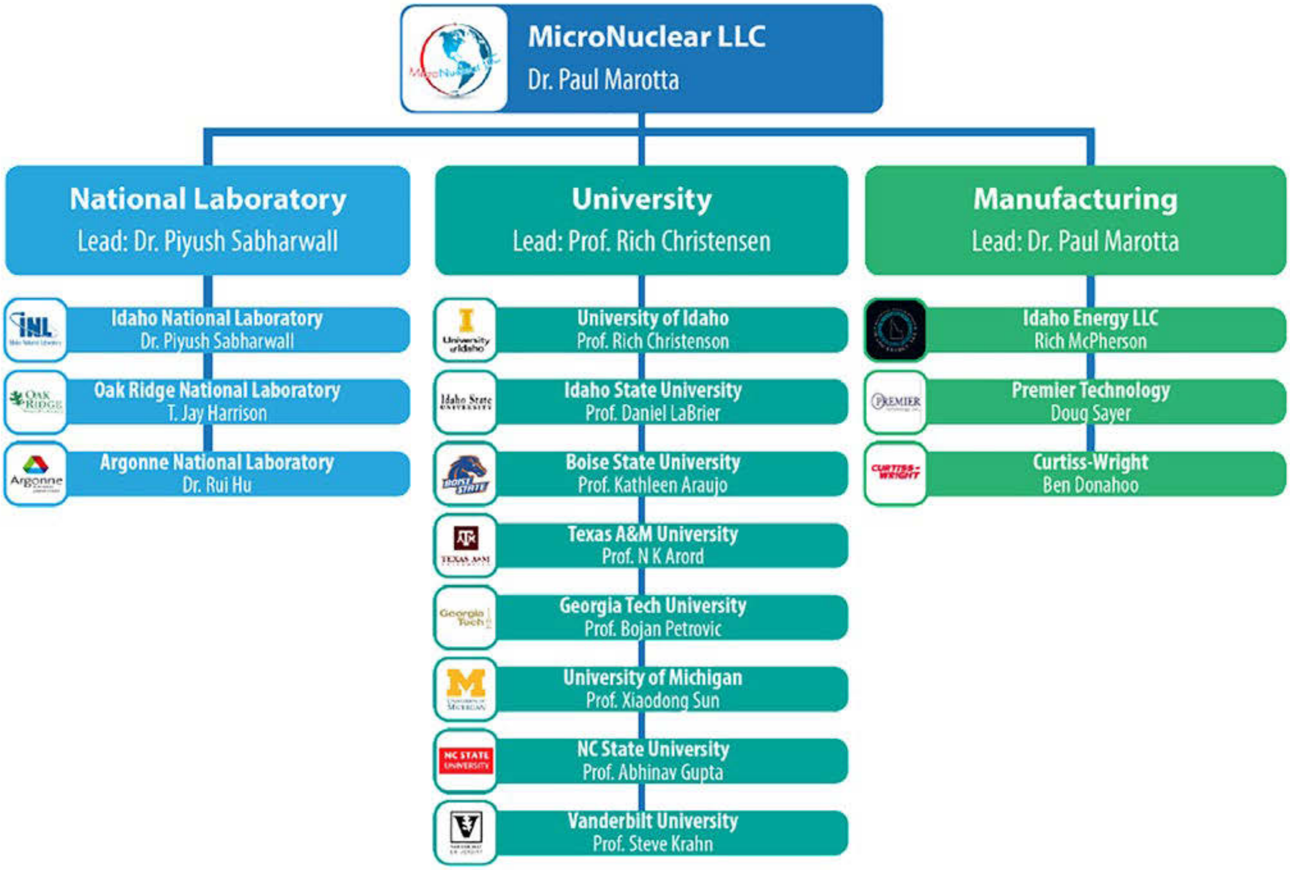

Fig. 5. MsNB project consortium.

MicroNuclear LLC plans to continue MsNB development with the support of several team members from the consortium illustrated in Fig. 5. We at MicroNuclear would like to acknowledge all the excellent supporting work conducted by students under the guidance of the University of Idaho and other supportive professionals passionate about the development of advanced nuclear energy.

Paul Marotta is chief executive officer of Tennessee-based MicroNuclear LLC. Richard Christensen is a professor at the University of Idaho. Piyush Sabharwall is a senior research scientist at Idaho National Laboratory. Robin Roper, Kristen Geddes, and G. C. and E. Carter helped with the experimentation and preparation of this article.

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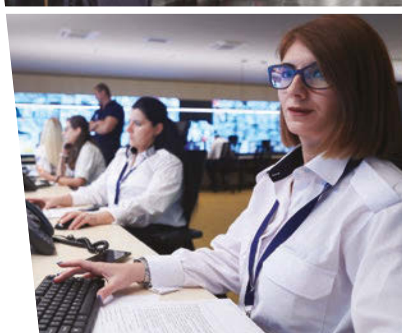


Extension of Hope Creek/ Salem subsidies approved

New Jersey's Board of Public Utilities (BPU) on April 27 voted unanimously to extend, for an additional three years, the zero-emission certificate (ZEC) program benefitting the state's two operating nuclear power plants, Hope Creek and Salem. The facilities produce more than 90 percent of New Jersey's carbon-free electricity and about 40 percent of its overall power.

Public Service Enterprise Group (PSEG), owner of Hope Creek and co-owner, with Exelon, of Salem, filed applications to extend the ZECs in October of last year, citing New Jersey's clean energy policy, the lower cost of ZECs compared with solar and offshore wind subsidies, and the continued deterioration of power markets. (ZECs allow nuclear plants to enter capacity auctions at a lower price point to compete with historically low natural gas prices and federally subsidized renewable generation.)

"We are pleased with the New Jersey Board of Public Utilities' unanimous decision to extend the ZECs at the current rate to help support New Jersey's largest supply of carbon-free electricity," PSEG stated in response to the vote. "The BPU's actions today helped the environment, saved jobs, and avoided higher energy costs. We appreciate the BPU's detailed review and consideration of PSEG Nuclear's ZEC applications."

Above: The Hope Creek nuclear power plant. (Photo: Peretz Partensky/Wikimedia)

Hope Creek/Salem trials

In December 2017, Ralph Izzo, PSEG's chairman and chief executive officer, told a committee of New Jersey lawmakers that Hope Creek and Salem would be unprofitable within two years and, without financial support from the state, would have to be retired. Legislation to address the issue was introduced the following March, and in May 2018, S. 2313 was signed into law by Gov. Phil Murphy. The law directed the BPU to establish a ZEC program—similar to programs implemented in Illinois and New York—with each certificate representing "the fuel diversity, air quality, and other environmental attributes of one megawatt-hour of electricity generated by an eligible nuclear power plant." The program was estimated to be worth about $300 million in annual subsidies to PSEG.

In April 2019, the BPU issued an order determining that Hope Creek and Salem were eligible to receive ZECs from April 18, 2019, through May 31, 2022. While the decision was cheered by nuclear advocates and some clean energy groups, it did not sit well with some others. In a May 2019 appellate court filing, the New Jersey Division of Rate Counsel, an independent state agency representing consumer interests, argued that PSEG had failed to prove financial need.

The Hope Creek and Salem subsidies survived that legal challenge in March of this year, when a three-judge appellate court rejected the Rate Counsel's argument. On April 19, however, the Rate Counsel filed a petition with the New Jersey Supreme Court, appealing the lower court's decision.

APPOINTMENTS

Katy Huff named to leadership post in DOE's Office of Nuclear Energy

Huff

Kathryn D. "Katy" Huff, an assistant professor of nuclear engineering at the University of Illinois at Urbana-Champaign (UIUC), has joined the Department of Energy's Office of Nuclear Energy as principal deputy assistant secretary, the DOE announced on May 10. Huff has also taken on the title of acting assistant secretary.

Following her swearing-in, Huff broke the news on Twitter. "I'm thrilled to finally share that today is my first day in the Department of Energy's Office of Nuclear Energy," she said. "I'm honored that the Biden-Harris administration has called me to serve . . . during a crucial time in humanity's endeavors toward sustainability, re-imagination of our energy infrastructure, and centering of environmental and energy justice in technology policy. . . . In this position, I hope to work across institutional and other barriers, listen to many voices, strive boldly, and serve responsibly."

Huff encouraged the nuclear community to engage with her on Twitter by asking open-ended questions, including: "What, specifically, would YOU like to see (or not see!) from @GovNuclear this year?"

Huff is taking an extended, unpaid leave of absence from her faculty position in UIUC's Department of Nuclear, Plasma, and Radiological Engineering. She joined the department in 2016 and has led the Advanced Reactors and Fuel Cycles Research Group and served as a Blue Waters assistant professor with the National Center for Supercomputing Applications. Before her faculty appointment, Huff worked as a postdoctoral fellow at the Berkeley Institute for Data Science and the Nuclear Science and Security Consortium at the University of California–Berkeley.

Huff earned a bachelor's degree in physics from the University of Chicago and a doctorate in nuclear engineering from the University of Wisconsin–Madison. Her dissertation and postdoctoral work focused on the development of software for nuclear engineering applications, such as the Cyclus simulator, PyNE, and extensions to MOOSE. Her research interests include modeling and simulation of advanced reactors,

Power & Operations continues

emphasizing scientific software engineering best practices.

An active member of the American Nuclear Society since 2008, Huff was elected to the ANS Board of Directors in April, but she has declined that position due to her new role with the DOE. She has held leadership positions in the Fuel Cycle and Waste Management Division, the Nuclear Nonproliferation Policy Division, the Mathematics and Computation Division, and the Young Members Group. She received the ANS Young Member Excellence Award in 2016 and the Mary Jane Oestmann Professional Women's Achievement Award in 2017.

Craig Piercy, ANS executive director and chief executive officer, welcomed the news of Huff's appointment. "Congratulations to Katy Huff for being named the principal deputy assistant secretary and acting assistant secretary of energy at the DOE's Office of Nuclear Energy," Piercy said. "We at the American Nuclear Society look forward to her tenure as NE-2 and acting NE-1."

VOGTLE

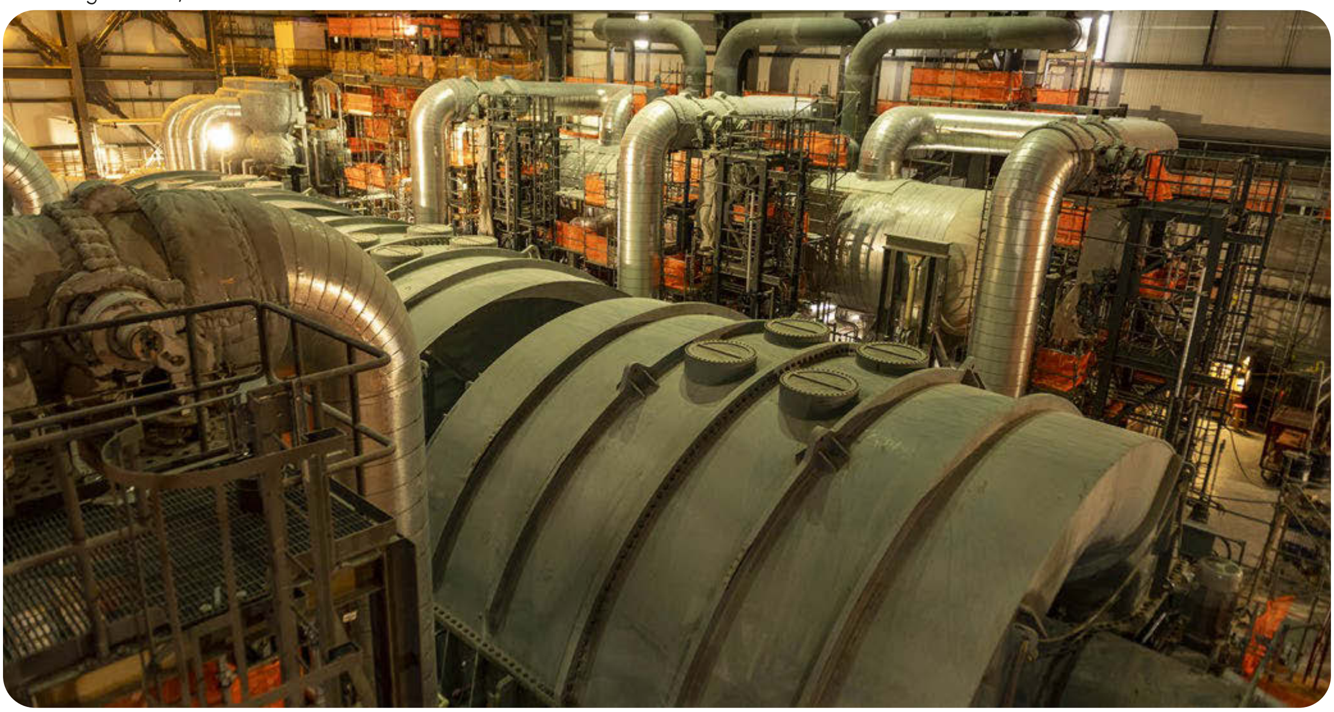
Southern targets December for Unit 3 startup

Southern Company is targeting December for placing Vogtle-3 in service, according to Tom Fanning, the company's chairman, president, and chief executive officer, who spoke with financial analysts on April 29 in a first-quarter earnings call. "The site work plan now targets fuel load in the third quarter and a late December 2021 in-service date for Unit 3," Fanning said. "Of course, any delays could result in a first-quarter 2022 Unit 3 in-service date."

Fanning added that direct construction of Unit 4 is now about 80 percent complete and that the site's current work plan "targets completion in the third quarter of 2022, which would provide margin to the regulatory approved November [2022] in-service date."

Southern subsidiary Georgia Power announced in March that Vogtle-3—the first of two 1,100-MWe AP1000 pressurized water reactors under construction at the Vogtle plant near Waynesboro, Ga.—would likely miss its November regulatory approved start date.

Vogtle-3 turbine generator. (Photo: Georgia Power)



Hot functional testing begins at Unit 3; Unit 4 water tank placed

Southern Company subsidiary Georgia Power on April 26 announced two significant milestones at the Vogtle nuclear plant's expansion project: the commencement of hot functional testing at Unit 3 and the placement of Unit 4's passive containment cooling water storage tank, known as CB-20.

Hot functional testing comprises the last series of major tests for Vogtle-3 ahead of initial fuel load. The tests are conducted to verify the successful operation of reactor components and systems together and confirm that the unit is ready for fuel load. As part of this testing, Georgia Power said, the site team will begin running Unit 3 plant systems without nuclear fuel and advance through the testing process toward reaching normal operating pressure and temperature.

Over the next several weeks, the heat generated by the unit's four reactor coolant pumps will be used to raise the temperature and pressure of plant systems to normal operating levels, according to the utility. Once normal operating temperature and pressure levels are achieved and sustained, the unit's main turbine will be raised to normal operating speed using steam from the plant. During this series of tests, nuclear operators will be able to exercise and validate procedures as required ahead of fuel load. Georgia Power expects hot functional testing to take six to eight weeks.

The CB-20 module is placed atop the Vogtle-4 containment vessel. (Photo: Georgia Power)

Placement of the CB-20 module atop the Unit 4 containment vessel and shield building roof represents the last major crane lift for the Vogtle project. Standing 35 feet tall and weighing more than 720,000 pounds, CB-20 will hold approximately 750,000 gallons of water that will flow down to help cool the reactor in the event of an emergency. The water can also be directed into the spent fuel pool, while the tank itself can be refilled from water stored elsewhere on-site.

INDIAN POINT

Plant closing ends nearly 60 years of clean power generation

The disturbingly long list of U.S. nuclear plants prematurely closed in recent years got even longer April 30, when the last reactor at the Indian Point Energy Center, Unit 3, powered down for the final time. The shutdown, at 11 p.m. local time, marked the end of some 59 years of zero-carbon electricity generation at the Buchanan, N.Y., facility.

The plant's closure was the result of a settlement agreement reached in 2017 by Entergy, the State of New York, and Riverkeeper, self-billed as New York's "clean water advocate." Indian

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Indian Point-3's turbine hall and generator. (Photo: Entergy)

Point's Unit 2 reactor ceased operation on April 30, 2020. (Unit 1 operated from 1962 to 1974.)

"Indian Point has been operated and maintained at the highest levels of reliability, safety, and security for many years," said Chris Bakken, Entergy's chief nuclear officer. "Indian Point's enduring legacy will be the thousands of men and women who operated the plant safely, reliably, and securely, while helping to power New York City and the lower Hudson Valley for nearly 60 years. We owe those who serve now, along with those who came before them, a debt of gratitude."

Unit 3's final run lasted 753 days—a world record for commercial light water reactors, according to Entergy. The previous record for continuous days on line was 739, set in 2006 by Exelon's LaSalle-1.

In Case You Missed It—Power & Operations

Another Canadian province has signed on for SMR development. Alberta premier Jason Kenney added his signature to a memorandum of understanding on small modular reactor development that was signed in 2019 by the premiers of New Brunswick, Ontario, and Saskatchewan. Kenney signed the document on April 14 at a virtual event that also promoted the release of *Feasibility of Small Modular Reactor Development and Deployment in Canada*—a study formally requested as part of the MOU.

Alberta premier Jason Kenney at an online event, after signing an agreement on small modular reactor development. (Photo: Chris Schwarz/ Government of Alberta)

The feasibility study was prepared by Ontario Power Generation, Bruce Power, NB Power, and SaskPower for the governments of New Brunswick, Ontario, and Saskatchewan. Those provinces, the study says, share a collective interest in SMRs as a clean energy option to address climate change and meet regional energy demands while also responding to the need for economic growth and innovation.

