LWRS LIGHT WATER REACTOR SUSTAINABILITY

Issue 40
January 2025

Aligning Work Processes with Digital Technologies


Anna C. Hall **Jeffrey C. Joe**
Plant Modernization Pathway

Nuclear power plant owners are updating analog equipment with modern digital systems. Producing information from digital systems in an electronic format allows its use by the many work processes used by the plant. It opens up possibilities to enhance work efficiency by automating many time-consuming tasks.

Digitization creates opportunities to integrate plant information into daily operations. By exploiting newfound digital opportunities, work processes can be reimagined and business practices reshaped in a process known as digital transformation. Digital transformation helps keep nuclear power plants financially competitive.

Continued on next page

Table of Contents

U.S. DEPARTMENT OF ENERGY

Continued from previous page

With thousands of routine work processes performed every day, it can be difficult for plants to know where to begin.

Researchers from the Light Water Reactor Sustainability (LWRS) Program at Idaho National Laboratory (INL) are collaborating with nuclear power plant staff on digital transformation. The Digital Strategy project aims to maximize the value of digital upgrades to enhance the long-term sustainability of nuclear power plants.

The LWRS Program research team composed of human factors specialists and plant engineers have created a roadmap to support industry digital transformation initiatives (Figure 1). The roadmap reflects the project lifecycle in performing a digital upgrade beginning with guiding principles to the other steps needed to achieve success. The digital transformation guiding principles developed by the team that apply to all nuclear reactors are [1]:

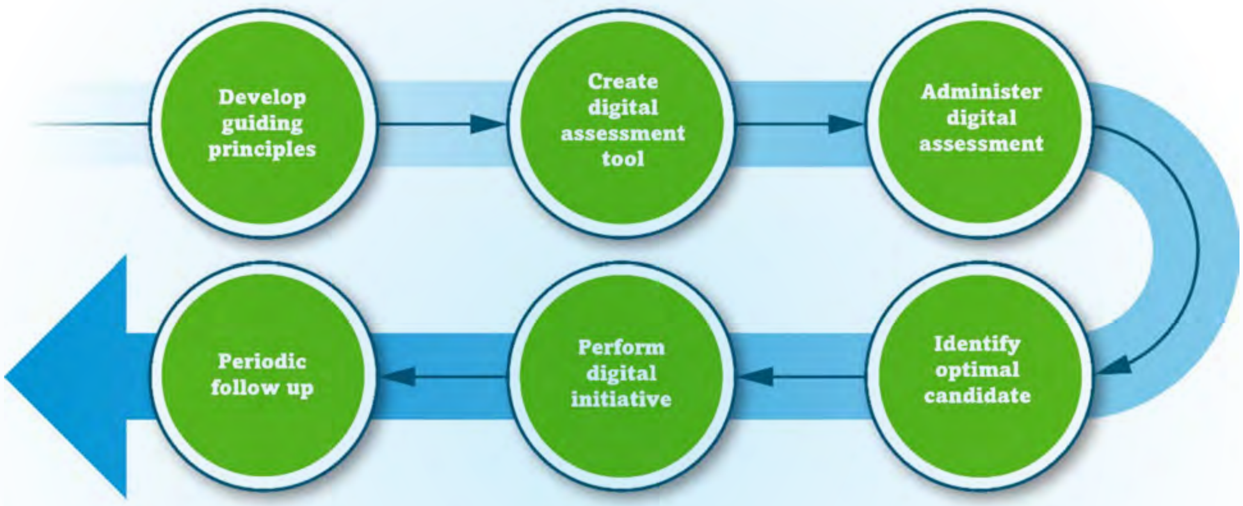


Figure 1. Digital Transformation Roadmap.

Principle #1: Develop a Digital Transformation Plan. Outline a vision and approach considering feasibility and any potential organizational barriers.

Principle #2: Apply Human Factors Engineering. Focus on user-centric design to enhance cooperation between humans and technology.

Principle #3: Establish Data Governance. Implement policies for managing and controlling data, ensuring accessibility, quality, security, and ownership.

Principle #4: Anticipate Unintended Consequences. Identify and mitigate unforeseen changes to improve overall human-system performance.

Different nuclear power plants are at different stages in their digitization journey. Therefore, it is important to determine a digital scope for a plant given its constraints, objectives, and capabilities. A new assessment tool was developed to measure seven health indicators for each work process, providing a quick digital status of a plant. This tool is very low-cost, easy to use, can be administered remotely, and is automatically tailored to each plant employee.

When tested with an industry partner, data from 167 nuclear power plant employees were collected and analyzed to find the best candidates for digital initiatives that offer the highest efficiency gains [2]. Processes were ranked to focus on those that combine significant time-savings with digital potential. Figure 2 shows processes categorized as "Do now," "Do next," "Do later," and "Do last."

The goal was to identify a maximum investment return to ensure cost-savings over time. For example, the top priority process identified, Action Items Tracking, could save the plant up to $2.8 million per year.

