The Human Systems Simulation Laboratory (HSSL) at Idaho National Laboratory is a full-scale test facility for performing human factors experiments with control room operators.

Staying Ahead of the Curve: Argonne, INL Collaborate on Software to Aid Power Plant Operators

by Paul Menser for DOE's Nuclear Energy University Program

If one word could sum up the guiding principle behind the operation of a commercial nuclear power plant, it might be "anticipation."

"Plant situational awareness" is a term any control room operator is familiar with. With complex mechanical systems and massive amounts of energy involved, it's not only desirable but necessary to be in front of any plant issue that has the potential to grow into trouble. The greatest danger operators face is falling behind the curve due to the countless little tasks their jobs involve.

Researchers at Argonne National Laboratory (ANL) and Idaho National Laboratory (INL) have recognized that the answer is not to replace control room operators with computers, but to provide them with a computerized operator support system (COSS), a collection of capabilities that helps them monitor plant performance and make timely, informed decisions.

The U.S. Department of Energy established the Nuclear Energy Enabling Technologies (NEET) Program to help address nuclear technology development challenges through innovative research. Under NEET, the Advanced Sensors and Instrumentation (ASI) technology area coordinates instrumentation and controls (I&C) research, such as this one, to support the nuclear industry.

In a collaboration that stretches back nearly ten years, Argonne and INL have developed competencies that complement each other. Argonne has done extensive research into equipment fault diagnosis. Its PRO-AID software for diagnosing component faults in nuclear power and process industry plants dates back to the 1990s. One goal—made possible by today's advances in software development tools—was to modernize PRO-AID so that its automated reasoning (AR) capability would be more maintainable and extensible. This essentially required a rewrite of the software using current generation AR coding techniques. On its side of the partnership, INL is home to the Human Systems Simulation Laboratory (HSSL), a high-fidelity, digitized control room simulation environment where four light water reactor (LWR) plant models can be used for assessment of human performance in a highly realistic setting.

Since 2015, the progress has been toward software that can manage and distill the enormous amount of information an operator must process to maintain awareness of a plant's

condition, particularly in nascent off-normal situations. "It doesn't encroach on their functions as much as it brings to their attention conditions that might become actionable," said Ken Thomas of INL, who collaborated on the project with Ron Boring, a distinguished human factors scientist at INL, and with Richard Vilim, the principal investigator from Argonne. "It's not some black box. It's an engine that reasons just like an operator would reason," adds Vilim.

The reasoning process is designed to be transparent and familiar to operators. It is based on nearly the same qualitative reasoning process by which they, given sufficient time and access to instrument readings, would make a fault diagnosis.

"It's engineered to be deployable," Vilim said. "It doesn't need a subject matter expert. It runs very quickly in real time. It looks at all the components in a system and uses this information to almost double the number of available process variables for improved awareness."

Human performance assessment with Palo Verde operators was done to simulate fault injection to gauge operator performance for PRO-AID assisted and non-PRO-AID-assisted scenarios.

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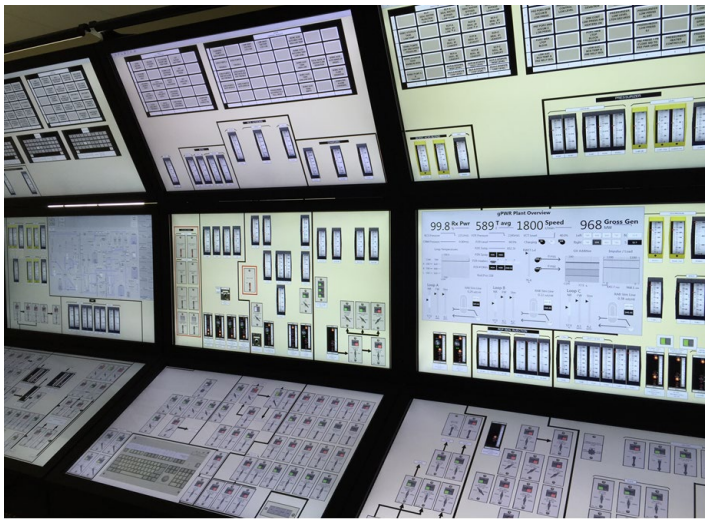
– Richard Vilim

One key consideration in the development of COSS was that it not become one more thing for operators to deal with. Automated systems perform more reliably than humans at rote tasks. Humans on the other hand perform much better at system oversight, evaluating complex situations and formulating an appropriate response. The goal was to develop a computer-based operator advisory system that would improve operational reliability, improve nuclear safety, and reduce human error through seamless integration of plant measurements, the physical laws, and automated reasoning.