One nuclear plant in Missouri (Callaway) isn't enough for state Rep. John Black (R., 137th Dist.). The lawmaker's H.B. 261, introduced earlier this year after a similar version failed to make headway in 2020, would create the Missouri Nuclear Clean Power Act, aimed at fostering the development of nuclear power in the state. Under the bill, companies that build clean baseload generating plants or renewable-source generating plants rated at 200 MW or more would no longer be prohibited from charging for construction costs before beginning operation.

Black

The legislation passed the Missouri House's Utilities Committee on March 10 and its House Administrative Oversight Committee on March 23. On Tuesday, April 13, the bill was placed on the "perfection calendar," where, at this writing, it awaits further debate on the House floor.

For in-depth coverage of these stories and more, see ANS's Nuclear Newswire *at ans.org/news.*

LEGISLATION

Grid cybersecurity bill reintroduced in Senate

Sen. Lisa Murkowski (R., Alaska) on April 28 reintroduced legislation from 2019 to strengthen the security of the U.S. electric grid. According to Murkowski, the Protecting Resources on the Electric Grid with Cybersecurity Technology (PROTECT) Act would enhance electric grid security by incentivizing electric utilities to make cybersecurity investments.

Introduced in the Senate as S. 1400, the bill would also establish a Department of Energy grant and technical assistance program to deploy advanced cybersecurity technology for utilities that are not regulated by the Federal Energy Regulatory Commission. Cosponsors of the PROTECT Act include Sens. Joe Manchin (D., W.Va.), Jim Risch (R., Idaho), Angus King (I., Maine), and Jacky Rosen (D., Nev.).

"The threat of cyberattacks by foreign adversaries and other sophisticated entities is real and growing, and COVID-19 has not helped reduce the threat of cyberattacks on America's networks, including our energy infrastructure," Murkowski said.

Manchin added, "The reliability and resilience of our electric grid goes hand in hand with the economic and national security of the United States, so it's critical that we're two steps ahead in planning for unexpected events and threats. The PROTECT Act would create incentives for utilities to enhance their cybersecurity efforts and increase their resilience to attacks. I urge my colleagues on both sides of the aisle to support this common sense, bipartisan legislation to ensure we're keeping our grid—and our nation—safe."


Murkowski

Key provisions of the bill include:

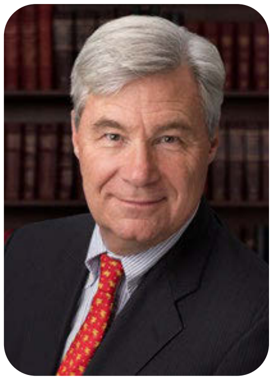
- Directing FERC to issue a rulemaking on rate incentives for advanced cybersecurity technology.
- Establishing a grant and technical assistance program at the DOE to deploy advanced cybersecurity technology on the electric systems of utilities that are not regulated by FERC. Examples include cooperatives and municipal utilities, as well as small investor-owned utilities that sell less than 4 million megawatt-hours of electricity per year.

Energy innovation tax credit proposal released

Sens. Sheldon Whitehouse (D., R.I.) and Mike Crapo (R., Idaho), both members of the Senate Finance Committee, have released a discussion draft of the Energy Sector Innovation Credit (ESIC) Act, a technology-inclusive energy tax proposal to encourage innovation in the clean energy sector.

According to its sponsors, the ESIC proposal would do the following:

- Promote clean energy innovation by allowing up to a 40 percent investment tax credit or a 60 percent production tax credit for low-market-penetration technologies across a range of energy sources, including nuclear, renewables, and fossil fuels.
- Phase out credits as technologies mature, which would provide an on-ramp for the most innovative technologies to get to market and then compete on their own, rather than allowing Congress to pick winners and losers when temporary credits expire.
- Group technologies that are substantively different from one another as determined by the Department of Energy, national labs, and other stakeholders.
- Provide flexibility for unforeseen clean energy technologies to be eligible for ESICs by including an expedited-consideration provision for Congress to take up new technology recommendations from the DOE.


Whitehouse


Crapo

Power & Operations continues

"We have plenty of good ideas for clean energy technology to battle climate change," Whitehouse said on April 26. "The challenge is bringing them online quickly enough to make a difference. That's why we need proposals like this one. Our legislation will hit the accelerator on promising new sources of clean energy and help those technologies compete with heavy-polluting sources on the open market. I'm glad to partner with Senator Crapo in beginning work on this bipartisan bill and look forward to strengthening it as others weigh in."

WATTS BAR

Company settles project dispute with TVA

Construction and maintenance services firm Day & Zimmermann (D&Z) has paid $200,000 to resolve allegations that it submitted false claims to the Tennessee Valley Authority for services performed in connection with capital improvement projects at the Watts Bar nuclear plant, the U.S. Attorney's Office for the Eastern District of Tennessee announced April 22.

In 2013 and 2014, in response to the Nuclear Regulatory Commission's Fukushima-inspired safety mandates, TVA amended an existing $700 million contract with D&Z by an additional $550 million, in part to fund improvements designed to enhance safeguards against nuclear meltdowns. One of those improvements was to construct an elevated "Flex" building, designed to provide backup operating controls in the event of an earthquake, flood, tornado, hurricane, or other extreme event.

According to the U.S. Justice Department, during the period from January 1, 2014, through May 5, 2014, D&Z knowingly shifted costs from various project codes that fell outside the scope of the Flex project and improperly charged those costs against the project by falsely using Flex project codes. The department also alleged that D&Z failed to correct mischarges that it knew or should have known were incorrectly applied and that resulted in false claims for payment, as well as overpayments that were not returned to TVA.

Responding to the settlement in an April 26 email, D&Z's vice president of marketing and communications, Matt Rivera, said, "Day & Zimmermann is a values-based organization, committed to integrity in all business transactions. This settlement is not an admission of any liability, and although we are confident in our position that we acted appropriately during the Flex project in all respects, we settled this matter to avoid further litigation costs and to resolve all issues to the mutual satisfaction of our customer and the appropriate governing authorities."

The Watts Bar nuclear power plant in Tennessee.

REPORTS

IEA: CO_2 emissions on their way back up

The decline in global carbon dioxide emissions recorded last year will not continue through 2021, a recent report from the International Energy Agency concludes. Released in April, *Global Energy Review 2021* finds that energy-related CO_2 emissions are on course for the second-largest increase in history, reversing most of 2020's COVID pandemic–related drop. The surge would be the largest since 2010, during the carbon-intensive recovery from the worldwide financial crisis, according to the agency.

The IEA report forecasts a 6 percent rebound in global economic output in 2021, pushing the global GDP more than 2 percent higher than 2019 levels, as well as a 4.6 percent boost in energy demand, more than offsetting 2020's 4 percent contraction and nudging demand 0.5 percent above 2019 levels. Almost 70 percent of the projected increase in demand, the report says, will come from emerging markets and developing economies, where demand should rise 3.4 percent above 2019 levels.

As a result, CO_2 emissions are expected to increase by almost 5 percent to 33 billion tons in 2021, with the key driver being demand for coal, which is set to grow by 4.5 percent, approaching its all-time peak in 2014. The electricity sector will account for three-quarters of this increase, the report states.

Despite the commissioning of new operating nuclear units in China and Russia, the report identifies a decrease in generation from power reactors of around 4 percent in 2020—the largest drop since the aftermath of the Fukushima Daiichi accident in 2011—with major reductions having occurred in the European Union (–11 percent), Japan (–33 percent), and the United States (–2 percent). The report does predict a 2 percent increase in global nuclear generation in 2021 but notes that this will reverse only half of last year's decline.

"This is a dire warning that the economic recovery from the COVID crisis is currently anything but sustainable for our climate," said Fatih Birol, the IEA's executive director. "Unless governments around the world move rapidly to start cutting emissions, we are likely to face an even worse situation in 2022."

POLICY

DOE kicks off cybersecurity plan

The Biden administration has launched an initiative to enhance the cybersecurity of U.S. electric utilities' industrial control systems (ICS) and secure the nation's energy sector supply chain, the Department of Energy announced on April 20. The 100-day plan is a coordinated effort between the DOE, the Cybersecurity and Infrastructure Security Agency, and the electricity industry.

"The United States faces a well-documented and increasing cyber threat from malicious actors seeking to disrupt the electricity Americans rely on to power our homes and businesses," said secretary of energy Jennifer Granholm. "It's up to both government and industry to prevent possible harms—that's why we're working together to take these decisive measures, so Americans can rely on a resilient, secure, and clean energy system."

According to the DOE, "Over the next 100 days, DOE's Office of Cybersecurity, Energy Security, and Emergency Response—in partnership with electric utilities—will continue to advance technologies and systems that will provide cyber visibility, detection, and response capabilities for industrial control systems of electric utilities."

The DOE said that in addition to modernizing cybersecurity defenses, the initiative will do the following:

Power & Operations continues

- Encourage owners and operators to implement measures or technology that enhance their detection, mitigation, and forensic capabilities.
- Include concrete milestones for owners and operators to identify and deploy technologies and systems that enable near real-time situational awareness and response capabilities in critical ICS and operational technology networks.
- Reinforce and enhance the cybersecurity posture of critical infrastructure information technology networks.
- Include a voluntary industry effort to deploy technologies to increase visibility of threats in ICS and operational technology networks.

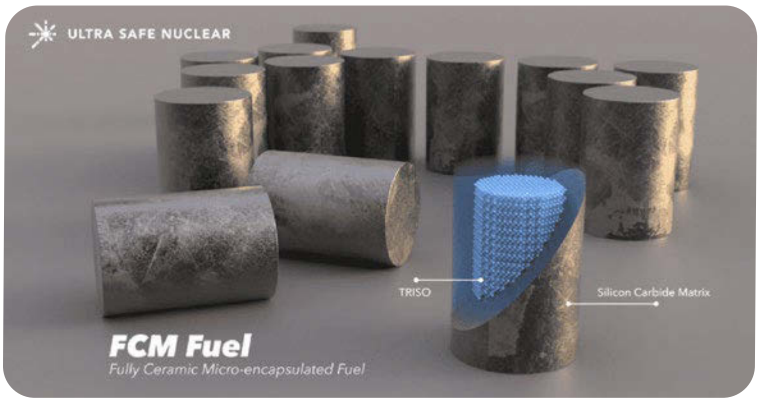
FUEL

A first: TRISO made in Canada

Canadian Nuclear Laboratories (CNL) announced in April that it has fabricated fully ceramic microencapsulated (FCM) fuel pellets, a proprietary reactor fuel designed by Ultra Safe Nuclear Corporation (USNC) for its Micro Modular Reactor (MMR). The FCM project, funded through the Canadian Nuclear Research Initiative (CNRI), represents the first time that tristructural isotropic (TRISO) fuel has been manufactured in Canada, according to CNL.

"The successful fabrication of this innovative fuel design represents a major milestone for SMR research here in Canada and demonstrates that CNL has the necessary expertise and capabilities to help move these advanced fuels from concept to reality," said Joe McBrearty, CNL's president and chief executive officer. "I'm thrilled that we were able to collaborate with USNC on this work through the CNRI program, a program designed to help SMR vendors gain access to our expertise in order to help advance the development and commercialization of their unique technologies."

Fully ceramic microencapsulated fuel. (Image: USNC)



Mark Mitchell, president of USNC-Power, added, "This achievement demonstrates the readiness of the FCM technology for deployment and furthers Canada's position as a leading innovator in the nuclear industry."

USNC's FCM pellet design consists of spherical TRISO particles dispersed in a matrix of silicon carbide. The particles contain a dense fuel kernel coated with layers of graphite and silicon carbide, rendering them robust and capable of withstanding intense heat and pressure, according to CNL. TRISO fuels have been proposed for a number of new small and advanced reactor designs currently under consideration in Canada.

CNL's CNRI program was launched in 2019 to accelerate the deployment of SMRs in Canada by enabling research and development and connecting the SMR industry with the facilities and expertise within CNL. The FCM project is part of a broader portfolio of work between CNL and USNC that includes the establishment of a functional laboratory for fuel analysis at CNL's Chalk River campus in Ontario. The work also includes the development of a multiyear testing program to support the validation of USNC's fuel and core as they progress through the Canadian Nuclear Safety Commission's vendor design review process.

USNC, along with Ontario Power Generation, is a key partner in Global First Power, the organization proposing to construct and operate an MMR at Chalk River. Licensing activities for the MMR project have begun, and an environmental assessment is underway at this writing.

Image: DARPA

Five-year target for cislunar nuclear thermal propulsion demo

The U.S. Department of Defense wants to demonstrate a novel nuclear thermal propulsion (NTP) system above low-Earth orbit by 2025. The Defense Advanced Research Projects Agency (DARPA) has awarded a contract to General Atomics Electromagnetic Systems (GA-EMS) for the design of the nuclear reactor that will power the Demonstration Rocket for Agile Cislunar Operations (DRACO). Blue Origin and Lockheed Martin will work on a parallel track to design a spacecraft tailor-made to demonstrate the NTP system.

General Atomics has received a $22.2 million cost-plus-fixed-fee contract, with an estimated completion date in October 2022. The contracts were announced April 12.

"The United States absolutely needs to be in cislunar space," Christina Back, vice president of Nuclear Technologies and Materials at GA-EMS, told *Nuclear News*. "At General Atomics Electromagnetic Systems, we are attuned to future mission needs and strove to achieve the lightest weight, most efficient nuclear propulsion system. Our concept is a result of careful analysis that explored the design trade space to define a compact reactor core configuration."

The DOD plans to deploy agile, responsive spacecraft in cislunar space—the spherical space between Earth's atmosphere and its orbiting moon—but current electric and chemical propulsion systems have limited thrust-to-weight and propellant efficiency. An NTP system using energy released by nuclear fission can heat hydrogen propellant to extreme temperatures before expelling it through a nozzle to produce thrust that outperforms electric and chemical propulsion systems.

"Compared to conventional space propulsion technologies, NTP offers a high thrust-to-weight ratio around 10,000 times greater than electric propulsion and two to five times greater specific impulse than chemical propulsion," according to DARPA. That combination could provide the maneuverability the DOD seeks in cislunar space and could also be used to expand the capabilities of future NASA missions.

Research & Applications continues

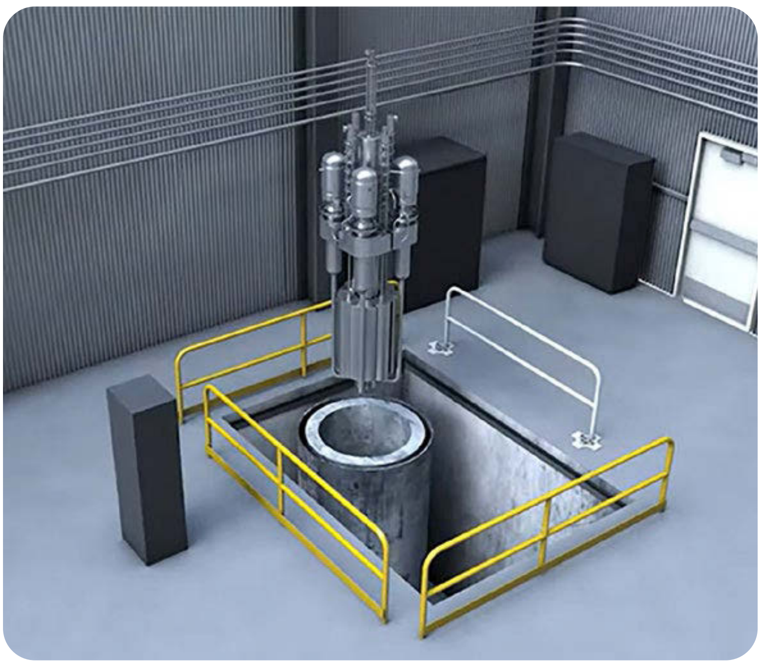
The task for GA-EMS over the next 18 months is to deliver a preliminary design of the NTP system to demonstrate and ensure that the system is operationally effective and able to be built and validated in low-Earth orbit within the next five years.

Key objectives of the DRACO program are classified, but according to DARPA, Phase 1 of the program will last 18 months and consist of two tracks. Track A—GA's role—will entail the preliminary design of an NTP reactor and propulsion subsystem concept and will culminate in a baseline design review. Blue Origin and Lockheed Martin will independently perform Track B work to produce an operational system spacecraft concept to meet mission objectives and design a demonstration system spacecraft concept as well. The demonstration system will specifically focus on demonstrating the NTP propulsion subsystem, according to DARPA.

DARPA anticipates that the objectives of Phase 2 will include a complete, detailed design of the demonstration; fabrication of the nuclear reactor; execution of a zero-power-critical test of the reactor; and acquisition of long-lead materials for the demonstration. Phase 3 would include fabrication, assembly, launch, and on-orbit demonstration of the system.

"GA-EMS's expertise in state-of-the-art nuclear fuels and advanced materials are key components to the NTP design to create a highly efficient and exceptionally safe propulsion system. Combined with our in-house capabilities to fabricate these components and others, we can ensure delivery of a superior NTP reactor on orbit and on time," Back said.

General Atomics' NTP work draws on experience from the company's involvement in the 1960s with Project Rover, a program of NASA and the Atomic Energy Commission that was one of the first programs to demonstrate the feasibility of NTP in space. In 1965, the company was also directly involved in nuclear fuel testing and characterization for the SNAP-10A reactor—designed to supply power to a satellite—which is the only U.S. nuclear power reactor launched into space to date.