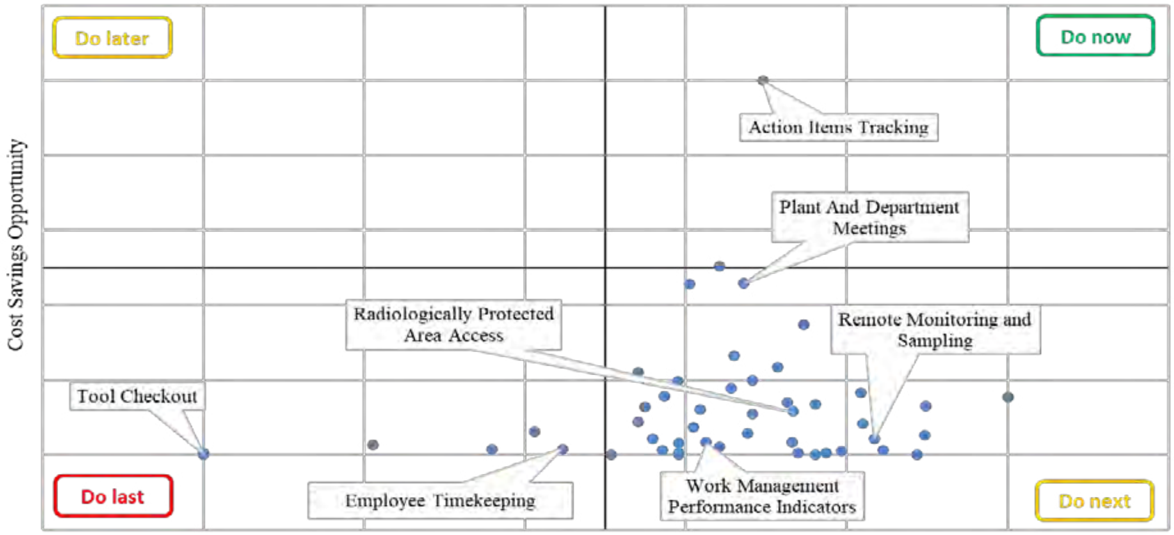


Figure 2. Digital transformation priority matrix.

The LWRS Program's Digital Strategy project helps stakeholders take stock of their digital capabilities, find a place to begin and understand the financial impact of digital initiatives when seeking technical approaches to automate and simplify work.

References

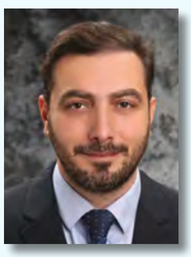
1. Hall, A., Miyake, T., Joe, J., Speilman, Z. and Oxstrand, J. (2023). Digitalization Guiding Principles and Method for Nuclear Industry Work Processes. INL/RPT-23-74429, Idaho National Laboratory, Idaho Falls, ID, USA.

2. Hall, A., Velazquez, M., Murray, P., Spangler, R., Speilman, Z., & Joe, J. (2024). Digitalization Mapping and Assessment Process Supporting ION Strategic Transformation Activities. INL/RPT-24-80099, Idaho National Laboratory, Idaho Falls, ID, USA.

Welcome Ahmad Al Rashdan as the Pathway Lead for the Plant Modernization Pathway

Dr. Ahmad Al Rashdan now leads the Plant Modernization Pathway in the Light Water Reactor Sustainability (LWRS) Program.

Ahmad brings a wealth of experience and expertise to this critical role, focusing on developing viable carbon-free energy solutions and modernizing the existing fleet of nuclear power plants. He holds a Ph.D. in Nuclear Engineering and has extensive experience in automation, instrumentation, and control systems. His impressive career spans over 18 years, including work at esteemed organizations such as Idaho National Laboratory, International Atomic Energy Agency, Asea Brown Boveri, and Texas A&M University.



Ahmad Al Rashdan

Ahmad is actively engaged with the scientific community, regularly participating in and co-organizing professional events and scientific conferences. He also holds leadership roles in numerous industry organizations, including the American Nuclear Society (ANS).

Ahmad 's dedication extends to international standards development. He serves on the American National Standards Institute (ANSI) United States National Committee Technical Advisory Group and participates in working groups developing International Electrotechnical Commission standards on artificial intelligence (AI) in the nuclear industry. Additionally, he leads the ANS AI for Nuclear Standards Committee.

With Help from Artificial Intelligence, Advanced X-Ray Technology Can Measure Aged Concrete's Strength




Amir Koushyar Ziabari **Amani Cheniour** **Yann Le Pape** **Elena Tajuelo Rodriguez**

Materials Research Pathway

Although, concrete is a tough substrate and can last many decades, it is still affected by radiation. Deep inside walls of a nuclear structure that may be as much as two meters thick, neutrons emitted by a nuclear reactor can disrupt the crystalline structure of the quartz and other minerals embedded in concrete. Gamma rays break up water molecules in the cement that binds everything together. LWRS Program researchers at Oak Ridge National Laboratory are researching ways to examine concrete using x-ray computed tomography (XCT) and then using artificial intelligence (AI) to interpret the results. An approach is being developed to study and assess the long-term performance of concrete in nuclear power plants.

