

# Plant Modernization Pathway: FY 2019 External Review Summary Report

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November 2018



U.S. Department of Energy  
Office of Nuclear Energy

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**November 2018**

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## ABSTRACT

This report describes an external review conducted by the Light Water Reactor Sustainability Program Plant Modernization Pathway (referred to as Pathway) to solicit feedback on the topics and results of the ongoing Instrumentation and Control (I&C) research program. This review was held in conjunction with the Nuclear Energy Institute (NEI) Digital I&C Working Group meeting that was held at Idaho National Laboratory on October 16–17, 2018. Members of the Nuclear Regulatory Commission (NRC) staff working on digital I&C issues through their Integrated Action Plan also attended. The NEI and NRC agreed that the meeting participants would serve as an external review panel for the purpose of obtaining expert input on the value and timing of the research projects. Five major research areas were presented, along with demonstrations of new technologies in the Human Systems Simulation Laboratory and the Computer-Assisted Virtual Environment.

Following the presentations, the external review was conducted by referring to a set of summary slides of the five research areas, and allowing each participant to enter ratings and comments on a survey form as each area was addressed. Fourteen forms were returned. These feedback forms were analyzed by the Pathway who compiled and responded to the data and comments, which are documented in this report. The participants also had opportunity to provide comments on the LWRS Program as a whole and to suggest additional research topics of value.

The feedback provided by the external review participants is taken to be a strong endorsement of the types of projects being conducted by the Pathway, the value they hold for the operating nuclear plants, and the general timing of need. The feedback aligns well with the priorities, levels of efforts allocated for the research projects, and project schedules of the current Pathway research program. The feedback also provides realistic observations on the practicality of some aspects of implementing these technologies.

The Pathway will consider all of the feedback and address the recommended research topics that have been identified by the external review participants. Pathway research plans will be adjusted as warranted.



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## ACRONYMS

|      |                                    |
|------|------------------------------------|
| CCF  | common cause failure               |
| CDM  | Compact Digital Modernization      |
| DOE  | Department of Energy               |
| EPRI | Electric Power Research Institute  |
| HFE  | human factors engineering          |
| HSI  | human-system interface             |
| HSSL | Human System Simulation Laboratory |
| INL  | Idaho National Laboratory          |
| ITS  | information technology system      |
| I&C  | instrumentation and control        |
| LWR  | Light Water Reactor                |
| LWRS | Light Water Reactor Sustainability |
| NEI  | Nuclear Energy Institute           |
| NRC  | Nuclear Regulatory Commission      |
| NRR  | Nuclear Reactor Regulation         |
| O&M  | operating and maintenance          |
| PRA  | probabilistic risk assessment      |
| RISA | Risk-Informed Safety Analysis      |
| R&D  | research and development           |
| VDU  | video display unit                 |



# Plant Modernization Pathway: FY 2019 External Review Summary Report

## 1. INTRODUCTION

This report describes an external review conducted by the Light Water Reactor Sustainability (LWRS) Program Plant Modernization Pathway (referred to as Pathway) to solicit feedback on the topics and results of the ongoing Instrumentation and Control (I&C) research program. This review was held in conjunction with the Nuclear Energy Institute (NEI) Digital I&C Working Group meeting that was held at Idaho National Laboratory (INL) on October 16–17, 2018. Members of the Nuclear Regulatory Commission (NRC) staff working on digital I&C issues also attended. The NEI and NRC agreed that the meeting participants would serve as an external review panel for the purpose of obtaining expert input on the value and timing of the research projects. Five major research areas were presented, along with demonstrations of new technologies in the Human Systems Simulation Laboratory (HSSL) and the Computer-Assisted Virtual Environment (CAVE).

Following the presentations, the external review was conducted by referring to a set of summary slides of the five research areas, and allowing each participant to enter ratings and comments on a survey form as each area was addressed. Fourteen forms were returned. The feedback forms were analyzed by the Pathway to compile and respond to the data and comments, which are documented in this report. The participants also had opportunity to provide comments on the LWRS Program as a whole, and to suggest additional research topics of value.

This report first provides a description of the Pathway research activities and the research facilities that it uses to conduct the research. It then describes how the external review was conducted, presents the ratings of the participants on the value and timing of each of the five research areas, and provides the Pathway's response to the feedback for each of the areas. In addition, the report provides statistical analysis of the data, presents feedback on the overall LWRS Program, and presents the additional research topics of interest suggested by the industry and NRC participants.

## 2. PLANT MODERNIZATION PATHWAY RESEARCH ACTIVITIES

The Pathway conducts targeted research and development (R&D) to address aging and reliability concerns with the legacy instrumentation and control and related information systems, as well as the related operational processes, of the U.S. operating LWR fleet [1]. This work involves two major goals:

1. To develop transformative digital technologies for nuclear plant modernization that renew the technology base for extended operating life beyond 60 years.
2. To enable implementation of these technologies in a manner that results in broad innovation and business improvement in the nuclear plant operating model, thereby lowering operating costs.

New value from I&C technologies is possible if they are integrated with work processes directly. Therefore, the new technologies of the Pathway are founded on a seamless digital environment for plant operations and support by integrating information from plant systems with plant processes for workers through an array of interconnected technologies [2]:

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

A strategy was developed to transform the nuclear power plant operating model by first defining a future state of plant operations and enabled by advanced technologies and then developing and demonstrating the needed technologies to individually transform plant work activities. The collective work activities are grouped into the following major areas of enabling capabilities:

1. Instrumentation and Control Architecture
2. Monitoring and Plant Automation
3. Advanced Applications and Process Automation.

In each of these areas, a series of pilot projects are being conducted that enable the development and deployment of new I&C technologies in existing nuclear power plants. A pilot project is an individual R&D project that is part of a larger strategy needed to achieve modernization according to a plan. Note that pilot projects have value on their own, as well as collectively. A pilot project is small enough to be undertaken by a single utility, demonstrating a key technology or outcome required to achieve success in the higher strategy, and supporting scaling that can be replicated and used by other 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 pathway serve as stepping stones to achieve longer-term nuclear plant modernization. These projects 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 pathway 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.

For the purposes of this external review, the I&C architecture was presented as two research areas: Control Room Modernization and I&C Modernization. The second and third area were presented as stated above. A research topic on I&C system risk margin being conducted by the Risk-Informed Safety Analysis (RISA) Pathway of the LWRS Program was presented as a fifth research area.

### **3. PLANT MODERNIZATION PATHWAY RESEARCH FACILITIES**

This Pathway research is mainly being conducted in the Department of Energy's (DOE) HSSL located at INL. The HSSL has two reconfigurable simulators for this work. One takes the form of the conventional nuclear plant control room using a broad line-up of control bench boards and vertical panels. The other is in the form of a fully digital control room typical of Generation 3 plants, using compact operator consoles in front of a large wall panel of plant overview information.

The HSSL at INL is used to conduct research in the design and evaluation of hybrid control rooms, integration of control room systems, development and piloting of human centered design activities with operating crews, and visualizations of different end state operational concepts. This advanced facility supports human factors research for operating nuclear plant control rooms, including human in the loop performance and human system interfaces, and can incorporate mixtures of analog and digital hybrid displays and controls. It is applicable to the development and evaluation of control systems and displays of NPP control rooms, and other command and control systems.