A video that describes how MARVEL could help researchers and industry partners test, develop, and demonstrate the integration of a microreactor's heat and electricity output with other technologies was released by INL. Here, a video still depicts MARVEL being installed in a concrete pit. (Source: INL)

INL

MARVEL to test microreactor readiness and end-user integrations

The Department of Energy's Office of Nuclear Energy is spreading the word about plans to build a tiny microreactor called the Microreactor Applications Research Validation & EvaLuation (MARVEL) project inside Idaho National Laboratory's Transient Reactor Test (TREAT) Facility and have it in operation within the next three years.

MARVEL would be a sodium potassium eutectic (NaK)–cooled microreactor fueled by uranium zirconium hydride (UZrH) fuel pins using high-assay, low-enriched uranium (HALEU) from existing research supplies. The 100-kWt reactor would be capable of generating about 20 kWe using Stirling engines and would have a core life of about two years.

The DOE proposes to install the MARVEL microreactor in a concrete storage pit in the north high bay of the TREAT reactor building. Modifications to the building to accommodate MARVEL are anticipated to take five to seven months, according to a draft environmental assessment released in January, while construction, assembly, and testing are expected to take another two to three months prior to fuel loading.

The MARVEL test platform is a collaborative effort between the DOE Microreactor Program and the National Reactor Innovation Center. It is intended to:

- Establish authorization, qualification, and validation processes for microreactor technologies, permitting industry partners to connect end-user applications to the system to test and demonstrate technology readiness.
- Test and demonstrate the reactor system's capability to balance grid demand and reactor power supply while supporting a range of applications, such as integrated renewable energy systems, water purification, hydrogen production, and heat for industrial processes.
- Evaluate autonomous technology to achieve optimal operation, supporting end users in testing and validating specific reactor components for remote monitoring and autonomous control, including sensors and instrumentation for live data collection and wireless transmission.

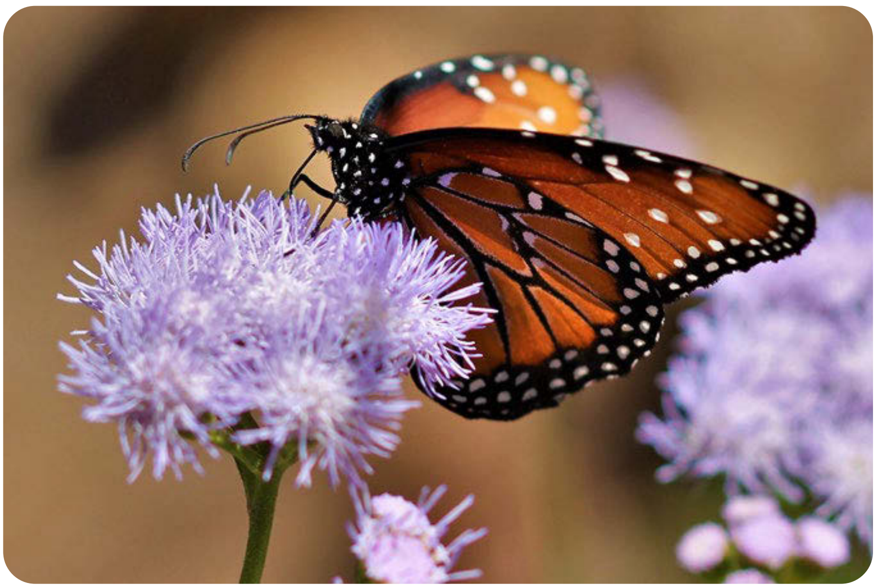
ISOTOPE APPLICATIONS

Isotopes hold clue to travel plans of migrating butterflies

While scientists can tag migrating birds, mammals, and other animals to track their movements, the precise migration patterns of butterflies and other insects too small for tagging evaded scientists' scrutiny for decades. That changed in 1996, when Leonard Wassenaar and Keith Hobson, working at the time as isotope scientists for Environment Canada, demonstrated that isotopic techniques could be used to determine the origin of individual monarch butterflies and deduce the species' annual migration routes. Now, the same technique is being used to study other butterfly species.

Decades ago, Wassenaar and Hobson collected 1,200 specimens of monarch butterflies and used an International Atomic Energy Agency (IAEA) database of stable isotopes in rainwater called the Global Network of Isotopes in Precipitation (GNIP) to determine the origin of individual butterflies by measuring the deuterium content in the insects' wings. GNIP was initiated in 1960 by the IAEA and the World Meteorological Organization, and decades of data have produced reliable maps of precipitation across latitudes.

Wassenaar now heads the Isotope Hydrology Laboratory within the IAEA's Isotope Hydrology Section, which maintains and operates



The Queen butterfly, one of six species studied, follows a "leapfrog migration" pattern: those born in northern parts of the continent follow longer migration routes, "leapfrogging" past their southern kin to spend the winter farther south. (Photo: Wikimedia Commons)

Research & Applications continues

several global isotope data networks for hydrology and climate studies, including GNIP.

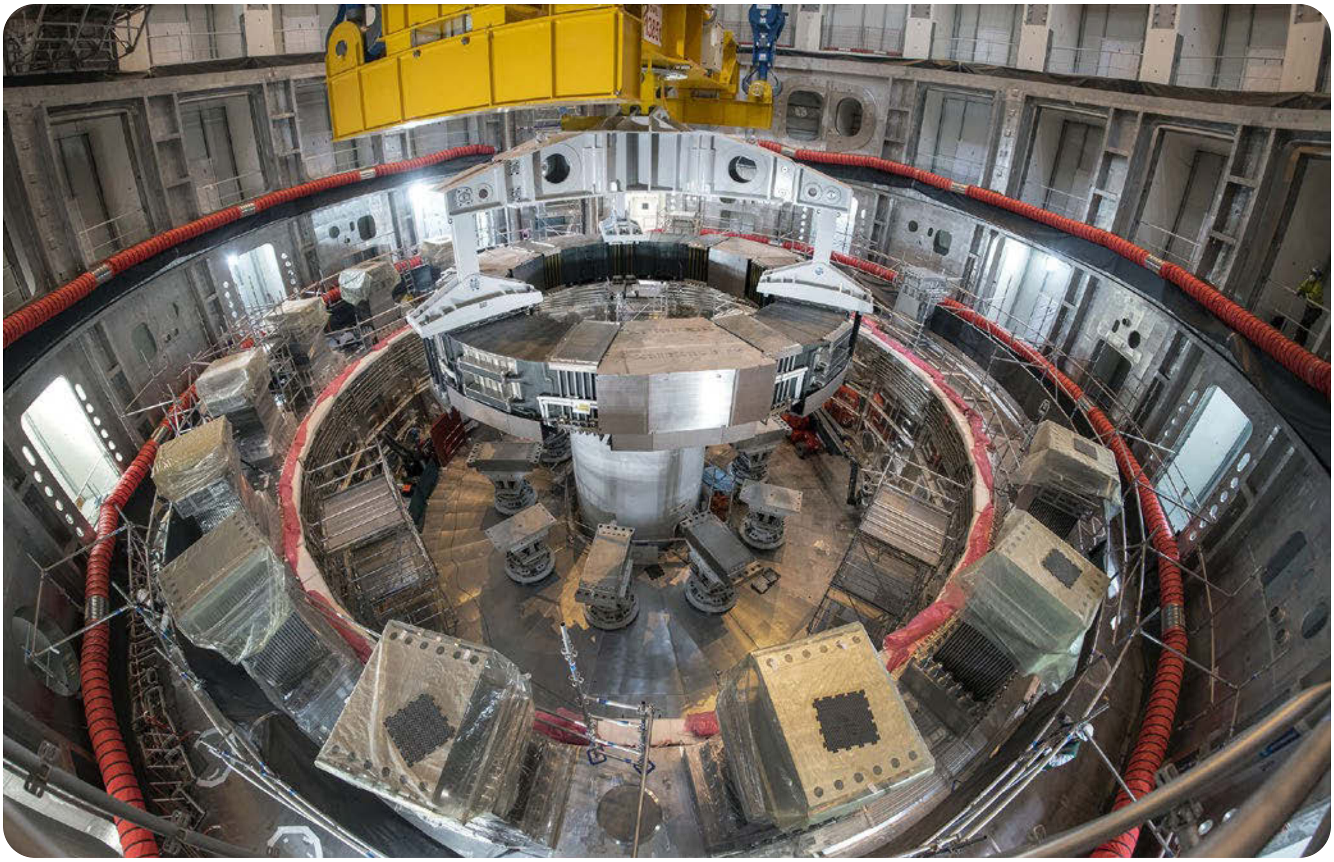
Hobson is now a researcher at the University of Western Ontario in Canada, and he recently coauthored a study published in the journal *Diversity* that used the same stable isotope technique to determine the probable origins and migration paths of six different North American butterfly species. The research was described in a news article released by the IAEA on April 8.

"Knowing where butterflies come from during migration helps to inform conservation strategies that may be needed to protect the resources in their breeding areas. Similarly, knowing where they go in winter helps to protect those habitats during the time they are there," said Wassenaar. "The linkage between geographic locations in the annual life cycle of butterflies cannot be established without using isotope methods."

The research team behind the recent study collected butterflies that had been killed by passing cars on a highway through the Sierra Madre Oriental mountains, near the city of Monterrey in northeastern Mexico. During the fall migration season, southbound butterflies must fly through narrow mountain valleys, and the same valleys are spanned by highway bridges.

The researchers were able to assume, based on the north-south movement of butterflies through the site, that the collected individuals were migrating from points north of the site and within the species' known distribution ranges. The study area was surveyed twice per week in September through November 2019, for a total of 13 sampling days.

The study revealed that four out of the six species studied had traveled from the northern United States or from southern Canada and provided clues on the different migration patterns of each species.



PF6 was lowered onto temporary supports, where it will remain during the installation of nine vacuum vessel subassemblies. (Photo: ITER)

FUSION

Divertor coil placement marks start of ITER magnet assembly

A 10-meter-diameter, 330-metric-ton ITER divertor coil that was seven years in the making was placed in the bottom of the ITER machine on April 21, marking the start of magnet assembly at the site in southern France. The ITER Organization announced the milestone on April 26.

Known as PF6, the divertor coil is thick and heavy because it has more conductor layers than any other poloidal field coil and more conductor turns per layer. The divertor coil is designed to create a null field point that allows for the removal of helium ash from the plasma, according to ITER. Lifting, handling, and installation of PF6 was an eight-hour operation that required a complex rigging system capable of rotating the coil and positioning it to within 4 millimeters of tolerance.

"In order to have zero magnetic field at the divertor null field point, the bottom magnet needs to generate a field equivalent in intensity to the one created by the plasma current—but with an opposite polarity," explained Nello Dolgetta, of the ITER Magnet Section. "And this is the reason why, despite its relatively small diameter, PF6 is so heavy. Since the magnetic field is defined by the intensity of the electric current times the number of conductor turns, we have 30 to 50 percent more coil turns in PF6 than in the other poloidal field coils."

PF6 was manufactured in China by the Institute of Plasma Physics of the Chinese Academy of Sciences. Finished in September 2019, the coil was shipped in March 2020 by barge on the Yangtze River to Shanghai, where it was loaded for ocean transport to the French port of Fos-sur-Mer.

PF6 will remain on temporary supports for a few years, pending the installation and welding of nine vacuum vessel subassemblies, according to ITER. A hydraulic system in the temporary supports will then slightly lift the coil to anchor it to the toroidal field coil superstructure. A similar sequence of events awaits the next poloidal field coil, which is to be installed inside the machine pit this summer. ITER's first plasma is currently scheduled for December 2025.

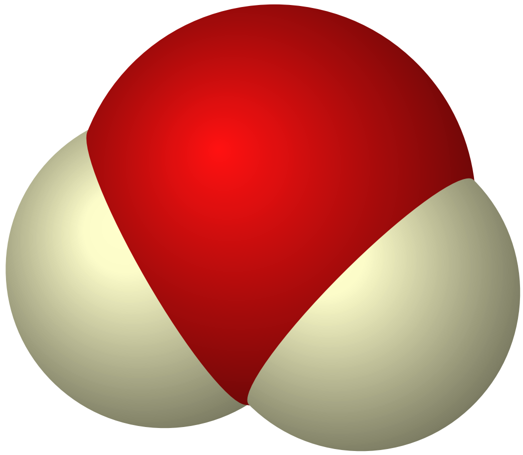
Research & Applications continues

ISOTOPE RESEARCH

Heavy water, light uranium: One sweet contrast

Is isotope science all sweetness and light? Recent headlines on research confirming the sweet taste of heavy water and the creation of the lightest isotope of uranium yet may give that impression. But the serious science behind these separate research findings has implications for human health and for the understanding of the process of alpha decay.

Heavy water (D_2O) is stable and naturally occurring. It differs from ordinary water (H_2O) in the substitution of deuterium (so-called heavy hydrogen) for hydrogen. Because it is less likely to absorb neutrons than H_2O, purified heavy water is used as a moderator and coolant in some nuclear power reactor designs, most notably in Canada's fleet of CANDU pressurized heavy water reactors.



Molecular model of heavy water (D_2O)

Deuterium was discovered in 1931 by Harold Urey, who received a Nobel Prize for his work. Soon after, scientists began to compare anecdotal reports after tasting heavy water. In 1935, *Science* published a short letter by Urey stating unequivocally after a blind taste test by two subjects (one of which was Urey himself) that "pure deuterium oxide has the same taste as ordinary distilled water." Recent research, however, has proven otherwise.

Pavel Jungwirth and Phil Mason, of the Institute of Organic Chemistry and Biochemistry of the Czech Academy of Sciences (IOCB Prague), led a research team that used molecular dynamics simulations, cell-based experiments, mouse models, and human subjects to show conclusively that heavy water tastes sweet to humans (but not, incidentally, to mice). In their research, published in *Communications Biology*, they concluded that the effect was mediated by the human sweet taste receptor TAS1R2/TAS1R3.

"Despite the fact that the two isotopes are nominally chemically identical, we have shown conclusively that humans can distinguish by taste (which is based on chemical sensing) between H_2O and D_2O, with the latter having a distinct sweet taste," said Jungwirth, in an article published on April 7 by IOCB Prague. "Our study thus resolves an old controversy concerning the sweet taste of heavy water using state-of-the-art experimental and computer modeling approaches, demonstrating that a small nuclear quantum effect can have a pronounced influence on such a basic biological function as taste recognition."

The sweet taste receptor responsible for the perceived sweetness is located not only in the human tongue but also in other tissues, and since heavy water is used in some medical procedures, the researchers believe that their findings could have clinical applications.

Ultralight uranium

A research team led by Zai-Guo Gan at the Chinese Academy of Sciences has created a new uranium isotope in a "fusion-evaporation" reaction by firing a beam of argon at a tungsten target and monitoring the output. The research was carried out at the Heavy Ion Research Facility in Lanzhou and published in the journal *Physical Review Letters* on April 14.

Naturally occurring uranium typically contains either 143 neutrons (fissile uranium-235) or 146 neutrons (uranium-238). The newly confirmed isotope has just 122 neutrons, one fewer than the previous record for the element.

The researchers identified two previously discovered light uranium isotopes—uranium-216 and uranium-218—as well as the novel uranium-214, which has a half-life of 0.5 milliseconds. Their findings could reportedly contribute to an understanding of alpha decay—the emission of an alpha particle consisting of two protons and two neutrons.

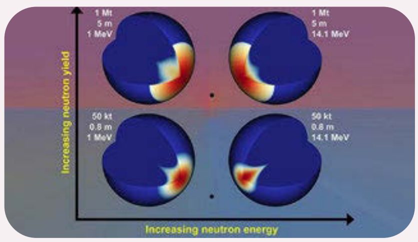
The researchers observed that uranium-214 and uranium-216 decay more easily than do light isotopes of other elements. According to

In Case You Missed It—Research & Applications

Accelerators were delivered to NorthStar Medical Radioisotopes' Wisconsin facility on April 22 after completing a 5,700-mile journey from Belgium. The two 24-ton particle accelerators, made by Belgium's Ion Beam Applications, will be used to produce molybdenum-99, the precursor of technetium-99m. Tc-99m is used in 40,000 medical procedures in the United States each day, and NorthStar is the only commercial producer of Mo-99 in the United States. NorthStar anticipates that its planned Beloit isotope processing facility will more than double its production of Mo-99.