The first successful demonstration of COSS at the HSSL occurred in 2017, when human factors interactive graphics and fault diagnostics algorithms were seamlessly integrated with a full-scope simulator, providing a real-time platform for human performance tests. One test simulation involved the failure of a reactor coolant pump seal while the other involved a leak in outside containment.

In working with the nuclear industry, the labs began work with Arizona Public Service, conducting human performance tests with operators from the utility's Palo Verde Nuclear Generating Station. The workshop provided an opportunity to allow operators to interact with the COSS prototype in real time.



The COSS displays at the HSSL reflect the real-time plant parameters for normal and fault conditions. The display to the left is the operator interface panel and the display to the right is the plant systems overview.

Operator participates in simulation testing at the HSSL.

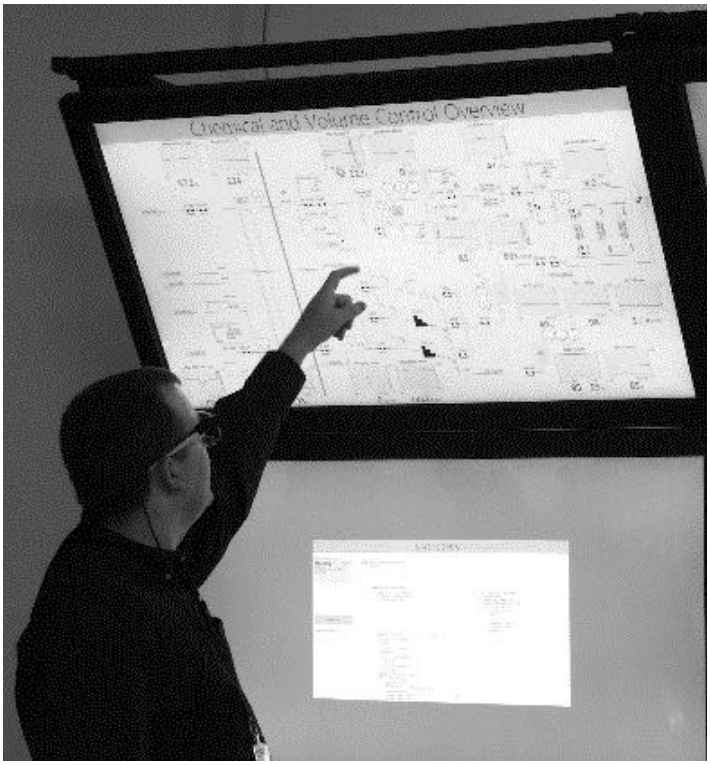
In order to benchmark their performance, the operators first performed a scenario using a traditional analog board layout. They then used the COSS interface displayed within the chemical and volume control system (CVCS) board. A number of different measures were collected during each scenario completion. Simulator logs, eye tracking, and audio logs were taken in real time, and following the scenario the operators completed a series of subjective questionnaires.

"They really engaged and liked the idea of it," Thomas said. "I think they really did see this as something that could help them."

Argonne is currently working with industry on applications of PRO-AID methods and software to improve efficiency of operations and maintenance activities at U.S. nuclear plants. The lab has partnered with an energy service company and nuclear utilities to deploy the software for improved situational awareness. In one application, PRO-AID provides a real-time estimate of equipment condition and serves as a basis for improved maintenance and optimization to reduce costs. In another, it is used to analyze the installed sensor set at a nuclear plant, recommending how it should be augmented to better meet the information needs of a prospective monitoring and diagnostics center. The software is also a candidate building block in the operations technology that is being developed for achieving a long-term goal of near autonomous operation of a nuclear plant.

The next logical step is to load the COSS interface onto a power plant's computer for a test case. There has been interest from utilities, but the main hurdle will be validating to regulators that it will not be a distraction to operators.

From there, "Adopting this from one plant to another would not be a great jump," Thomas said.



Operator using COSS at the INL Human Systems Simulation Laboratory.


Operator support technology includes simulated diagnostic technology, an operator alarm display, and the fault scenario.

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