The simulator consists of 15 bench board-style touch panels that respond to touch gestures similar to the control devices in an actual control room (see Figure 1). The simulator is able to run actual LWR plant simulation software used for operator training and other purposes. It is reconfigurable in the sense that the simulator can be easily switched to the software and control board images of different LWR plants, thus making it a universal testbed for the LWR fleet.



Figure 1. Department of Energy's Human System Simulation Laboratory reconfigurable simulator for conventional control rooms.

Three dimensional modeling software is used to create accurate models of the baseline and end state concepts for the control rooms [3]. These models depict both the physical arrangement of the rooms and control panels, as well as the devices on the control boards. This includes details right down to the size and font of the text on component labels. Because the models are dimensionally accurate, they serve as a basis for verifying the human factors principles that apply to control room design. For example, these models can verify that text sizes are adequate for viewing by the operators from a prescribed distance.

Using these models, human factors engineering (HFE)

Evaluations are conducted to ensure that the end state concepts, including interim configurations, conform to human factors requirements, especially those described in NRC review guidance, such as NUREG 0700. Operator figures are placed in the models to represent the range of human attributes (height, eye sight, reach, peripheral vision, etc.) that are of interest in validating the suitability of the operating environment.

The CAVE is a virtual reality facility that allows researchers to literally walk into their data and examine it from various angles [3]. With the help of specialized goggles and a handheld controller, the user is able to step into the CAVE and manipulate the data. The system is designed to track the movement of the user's head and the controller so the images can react accordingly.

The CAVE will be used to create a three-dimensional (3-D) projection of the baseline and end state concepts for the PVNGS control room modernization project. This will include interim stages so plant staff can visualize the interim and final configurations of the control room, allowing them to virtually "step into" the end state concept to gain a realistic sense of what it will be like to be in the modernized control room.

The external review team was provided a full tour of the facilities to gain an understanding of how the research is conducted and to have a demonstration of the science-based methods and tools that are used in the research (Figure 2).



Figure 2. NEI-NRC tour of the LWRS Program research facilities at INL.

#### **4. CONDUCT OF THE EXTERNAL REVIEW**

The external review was conducted as the last activity on the first day see Figure 3, following presentations on the five research areas of the Pathway research LWRS Program, the Pathway research activities, and the RISA Pathway. The agenda for the meeting is found in Appendix A.



Figure 3. NEI-NRC meeting at INL serving as the external review.

A feedback form was given to each of the participants to fill out as a group (Appendix A). A summary slide of each research areas was displayed and discussed as it was addressed by the panel, as a reminder of what had been presented and which technologies were in each of the five research areas. The feedback forms were collected during the meeting and analyzed following the meeting.

#### **5. EXTERNAL REVIEW OF PLANT MODERNIZATION TECHNOLOGY AREAS**

The following sections present the data and comments for the following five research areas as provided in the feedback forms received from the participants in the external review.

1. Control Room Modernization
2. I&C Modernization

3. Risk-Informed Methods
4. Online Monitoring and Plant Automation
5. Advanced Applications and Process Automation.

For each research area, a description is first provided of the technology and motivation for development. This is followed by a summary of the external review feedback for both the value and time frame ratings. Then the II&C Pathway response to the feedback is provided, addressing the comments, concerns, and suggestions.

The participant’s value and time frame ratings (and rating averages) are found in Appendix C. The comments from the participants on each of the research areas are found in Appendix D.

## 5.1 Control Room Modernization

The Pathway is conducting leading research on control room modernization, focusing specifically on HFE for fully digital control rooms and the integration of the plant digital I&C systems into the operator human-system interface (HSI). Utility partners in control room human factors research include Southern California Edison, Duke Energy, Arizona Public Service, Exelon Nuclear, Southern Nuclear, and Dominion Energy. This research is focused on:

1. Evaluating the impact of control room modernization on human-system performance
2. Establishing the technical basis for upgrade decisions.

The project work for fiscal year (FY) 2019 builds on previous developments new concepts for both hybrid (mixture of analog and digital) and fully digital control rooms. This includes use of task-based displays to improve operator accuracy and efficiency. It also addresses the implementation of digital technology to address obsolescence and reliability issues for the analog control devices.

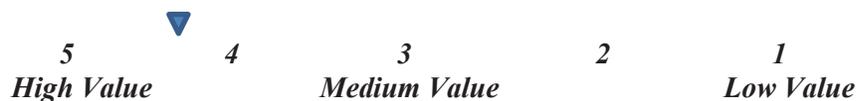
New work is centered on advanced alarm management systems and the introduction of large overview displays in the control rooms into the control rooms. Future work will introduce computer-based procedures and computerized operator support systems in the control rooms.

A key element of the research approach of the Pathway is the objective measurement of operator performance, comparing the new control room technologies to the baseline of the current control rooms. This is accomplished by installing the plant training simulator software in the HSSL and then modifying the HSI to reflect the use of the new technologies. Then direct comparisons can be made using a variety of measurement tools and methods to measure actual performance.

Another key element of the research method has been the development of a crosswalk between the HFE methods that are used and the NRC regulatory guidance for human factors, notably NUREG-0711, HFE Program Review Model, and NUREG-0700, “Human-System Interface Design Guidelines.” This ensures that all regulatory considerations are covered in the HFE activities.

### 5.1.1 Summary of External Review Feedback and Ratings

*Value Rating = 4.2*



With a rating of 4.2, the control room modernization research is rated in the external review as the second highest area in value. From the industry side, the importance of this area was linked to the viability of the nuclear power industry in the longer term. That is, modernization is needed not only to

address growing obsolescence and reliability issues with the legacy I&C systems, but also to enable new operational efficiencies that lead to lower operating costs. Otherwise, much of the operating nuclear plants will not be able to compete on the cost of generation going forward. The industry recognized the value of the HFE expertise involved in the research activities, noting that this depth of expertise exceeds that which utilities typically have. During the course of the tours of the research facilities, it was noted by the industry representatives that the objective measurement of operator performance using advanced digital technologies was very valuable in demonstrating benefits within the operating utilities as well as demonstrating regulatory compliance.

Key industry takeaways include the thought that many utilities might not be capable of undertaking control room upgrades on their own. This points to the need for a comprehensive industry approach that uses a set of first-mover utilities that are willing to take on the initial challenges of developing a comprehensive control room concept, the business case for such, an effective regulatory approach, and finally a sound implementation plan. Then, on the basis of that initial success, other utilities can follow suit, knowing that the risk has been greatly reduced and that investment costs are known and manageable.

From the NRC-side, it was noted that this review was very helpful in getting a clearer picture of where the industry is potentially going with control room modernization. Additional information was requested on the HFE methods. A number of technical issues were raised by the NRC participants, including a need to define the technical characteristics of the new control room technologies, concern on degraded systems providing incorrect information to the operators, susceptibility of operators to mode errors, the integration of different I&C platforms, and general questions on what features of a modernized control room are mandatory versus licensee choice. It was pointed out that discussions with the NRC Human Factors staff would be beneficial to both parties.

The key NRC-side takeaway is the need for more detailed discussions with the NRC on the concepts of control room modernization, the technologies being deployed, and the consideration of regulatory requirements.