In light water nuclear reactors, concrete structural integrity is essential to ensuring safety and longevity of key structural systems. Reactor vessels are placed on concrete cradles, and inlet and outlet piping often rest on steel saddles embedded in the concrete. Maintaining the plant's structural integrity during an earthquake or accident depends on the concrete being structurally sound, even after being barraged by radiation for decades.

When neutron radiation breaks the crystalline structure of the rocks in concrete, they expand in different directions, causing cracks and a weakening of the bond between the aggregate and the cement. This radiation-induced volumetric expansion varies with the mineral composition of the rocks. Modeling and simulation, together with experimental efforts, provide insights into the damage and expansion of concrete under irradiation, although the analysis may be simplified due to the complexity of the concrete's microstructure.

Recently, simulations have become more realistic through the use of high-resolution characterization. XCT, a non-destructive technique, offers detailed three-dimensional (3D) insights into the internal structure of the concrete samples. This overcomes some of the challenges posed by other characterization techniques that are mostly two-dimensional (2D) and can be destructive. However, XCT has its own limitations because in the images, the aggregates and cement paste do not look very different from each other. This poses challenges for effective image segmentation, a crucial step for making a mineral map of the concrete, and then creating an accurate 3D reconstruction of the microstructure. Traditional, unsupervised segmentation techniques often fall short in distinguishing among the phases present in the material in the concrete microstructure XCT images.

To overcome these challenges, the approach described in this article leverages a branch of AI [1] called U-Net deep-learning-based approach, which improves traditional segmentation. A 2.5D (restricted to a 2D plane with little to no access to 3D) U-Net model [2] was developed allowing for learning 3D features from multiple neighboring slices of a 3D XCT volume without the need to perform model training used with an expensive 3D model. During the test, the model analyzes a few slices of the sample in the perpendicular direction to perform segmentation for every single slice in the 3D volume. Such an approach allows for capturing the 3D information while not incurring the cost of training and testing using a fully 3D model.

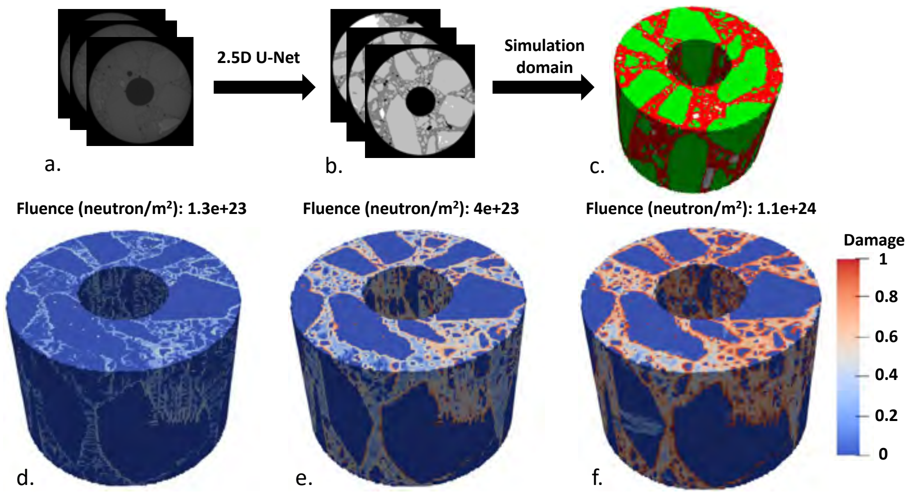


Figure 3. (a) Concrete microstructure XCT reconstruction slices. (b) Deep-learning-based segmentation of the XCT data in various phases. (c) 3D FEM volume. (d-f) Damage under various irradiation sources.

Using the 2.5D model, a computer can distinguish different phases of a material (in this case cement paste and aggregates) in a small set of annotated images (labeled images in a dataset), fewer than fifty, while AI takes over in analyzing the others. This method accurately analyzed hundreds of XCT data layers, with Ziabari's model achieving about 96% accuracy in distinguishing between the different phases of the concrete microstructure.

An example of XCT slices where the different components look very similar, and the corresponding deep-learning-based segmented microstructure, can be observed in Figure 3(a) and Figure 3(b), respectively. This accurate image segmentation facilitated a 3D representation, or digital twin (virtual representation of an object or system designed to accurately reflect a physical object), for concrete. Getting samples of irradiated concrete from an operating nuclear power plant is not always practical, but a computer model can estimate the amount of damage at various radiation levels. A digital twin can then be used to create a detailed 3D model which can be used to predict behavior of concrete. An example of simulated damage under various irradiation sources is shown in Figure 3(d–f). While promising, the results suggest the model may overestimate irradiation damage, which can be addressed by further characterization of the smaller aggregates and features that were not captured by the XCT, and integrating them into the modeling process.