NorthStar is capable of producing Mo-99 using non-uranium-based processes. (Photo: NorthStar Medical

Asteroid deflection research by a team from Lawrence Livermore National Laboratory and the Air Force Institute of Technology found that the detonation of nuclear devices with different neutron energies and neutron yields could variably affect the path and speed of an asteroid on a collision course with Earth by melting and vaporizing portions of the asteroid. The work, which was based on simulations, was recently featured in the journal *Acta Astronautica.*

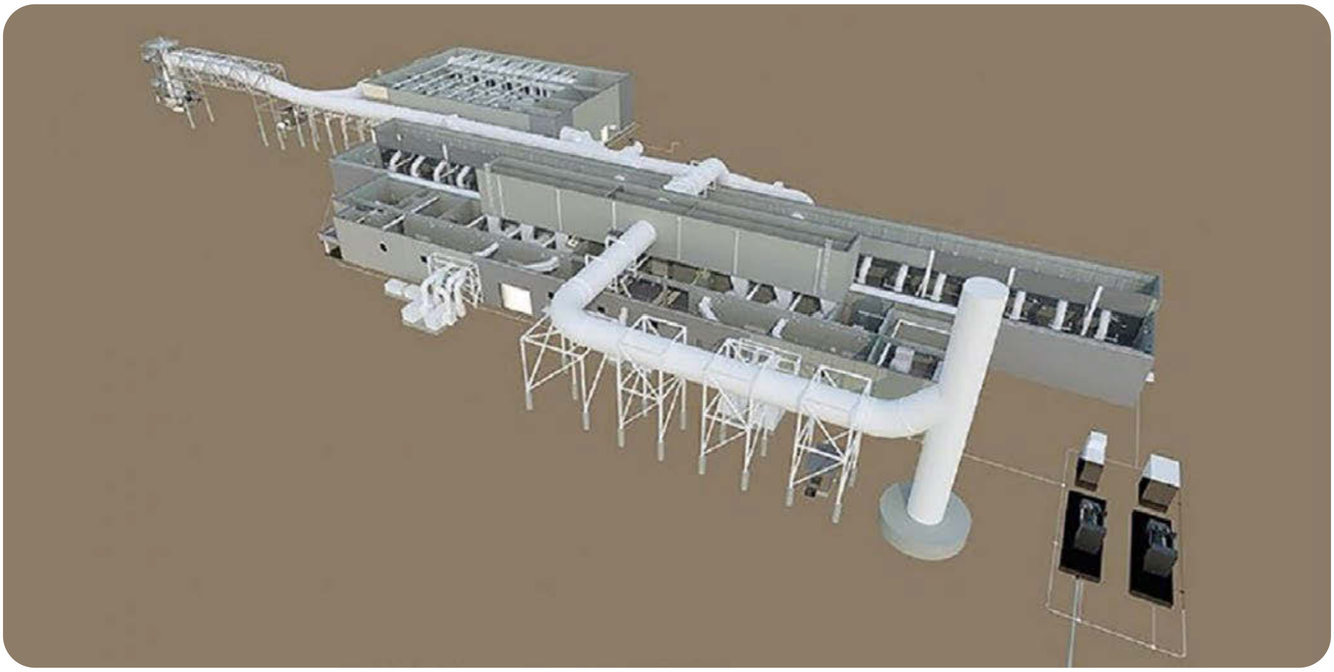


The effects of two neutron yields and two neutron energies were studied. (Image: LLNL)

TAE Technologies says it can scale its fusion technology "to the conditions necessary for an economically viable commercial fusion power plant by the end of the decade" now that its 24-meter-long fifth-generation device, nicknamed Norman, has produced a stable plasma of over 50 million °C. The company said in an April 8 press release that the results indicate the design's beam-driven, field-reversed, linear configuration improves plasma confinement as temperatures rise.

Construction of Norman was completed in 2017. (Photo: TAE Technologies)

For in-depth coverage of these stories and more, see ANS's Nuclear Newswire *at ans.org/news.*



New $163 million contract awarded for WIPP ventilation system

Above: An illustration of WIPP's Safety Significant Confinement Ventilation System, expected to be completed in 2025. (Image: DOE)

Nuclear Waste Partnership (NWP), the management and operations contractor for the Department of Energy's Waste Isolation Pilot Plant in southeastern New Mexico, announced that it has awarded a subcontract valued at approximately $163 million to The Industrial Company (TIC) to complete the construction of the transuranic waste repository's Safety Significant Confinement Ventilation System (SSCVS).

Along with the construction of a utility shaft, the SSCVS is one of two major capital projects at WIPP meant to increase ventilation to the underground repository. The increased airflow will allow simultaneous mining, rock bolting, waste emplacement, maintenance, and experimental scientific operations.

"We are extremely pleased to bring TIC onboard," said NWP's president and project manager, Sean Dunagan. "After an exhaustive and thorough procurement process, we believe TIC is the right contractor to complete the largest construction project at WIPP in almost three decades."

The new agreement, announced on April 21, replaces NWP's original $135 million subcontract for the construction of the SSCVS. That contract, awarded in 2018 to Critical Applications Alliance, was terminated in August 2020 by NWP, which claimed that the termination was necessary to ensure "the quality, safety, and timely completion of the ventilation project."

Critical Applications Alliance is currently suing WIPP for $32 million over the contract termination, arguing that the project suffered from delays and frequent design changes resulting from NWP's inexperience in major construction projects.

The largest containment fan system among DOE facilities, the SSCVS is to provide a modern air supply system designed to run continuously in unfiltered or HEPA filtration mode. After installation, scheduled to be completed in 2025, the system will provide approximately 540,000 cubic feet per minute (cfm) of air to the underground. The current ventilation system provides a maximum of 170,000 cfm.

700-C fan

During an April 15 virtual town hall meeting, the DOE's Carlsbad Field Office and NWP shared environmental monitoring data from a four-hour test of WIPP's 700-C ventilation fan held in January. The DOE and NWP plan to restart the 700-C fan, one of WIPP's legacy unfiltered exhaust fans, to increase airflow during maintenance work underground.

According to the DOE, sampling data conducted during the test confirmed that routine operation of the 700-C fan would result in annual exposures 5,000 times less than the Environmental Protection Agency's threshold limit of 10 millirem per year. Prior to the test, 700-C was examined to ensure any radiological emissions caused by running the fan would be well below regulatory standards.

The 700-C fan has a capacity of up to 240,000 cfm of air to the underground. The increased ventilation will improve the overall air quality in the repository by more efficiently exhausting emissions from diesel equipment used during mining and ground control activities. Because 700-C exhausts directly to the environment, the fan will not be run while waste is being emplaced underground.

Outage

WIPP began accepting shipments and processing transuranic waste in April following a two-month annual maintenance outage. As announced by the DOE on April 20, the repository was accepting five waste shipments per week, with post-pandemic plans to increase shipments to 10 per week.

The maintenance outage lasted from February 15 to April 15, with 97 work activities using personnel from six departments, including mine operations, waste handling, hoisting, work control, safety, and engineering. The break included sitewide power outages to accommodate electrical work.

"The amount of equipment repairs performed during the outage resulted in a huge improvement for waste handling," said WIPP waste handling manager Mars Dukes. "To have all of our equipment operating properly allows us to safely meet the demands of the accelerated shipping schedule and positions our team for success."

Preventive maintenance at WIPP is done on a schedule that can range from daily to annually. Quarterly efforts generally take about a week to tackle. Once a year, a multiweek outage is scheduled to handle projects needing the greatest effort that cannot be performed while normal transuranic waste operations are ongoing.

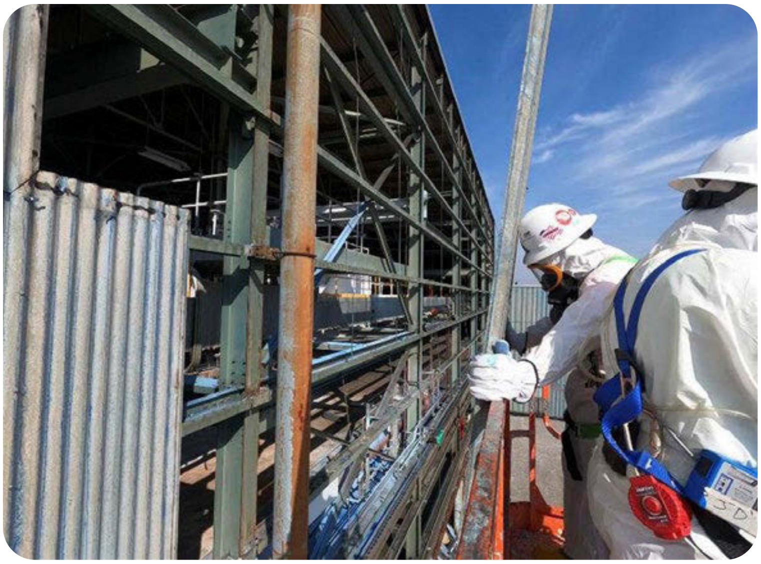
PORTSMOUTH

Fluor, BWXT partnership awarded $690 million contract extension

Fluor-BWXT Portsmouth, a joint venture of Fluor and BWX Technologies, along with engineering company Jacobs, have received a contract extension valued at up to $690 million, including options, from the Department of Energy. The contract, announced April 6, is for environmental management work at the former Portsmouth Gaseous Diffusion Plant near Piketon, Ohio.

Fluor-BWXT Portsmouth was first awarded the decontamination and decommissioning contract for the Portsmouth site in 2010. The plant, which operated from 1954 to 2001, was one of three large gaseous diffusion plants in the United States initially constructed to produce enriched uranium to support the nation's

Waste Management continues


Workers remove asbestos siding panels from a Portsmouth Gaseous Diffusion Plant building. (Photo: Business Wire)

nuclear weapons program and, in later years, enriched uranium used by commercial nuclear reactors. Environmental cleanup of the site began in 1989 and continues today.

The current contract agreement took effect on March 29 and includes a one-year extension with two additional six-month options.

The scope of the project includes the continued deactivation, demolition, and disposal of selected site facilities, process equipment, related process buildings, and other ancillary facilities. It also includes continuing environmental remediation, uranium stewardship, and community outreach programs.

"In partnership with the DOE, the Fluor team has done a tremendous job of delivering on the important decontamination and decommissioning work that is well underway at Portsmouth," said Tom D'Agostino, president of Fluor's Mission Solutions business. "We have been working at Portsmouth for 10 years, and this extension provides a continuity of service crucial for the site and the DOE as the project moves into the next phase of demolition and waste placement."

Ken Camplin, president of BWXT's Nuclear Services Group, said, "BWXT is very pleased that the DOE has extended another contract for the important work at Portsmouth in partnership with Fluor. We believe that BWXT's footprint at seven sites supporting the DOE's environmental management mission demonstrates the breadth and depth of our company's waste management, environmental remediation, and site cleanup capabilities."

HANFORD

Leak discovered in single-shell waste tank

The Department of Energy has determined that an underground single-shell waste tank at its Hanford Site near Richland, Wash., is likely leaking into the soil beneath the tank. The DOE said that the leaking tank poses no increased health or safety risk to the Hanford workforce or the public.

The leak determination was made after monthly monitoring detected a small drop in the level of liquid in the tank, equivalent to approximately 3.5 gallons per day. A formal leak assessment began in July 2020 and concluded on April 29, when the DOE made the announcement.

The DOE said that the Washington State Department of Ecology and the U.S. Environmental Protection Agency have been notified of the leak at Tank B-109, which was previously emptied of pumpable liquids, leaving a very small amount of liquid waste in the tank.

A total of 149 single-shell tanks were built at Hanford between 1943 and 1964 to hold chemical and radioactive liquid waste generated from the production of plutonium for the U.S. nuclear arsenal. Heat generated by the waste and the composition of the waste caused an estimated 67 of these tanks to leak some of their contents into the ground. Most of the waste from the single-shell tanks has been pumped to 28 sturdier double-shell tanks that were built between 1968 and 1986.

One double-shell tank, AY-102, was emptied and taken out of service after it was discovered in 2012 that waste was leaking into the annulus between the primary and secondary tanks.

Because of the previous leaking single-shell tanks, mitigation actions have been in place at Hanford for decades. Active groundwater treatment systems operating in the B Complex area, where Tank B-109 is located, were installed several years ago to capture and treat contamination resulting from the discharge of approximately 52 million gallons of contaminated liquids to the soil surrounding the tank farm during historical operations, the DOE said.

The B Complex area tank farm at the DOE's Hanford Site in Washington. (Photo: DOE)

The water table in the area ranges from 210 to 240 feet below Tank B-109. The DOE estimates that it could take more than 25 years for any contamination from the tank to reach the water table, and it would then be captured and removed by the pump and treat systems. The DOE said it is continuing to assess and explore other capabilities to reduce the release of contaminants to the environment, such as surface barriers meant to prevent water from precipitation from intruding into the tank.

Waste Management continues

SPENT NUCLEAR FUEL

Risk-informed concept can be better applied to licensing, OIG says

How the Nuclear Regulatory Commission collects information in the licensing of spent nuclear fuel can be improved by a better understanding of the concept of risk-informed decision-making, according to a report, *Audit of the NRC's Use of Requests for Additional Information in Licensing Processes for Spent Nuclear Fuel* (OIG-21-A-08), by the agency's Office of Inspector General (OIG).

The report assesses the efficiency and effectiveness of the agency's use of requests for additional information (RAIs) in reviewing applications to store spent nuclear fuel, either at commercial nuclear power plants or at separate storage facilities. RAIs are the method by which NRC staff collects needed information from license applicants before making a regulatory decision.

According to the OIG, while the use of RAIs by staff is effective and efficient, there is an inconsistent understanding of how the risk-informed concept is applied to such requests.

"Agency positions should be readily understood; however, the expectations regarding how to risk-inform RAIs are unclear. As a result, there can be tension between licensing and technical staff during the RAI process," the OIG said in its audit.

To enhance its regulatory framework, the NRC has adopted a more risk-informed, performance-based approach to its licensing process. In May 2018, the NRC issued SECY-18-0060, *Achieving Modern Risk-Informed*

In Case You Missed It—Waste Management

A new strategic vision for cleaning up U.S. legacy waste sites has been released by the Department of Energy's Office of Environmental Management (EM). *Strategic Vision 2021–2031* provides a blueprint to the anticipated accomplishments of EM's cleanup program over the next decade and updates the office's previous report, *A Time of Transition and Transformation: EM Vision 2020–2030,* released in March of last year.

According to EM, the updated strategic vision was developed with feedback from regulators, tribal nations, local communities, and other partners. The report outlines goals for the coming decade, focused on safety, environmental cleanup priorities, innovation, and improved performance.

A draft request for proposals for a new Savannah River Site contract worth up to $21.5 billion over 10 years has been issued by the Department of Energy's Office of Environmental Management. The draft RFP contemplates a standalone, performance-based, cost-plus-award-fee management and operating (M&O) contract containing discrete contract line-item numbers/specifications with the potential for other contract types.

The Savannah River Site's current M&O contract is held by Savannah River Nuclear Solutions, a partnership of Fluor, Newport News Nuclear, and Honeywell. That contract expires on September 30, 2021, although one 12-month option (October 1, 2021–September 30, 2022) remains in the contract.

For in-depth coverage of these stories and more, see ANS's Nuclear Newswire *at ans.org/news.*

Regulation, which discussed the need for systematic and expanded use of risk and safety insights in making decisions.

The OIG found, however, that there is no agreed-upon definition or clear expectation regarding what "risk-informed" means in the context of RAIs among NRC staff and program managers. As a result, the OIG said, "Some staff have difficulty balancing the push to be risk-informed with ensuring the applicant is meeting the regulations."

To enhance the agency's use of RAIs during the spent fuel licensing process, the OIG report recommends that the NRC update guidance to document strategies or tools to be used for risk-informing RAIs; conduct training on how to risk-inform relative to the RAI process and conduct refresher training on an as-needed, periodic basis; and create and implement a formalized process to facilitate effective management transitions in the NRC's Division of Fuel Management.

UKRAINE

Chernobyl's spent fuel storage facility approved to operate

Ukraine's State Nuclear Regulatory Inspectorate (SNRIU) has authorized the operation of Chernobyl's Interim Storage Facility (ISF-2), allowing spent nuclear fuel from the plant's three undamaged reactors to be loaded into the dry storage facility. The handover of the ISF-2 operating license was carried out during a ceremony held on April 26, the 35th anniversary of the Chernobyl accident, and was attended by Ukraine's president, Volodymyr Zelensky.

Participating in the ceremony to hand over the ISF-2 operating license are (from left) Valery Seyda, acting director general of the Chernobyl nuclear power plant; Ukrainian President Volodymyr Zelensky; and SNRIU chairman Grigoriy Plachkov.

Holtec International, which took over the construction of the storage facility in 2011, said that the Chernobyl ISF-2 is the world's largest and most complex dry storage project, with numerous unique challenges that had to be overcome. The issuance of the operating license and the safe loading of used fuel assemblies from Chernobyl's aging storage facility mark the culmination of over two decades of effort to bring the facility to full operation, the company said.

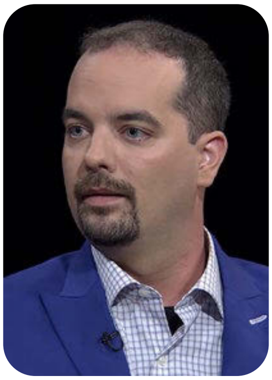
To allow for the decommissioning of Chernobyl, ISF-2 will provide for the processing and storage of spent fuel from Units 1, 2, and 3. A total of 232 double-walled canisters will be safely stored and monitored for a minimum of 100 years in individual concrete modules at the site, according to the European Bank for Reconstruction and Development, which helped finance the project.

Late last year, Holtec loaded two double-walled canisters of Chernobyl's RBMK spent fuel into ISF-2 as part of a demonstration of the system's efficacy. Holtec said that the demonstration was the last step in a string of required commissioning operations prior to the issuance of the license.

"This is a significant step for security in the Chernobyl zone, security in Ukraine, security in Europe, and around the world—the step we are taking today with boundless gratitude and respect to all liquidators of the Chernobyl accident, as well as with boundless faith and readiness to work for the safe, ecological future of our children, our next generations," said President Zelensky.

ANS elects new VP/president-elect, treasurer, and board members

Arndt



Wharton

Prat

Bachman

The results are in. Steven Arndt, ANS Fellow and member since 1981, has been elected the next ANS vice president/president-elect, and W. A. "Art" Wharton III, ANS member since 2004, was elected for a second two-year term as treasurer. Four candidates were elected to serve three-year terms as at-large members of the Board of Directors.

