Radwaste Solutions

Spring 2022

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Tool & Metal Decon
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Waste not, want not

"The nagging thought is, are we throwing away a very valuable material?" That was the question posed by Steve Palethorpe, of the United Kingdom's National Nuclear Laboratories, to attendees of a recent webinar hosted by the American Nuclear Society. The webinar, "Creating Value from Waste: Recycling Valuable Isotopes and Surplus Energy," explored ways in which radionuclides can be separated from nuclear waste and used for other purposes, including medical, space, and agricultural applications.

As Palenthorpe pointed out during the webinar, it was not long ago that nuclear waste was simply considered "nasty" stuff that needed to be buried deep in the earth for all time. That view has begun to change, as it has become apparent that there are materials in that waste that have beneficial uses. Moreover, it has become clear that if nuclear energy is to succeed, it must demonstrate that it can reduce its environmental footprint by reducing waste volumes and optimizing its resources.

"You start to realize just how many different materials are present in those waste streams, and you wonder why we aren't making more use of them," Palethorpe said.

In this issue of *Radwaste Solutions* you will find three articles that showcase how waste can be converted from a liability into an asset. Beginning on page 26, Charles Forsberg and Jacopo Buongiorno, of the Massachusetts Institute of Technology, along with Eric Ingersoll, of LucidCatalyst, explore the socioeconomic benefits of collocating waste management sites with nuclear production facilities, namely fission battery plants and hydrogen/synfuel gigafactories. Geographically separating waste disposal facilities from commercial nuclear facilities, the authors argue, is a "historical artifact."

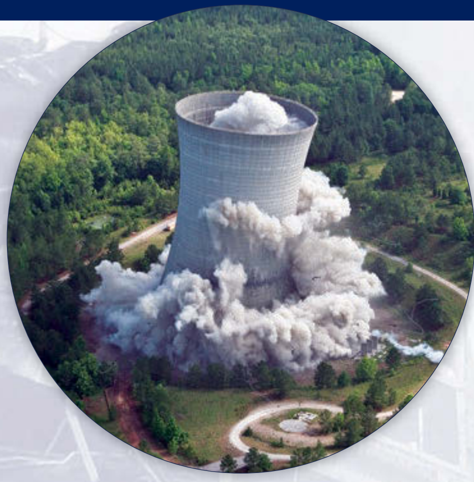
Next, on page 40, you'll find a recap of a joint program of the Department of Energy, contractor Isotek, and Bill Gates's company TerraPower to extract thorium-229 from uranium-233 that has been stored for decades at Oak Ridge National Laboratory and is slated for disposal. The Th-229 is used to produce actinium-225 for use in the treatment of cancer. An excellent example of how public-private partnerships can work to everyone's benefit, the program has successfully recovered valuable material while expediting the cleanup of legacy nuclear material, all while saving taxpayer dollars.

Finally, authors Glen Jackson, of the Savannah River National Laboratory, and Jeffrey Galan, of the National Nuclear Security Administration, describe a years-long effort involving multiple organizations to ship high-enriched uranyl nitrate liquid from Canada's Chalk River Laboratories to the Savannah River Site in South Carolina. The material, called target residual material, was left over from the production of molybdenum-99, which is used in medical diagnostic imaging, and is currently not considered a waste product by the DOE. The article begins on page 54.

Also in this issue, you will find an update on a multiple-phase experiment to test how hot nuclear waste containers behave in a salt-bed. The Brine Availability Test in Salt (BATS) project, being conducted at the Waste Isolation Pilot Plant, was first featured in the Spring 2021 issue of this magazine, and the current article, beginning on page 46, describes the experiment's latest phase.

A look at the DOE's current consent-based siting efforts and tips on transporting and disposing of radiological waste from a decommissioning manager's perspective round out the issue.

As always, we hope you find *Radwaste Solutions* a valuable resource and never a waste of your time.—*Tim Gregoire, Editor*



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DOE resumes consent-based siting process

Above: Spent fuel in dry cask storage at the closed Kewaunee nuclear power plant. (Photo: NAC International)

The Department of Energy has restarted its consent-based siting process for identifying sites to house the nation's spent nuclear fuel. On December 1, 2021, the DOE published in the *Federal Register* a request for information that "will be used to further develop DOE's consent-based siting process and overall waste management strategy in an equitable way."

In issuing the request for information, the DOE picks up where it left off in January 2017, when it released a draft consent-based siting process for public comment. The DOE said that comments received from both the 2017 draft process and this current request for information will be used in developing a consent-based process for siting federal interim storage facilities, as well as planning an overall integrated waste management system strategy, and possibly a funding opportunity.

The DOE's resuscitation of its consent-based siting program follows Congress's passing of the Consolidated Appropriations Act of 2021, which provides funding and directs the DOE to move forward with interim storage activities. The DOE said that nuclear energy is essential to achieving the current administration's goals for reducing carbon emissions and that managing waste not only makes nuclear a more sustainable option but also helps fulfill the government's spent fuel obligations.

For more, turn to "Informing Consent: The DOE's Latest Attempt to Implement Consent-Based Siting," starting on page 34.

Source Points continues

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WASTE MANAGEMENT

Biden administration affirms DOE's HLW interpretation

With a notice published in the December 21, 2021, *Federal Register*, the Department of Energy has affirmed its interpretation of the statutory term "high-level radioactive waste" to mean that not all wastes from the reprocessing of spent nuclear fuel are HLW. The DOE said it interprets the statutory term such that some reprocessing wastes may be classified as non-HLW and may be safely disposed of in accordance with its radiological characteristics.

"DOE confirms that the HLWI [HLW interpretation] is consistent with the law, the best available science and data, and the recommendations of the Blue Ribbon Commission on America's Nuclear Future," the *FR* notice states.

Following a lengthy public comment period that began in October 2018, the DOE finalized its HLW interpretation in 2019, with a supplemental notice issued in June 2019. The interpretation was first implemented in 2020 on a single waste stream.

By classifying waste according to its radiological characteristics rather than its origin, the HLW interpretation is a science-based tool to help further the tank waste cleanup mission across the United States, the DOE said.

Currently, the DOE is considering solidifying 2,000 gallons of tank waste from the Hanford Site in Washington and disposing of it off-site as low-level radioactive waste using the department's HLW interpretation. Disposal of the tank waste as LLW is part of the DOE's Test Bed Initiative, under which a portion of liquid waste from tank SY-101 at the Hanford Site will be pretreated to remove most key radionuclides, shipped off-site to be grouted into a solid, then disposed of at either EnergySolutions' LLW facility near Clive, Utah, or Waste Control Specialists' federal waste facility in Andrews County, Texas.

In December 2017, the DOE completed a proof-of-concept demonstration using three gallons of Hanford tank waste. The waste was successfully pretreated, transported to Perma-Fix Environmental Services Northwest, adjacent to the Hanford Site, for solidification, and disposed of as treated LLW at Waste Control Specialists' Texas facility.

On November 5, 2021, the DOE published in the *Federal Register* the availability of the *Draft Waste Incidental to Reprocessing (WIR) Evaluation for the Test Bed Initiative Demonstration*, which demonstrates that waste will be incidental to reprocessing of spent nuclear fuel, will not be high-level radioactive waste, and may be managed as LLW.

Crews pump waste from single-shell tanks at the Hanford Site to more stable double-shell tanks. (Photo: DOE)

Source Points continues

DECOMMISSIONING

NRC approves proposed decommissioning rulemaking

On November 3, 2021, the Nuclear Regulatory Commission approved a proposed rule to amend its regulations for nuclear power plants that are transitioning from operations to decommissioning. After changes requested by the NRC commissioners are made by agency staff, the proposed rule is to be published in the *Federal Register*, initiating a 75-day comment period. As of this writing, the proposed rule has not been published.


Nebraska's Fort Calhoun nuclear power plant, which shut down in 2016, is being decommissioned by EnergySolutions. (Photo: Wikimedia Commons)

In December 2014, in response to the growing number of nuclear power plant closures, the commissioners directed the NRC staff to develop a rulemaking on power reactor decommissioning. The rulemaking is intended to take into account the reduced radiological risks associated with power reactors that have been permanently shut down and defueled. Current regulations make little distinction between an operating reactor and one that is shut down and has been defueled, requiring licensees to seek exemptions and license amendments on a case-by-case basis as they transition to decommissioning.

The proposed decommissioning rule has been before the commission since May 2018, when the NRC staff, in response to the commissioners' rulemaking request, issued a paper (SECY-18-0055) outlining the rule changes. The staff said that the goal of the changes is to "provide for a safe, effective, and efficient decommissioning process; reduce the need for exemptions from existing regulations and license amendment requests; address other decommissioning issues that the NRC staff considers relevant; and support the principles of good regulation, including openness, clarity, and reliability."

In approving the proposed rule, the commission disapproved two proposals put forward by the NRC staff regarding the management of spent nuclear fuel. It disapproved the staff's recommendation to generically allow plant operators to use decommissioning trust funds to manage and decommission their independent spent fuel storage installations (ISFSIs). The commission also disapproved the staff's recommendation to remove preliminary approval and final NRC review of a licensee's irradiated fuel management program.

"Several nuclear power plants have begun decommissioning over the past decade, and at least three more reactors are expected to cease operations within the next four years," said NRC chairman Christopher Hanson. "This regulation incorporates lessons learned from plants that have already transitioned to decommissioning and will establish clear and transparent requirements for the future. I am convinced that the proposed approach will provide adequate protection while improving the effectiveness and efficiency of the decommissioning regulatory framework."

Source Points continues

Palisades, Big Rock Point NPPs transferred to Holtec

The Nuclear Regulatory Commission has approved the transfer of the Palisades nuclear power plant licenses from Entergy Nuclear Operations to Holtec International, as owner, and Holtec Decommissioning International (HDI), as decommissioning operator. Holtec and HDI intend to decommission the single-unit pressurized water reactor, located in Covert, Mich., under an accelerated schedule. The transfer also includes the Palisades independent spent fuel storage installation (ISFSI), as well as the licenses for the decommissioned Big Rock Point nuclear power plant in northern Michigan, where only the ISFSI remains.

While the NRC's December 13, 2021, order approving the transfer was effective immediately, the license transfer will not be finalized until after permanent shutdown of Palisades and the completion of the transaction between Entergy, Holtec, and HDI. Palisades is scheduled to be closed on May 31, and Holtec and Entergy expect to conclude the transaction, whereby Holtec will assume ownership of the site, real property, and spent fuel, by June 30. Holtec said it plans to move all the fuel in the plant's spent fuel pool to the ISFSI within three years of shutdown.

The completion of the transfer of Palisades is also dependent on the outcome of several hearing requests that are currently pending before the NRC. Under NRC policy, a license transfer approval is subject to the commission's authority to rescind, modify, or condition the transfer, based on the outcome of any subsequent hearing on the application.

Source Points continues

Humboldt Bay officially decommissioned, site released

The license for Pacific Gas & Electric Company's Humboldt Bay Unit 3 nuclear power plant near Eureka, Calif., has been terminated by the Nuclear Regulatory Commission, and the site has been released for unrestricted use. A 65-MWe boiling water reactor plant, Humboldt Bay-3 operated commercially from 1963 to 1976.

The Humboldt Bay nuclear power plant as seen from Humboldt Hill in 2010. (Photo: Wikimedia Commons)

After decommissioning the facility to meet the NRC's radiation protection standards, PG&E in October 2021 submitted final status surveys of the Unit 3 site and requested license termination. The NRC said that its staff evaluated the surveys, conducted inspections, and reviewed confirmatory analyses before concluding that the site meets its criteria for license termination for unrestricted use. The NRC issued a safety evaluation report on November 18, 2021, in response to PG&E's request to terminate the Humboldt Bay-3 license.

Humboldt Bay was unique in that the reactor core was situated in a watertight, 60-foot-diameter concrete caisson buried 80 feet below grade. The caisson was a first of its kind to house a nuclear containment structure, pressure suppression chamber, and nuclear steam supply system underground. While the caisson made decommissioning the site challenging, crews were able to remove the structure by 2018.

Source Points continues


Bear Creek Processing Facility


Shipping Casks


Bergen, NJ Transload Facility


Securing RPV at SONGS

RPV traversed road and rail.

Reactor pressure vessel (RPV) from Unit 1 of the San Onofre Nuclear Generating Station (SONGS) arrives at Energy*Solutions'* Clive disposal facility.

TRANSPORTATION

Proposals being sought to build and test high-tech railcar for SNF

The Department of Energy issued a request for proposals in January for the fabrication and testing of a prototype eight-axle railcar to carry the nation's spent nuclear fuel and high-level radioactive waste. The heavy-duty, flat-deck railcar design known as "Fortis" received approval from the Association of American Railroads (AAR) in January 2021 to proceed to building and testing.

The proposal includes the fabrication of a prototype Fortis railcar, the acquisition of instrumented wheelsets necessary to measure railcar performance, and the conduct of the railcar testing required by AAR Standard S-2043, *Performance Specification for Trains Used to Carry High-Level Radioactive Material*. The design for the Fortis railcar will be provided to the contractor by the DOE, and the Fortis project will receive technical support for fabrication and testing from Pacific Northwest National Laboratory.

Development of the Fortis railcar is part of the DOE's overall effort to develop a robust transportation capability for spent fuel and HLW. Commercial spent fuel is packaged in casks that weigh between 80 tons and 210 tons. Weight limits for legal-weight trucks transported in the United States are around 40 tons, making rail the preferred mode to move these heavy casks.

The DOE has already designed and fabricated the 12-axle Atlas railcar that is currently undergoing testing. Together, the Fortis and Atlas railcars will provide the department with a capability to move radioactive materials safely and efficiently by 2027, the DOE said.

Also in January, the DOE announced that a railcar specifically designed to transport security personnel during the shipment of spent fuel and HLW was being sent to a site near Pueblo, Colo., for multiple-car testing. Developed by the U.S. Navy and the DOE, the Rail Escort Vehicle (REV) is the last piece needed to complete the department's railcar system, the DOE said.

The REV was scheduled to arrive at the test site in late February, after which it was to be connected to the Atlas railcar and buffer railcars to form a complete train. According to the DOE, the entire train will then undergo two years of multiple-car testing, which will allow initial operations capabilities as early as 2024.

Graphical rendering of Fortis railcar design with spent nuclear fuel cask. (Image: DOE)

SECURITY

NRC commissioners vote to continue ISFSI security rulemaking

The Nuclear Regulatory Commission will continue work on a new rule covering security requirements for independent spent fuel storage installations (ISFSIs), with two of the agency's three commissioners voting to disapprove a request by NRC staff to discontinue the proposed rulemaking. The commissioners' votes on the request were recorded on August 4, 2021, but were not made public until January 24.

The commissioners also voted to disapprove NRC staff's recommendation to deny an associated petition for rulemaking filed by the C-10 Research and Education Foundation. That petition, filed in 2008, asked that the NRC require hardened on-site storage at all nuclear power plants, as well at as dry cask spent fuel storage sites away from operating reactors.

The NRC, in response to the terrorist attacks of September 11, 2001, issued security orders to ISFSI licensees, and in 2007, the commission approved a staff recommendation to develop a rulemaking to "establish a risk-informed and performance-based approach to ISFSI security using scenarios and dose calculations that considered site-specific information." After suspending work on the rulemaking for a time, the commission directed the staff in 2018 to proceed with the rulemaking "with the exclusive scope of codifying the requirements of the post-9/11 security orders into the NRC's regulations."

While developing a revised regulatory basis for the rulemaking, NRC staff conducted a preliminary cost and benefit analysis of continuing work on the rule. The staff found that the proposed rule "would not further improve the public health and safety or the common defense and security and would not be cost-justified." In 2019, the staff requested commissioner approval to discontinue the rulemaking and deny the C-10 petition.

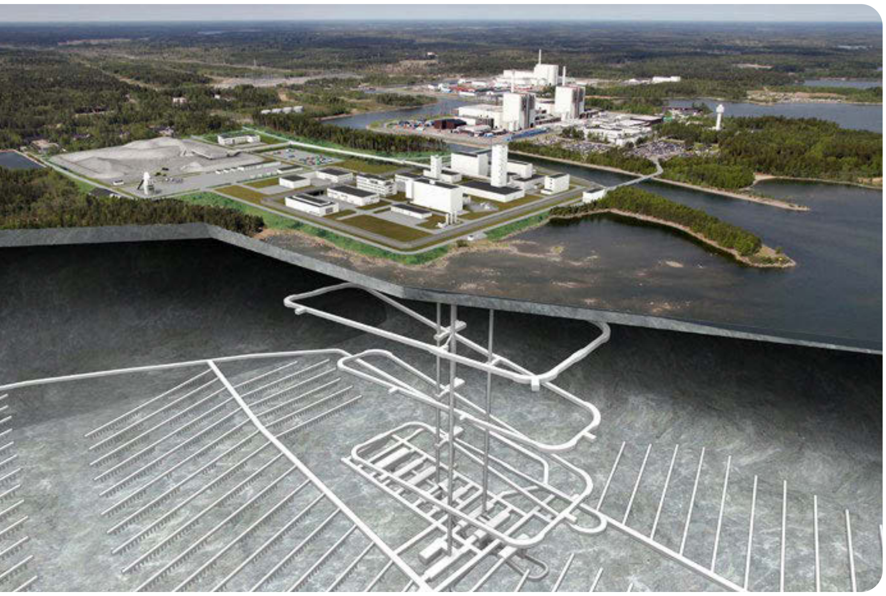
NRC Chairman Christopher Hanson and Commissioner Jeff Baran voted to disapprove the staff's request to discontinue the rulemaking and deny the petition, while Commissioner David Wright voted to approve. The majority commissioners asked agency staff for an "analysis of more options for the scope of the rule and the potential regulatory, resource, and timing impacts of those options."

Source Points continues

SWEDEN

Permits issued for geologic disposal facility, encapsulation plant

The government of Sweden announced on January 27 that it has issued a permit to the Swedish Nuclear Fuel and Waste Management Company (SKB) to build a repository for spent nuclear fuel at Forsmark in the municipality of Östhammar. The government also issued a permit to construct a spent fuel encapsulation plant in Oskarshamn, where the country's inventory of spent fuel is currently being stored. Sweden becomes only the second country in the world to license a deep geologic repository for commercial spent fuel, after Finland, which approved the Onkalo repository in 2015.



Rendering of the Forsmark geologic repository for spent nuclear fuel in Sweden. Below ground, the repository covers three to four square kilometers at a depth of 500 meters. (Image: SKB)

The method SKB uses for the final disposal of the spent nuclear fuel is called KBS-3 and is based on three protective barriers: copper canisters, Bentonite clay, and the Swedish bedrock. The Swedish Radiation Safety Authority (SSM) reviewed the disposal method and recommended that the government grant licenses for the repository and encapsulation plant in 2018. In approving the permits, the Swedish government said it supports SSM's expert assessment that the KBS-3 method is the best possible technology for final disposal, is safe, and meets the country's legal requirements over a very long time.

The next step in the licensing process is for Sweden's Land and Environment Court, which shares regulatory authority over the sites with the SSM, to establish conditions for the facilities. The SSM will also decide on permit conditions under the country's Nuclear Activities Act. SKB said that construction can start only when all licenses are in place, after which time it will take about 10 years to build the repository.

According to SKB, the final repository project will bring investments of around 19 billion Swedish kronor (about $2 billion) and will create about 1,500 jobs. The projects will be financed by funds from Sweden's Nuclear Waste Fund. The municipalities Östhammar and Oskarshamn, which had retained the right of veto in the matter, both previously agreed to host the facilities.

