Human-Centered Design of Systems to Enable Integrated Operations for Nuclear

Larry J. Hettinger, PhD
Lawrence J. Hettinger PhD, LLC,

Jeffrey C. Joe
Plant Modernization Pathway

One objective of the LWRS Program is to develop innovative technical and organizational approaches to promote the sustainability of nuclear energy as an economically viable source of clean energy. In support of this objective, the concept of Integrated Operations for Nuclear (ION) is an initiative being pursued in conjunction with the nuclear industry to develop effective, integrated technical and organizational solutions to emerging socio-economic challenges in the industry.

The nuclear power industry is looking for ways to take advantage of current and emerging technologies to reduce operations and maintenance (O&M) costs while maintaining or improving safety and performance. These technologies (e.g., AI, robotics, augmented reality) will significantly reduce the O&M costs associated with many tasks at nuclear power plants. The introduction of new and emerging technologies must be done systematically within the context of organizational systems. Changes in technology and related changes in organizational structure and performance are inextricably intertwined. The goal of ION is to help manage this process in an efficient, scientifically valid manner.

Partnering with the industry is an important means of grounding scientific research in the realities of existing and planned systems. During 2021, LWRS Program researchers, at Idaho National Laboratory, collaborated with Xcel Energy on the design and selection of advanced technologies to support two separate sociotechnical areas of concern. These included: (1) the design of a set of prototype human-computer interface displays to support the reduction of human workload associated with the preparation, conduct, and follow-up of management review meetings; and (2) the identification of potential commercial-off-the-shelf (COTS) systems to support the safe and effective performance of maintenance activities, particularly those taking place within irradiated spaces.

As seen in Figure 6, each of these efforts, or use-cases, involved the application of analysis and design approaches focused on the joint optimization of safety, efficiency, and effectiveness across people, technology, processes, and governance through knowledge representation, knowledge elicitation, and cross-functional integration. Generally referred to as 'sociotechnical' methods, these techniques incorporate the design principles summarized above through an emphasis on user-centered design and the application of a set of analytic tools derived from systems engineering, human factors engineering, cognitive engineering, and other related domains. Each use case provided the opportunity to assess the effectiveness of sociotechnical methods in helping to establish and achieve nuclear power plant design objectives, while also assisting Xcel Energy in achieving its own design and cost-savings objectives.

There were two common themes underlying each use case. This first concerned the team's focus on the sociotechnical implications of introducing novel technologies into current and future organizational systems, while the second emphasized the importance of user-centered design. Sociotechnical concerns primarily involve accounting for the impact of new technologies on the structure and function of existing and future organizational structures, with the goal of developing both in a coordinated, synchronous manner. User-centered design is an approach to the design of these novel technologies that emphasizes the importance of including representative end-users in all stages of system development and integration. Now commonly used in industry and government, user-centered design helps to reduce risks associated with problems such as attempting to introduce technical systems that do not address user needs, do not support performance objectives, and/or are poorly usable.

In the first use case, the LWRS Program, Xcel team collaborated on the design of a set of prototype human-computer interfaces intended to facilitate management-level communications, decision-making, and other activities. The specific problem area the team selected involved reducing the amount of human workload associated with management review meetings, while improving related efficiencies and performance. The

amount of human workload that goes into preparing for, conducting, and following up on actions from management review meetings can be enormous, typically regarding data collection, reduction, analysis, preparation and presentation of the findings, and assignment and tracking of the actions. Given that no acceptable COTS systems currently exist supporting these goals, the team focused on developing a novel system of its own. These efforts resulted in a set of prototype human-computer interfaces whose development will continue throughout 2022, culminating in a proof-of-concept assessment and requirements documentation.

The second use case focused on the identification of current and emerging COTS technologies whose integration with maintenance activities, particularly those in irradiated spaces, could help reduce O&M costs while enhancing overall safety and performance. COTS solutions were examined in this use case because of their increasing, successful use in other current industrial settings. Following a detailed analysis of current technical, personnel, and procedural requirements, the team identified specific sets of tasks that might benefit most from the integration of technologies such as robots, drones, virtual and augmented reality, wear sensors, and computers. This was followed up by discussions with vendors of systems of these types to gain further specificity on their performance characteristics and suitability for supporting the desired tasks. These efforts culminated in the team's presentation in 2022 to Xcel leadership of existing and emerging systems that could potentially support their economic and performance goals.

The overall process and its outcomes were well received by Xcel Energy, which demonstrated the utility of sociotechnical methods in nuclear power plant systems design efforts. Further details can be found in the report, titled, Nuclear Work Function Innovation Tool Set Development for Performance Improvement and Human Systems Integration, INL/EXT-21-64428. The LWRS Program looks forward to continuing this partnership and generating useful findings and approaches for the industry.

Figure 6. Joint optimization of safety, efficiency, and effectiveness through knowledge representation, knowledge elicitation, and cross-functional integration.