In addition, Catherine M. Prat, ANS member since 2011 and a senior engineer at Westinghouse Electric Company, was elected as the Young Member director, a position created in 2020. Amanda M. Bachmann, ANS member since 2016 and a student at the University of Illinois–Urbana-Champaign (UIUC), was elected Student director.

The new vice president/president-elect, treasurer, and directors will begin their terms on June 17 during the 2021 ANS Annual Meeting, which is again being conducted online due to the COVID-19 pandemic.

Arndt, distinguished scientist at Oak Ridge National Laboratory, will succeed current ANS vice president/president-elect Steven P. Nesbit, an ANS member since 1989 and president of LMNT Consulting. Nesbit will succeed President Mary Lou Dunzik-Gougar, an ANS member since 1994 and an associate dean in the College of Science and Engineering at Idaho State University. Dunzik-Gougar will remain on the board for a one-year term in her role as immediate past president.

The four newly elected members of the board are Harsh S. Desai, ANS member since 2005 and senior manager at the Nuclear Energy Institute; Julie G. Ezold, ANS member since 1992 and section head of Radioisotope Production and Operations at ORNL; Jess C. Gehin, ANS member since 1993 and associate laboratory director for Nuclear Science and Technology at Idaho National Laboratory; and Kathryn D. Huff, ANS member since 2008 and an assistant professor at UIUC. Huff, however, has declined a seat to focus on her new appointment as Department of Energy principal deputy assistant secretary (see page 59).

The 2021 election results were certified by the election services company Survey and Ballot Systems on April 12, following the completion and return of 21.67 percent of the 10,245 ballots sent to ANS members eligible to vote in the election.

Desai

Ezold

Gehin

Huff

Dickman sheds light on Fukushima wastewater issue during CNBC interview


Dickman

Paul Dickman, former senior official with the Nuclear Regulatory Commission who served as the study director for the ANS Special Committee on the Fukushima Daiichi accident, discussed Japan's plans to dispose of Fukushima wastewater during an appearance on CNBC's *Street Signs Asia* with hosts Amanda Drury and Tanvir Gill on April 16.

Appearing on the show as an ANS spokesperson, Dickman assured the hosts that there will be no negative environmental impact from releasing the advanced liquid waste processing system (ALPS)–treated water into the Pacific Ocean. "The Japanese government has done an extraordinary effort to mitigate any harm that would be from the release of this water," Dickman said. "Frankly, they've diluted it to such an extent that it would hardly be detectable above background [radiation]."

Dickman explained that the key element remaining in the wastewater is tritium, a naturally occurring radioactive element found in water everywhere on the planet. "It's in all water and always has been," he said. "Your body, the water you drink, everything has tritium in it."

The Chinese and South Korean governments have been vocal opponents of Japan's plans for the wastewater. Dickman charged that those countries are using the situation for political reasons rather than technical or environmental ones. "Disposing in the ocean is something that happens every day at all the other nuclear power plants," he said. "And all nuclear power plants emit tritium, including those in China and Korea. To be critical of the discharge of tritium is actually being somewhat hypocritical."

Antinuclear environmental groups, such as Greenpeace Japan, have also voiced opposition to the wastewater plan, incorrectly asserting that it could damage human DNA and other organisms if released into the ocean. "That's just false," Dickman said in response to the question from Gill. "The fact is that radiation does damage, but it has to be in very high concentrations. There is no place in the world that isn't radioactive and hasn't always been. Radiation is part of our natural environment. When you fly on an airplane you actually receive a lot more radiation than if you were standing at a fencepost of the Fukushima reactor site."

Dickman also noted that one of the important lessons learned was the Japanese government's failure to communicate adequately during and after the accident. That failure resonates today in that Japanese citizens don't know if they can trust their government officials regarding the wastewater disposal plan. "This is a decision that should have been made several years ago, but they delayed for a variety of reasons because of the reputational damage and loss of faith in their institutions by the Japanese people," Dickman said. "It's going to take them a long time to recover [that trust]."

The Fukushima region is well known for its agriculture, which has rebounded well in most cases since the accident. Dickman pointed out, however, that the fisheries have been slow to recover, citing as the reason the same reputational damage he mentioned earlier. "The reality is the seafood from that area is perfectly safe," he said. "The Japanese government has actually done a very good job in terms of their food safety and testing. But it takes time for people to rebuild their faith in this process."

ANS News continues

New ANS professional division officers and executive committee members selected

Listed below are the ANS professional divisions' 2021–2022 officers and newly elected executive committee members. All terms begin during the 2021 ANS Annual Meeting in June. (Executive committee members whose three-year terms are continuing are not included.)

More information about ANS's 19 professional divisions and two working groups is available at ans.org/communities/divisions/.

Accelerator Applications Division
Lin Shao, vice chair
Fredrik Tovesson, secretary
Steven A. Coleman, treasurer
Executive committee members:
Reginald M. Ronningen, Peter W. A. Brown, Ganapati Myneni, Charles D. Bowman

Aerospace Nuclear Science & Technology Division
Richard Howard, secretary
Aaron P. Selby, treasurer
Executive committee members:
Michael P. Schoenfeld, Matthew A. Krecicki (tie for third member will be determined by the executive committee)

Decommissioning & Environmental Sciences Division
Douglas A. Davis, vice chair
Leah Spradley Parks, secretary/treasurer
Executive committee members:
Richard St. Onge, William J. Szymczak, William R. Roy

Education, Training & Workforce Development Division
Travis W. Knight, vice chair
Robert "Craig" Williamson, secretary
Kyle C. Hartig, treasurer
Executive committee members:
Ishita Trivedi, Kostas "Kos" Dovas, Zaijing Sun

Fuel Cycle & Waste Management Division
John H. Kessler, vice chair
Hatice Akkurt, secretary/treasurer
Executive committee members:
Terry Todd, Jenifer Shafer, Ruth F. Weiner, Kathryn A. Mummah, Chris Robinson

Fusion Energy Division
Executive committee members:
Sergey Smolentsev, Yuji Hatano, Thomas F. Fuerst

Human Factors, Instrumentation & Controls Division
Hyun Gook Kang, 2nd vice chair
Ronald L. Boring, secretary
Pradeep Ramuhalli, treasurer
Executive committee members:
Shannon Eggers, Katrina M. Groth (tie for student representative will be determined by the executive committee)

Isotopes & Radiation Division
Kimberly A. Burns, vice chair
Robert G. Downing, treasurer
Executive committee members:
Erik H. Wilson, Kenan Unlu, Samuel Glover, Padhraic L. Mulligan, Jung H. Rim, Vaibhav Sinha

Materials Science & Technology Division
Kenneth J. Geelhood, vice chair
Assel Aitkaliyeva, secretary/treasurer
Executive committee members:
J. Rory Kennedy, Annabelle Le Coq, Christopher "Topher" Matthews, Djamel Kaoumi, Jonathan G. Gigax, Haiyan Zhao

Mathematics & Computation Division
Tara M. Pandya, vice chair
Executive committee members:
Brendan Kochunas, Adam G. Nelson, Farzad Rahnema

Nuclear Criticality Safety Division
Katherin L. Goluoglu, vice chair
Theresa Cutler, secretary
Brittany Williamson, treasurer
Executive committee members:
Amber McCarthy, Nicholas W. Brown, Joseph A. Christensen, William "Mac" Cook

Nuclear Installations Safety Division
Andrew J. Clark, vice chair
Executive committee members:
Ronald L. Boring, Eric L. Harvey, Aaron S. Epiney, Casey Sundberg

Nuclear Nonproliferation Policy Division
Chloe McMath, vice chair
Athena A. Sagadevan, secretary
Stefani Buster, treasurer
Executive committee members:
Alicia L. Swift, Angela Di Fulvio, William H. Tobey, William A. Boettcher III

Operations & Power Division
Garry G. Young, 2nd vice chair
Ben Holtzman, treasurer
Keith Drudy, secretary
Executive committee members:
Sarah Camba Lynn, Daniel L. Churchman, Temi Adeyeye, Craig Stover, James W. Behrens

Radiation Protection & Shielding Division
David A. Dixon, vice chair
Alexander Barzilov, secretary
Joel Kulesza, treasurer
Executive committee members:
Irina Popova, Shaheen A. Dewji, Amir A. Bahadori, Zachary M. Weis, Andrew R. Rosenstrom (student)

Reactor Physics Division
Matthew A. Jessee, vice chair
Shane G. Stimpson, secretary
Christopher M. Perfetti, treasurer
Executive committee members:
Jason Hou, Andrew Osborne, Steven J. Douglass, Ville Valtavirta, Sterling M. Harper

Robotics & Remote Systems Division
Adam J. Carroll, secretary
Anthony Abrahao, treasurer
Executive committee members:
William "Chris" Eason, Rustam Alexander, George Stolkin, Sungmoon Joo

Thermal Hydraulics Division
Bao-Wen Yang, vice chair
Annalisa Manera, secretary
Igor A. Bolotnov, treasurer
Executive committee members:
W. David Pointer, Xiaodong Sun, Dillon R. Shaver, Hyoung Kyu Cho, Musa Moussaoui

Young Members Group
Kelsey Amundson, vice chair
Sarah C. Lynn, treasurer
Matt Wargon, secretary
Executive committee member:
Ishita Trivedi

New Members

The ANS members and student members listed below joined the Society in April 2021.

Anderson, Nolan A., Idaho National Laboratory

Carman, Joseph L., Enercon
Chock, Alfred W., Jr., LPI Inc.
Cook-Nelson, Kimberly S., Entergy

Davis, Jason E., Oak Ridge Associated Universities
Dunlap, Russell, GSE Solutions

Ellis, Troy, Duke Energy–Robinson plant

Fitz-Coy, Shayne

Gatchalian, Ronald D. E., Texas A&M University
Gerencir, Nathan C., Fluor Marine Propulsion
Gleicher, Frederick N., Idaho National Laboratory
Guzina, Bojan B., University of Minnesota

Heim, Jordan, Blue Wave AI Labs
Henshaw, James, National Nuclear Laboratory (U.K.)
Hills, Stephen M., U.S. Air Force

Jankowski, Keith

McCalley, Phil, Blue Wave AI Labs
Miller, Thomas P., Blue Wave AI Labs
Mingst, Barry C., Meta (Canada)
Mogin, Jamileh, National Nuclear Security Administration
Mueterthies, Michael J., Blue Wave AI Labs

Nistor, Johnathan M., Blue Wave AI Labs

Ollila, Mikko V., Capital Group
O'Neill, Martin J., Nuclear Energy Institute

Pappa, Aadil A., Space Exploration Technologies
Patel, Ankit, Blue Wave AI Labs
Phillips, Jeffrey, Idaho National Laboratory
Pitts, Stephanie A., Idaho National Laboratory

Rajagopala, Abhi, Virginia Commonwealth University

Sathiyanathan, Kartheep
Sayyaparaju, Vivek T., Blue Wave AI Labs
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White, Destiny
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Muffet, Megan
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Hegazy, Aya
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Frey, Hunter

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Howard, Jerry R.

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University of Pennsylvania
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University of Rochester
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University of Wisconsin–Madison
Benysh, Samuel W.
Johnson, Brienna

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Gardner, Daniel

Vanderbilt University
Ibrahim, Irfan R.

Virginia Commonwealth University
Atkinson, Deion
Butler, Jacob P.
Redding, Justin D.

Virginia Polytechnic Institute and State University
Manfred, Nicolas R.

Institution not provided
Farha, Farhana
Martinez, Roman
Rogers, Rayna
Schoffstall, Logan
Schuldheiss, Wyatt W.

Note: Nuclear News *publishes news about nuclear industry contracts—but only about contract awards. We generally do not publish announcements that the work is underway or announcements that the work has been completed. Email your new contract award announcements to nucnews@ans.org.*

BUSINESS DEVELOPMENTS

Framatome projects funded as part of France Relance recovery plan

Framatome projects related to investing in new activities and modernizing the nuclear energy industry were selected to receive funding as part of the France Relance recovery plan, the company announced on April 16. The project known as FAB-ATF focuses on developing and qualifying new manufacturing capacity for fabricating accident tolerant fuel. The project named Cap Industriel aims to modernize and scale up production, quality control, and compliance of the mechanical parts needed to construct the latest generation of nuclear reactors and modernize and extend operations of those currently in service around the world. The French Fab Métallurgie project aims to heighten regulatory controls and enhance the manufacture of large-scale nuclear forgings at the Framatome site in Le Creusot. **Corys**, a subsidiary of Framatome, received support from France Relance through the ICAREx project, which focuses on building virtual reality digital twins of new nuclear reactors.

In addition, Framatome announced that it has commissioned a high-precision measurement facility in Jeumont, France, and that it opened its Inspection Academy in early March. Extending over an area of 11,600 square meters, the Jeumont plant manufactures two key components for the primary circuit of a nuclear power plant: control rod drive mechanisms and reactor coolant pumps. The Framatome Inspection Academy will train EDF Group professionals who are interested in a nuclear safety and technical inspection career.

■ **ASC Engineered Solutions** has been announced as the new name for **Anvil International** and **Smith-Cooper International** after their 2019 merger. With more than 1,400 employees, the company's portfolio of precision-engineered piping support, valves, and connections provides products to more than 4,000 customers across industries, such as nuclear, mechanical, industrial, fire protection, and commercial and residential construction.

■ **Curtiss-Wright**'s Nuclear Division has signed an agreement with **Exelon Generation** to license the company's valve program performance data. Working in partnership with Exelon Generation, Curtiss-Wright will leverage the performance data to increase the effectiveness of its StressWave ultrasonic leak detection technology and promote the implementation of best practices in valve assessment, analysis, and performance across the U.S. nuclear fleet and power generation industry.

■ **NuScale Power** has announced that it has finalized an investment and strategic partnership agreement with **JGC Holdings Corporation** (JGC HD), a holding company of the world's leading engineering, procurement, and construction (EPC) contractor group companies headquartered in Japan. As part of a commercial relationship with **Fluor Corporation**—NuScale's majority investor and EPC partner in the United States—JGC HD will provide a $40 million cash investment in NuScale Power and will partner with Fluor on the deployment of NuScale power plants.

■ **SHINE Medical Technologies** and **Phoenix** have announced that the companies have completed a merger under which Phoenix has become a wholly owned subsidiary of SHINE. Phoenix was founded in 2005 by Greg Piefer to develop and commercialize a unique technology that generated neutrons through fusion. He spun SHINE out of Phoenix in 2010 to apply that technology to medical isotope production and other applications.

■ **Terrestrial Energy** has announced a pair of agreements that support integral molten salt reactor (IMSR) development. On April 1, it announced the signing of an engineering and construction services agreement with **Aecon Group**. Aecon will review Terrestrial's construction costs and schedules for IMSR as well as undertake constructability, modularization, and supplier assessments for a range of activities, including plans for site development and heavy civil construction. On April 8, Terrestrial announced that it has contracted with **ENGIE Laborelec** in Belgium for technical services. This contract is part of Terrestrial's nuclear fuel salt qualification program for IMSR. ENGIE Laborelec will perform confirmatory electrochemical and thermophysical measurements as well as confirmatory corrosion testing.

CONTRACTS

BWXT inks deals with U.S. government and NASA

BWX Technologies (BWXT) has been awarded **U.S. Naval Nuclear Propulsion Program** contracts totaling approximately $2.2 billion, including future-year options, for the manufacture of naval nuclear reactor components and fuel. The initial contracts were awarded in the first quarter of 2021 and will constitute approximately half of the $2.2 billion. The contract options are subject to annual congressional appropriations and constitute the remainder of the total value.

Earlier in April, BWXT announced that it is continuing its nuclear thermal propulsion (NTP) design, manufacturing development, and test support work for **NASA**. NTP is one of the technologies that is capable of propelling a spacecraft to Mars, and this contract continues BWXT's work that began in 2017. Under the terms of a $9.4 million, one-year contract awarded to its **BWXT Advanced Technologies** subsidiary, BWXT will focus primarily on nuclear fuel design and engineering activities.

■ **Framatome** recently signed a multimillion-dollar contract with **Dominion Energy** to support the long-term operation of the company's nuclear fleet. This contract covers nuclear plant outage and maintenance work, including fleet steam generator services, refuel services, and inspections through 2026.

■ **National Technical Systems** (NTS), an independent provider of qualification testing, inspection, and certification solutions in North America, has been awarded multiple contracts to test critical components on the ITER project, the world's largest fusion reactor. Two manufacturers involved in the ITER initiative, **Hayward Tyler** and **Vacuum Technology,** chose NTS to provide qualification testing of critical components in support of U.S. ITER. The ITER project's joint international research collaboration includes the United States, China, India, Japan, Korea, Russia, and the European Union.

■ **Palantir Technologies** has been selected by the National Nuclear Security Administration to provide its Office of Safety, Infrastructure, and Operations with a platform for effective knowledge management and data-driven decision-making in an agreement worth up to $89.9 million for a duration of up to 5 years. Palantir will serve as the platform for NNSA's Safety Analytics, Forecasting, and Evaluation Reporting (SAFER) project.

Standards

Comments requested

Comments are requested on the following standards by June 21, 2021:

■ ANS-2.3-2011 (R201x), *Estimating Tornado, Hurricane, and Extreme Straight Line Wind Characteristics at Nuclear Facility Sites* (reaffirmation of ANSI/ANS-2.3-2011 [R2016]).