HANFORD

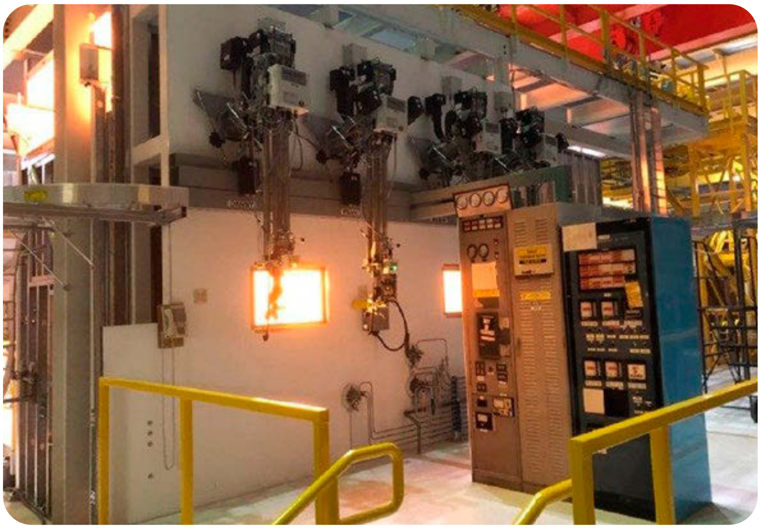
Preparations made to transfer Cs/Sr capsules to dry storage

The Department of Energy's Office of Environmental Management (EM) announced on January 25 that preparations are well underway for the transfer of nearly 2,000 highly radioactive cesium and strontium capsules from the Waste Encapsulation and Storage Facility (WESF) to interim dry storage at the Hanford Site near Richland, Wash.

EM's Richland Operations Office contractor Central Plateau Cleanup Company completed a number of modifications to the facility needed to install a system that will move the capsules

Source Points continues

from the underwater basin into dry-storage casks, onto trucks, and into a new storage area close to the facility. Final construction activities at the dry-storage area were completed last fall.


Workers recently installed manipulator equipment at a full-scale mock-up of areas of the Hanford Site's Waste Encapsulation and Storage Facility. (Photo: DOE)

Additional upgrades are needed at WESF's truck transfer area to enable the half-mile trip to the dry-storage concrete pad.

The 1,335 cesium capsules and 601 strontium capsules have been stored in an underwater basin at WESF since the mid-1970s. Cesium (in the form of cesium chloride, mostly Cs-137, with minor amounts of the much longer-lived Cs-135) and strontium (as Sr-90 in strontium fluoride) were removed from Hanford's underground waste storage tanks to reduce the internal temperature. While the capsules are currently in safe storage in the underwater basin, moving them to dry storage eliminates a longer-term risk of a radioactive release in the unlikely event of a loss of water from the basin during a beyond-design-basis earthquake. Dry storage will also reduce operating costs.

EM also noted that progress continues at a full-scale mock-up about 15 miles south of WESF at Hanford's Maintenance and Storage

Facility. It is designed to replicate the areas of WESF that the capsules will be moved through while transferring them into casks and putting the casks on trucks. The mock-up includes a replica shielded hot cell, an operating canyon, and a truck loading area, and will allow workers to get comfortable with the system before going live in the WESF facility.

Cesium removal system begins treating tank waste

The Department of Energy announced on February 2 that the first large-scale treatment of radioactive and chemical waste from underground tanks at the Hanford Site near Richland, Wash., has begun with the start of operations of the Tank-Side Cesium Removal (TSCR) System. The newly operational TSCR System removes radioactive cesium and solids from the tank waste. The treated waste will be fed directly to the nearby Waste Treatment and Immobilization Plant (WTP) for vitrification when the plant comes on line next year.

In a message of congratulations to the Hanford workforce, William "Ike" White, senior advisor to the DOE's Office of Environmental Management (EM), called the TSCR System a "cornerstone" of Hanford's Direct-Feed Low-Activity Waste program.

"It's a capability that will transform the Hanford Site and benefit the entirety of the EM program," White said. "I'm optimistic about what Hanford will achieve this year as we work toward around-the-clock operations to treat tank waste."

Source Points continues

An aerial view of the Hanford Site's AP tank farm and Tank-Side Cesium Removal System, bottom center. (Photo: DOE)

Hanford tank operations contractor Washington River Protection Solutions, working with EM staff, other site contractors, and regulatory agencies, built and installed the cesium removal system next to large underground storage tanks. Those tanks, called the AP tank farm, are located near the center of the Hanford Site, which is less than a quarter mile from the WTP, also known as the Vit Plant.

The DOE announced late last year that the WTP was moved to the commissioning phase, having completed all startup testing of components and systems. Hanford work crews across the site are preparing for a shift to 24/7 operations when vitrification of tank waste begins in 2023, the DOE said.

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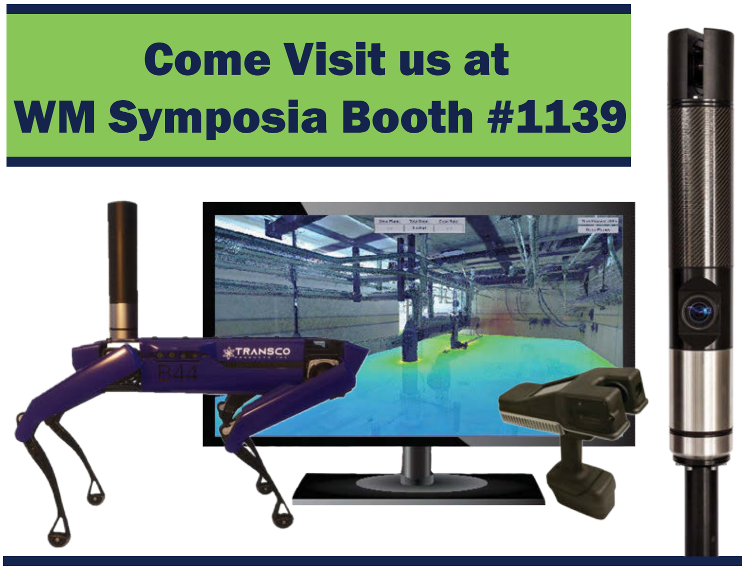

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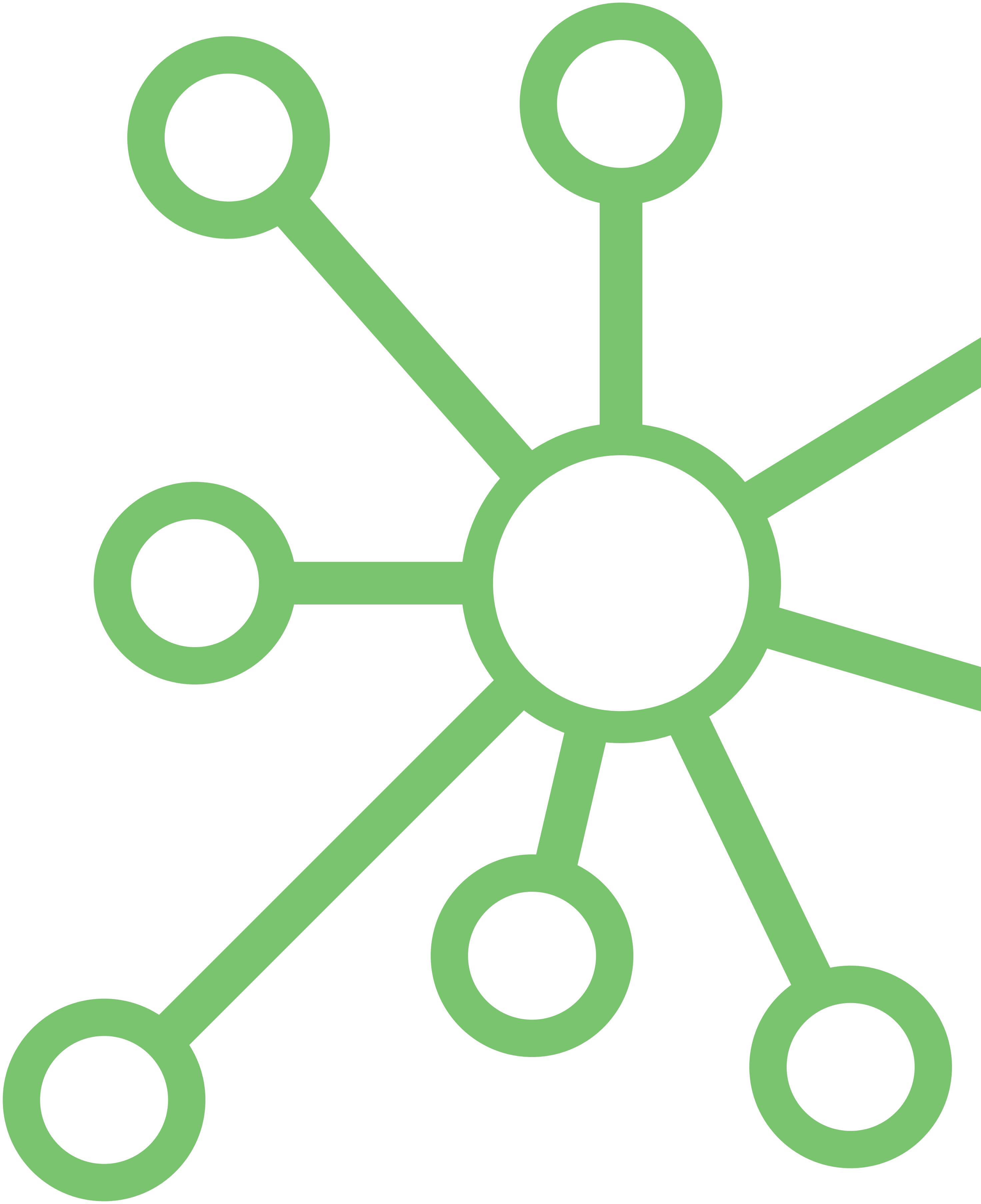


NUCLEAR TECH HUB:

Co-siting cutting-edge nuclear facilities with waste management sites

By Charles Forsberg, Jacopo Buongiorno, and Eric Ingersoll

The organization of the commercial fuel cycle with the geographical separation of waste disposal facilities from other nuclear facilities is a historical artifact. There are large economic and institutional incentives to collocate many fuel cycle facilities with the repository. Similarly, there are large economic and institutional incentives to collocate proposed fission battery factories and nuclear hydrogen/synthetic fuel (synfuel) gigafactories with other waste management facilities (used fuel storage, low-level waste disposal, etc.) to create nuclear technology hubs that create economic savings, generate jobs and tax revenue, and simplify waste management.

The economic savings are from shared services (e.g., security and environmental monitoring), a larger infrastructure of local supporting organizations (e.g., consultants, specialty supply companies, and worker training programs), and the elimination of transportation links. The institutional incentives include (1) creating strong local and state support because new business opportunities, high-paying jobs, tax revenue, and waste management are coupled together; and (2) a knowledgeable local and state government in terms of permitting and support, such as local worker training classes and universities.

The start of such technology hubs is becoming visible around existing Department of Energy sites at Savannah River (South Carolina), Oak Ridge (Tennessee), and Hanford (Washington). The Vogtle nuclear plants are next to the Savannah River Site, and the Columbia nuclear plant is next to Hanford. The first Generation IV reactor, the Kairos Power Fluoride Salt-Cooled High Temperature Reactor test reactor, is to be built at Oak Ridge. Each of these sites has a wide array of government and commercial nuclear facilities on government and private lands—along with specialized technical firms that locate nearby to serve multiple government and private customers.

Continued


The Hartsfield-Jackson Atlanta International Airport in Georgia. (Photo: @ATLairport)

The nearest nonnuclear analogy to a nuclear technology hub can be found in some airports, such as the Hartsfield-Jackson Atlanta International Airport, Mojave Air and Space Port, and Charleston International Airport. Each of these airports has commercial air flights but also other activities that share taxiways, security, and many other services on public and private land. Atlanta has the massive Delta Airlines operations, aircraft maintenance, and training facilities. Charleston is a joint civilian military airport that includes a Boeing commercial aircraft manufacturing plant and other facilities. Mojave has commercial flight testing, space industry development, heavy aircraft maintenance, and commercial aircraft storage.

One would expect a nuclear technology hub to have many types of facilities, including an industrial park with nonpublic rail and roads connecting facilities to allow the on-site transport of radioactive materials without the requirements for shipping over public highways. That capability enables moving radioactive wastes to central processing and disposal facilities. If there is a low-level waste disposal site, it enables moving large radioactive components used in the hub facilities to the disposal site without cutting components into small pieces to meet over-the-road shipping requirements. The on-site transport of radioactive materials simultaneously reduces costs and risks.

Here we describe three candidate nuclear technology hubs—the repository, the nuclear hydrogen gigafactory, and a fission battery refurbishment facility. The long-term coupling of large numbers of high-paying jobs, tax revenue, and waste management facilities can make such hubs attractive to communities and states, as opposed to isolated waste management facilities, which are typically perceived by the public as "dumps."

GEOLOGICAL REPOSITORIES

If one were designing a nuclear power system for the United States to minimize costs, risks, social opposition, and environmental impact, what facilities would be collocated with the repository? As the U.S. Department of Energy [1] once again attempts to site a spent nuclear fuel storage facility and then a repository, it is an appropriate time to ask that question. One concludes [2, 3, 4] that such a repository would have thousands of high-paying, nonconstruction, long-term jobs, with the majority of those jobs not associated with repository operations. Those jobs would be associated with the following:

International safeguards training and development center. The repository's receiving facilities will have the largest and most varied collection of incoming spent nuclear fuel in the world. That makes it a preferred location for training International Atomic Energy Agency inspectors and testing safeguards systems on multiple types of SNF. Such a center generates large numbers of secondary hotel and restaurant jobs because of the continuous influx of people for training.

SNF and high-activity materials testing and processing. The United States has a large number of facilities that inspect, test, and treat SNF (including failed fuel), highly radiative sources such as cobalt-60 and cesium-137, and high-activity wastes from producing medical and other isotopes. The costs of operating and maintaining these facilities are high for several reasons. First, each facility has its own security, environmental monitoring, and similar overhead functions. Second, these facilities generate complex mixtures of high-level radioactive waste, high-activity wastes, irradiated metals, and other wastes. Collocation with a repository enables (1) sharing of security, environmental monitoring, and other overhead services and (2) lower-cost waste disposal.

The processing and disposal of many nuclear waste streams are expensive because of the conflicting requirements for transportation and disposal. For transport, waste volumes are best minimized to minimize transport costs. Large, contaminated components are size-reduced to fit within transport containers. For disposal, one wants waste forms with good long-term performance. With collocated facilities, one can use alternative lower-cost waste forms, such as special cements that perform better than HLW glass, but are not used today because these waste forms increase final waste volumes and thus shipping costs. (One factor for better waste-form performance is that with lower concentrations of radionuclides in the waste form, there is less radiation damage to the waste form.) With collocation, highway size and weight requirements are eliminated.

The current facilities that treat and package these materials range in size from large facilities, such as the Naval Reactors Facility in Idaho, to smaller facilities with a few tens of employees. In the Navy facility, samples are taken from Navy SNF and destructively tested to determine long-term fuel performance, and thus how long nuclear naval vessels can remain in operation without refueling or decommissioning. Similar types of operations are performed on commercial and research fuels. There is a long list of such facilities that logically belong at the repository site.

Nuclear fuel reprocessing. Collocation of future reprocessing and fuel fabrication facilities at the repository site results in massive reductions in capital and operating costs from front-end receiving facilities to waste management—possibly by a third or more. During the Cold War, the Hanford PUREX plant processed 5,000 to 7,000 tons of short-lived targets and fuel per year to recover weapons plutonium, and yet it was much smaller than the French La Hague commercial facility with a throughput of only 1,600 tons per year. On-site waste disposal was the primary difference.

Continued

For example, chemical de-cladding of fuel (Hanford) is less expensive than mechanical de-cladding but generates much larger waste volumes—volumes that make it expensive to ship such wastes off-site for disposal. The actual separations section of a reprocessing plant that separates fissile and fertile material is less than 10 percent of the total capital cost.

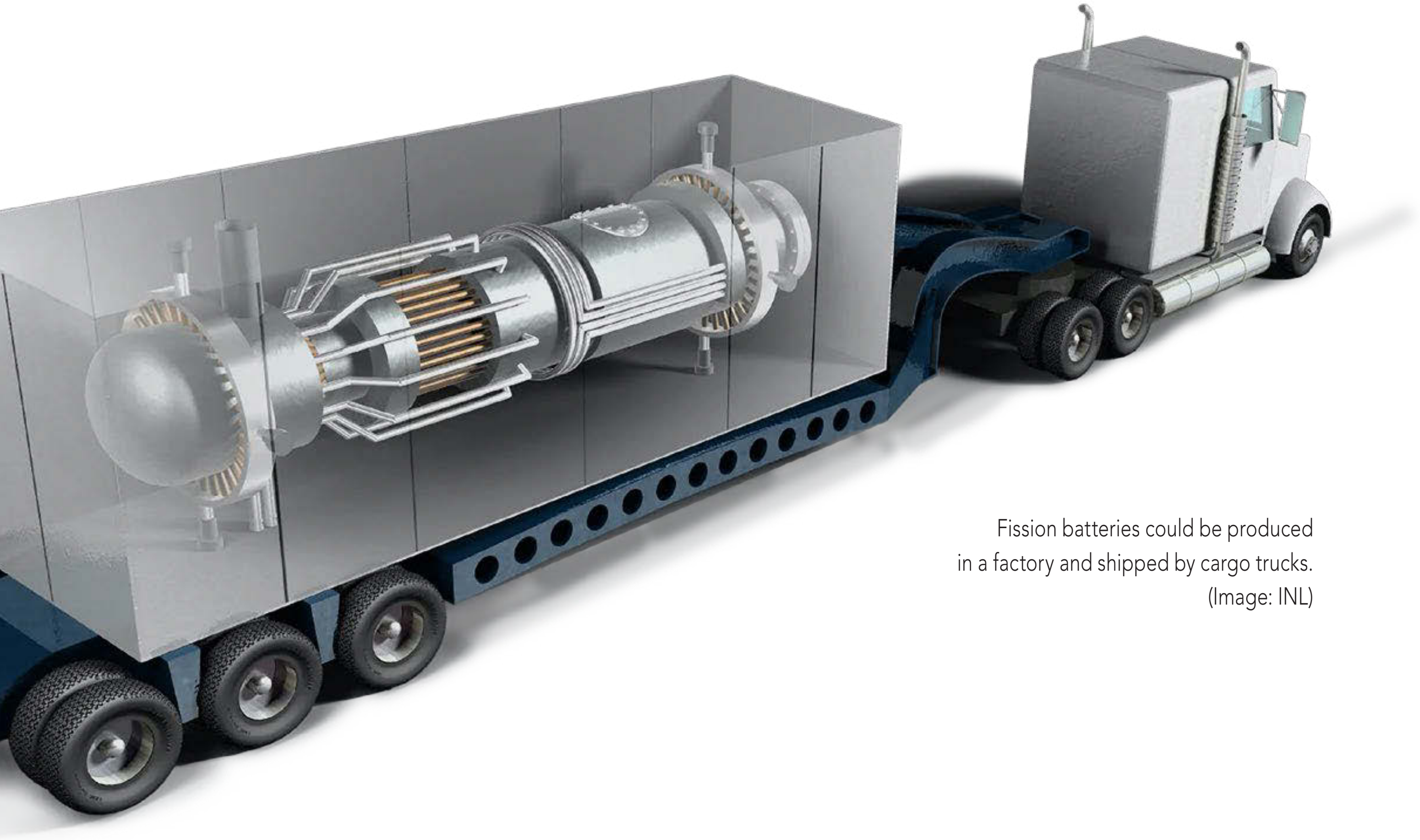
Hanford had many failures in waste management because of the use of shallow-land disposal and tank storage for these long-lived wastes. These challenges, however, are eliminated if the reprocessing plant is collocated with the repository and the use of lower-cost, higher-performance, higher-volume waste forms.