In summary, an innovative approach was developed using AI and deep-learning (a method that teaches computers to process data in a way that is inspired by the human brain) for developing accurate predictive models for irradiation-induced damage in concrete, particularly within the context of major concrete structures in most plants. By enhancing the segmentation of XCT images and developing detailed 3D models, this research contributes significantly to the understanding of concrete behavior under irradiation, paving the way for more reliable evaluations of structural integrity in nuclear applications.

References

1. Ronneberger, O., P. Fischer, and T. Brox. (2015). "U-net: Convolutional networks for biomedical image segmentation." In: Navab, N., J. Hornegger, W. Wells, and A. Frangi (eds.), Medical Image Computing and Computer-Assisted Intervention (MICCAI) 2015. 5–9 October 2015, Munich, Germany. Lecture Notes in Computer Science, 9351, 234 241. Springer, Cham. https://doi.org/10.1007/978-3-319-24574-4_28.
2. Amani Cheniour, Amir Koushyar Ziabari, and Yann Le Pape. "A mesoscale 3D model of irradiated concrete informed via a 2.5 U-Net semantic segmentation." Construction and Building Materials 412 (2024): 134392. https://www.sciencedirect.com/science/article/abs/pii/S0950061823041107.

Determining How Fast an Adversary Can Get Through a Chain Link Fence

W. Gary Rivera
Physical Security Pathway

The fences surrounding nuclear power plants mark boundaries and help security personnel detect intruders and slow them down. But security managers may not know how effective the fences are within their overall security systems.

To address this knowledge gap, an LWRS Program team at Sandia National Laboratories (SNL) has conducted a comprehensive study to evaluate the effectiveness of 9-gauge chain link fencing, a material commonly used around government buildings and other secured sites. The LWRS team, the Access Delay and Structural Assessment Group, tested this fencing against established government standards [1]. The data will help in developing force-on-force scenarios and estimating the delay value of security hardware, information that plant security managers need but do not have much data for.

The team used a variety of attack techniques and tools. The researchers threw mock explosive charges to determine where and how a charge would land, tested to see whether an explosive charge would make a hole in the fence fabric big enough for an attacker to pass-through, and then assessed how long it would take for an intruder to breach. The work was done at SNL's Access Delay Lab, in Albuquerque, NM, and at the New Mexico Institute of Mining and Technology Energetic Materials Research and Testing Center, in Socorro, NM.

Figure 4. A simulated intruder throws a mock C-4 charge.

Between June and October of 2023, researchers threw 540 charges with mock explosives and conducted 20 hand-placed tests with actual C-4 explosives, charged through the holes in 16 tests, and cut fences in another 57 tests. This study included an evaluation of ten fence fabrics and meshes, though only the 9 gauge chain link fence fabric is discussed here [2].

A primary objective of the study was to see how often the testers could throw a charge so that it would land at an optimum distance (i.e., within 10 inches of the fence) and create a breach large enough for a person to pass-through. This was significantly more difficult than had been expected, with only a third of the thrown charges landing in this zone. About another third of the thrown charges landed between 10- and 18-in., which is much less likely to cause a usable breach. Anything beyond 18-in. would cause any damage to be negligible.

When the charge had hooks fastened to catch the fence fabric, as shown in Figure 4, 63% of the throws successfully attached to the fence. Of those, 55% caught the fence below a 50-in. height, which would result in a successful breach. Several of the hook charges were unintentionally thrown over the fence, well beyond the distance where any damage would be expected.

Testers also placed charges by hand, with one in contact with the fence, one at 10-in., one at 15-in., one at 20-in., and one hanging on the fence. Figure 5 shows the fireball created by the explosive charge, while Figure 6 shows the explosive damage to the fence from the charge that was hanging in contact. Then, an attacker pass-through attempt was conducted and timed for each test.

Figure 5. C-4 Charge explosive detonation fireball.

Figure 6. Explosive damage to fence.

In addition to measuring the performance of the barrier against explosives, the researchers also determined how long it would take an adversary to breach the fence with various hand or power tools, and then cross through the hole. Figure 7 shows mechanical breaching of the 9-gauge fence installation.

Figure 7. 8-in wire cutter and 36-in bolt cutter hand mechanical breach tests.

The researchers analyzed six scenarios involving a team of four attackers breaching a 9-gauge chain link fence with explosives, hand tools, and power tools. The delay times for these six scenarios ranged between 26 and 91 seconds.

While explosives contain an enormous amount of energy, their effectiveness against perimeter fencing depends on several factors. Among these factors are the size of the charge, its proximity to the fence, and the strength of the target. When conducting a task time delay analysis of any barrier, it is important to consider all the steps required to complete the operation, the time to conduct those steps, and the difficulty of achieving success. The full report [2] contains testing details and comprehensive results of all the fence fabrics tested, as well as their overall performance.

By providing data-driven insights into fencing effectiveness, the LWRS Program empowers nuclear power plant security managers to make informed decisions regarding security upgrades and resource allocation. This will both improve the ability of these officials to efficiently manage threats and security-related costs. Ultimately, this research will contribute to enhancing the safety and security of our nation's nuclear facilities.