This standard defines site phenomena caused by (1) extreme straight-line winds, (2) hurricanes, and (3) tornados in various geographic regions of the United States. These phenomena are used for the design of nuclear facilities.

■ ANS-15.11-2016 (R201x), *Radiation Protection at Research Reactor Facilities* (reaffirmation of ANSI/ANS-15.11-2016).

This standard establishes the elements of a radiation protection program and the criteria necessary to provide an acceptable level of radiation protection for personnel at research reactor facilities and the public, consistent with keeping exposures and releases as low as reasonably achievable.

All published standards can be ordered through Techstreet at techstreet.com/ans or by calling 855/999-9870. Comments on draft standards should be sent to ANS standards manager Patricia Schroeder at pschroeder@ans.org, with a copy of the comments sent to the Board of Standards Review at the American National Standards Institute.

Volunteer support needed

The following standards projects are in need of volunteer support. Interested individuals should contact standards@ans.org for more information.

■ ANS-2.17, *Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants* (revision of ANSI/ANS-2.17-2010 [R2016]).

■ ANS-2.32, *Guidance on the Selection and Evaluation of Remediation Methods for Subsurface Contamination* (development of new standard).

■ ANS-8.14, *Use of Soluble Neutron Absorbers in Nuclear Facilities Outside Reactors* (revision of ANSI/ANS-8.14-2004 [R2016]).

■ ANS-3.13, *Nuclear Facility Reliability Assurance Program (RAP) Development* (development of new standard).

■ ANS-53.1, *Nuclear Safety Design Process for Modular Helium-Cooled Reactor Plants* (revision of ANSI/ANS-53.1-2011 [R2016]).

■ ANS-56.2, *Containment Isolation Provisions for Fluid Systems After a LOCA* (new standard, historical revision of ANS-56.2-1984 [W1999]).

Value and ethics of LNT

By James Conca

The nuclear industry certainty values human life. All one has to do is look at Occupational Safety and Health Administration data to see that nuclear workers have the safest work environment, the lowest mortality rates, and the highest average pay of almost any industry.

Most of this is due to strict adherence to procedures and protocols that we have developed over the past 70 years, plus the fact that we understand the behavior of radiation and radioactive materials so well. None of this needs to change.

Society, however, has a skewed idea of the value of human life. We have spent upward of a trillion dollars trying to adhere to the ultra-low radiation limits foisted upon us by the linear no-threshold hypothesis, or LNT. The LNT tries to save a few theoretical lives far in the future, while not saving tens of millions of real lives now for the same amount of money. This is as much an ethical issue as it is a scientific one.

Unjustified fear of low levels of radiation (<10 rem or 0.1 Sv, acute or otherwise) was an important part of the Cold War, purposely pushed by nongovernmental organizations and countries such as the Soviet Union and China as a way to stop aboveground nuclear tests by the United States. No human cohort has ever been found to be adversely affected by doses below 10 rem/yr, or even 10 rem acute, not even the Japanese bomb survivors. And we have tried very hard to find them.

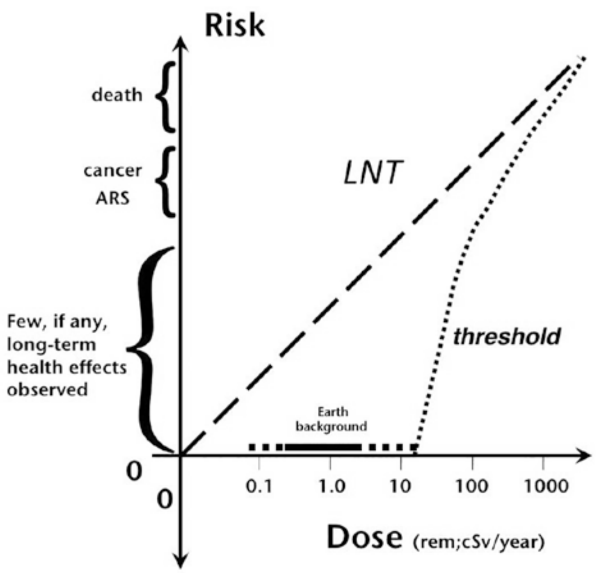


Fig. 1. The assumption of the LNT: any radiation dose, no matter how small, will cause harm. However, small doses of radiation, <10 rem(cSv)/yr, appear to be easily handled by cellular repair mechanisms that evolved as a normal adaptive response with the emergence of the eukaryotic cell 2.3 billion years ago. It would be odd indeed if the upper end of Earth background radiation (1 Sv/yr) was not near the threshold for significant radiation-induced biological effects.

This fear has led to some unintended consequences, such as people foregoing lifesaving diagnostic procedures and treatments, as well as an intransigence on the part of lawmakers and antinuclear groups to value nuclear energy, the best low-carbon, safest energy source we have to fight global warming.

More immediate, however, is the large amount of money and effort spent by our country, as well as others, to protect against what has never been demonstrated to be at all harmful.

This fear of radiation originated after the dropping of the atomic bombs in 1945 and was codified into regulations around 1959, when the world adopted the singularly unproven LNT hypothesis for the negative biological effects of radiation and its resultant policy, ALARA (as low as reasonably achievable).

The LNT assumes, in contrast to almost all data on living organisms, that any radiation is bad and there is no threshold of radioactivity below which there is no risk, even at Earth background radiation levels (Fig. 1). Following ALARA means that we should protect everyone from all radiation, making doses as low as we possibly can, even if it costs billions of dollars. The latter point undermines the reasonableness embedded in the term ALARA.

Indeed, we spend billions each year protecting against what were once background levels. It's right out of a *Road Warrior* movie. No wonder the fear of radiation took over the worldview. Science fiction is much more fun to study than real science.

A classic example of this is the "downwinder" cohorts in Utah. It was assumed that fallout during bomb testing in the 1950s and 1960s was harmful and created a cancer epidemic in Utah. But Utah has the lowest cancer rate in the nation, and Washington County, where the fallout was the highest, has the second-lowest cancer rate in the state. These data have been summarized in Antone L. Brooks's book, *Low Dose Radiation: The History of the U.S. Department of Energy Research Program*.

Most of the fears and questions surrounding radiation have been answered very well over the intervening years, and all studies point to the need to have a reasonable threshold for radiation below which we don't have to worry about health effects, or put differently, below which all other risks far surpass that of radiation. And we don't have to spend billions protecting against a phantom menace.

Unless you are in a boat in the middle of the Pacific Ocean, you're getting a radiation dose between 200 and 1,000 mrem/yr (2 to 10 mSv/yr) in the United States, just from background sources such as rock, dirt, potato chips, and cosmic rays and the radioactive isotopes of uranium, thorium, radon, and potassium that are in them.

Some places in the world have background doses 10 times higher than that of the United States, but there have never been any observable health effects from these doses. Ever. Anywhere.

On the other hand, regulations require nuclear waste disposal systems and cleanup standards to meet release criteria of less than 4 mrem/yr (0.04 mSv/yr) to downgradient drinking water supplies even in the distant future. Moving from Seattle to Spokane will give you an extra 50 mrem/yr (0.5 mSv/yr) or more. Should we make moving to Spokane against the law? Yes, according to these regulations. No, according to common sense.

There are different types of radiation and different biological effects of each, and it doesn't matter whether the radiation is natural or man-made. The measure of dose (rem or Sv) takes all that into account. However, we have made our regulations seem as if they are different, which is not particularly scientific (Fig. 2).

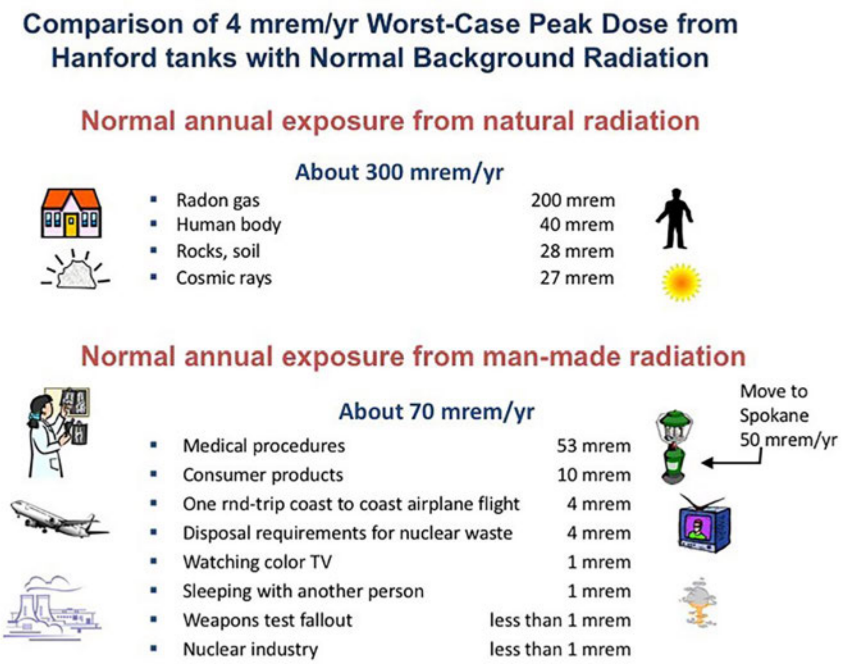


Fig. 2. Comparisons of normal doses from various natural and man-made sources of radiation showing the extremely conservative value of the LNT-regulated 4 mrem/yr (0.04 mSv/yr) dose limits to downgradient water sources. By accepting these waste limits, the EPA is suggesting that these other sources should be restricted to as low a level as well, eliminating more than one plane flight per year, as well as most medical procedures. (Figure: State of Connecticut)

Opinion continues

It is not possible to see statistical evidence of public health risks at exposures less than 10,000 mrem/yr (100 mSv/yr) because any risk is well below the noise level of all other risks faced by humans or the environment. That's why we will never see any deaths, or even excess cancers, demonstrably from Fukushima radiation, but 1,600 people died in the days following the accident from the frantic forced evacuations that resulted mainly from fear generated by decades of adherence to the LNT.

As a result of these 1,600 deaths, the U.S. Government Accountability Office (GAO) considers the fear of low radiation levels as a vulnerability in itself because the most dangerous effect of a minor leak or a dirty bomb is the panic fed by these LNT-generated historic fears.

It is useful to note that in the 1950s in the debate surrounding the LNT, it sounded like a good conservative idea, but little did we know the collateral damage that would follow, such as fear of radiological medical diagnostics and treatments that save millions of lives each year.

Health physicists get a little frustrated that although they know there is no real risk from any radiation below background they are required to keep to limits a hundred times lower. The public often asks, "If it's so safe, why are you working so hard to keep it so low?"

Good question. And the answer is, "Because we're told to. It's the rules."

So what are the costs of regulating radiation doses to such absurdly low levels? A better question might be, "How much do we consider the value of a human life to be?" It depends on how you view it, and who is paying:

- $7 million is the value of a human life, according to the Environmental Protection Agency (EPA).
- $316,000 is the average paid out by the American health care industry over an average lifetime.
- $129,000 is the average historic legal value of a human life in the United States as paid out in wrongful death suits.
- $12,420 is the death benefit to families of deceased soldiers, although circumstances in combat can increase that amount.
- $45 million is the value of a single healthy human body when chopped up and sold on the black market for body parts.
- $2.5 billion is the amount we spend to save a single theoretical human life based on the LNT, although it is doubtful that we will save any lives at these levels.
- $100 is the cost to save a human life by immunizing against measles, diphtheria, and pertussis in sub-Saharan Africa.

This last point is the most important of all. We could save 25 million lives in Africa in a year for the cost of saving one theoretical life from low levels of radioactivity by keeping to the LNT in our nuclear waste disposal programs.

This is nuts, and it creates an ethical dilemma we have not faced up to yet because of the stovepiping caused by regulations that the public and their elected officials do not understand.

The best way to illustrate this dilemma is to look at the Department of Energy's environmental management programs. In 2019, the GAO reported that the fiscal liability for cleaning up DOE sites such as Hanford will probably exceed $600 billion.

What will this amount of money accomplish? How does the LNT drive this? How does it compare to using more reasonable cleanup limits?

The LNT has resulted in the DOE and the EPA using a 15 mrem/yr (0.15 mSv/yr) threshold for the cleanup of radiologically contaminated sites, declaring with no real data that this level has a cancer risk of about 1 in 10,000. But this is about 25 times lower than natural background in most places on Earth, and a hundred times lower than natural background in many places, including Brazil, Iran, and China, where these radiation levels have not shown any increased cancer risk.

If we just raised this limit to 100 mrem/yr (1 mSv/yr), still well below background, then the LNT-based cancer risk would be about 1 in 2,000, although, again, we have never seen any excess cancers at these levels.

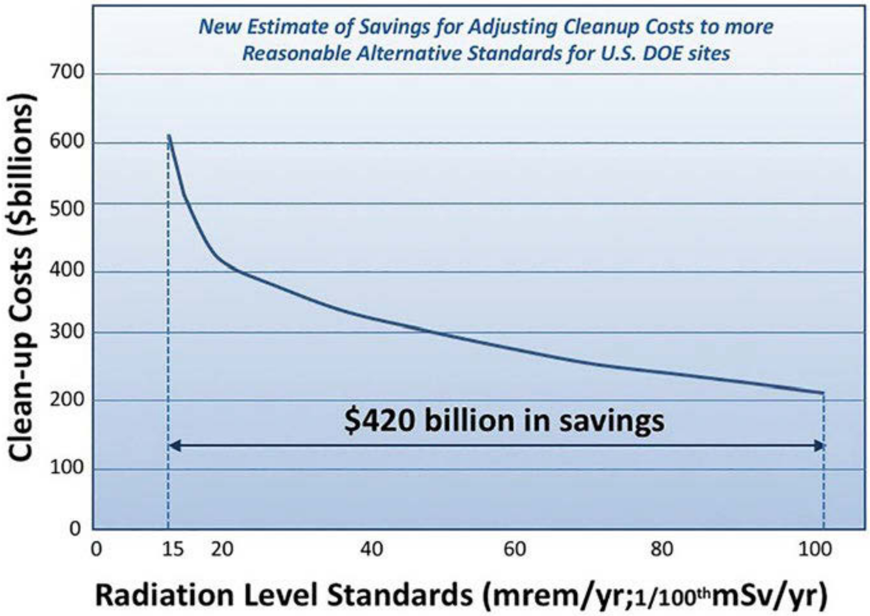


Fig. 3. The DOE could save billions—and clean up more sites—if society adopted a more reasonable limit for radiation, still well below background levels, where no harm has ever been observed. (Chart: DOE)

But the DOE would save over $400 billion (Fig. 3), which, if put toward immunization in Africa against the three largest scourges, would save up to a billion lives over the next 20 years. If spent in the United States on health care and medical research, it would save millions of lives. Compared to saving a few virtual lives in the distant future, this is an easy, and correct, ethical decision to make.

The presence or absence of a threshold dose for radiation is a societal decision that society has been left out of. That needs to change. We have real problems that need to be solved. Yes, we need to deal with radiation doses above, say, 5 rem, 7 rem, or whatever level is decided upon as the threshold. But epidemiologically, there is always a threshold. No different than mercury, cadmium, or lead. Everything is in the environment at some level, but the old adage that dose makes the poison is still true.

James Conca is a scientist in the field of the earth and environmental sciences, specializing in geologic disposal of nuclear waste, energy-related research, planetary surface processes, radiobiology and shielding for space colonies, and subsurface transport and environmental cleanup of heavy metals. Conca also writes about nuclear, the environment, and energy for Forbes; you can view his stories online at forbes.com/sites/jamesconca.

People

Haiyan Gao has joined the Department of Energy's Brookhaven National Laboratory as associate laboratory director for nuclear and particle physics.

Gao

Previously a professor of physics at Duke University, Gao will help develop BNL's collective long-term vision for the next 10 years. She'll also work across the laboratory and beyond to craft its emerging expertise at the future Electron-Ion Collider, a one-of-a-kind nuclear physics research facility that will be built at the lab over the next decade.

Kamal Verma has been appointed chief nuclear engineer for Canadian Nuclear Partners SA (CNP), a subsidiary of Laurentis Energy Partners (LEP) based in Europe. Verma is responsible for supporting CNP's growth and delivery in the European market.

Verma

In addition, he will join LEP as an executive advisor, helping to drive LEP's commitment to safe and high-quality performance and its client interaction while further diversifying the company's support of the worldwide CANDU-6 fleet.

Rita Baranwal, vice president of nuclear and chief nuclear officer at the Electric Power Research Institute (EPRI) and ANS Fellow and member since 2008, has joined the Atlantic Council's Nuclear Energy and National Security Coalition.

Baranwal

Baranwal previously served as assistant secretary for the Department of Energy's Office of Nuclear Energy. The Nuclear Energy and National Security Coalition, housed within the Atlantic Council Global Energy Center, works to address challenges present at the intersection of nuclear energy, national security, and climate change.

Ho Nieh has joined Southern Nuclear as future vice president of regulatory affairs. He will succeed **Mike Meier**, who has announced his intent to retire at a later date. Nieh will be responsible for the company's regulatory, security, and licensing efforts.

Nieh

Nieh has over 20 years of experience with the Nuclear Regulatory Commission, most recently serving as director of the Office of Nuclear Reactor Regulation, where he was responsible for NRC reactor safety licensing and oversight programs for operating and new reactors.

