Engineering team tests gaming technology to train nuclear workforce

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Like many in today's nuclear workforce, Kultgen and engineer and technician colleagues were born after most nuclear reactors currently operating in the United States were constructed. Credit: Argonne National Laboratory

A new report details how Argonne engineers have tested extended reality tools at the nation's largest liquid metal test facility.

Most nuclear reactors in the U.S. were built decades ago by a workforce

that has retired or will do so soon. That generation used paper checklists and traditional blueprints, tended to stay with one employer for years and often worked locally.

Today's technicians, subject matter experts and engineers have different skills and expectations. They came of age in a world where computers seem to be everywhere, where employers and hometowns change often, and where remote work is more possible. They're also very familiar with video games, digital paths to information and ubiquitous personal devices. The nuclear power industry, undergoing a renaissance because of its potential to reliably deliver more clean electricity, urgently needs to attract and train these workers to maintain existing plants and build anticipated new ones.

A small group of engineers at the U.S. Department of Energy's (DOE) Argonne National Laboratory addresses this need in a recently released report titled Deploying Extended Reality (XR) for Digital Operations and Maintenance at the Mechanisms Engineering Test Loop (METL). Their approach focuses on interest in and familiarity with personal devices and video game technology to explore how they can be used as a toehold for the next generation of nuclear professionals.

Engaging a new generation

According to the Nuclear Energy Institute, a single nuclear power plant employs 500 to 800 workers in an impressive range of highly trained positions: carpenters, welders, electricians, health physicists, nuclear engineers, financial managers and more. The nuclear power industry wants and needs to develop this talent from a wide pool of trades, community colleges, four-year universities and the military.

Derek Kultgen thinks a more engaging, digitally enhanced workplace can help. Kultgen is operations manager of Argonne's Mechanisms Test

Loop Facility (METL), the nation's largest liquid metal test facility where small- and medium-sized components are tested for use in advanced, sodium-cooled nuclear reactors. The facility holds 750 gallons of reactor-grade sodium that can be heated to 650 degrees Celsius and it is equipped with more than 1,000 sensors that collect diagnostic data. Even when scientists aren't running experiments at METL, it provides enormous value because of its usefulness in training people and collecting operational data.

"As everything transitions to digital, there is an opportunity for the nuclear industry to use extended reality to break down the silos where useful data resides and bring data to the people who need it," said Kultgen. "These digital silos include Computer-Aided Design (CAD) information, operating and maintenance procedures, real data coming off the equipment, manufacturer data, data on spare parts, historical data of how this equipment has operated, and more."

"This breaking down of information barriers between occupations means meaningful work across the board, and that may result in a future workforce that is trained, competent and content enough to stay for a while," he continued.

Kultgen and his colleagues at METL began experimenting with assisted, augmented, virtual and mixed reality. They investigated off the shelf hardware and software that will be familiar to many video gamers: headsets, high-fidelity visualization software, tablets with light detection and ranging (LiDAR) technology, and hard hats equipped with advanced optics, short-range wireless technology and voice-activated software. With help from a computational designer, Kultgen used these items to create a digital version of METL. The result, in conjunction with a live data feed from METL, is a digital twin of the 220+ heater zones used to keep METL's sodium molten.

In one example, Kultgen's team overlaid images of an 800-gallon sodium tank with accompanying valves and pipes clearly labeled. The tank appeared true to size, oriented correctly and fitted properly within the actual space. In its virtual form, a technician could see it covered in insulation and casings or as a rendering with obscuring layers removed. Each part was linked to a unique QR code containing its product serial number. If a novice technician was sent to METL to find and repair a single valve or pipe on that tank, she could find it quickly and repair it with fewer mistakes.

From personal experience, Kultgen knows tradesmen would have found this and other features helpful as they constructed or maintained the facility. Moreover, hard hats equipped with voice-activated software mean workers can access information from multiple sources or complete computer-based tasks hands-free.

Imagine standing in front of a pump and being able to see its graph of flow rates and temperatures on a digital screen built into your hard hat. Say, "Asset Information," and the screen shows you the pump's serial number, manufacturer and vendor with its tech support's email address and information about ordering lead time. Capture a screenshot or stream live video of the failing pump, send it to a colleague in another city and get a response in your ear or via text on a tiny screen positioned on a small boom at your cheekbone, just below your line of sight. This capability brings the power of a laptop onto the facility floor—minus the laptop.

"We are often working in tight spaces where even a tablet can seem cumbersome," said Kultgen, who sometimes wears full-body, insulated protective gear while working with others to adjust unwieldy 100-pound pieces of equipment. "The technology is so good now that a lot of information can be communicated between headsets and an ordinary smart phone. Being able to work hands-free with unobstructed vision and

maximum reliable data starts to present more practical applications."

A mutually beneficial direction

The technology is decidedly cool. Future workers of all backgrounds will already be familiar with it on some level. That's not because they were introduced to it formally in school, but because they learned so much about it informally, outside of school. They are already comfortable with the digital path to data, which again means a positive breakdown of previously siloed information.

This can lead to new frontiers of innovation and opportunity. According to one vision narrative circulating among industry, academia and government, modernizing the nuclear workforce with digital twins, artificial intelligence, and integrated big data could result in reduced operating costs, improved safety, fewer human errors and consequential events, and greater employee attraction, satisfaction and retention.

More trial runs at places like METL may help the gaming industry, too. Real-life industrial applications and experiments can expand the technology's use beyond the entertainment industry and into advanced manufacturing and facility operations and maintenance.

After their experiments, the METL team has feedback to share. For example, one tested headset with excellent optics was deemed more appropriate for occasional communications between on-site technicians and remote subject matter experts than for everyday use due to its weight and bulkiness. Workers could use the headset to communicate and solve a problem together even if one was in London and the other was in Idaho.

"From an industry perspective, when a person on-site can use an iPad to run a complex diagnostic and then have a service technician from afar

advise on how to fix an issue, it saves money on travel and increases uptime," said Chris Heckle, Argonne's director of the Materials Manufacturing Innovation Center, where scientists and engineers work to accelerate and scale up materials and processes. Kultgen added that an additional benefit is that it expands the range of locations where nuclear industry hires might do their jobs.

The METL team has ideas on what the gaming industry could test at the facility next, too.

"Infrared cameras could be useful," said Alex Grannan, a nuclear engineer who co-authored the report. "Smoothly combining artificial intelligence and machine learning techniques to allow for natural language processing to understand commands and object detection, and identifying components and accessing schematics would also be cool. Many of these features exist to some extent already but they can improve in the future."

The adoption of extended reality tools may be an unexpected bridge between the nuclear industry's historical and future success.

"We have to ask not only how we can get a reactor built on budget and on deadline, but we need to attract and retain a knowledgeable workforce capable of operating and maintaining it," said Kultgen. "These huge investments take time, so how do we keep trained, skilled people engaged in and committed to the nuclear industry?"

At METL, where Argonne conducts some of the most serious and advanced nuclear reactor experiments in the U.S., the answer looks smart—and fun.

More information: Derek Kultgen et al, Deploying Extended Reality (XR) for Digital Operations and Maintenance (O&M) at the

Mechanisms Engineering Test Loop (METL), (2023). DOI: 10.2172/1962795