

Long-Term Instrumentation, Information, and Control Systems (II&C) Modernization Future Vision and Strategy

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The Advanced Instrumentation, Information, and Control (II&C) Systems Technologies Pathway conducts targeted research and development (R&D) to address aging and reliability concerns with the legacy instrumentation and control and related information systems of the U.S. operating light water reactor (LWR) fleet. This work involves two major goals: (1) to ensure that legacy analog II&C systems are not life-limiting issues for the LWR fleet, and (2) to implement digital II&C technology in a manner that enables broad innovation and business improvement in the nuclear power plant operating model. Resolving long-term operational concerns with the II&C systems contributes to the long-term sustainability of the LWR fleet, which is vital to the nation's energy and environmental security.

A key tenet of the Advanced II&C Systems Technologies Pathway is to continuously engage the nuclear power industry to ensure a correct understanding of the II&C issues and requirements *as currently experienced in the operating nuclear power plants*, and to develop approaches to address aging instrumentation and control systems and demonstrate them in individual pilot projects with operating nuclear power plants. This provides validation of the developed technologies as fully meeting utility requirements. The results can be used by other owner-operators to address similar aging issues and to achieve new efficiencies. This approach is unique to this pathway and is essential because future planned R&D efforts are built on the concepts of and successes from prior projects. This creates a stepwise approach to long-term modernization and refurbishment of instrumentation and control technologies across the LWR fleet. The engagement strategy with nuclear utilities serves to identify priorities for modernization and safety enhancement, timeframes for action, a means of coordinating resources and research partnerships, and a forum to communicate the results of research efforts to the broader nuclear industry and vendor community.

Instrumentation, Information, and Control Systems are a vital part of plant safety and provisions for their refurbishment must be included in long term planning

Reliable instrumentation, information, and control (II&C) systems technologies are essential to ensuring safe and efficient operation of the U.S. light water reactor (LWR) fleet. These technologies affect every aspect of nuclear power plant (NPP) and balance-of-plant operations. They are varied and dispersed, encompassing systems from the main control room to primary systems and throughout the balance of the plant. They interact with every active component in the plant and serve as a kind of central nervous system.

Current instrumentation and human-machine interfaces in the nuclear power sector employ analog technologies. In other power generation sectors, analog technologies have largely been replaced with digital technologies. This is in part due to the manufacturing and product support base transitioning to these newer technologies. It also accompanies the transition of education curricula for II&C engineers to digital technologies. Consequently, product manufacturers refer to analog II&C as having reached the end of its useful service life. Although considered obsolete by other industries, analog I&C continues to function reliably, though spare and replacement parts are becoming increasingly scarce as is the workforce that is familiar with and able to maintain it. In 1997, the National Research Council conducted a study concerning the challenges involved in modernizing existing analog-based instrumentation and controls with digital instrumentation and control systems in NPPs. Their findings identified the need for new II&C technology integration.

Replacing existing analog with digital technologies has not been undertaken to a large extent within the nuclear power industry worldwide. Those efforts that have been carried out are broadly perceived as involving significant technical and regulatory uncertainty. This translates into delays and substantially higher costs for these types of refurbishments. Such experiences have slowed the pace of analog II&C replacement and further contribute to a lack of experience with such initiatives. In the longer run, this may delay progress on the numerous II&C refurbishment activities needed to establish plants that are cost competitive in future energy markets when plants enter long term operation. Such delays could lead to an additional dilemma: delays in reinvestment needed to replace existing II&C systems could create a 'bow

wave’ of needed future reinvestments. Because the return period on such reinvestments becomes shorter the longer they are delayed, they become less viable. This adds to the risk that II&C may become a limiting or contributing factor that weighs against the decision to operate nuclear power assets for longer periods.

II&C replacement represents potential high-cost or high-risk activities if they are undertaken without the needed technical bases and experience to facilitate their design and implementation. The II&C R&D program addresses critical gaps in technology development and deployment to reduce risk and cost. The objective of these efforts is to develop, demonstrate, and support deployment of new digital II&C technologies for nuclear process control, enhance worker performance, and provide enhanced monitoring capabilities to ensure the continued safe, reliable, and economic operation of the nation’s NPPs.

II&C Systems can deliver new value through integrated long-term planning.