Reference

1. Unified Facilities Criteria (UFC). (2013). "Security Fences and Gates." UFC 4-022-03, 1 October 2013. U.S. Department of Defense, Washington, D.C., USA.

A Better, Faster, More Economical Way to Measure Fire Risk

Steven R Prescott **Robby Christian**
Risk-Informed Systems Analysis Pathway

Ramprasad Sampath
Centroid LAB

Measuring fire risk at a nuclear power plant is essential but is also time-consuming and expensive. A new software package integrates several existing analytical tools into an intuitive user interface has been shown in a case study to effectively automate many manual tasks, dramatically cutting time and the expense. Accurately determining the risk from numerous fire sources is currently done through a fire probabilistic risk assessment which involves many hours of evaluating cable trays, measuring distances, performing fire calculations, and then integrating all the various results into the plant's overall risk analysis model. The LWRS Program's Risk-Informed Safety Analysis pathway has completed a five-year project to create a better way to perform these tasks using a program called Fire Risk Investigation in 3D (FRI3D, pronounced "fried") [1].

This innovative software streamlines fire modeling and risk assessment, ensuring precision and efficiency by automating many tasks and providing advanced visualization features. FRI3D is being commercialized by Centroid LAB, which created the user interface and will market the product. Early indications suggest FRI3D will be attractive to the nuclear power plant and fire analysis industries. The LWRS Program researchers conducted a cost analysis using a current industry plant modification to evaluate the savings. Plants need to perform a fire analysis for all modifications, which can require new analyses up to several times a year. FRI3D reduces these manual steps, as well as the number of work hours needed to complete these tasks by personnel with specialized expertise, by using an intuitive user interface that simplifies fire modeling tasks. Engineers can import existing plant data, including floor plans, equipment locations, schematics, cable raceway locations, fire barriers, and smoke and fire detectors. Previously scanned fire models can also be imported using standard formats or by configuring custom data tools. By dragging and dropping plant components into the 3D modeling environment, users can swiftly create accurate models of the specific areas being analyzed. The 3D modeling interface resembles commercial products used to help the average person with home interior design plans.

After the model is completed, FRI3D allows users to add fire sources. With a few clicks, the software simulates a fire spreading through a modeled environment. It uses fire simulation codes that are already validated and proved, so using the program does not trigger new regulatory requirements. The simulation predicts cable and equipment failures, as shown in Figure 8. The resulting time progress fire scenario visualizes all failed items in the 3D environment, enabling analysts to assess the progression and potential damage of a fire. Upon finalizing the fire scenario, the analysts can integrate it into their own overall risk analysis software with the click of a mouse. Using FRI3D provides an average time-savings of 50% when compared to current semi-manual practices. This time-savings is especially helpful if the fire analysis is part of the critical path of a larger project, such as adding new equipment.

A nuclear power plant and fire analysis consulting company, Engineering Planning and Management, Inc. volunteered to help with a pilot case study to perform a cost-savings analysis. The plant was installing two new chillers in different locations, so calculating their fire significance was chosen as a test case. Engineering Planning and Management, Inc. performed the task using its current semi-manual methods and tools and then used FRI3D to perform a detailed analysis. Various task times were tracked, such as determining failure calculations from the zone of influence and converting to risk analysis scenarios for current methods, and then importing the plant data, compartment or zone modeling, raceway modeling, and fire source simulations for FRI3D.

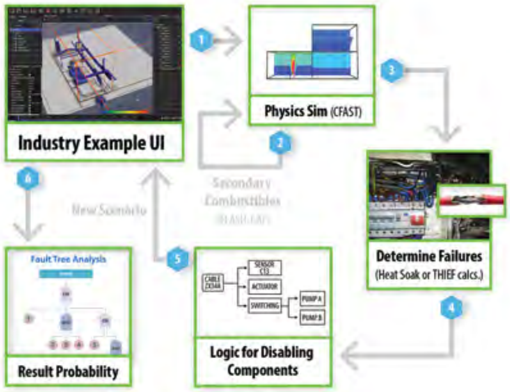


Figure 8. Automated fire scenario generation steps using the FRI3D software.

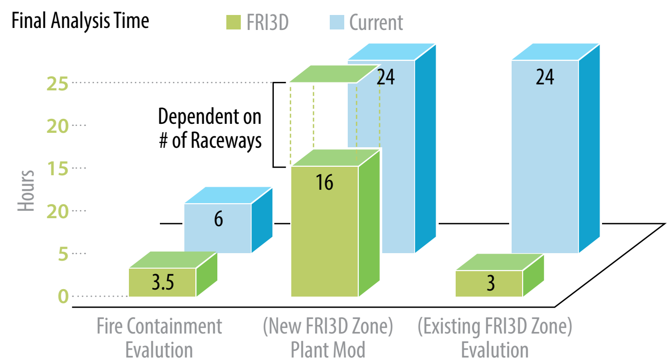


Figure 9. Timing evaluations from the industry case study comparing current methods vs. using FRI3D.