The other area of saving is joint services (security, radiation monitoring, etc.) and facilities such as front-end receiving facilities for SNF and HLW at the repository and reprocessing plant. If economics drives reprocessing decisions, SNF with high fissile content will be reprocessed, but SNF with low fissile content or SNF that is difficult to process will be considered waste. The same front-end facilities can be used for both facilities.

Collocation imposes siting requirements because of the need for good transportation connections and a sufficiently large labor force. In terms of economics, the lowest-cost repositories would be in salt. Salt has also been recognized as a preferred geology for disposal of long-lived radioactive wastes because of its capabilities to assure waste isolation for very long periods of time [5]. The one operating permanent repository in the United States, the Waste Isolation Pilot Plant for defense wastes in New Mexico, is in salt. In Europe, multiple geological repositories for the disposal of toxic heavy-metal wastes exist in salt deposits, including the Herfa-Neurode hazardous waste repository in Germany, which was the first geological repository in the world to be built.

As shown in Fig. 1, salt deposits exist across much of the United States. Other geologies can be used but the disposal costs would be higher. A significant fraction of the United States is suitable for shallow-land and geological disposal of different radioactive wastes. Siting is not limited by geology.

Fig. 1. Rock salt deposits in the United States. (Image: Salt Institute)



Fission batteries could be produced in a factory and shipped by cargo trucks. (Image: INL)

FISSION BATTERIES

Fission batteries (FB), also called nuclear batteries, are a class of advanced nuclear reactors defined by four characteristics [6, 7, 8, 9]: (1) mass-produced in factories in standard sizes to economically compete in major markets, (2) shipped as complete systems to the customer and returned to the factory after use, (3) operate in a secure and unattended manner, and (4) highly reliable. Mass production and transportability enables widespread use and lowers the cost, but this also limits the reactors' physical size and thus their power output. Market, manufacturing costs, and technology limits indicate likely sizes between 5 and 30 MWt.

The markets in a low-carbon world would be for customers using less than 250 MWt for heat and/or electricity production, with many customers having multiple FBs. These batteries would replace oil and natural gas and could be 10 percent of the total energy market—including chemical plants, large institutions (universities, hospitals, etc.), biofuels, industrial customers, data centers, and container ships. Larger energy users in a low-carbon world have other options, such as larger modular reactors and fossil fuels with carbon capture and sequestration—options that may be economically preferred at larger outputs but that require major on-site construction and facilities, and thus likely to be noncompetitive at smaller scales.

The likely business model is the leasing of FBs [7], similar to the practice of leasing commercial jet engines and aircraft. This places the regulatory burden on the lessor and not the customer, who is not in the energy business but needs energy for his own uses. A single supplier would manufacture and lease thousands of FBs and refuel/refurbish them at the factory for reuse. The FB factory/refurbishment facilities would be the largest radioactive waste generators by volume and second to reprocessing plants by radioactivity—far larger than any single nuclear power plant site.

There would be large incentives for access to the sea by barge for receipt and delivery to different customers. SRS/Vogtle, Oak Ridge, and Hanford have barge access. There also would be large incentives for sites with existing local LLW and SNF storage facilities, such as dry cask storage. A key characteristic is the tight coupling of jobs, tax revenue, and multiple waste management facilities.

Continued

NUCLEAR HYDROGEN PRODUCTION SITES

Any low-carbon future will require massive quantities of hydrogen; partly for industrial uses (e.g., fertilizer, steel, and biofuels) and potentially as a replacement for natural gas. Recent studies [10, 11] have proposed a new model for nuclear hydrogen production—the gigafactory (Fig. 2). A single site would have manufacturing facilities to build modular reactors and use the heat and electricity from those reactors to produce hydrogen. The hydrogen would be consumed by a downstream process (e.g., synfuel and ammonia) or injected into the gas grid. The reactors would be installed during the multiyear construction process and returned to the collocated factory for refurbishment or decommissioning as appropriate.

There are massive economic gains obtained by serial production, maintenance, operation, and refurbishment of all reactors on a single site, as all the potentially high costs associated with the conventional approach to these activities can be replaced with high-productivity, lower-cost manufacturing processes. Initial studies examined a site with 36 reactors of 600 MWt each for a hydrogen production rate of 2 million tons per year, or equivalent to the output of a medium-size refinery—about 200,000 barrels per day of synfuel. Current U.S. hydrogen production is about 11 million tons per year, but many low-carbon energy futures predict that hydrogen demand will grow to 100 million tons per year.

The gigafactory is made possible by the characteristics of hydrogen/synfuel. The energy output of such a facility would be similar to a large integrated oil refinery. In this context, there is a major difference between the capabilities of large electricity transmission systems and large pipeline systems and their associated storage facilities. Large electricity transmission lines have capacities of 1 to 3 gigawatts and essentially no storage. Pipelines have transmission capacities measured in tens of gigawatts. Hydrogen and synfuels, like natural gas and liquid products, can be stored in underground facilities. Those facilities today store a 30-day supply of natural gas. It is the ability to produce and store hydrogen at scale and transport it to a wide customer base that makes large, centralized facilities like the gigafactory a technical and economically viable option. Synfuels enable even longer-range tanker transport and sales to the global market.

Fig. 2. Hydrogen gigafactory with factory in back, reactor field in the middle, and hydrogen plant in the front. (Image: LucidCatalyst)

The second factor is the economics of low-carbon hydrogen production. Hydrogen production facilities have high capital costs and must be operated at high capacity factors to be economical, as shown in Fig. 3. That requirement couples well with nuclear plants but makes hydrogen expensive if the energy comes from sources such as solar with low capacity factors. Nuclear plants have capacity factors of about 90 percent, versus wind (about 35 percent) and solar (about 25 percent). Hydrogen plants, like all other chemical plants, have large economics of scale and strongly favor steady-state operation—matching nuclear plant characteristics.

A gigafactory with tens of gigawatts output implies large waste generation rates—larger than any existing nuclear power reactor site. This creates incentives to choose existing sites with existing SNF storage facilities and/or LLW disposal sites.

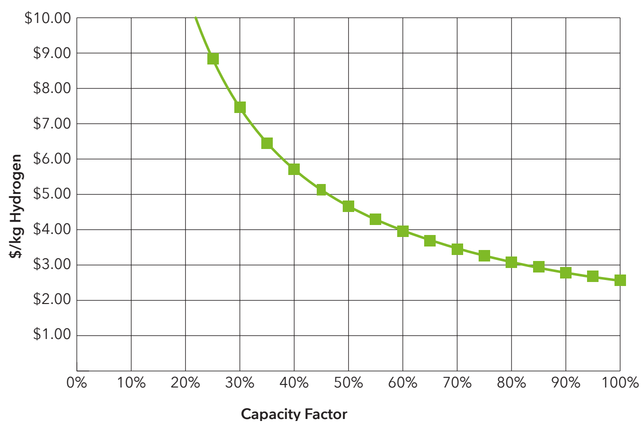


Fig. 3. Illustrative cost of hydrogen vs. capacity factor. (Graph: LucidCatalyst)

INSTITUTIONAL STRUCTURES

Nuclear technology hubs require a different business and institutional structure [2, 4] because the different owners of facilities have different priorities but must cooperate to be successful. As mentioned, a few airports provide models for such nuclear technology hubs. There are different security zones and internal roads or railroads for the transport of materials, including radioactive wastes, between facilities. There also must be sufficient land for expansion and good transportation links. Nuclear technology hubs would be the logical sites for regional SNF storage and other waste management activities because such sites would have lifetimes of many decades or centuries. Such a nuclear technology hub can be primarily private, public, or some combination of private and public partnership.

There are large incentives to work with local and state governments. Nuclear technology hubs can potentially break the deadlock over waste and repository facility siting. Imagine if the federal government promised several thousand long-term nonconstruction jobs within 10 years of opening a repository with massive added tax revenue—rather than designing repositories that minimize local jobs and benefits. This defines a research and development agenda: identify and understand what facilities and functions should be collocated to minimize total economic and societal costs.

The geographical characteristics of the U.S. nuclear fuel cycle system reflects history. The potential deployment of fission batteries, gigafactories for hydrogen production, and a repository system provides incentives to rethink how we should organize the system to reduce costs and environmental impacts while breaking the roadblocks to a fully functional waste management system. There are similar systems in other industries. A few airports have become aircraft technology hubs, where shared facilities and services provide economic benefits to everyone. For a nuclear repository, the burden of rethinking belongs to the government, while for the other nuclear technology hubs, the burden of rethinking belongs to the private sector.

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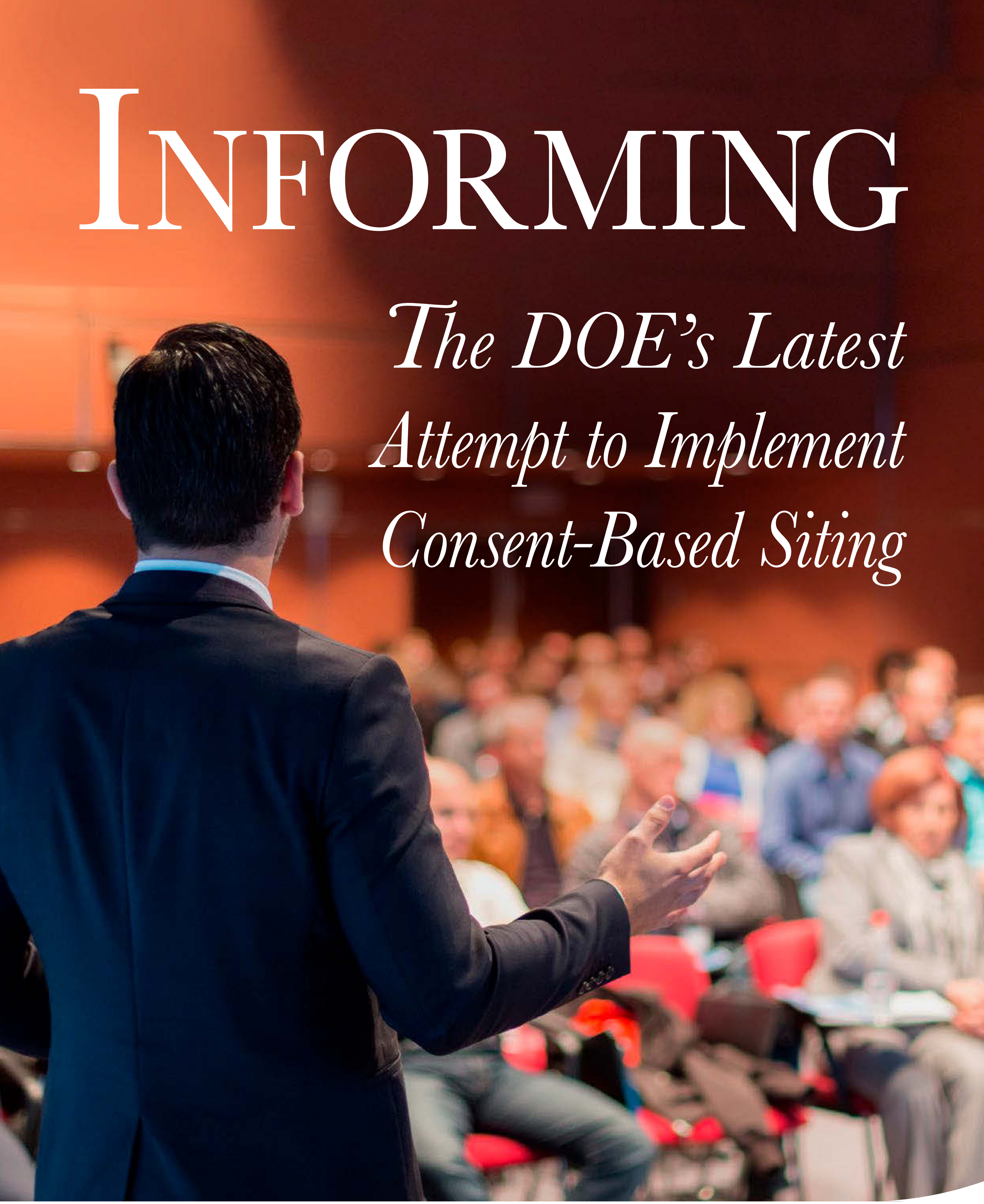
Informing

The DOE's Latest Attempt to Implement Consent-Based Siting



CONSENT:

BY TIM GREGOIRE

On December 1, 2021, the Department of Energy restarted its consent-based approach to siting spent nuclear fuel storage facilities, publishing in that day's *Federal Register* a request for information (RFI) on using a consent-based siting process to identify federal interim storage facilities. Responses to the RFI, the notice states, "will inform development of a consent-based siting process, overall strategy for an integrated waste management system, and possibly a funding opportunity."

With the issuance of the RFI, the DOE picks up where the Obama administration left off in January 2017, when just days before the new administration was sworn in, the department released a draft consent-based siting process for public comment. While that effort was more comprehensive in its approach, considering both permanent and interim storage sites, this latest RFI narrows the subject down, asking for information on how to site facilities only for the "temporary, consolidated storage of spent nuclear fuel using a consent-based approach."

The RFI, with its focus on interim storage, follows the passage by Congress of the Consolidated Appropriations Act of 2021, which provides funding and directs the DOE to move forward with interim storage to support near-term action in managing the nation's spent fuel. It also follows the recent license applications by both Holtec International and Interim Storage Partners (ISP) (a joint venture of Waste Control Specialists and Orano USA) for consolidated interim storage facilities in New Mexico and Texas, respectively. The Nuclear Regulatory Commission approved the license for Interim Storage Partners' facility on September 13, 2021, and a decision on Holtec's application is expected soon.

The DOE's new RFI also aims to be more equitable in its approach to engaging with stakeholders, welcoming insights from "people, communities, and groups that have historically not been well-represented in these discussions."

This updated approach to consent-based siting was discussed by Kathryn Huff, principal deputy assistant secretary in the DOE's Office of Nuclear Energy, during a session of the 2021 winter meeting of the American Nuclear Society, held November 30 to December 3. "We have learned a few things since 2017 about energy justice, environmental justice, and inclusion and equity," Huff said. "And we would like to incorporate all those things into the process as we try to identify a location for an interim storage facility."

Huff added, "Consent-based siting has certainly begun to work in some other nations, and we are hoping that is a sign that it will work here in the United States, at the very least for this very beginning part of what is going to be a marathon."

A bit of history

The concept of consent-based siting is not new to the United States. In 1978, President Jimmy Carter established the Interagency Review Group on Nuclear Waste Management to obtain a broad range of inputs and views from many sources on the long-term management of high-level radioactive waste. With the Obama administration's abandonment of the Yucca Mountain project in 2009, consent-based siting received renewed interest, and in 2012 Obama's Blue Ribbon Commission on America's Nuclear Future released a report proposing eight key elements needed to develop a strategy for managing the back end of the nuclear fuel cycle. First among those elements was the recommendation for a new, consent-based approach to siting nuclear waste management facilities.

Following the Blue Ribbon Commission report, the administration issued *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*. Released in 2013, the strategy called for "a phased, adaptive, and consent-based approach to siting and implementing a comprehensive management and disposal system" for spent nuclear fuel and HLW.

To launch a consent-based siting effort, the DOE issued "Invitation for Public Comment to Inform the Design of a Consent-Based Siting Process for Nuclear Waste Storage and Disposal Facilities" in the December 23, 2015, *Federal Register*. The invitation included five questions for the public to consider when providing input:

1. How can the DOE ensure the process for selecting a site is fair?
2. What models and experience should the DOE use in designing the process?
3. Who should be involved in the process for selecting a site, and what is their role?
4. What information and resources do you think would facilitate your participation?
5. What else should be considered?

Spent fuel in dry storage at the decommissioned Zion site in Illinois awaits a permanent home. (Photo: EnergySolutions)

In conjunction with the invitation for public comment, the DOE hosted eight public meetings across the country to encourage participation and provide additional opportunities for public input.

Based on that feedback, as well as the findings of several expert groups, the DOE developed a draft report, *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste*, which was issued for public comment on January 13, 2017.

In the 2017 draft report, the DOE laid out its vision for an integrated waste management system, which the department said could include a pilot interim storage facility, initially focused on accepting spent nuclear fuel from shutdown commercial reactor sites; a larger, consolidated interim storage facility, potentially collocated with the pilot facility and/or with a geologic repository; and one or more geologic repositories for SNF and HLW.

The DOE said it was also investigating the concept of deep borehole disposal as an option for disposing of smaller and more compact waste forms that are currently stored at DOE sites.

In response to the request for comments on the draft report, the DOE said it received 45 pieces of correspondence. Of these, 30 were unique pieces of correspondence, 10 items were duplicates, and 5 contained no comments.

Among the comments received, some expressed concern that the DOE did not have clear authorization from Congress to move forward with a consent-based approach to siting and that the consent-based siting process was incompatible with the Nuclear Waste Policy Act (NWPA). Particularly, some said that Congress needed to change House Joint Resolution 87, which designates Yucca Mountain as a repository site; update the NWPA to shift from a repository to storage; address the issue of state veto rights; and update the NWPA to allow for the Nuclear Waste Fund to be used for storage.

Several commenters also said that the DOE needs to provide clearer definitions of "community" and "potentially affected community." Indeed, many commenters asked for further information from the DOE on the nature of consent and who could or should provide consent for siting a facility.

A rendering of ISP's proposed consolidated interim storage facility in Texas. (Image: ISP)

The new RFI

According to the DOE, comments received from both the 2017 draft process and the December 2021 RFI will be used in developing a consent-based process for siting federal interim storage facilities, as well as planning an overall integrated waste management system strategy, and possibly a funding opportunity.

The DOE's Kathryn Huff, speaking at the ANS winter meeting, said, "We are not at the stage right now that we are asking communities to raise their hands and say, 'We are interested in being a host.' What we are asking for today is listening and receiving comments regarding how we should approach a consent-based siting process in an egalitarian and energy-just manner, how we should think about consent-based siting in the context of our integrated waste management system, and what kind of resources and information and strategies DOE can use to enable communities to understand their own level of consent."

In publishing the RFI, the DOE included for consideration 16 questions in three different areas. The DOE said that respondents did not need to address every question, but it welcomed input in all of the following:

Area 1: Consent-based siting process.

1. How should the department build considerations of social equity and environmental justice into a consent-based siting process?
2. What role should tribal, state, and local governments and officials play in determining consent for a community to host a federal interim storage facility?
3. What benefits or opportunities could encourage local, state, and tribal governments to consider engaging with the DOE as it works to identify federal interim storage sites?
4. What are barriers or impediments to the successful siting of federal interim storage facilities using a consent-based process and how could they be addressed?
5. How should the department work with local communities to establish reasonable expectations and plans concerning the duration of storage at federal interim storage facilities?
6. What organizations or communities should the department consider partnering with to develop a consent-based approach to siting?
7. What other issues, including those raised in the draft consent-based siting process, should the department consider in implementing a consent-based siting process?

Area 2: Removing barriers to meaningful participation.

1. What barriers might prevent meaningful participation in a consent-based siting process, and how could those barriers be mitigated or removed?
2. What resources might be needed to ensure that potentially interested communities have adequate opportunities for information sharing, expert assistance, and meaningful participation in the consent-based siting process?
3. How could the DOE maximize opportunities for mutual learning and collaboration with potentially interested communities?
4. How might the DOE more effectively engage with local, state, and tribal governments on consent-based siting of federal interim storage facilities?
5. What information do communities, governments, or other stakeholders need to engage with the department on consent-based siting of federal interim storage facilities?