Most digital II&C implementation projects today result in islands of automation distributed throughout the plant. They are physically and functionally isolated from one another in much the same way as were their analog predecessors. Digital technologies are largely implemented as point solutions to performance concerns with individual II&C components – such as aging. This approach is characterized by planning horizons that are short and typically only allow for ‘like-for-like’ replacements. It is reactive to incipient failures of analog devices and uses replacement digital devices to perform the same functions as analog devices. Consequently, many features of the replacement digital devices are not used. This results in a fragmented approach to refurbishment that is driven by immediate needs. This approach to II&C aging management minimizes technical and regulatory uncertainty though, ironically, it reinforces the current technology base.

To displace the piecemeal approach to digital technology deployment, a new vision for efficiency, safety, and reliability is needed that leverages the benefits of digital technologies. This includes considering goals for NPP staff numbers and types of specialized resources; targeting operation and management costs and the plant capacity factor to ensure commercial viability of proposed long-term operations; improved methods for achieving plant safety margins and reductions in unnecessary conservatism; and leveraging expertise from across the nuclear enterprise.

New value from II&C technologies is possible if they are integrated with work processes, directly support plant staff, and are used to create new efficiencies and ways of achieving safety enhancements. For example, data from digital II&C in plant systems can be provided directly to work process applications and then, in turn, to plant workers carrying out their work using mobile technologies. This saves time, creates significant work efficiencies, and reduces errors. A goal of these efforts is to motivate development of a seamless digital environment (Figure 1) for plant operations and support by integrating information from plant systems with plant processes for plant workers through an array of interconnected technologies.

- Plant systems – beyond centralized monitoring and awareness of plant conditions, deliver plant information to digitally based systems that support plant work and directly to workers performing these work activities.
- Plant processes – integrate plant information into digital field work devices, automate many manually performed surveillance tasks, and manage risk through real-time centralized oversight and awareness of field work.
- Plant workers – provide plant workers with immediate, accurate plant information that allows them to conduct work at plant locations using assistive devices that



Figure 1. Seamless information architecture

minimize radiation exposure, enhance procedural compliance and accurate work execution, and enable collaborative oversight and support even in remote locations.

To create capabilities needed for long term operation, an approach to R&D is being taken that enables the stepwise deployment of new II&C technologies.

The path to long-term operability and sustainability of plant II&C systems will likely be accomplished by measured, stepwise modernization through refurbishments. Through successive refurbishments, the resulting collection of II&C systems will reflect a hybrid mixture of analog and digital technologies. Operators and maintainers of II&C systems will, for an extended duration, require competencies with both types of technologies. This represents a least-risk and most realistic approach to refurbishment that allows plant personnel to become familiar with newer digital systems as they gradually replace analog devices.

Within this R&D framework, six areas have been identified that enable capabilities needed for long-term sustainable plant operation. Through a consensus development process involving industry staff representing 70% of the existing LWR fleet, these areas were identified to address the aging of existing I&C technologies, to create capabilities needed to enable power plant staff to perform their jobs more efficiently with digital technologies, and to create the underlying digital II&C architecture that is needed by plants during periods of long term operation. These are shown in Figure 2. In each of these areas, a series of pilot projects are planned that enable the development and deployment of new II&C technologies in existing nuclear plants. Through the LWRS program, individual utilities and plants are able to participate in these projects or otherwise leverage the results of projects conducted at demonstration plants.

The pilot projects conducted through this program serve as stepping-stones to achieve longer-term outcomes of sustainable II&C technologies. They are designed to emphasize success in some crucial aspect of plant technology refurbishment and sustainable modernization. They provide the opportunity to develop and demonstrate methods to technology development and deployment that can be broadly standardized and leveraged by the commercial nuclear power fleet. Each of the R&D activities in this program achieves a part of the longer-term goals of safe and cost-effective sustainability. They are limited in scope so they can be undertaken and implemented in a manner that minimizes technical and regulatory risk. In keeping with best industry practices, prudent change management dictates that new technologies are introduced slowly so that they can be validated within the nuclear safety culture model.