***Time Frame Rating = 4.1***



Industry-side comments stressed the urgency of enabling control room modernization in the near-term. In fact, this is being pursued by some of the utility participants within their respective companies. The NRC-side noted that it was not their proper role to state a need date as this is an industry decision. There was general agreement during the course of the meeting that the research information being developed will be useful to the NRC at the time they are involved in any regulatory reviews for control room modernization. One NRC participant noted that the timing might be subject to the required time for operator training on a modernized control room.

The key takeaway is to make this a top priority in the research program, keeping pace with the first-mover utilities to be sure that the technical and regulatory aspects are addressed before they are a source of delay in implementation. Also, it was noted by one of the respondents to adequately factor in the effect on operator training in the implementation planning.

**5.1.2 Pathway Response**

The Pathway research plan is currently well-positioned to address this feedback. Control room modernization is a top research priority and has the highest level of funding of any FY 2019 Pathway project. The Pathway is pursuing an approach of enabling a set of first-mover utilities to work together to

address the elements of a control room modernization strategy and, this in turn, will enable other nuclear utilities to follow suit. The Pathway is also conducting this research as quickly as opportunity and resources permit, recognizing the urgency to provide technology and a technical basis for implementing it as soon as practical.

Regarding the technologies, it is noted that the important characteristics that relate to regulatory requirements must be identified. In fact, this is the point of the regulatory guidance crosswalk that has been developed. This perspective will be continued throughout the technology and concept development as more research is conducted.

Additional communications and meetings will be conducted with the NRC in the coming year to address the information needs, gain better insight into regulatory impacts of the proposed technologies, and exchange information on human factors regarding control room modernization.

## 5.2 I&C Modernization

The Pathway research in the area of I&C modernization was presented to the external review team. This has been focused on a highly integrated I&C architecture that addresses two critical requirements:

1. Accomplishes all design and licensing bases requirements (including beyond-design basis requirements)
2. Provides advanced features that enable substantial operating and maintenance (O&M) cost savings in terms of reduced initial capital investment cost, reduced testing and maintenance, reduced engineering support, and reduced life-cycle costs (e.g., spare parts).

The Pathway has developed a reference I&C architecture known the Compact Digital Modernization (CDM) [4], which was presented in the meeting and compared to a conventional control room typical of all operating plants today (Figure 4). The CDM is a complete plant-wide generic design that encompasses all safety and non-safety I&C systems of a nuclear plant, including HSI, and the interface to plant sensors and controlled plant components (e.g., pumps, valves, electrical breakers).

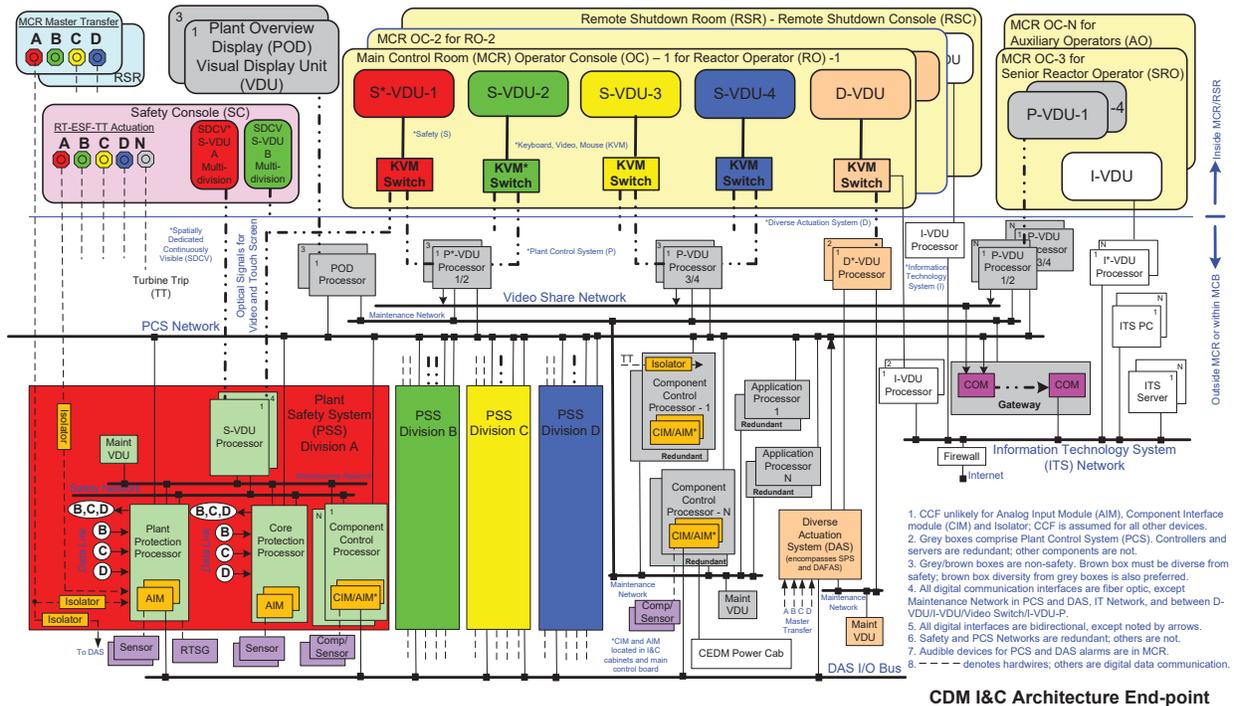


Figure 4. The Compact Digital Modernization I&C architecture.

The CDM is characterized by:

- A plant overview display that is the apex of the information hierarchy in the main control room. The plant overview display continuously displays the status of all critical power and safety functions, and the plant systems used to control those functions. It also displays all plant alarms including those corresponding to the critical functions and systems.
- Individual video display unit (VDU) - based workstations for each operator; in the CDM these are referred to as operator consoles. Each operator console allows each operator to access all plant information and controls for all plant systems (safety and non-safety), and all plant process computer and information technology system (ITS) applications, through selectable graphic displays.
- A very high level of I&C system integration, while maintaining sufficient segmentation to comply with safety criteria, including common cause failure (CCF) that can result from shared hardware resources and common designs.

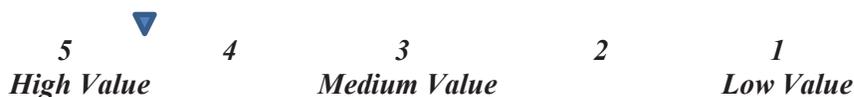
The technical features of the CDM were reviewed as to how they work and what benefits they enable. This included how field devices (instruments and control devices) are connected to the major platforms and how these interfaces can eliminate the need for a large population of existing field devices and associated cabling that are very expensive to test and maintain.

A migration path was also presented on how to take the control room and current I&C infrastructure from the present state to the fully modernized state. This is a step-wise approach that would allow the total transformation to be conducted within a series of normal-length refueling outages. A single-step implementation was also discussed.

The incorporation of the enabled benefits into a I&C modernization business case were also discussed. The major categories were reviewed and examples were shown from a previous control room modernization business case that estimated the resulting O&M savings.