Creating the model in FRI3D and modeling the fire sources took about 32 hours. But the time-savings for auto generating the scenarios compared with current methods more than made up for the additional time. The results, including those displayed in Figure 9, showed that for fire compartments never modeled in FRI3D, there would be 0–30% time-savings (middle column), depending on how many raceways are in the room vs. the analyzed sources. If there are less than 50 raceways and several fire scenarios to analyze, a 30% time-savings is easily achieved. On the other hand, if there are more than 100 raceways and only one scenario being analyzed, there may be no time-savings for the first analysis of that compartment analyzed in FRI3D. For any subsequent changes or future fire evaluations in already modeled compartments, time would be cut by 80% (right column). More cases would need to be evaluated to determine an average time-savings per project or compartment.

Centroid LAB is working with EPM, Risk Spectrum, and PLC Fire Protection Engineering. These companies specialize in nuclear risk analysis and fire modeling and will help bring FRI3D to the nuclear industry, thereby helping to cut costs and increase realism in fire analysis. Researchers hope to add the option of flooding analysis modeling into FRI3D in the future.

Reference

1. Prescott, S., R. Christian, and R. Sampath. (2023). "FRI3D Fire Simulation Options and Verification Tasks." INL/RPT-23-70843. Idaho National Laboratory, Idaho Falls, ID, USA. Available at: https://lwrs.inl.gov/RiskInformed%20Safety%20Margin%20Characterization/FRI3D_CFAST_FDS.pdf (accessed 11 June 2024).

Welcome Brenton M. Pickrell as the Pathway Lead for the Physical Security Pathway

Brent Pickrell is the new Physical Security Pathway Lead in the Light Water Reactor Sustainability (LWRS) Program at Sandia National Laboratory. He will advance cutting-edge physical security solutions and improve risk-informed decision-making for the long-term safe and reliable operation of existing nuclear power plants. With extensive experience in leadership, and physical and nuclear security, Brent brings unique expertise to this role, supported by a B.S. from Ohio University and M.S. of Aeronautical Science from Embry-Riddle Aeronautical University.

Brenton M. Pickrell

Brent's career began in the U.S. Marine Corps and culminated 26 years later in retirement from the U.S. Air Force as a Security Forces Officer, where he led security operations on three continents, safeguarded the nation's most critical assets, and forged partnerships with local law enforcement, the Secret Service, FBI, and defense agencies of nearly 100 nations.

With demonstrated talent in leading interdisciplinary teams, integrating emerging technologies, and forging partnerships that strengthen the security landscape, Brent excels at aligning multi-billion-dollar modernization efforts with strategic directives, and championing continuous improvement to address evolving threats. Beyond his professional acumen, he is a staunch advocate for team development and building cultures grounded in trust, ethics, and mutual respect across cultural or demographic lines.

Co-location of Hydrogen Plants and Other Industrial Plants Near Nuclear Reactors






Kurt G. Vedros **Robby Christian** **Courtney M. Otani** **Wen-Chi Cheng** **Ronald L. Gonzales**

Flexible Plant Operation and Generation Pathway

Austin Glover

Sandia National Laboratories

Nuclear reactors make steam, which is then used to produce electricity. But steam can also be used in various industrial processes, reducing the need to burn fossil fuels, a national policy goal. One such process is making hydrogen cleanly, through electrolysis, another national policy goal, which can be achieved using electricity and/or heat from nuclear reactors. Making hydrogen with electrolysis can replace hydrogen from methane reformation, a method that results in carbon dioxide (CO_2) emissions.

Electricity is easy to transport but steam is not, so a nuclear power reactor and an industrial plant must be located within some proximity to each other. A new risk analysis created by LWRS Program researchers at INL and SNL shows hydrogen production is safe at a short distance from a nuclear power plant.