Area 3: Interim storage as part of a waste management system.

1. How can the DOE ensure that considerations of social equity and environmental justice are addressed in developing the nation's waste management system?
2. What are possible benefits or drawbacks to collocating multiple facilities within the waste management system or collocating waste management facilities with manufacturing facilities, research and development infrastructure, or clean energy technologies?
3. To what extent should the development of an interim storage facility relate to progress on establishing a permanent repository?
4. What other issues should the department consider in developing a waste management system?

The DOE's deadline for responding to the RFI was March 4. While the DOE could choose to extend that deadline, as of this writing it has not done so.

Consent-based criticism

Given past experiences with attempts to develop a workable, comprehensive nuclear waste management program in the United States, it is difficult to guess as to the outcomes of this current DOE effort.

Speaking at the 2021 Radwaste Summit in Summerlin, Nev., Leo Blundo, a Nye County, Nev., commissioner, said consent-based siting is just another way for states and the federal government to stall progress on the nuclear waste issue. "The consent discussion gives Congress, governors, and those in the political class the talking points they need to alleviate political pressure at the expense and impasse of enacting the [NWPA]," Blundo said.

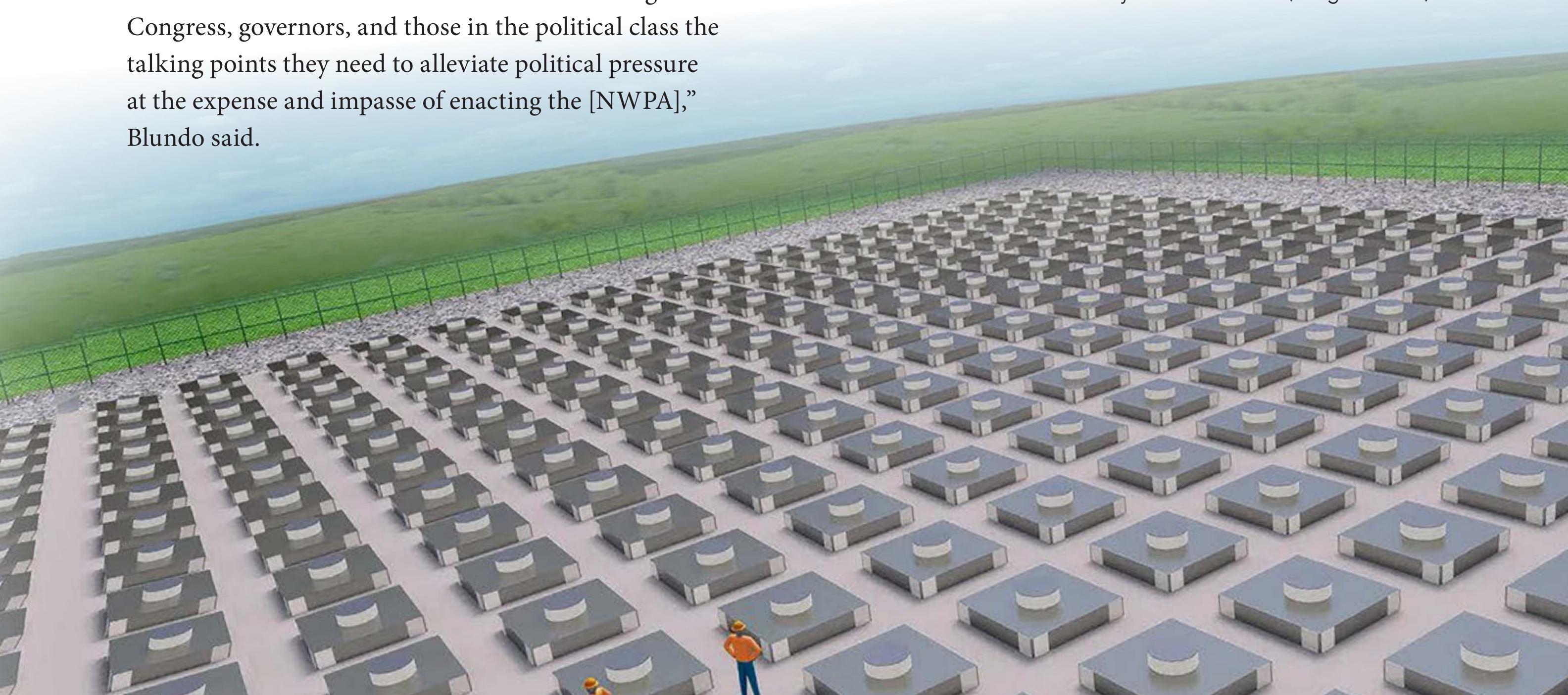
David Carlson, president and chief operating officer for Waste Control Specialists, also addressed consent-based siting during the Radwaste Summit, saying that it was difficult to define. "We have to understand really what is consent before we can head toward consent-based siting," Carlson said. "If you go to the most extreme definition of what is consent, then you are talking about something that may be impossible to achieve."

The Energy Communities Alliance (ECA), an organization of local governments adjacent to or impacted by DOE sites, also addressed the latest RFI. While saying it was still reviewing the request, the ECA said it had several initial concerns, including the fact that the RFI does not address legacy HLW remaining at the DOE's Savannah River, Hanford, and Idaho sites. The ECA is also concerned that it appears the DOE is moving ahead to develop an interim storage site absent a permanent repository and that only federal facilities seem to be under consideration.

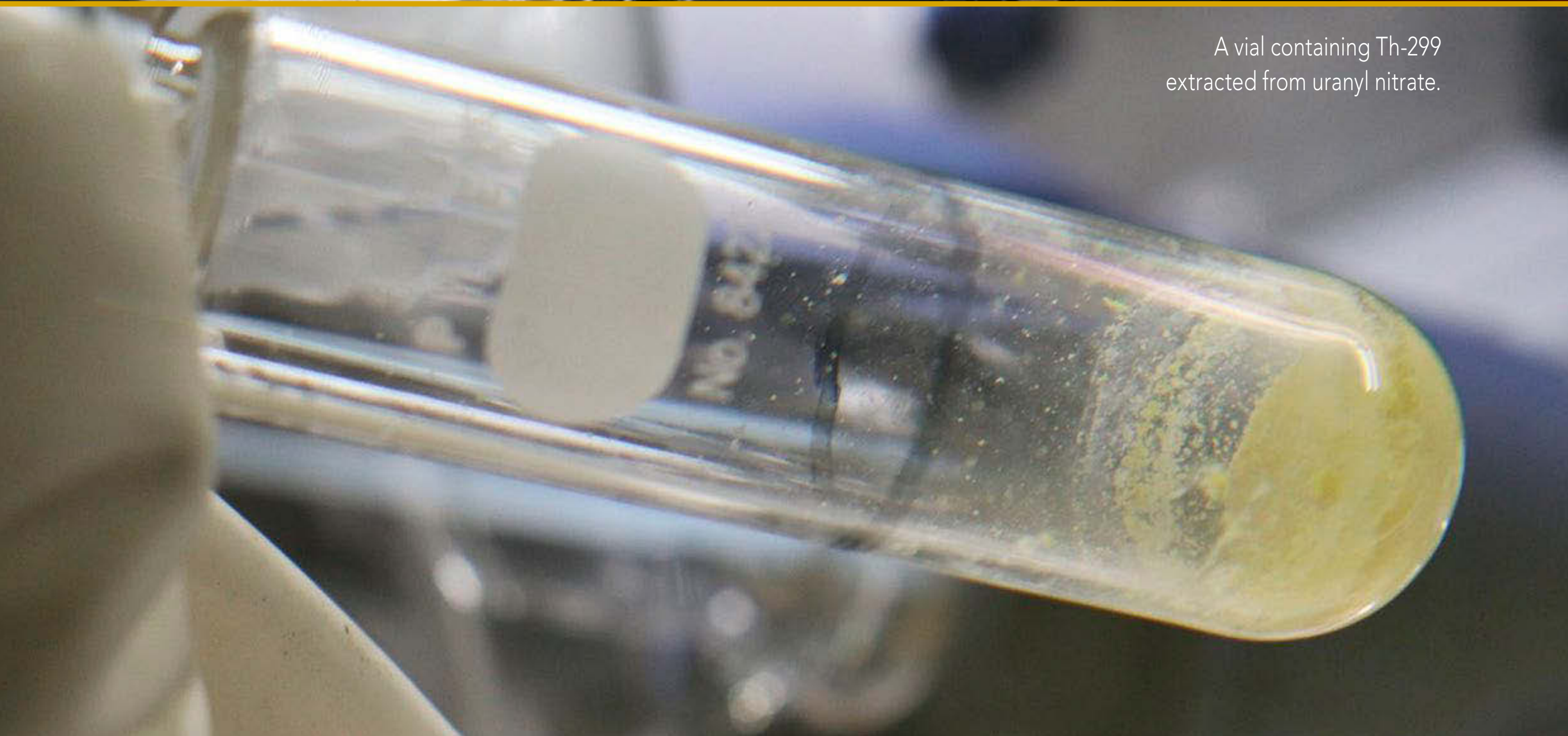
The ECA, however, added that it is optimistic that this latest effort can succeed *if* [emphasis added] that effort is built upon five basic assumptions: that there is trust between parties, decisions are perceived as fair and based on sound science, there is meaningful and ongoing engagement, consent is understood to be informed, and it is understood there is no one-size-fits-all model for a consent-based siting agreement.

"We've been down this road before—Let's see if we can get to the end this time," the ECA said.

A rendering of Holtec International's proposed HI-STORE facility in New Mexico. (Image: Holtec)



An Isotek employee processes low-dose uranium-233 material in a glove box at Oak Ridge National Laboratory. (Photos courtesy of DOE)



A vial containing Th-299 extracted from uranyl nitrate.

One Man's Trash:

Extracting Valuable Isotopes from Waste Material

The DOE and a contractor recently succeeded in disposing of Oak Ridge's low-activity U-233, but not before recovering Th-229 from the material.

This past October, the Department of Energy's Oak Ridge Office of Environmental Management (OREM) and its contractor Isotek successfully completed processing and disposing the low-dose inventory of uranium-233 stored at Oak Ridge National Laboratory (ORNL), ending a two-year effort that has eliminated a portion of the site's legacy nuclear material and provided rare nuclear isotopes for next-generation cancer treatment research.

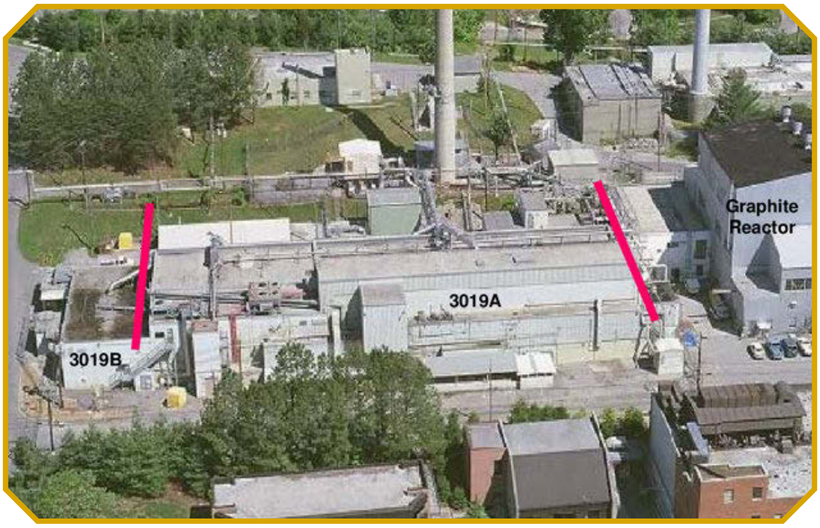
Known as the Thorium Express Project, the effort began with the DOE's announcement on November 22, 2019, of an innovative public-private partnership between the department and TerraPower, the nuclear company Microsoft co-founder Bill Gates helped launch in 2006. Under the partnership, Isotek, a subsidiary of SNC-Lavalin, extracted thorium-229 from U-233 during downblending operations, whereby the uranium material was processed into a disposal-ready form. The recovered Th-229 was then shipped to TerraPower, which used it to produce actinium-225, an alpha-emitting isotope used for targeted alpha therapy (TAT), a promising new cancer treatment.

Because of its short half-life of 10 days, Ac-225 is ideal for TAT, which works by combining the targeting capabilities of cancer-cell-specific biological carriers with the destructive capabilities of the radioactive isotope. This treatment can be more effective than standard chemotherapy because standard chemotherapy has a larger destructive radius, potentially destroying healthy cells along with cancer cells. The partnership was expected to allow TerraPower the ability to make 100 times more Ac-225-based cancer treatment doses per year than the 4,000 doses that are currently available worldwide.

While the partnership produced vital material for future cancer research, it had another beneficial result: expediting removal of legacy nuclear material stored at ORNL at a savings to the federal government.

"This partnership is a success for all involved," said OREM manager Jay Mullis at the time of the partnership announcement. "Through Isotek's innovative approach, we are able to accelerate one of our highest priority projects, spend less taxpayer dollars to complete the project, and provide material that will greatly benefit the public in the future."

Continued



The Building 3019 Complex at ORNL.

The inventory

During the Cold War, the United States produced a significant quantity of U-233 in support of national defense and other missions, including as an alternative fuel source for nuclear reactors. The material was made by irradiating naturally occurring thorium-232 with neutrons. This process, however, also created trace amounts of the highly unstable radioactive isotope U-232, making U-233 more difficult to use as a fuel source.

After it became clear that the supply of naturally occurring uranium-235 would be adequate to fuel the U.S. fleet of nuclear reactors, U-233 was sent to Oak Ridge for storage. For decades, more than 1,000 containers of U-233 was stored in ORNL's Building 3019 Complex. Built in 1942, the complex is the world's oldest operating nuclear facility.

Samples of containers holding U-233 stored at ORNL.

The continued long-term storage of the fissile material represented a significant financial liability for DOE. Following recommendations made by the Defense Nuclear Facilities Safety Board in 1997 to address storage vulnerabilities in the aging Building 3019, the department issued an environmental assessment in 2004 that proposed the following objectives:

1. Modify Building 3019 to accommodate processing equipment and support operations necessary to downblend the U-233 inventory.
2. Render the material suitable for safe, long-term, economical storage to eliminate the need for safeguards, security, and nuclear criticality controls.
3. Extract Th-229 from the U-233 to increase its availability for medical research and treatment.
4. Place Building 3019 in a safe and stable state for transfer to the DOE's program for decontamination and decommissioning.

The DOE announced in 2003 that it would award a U-233 disposition contract to Isotek, and in 2007 the company took over Building 3019. According to Isotek, roughly half of the U-233 inventory was in a state that made it safe for transportation and disposal, and the company began shipping that portion off-site for disposal (primarily the Nevada National Security Site) in 2011. The company said it finished that campaign in 2017.

Removal and disposition of the remainder of Oak Ridge's U-233 had since become one of the highest priorities of the DOE's Office of Environmental Management.

Material handlers open a container of U-233 to begin the Th-229 extraction process.

Thorium Express

According to the DOE, as a result of the partnership between the DOE and TerraPower, Isotek was able to use proceeds from the sale of Th-229 to accelerate its cleanup of Oak Ridge's U-233 and begin downblending the remaining inventory of low-dose U-233 canisters for disposal a year ahead of schedule. At the time, this was projected to save taxpayers approximately $90 million.

Initially, Isotek was scheduled to begin processing the remainder of U-233 in October 2020, when upgrades to hot cells in ORNL's Building 2026 were first set to be completed. The COVID-19 pandemic, however, temporarily halted operations, delaying completion of the upgrades. The upgraded cells are designed to handle larger amounts of uranium, providing more shielding for workers equipped with mechanical arm manipulators.

Fortunately, rather than wait for the hot cells to be completed for larger-scale processing, Isotek arranged for workers to begin processing the portions of the U-233 inventory with lower levels of radioactivity in glove boxes. Isotek received DOE approval to implement the glove box approach in August 2018, and the department announced the beginning of operations in October 2019.

"We wanted to find a way to continue the disposition process while facility modifications were being planned and executed," Isotek Deputy Project Manager Sarah Schaefer said at the time. "In the span of a year, we were able to design the glove boxes, procure the equipment, train operators, and pass the readiness assessment to begin processing."

The Th-229 extraction process begins by dissolving samples of U-233 material with nitric acid, breaking it down to uranyl nitrate, plutonium, and thorium. Resin columns were then used to filter and separate the Pu and Th, after which nitric acid was again used to dissolve the resin and remove the Th-229, which was dried and packaged for shipment to TerraPower. The remaining material was then grouted, dried, and packaged for disposal.

"It's important to extract thorium from our U-233, because Th-229 only comes from U-233," Shaefer said. "And since, by and large, the world's supply of U-233 is stored here [at ORNL], once this material is dispositioned there will be no more Th-229 available."

Continued

Isotek employees gather in front of drums containing the final low-dose U-233 material they processed for disposal.

Isotek said that by the time it completed the Thorium Express Project, it had disposed of over 10 kilograms of nuclear waste and provided 1.67 grams of Th-229 for cancer research. The company will continue recovering Th-229 during processing of the higher activity U-233 in the upgraded Building 2026 hot cells.

The DOE announced in October 2021 that the Building 2026 upgrades have been completed and that Isotek is to begin the next phase of its disposition campaign, processing the canisters of higher activity U-233, early this year.

In January 2021, it was announced that the Thorium Express Project was awarded a Secretary of Energy Achievement Award by the DOE, one of the department's highest honors.

Trading Uranium for Moly-99

On January 6, the Department of Energy's National Nuclear Security Administration (NNSA) and Office of Environmental Management (EM) announced it has signed the first contracts as part of the department's Uranium Lease and Take-Back Program with SHINE Technologies, a producer of medical radioisotopes. The program is part of the DOE's efforts to increase the domestic production of molybdenum-99, used in over 40,000 daily medical diagnostic procedures across the United States. The NNSA's lease contract will provide SHINE with the low-enriched uranium necessary to produce Mo-99, while SHINE's contract with EM details requirements surrounding the return of any resulting radioactive waste without a commercial disposition path once Mo-99 production is complete.

SHINE's Mo-99 production facility under construction in Wisconsin. (Photo: SHINE Technologies)

The American Medical Isotopes Production Act of 2012 directed the DOE/NNSA to establish a program to make uranium available to medical isotope producers in the United States. Although the act also requires the DOE to establish take-back contracts for spent nuclear fuel and radioactive waste resulting from medical isotope production without a disposal path, there is no spent fuel or radioactive waste involved in these contracts.