### 5.2.1 Summary of External Review Feedback and Ratings

*Value Rating = 4.5*

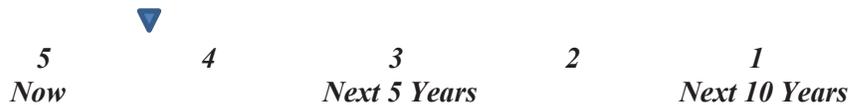


With a rating of 4.5, I&C modernization is the highest rated area in the external review in terms of value. Overall, the direction on I&C modernization was well-received by the meeting participants, with comments from the industry-side such as it is the only way ahead for nuclear power. Other feedback recognized the importance of a business case for I&C modernization. Also, it was noted that requirements development and gap analysis with respect to what is available to implement will be a key to utility adoption. A utility representative stated that this research was of high value, but also noted that this is crossing “political boundaries,” which is taken to mean that there are a lot of stakeholders and positions that need to be addressed beyond just the technical developments. Informing all nuclear power stakeholders of the necessity, means, and benefits of I&C modernization will continue to be a strong emphasis of the Pathway.

Feedback from the NRC-side noted that it was good to understand what the industry is facing. Also, it was stated that the industry needs to work with the NRC to identify possible regulation challenges and develop a path forward. One comment on the reference I&C architecture that was presented was to the effect that it demonstrates that this level of modernization is possible, and that there is a viable migration path from the configuration of the I&C systems today.

One issue expressed from the NRC-side is that the merging of signals and data sources will possibly create regulatory issues if the industry and NRC do not work together to resolve them in advance of an application. It was also mentioned that such a highly integrated architecture would need to be analyzed to be sure it meets all regulatory criteria for I&C systems. One NRC participant pointed out that the architecture needs to be simple to understand (e.g., how it meets the independence criterion). It was also stated that there should be consideration of standardization on the part of the industry. Finally, it was noted that the architecture must be able to address common cause failure.

***Time Frame Rating = 4.3***



I&C modernization received the highest score in regard to time frame of all the research areas. The industry noted that it must move quickly in view of the pressing needs for I&C modernization. Also, it was stated that obsolescence is going to force our hand and that we need to be proactive. It was noted that other countries have been modernizing their I&C systems for years.

From the NRC-side, it was again mentioned that it was not their role to address time frame, although scores on time frame from NRC members indicate that it is thought to be a near-term issue. One participant noted that new rules might be need to be made to approve the changes.

### **5.2.2 Pathway Response**

The Pathway agrees with the external review feedback in regard to the importance and urgency for I&C modernization. It is the “only way ahead” in the sense it is the single greatest enabler of O&M cost savings, while addressing the pressing issues of I&C obsolescence and reliability. The Pathway is pursuing the development of a requirements specification for the CDM I&C architecture as the next activity in this research. Also, along with other key industry organizations, the Pathway is pursuing a number of means of engaging the range of stakeholders, from the technical level to senior leadership, and across the spectrum of organizations—the nuclear operating companies, the regulator, the supplier community, and the industry support organizations. It is recognized that a consensus for I&C modernization must be built on a foundation of demonstrated technical capability, conformity to regulatory requirements, and a sound business case for this level of investment. And this must be achieved in the relative short-term to achieve the resulting cost savings in time to avoid premature shutdown of these operating plants.

It is the position of the Pathway that the CDM reference architecture meets all current I&C regulatory requirements and that there is no need for additional regulations or regulatory guidance relative to the CDM. However, it is recognized that not all of the features of the CDM have received regulatory review. It is a key part of the Pathway modernization strategy to work with the industry to address the regulatory conformance of the I&C architecture (CDM or alternative) and to obtain regulatory approval of the enabling features well ahead of any licensee submittal. The Pathway will continue to meet and communicate with the NRC to explore and clarify these issues.

In addition, the Pathway will promote the development of an industry-consensus I&C architecture so that a review of the general features of the architecture concepts by the NRC is possible. This would address the desired industry standardization to the degree possible. Thus, implementing utilities would possibly just undergo the review of the site-specific design and implementation features. Again, this will be coordinated with the utilities desiring to move forward with implementation so that the reviews are grounded in actual licensing actions.

## 5.3 Risk-Informed Methods

A presentation of the RISA Pathway was provided, highlighting the purpose and strategy of the risk-informed methods and tools being developed through this research. While this external review is focused on the Pathway, the work of the RISA Pathway in regard to digital I&C is highly complementary and was presented to solicit similar external feedback.

The RISA Pathway provides enhanced capabilities for analyzing and characterizing LWR systems performance by developing and demonstrating methods, tools, and data to enable risk-informed margins management. The purpose of the RISA Pathway R&D is to support plant owner-operator decisions with the aim to improve the economics, reliability, and maintain the high levels of safety of current nuclear power plants over periods of extended plant operations. The goals of the RISA Pathway are two-fold [1]:

1. To demonstrate risk-assessment methods coupled to safety margin quantification that can be used by decision-makers as a part of their margin recovery strategies;
2. To apply the “RISA toolkit” to enable more accurate representation of safety margins for the long-term benefit of nuclear assets.

A strategy to accomplish the above RISA Pathway goals employs the following:

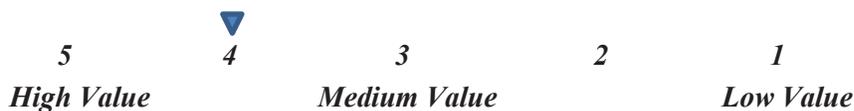
1. Conduct research to develop and demonstrate industry applications through Use Cases employing RISA methodology in collaboration with organizations from the U.S. commercial nuclear power industry.
2. Align the RISA Pathway Use Cases with existing RISA methods and tools capabilities.
3. Leverage demonstrations with individual U.S. plants to address gaps needed by the entire industry to demonstrate the use of risk-informed techniques to improve plant efficiency and increase confidence in their use through validation and further development of the RISA methodology.

The RISA Pathway has two primary goals to guide R&D activities. The first involves developing a set of tools and methods that can be used to develop the technical basis for plant safety margins and support their use in applications of risk-informed decision-making. These methods are under development and will be described in the RISA Pathway R&D Technical Program Plan, scheduled for completion in September 2018. The second focus area is on industry use case demonstrations using modern software and associated tools to quantify safety margins that can be used for commercial deployment. This set of tools, collectively known as the RISA Toolkit, will enable a risk analysis capability that currently does not exist, as well as to augment ones currently in use.

The presentation highlighted a proposed project on digital I&C risk assessment that will investigate the effects of CCF in view of certain plant design features (existing and new) that heretofore have not been considered in the safety analysis (and in some cases, cannot be because they are not safety-related components). The goal is to demonstrate that the outcome of a CCF might be considerably less concerning in view of these features. This, in turn, might beneficially impact CCF analysis, with such factors as demonstrating minimal increase in likelihood or effects of CCF, providing additional design margins to event consequences, or demonstrating reduced consequences of CCF events.

### 5.3.1 Summary of External Review Feedback and Ratings

*Value Rating = 4.0*



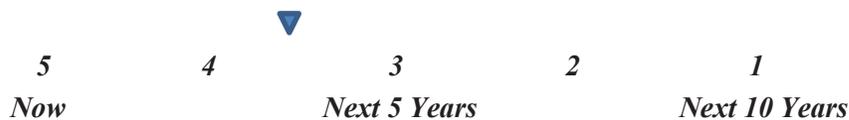
The overall rating is of generally high value at a score of 4.0. Interestingly, the industry related this somewhat lower (3.7) than the NRC (4.3). This might reflect the current direction of the NRC to expand risk-informed regulation.