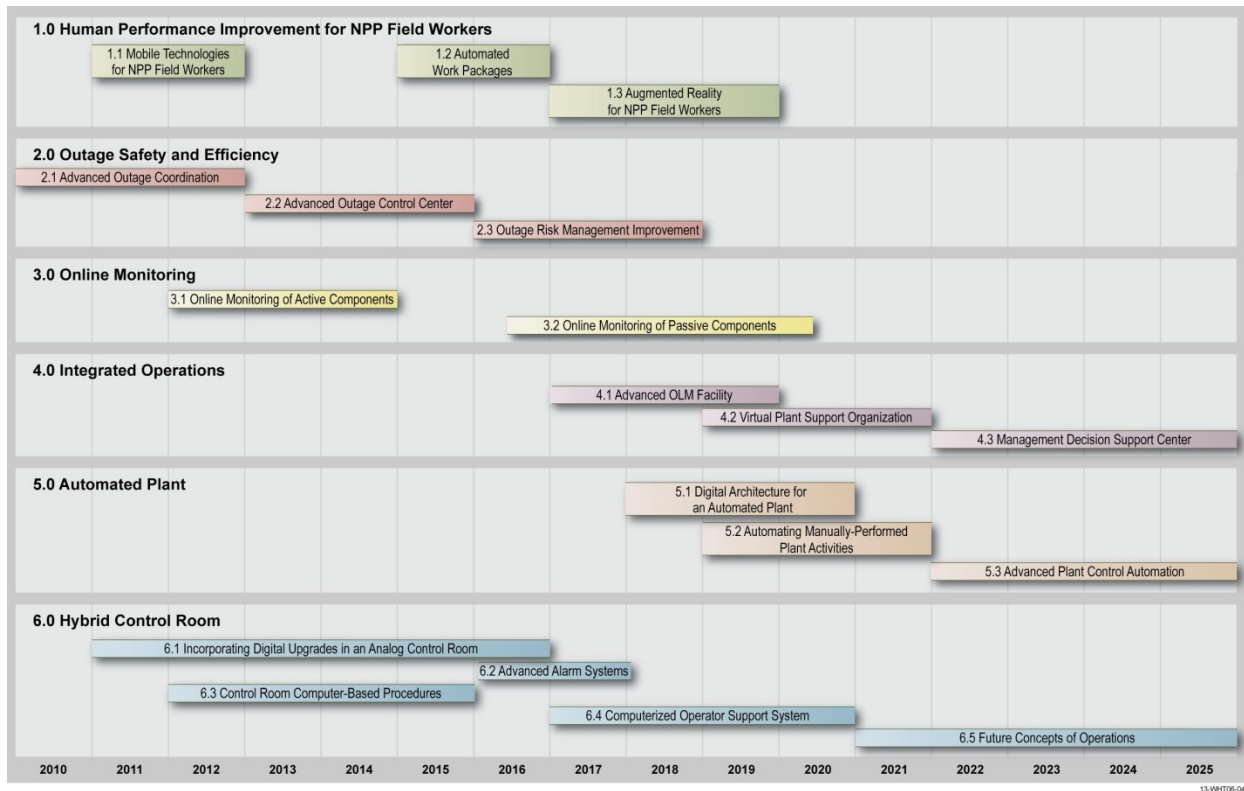


Figure 2. Pilot projects grouped in six areas of enabling capabilities

Cost and Performance improvements are being targeted through II&C R&D to enhance the existing fleet's long-term viability.

Analog II&C has been the predominant means used for process control in the nuclear power industry for decades. Its use dates back to an era when human labor was more affordable, and maintaining an II&C technology base through a larger workforce conducting frequent rounds for surveillances, inspections, and tests was accepted in the nuclear power generation business model. Today's power generation business climate is much different than the preceding decades and II&C technologies are needed in the long run that are more highly automated and require less cost to operate and maintain, are as highly reliable as those used today, and will be familiar to a future work force. They should also enable performance gains for nuclear utilities so that they are not merely a sunken cost, as this would weigh heavily on the balance sheet at a time of particularly high cost competitiveness in electricity markets. The growing presence of gas generation is resulting in substantial cost pressure on nuclear generation, particularly in non-regulated markets. The closing of Kewaunee Nuclear Station is such an example of an immediate impact. For other nuclear plants, long term cost implications will bear on life extension options.

Improvement in the competitive position of the nuclear plants can come from either higher capacity factors or lowered costs. There remains some upside in capacity factors, but the industry has been quite successful in maximizing this opportunity. Now the larger opportunity is in cost reduction. For a typical plant, around 70 % of non-fuel O&M costs are labor. Therefore, work efficiency and work elimination are the most promising means of appreciable reductions. In non-nuclear power generation sectors, this has taken the form of a shift in the business model from one that is labor-centric to one that is technology-centric. Granted, for current nuclear plants, many labor requirements are embedded in and reflect elements of plant design. However, there is an ever-expanding opportunity to reduce labor dependence with the development and application of advanced technologies.