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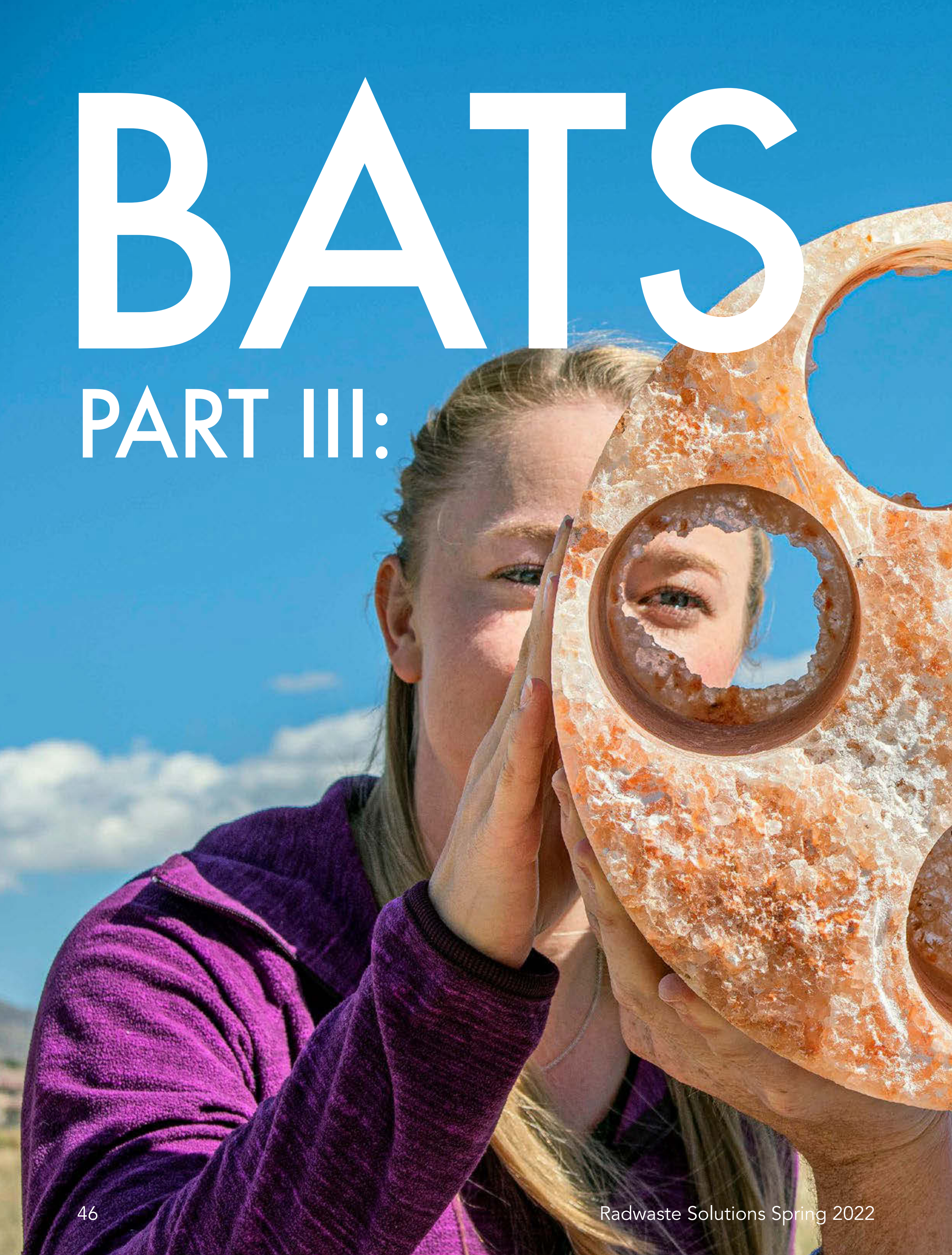
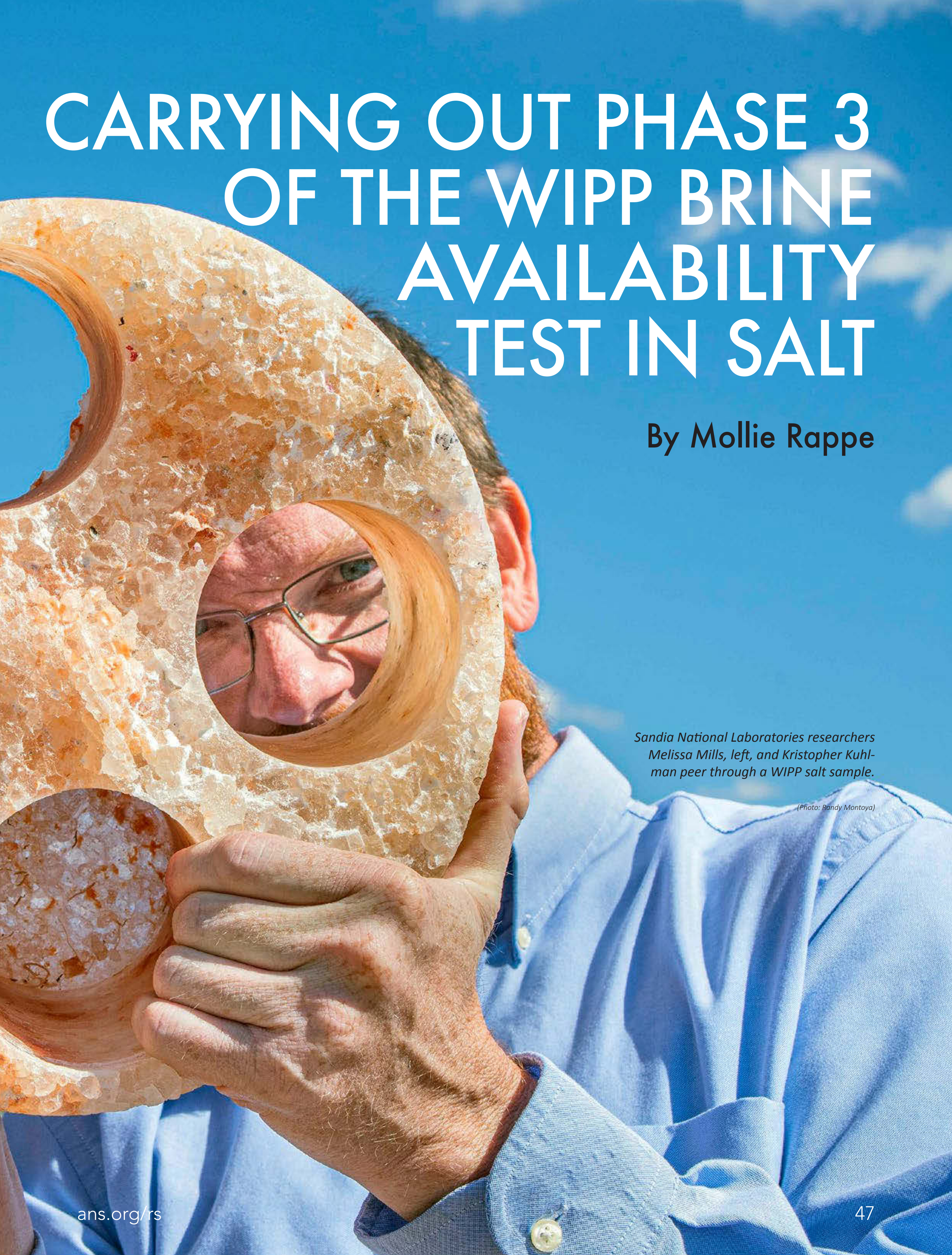


CARRYING OUT PHASE 3 OF THE WIPP BRINE AVAILABILITY TEST IN SALT

By Mollie Rappe



Sandia National Laboratories researchers Melissa Mills, left, and Kristopher Kuhlman peer through a WIPP salt sample.

(Photo: Randy Montoya)

Last fall, scientists from Sandia, Los Alamos, and Lawrence Berkeley national laboratories began the third phase of a years-long experiment to understand how salt and very salty water behave near hot nuclear waste containers in a salt-bed repository. Initiated in 2017, the Brine Availability Test in Salt (BATS) project is part of a spent nuclear fuel research campaign within the Department of Energy's Office of Nuclear Energy (DOE-NE).

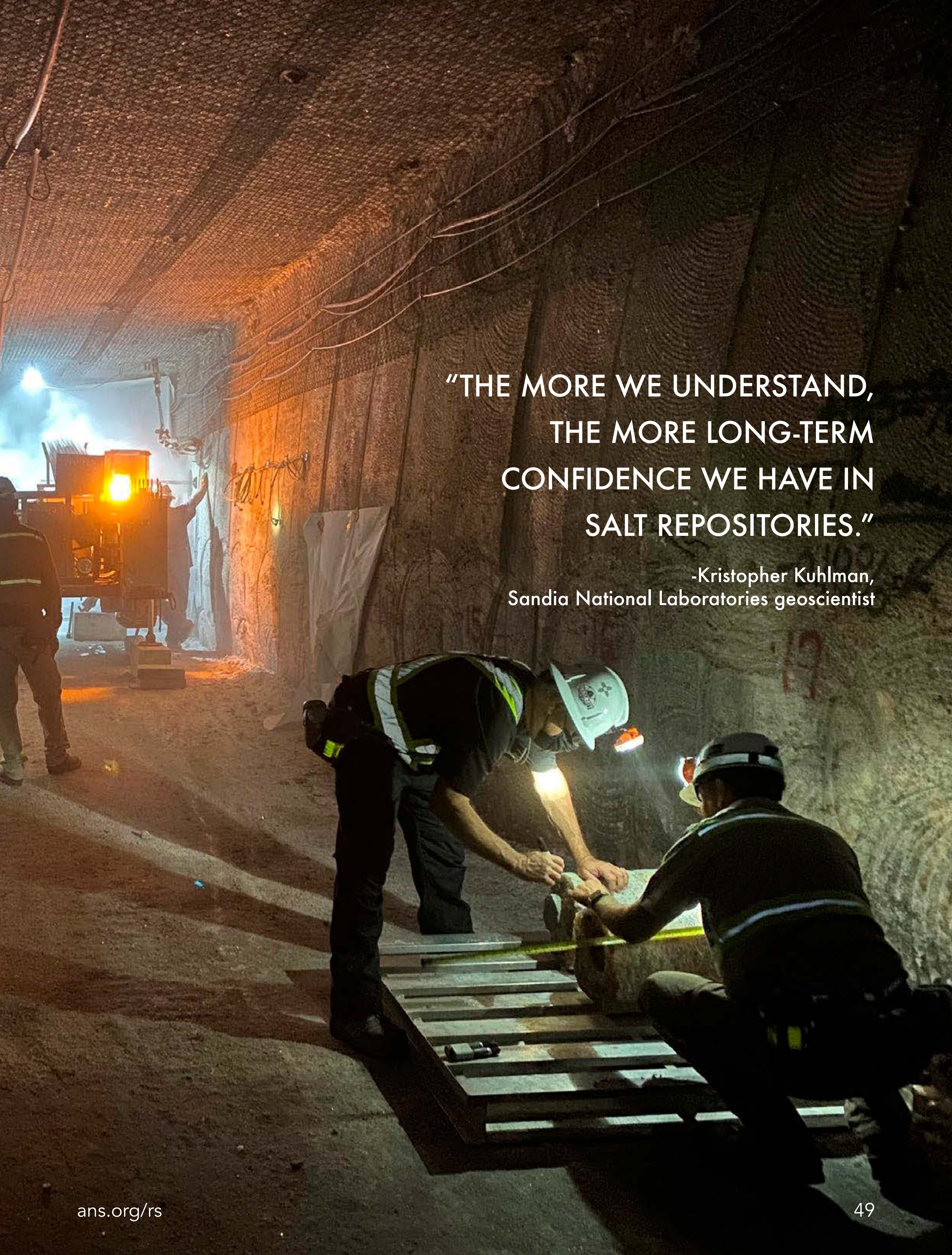
Salt's unique physical properties can be used to provide safe disposal of radioactive waste, said Kristopher Kuhlman, a Sandia geoscientist and technical lead for the project. Salt beds remain stable for hundreds of millions of years. Salt heals its own cracks, and any openings will slowly creep shut.

For example, the salt at the Waste Isolation Pilot Plant outside Carlsbad, N.M.—where some of the nation's Cold War-era nuclear waste is interred—closes on the storage rooms at a rate of a few inches a year, protecting the environment from the radioactive waste. The transuranic waste interred at WIPP, however, does not produce the same levels of heat as spent fuel.

The DOE-NE's Spent Fuel and Waste Disposition initiative seeks to provide a sound technical basis for multiple viable disposal options in the United States, and specifically how heat changes the way liquids and gases move through and interact with salt, Kuhlman said. The understanding gained from this fundamental research will be used to refine conceptual and computer models, eventually informing policymakers about the benefits of disposing of spent nuclear fuel in salt beds. Sandia National Laboratories is the lead laboratory on the project.

"Salt is a viable option for nuclear waste storage because far away from the excavation any openings are healed up," Kuhlman said. "However, there's this halo of damaged rock near the excavation. In the past people have avoided predicting the complex interactions within the damaged salt because 30 feet away the salt is a perfect, impermeable barrier. Now, we want to deepen our understanding of the early complexities next to the waste. The more we understand, the more long-term confidence we have in salt repositories."

As part of the latest phase of the BATS experiment, salt cores are removed from the Waste Isolation Pilot Plant underground to study how brine behaves near hot nuclear waste containers in a salt-bed repository. (Photos courtesy of SNL)



"THE MORE WE UNDERSTAND, THE MORE LONG-TERM CONFIDENCE WE HAVE IN SALT REPOSITORIES."

-Kristopher Kuhlman,
Sandia National Laboratories geoscientist

Trial and error in the first experiment

To understand the behavior of damaged salt when heated, Kuhlman and colleagues have been conducting experiments 2,150 ft underground at WIPP in an experimental area more than 3,200 ft away from ongoing disposal activity. They also monitor the distribution and behavior of brine, which is salt water found within the salt bed left over from an evaporated 250 million-year-old sea. The little brine that is found in WIPP is 10 times saltier than seawater.

"Salt behaves much differently when it's hot. If you heat up a piece of granite, it isn't that different," Kuhlman said. "Hot salt creeps much faster, and if it gets hot enough, the water in brine could boil off leaving a crust of salt on the waste container. Then that steam could move away until it gets cool enough to return to liquid and dissolve salt, possibly forming a complex feedback loop."

In other words, the scientists are looking at whether the heat from spent nuclear fuel could help enclose waste containers and even protect them from the corrosion that salty water can cause.

Planning for the BATS experiment's first phase began in 2017, using existing horizontal holes at WIPP. During this "shakedown" phase, researchers learned what equipment to use in subsequent experiments. For example, the first heater, which worked like a toaster, did not get the nearby salt hot enough to boil brine, said Phil Stauffer, a geoscientist with an expertise in combining computer models and real-world experiments who is leading Los Alamos National Laboratory's contributions. However, the second heater the team tried, an infrared model, was effective; it worked more like the sun.

Melissa Mills, left, a Sandia National Laboratories geochemist, and Kristopher Kuhlman, a Sandia geoscientist, display salt samples from WIPP. (Photo: Randy Montoya)

"When we put the first radiative heater into the first borehole, as part of the shakedown phase, it turns out the air didn't allow the heat to efficiently move into the rock," Stauffer said. "Then we switched to an infrared heater, and the heat moved through the air with little energy loss. In the early numerical simulations, naively we just put in heat; we didn't worry about how the heat got from the heater into the rock."

How brine and gases move through salt

During the BATS experiment's second phase, the team drilled two sets of 14 horizontal holes into the side of a hall and inserted more than 100 different sensors into the holes around the central horizontal hole containing the heater. These sensors monitored the sounds, strains, humidities, and temperatures as the salt was heated and cooled.

Melissa Mills, a Sandia geochemist, made a special salt-concrete seal for testing the interactions between cement and brine.

Among the sensors used were almost 100 temperature sensors, like those found in home thermostats, so researchers could measure temperature through time at locations around the heater. Yuxin Wu, a geoscientist from Lawrence Berkeley National Laboratory, also installed fiber-optic temperature sensors, strain gauges, and electrical resistivity imaging.

Kuhlman, front, and Thom Rahn, a Los Alamos National Laboratory scientist, carefully extract a sample of brine from one of the WIPP boreholes.

Charles Choens, a Sandia geoscientist, used special microphones, called acoustic-emissions sensors, to listen to the "pop" of salt crystals as they expand while heated and contract while cooling, Kuhlman said. The team used these microphones to triangulate the location of the popping salt crystals.

"Those pops are evidence of the transient permeability of the salt bed—the cracks between the salt crystals, which brine can percolate through." Kuhlman said. "When you heat it up, it closes those little cracks. When the salt is hot, the permeability goes down, but when it cools down, the cracks temporarily open up and the permeability increases."

To test the flow of gases through the damaged salt, the researchers injected small amounts of rare gases, such as krypton and sulfur hexafluoride, into one borehole and monitored their emergence in another, Kuhlman said. "When the salt was hot, the gases didn't go anywhere. When we turned the heat off, the gases permeated the salt and came out in another borehole."

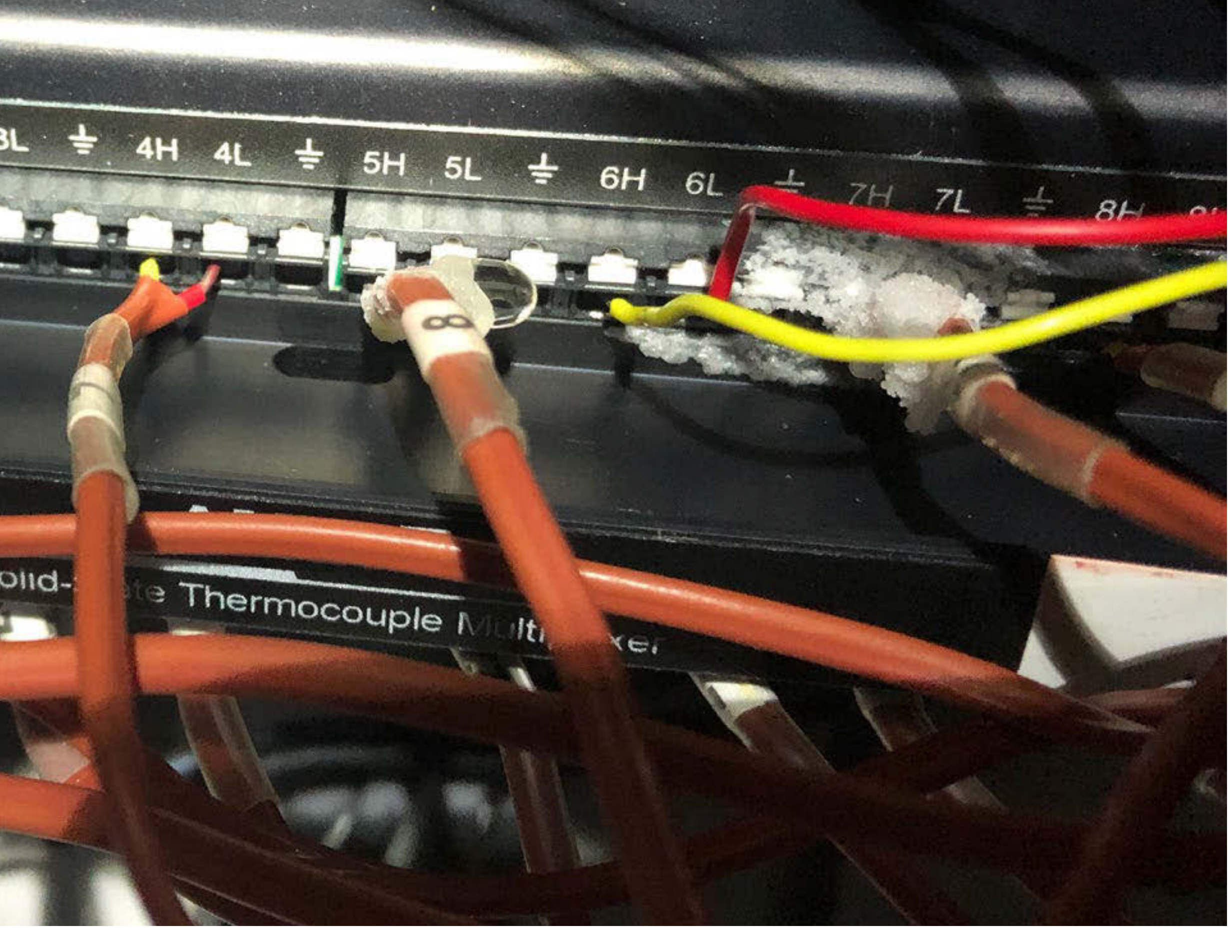
Similarly, the team injected lab-made brine into one borehole with a small amount of the element rhenium and fluorescent blue dye as "tracers." The team was monitoring for the emergence of the liquid in other boreholes, which would be sampled at the end of the test.