On the industry-side, the feedback indicates a need for greater understanding of how risk-informed methods would complement the deterministic regulatory framework for I&C that they are dealing with now. One participant commented that a few examples are needed to show the value. Similarly, there was a comment that more information on the tool suite would be helpful. A utility participant noted that this research has high value, but that this approach has been used before to eliminate rather than optimize maintenance, with mixed results. Another participant commented that this might inform regulatory discussions, but it is not likely to happen soon, reflecting some skepticism as to whether risk-informed analysis will be permitted in regulatory reviews for digital I&C modernization.

On the NRC-side, it was noted that this topic should be discussed with the NRC Integrated Action Plan Team 4b Team [5], which is targeting a simpler and more streamlined I&C regulatory infrastructure. One NRC reviewer remarked that these kinds of approaches are already happening. Another asked for clarification as to whether the results of these analyses would be used just to inform the industry of the economic value of certain choices, or to pursue plant changes that would require regulatory approval.

Specifically on applying the methodologies to digital I&C, a NRC participant stated that clarity is needed on a dependency model of all I&C (not just safety-related) to assure that it adequately addresses digital behavior, failure modes, and failure propagation. This participant further stated that it is unclear how probabilities for digital will be established or otherwise used in the analysis. Similarly, another NRC participant suggested that research might be conducted to quantify the digital I&C risk, if possible. Finally, one NRC participant stated that it would be helpful to know which I&C components need more focus and attention.

***Time Frame Rating = 3.7***



A time frame rating of 3.7 indicates that most participants would like to see a risk-informed approach to I&C modernization in the relative near-term. However, one NRC participant stated that the time frame depends on how it is used. Another stated that this type of technology is essential for transformation of the NRC (apparently referring to the NRC stated direction of moving to risk-informed regulation).

### **5.3.2 Pathway Response**

The Pathway is now working with the RISA Pathway to employ these new risk-based tools in addressing digital I&C CCF. It is recognized that there needs to be a demonstration of feasibility and value to establish this as a viable new method of addressing certain technical and regulatory issues. Also, it is believed that these new methods can demonstrate that there are appreciable design margins that have not been quantified or credited in these types of deliberations, and that these margins can be used to show that the actual risk in use of digital systems is much less than what is currently assumed. In regard to time frame, the application of risk-informed methodologies to digital I&C is proceeding in the current fiscal year.

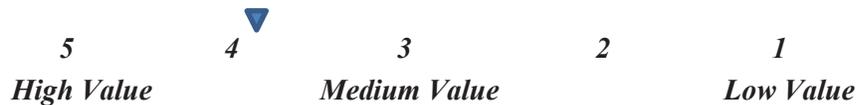
## 5.4 Online Monitoring and Plant Automation

The research area of Online Monitoring and Plant Automation was presented as an area of research that will enable operating plants to substantially shift to condition-based maintenance and automated plant support, thereby reducing labor requirements to an affordable and sustainable level. One new initiative is the Technology-Enabled Risk-informed Maintenance Strategy project, which is focused on reducing maintenance costs by integrating advancements in online monitoring technology and data analytics with advanced risk assessment methodologies to develop risk-informed condition-based maintenance strategy to enhance safety, reliability, and economics of operation of plant assets. Another initiative presented was the Advanced Remote Monitoring for Operation Readiness project, which will automate the labor intensive processes of monitoring plant operation at nuclear power plants. This will be achieved through enhanced monitoring for, and identification of, process anomalies. The result will be to reduce the number of plant workers gathering data, and instead focus the operations team on ensuring optimal plant performance.

The presentation also included technical discussions of current developments in concrete and secondary piping systems, being developed to detect and characterize degradation that might impair structural health and life of the asset. Centralized online monitoring capabilities will be expanded into more and more plant testing and surveillance applications as new sensors and analytical capabilities are developed and added to the existing based in use today. Many plant support functions currently performed manually will be replaced by online technologies that are integrated into plant work and risk management processes so that decisions and actions are performed more effectively.

### 5.4.1 Summary of External Review Feedback and Ratings

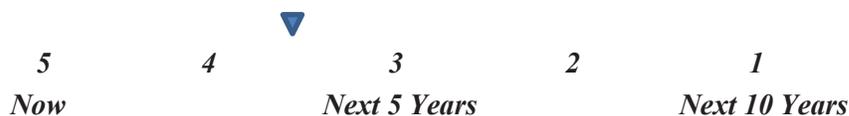
*Value Rating = 3.9*



This area of research was deemed very important by the industry. A supplier representative noted that it is one of the highest value areas we can exploit in the same manner as other industries (e.g. airlines) with great success. Other industry participants similarly endorsed the importance of automating plant work activities. One participant noted that there is much of this technology already available in commercial platforms. One other industry participant stated that this area of online monitoring and plant automation must go hand-in-hand with digital I&C modernization.

From the NRC-side, it was noted that this technology would be beneficial as a means of performing Technical Specification surveillance requirements. However, one participant stated that a justification be provided should any online monitoring or testing function be credited for surveillance requirements. Also, it must be explained how online monitoring data is interpreted. Another NRC participant noted that where this capability is credited for requirements, the faulted behavior of these technologies must be understood, and that nothing should be permitted to inhibit these functions. The benefits to safety should be demonstrated. Finally, it was recommended that the industry start using wireless loops so that the results can be compared with those coming from existing wired loops.

*Time Frame Rating = 3.5*



The overall time frame rating of 3.5 indicates that the external review team thought that this should be implemented in the relative near-term. However, the only comment received for this research area came from the NRC to the effect that it was not the regulators role to address the industry time frame of need.

#### **5.4.2 Pathway Response**

The Pathway recognizes the strategic importance of the industry moving to condition-based maintenance as a means of reducing O&M costs, as well as actually improving the availability and service life of plant components. It is also recognized that this has transition to condition-based maintenance has been successfully achieved in many other safety-critical industries, such as aviation and process industries. It is agreed that these kinds of technologies are available today in commercial platforms. However, the Pathway is not duplicating these capabilities, but rather building on them with more advanced monitoring capabilities that are not yet developed. A good example is the work being done in characterizing internal degradation in concrete, for which there are no commercially available solutions at this time of the type the Pathway is developing.

The Pathway will also support an industry regulatory strategy to address the issues raised by the NRC attendees, especially any needed justifications for where these technologies might be used to satisfy Technical Specification surveillance requirements. A scientific basis for interpreting the results is an integral part of this research. Also, it is understood that the technologies must have the highest reliability and have diagnostics that can detect any failures that would call into question the resulting monitoring data. Finally, the Pathway has plans to work with new wireless monitoring loops and will be able to compare the performance and resulting monitoring data to that which is obtained with conventional wired loops.

Regarding the time frame, the Pathway is pursuing the development of online monitoring and plant automation technologies as a high priority, recognizing the potential to help operating plants manage their operating costs in the near term. This is regarded as an opportunity to implement the technologies that are proven today, and then continually build up this capability with new monitoring technologies as they are validated. In this way, there will be a gradual and manageable transition from time-based maintenance to condition-based monitoring.