The National Nuclear Security Administration named **Jason A. Armstrong** manager of the NNSA Savannah River Field Office. Armstrong will provide oversight of Savannah River Site programs, nuclear operations, security, quality assurance, environment, safety and health, and the overall execution of key mission deliverables. He is a member of the Senior Executive Service.

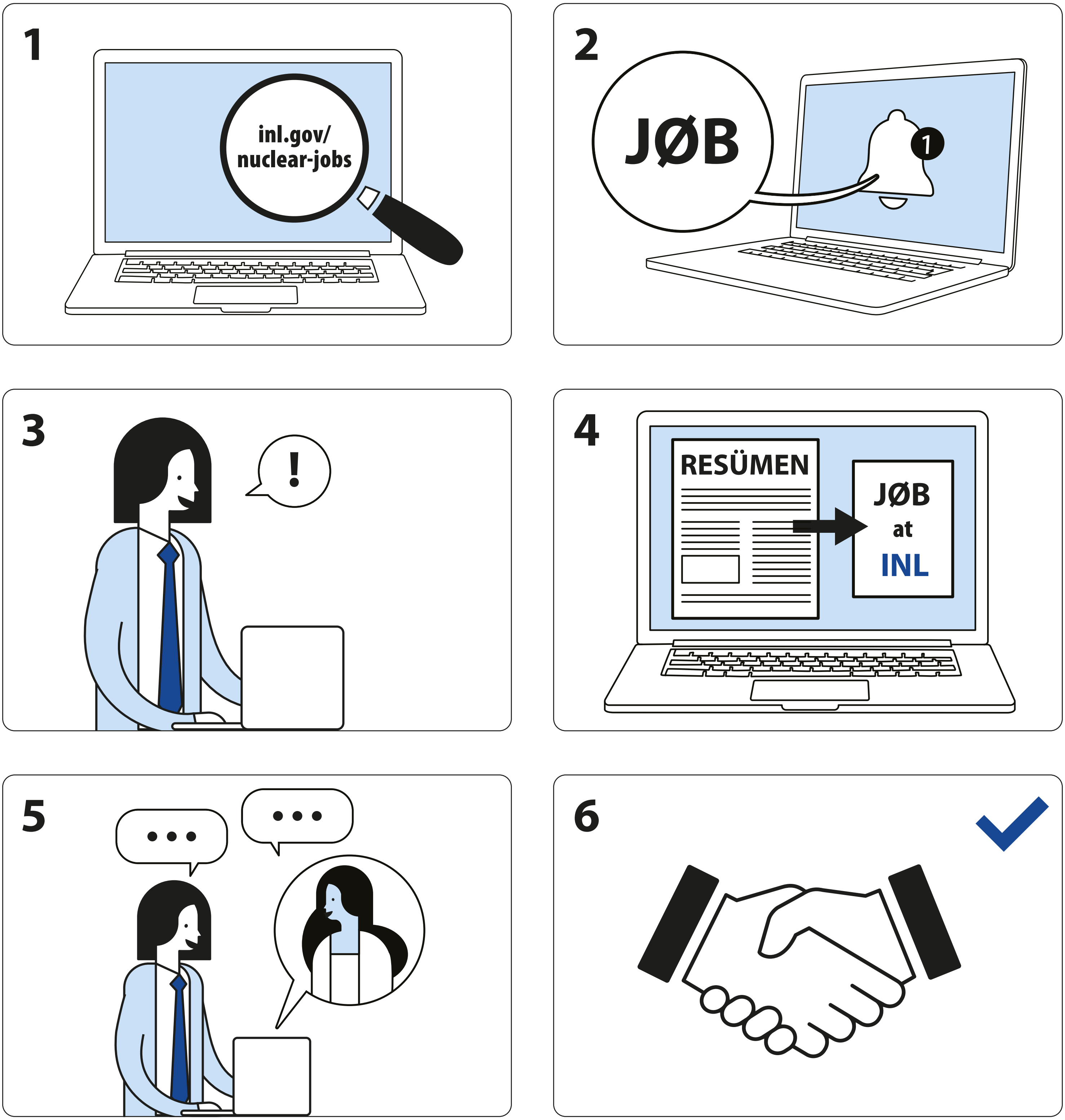
Armstrong

William Von Hoene Jr., senior executive vice president and chief strategy officer, left Exelon on March 31, according to a company press release. Among his accomplishments at Exelon, Von Hoene guided the company through two successful mergers—with Constellation in 2012 and with Pepco Holdings in 2016. He also advanced policies in New York, Illinois, and New Jersey that preserved the emissions-free power from the company's nuclear fleet and saved thousands of jobs.

Von Hoene

People continues

JØB LOOKEN



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Idaho National Laboratory

The NRC recently announced several personnel decisions. **Vicki M. Bier** and **Gregory H. Halnon** were appointed to the Advisory Committee on Reactor Safeguards (ACRS) for four-year terms, effective April 12. The ACRS advises the commission, independently of the NRC staff, on safety rules and issues related to the licensing and operation of nuclear power plants, health physics, and radiation protection. Bier is professor emerita in the Department of Industrial and Systems Engineering and the Department of Engineering Physics at the University of Wisconsin–Madison. Halnon works as an independent nuclear industry consultant with more than 40 years of experience in the nuclear and utility industries.


Bier


Halnon

In addition, the NRC has selected **Mark Lombard** as director of its Office of Enforcement. Lombard had been serving as the deputy office director, Office of Nuclear Security and Incident Response, and also as the agency's COVID-19 task force lead. Last, the NRC has assigned **Jason Parent** and **Brian Griman** as the new resident inspectors for Southern Nuclear's Vogtle Units 3 and 4, located near Waynesboro, Ga. Parent began his career with the NRC in the Resident Inspector Development Program and qualified as a reactor operations inspector in the agency's Region II office in Atlanta. Griman joined the NRC in 2015 as an intern with the Division of Construction Oversight and has held several positions, including acting resident inspector at Vogtle-3 and -4, acting resident inspector at the Mixed Oxide Fuel Fabrication Facility, and acting resident inspector at McGuire Nuclear Station in North Carolina.


Lombard


Parent


Griman

Kudos

Three ANS members were coauthors of a paper that was honored with the American Society of Mechanical Engineers 2020 Lewis F. Moody Award. Lead author **Dillon Shaver**, ANS member since 2009 and principal nuclear engineer with Argonne National Laboratory; **Lane Carasik**, ANS member since 2011, assistant professor of mechanical and nuclear engineering at Virginia Commonwealth University, and director of VCU's High Performance Research Computing core facility; and **Elia Merzari**, ANS member since 2009 and associate professor of nuclear engineering in the Penn State College of Engineering, were recognized for their paper on novel heat exchangers for potential use in molten salt clean energy systems. The paper was published in the conference proceedings of the ASME 2018 Fluids Engineering Division Summer Meeting.


Shaver


Carasik


Merzari

Obituaries

Thomas F. Farrell II, 66; served as Dominion Energy chairman, president, and chief executive officer; after graduation from the University of Virginia School of Law, spent more than 15 years practicing law before joining Dominion as general counsel in 1995; served in several senior management positions at Dominion over the following nine years; named president and chief operating officer in 2004 and president and chief executive officer in 2006; elected chairman in 2007 and held that post until April 1, 2021; chaired the board of the Edison


Farrell

Electric Institute and the Institute of Nuclear Power Operations; died April 2.

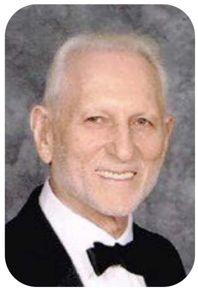

Detandt

John M. Detandt, 64, ANS member since 1999; worked at the James C. White Company in Greenville, S.C., for nearly 43 years, most recently as quality assurance manager; died February 9.

David V. LeMone, 87, ANS member since 1990; earned a bachelor's degree from Colorado School of Mines and a master's degree from the University of Arizona; worked in the mining and oil industries prior to receiving a Ph.D. in geology from Michigan State University in 1964; instrumental in developing the Geology Department at the University of Texas–El Paso; taught nuclear waste management among other topics; retired as UTEP professor emeritus in 2004; died February 22, 2020.


LeMone

Cecil R. Lubitz, 95; a world-renowned expert in the nuclear data field; graduated in 1945 from the U.S. Naval Academy and served in the Navy until 1947; earned a master's degree in electrical engineering and a doctorate in physics at the University of Michigan; worked for the Naval Nuclear Propulsion Program at Knolls Atomic Power Laboratory, retiring at 89 in 2014 after 54 years of service; was a charter member of the Cross Section Evaluation Working Group and a key contributor to the early development of the Evaluated Nuclear Data File project; was also a member of the Nuclear Energy Agency Working Party on International Evaluation Cooperation, most recently with the Collaborative International Evaluated Library Organization pilot project; died March 5.


Lubitz

Direct Answer

Index to Advertisers

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June

June 1–2—**Nuclear Power Plants Expo & Summit**, virtual meeting. nuclearpowerplantsexpo.com

June 2–5—**HTR 2021: International Conference on High Temperature Reactor Technology**, virtual meeting. htr2020.org

June 6–9—**40th Annual CNS Conference/45th Annual CNS/CNA Student Conference**, virtual meeting. cns-snc.ca/events/annual/

June 7–8—**European Cooperative Group on Corrosion Monitoring of Nuclear Materials (ECG-COMON) Annual Meeting 2021**, virtual meeting. ecg-comon.org/meetings/ecgcomon-meeting-2021

● June 7–9—**Nuclear Energy Assembly**, virtual meeting. https://www.nei.org/conferences/nuclear-energy-assembly

June 7–11—**3rd International Conference on Nuclear Photonics (NP2020)**, virtual meeting. photon.osaka-u.ac.jp/NP2020Kurashiki/

June 8–10—**Nordic Nuclear Forum, Suppliers Edition Online**, virtual meeting. nordicnuclearforum.fi

✖ June 9–11—**16th IAEA-FORATOM Joint Event on Management Systems—Management Systems for a Sustainable Nuclear Supply Chain**, Helsinki, Finland. events.foratom.org/mstf2021/
Meeting has been rescheduled to September 7–9, 2021

June 9–11—**NUWCEM 2021: International Symposium on Cement-Based Materials for Nuclear Wastes**, Avignon, France. sfen-nuwcem2021.org
Meeting has been rescheduled to May 4–6, 2022

■ June 14–16—**2021 ANS Annual Meeting**, virtual meeting. ans.org/meetings/am2021/

■ June 14–17—**12th Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies (NPIC&HMIT 2021)**, virtual meeting. ans.org/meetings/npichmit2021/

June 21–25—**12th International Conference on Clustering Aspects of Nuclear Structure and Dynamics**, Dubna, Russia. indico.jinr.ru/event/1026/overview

● June 23–24—**Maintenance in Power Plants 2021**, virtual meeting. vgb.org/en/instandhaltung_kraftwerken2021.html

✖ June 29–July 1—**RICOMET 2021**, Athens, Greece. sckcen.be
Meeting has been rescheduled to September 8–10, 2021

July

July 5–8—**The Society for Radiological Protection Annual Conference**, Bournemouth, U.K. srp-uk.org/events/2021AnnualConference

● July 8—**Nuclear Solutions Exhibition**, Warrington, U.K. https://nuclear-solutions.co.uk/

July 13–15—**ASME Pressure Vessels and Piping Conference (PVP 2021)**, virtual meeting. event.asme.org/PVP

July 16–23—**2021 IEEE Nuclear and Space Radiation Effects Conference (NSREC)**, virtual meeting. nsrec.com/nsrec_2021.html

July 20–22—**Power 2021**, virtual meeting. event.asme.org/POWER

July 21–22—**Enlit Australia**, Melbourne, Australia. enlit-australia.com

July 28–30—**48th Annual Review of Progress in Quantitative Nondestructive Evaluation**, virtual meeting. event.asme.org/QNDE

August

Aug. 2–6—**Technical Meeting on Good Practices for the Operation and Maintenance of Research Reactors**, Vienna, Austria. iaea.org/events/evt1904070

Aug. 3–5—**13th Annual Nuclear Deterrence Summit**, Alexandria, Va. exchangemonitor.com/events/nuclear-deterrence-summit/

Aug. 4–6—**28th International Conference on Nuclear Engineering (ICONE 28)**, virtual meeting. event.asme.org/ICONE

■ Aug. 8–11—**Utility Working Conference and Vendor Technology Expo**, Marco Island, Fla. ans.org/meetings/view-uwc2021/

Meetings listed in the calendar that are not sponsored by ANS do not have the endorsement of ANS, nor does ANS have financial or legal responsibility for these meetings.

Calendar continues

- Aug. 21–26—**INMM & ESARDA Joint Annual Meeting**, virtual meeting. https://inmm.org/mpage/INMMESARDA2021

Aug. 23–Sep. 3—**International School of Nuclear Law (ISNL)**, Montpellier, France. oecd-nea.org/law/isnl

Aug. 25–27—**KONTEC 2021**, Dresden, Germany. kontec-symposium.com/

✖ Aug. 29–1Sep. 3—**2021 International Topical Meeting on Probabilistic Safety Assessment and Analysis (PSA 2021)**, Columbus, Ohio. psa.ans.org/2021
Meeting has been rescheduled to November 7–12, 2021

Aug. 30–Sep. 3—**International Conference on Operational Safety of Nuclear Power Plants**, Beijing, China. iaea.org/events/international-conference-on-operational-safety-of-nuclear-power-plants-2021

September

- Sep. 6–9—**30th International Conference Nuclear Energy for New Europe (NENE 2021)**, Bled, Slovenia. https://www.djs.si/nene2021/

- Sep. 7–9—**16th IAEA-FORATOM Joint Event on Management Systems—Management Systems for a Sustainable Nuclear Supply Chain**, virtual meeting. https://events.foratom.org/mse2021/

Sep. 8–10—**World Nuclear Association Symposium 2021**, London, U.K. wna-symposium.org/

- Sep. 8–10—**RICOMET 2021**, Budapest, Hungary. https://www.ssh-share.eu/ricomet2021/

✖ Sep. 12–16—**14th International Conference on Radiation Shielding and 21st Topical Meeting of the Radiation Protection and Shielding Division (ICRS 14/RPSD 2021)**, Seattle, Wash. ans.org/meetings/icrs14rpsd21/
Meeting has been postponed until September 25–29, 2022

Sep. 13–15—**International Conference on Decommissioning Challenges: Industrial Reality, Lessons Learned and Prospects**, Avignon, France. sfen-dem2021.org/

- Sep. 15–17—**CNA2021**, virtual meeting. conference2021.cna.ca/

Sep. 20–21—**Decommissioning Strategy Forum**, Las Vegas, Nev. decommissioningstrategy.com/

Sep. 21–22—**Advanced Clean Energy Summit (ACES 2021)**, virtual meeting. event.asme.org/ACES

Sep. 22–24—**RadWaste Summit**, Las Vegas, Nev. radwastesummit.com/

Sep. 23–24—**Valve World Expo & Conference Asia 2021**, Shanghai, China. valve-world.net/vwa2021/valve-world-asia-2021.html

- Sep. 27–28—**2nd International Conference of Materials, Chemistry and Fitness-for-Service Solutions for Nuclear Systems (MCFD2021)**, virtual meeting. https://www.cns-snc.ca/events/mcfd2021/

Sep. 27–Oct. 1—**NPC 2021: International Conference on Nuclear Plant Chemistry**, Antibes, France. new.sfen.org/evenement/npc-2021/

- Sep. 27–30—**European Nuclear Young Generation Forum (ENYGF 2021)**, Tarragona, Spain. https://enygf.org/

Sep. 28–30—**Enlit Asia**, Jakarta, Indonesia. enlit-asia.com/

October

■ Oct. 3–7—**International Conference on Mathematics and Computational Methods Applied to Nuclear Science and Engineering (M&C 2021)**, Raleigh, N.C. mc.ans.org

Oct. 4–5—**2021 AtomExpo**, Sochi, Russia. 2021.atomexpo.ru/en/

Oct. 4–6—**International Conference on Environmental Remediation and Radioactive Waste Management (ICEM 2021)**, virtual meeting. asme.org/conferences-events/events/international-conference-on-environmental-remediation-and-radioactive-waste-management

Oct. 12–13—**TotalDECOM 2021**, Manchester, U.K. totaldecom.com/2021-expo-manchester/

■ Oct. 17–21—**2021 International Congress on Advances in Nuclear Power Plants (ICAPP2021)**, Abu Dhabi, UAE. ans.org/meetings/view-368/

Oct. 24–28—**TopFuel 2021**, Santander, Spain. euronuclear.org/topfuel2021

Oct. 25–29—**Technical Meeting on Artificial Intelligence for Nuclear Technology and Applications**, virtual event. iaea.org/events/evt2004304

Oct. 27–28—**All-Energy Australia**, Melbourne, Australia. all-energy.com.au/en-gb.html

Oct. 27–29—**POWERGEN India**, New Delhi, India. powergen-india.com/

November

- Nov. 7–12—**2021 International Topical Meeting on Probabilistic Safety Assessment and Analysis (PSA 2021)**, Columbus, Ohio. psa.ans.org/2021

Nov. 8–12—**International Conference on a Decade of Progress after Fukushima-Daiichi: Building on the Lessons Learned to Further Strengthen Nuclear Safety**, Vienna, Austria. iaea.org/events/international-conference-on-a-decade-of-progress-after-fukushima-daiichi-building-on-the-lessons-learned-to-further-strengthen-nuclear-safety-2021

Nov. 15–17—**NESTet 2021—Nuclear Education & Training Conference**, Brussels, Belgium. ens.eventsair.com/nuclear-education-and-training/

Nov. 30–Dec. 2—**Enlit Europe**, Milan, Italy. enlit-europe.com/live

Nov. 30–Dec. 2—**World Nuclear Exhibition**, Paris, France. world-nuclear-exhibition.com/

- Nov. 30–Dec. 4—**2021 ANS Winter Meeting and Technology Expo**, Washington, D.C. ans.org/meetings/wm2021/

Call for Papers

ANS

International Conference on Physics of Reactors 2022 (PHYSOR 2022)

Making Virtual a Reality: Advancements in Reactor Physics to Leap Forward Reactor Operation and Deployment

May 15-20, 2022 | Pittsburgh, PA

CALL FOR PAPERS

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FULL PAPER DEADLINE: SEPTEMBER 30, 2021

SEPTEMBER → FULL PAPERS DUE: **September 30, 2021**

NOVEMBER → FULL PAPERS NOTIFICATION TO AUTHORS: **November 15, 2021**

DECEMBER → FINAL FULL PAPERS DUE: **December 15, 2021**

ABOUT THE MEETING

Following the success of the past meetings, the PHYSOR topical meeting is back in Pittsburgh. PHYSOR 2022 will focus on the future of reactor physics and related nuclear technologies. The meeting aims to provide a platform for international experts from vendors, utilities, research laboratories, and universities to exchange ideas and latest developments on a wide spectrum of topics. Technical sessions include standard topics of interest as well as special sessions including novel analysis methods, advanced reactor designs, machine learning and artificial intelligence applications, high enrichment/high burnup core design challenges, space nuclear technologies, and high-performance computing. The meeting will also include plenary sessions focusing on advanced reactor design development and demonstration programs, panel sessions, and several workshops on state-of-the-art reactor physics tools.