"The goal with the fluorescent dye—once we drill out post-test samples—is to map where the tracer went," Mills said. "Obviously, we'll be able to say that it went from one borehole to the other, if we detect a rhenium signal, but we won't know the path it took. Also, brine will interact with minerals in the salt, like clay. The fluorescent dye is a visible way to identify where the liquid tracer actually went in the field."

In the third phase, which began in mid-October, the team drilled a new array of nine heated boreholes, building on what they learned in the prior phases of the experiments.

"MANY THINGS CAN GO WRONG WHEN YOU TAKE SENSITIVE LAB EQUIPMENT AND PUT IT IN A SALT MINE."

-Kristopher Kuhlman



An example of corroded electronic equipment from brine seeping down an insulated wire. The pervasive nature of brine in WIPP was just one of the challenges the research team overcame during the first two phases of the BATS experiment.

Working in challenging conditions underground

The team has learned a lot from the first two phases of the BATS experiment, including the best heater type, when to drill the boreholes, and just how corrosive the brine is, Stauffer and Mills said.

"The first two phases involved a lot of equipment testing; some has failed, and some was sent back to the manufacturer," Mills said. "We've also learned to keep backup equipment on hand because salt dust and brine destroys equipment. We need to double-seal things because the brine can seep down insulated wire, and then equipment dies. It's been a process to learn how to work in the salt environment."

Kuhlman agreed. "Many things can go wrong when you take sensitive lab equipment and put it in a salt mine. We went back and read the reports from the WIPP experiments in the 1980s. We want to learn from the past, but sometimes we have had to make our own mistakes."

Through the DECOVALEX (DEvelopment of COupled models and their VALidation against Experiments) (decovalex.org) project, the researchers are collaborating with international partners to use the data from the BATS project to improve computer models of the complex chemical, temperature, water-based, and physical interactions that take place underground. This will improve future modeling of nuclear waste repositories globally.

Ultimately, the team would like to scale up to larger and longer experiments to obtain data relevant to future salt repositories, said Kuhlman and Stauffer. These data, supplementing already collected data, would inform repository designers and policymakers about the safety of permanently disposing heat-generating nuclear waste in salt repositories.

"It's been really intriguing and interesting, for me, to work on a project that is so hands-on," Mills said. "Getting to design and build the systems and going underground into WIPP has been really rewarding. Doing research in an active mine environment can be a challenge, but I've been proud to work down there and implement our ideas."

Mollie Rappe is a science writer at Sandia National Laboratories.

From Canada with Love: Repatriating HEU to the U.S.

As part of a nonproliferation agreement, Canada and the U.S. undertook a multi-year campaign to ship liquid high-enriched uranium material from Chalk River to Savannah River.

BY GLEN JACKSON AND JEFFREY GALAN

State troopers and first responders at a TRM roadshow stop in Virginia. The display LWT cask can be seen at the far right in its shipping container. (Photos courtesy of DOE/NNSA)

Canada's Chalk River Laboratories. (Photo: Wikimedia Commons/Padraic Ryan)

In March 2012, during the Nuclear Security Summit in Seoul, South Korea, the governments of Canada and the United States committed to work cooperatively to repatriate approximately 6,000 gallons of high-enriched uranyl nitrate liquid (HEUNL) target residue material (TRM) stored at the Chalk River Laboratories in Ontario to the U.S. Department of Energy's Savannah River Site in South Carolina. The announcement was part of a larger agreement between the two countries to reduce proliferation risks by consolidating high-enriched uranium at a smaller number of secure locations.

The TRM, which was the by-product of medical radioisotope production at Chalk River, was shipped to Savannah River's H-Canyon to be separated. Involving numerous government agencies, local governments, a tribal nation, contractors, and other stakeholders, the TRM shipping campaign took extensive coordination and planning. By the time the campaign was completed in January 2021, Atomic Energy of Canada Limited (AECL) had safely conducted 115 individual truck shipments of TRM covering approximately 150,000 highway miles.

The H-Canyon at the Savannah River Site in South Carolina. (Photo: DOE-SRS)

Molybdenum-99 production

In the 1950s, molybdenum-99 was identified as a potentially useful medical radioisotope, as its decay product, technetium-99m, is a pure gamma emitter with a 6-hour half-life, making it ideal for diagnostic medical imaging. Tc-99m is used in approximately 80 percent of all nuclear medicine diagnostic procedures and in roughly 40,000 diagnostic and therapeutic nuclear medicine procedures performed daily in the United States, including diagnosis of heart disease, treatment of cancer, and study of organ structure and function. The short half-life, however, makes the distribution of the substance very challenging and means that it must be produced continuously to meet the medical community's needs.

In 1957, what is now Canadian Nuclear Laboratories (CNL) began using the National Research Universal (NRU) reactor at the Chalk River site to produce Mo-99—it was the first reactor able to commercially produce medical isotopes. The U.S. sent HEU fuel elements and targets to Canada for use in the production of medical isotopes. Until October 2016, CNL was one of the world's largest producers of medical isotopes used in the diagnosis and treatment of cancer and other serious diseases, producing approximately 60 percent (and at times 100 percent) of U.S. demand for Mo-99, as well as other isotopes such as iodine-131 and xenon-133.

The HEU targets were irradiated for approximately seven days in the reactors and then dissolved in a nitric acid

solution in order to separate out the Mo-99. CNL then transferred the HEUNL TRM—what was left after the Mo-99 was separated by dissolution—to a double-walled stainless steel vessel known as the fissile solution storage tank (FISST) at Chalk River. At the end of Mo-99 production, approximately 6,000 gallons of TRM were being stored in the FISST.

A plan to repatriate

The campaign to ship the TRM to SRS was part of the U.S.-Origin Nuclear Material Removal Program conducted by the DOE National Nuclear Security Administration's Office of Material Management and Minimization. That office works with civilian nuclear facilities around the world to remove or confirm the disposition of excess HEU and plutonium to ensure it does not fall into the hands of terrorists or other malevolent actors. Eliminating this material, kilogram by kilogram, that much further reduces the risk of such bad actors acquiring material for use in an improvised nuclear device, thereby achieving permanent threat reduction.

At CNL, the operational demands associated with maintaining isotope production, combined with constrained shielded facility capabilities, precluded the conversion of the TRM to a standard solid form (e.g., calcine). This necessitated the transport of the TRM in liquid form.

In 2008, AECL expressed interest in transporting this material to SRS for disposition. SRS staff conducted an engineering study that determined the site would need to develop a capability to remove the HEU liquid from the shipping cask and transfer it to H-Canyon.

Discussions then began between AECL and the DOE/NNSA. AECL would be responsible for transport activities from Chalk River to SRS, and the DOE/NNSA would be responsible for coordinating with organizations and states along the route in the United States. A contract was signed on September 28, 2012, detailing the plan.

The material would be transported by truck, and each shipment was planned to include two casks. Based on optimistic projections at that time, a total of 88 casks would be needed to make 44 shipments, and it was expected to take a year or less to complete all shipments.

Top: A cutaway view of a LAC-LWT Type B cask showing how the four 15-gallon canisters fit inside the cask.

Bottom: The completed TRM canisters. The white strips are plastic slides designed to allow the canister to easily slide in and out of the LWT cask.

HEUNL canisters

Transporting liquid HEUNL material presented numerous first-time technical and regulatory challenges. To ship the material, AECL contracted with NAC International to design and license a canister to fit inside the company's NAC-LWT Type B package (LWT) for transporting the TRM directly to H-Canyon.

The LWT cask is a lead-lined package with a cylindrical cavity designed to enable the shipment of HEU and various types of spent nuclear fuel by reconfiguring the internal components (baskets) that secure the shipped material within the cavity. For the TRM project, several designs were developed for the inner canister, with the final design consisting of four self-contained canisters placed in the LWT.

Continued

To handle the loading of the HEUNL at CNL and the unloading at SRS, both CNL and SRS had to design, fabricate, and install specialized equipment and processes. Transfer hoses and fittings for all the equipment designed for use in Canada also had to work at SRS. To ensure this interoperability of processes and equipment for loading and unloading, engineers from Savannah River National Laboratory worked in conjunction with CNL engineers to design the withdrawal and transfer systems, as well as the transfer system and processing equipment that would be used during the unloading operation at H-Canyon.

Challenges in Canada included determining how to remove the material from the FISST and safely transfer it to the canisters (while accurately measuring what had been transferred for material control and accountability purposes) and loading the filled canisters into the LWT. Challenges at SRS included determining how to safely remove the canisters from the LWT and then fully emptying the HEUNL from the canisters while, again, accurately measuring volume.

NEPA review

The National Environmental Policy Act (NEPA) requires U.S. federal agencies to assess the environmental effects of their proposed actions prior to making decisions. A comprehensive environmental impact statement (EIS), completed in 1996, addressed the DOE's decision to accept and manage foreign research reactor spent fuel, as well as certain target material. A NEPA supplemental analysis, completed in 2015, specifically evaluated the transportation of the TRM material from Canada to SRS.

In an effort to halt the TRM shipments, several U.S.-based environmental interest groups filed suit in federal court against the DOE/NNSA on August 12, 2016. The plaintiffs alleged that the DOE/NNSA violated NEPA by not preparing a new or adequately supplemental EIS prior to the planned transportation. The DOE/NNSA negotiated an accelerated path for resolution of this case by voluntarily refraining from undertaking any TRM shipments until the case was decided.

On February 2, 2017, the court ruled in favor of the DOE/NNSA, concluding that the government met its NEPA obligations, and an order was issued dismissing the plaintiffs' case. The DOE/NNSA then began the TRM transportation campaign, with the first shipment conducted on April 15, 2017.

Transportation planning

To conduct the campaign, the DOE/NNSA closely coordinated with its Canadian partners, the shipping contractor, a tribal nation, and multiple U.S. federal and state agencies—including the Department of Homeland Security and the Federal Bureau of Investigation—to ensure that the material would be transported safely and securely. The DOE/NNSA also provided specialized training free of charge to prepare emergency responders for any potential transportation accidents involving radioactive material.

While the DOE/NNSA is not a Nuclear Regulatory Commission licensee and therefore not subject to enforcement actions, the decision was made to conduct all DOE Foreign Research Reactor Spent Nuclear Fuel Acceptance Program shipments in compliance with NRC regulations. The DOE/NNSA, through its management directives, orders, and contractual agreements, ensured the protection of public health and safety by imposing on its transportation activities standards equivalent to those of the NRC.

All TRM shipments complied with NRC regulatory requirements for the specific highway routing that each shipment had to follow. Each chosen route was reviewed and approved by the NRC to ensure it met applicable security and safeguards requirements, and all information regarding shipping dates, times, and routes was secured and managed according to NRC "information safeguards" regulations.

Transportation coordination

To ensure the successful, safe, and efficient transportation of the TRM by truck, a transportation plan was developed that identified the necessary responsibilities, requirements and procedures, transportation activities, organizational responsibilities, and emergency preparedness guidelines, as well as other methods for achieving safe transport. This plan was prepared under the direction of the DOE/NNSA in cooperation with the states and tribe along the route, along with the Southern States Energy Board, the Council of State Governments Northeastern Office, and the transportation contractor and commercial carrier.

Numerous federal, state, tribal, and commercial entities were involved in the supporting the TRM shipping campaign. Primary among them were the following:

- **DOE/NNSA:** Had overall responsibility for the TRM shipping campaign in the United States.
- **AECL:** Had overall responsibility for the TRM shipping campaign in Canada.
- **Secured Transportation Services (STS):** Had

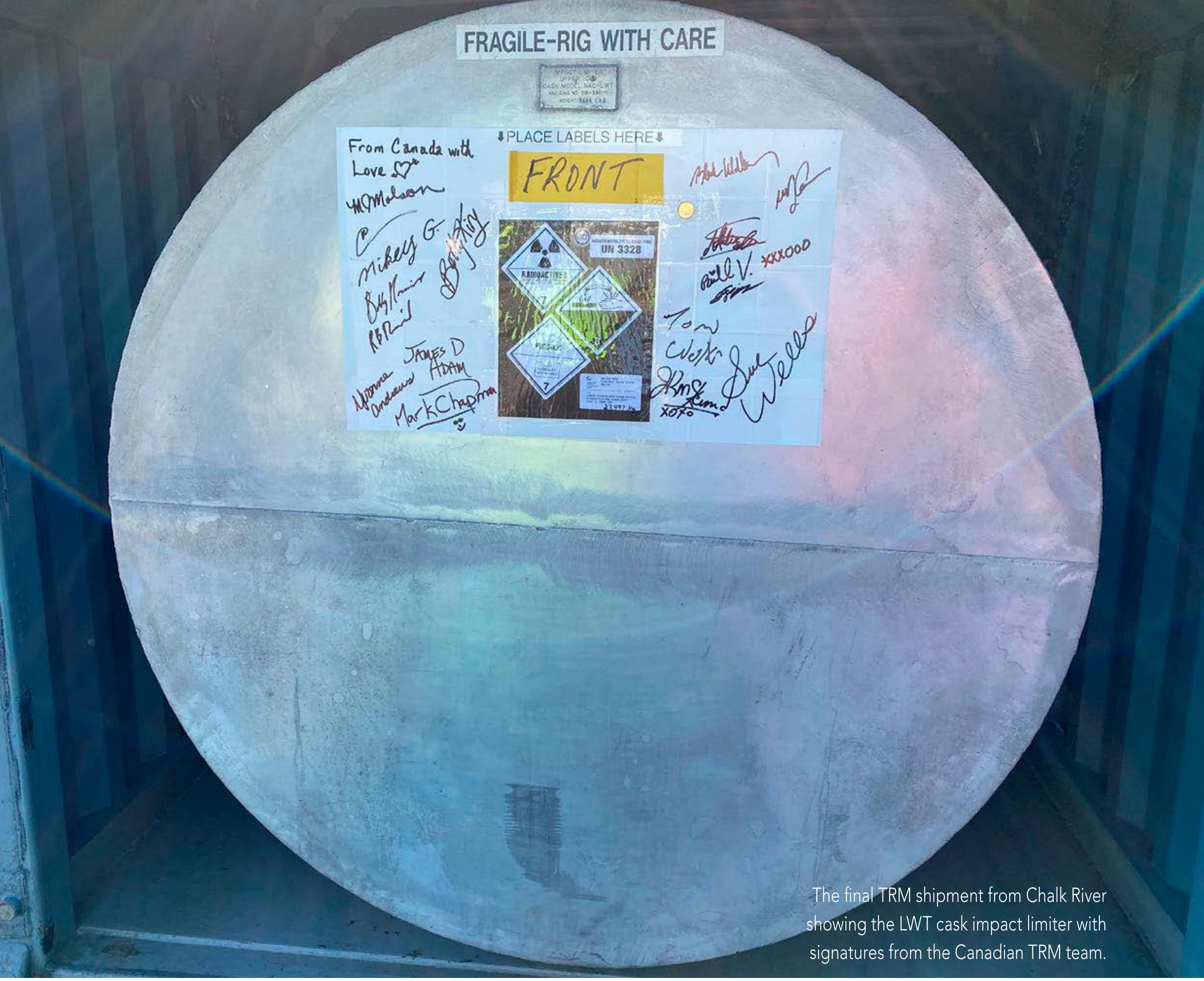
A loaded TRM shipment ready for transport to Savannah River.

responsibility for overall management of transportation in Canada and the United States.

- **Corridor states/tribe:** Had responsibility for providing security escorts, establishing procedures, and providing personnel and equipment to take charge of emergency situations if necessary. This included the Seneca Nation of Indians, along with the states of New York, Pennsylvania, West Virginia, Virginia, Maryland, North Carolina, South Carolina, and Georgia.
- **FBI:** Provided threat assessments and coordinated with each state's fusion center regarding overall security planning.
- **Savannah River Nuclear Solutions:** Established an integrated baseline planning schedule and provided logistical and administrative support to implement the TRM shipping campaign. Took responsibility for the TRM upon arrival at SRS.
- **CNL:** Prepared all TRM shipments for departure in Canada.
- **Commercial motor carrier:** Had responsibility for safely transporting the TRM from Canada to SRS and returning empty transport packages to the vendor or Chalk River.
- **NRC:** Approved the U.S. ports of entry and certified the routes of movement plans submitted by STS.
- **TRANSCOM:** The DOE's unclassified Transportation and Communications Tracking System, was used to monitor the progress of the TRM shipments. TRANSCOM utilized onboard satellite GPS to track the truck shipments as they made their way from Chalk River to SRS.
- **Transportation Emergency Preparedness Program (TEPP):** DOE-wide program that integrated the transportation emergency preparedness activities under a single program to address the emergency response concerns of state, tribal, and local officials affected by the shipments.
- **Commercial Vehicle Safety Alliance (CVSA):** All equipment and drivers used to transport TRM received a Level VI inspection per the Enhanced North American Inspection Standards of the CVSA at Chalk River before the start of every shipment and prior to departure from the U.S. port of entry. Each state a shipment passed through had the option to conduct their own CVSA Level VI inspection. Several states did exercise this option at the beginning of the shipping campaign, until they gained confidence in the Level VI inspections that were conducted before a shipment left the U.S. port of entry.

TRM ROADSHOW

The TRM campaign was the first time irradiated HEUNL would be shipped internationally into the United States. Most jurisdictions had little experience in providing security escorts and responding to highway incidents involving radioactive materials in large quantities. To inform and educate local community first responders, state agency points of contact, and tribal representatives,



The final TRM shipment from Chalk River showing the LWT cask impact limiter with signatures from the Canadian TRM team.

the NNSA, AECL, CNL, NAC International, and STS teamed up to conduct "TRM roadshows" with these stakeholders.

Each TRM roadshow consisted of a static display of an actual NAC-LWT cask, TRM canisters, and the transport truck at the stakeholder's locations. The roadshow gave stakeholders the opportunity to examine all the safety measures that would be in place during the transport of the TRM through their areas and aimed to give them an understanding of the makeup of the HEUNL. Over the course of two weeks, more than a dozen roadshows were conducted along the two interstate highway routes.

Prior to the commencement of TRM shipments, the DOE/NNSA reached out to the tribal nations along the U.S. transportation corridors and conducted in-person briefings with tribal leaders, including conducting TRM roadshow events. In addition, the DOE/NNSA complied with the NRC rule "Advance Notification to Native American Tribes of Transportation of Certain Types of Nuclear Waste." The DOE/NNSA also used the National Transportation Stakeholders Forum to meet with the tribal partners to share information about the TRM campaigns and extended the free TEPP training along the highway routes to interested tribes.

The DOE/NNSA provided free specialized TEPP training courses for emergency responders along the two highway routes for many years, even though the probability of an event was extremely low. A component of TEPP, the Modular Emergency Response Radiological Transportation Training, provided first responders with training on the how to properly respond to a radiological incident. Over the course of the campaign, the DOE/NNSA conducted more than 100 training classes in seven states, attended by more than 2,000 participants.

Conducting the Shipments

The TRM campaign began in April 2017 and made quick progress, with 17 shipments completed in the first five months. A core team of shipment planners conducted weekly calls to discuss near-term shipments and long-term plans for the campaign. The TRM campaign was undertaken concurrently with a spent nuclear fuel shipment campaign from the NRU and National Research Experimental (NRU/NRX) reactors, also located at Chalk River. The NRU/NRX and TRM campaigns used the same cask, trucks, and highway routes and were often conducted as joint shipments, moving two casks at a time. This streamlined the campaigns and limited the impact on the corridor states and tribe.