### **5.5 Advanced Applications and Process Automation**

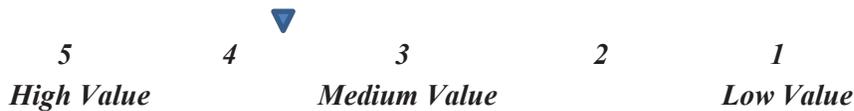
The Advanced Applications and Process Automation research area highlighted developments in the digital architecture for highly automated plants, automation of work processes, and new technologies for outage risk management. All of these areas rely on a seamless integration of digital information and new data analytics capabilities. The digital architecture will span all domains of plant operations and support activities, including the digital I&C systems. In this way, it will serve as a common information model supporting plant work activities while enabling improved decision making.

Building on previous Pathway development in Automated Work Packages, the current research activities are focused on more advanced process automation technologies that will make certain plant functions more efficient and accurate. One promising application is the use of near-field communications (blue tooth, RFID, etc.) to automate functions that plant workers today perform manually. An example would be automatic logging of items going into a foreign material exclusion zone. Other technologies to be developed for nuclear plant applications include use of computer vision and drones.

Finally, a number of analytic applications are being developed to better manage risk in outages, building on earlier work to make the execution of outages more efficient. These include new types of dashboards that can readily depict true work status and identify potential threats to the outage schedule. They can also detect undesired work interactions that might threaten nuclear safety or regulatory compliance. These will employ advanced information technologies such as natural language processing to be able to read plant documents in text form (procedures, status reports, material lists, etc.) and extract information relevant to work management activities.

### 5.5.1 Summary of External Review Feedback and Ratings

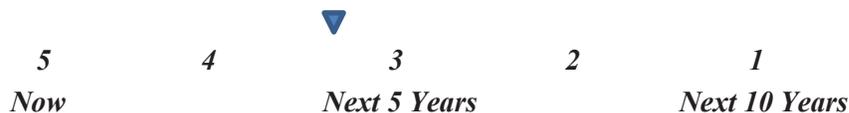
*Value Rating = 3.7*



External review feedback from the industry-side was that these new technologies look interesting and that they are opportunities for improved efficiency in nuclear plant work activities. A particular interest in the outage improvement technology was expressed. One supplier representative asked for a summary of the current technologies and initiatives, and stated that it would be beneficial for his company to discuss their technologies with the Pathway researchers.

An NRC participant noted that these technologies could simplify the operations process and reduce human error. It was noted that it wasn't clear what sort of applications of these technologies would require regulatory review and that would depend on what the licensees want to credit in their application. One NRC participant commented that the nuance between "plant" and "process" automation wasn't clear.

*Time Frame Rating = 3.3*



The time frame rating of 3.3 was the lowest score (meaning less urgent) of all the research areas, but still it represents the relative near term. The only comment was from the NRC again to the effect that it was not the regulator's role to address the industry need date. There was a comment from a utility representative that he was going to approach his management right away on engaging in the outage improvement technologies.

### 5.5.2 Pathway Response

The Pathway very much agrees that these classes of digital technologies are good opportunities to improve plant work efficiency and therefore are useful in reducing O&M costs. As requested, a summary of the technologies in each of these major research areas is being prepared and will be distributed to the meeting attendees as well as all industry stakeholders. Regarding direct discussions with the supplier company that mentioned this, these are already underway and will likewise be offered to any interested supplier.

Regarding the NRC feedback, consideration is being given to which work process technologies might require regulatory review, and the Pathway will support industry efforts in this regard. The Pathway takes note of the comment on the difference between "plant" and "process" automation and will clarify this in future communications.

Regarding the time frame, this research area is similar to the Online Monitoring and Plant Automation area, in that it is building on previous technology developments, and that new more-advanced capabilities will be added over time as operating plants implement those technologies that are proven to be successful.

## 6. ANALYSIS OF RATINGS DATA

Below are three Likert plots (more formally known as diverging stacked bar charts) displaying the NEI-NRC Survey Feedback Analysis data. The Likert plots show the proportion of total responses in each of the 5 possible response categories. In general, these plots depict the percentage of responses that are above, below, or in the mid-range of the scale. The vertical line at 0% on the x axis represents the neutral, or medium-value, category.

Likert plots make it easier to compare the perceived value held survey participants for the five primary research areas than other more typical data presentations such as tables or bar charts. Figure 5 depicts the Likert plot for the total responses to the surveys, meaning both industry and NRC feedback. The plot indicates strong endorsement for I&C modernization and control room modernization, both in value and time frame. The other areas reflect a broader range of opinion on these technology areas.

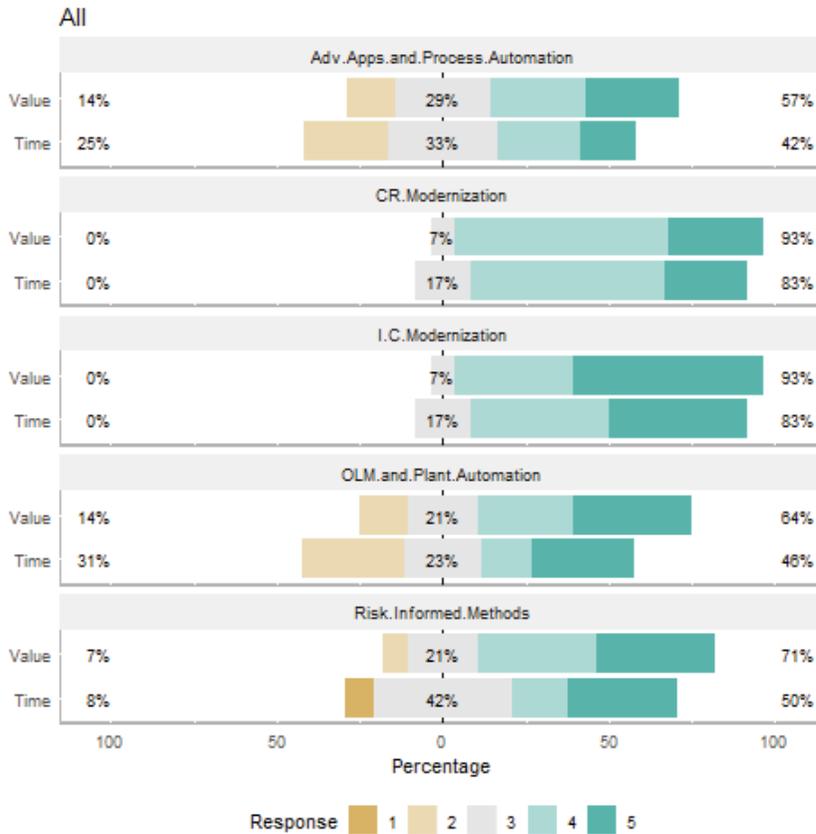


Figure 5. Likert plot for total survey response.

Figure 6 depicts just the industry responses. In this case, the advanced applications and Process Automation area joins the first two as high consensus on high value and time frame. In fact, all responses placed a medium or high value on Control Room Modernization, with a preferred time frame of less than 5 years. In comparison, the responses for Risk Informed methods indicated a wide-range of opinions on both the value and the time frame.