Digital technology has long been an enabler of business models in power generation that seek to lower production costs. Significant efficiencies can be gained in process improvement through applications of this technology. For example, for a typical plant support activity, no more than 35% of the labor effort is applied directly to the task (wrench time); the bulk of the labor effort is associated with various pre-and post-job activities, or resolving issues that arise during the course of work execution. Real-time process-related information access as well as collaboration with remotely situated support staff can greatly improve the efficiency of in-plant activities. In some cases, activities can be eliminated altogether, such as through on-line monitoring of active components in lieu of periodic or condition-based testing.

Results of II&C R&D will support continued safe operation.

Another opportunity for reducing cost and enhancing safety is by reducing human error and its consequences. There are substantial direct and indirect costs that result from human error. This includes the immediate consequences of the error (lost production, delayed outages, etc.), as well as the indirect activities such as event investigations, remedial training, apparent and root causes, analysis of extent of condition/cause, management reviews, corrective actions, regulatory actions, operating experience reports, and so forth. When reactor trips are involved, there are even further costs in reactor trip reports, plant safety committee reviews, and recovery and restart activities. An appreciable percentage of plant staff time is consumed in these types of activities when they occur.

In 2010, the Institute for Nuclear Power Operations (INPO) issued *Significant Operating Experience Report (SOER) 10-02 Engaged, Thinking Organization* [1] which described a number of safety lapses that had recently occurred in the industry and highlighted a number of human performance concerns associated with these events.

The SOER recommended reinforcing desired operator behaviors as the means of resolving these human performance issues. While this is certainly appropriate, technology remains underutilized in the nuclear industry as a means to improve human performance, as well as to correct performance deficiencies. Other power generation and process control industries have demonstrated that technologies such as operator advisory systems can significantly enhance operator performance without supplanting their licensed role as ultimate decision-makers.

Similar human performance problems occur in nuclear plant field activities. This includes problems such as incorrect component identification, procedure use, and procedure adherence. The current approach to address this problem frequently employs human performance improvement techniques that add additional time and labor to the task. Current human performance improvement techniques may asymptote in their potential to reduce human error and its consequences since there is a practical limit to how far human performance issues can be dealt with through additional human performance.

This research program investigates a variety of ways that technology may enhance human performance. It has already demonstrated that digital technology is well-suited to help workers maintain situational awareness of plant conditions, and is effective in verifying that field work activities are appropriately conducted on the correct components. Technology can also alleviate the need for independent verifications in some situations due to the highly reliable confirmations that can be obtained with advanced digital capabilities (e.g., knowledge of plant mode and configuration, bar code readers, etc.).

These efforts are coordinated with relevant stakeholders to ensure their relevance and adoption to maximize benefits and deliver value from federal R&D and private investments.

This R&D initiative engages relevant stakeholders to plan and execute the appropriate R&D activities needed to create a sustainable and efficient plant technology base for operating organizations. It is a public-private partnership with each party making in-kind contributions through R&D, engineering, infrastructure, investments, and finances to address common issues and needs.

A Utility Working Group, currently comprised of 13 nuclear operating companies, provides a forum for utility input regarding issues and priorities related to II&C technologies. It also serves as a means for utilities to participate in the pilot projects when there is a match between their own performance improvement needs and the objectives of the research program.

The Electric Power Research Institute participates in the research program in a jointly coordinated and collaborative research role. EPRI technical experts directly participate in the formulation of the project technical plans and in the review of the pilot project results, bringing to bear the accumulated knowledge from their own research projects and collaborations with nuclear utilities.

The LWR fleet coordinates with other major industry support groups such as the Institute of Nuclear Power Operations (INPO), the Nuclear Energy Institute (NEI), and the Nuclear Information Technology Strategic Leadership (NITSL). All of these organizations have active efforts in the I&C area related to operational standards of excellence, regulatory initiatives, IT infrastructure, and cyber security.

Periodic meetings are held with both DOE and NRC to exchange information regarding research plans and activities of each of the respective organizations. Industry conference, workshops, and technical meetings also serve as important vehicles for information exchange and communication of the research program developments to the industry at large. Likewise, direct discussions with major nuclear industry suppliers ensure that there will be a viable technology transfer path from research results to solid commercial product offerings.

Altogether, these partnerships and collaborations ensure that the II&C R&D program focuses on those capabilities that are needed to position nuclear power assets to remain a safe and viable source of long-term electricity. By coordinating with relevant stakeholders who play vital roles in the nuclear power industry, the investments in R&D are targeting issues and priorities incrementally. This improves the chances that individual utilities can apply the results of individual pilot projects – technologies and methods for their successful introduction – to address challenges of aging II&C technologies at their own sites.