Every shipment was tracked on the DOE's TRANSCOM system, and the team provided regular updates to the various security and programmatic organizations actively following its progress. Once a shipment arrived at SRS, the full cask was off-loaded and an empty cask was placed back on the truck for the return trip to Canada.

The four-year shipping campaign involved 115 separate truck shipments and covered approximately 150,000 miles, equal to traveling around the earth six times. In the end, the TRM removal team successfully completed all shipments without incident, despite loading, unloading, and shipping material year-round in all weather conditions, from freezing Canadian winters to broiling southern U.S. summers. More than 161 kilograms (354 pounds) of HEU were returned during this multi-year campaign, which marked another important step in the global effort to minimize the civilian use of HEU. ⌘

Glen Jackson is an engineer with the Nuclear Materials Programs at Savannah River National Laboratory, and Jeffrey Galan is program manager for the National Nuclear Security Administration Office of Nuclear Material Removal.

This article is based on a paper presented at the 2021 INMM & ESARDA Joint Annual Meeting, held online August 23–26.

RADIOLOGICAL WASTE TRANSPORTATION & DISPOSAL

A Decommissioning Manager's Perspective

By Andy Lombardo

Waste packages are loaded with contaminated soil during remediation work at Lawrence Berkeley National Laboratory. (Photo: PermaFix)

Depending on the size and complexity of a decommissioning project, the transportation and disposal of radioactive waste will have an oversized impact on planning, schedule, and budget. The scope of decommissioning a site contaminated with radioactive material begins and ends with the proper and safe packaging of waste and subsequent transportation from the site to the final disposal location.

Once all of the waste is gone from the site, the compliance exercise can be completed and the site released from controls (i.e., the radioactive materials license is terminated and the site is decommissioned).

Having managed multiple decommissioning projects, including both open-land areas and structures, I have learned that the number one lesson is to plan work "in reverse," that is, from the end point of off-site disposal of all waste streams generated during decommissioning, to the beginning of deconstruction and decontamination efforts—specifically to avoid delays in schedule, rework, and unplanned costs.

Planning should start with the identification of waste streams, followed by the identification of corresponding disposal options. The waste acceptance criteria and packaging requirements for receiving the waste at identified disposal facilities can then be considered and used to plan deconstruction and decontamination of the site.

Planning for transportation of the packaged waste streams is next and results in the planning of on-site resources (rail spur, truck haul routes, cranes, and other equipment for loading, storage areas, facilities for waste, etc.) and off-site resources, including the limitations of the transporter and processing/disposal facility for the receipt of waste. Planning in reverse will help prevent potential bottlenecks in work flow resulting from waste accumulating on the site because it is not in the appropriate form, size, and/or package for transportation and off-site disposal.

Waste classification and disposal

The planning of a decommissioning project is captured, reviewed, and approved within the overarching decommissioning plan (DP). The Nuclear Regulatory Commission's NUREG-1757, *Consolidated Decommissioning Guidance*, Volume 1, *Decommissioning Process for Materials Licensees*, provides guidance on appropriate content for the DP and includes a prescribed section on waste. The NUREG guidance provided is for solid, liquid, and mixed radioactive waste. For solid waste, the following information is recommended for inclusion in the DP and subsequently in the project work plans:

Radiation control technicians analyze samples in a mobile radiation lab during cleanup work at the West Valley site. (Photo: DOE-WVDP)

A long-reach fork truck loads waste packages onto a flatbed truck for removal from the West Valley Demonstration Project cleanup site. (Photo: DOE-WVDP)

- A summary of the types of solid radioactive waste that are expected to be generated during decommissioning operations, including, but not limited to, soil, structural and component metal, concrete, activated components, contaminated piping, wood, and plastic.
- A summary of the estimated volume, in cubic feet, of each solid radioactive waste type summarized in the above bullet point.
- A summary of the radionuclides (including the estimated activity of each radionuclide) in each estimated solid radioactive waste type summarized under bullet No. 1.
- A summary of the volumes of Class A, B, C, and greater-than-Class C solid radioactive waste that will be generated by decommissioning operations.
- A description of how and where each of the solid radioactive wastes summarized under bullet No. 1 will be stored on-site prior to shipment for disposal.
- A description of how each of the solid radioactive wastes summarized under the bullet No. 1 will be treated and packaged to meet disposal-site acceptance criteria prior to shipment for disposal.
- If appropriate, a description of how the licensee intends to manage volumetrically contaminated material.
- A description of how the licensee will prevent contaminated soil or other loose solid radioactive waste from being redispersed after exhumation and collection.
- The name and location of the disposal facility that the licensee intends to use for each solid radioactive waste type summarized under bullet No. 1.

Similar information is required for liquid waste streams. And for mixed waste, in addition to the information requested above, the following should be included in the DP:

- A discussion of the requirements of all other regulatory agencies having jurisdiction over the mixed waste.
- A demonstration that the licensee possesses the appropriate permits from the Environmental Protection Agency and/or state to generate, store, and/or treat the mixed wastes.

A key step in decommissioning planning, specifically for anticipating transportation and disposal requirements, is characterization of all waste streams. The first step is an extensive review and analysis of all existing site data. In addition to the obvious waste characterization sample and analyses data, there are other sources of historical data that may help appropriate planning.

Survey data can be used to identify potential waste. Process data may shed light on potential mixed waste streams (e.g., where hazardous constituents were routinely used). Groundwater monitoring data is a good source for identifying both potential soil and water waste. Effluent discharge data can identify other potential contamination pathways. Historical data and walk-downs of the site may identify asbestos-bearing materials from old construction and a litany of other historically used hazardous constituents, such as lead-based paints. The overall review of existing data will identify data needs, and appropriate characterization surveys, sample, and analysis can be designed and implemented to fill in data gaps.

A building at Lawrence Berkeley's Old Town is taken down. Care is taken that waste streams are not unintentionally comingled during demolition work. (Photo: PermaFix)

Waste packaging and transportation

Once all the potential waste streams are compiled and appropriate disposal facilities for each have been identified, planning on how each waste stream is to be packaged for transportation from the site to the disposal facility can begin. Package requirements should consider all of the following factors:

- Disposal facility receiving requirements
- Transportation method (truck, railcar, boxcar, gondola car, etc.) requirements
- On-site storage requirements
- Loading for shipment off-site requirements
- Waste stream-driven requirements (e.g., acids and bases)
- Criticality safety requirements
- Shielding requirements
- Weight limits
- Size limits
- Time (i.e., shelf-life requirements)
- Equipment for loading packages

Lessons learned and good practices

Experience is the best teacher! After 40 years in the nuclear services business, the last 20-plus years managing decommissioning efforts, many missteps have occurred and lessons have been learned. Here are some missteps to avoid by proper planning of transportation and disposal.

1. Don't create an unexpected waste stream. This can easily happen during decontamination and/or deconstruction when waste streams are comingled unintentionally or unknowingly. The costliest of these is when a hazardous waste stream is mixed with a rad-only waste stream, driving the cost of transportation and disposal up by a factor of two or more, sometimes as high as a factor of 10.

2. Don't package waste in bags or other containers with a shelf life shorter than the wait time to be shipped off-site. Repackaging costs and lost schedule will result.

3. Understand completely the waste acceptance criteria for the disposal facility being used. Nothing hurts more than shipments rejected at the disposal site. Surcharges for acceptance and/or the cost to ship back to the site can quickly break the project budget.

4. Understanding the waste acceptance criteria can lead to efficiencies and cost savings. For example, when using large containers such as gondola cars, physical types of waste with the same classification can be mixed (e.g., soil and construction debris). Creative loading can maximize the weight of each container, whereas poor planning can minimize the weight and result in additional shipments.

5. On-site blending to meet the radionuclide concentration limits of the waste acceptance criteria may be allowed with prior approval by the regulator(s). The savings can be significant for large volumes of waste blended to meet a lower-cost waste classification. On-site blending plans can be developed to ensure each package is maximized and other conditions of the shipment can be addressed during the process. For example, meeting the moisture content requirements by adding a drying agent to your waste (often the case for excavated soils) can be accomplished during the same process.

6. Designing a package specific to the waste shipment campaign can add value to the project. Having the right package can save time (schedule) and budget. Allowing lead time for the construction and delivery of custom packages and of off-the-shelf packages is critical to keeping the overall project on schedule.

7. Engineering the space and equipment needed for a successful shipping campaign is critical to both schedule and budget. Rail spurs, loading docks, truck routes including turnarounds, survey areas, lift areas, and package closure areas may all be critical elements of a cost-effective and efficient campaign.

8. Scheduling trucks, trains, cars, packages, and other elements needed for shipping is critical. Often, train routes and access are limiting and should be considered immediately if train transportation is part of the plan.

9. Weather can impact all aspects of the packaging, loading, and shipping of waste.

10. The availability of qualified waste certifiers and an experienced waste manager cannot be underestimated.

11. It is critical to coordinate waste shipping with the overall site decommissioning schedule to avoid bottlenecks. The critical steps and schedule may be driven by the availability of space on site for the temporary storage of waste, both before and after on-site packaging.

All these factors may be considered and incorporated into the DP, work plans, and procedures, and still unforeseen circumstances will likely arise during the project. Building contingency into your schedule, as well as into all the processes involved in transportation and disposal, is a necessary and important element of a successful decommissioning project. Now that you have all your waste streams identified and a good plan for packaging and transportation off-site, you can begin planning how to decontaminate and deconstruct your site. Good luck!

Andy Lombardo is executive vice president of Nuclear Services for PermaFix Environmental Services.

EDUCATION & OPPORTUNITY IN RADWASTE MANAGEMENT

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WM Symposia:

The best presentations/ papers of 2021

Hosted by Waste Management Symposia, the annual Waste Management Conference is widely regarded as the premier international conference on the management of radioactive material and related topics. After holding a fully online conference last year due to the COVID-19 health crisis, the 2022 WM Conference is once again being held in-person at the Phoenix Convention Center, where the conference has been held since it was relocated from Tucson, Ariz., in 2008.

The theme of this year's conference, being held March 6–10, is "Globally Focused, Innovated, Connected: WMS is Engaging the Future," with more than 600 presentations planned in over 160 sessions during the four and a half days. The United Kingdom is the conference's featured country, and Oak Ridge, Los Alamos, and Portsmouth/Paducah are the featured Department of Energy sites.

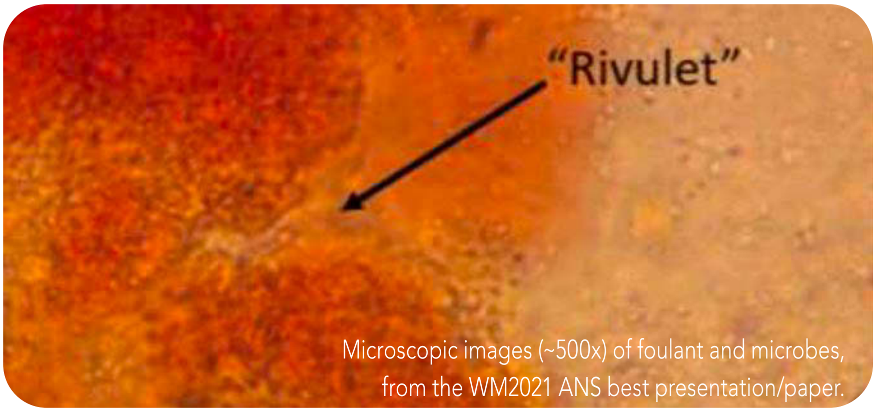
Each year, the two best oral presentations/papers from the previous year's conference are recognized. Honoring the highest-quality presentations, the American Nuclear Society and the American Society of Mechanical Engineers each present an award for best presentation/paper. The following are the abstracts for the best ANS and ASME papers of 2021. The full papers are available to 2022 WM Conference participants through the WM Symposia website, at wmsym.org.

Craig Piercy, ANS executive director and chief executive officer, virtually presents the ANS best paper award during last year's WM Conference, held online March 8–12, 2021.

Continued

Biofouling in a Chromium Plume-Control Interim Measure Extraction Well at Los Alamos National Laboratory

By Brinson Willis, Giday WoldeGabriel, Danny Katzman, and Paul Reimus (Los Alamos National Laboratory)



Microscopic images (~500x) of foulant and microbes, from the WM2021 ANS best presentation/paper.

Abstract

The discovery of elevated chromium in a part of the aquifer at Los Alamos National Laboratory in 2005 prompted an extensive characterization program and the design and implementation of an interim measure for control of the plume. Following a couple of years of operation, the treatment system influent filters began experiencing accelerated pressure increases and flowrate losses from the extraction wells system to the treatment system feed. While changeout of influent bag filters was found to reset the system's feed parameters, such action proved to be only a fleeting solution, as pressures and flows would again quickly deteriorate. The filter clogging complicated operations and added to operational downtime.

Subsequent investigation identified a new red gelatinous foulant to be accumulating and initially "masked" by other typical solids on the filters as being responsible for the clogging. This paper describes studies conducted to understand the nature and origins of the foulant from extraction well water. Foulant, solids, and water samples from different locations were analyzed using field and laboratory techniques. Early results helped confirm the foulant's origin as being exclusively from one of the plume extraction wells. Further testing, including optical and scanning electron microscopy, revealed compositional and morphological attributes that suggested the foulant was predominantly a biofilm rather than a chemical scalant or mineral precipitate. Additional results, including 16s rRNA sequencing, depicted different types of microbial populations and habitats across well locations. Data also supported hypotheses regarding a likely nexus between the extracted foulant well and injections of either organic tracers or an organic biostimulant into nearby wells, both of which could have potentially promoted biofilm growth. The investigation has supported planning of forthcoming well rehabilitations to improve operations and has offered insights into potential future engineering alternatives should fouling persist.

Problematic Waste: The Road to Implementing Improved Management Solutions, a U.K. Case History

ASME SETTING THE STANDARD

AWARD WINNER

By Mark Cowper, Marc Rigby, and Irina Tanase (Radioactive Waste Management Ltd.); Matthew Buckley (NDA); Helen Cassidy, Holly Cresswell, Tom Fletcher, and Oliver Steele (LLW Repository Ltd.); and Jenny Kent and Sally Scourfield (Galson Sciences Ltd.)

Abstract

"Problematic radioactive waste," in the nuclear industry in the United Kingdom, describes any waste for which no defined waste management route is either available or currently planned in detail, or for which the existing solution is suboptimal. These wastes are considered problematic by virtue of their physical, chemical, and/or radiological properties and are from across the radiological spectrum, including low-level waste and higher activity waste. Alternative names for problematic wastes include "challenging wastes," "orphan wastes," or "wastes requiring additional treatment." Examples of problematic waste in the U.K. include mercury and mercury-contaminated wastes, oils and oily sludges, tritiated wastes, and historically conditioned wastes that no longer comply with waste acceptance criteria for available disposal routes.

Integrated waste management is an increasingly important component of the Nuclear Decommissioning Authority's (NDA) strategy as outlined in a number of publications since 2016. These recognize the need to ensure that effective waste plans are being implemented across the NDA estate and that risks are managed and opportunities pursued at both site and estate level. NDA uses an integrated project team (IPT) approach that involves the formation of multidisciplinary teams that can span a range of organizations to solve industry or estate-wide challenges and allows NDA to provide leadership while leveraging skills, capabilities, and resources from their subsidiaries, site license companies (SLCs), and the supply chain. They have also developed a strategy management system (SMS) tool to develop, control, and communicate their strategy for decommissioning and cleaning up the U.K.'s civil public sector nuclear sites. It also provides the basis for periodic review of their Strategic Plan.

The Problematic Waste Integrated Project Team (PW IPT) was established in May 2016. Its overarching objective was to develop and communicate a coordinated and improved approach to the industry-wide management of problematic radioactive waste in the U.K. NDA published a Gate A SMS "credible options" paper in September 2016 that identified 12 high-level options to achieve this objective. These were unpacked into a list of over 100 opportunities for improved management of problematic waste, and 46 of these were shortlisted in a Gate B SMS "preferred options" paper submitted to NDA in March 2017.

In March 2020, the PW IPT completed a three-year program of work (known as the "tactical phase" of the IPT) to address 39 short-term opportunities. (Seven of the 46 opportunities in the Gate B list were not achievable within a three-year program.) These included developing a blueprint and benefits map for problematic waste management and creating a community of practice (CoP) made up of waste owners with declared inventories of problematic waste from across the whole of the U.K.'s nuclear industry (including organizations outside the NDA estate). The objectives of the CoP were to facilitate and participate in sustainable exchange of information, good practices, and learning from experience with problematic waste management.

In September 2019, the NDA published its Radioactive Waste Strategy, which recognized the work of the PW IPT and emphasized that problematic waste is a key area of investigation for waste treatment requirements. As a result, the lifetime of the PW IPT has been extended by a further three years to March 2023, with the focus now on "implementation," during which it aims to start treating problematic waste.

This paper gives an overview of the outcome of the PW IPT's tactical phase and the key challenges ahead as the PW IPT moves toward implementation.

Index to Advertisers

If your company is performing or seeking work related to the generation, handling, treatment, cleanup, transportation, storage or disposal of radioactive waste, *Radwaste Solutions* was created for you! For more than 25 years, this specialty magazine has been providing expanded coverage of decommissioning and environmental cleanup of the DOE EM Sites, as well as worldwide waste management activities.

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Business Developments

Terrestrial Energy and Australia's **ANSTO** have agreed to explore ANSTO Synroc (synthetic rock) waste treatment technology for spent fuel management. Under the agreement, ANSTO will provide technical consulting services to Terrestrial Energy for the conditioning of spent fuel from the operation of Terrestrial Energy's Integral Molten Salt Reactor heat and power plants in Canada, the United Kingdom, the United States, and other markets. ANSTO Synroc is based on crystalline or mineral phases that have survived in natural geological environments at elevated temperatures in the presence of water for hundreds of millions of years.

Cyclife, the EDF subsidiary in charge of international dismantling and radioactive waste management services, is pursuing its development in Europe by acquiring **Aquila Nuclear Engineering**, which provides turnkey solutions in the fields of containment, shielded installations, remote handling, and transport/packaging.

Orano has opened its $35 million Center for Innovation in Extractive Metallurgy (Centre d'Innovation en Métallurgie Extractive) at its Bessines-sur-Gartempe site in the New Aquitaine region of France. The new 27,000-square-foot research center will host pilot tests for Orano projects under development, such as the recycling and recovery of radioactive and nonradioactive materials.

WM Symposia has donated $4,000 for STEM educational materials to the **Blossom Center for Childhood Excellence**, located in Oak Ridge, Tenn. WMS has expanded its focus and contributions for STEM activities and students in the past three years because of the importance of developing and maintaining a pipeline that delivers the future workforce.

NAC International has received certification from the NRC for its OPTIMUS-L transport packaging. The OPTIMUS-L is designed to accommodate low-activity nuclear waste and fuel contents, such as low-level wastes, mixed wastes, contact-handled transuranic waste, lower activity intermediate-level waste, low-enriched uranium fuel materials, and other low-activity contents normally requiring shipment under Type A(F) or Type B packaging requirements.

Environmental Management

SNC-Lavalin's Atkins Nuclear Secured Holdings Corporation, in a joint venture partnership with **Westinghouse Government Services** and **Fluor Federal Services**, has been awarded a 14-month extension to continue operating the depleted uranium hexafluoride conversion facilities at the Department of Energy's Paducah Gaseous Diffusion Plant in Kentucky and the Portsmouth Gaseous Diffusion Plant in Ohio. The partnership will continue services to support the conversion project, valued at $153.5 million, which processes the DOE's inventory of depleted uranium hexafluoride into uranium oxides for disposition.