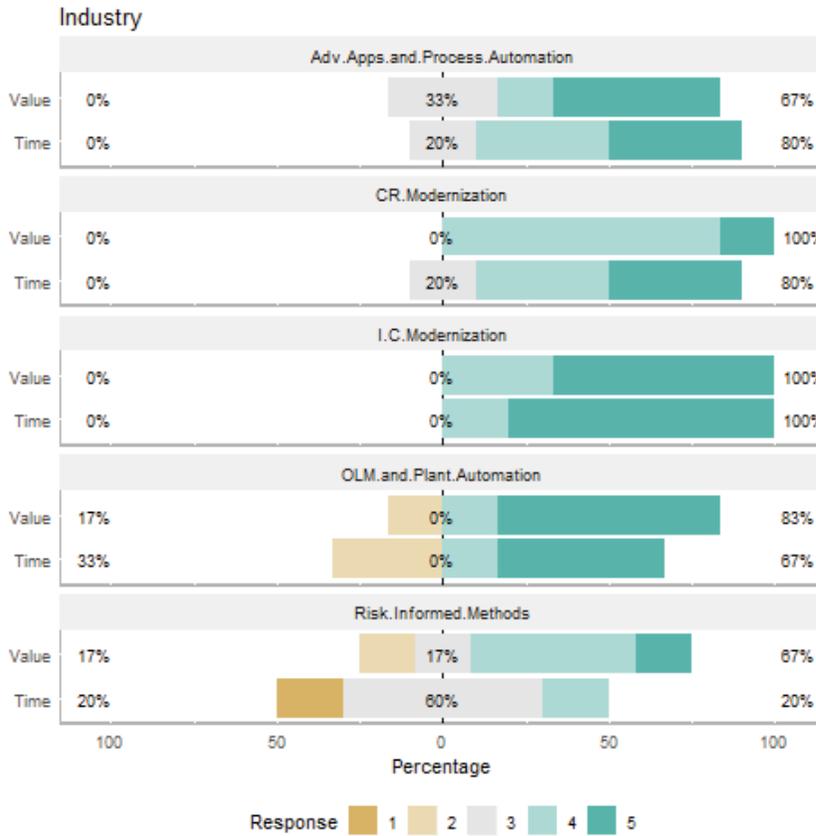


Figure 6. Likert plot for total survey response.

Figure 7 depicts just the NRC feedback. It is in agreement with the control room modernization and I&C modernization as tight consensus. However, rather than the Advanced Applications and Process Automation, it adds the Risk-Informed Methods as a third area of tight consensus. This is not surprising in that the NRC has stated a desire to move in the direction of risk-informed regulation.

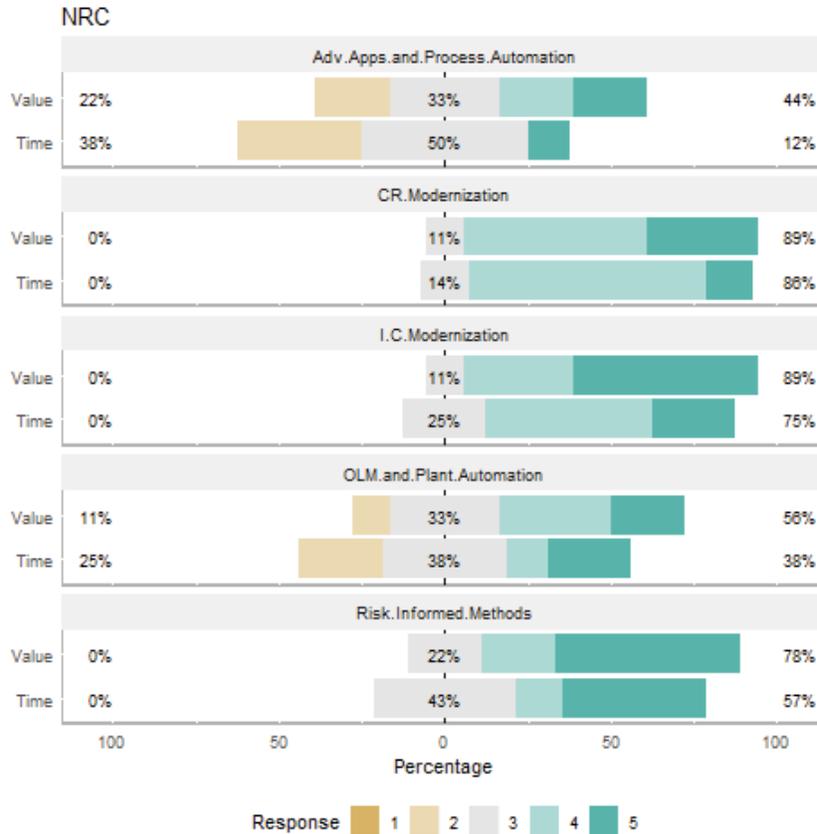


Figure 7. Likert plot for total survey response.

## 7. GENERAL COMMENTS ON PLANT MODERNIZATION PATHWAY RESEARCH PROGRAM

The external review survey form provided space for the attendees to offer general comments on the LWRS Program research that was presented during the meeting. Overall, the comments were very positive and a summary is presented in this section.

### 7.1 Industry Comments

Six comments were offered by the industry on the overall LWRS Program. A consistent theme in these comments is the need to work in concert with industry stakeholders. Specific points made by the industry are:

- This research is an urgent need, but needs to be done in concert with end users and industry stakeholders. There were several topics that overlap with other industry initiatives.
- Must interface with Electric Power Research Institute (EPRI) efforts and in coordination with industry efforts.
- Overall good program. Would be helpful to have more utility participation.
- Education is great. This is where technology transfer begins.
- Cybersecurity is going to have implications across the board and we are going to need to factor this into the larger landscape.

- It is important to interface with existing plant software platforms – makes adoption by the fleet more likely and more efficient.

## 7.2 NRC Comments

Six comments were also offered by the NRC on the overall LWRS Program. The feedback on the overall program from the NRC is generally directed towards the regulatory implications of the research. A consistent theme is the need for greater understanding of the technologies through additional dialogue. Along with that, the NRC indicated a willingness to address the industries priorities in plant modernization once they are identified. Specific points made by the NRC are:

- Overall, the NRC would need to understand the industry priorities for initiatives it wishes to explore. Then the NRC could prioritize its resources to support these activities.
- The technologies are technical sound and feasible, but the regulatory implications are not adequately addressed. It is recommended that the Pathway meet with NRR regularly to discuss potential regulatory challenges.
- It would be useful to identify specific technologies as examples of the classes of technologies or applications, ideally ones that will be used soon.
- It is important to identify what credit a licensee will take with these technologies.
- The term “risk assessment” needs to be identified or better defined. It means “PRA” in NRC, but LWRS also refers to some deterministic analysis.
- Not clear how Pathway really intends to address digital common cause failure:
  - Diverse Actuation System approach in the I&C architecture that was presented for protection function modernization (architecture constraint).
  - Risk-informed reliance in “probability” of failures, including efficacy of preventative/limiting measures.
  - Risk-informed analysis of presuming failure occurs.
  - Bounding non-safety integrated system effects so they don’t violate safety system design basis.