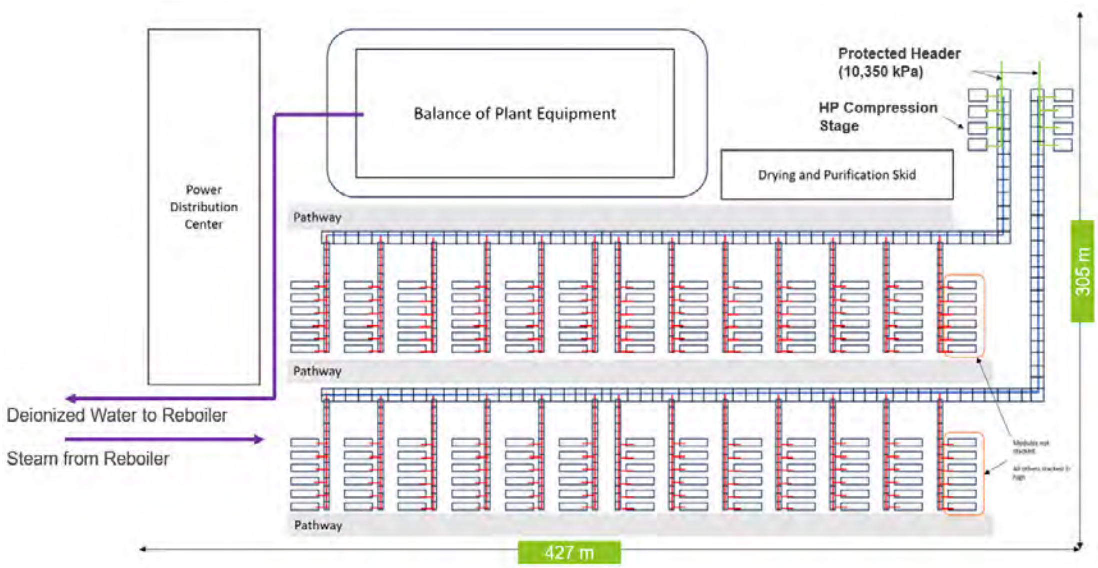


Figure 10. High-Temperature electrolysis facility layout.

The LWRS Flexible Plant Operation and Generation program continues to lead the way in safety research for siting industrial facilities near nuclear power plants. In 2023, laboratory researchers worked closely with representatives of the hydrogen and nuclear industries, along with regulators, through the LWRS Program's Hydrogen Regulatory Research and Review Group (H3RG) to assess safety hazards applicable to nuclear power plants supporting a hydrogen facility [1]. The participants identified the three most likely sizes for a high-temperature electrolysis facility (HTEF) at 100, 500, and 1000° $MW_{nominal}$ power. Sargent and Lundy, the architectural engineering firm, worked closely with the INL risk assessment team on the HTEF design, as shown in Figure 10, as well as the corresponding thermal extraction system for the reactors.

The HTEF specifications allowed for more precise assessment of the two major co-location risks: (1) heat from fire, and (2) deflagration/detonation overpressure. Heat flux determines the minimum safe distance between the HTEF and nearby structures and vegetation. If hydrogen leaks from a pipe or a tank and ignites and burns rapidly in a process called deflagration, the result is a pressure wave. Detonation, or the explosion of hydrogen, also produces a pressure wave. The U.S. Nuclear Regulatory Commission (NRC) prohibits locating an explosive source that would produce an overpressure exceeding 1.0 pound per square inch gauge (PSIG) at any nuclear plant safety system, structure, or component [3]. A 1.0 PSIG overpressure is enough to shatter glass [3].

The team analyzed the safety risk to the nuclear power plant using two methods: (1) deterministic, and (2) probabilistic. The deterministic analyses calculated the distance at which the overpressure from a detonation or deflagration would dissipate to 1.0 PSIG. To make this calculation, hydrogen explosion experts used the HTEF specifications to determine hydrogen volume and pressure throughout the facility. Then, they determined the amount of hydrogen available for an explosion based on the plume of the hydrogen leak.

The team used the hydrogen detonation overpressure and fire regulation standards from the National Fire Protection Agency (NFPA) [4] to determine the safe standoff distances for explosions and fires. A siting analysis was performed for several representative sites, which showed that an HTEF could be placed safely within the hydrogen facility boundary dictated by the NFPA approximately 21 meters away from the perimeter of the nuclear power plant in all cases by orienting the higher explosive risks further away from the plant, as indicated in Figure 11.

Figure 11. Safe standoff distances from a nuclear power plant to a HTEF.

The INL risk assessment team modeled the hardware changes required to extract steam from a nuclear power plant in a probabilistic risk analysis (PRA). All nuclear plants have PRAs, which estimate the initiating events of accidents and safety system performance that prevent an accident from causing damage to the nuclear fuel. For this analysis, experts added the steam extraction system and connection feeding electricity directly to the hydrogen plant in the PRA. The evaluation of these modifications was required because they increased the frequencies of possible initiating events and their consequences. The conclusion of the PRA [1] was that under the NRC rules in 10 CFR 50.59 [5] covering power plant modifications, a hydrogen production facility could be safely added if the safe standoff distances are met.

In 2024, the risk assessment team has continued working with the LWRS and Integrated Energy Systems Program to focus on other industrial processes that may be supported by nuclear power plants beyond hydrogen and the hazards they present. Hazard and risk analyses are being performed for facilities to produce methanol, oil refining, synthetic fuels, and wood pulp and paper. In addition to explosion or fire, the hazards being assessed include the release of toxic, corrosive or caustic materials, and non-toxic pollution.