The Department of Energy has awarded a business management support services contract for its Office of Environmental Management (EM) to **BluePath Labs**, a service-disabled veteran–owned small business. The contract is valued at up to $4 million over three years. The work will be performed at EM's headquarters offices in Washington, D.C., and Germantown, Md.

The Department of Energy's Office of Environmental Management has awarded a cleanup contract to **North Wind Portage** for completion of environmental remediation of a uranium ore processing site near Moab, Utah. North Wind Portage is located in Idaho Falls, Idaho. The contract, which has a ceiling of approximately $614 million over a 10-year period and includes both cost reimbursement and fixed-price task orders, calls for the completion of excavation and disposal of all residual radioactive material, relocation of the estimated 16-million-ton pile of uranium mill tailings and other contaminated material,

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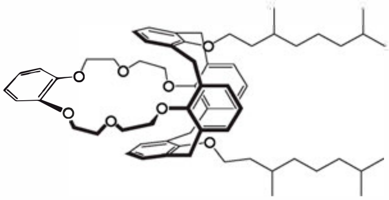

completion of disposal cell construction at nearby Crescent Junction, Utah, to include final cover, and restoration of the Moab site and Crescent Junction.

The Department of Energy's Office of Environmental Management has awarded a financial assistance grant to the **Ohio Environmental Protection Agency** for oversight and monitoring of the Portsmouth Gaseous Diffusion Plant Decontamination and Decommissioning Project, in Portsmouth, Ohio. With this award, the DOE is increasing the size of a grant, originally awarded in 2016, by $3.5 million, for a total of $7.5 million, to incorporate new air monitoring strategies that will support the Ohio EPA's and Ohio Department of Health's efforts in providing collocated monitoring and independent verification of the DOE's open-air demolition.

Savannah River Nuclear Solutions has given mini-grants totaling $25,000 to schools near the Savannah River Site in South Carolina to develop the site's employment pipeline by providing science, technology, engineering, and math classroom materials and equipment to area educators. Using the grants, teachers can purchase equipment, computer programs, hands-on kits, and other products to enhance their students' performance and STEM learning experience. For decades, SRNS has provided mini-grants to schools throughout the region. Over $700,000 has been contributed to date through the program.

International

Westinghouse Electric Company has signed a contract with **RWE Nuclear GmbH** to dismantle two reactors at the Gundremmingen nuclear power plant in Germany. The contract includes several scopes, including the dismantling and packaging of the reactor pressure vessels, reactor heads, reactor internals, storage racks, and adjacent concrete shielding structures.

Cavendish Nuclear has been awarded an approximately £20 million (about $27 million) contract that will provide the Dounreay site in Scotland with the capability to package solid intermediate-level waste. The contract is for the site's Drum Handling Facility. The scope covers detailed design, manufacture, installation, and inactive commissioning over a five-year time frame. The Drum Handling Facility will process and package a variety of waste streams into 500-liter drums, which will then be encapsulated before being placed in a shielded cask. The project is part of the Shaft and Silo program, which will provide Dounreay with the capability to retrieve, sort, process, and package waste for passive long-term storage.

The government of the United Kingdom on January 31 announced the launch of **Nuclear Waste Services**. The new organization brings together site operator Low Level Waste Repository Limited, geological disposal facility developer Radioactive Waste Management Limited, and the Nuclear Decommissioning Authority's Integrated Waste Management Program. According to the U.K. government, Nuclear Waste Services will maintain current commitments to the Low-Level Waste Repository in West Cumbria, the geological disposal facility program, and the communities involved with both, while also creating a business with the capability to manage U.K. nuclear waste "safely and securely for generations to come."

Nuclear Waste Solutions, a joint venture of **React Engineering** and **Shepley Engineers Limited**, announced in January that it has won a place on the four-year framework contract worth £7 million (about $9.5 million) with the Low Level Waste Repository Limited (LLWR). According to the company, the expert support and alternative treatment framework contract will provide LLWR and waste generators throughout the United Kingdom with a flexible, highly capable, efficient, and client-focused service offering.

Kudos

Petersen Inc. has been awarded a **2020–2021 Supply Chain Excellence Award** by Bechtel for its contributions to the Department of Energy's Hanford Vit Plant (Waste Treatment and Immobilization Plant) project. Companies were evaluated on multiple factors, including overall performance, ability to deliver quality services, and meeting or exceeding expectations of safety, performance, technical expertise, and environmental compliance. For the Vit project, Petersen built two 300-ton melters that will process a portion of the 56 million gallons of radioactive and chemical waste generated during the Manhattan Project and the Cold War. Designing and manufacturing the two melters included 1,200 engineering drawings, and fabrication took nearly three years to complete. A third melter is in fabrication as a spare. Petersen is currently manufacturing the stainless steel containers used to dispose of the waste.

Orano TLI was recognized in 2021 by U.S. regulators for "Excellence" in error-free reporting and tracking using the Nuclear Materials Management and Safeguards System, the government's digital system used to track movements, uses, and inventories of U.S. nuclear materials. During 2020, Orano TLI said it securely managed and handled more than 300 international and domestic transactions of nuclear materials, including several new and complicated shipments, without any reporting or tracking errors and in full compliance with regulatory standards.

BWX Technologies has named **Robb A. LeMasters** senior vice president and chief financial officer. He succeeds **David S. Black**, who is retiring after 30 years of service to BWXT but will remain with the company through April 1, 2022, working as a special advisor to Rex Geveden, president and chief executive officer. LeMasters was previously senior vice president and chief strategy officer for BWXT.

LeMasters

John Matthews has joined Deep Isolation as general counsel. He retired as a partner from Morgan Lewis's Energy Practice in 2020 to become a consultant, advising clients on commercial issues related to nuclear power plants and other nuclear assets, decommissioning, Nuclear Regulatory Commission license transfers, decommissioning trusts, security matters, and insurance and liability issues associated with the ownership and operation of nuclear assets. His other areas of expertise include foreign investment in U.S. nuclear assets, nuclear plant development, decommissioning funding, decommissioning trust funds, and sale leaseback arrangements involving nuclear facilities or nuclear fuel.

Matthews

BWX Technologies also promoted **Joey Hoskins** to the position of vice president of business development. Hoskins joined BWXT in 2007 and has held positions of increasing responsibility, including serving as a finance manager and a division controller before assuming his most recent role as business development director. Hoskins replaces **Mark Barth**, who is transitioning to a new role as the business manager for Savannah River Mission Completion, the new BWXT-led environmental management contractor for the Department of Energy's Savannah River Site Integrated Mission Completion Contract.

Barth

Paul Longsworth has been appointed president of Westinghouse Government Services (WGS). Longsworth joined WGS in June 2021, bringing more than 35 years of experience in nuclear energy, national security, and environmental industries. Previously, he served as vice president of secure services at Fluor and was the deputy administrator for defense nuclear nonproliferation at the Department of Energy. Longsworth succeeds **Bob Cochran**, who has retired.

Longsworth

Ronald K. Dailey has been named president of Nuclear Fuel Services in Erwin, Tenn. He succeeds **John A. Stewart**, who has moved into a senior leadership role with BWX Technology's Nuclear Services Group. Dailey leads a workforce of about 1,000 employees and contract security personnel in the manufacture of fuel material for naval nuclear reactors used in U.S. submarines and aircraft carriers, the downblending of Cold War–era government stockpiles of high-enriched uranium into material suitable for further processing into commercial nuclear reactor fuel, and ongoing preparations to provide uranium conversion and purification services for the National Nuclear Security Administration.

DOE

The Department of Energy's Office of Environmental Management has selected **Joel Bradburne** to serve as field manager of the Portsmouth/Paducah Project Office (PPPO) in Lexington, Ky. In this role, Bradburne will oversee the deactivation and demolition of the former gaseous diffusion facilities in Portsmouth, Ohio, and Paducah, Ky., and the Depleted Uranium Hexafluoride Conversion Project, which includes operations at both locations. Bradburne was named acting manager in July 2021. Prior to that, he served as PPPO deputy field manager.

Bradburne

Kathryn "Katy" Huff has been nominated by President Biden to head the Department of Energy's Office of Nuclear Energy as assistant secretary

Continued


Huff

of energy. The role has been vacant since Rita Baranwal left the position on January 8, 2021. Huff was named principal deputy assistant secretary of nuclear energy and acting assistant secretary of energy for nuclear energy in May 2021. A member of the American Nuclear Society since 2008, Huff was elected to the ANS Board of Directors in April 2021 but declined that position when she assumed her duties at the DOE.


Krohn

Jeff Krohn, Savannah River Nuclear Solutions (SRNS) chief information officer, has been recognized as a Government Hero of the Year in the Stevie Awards program's COVID-19 response category during the 18th annual International Business Awards program in December 2021. Krohn reprioritized and rallied for funds, equipment, and other resources required to adequately transition the SRNS workforce during the pandemic, while negotiating licensing terms, lease agreements, and other critical services. SRNS is a Department of Energy contractor at the Savannah River Site. The Stevie Awards recognize outstanding performances in the workplace worldwide.

NRC


Dorman

Daniel H. Dorman has been selected by the Nuclear Regulatory Commission as the agency's executive director for operations, the highest-ranking NRC career position. Dorman succeeds **Margaret M. Doane**, who left the agency to become deputy director general for management at the International Atomic Energy Agency. Dorman previously served as the deputy executive director for reactor and preparedness programs, which included oversight over all four

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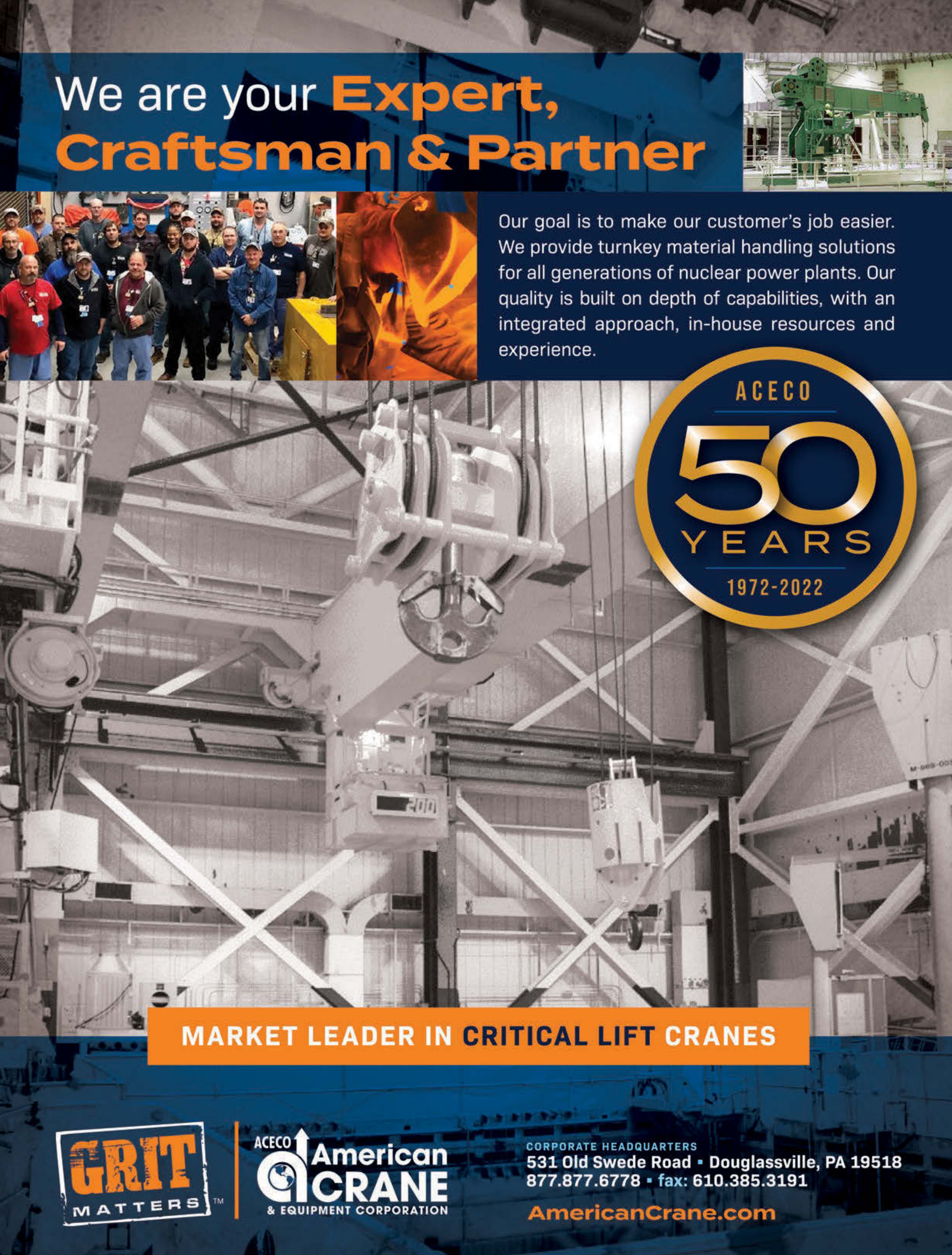

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NRC regional offices. He also previously served as the acting deputy executive director for materials, waste, research, state, tribal, compliance, administration, and human capital programs.

The Nuclear Regulatory Commission has named **Tracy Higgs** director of the Office of Investigations. She replaces **Edward Shuttleworth**, who has retired. Higgs joined the NRC in 2017 as an operations officer in the Office of Investigations, also serving as deputy director and assistant to the office director. Before joining the NRC, Higgs served in senior leadership roles with the U.S. Naval Criminal Investigative Service.


Higgs

The Nuclear Regulatory Commission has selected **Brooke Poole Clark** as the new secretary to the commission. She will replace **Annette Vietti-Cook**, who is retiring after nearly 40 years of service. Clark joined the NRC in 1998 and had a break in service from 2001 to 2004, when she worked as an associate attorney with the law firm of Winston & Strawn, before rejoining the NRC's Office of the General Counsel. Since then, her responsibilities have included various positions with the NRC.


Clark

Dave Pelton has been selected as the NRC's deputy regional administrator for the Nuclear Regulatory Commission's Region II office in Atlanta, Ga. Pelton will assist the regional administrator in providing executive leadership to staff overseeing 33 commercial nuclear power plants in seven southeastern states and all NRC-licensed nuclear fuel cycle facilities in


Pelton

the U.S. He succeeds **Joel Munday**, who has retired.

International

Adrienne Kelbie has been appointed to a three-year term as chair of the U.K. Nuclear Decommissioning Authority's new division, Nuclear Waste Services.


Kelbie

Kelbie was previously chief executive officer of the U.K.'s Office for Nuclear Regulation. The NDA is responsible for the management, decommissioning, and cleanup of 17 nuclear sites across the U.K. The new division merges two NDA subsidiaries, Low Level Waste Repository Limited and Radioactive Waste Management Limited, and oversees the NDA's Integrated Waste Management Program. Nuclear Waste Services will be led by chief executive officer **Corhyn Parr**, formerly the NDA's director of integrated waste.

Canada's Nuclear Waste Management Organization has announced two promotions within its executive team. **Derek Wilson**, formerly chief engineer and vice president of construction and projects, has been promoted to the newly created position of chief operating officer. **Chris Boyle**, former director of


Wilson


Boyle

engineering, will assume the role of vice president and chief engineer. NWMO is a not-for-profit organization implementing Canada's plan to contain and isolate spent fuel in a deep geological repository. ⌧

March

Mar. 6–10—**WM Symposia 2022**, Phoenix, Ariz. wmsym.org/

Mar. 22–24—**World Nuclear Fuel Cycle**, The Hague, Netherlands. wnfc-event.com/website/21771/home/

April

Apr. 4–8—**Sixth International Conference on Geological Repositories (ICGR): Advancing Geological Repositories from Concept to Operation**, Helsinki, Finland. oecd-nea.org/jcms/pl_31984/sixth-international-conference-on-geological-repositories-icgr-advancing-geological-repositories-from-concept-to-operation

Apr. 11–13—**2022 Council on Ionizing Radiation Measurements & Standards (CIRMS) Meeting**, virtual event. cirms.org/registration.html

Apr. 14–16—**2022 Student Conference**, Urbana, Ill. ans.org/meetings/student2022/

May

May 4–6—**4th International Symposium on Cement-Based Materials for Nuclear Wastes**, Avignon, France. new.sfen.org/evenement/nuwcem-2022/

May 9–13—**Tenth International Symposium on Naturally Occurring Radioactive Material**, Utrecht, Netherlands. iaea.org/events/evt2100681

June

June 5–8—**2022 Canadian Nuclear Society Annual Conference**, virtual event. cns-snc.ca/event/2022-cns-annual-conference/

June 6–7—**2022 Decommissioning Strategy Forum**, Summerlin, Nev. decommissioningstrategy.com/

June 8–10—**2022 RadWaste Summit**, Summerlin, Nev. radwastesummit.com/

June 12–16—**2022 ANS Annual Meeting**, Anaheim, Calif. ans.org/meetings/view-312/

June 12–16—**Advances in Thermal Hydraulics (ATH 2022)**, Anaheim, Calif. ans.org/meetings/view-312/

June 12–16—**Nuclear Criticality Safety Division Topical Meeting (NCSD 2022)**, Anaheim, Calif. ans.org/meetings/view-312/

June 12–16—**Technology of Fusion Energy (TOFE 2022)**, Anaheim, Calif. ans.org/meetings/view-312/

June 13–15—**Integrated Waste Management 2022**, Manchester, United Kingdom. nuclearinst.com/All-Nuclear-Events/Integrated-Waste-Management-2022---Shaping-our-Waste-Future/79979

June 13–16—**International Conference on Nuclear Knowledge Management and Human Resources Development: Challenges and Opportunities**, Moscow, Russian Federation. iaea.org/events/nkmhrd-2022

June 19–23—**11th International Conference on Isotopes**, Saskatoon, Canada. ans.org/meetings/view-362/

June 20–22—**Nuclear Energy Assembly**, Washington, D.C. nei.org/conferences/nuclear-energy-assembly

June 20–24—**International Conference on the Safety and Security of Radioactive Sources – Accomplishments and Future Endeavours**, Vienna, Austria. iaea.org/events/safety-security-radioactive-sources-2022

June 28–July 1—**2022 USA Nuclear Generator & Supplier Executive Summit**, Coeur d'Alene, Idaho. usainc.org/executive-summit/

July

July 6–8—**Global 2022**, Reims, France. new.sfen.org/evenement/global-2022

July 16–21—**67th Annual Health Physics Society Meeting**, Spokane, Wash. hps.org/meetings/meeting53.html

July 20—**DECOM2022**, Telford, Shropshire, United Kingdom. www.decom2022.com

July 24–28—**INMM 63rd Annual Meeting**, virtual event. inmm.org/mpage/INMM22

August

Aug. 1–3—**2022 Nuclear Information Management Conference**, Las Vegas, Nev. nirma.org/annual-conference/

Aug. 7–10—**Utility Working Conference and Vendor Technology Expo**, Marco Island, Fla. ans.org/meetings/view-352/

Aug. 8–12—**29th International Conference on Nuclear Engineering (ICONE 29)**, Shenzhen, China. event.asme.org/ICONE

Aug. 28–Sept. 1—**PATRAM 2022 (Packaging and Transportation of Radioactive Materials Symposium)**, Nice, France. patram.org/

September

Sept. 7–9—**World Nuclear Association Symposium 2022**, London, United Kingdom. wna-symposium.org/

Sept. 25–29—**14th International Conference on Radiation Shielding and 21st Topical Meeting of the Radiation Protection and Shielding Division**, Seattle, Wash. ans.org/meetings/icrs14rpsd21/


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