GUIDELINES

Submit full papers describing work that is of value to the reactor physics community and the nuclear industry in general. Papers are presented orally at the meeting, and presenters are expected to register for the meeting. All accepted papers will be published in the Proceedings of the Topical. Published papers become the property of ANS. Under no circumstances should a paper be published in any other publication prior to presentation at the PHYSOR 2022 meeting. An ANS copyright form is required for all papers and posters.

FORMAT

We are soliciting full papers with ten pages maximum. Word and LaTeX templates are available at https://www.ans.org/meetings/physor2022. Papers not formatted according to the template will be rejected. Papers exceeding 10 pages will be rejected. Accepted papers will be published in the Proceedings of the Topical.

POSTERS

Authors desiring a poster presentation must also submit a full paper in the proper format as described above. A poster template is available at https://www.ans.org/meetings/physor2022.

JOURNAL COLLABORATION

We will invite some authors to submit a full-length journal article for a special issue of Nuclear Science and Engineering.

SUBMIT A FULL PAPER

https://epsr.ans.org/meeting/?m=353

PROGRAM SPECIALIST

Janet Davis
708-579-8253
jdavis@ans.org

Call for Papers

International Conference on Physics of Reactors 2022 (PHYSOR 2022)

Making Virtual a Reality: Advancements in Reactor Physics to Leap Forward Reactor Operation and Deployment

May 15-20, 2022 | Pittsburgh, PA

TOPICS OF INTEREST

TRACK 1: DETERMINISTIC TRANSPORT METHODS
TRACK 2: MONTE CARLO METHODS
TRACK 3: MULTI-PHYSICS REACTOR SIMULATIONS & VALIDATION (W/ OECD)
TRACK 4: CORE ANALYSIS METHODS
TRACK 5: LIGHT-WATER REACTORS DESIGN & CORE ANALYSIS
TRACK 6: ADVANCED REACTORS DESIGN & CORE ANALYSIS
TRACK 7: TRANSIENT SYSTEMS & ANALYSIS
TRACK 8: DATA, METHODS, CODE VALIDATION
TRACK 9: FUEL MANAGEMENT AND OPTIMIZATION
TRACK 10: FUEL-CYCLE PHYSICS AND SCENARIOS
TRACK 11: CORE MONITORING SYSTEMS
TRACK 12: NUCLEAR CRITICALITY & SAFETY
TRACK 13: ISOTOPES PRODUCTION
TRACK 14: NONPROLIFERATION AND SAFEGUARDS

SPECIAL SESSIONS

Track 15S: In Memory of Massimo Salvatores (invited)
A tribute to Massimo Salvatores with submissions from his colleagues and younger generation researchers, covering different reactor physics aspects, experimental techniques and integral experiments, methods, and analyses.

Track16S: PHYSOR 2020 Highlights (invited)
Select papers representing best research trends in PHYSOR2020 and update on accomplishments/developments in 2022

Track17S: Neutronics Benchmark of CEFR Start-up Tests (In cooperation with IAEA)
Session to present up-to-date research and results from key participants in the IAEA effort on CEFR Start-up benchmarks.

Track18S: High Enrichment/High Burnup Core Analysis
Core physics analyses and experiments to fulfill licensing needs for the nuclear industry.

Track 19S: Micro-reactors Design & Core Analysis
Focus on multi-physics and higher order analyses along with challenges due to aggressive deployment plans of micro-reactor designs.

Track 20S: Challenges and Improvements in Accident Dose Analysis; Regulatory and Industry Perspective
Focus on recent regulatory changes along with continued evolution of analysis methodologies to address both evolving regulatory and operational requirements.

Track 21S: Challenges and Improvements in Vendor Independent Nuclear Analysis and Regulatory Approval
Session to share industry experience for process and method development, benchmarking, and topical report development for NRC approval. The session invites participants from utilities and other organizations to present their experiences and challenges in this area.

Track 22S: VERA Industry Applications (in cooperation with VERA User Group)
Most recent applications for VERA to solve PWR and BWR challenge problems.

Track 23S: Trends in HPC/Exascale in Reactor Physics
Most recent reactor physics analysis applications using HPC/Exascale Computing using advanced computer platforms (e.g., GPUs) for "ultimate" fidelity analyses (e.g., CFD coupled with Monte Carlo)

Track 24S: Advancements in UQ and Validation Methodologies
Latest progress in uncertainty quantification with particular focus on advanced reactor concept deployment.

Track 25S: Machine Learning and Artificial Intelligence for Reactor Physics
Focus on applications of ML and AI in reactor physics analyses (e.g., loading pattern optimization, surrogate model developments, etc).

Track 26S: Designing Reactors for Integrated Energy Systems
Focus on the analysis and design of advanced reactors to be operated as part of integrated energy systems on the path to deep decarbonization

Track 27S: Advances on open-source software for nuclear reactor analysis (In cooperation with IAEA)
Most recent contributions from the participants of IAEA's initiative on the use of open-source code for nuclear reactor applications, as well as from the nuclear open-source community at large.

Track 28S: Space Nuclear Program
Design and analysis of radioisotope systems and micro-reactors with heat pipes for propulsion and terrestrial power.

Track 29S: Hybrid Methods in Reactor Physics Analyses
Research and applications combining deterministic and stochastic methods for solving reactor physics problems.

Track 30S: Neutronics for Fusion Reactors
Deterministic or Monte Carlo neutronics simulations to support fusion reactor design and safety analyses, radioactive waste issues, neutron generator characterization, and other topics related to fusion reactor neutronics.

PANEL SESSIONS

Track 31P: Past, Present and Future Direction of Industry Core Simulators
A forum to discuss new developments in core simulators used routinely for LWR core design analyses.

Track 32P: Current Issues in LWR Core Development and Design
A forum for the utilities to gather key stakeholders and discuss relevant industry issues in LWR core design development and operation

Track 33P: Application and Development of Digital Twins for Nuclear Reactors
Panel on potential benefits of developing digital twins for nuclear reactors with focus on the most promising methodologies and challenges.

Track 34P: Digital Collaboration in Reactor Physics
Discussion on new ways to collaborate across the universities, national laboratories, and vendors to develop the next generation analysis codes and tools

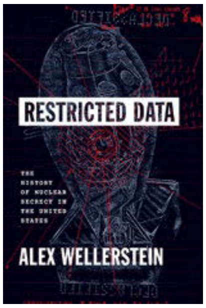
Track 35P: Advanced Reactor Demonstration Program
Continuation of the high-level plenary discussions to allow for detailed technical discussion and presentations on advanced reactor design and developments.

PLANNED WORKSHOPS

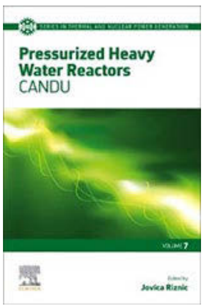
- **Open MC (half-day)**
- **McCARD uncertainty analysis workshop (half-day)**
- **Kraken: a Serpent-based multi-physics framework (half-day)**
- **URANIE open source platform for uncertainty propagation, surrogate models, optimizations, code calibration (full-day)**
- **VERA training (full-day)**
- **OpenFOAM for the analysis of advanced nuclear reactors (full-day)**
- **Multi-physics analysis and UQ of REA with STREAM/RAST-K (half-day)**
- **RAPID (half day)**
- **FRENDY nuclear data processing system (full day)**
- **New physics, new capabilities, what's changing in ENDF/B (half day)**
- **NEAMS (Full Day)**

Publications

Recently Published



Restricted Data: The History of Nuclear Secrecy in the United States, by Alex Wellerstein. The atomic bomb was born in secrecy. From the moment scientists first conceived of its possibility to the bombings of Hiroshima and Nagasaki and beyond, there were efforts to control the spread of nuclear information and the newly discovered scientific facts that made such powerful weapons possible. Drawing on troves of declassified files, including records released by the government for the first time through the author's efforts, this book traces the complex evolution of the U.S. nuclear secrecy regime, from the first whisper of the atomic bomb through the mounting tensions of the Cold War and into the early 21st century. (528 pages, hardback, $35, ISBN 978-0-226-02038-9, University of Chicago Press; order at press.uchicago.edu)



Pressurized Heavy Water Reactors: CANDU, edited by Jovica Riznic. The seventh volume in the Japan Society of Mechanical Engineers' series on thermal and nuclear power generation, this book provides a comprehensive review of a single type of reactor in a very accessible and practical way. It presents the full life cycle, from design and manufacturing to operation and maintenance, and it covers fitness-for-service and long-term operation. It does not relate to any specific vendor-based technology but rather provides a broad overview of the latest technologies from a variety of active locations, which will be of great value to countries invested in developing their own nuclear programs. Professionals involved in nuclear power plant life cycle assessment and researchers interested in the development and improvement of nuclear energy technologies will gain a deep understanding of PHWR nuclear reactor physics, chemistry, and thermal-hydraulic properties. (400 pages, paperback, $200, ISBN 978-0-12-822054-2, Elsevier; order at elsevier.com/books)

Nuclear Energy Data 2020, by the OECD Nuclear Energy Agency. This annual compilation of statistics and country reports documents the status of nuclear power in NEA member countries and in the Organization for Economic Cooperation and Development (OECD) area. Information provided by governments includes statistics on total electricity produced by all sources and by nuclear power, fuel cycle capacities and requirements, and projections to 2040, where available. Country reports summarize energy policies, updates of the status of nuclear energy programs, and fuel cycle developments. (128 pages, PDF, free download at oecd-nea.org)

The following are listings of the most recent issues of ANS's three technical journals. ANS members, access your free electronic subscription by visiting ans.org/pubs/journals and signing in to your ANS account.

ANS Technical Journals

FUSION SCIENCE AND TECHNOLOGY • MAY 2021

Spent Nuclear Fuel Incineration by Fusion-Driven Liquid Transmutator Operated in Real Time by Laser *T. Tajima et al.*

Matter Injection in EU-DEMO: The Preconceptual Design *B. Ploeckl et al.*

Thermogravimetric Oxidation Analyses of Carbon Tokamak Codeposits and Flakes *U. Shahid et al.*

Variation of Plasma Properties in Cylindrical Inertial Electrostatic Confinement Device by Changing the Anode Transparency *Z. S. Abd El-Salam et al.*

Manufacturing Technologies for Ultra-High-Vacuum–Compatible 10 MW/M² High Heat Flux Components for Application in Fusion Devices *H. Patel et al.*

Performance of W-1%Y_2O_3-0.5%Ti Plasma-Facing Composite Under Fusion Relevant Transient Heat Flux *C. Li et al.*

Power Quality Analysis for Poloidal Field Power Supply System in EAST *J. Qu et al.*

Application of High-Energy Tritium Ions and Alpha Particles Formed in ^{6}Li(n,α)T Nuclear Reaction to Excite the Luminescence of Inert Gas Mixtures *Y. Ponkratov et al.*

NUCLEAR SCIENCE AND ENGINEERING • JUNE 2021

Evaluation of Yttrium Hydride (δ-YH_{2-x}) Thermal Neutron Scattering Laws and Thermophysical Properties *V. K. Mehta et al.*

The Time-Dependent Asymptotic P_N Approximation for the Transport Equation *R. Harel et al.*

On the Regularity Order of the Pointwise Uncollided Angular Flux and Asymptotic Convergence of the Discrete Ordinates Approximation of the Scalar Flux *X. Hu, Y. Y. Azmy*

Optimization of Beta Radioluminescent Batteries with Different Radioisotopes: A Theoretical Study *H. Moayedi et al.*

Prediction of Neutronics Parameters Within a Two-Dimensional Reflective PWR Assembly Using Deep Learning *F. Shriver et al.*

Mechanism of the Initial States of a Bubble Formation and Departure from a Heated Surface in a Subcooled Flow *M. Medghalchi, N. Ashgriz*

Uranium Extraction from Gattar Granite Sample After Leaching Using Nitrate Solution in Presence of Peroxide *E. A. Manaa*

NUCLEAR TECHNOLOGY • JUNE 2021

This special issue features 13 selected articles from the 2020 Nuclear and Emerging Technologies for Space Topical Meeting (NETS 2020).

A Concept Study on Advanced Radioisotope Solid Solutions and Mixed-Oxide Fuel Forms for Future Space Nuclear Power Systems *R. M. Ambrosi et al.*

Empirical Analysis of the Multi-Mission Radioisotope Thermoelectric Generator Qualification Unit Operated at a Low Thermal Inventory with Potential for Improved End-of-Life Power *C. E. Whiting*

Development of Engineering Qualification Model of a Small ETG for a Launch Environmental Test *J. Hong et al.*

Development of a Novel Miniature Power Converter for Low-Power Radioisotope Heat Sources: Numerical and Experimental Results *F. I. Valentín, G. Daines*

Fabrication of UN-Mo CERMET Nuclear Fuel Using Advanced Manufacturing Techniques *A. M. Raftery et al.*

Toward an In-Depth Material Model for Cermet Nuclear Thermal Rocket Fuel Elements *W. C. Tucker et al.*

Trade-Offs Between Space Nuclear Systems Fueled with Highly Enriched Uranium and Low-Enriched Uranium *B. Lal, J. Locke*

Considerations for Implementing Presidential Memorandum-20 Guidelines for Nuclear Safety Launch Authorization for Future Civil Space Missions *Y. Chang*

Operational Considerations for Space Fission Power and Propulsion Platforms *A. C. Klein et al.*

Stay Cool—Alternatives for Long-Term Storage of Large Quantities of Liquid Hydrogen on a Mars Transfer Vehicle *N. A. Morris et al.*

Novel Deep Space Nuclear Electric Propulsion Spacecraft *T. Howe et al.*

Space Nuclear Power and Propulsion at USNC-Tech *P. Venneri, M. Eades*

Space Nuclear Propulsion Fuel and Moderator Development Plan Conceptual Testing Reference Design *J. L. Gustafson*

What is the most difficult nuclear plant part to replace?

John Portillo

John Portillo (JPortillo@ParagonES.com) is senior director of nuclear sales operations at Paragon Energy Solutions.

The nuclear industry should give itself a pat on the back: a quick review of plant capacity factors and plant trip trends demonstrates that by and large, the industry is very resourceful when it comes to locating even the most difficult-to-find replacement parts. That said, some parts are harder to replace than others. It's important to note, however, that the challenge of replacing parts is generally not due to the part itself but instead is the result of inadequate planning at the plant.

In our experience, the level of difficulty varies from situation to situation and is highly dependent on the timeline required to have the component back in service. The easiest part to replace is the one that plant management knows well in advance will need to be replaced. Forward-looking, plant-managed programs such as a critical spares program, an active obsolescence program, or a repair/refurbishment maintenance program can all help mitigate part replacement challenges. Paragon has partnered with several utilities to develop data-informed programs to identify critical spares, obsolescence issues, I&C circuit card repairability, parts quality issues, and reverse engineering opportunities. If a plant does not have a well-defined and effective parts management process, then every needed part can become an urgent issue and likely becomes more difficult to replace.

Of course, no plant can plan perfectly or have every potential part in stock. Luckily, the nuclear industry has pooled resources so that plants can buy parts 24 hours a day, 7 days a week. A buyer can easily search a parts database, such as PeAks or RAPID, to determine whether other plants or suppliers have the needed part in inventory. If the item is available, the plant can usually take delivery of the part the next day.

However, some of the most difficult-to-replace parts are typically associated with unique metal castings, custom transformers, or large custom motors. Parts in these categories create significant problems with long-lead-time solutions. Often, a utility has no option but to wait for the part to be manufactured.

While there are many options available to the nuclear industry for parts supply, it is incumbent on utilities to build a relationship with a trusted supplier and—most important—to form a strategy for long-term operation. In the end, the most difficult part to replace is the one that is not planned.