References

1. Vedros, K. G., R. Christian, and C. M. Ohtani. (2023). "Expansion of Hazards and Probabilistic Risk Assessments of a Light-Water Reactor Coupled with Electrolysis Hydrogen Production Plants," INL/RPT-23-74319, Rev. 1, October 2024, Idaho National Laboratory, Idaho Falls, ID, USA. https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_67319.pdf.
2. U.S. Nuclear Regulatory Commission (NRC). (2021). "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes Near Nuclear Power Plants." NRC Regulation Guide 1.91, Revision 3, November 2021. NRC, Washington, D.C., USA.
3. U.S. Environmental Protection Agency (EPA). (2024). "Areal Locations of Hazardous Atmospheres (ALOHA)" software. EPA, Washington, D.C., USA. Available at: https://www.epa.gov/cameo/aloha-software (accessed 11 June 2024).
4. U.S. National Fire Protection Association (NFPA). (2023). "NFPA 2: Hydrogen Technologies Code." NFPA, Quincy, MA, USA.
5. Federal Register. (2022). "Changes, Tests and Experiments," CFR 10.50.59, RG 2.8, Feb. 2022. Washington, D.C. Available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0059.html (accessed 11 June 2024).

Welcome Shawn St. Germain as the Deputy Pathway Lead for the Physical Security Pathway

Shawn St. Germain is the newly appointed Physical Security Deputy Pathway Lead for the Light Water Reactor Sustainability (LWRS) Program. He manages the Reliability, Risk, and Resilience Sciences Department at Idaho National Laboratory (INL). He is also the principal investigator of research aimed at enhancing the physical security at commercial nuclear power plants using innovative technologies and risk methods. With an 18-year tenure at INL, Shawn has amassed significant expertise in reactor operations, process engineering, and probabilistic risk assessment.

Shawn St. Germain

He possesses an M.S. in nuclear engineering, an M.S. in engineering management, an MBA, and a B.S. in mechanical engineering. Before INL, he served as a Senior Reactor Operator Certified Shift Technical Advisor at Columbia Generating Station and was a nuclear trained surface warfare officer in the United States Navy.

Recent LWRS Program Reports

Materials Research

- *Produce first phase consensus roadmap for development of condition-based cable reliability assurance, PNNL-36630*
- *Complete the Second Weld Campaign on Ni Alloy 182 Using Optimized Welding Parameters and Complete the Initial Weld Quality Evaluation, ORNL/SPR-2024/3575*
- *High Neutron and Gamma dose effects on Calcium Silicate Deuterate, ORNL/SPR-2024/3454*
- *Assessment of Neutron-Induced Crack Volume on Aggregates of Varied Mineralogy and Estimation of Irradiation Damage Depth in the Concrete Biological Shield, ORNL/SPR-2024/3581*
- *SSTDR and FDR Detection of Un-Energized and Energized Cable Anomalies Including Thermal Degradation Using Machine Learning, PNNL-36573*
- *Evaluation of Clamshell Current Coupler for Online Frequency Domain and Spread Spectrum Time Domain Reflectometry to Detect Anomalies in Energized Cables, PNNL-36530*

Plant Modernization

- *Demonstration and Evaluation of Explainable and Trustworthy Predictive Technology for Condition-based Maintenance, INL/RPT-24-80727*
- *Scalable Methods to Automate Manual Work Management Activities Using Artificial Intelligence, INL/RPT-24-80159*
- *Mapping Data to Support Optimum Work Automation: The Socio-Technical-Organizational Modeling Process, INL/RPT-24-80094*
- *ION Work Reduction Opportunity Realization Demonstration, INL/RPT-24-80282*

Risk-Informed Systems Analysis

- *Development of New Reactor Core Configuration for Power Uprate – Fuel Reload & Heat Processing Analyses, Core Design, System Safety Assessments, and Fuel Performance Analyses, INL/RPT-24-80710*
- *An Integrated Framework for Risk Assessment of Safety-related Digital Instrumentation and Control Systems in Nuclear Power Plants: Methodology Refinement and Exploration, INL/RPT-23-74412*
- *A Full-scale Demonstration of Pressurized Water Reactor Core Design Optimization using Multi-Cycle Optimization Methodology, INL/RPT-24-80449*
- *Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER 3.0) User Guide, INL/RPT-24--80110*
- *Automated Knowledge Extraction from Plant Records to Support Predictive Maintenance, INL/RPT-24-78817*

Flexible Plant Operations & Generation

- *Flexible Plant Operation and Generation: Hazards and Probabilistic Risk Assessments of a Light-Water Reactor Coupled with Industrial Facilities, INL/RPT-24-80742*
- *Nuclear Energy Prospector for Identifying U.S. LWR Non-Grid Opportunities, INL/RPT-24-80742*
- *Hydrogen Generation and Industrial Heat Opportunities for Nuclear Plants in the Gulf Coast, INL/RPT-24-80189*
- *Value of Nuclear Energy to the Reliability of the North American Power System: Results for Western and Eastern Interconnections, INL/RPT-24-79840*

Physical Security

- *An Evaluation of The Dynamic Physical Security Risk Assessment Methodology for Fleet-Wide Applications; INL/RPT-24-80303*

(Click on the report title to download the document.)

Editor: Gordon Holt
Designer: Jason Smith

To submit information or suggestions, contact Cathy J. Barnard at **Cathy.Barnard@inl.gov**.