## 7.3 Pathway Response

Regarding the industry feedback on coordinating the research with the industry, as the meeting presentations pointed out, the Pathway has extensive involvement with nuclear utilities on all of the project areas. However, it is understood that the intent of the comment is to work closely with recent industry efforts in plant modernization. The Pathway has been engaged with NEI through the Digital I&C Working Group to address regulatory barriers to digital I&C modernization and with EPRI through the Memorandum of Understanding providing for joint research between the LWRS Program and the EPRI Long-Term Operation Program. More recently, the Pathway is participating in the EPRI Plant Modernization initiative that was begun in June 2018. Prior to that, the Pathway participated in an unsuccessful EPRI-led application for funding for full plant modernization under the 2017 DOE Funding Opportunity Announcement (DE-FOA-0001817) U.S. Industry Opportunities for Advanced Nuclear Technology Development. The Pathway will continue to cooperate with and support industry initiatives in plant modernization, directing research activities in a complementary manner. While there might be an appearance of program overlap in a broad sense of topical areas, it is not clear that there are actual overlaps in any specific technology developments. However, through the ongoing engagements with EPRI (meetings and regularly scheduled conference calls), any potential overlaps will be identified and resolved.

It is agreed that cybersecurity is a significant factor in use of digital technology for plant modernization. The Pathway has substantial research activity in this area to complement what the industry

is doing as well. Cybersecurity will continue to be a primary consideration in the formulation of these technologies. For example, the reference I&C architecture that was presented in the meeting is believed to be compliant with all regulatory requirements and good business practices for cybersecurity. Similarly, cybersecurity is an important part of the development of the plant-wide digital architecture, particularly in regard to wireless applications.

Regarding interface to existing digital platforms that might be used by operating plants, it is a key element of the Pathway's research plan to work with suppliers to incorporate a representative set of platforms into the HSSL reconfigurable simulator – either through hardware-in-the-loop or through virtualization of these platforms. The Pathway agrees that new digital technologies must be demonstrated to work in commercial platforms. Such discussions have been held with major platform suppliers and will be pursued as an industry-consensus I&C architecture is developed.

Regarding the NRC feedback, it is understood that increased communication on these emerging digital technologies is beneficial to all. Such meetings and other communications will be arranged in the coming year to address these information needs and to determine where there are regulatory issues to be resolved. One obvious example would be to conduct a detailed review of the reference I&C architecture and look at the potential regulatory implications of each element. From these discussions, insights would be obtained on what regulatory reviews might be needed and how they could be conducted so that there is no impact or delay to any future license amendment requests by first-mover utilities.

At the same time, the Pathway will continue to work with industry, largely through the NEI Digital I&C Working Group, to support the industry initiatives in addressing regulatory barriers to digital I&C modernization. It is recognized that the NRC wants to focus on topics and technologies that industry plans to actually implement and thereby prioritize the NRC resources in the most effective manner.

The Pathway will clarify the use of risk assessment in future communications to avoid any confusion with how the term is understood by the NRC. In addition, the specific points on the Pathway's addressing of CCF issues will be evaluated and incorporated into the I&C research plans where there is an appropriate role for a national laboratory.

## **8. RECOMMENDATIONS FOR ADDITIONAL RESEARCH TOPICS OF INTEREST**

The external review survey form provided a section in which participants could suggest topics for research that would be beneficial to plant modernization. The following is the list of topics, followed by a response from the Pathway.

### **8.1 Research Topics Submitted by Meeting Participants**

It is interesting to note that of the seven research topics that were submitted, five of them deal with digital I&C regulatory issues in one way or another. The other two concern the integration of digital I&C platforms in regard to combining component functions into a more simplified architecture or integrating components of the overall architecture when it involves multiple supplier platforms.

1. **Testability of Digital Systems.** NRC Branch Technical Position 7–19, Section 1.9 defines *testability* as the following: a system is sufficiently simple such that every possible combination of inputs and every possible sequence of device states are tested and all outputs are verified for every case (100% tested).
2. **Risk-Informed Pilot Study versus NRC Risk-Informed Regulatory Framework.** NRC formulates its risk-informed regulatory framework in Regulatory Guide 1.174. It would be beneficial to align this pilot with the Regulatory Guide 1.174 method.
3. **Common Cause Failure.** Research on how rare this is, technical basis on keeping it a beyond-design basis issue.

4. **Embedded Digital Devices.** Digital upgrades to a wide range of plant equipment from relays to power supplies to pumps. Some may just be for obsolescence, but others may offer substantially different capabilities.
5. **Interaction of Multiple Vendor Systems at a Plant.** The reality is multiple vendors will have their equipment installed and interfacing. There might be a need to look at that cross interaction.
6. **Consolidating Plant Computer Into Whole I&C System**
7. **Research Digital I&C Safety Topics:**
  - Diverse Actuation System approach in the I&C architecture that was presented for protection function modernization (architecture constraint).
  - Risk-informed reliance in “probability” of failures, including efficacy of preventative/limiting measures.
  - Risk-informed analysis of presuming failure occurs.
  - Bounding non-safety integrated system effects so they do not violate safety system design basis.

## **8.2 Pathway Response**

In regard to the “Testability of Digital Systems” suggested topic, research in this area is in fact being conducted within the Pathway at this time. This is being investigated as a means of addressing CCF, and so it actually addresses two of the suggested research topics. This project was mentioned during the meeting, but the initial work was not presented in that it is still being validated. Research in this area will continue as long as it shows promise in finding new and cost-effective means of qualifying digital I&C devices and systems for safety-related applications. Additional ideas on CCF are currently being explored as possible research projects in the near term. These ideas will be vetted with the industry and the NRC as to value in addressing CCF.

Regarding Embedded Digital Devices, research is underway on this topic a different DOE research program known as Nuclear Energy Enabling Technologies–Advanced Sensors and Instrumentation Pathway. These projects were not discussed in this meeting, but information will be provided on them. In addition, EPRI is conducting a project on qualification of systems and components (which would include embedded digital devices) based on IEC standards that rely on Software Integrity Level certifications. Beyond these, the Pathway will consider other projects that would be beneficial in qualifying embedded digital devices.

Finally, all other topics will be considered by the Pathway for inclusion in either current or future digital I&C projects as appropriate for national laboratory research.

## **9. SUMMARY**

In all, the feedback provided by the external review participants is taken to be a strong endorsement of the types of projects being conducted by the pathway, the value they hold for the nuclear plants, and the general timing of need. The feedback aligns well with the priorities, levels of efforts allocated for the research projects, and project schedules. This is not unexpected in that the Pathway has worked with utility partners, suppliers, and industry support groups throughout its history to gain a direct understanding of the needs and challenges facing the stations. Indeed, many meetings and discussions have been held with knowledgeable people in the industry, from chief nuclear officers, senior station managers, as well as the staff who conduct these related activities day-to-day.

That said, the pathway very much appreciates the insights and suggested improvements provided by the external review participants. The feedback represents realistic observations on the practicality of some aspects of implementing these technologies. In some cases, the participants provided thoughtful challenges to certain assumptions in the formulation of the technologies or in deployment plans. These deserve further review and revision of plans if warranted.

In summary, the external review has been a very valuable exercise for the Pathway, resulting in practical insights that will improve the focus of the research and enhance the value of the developing technologies to the benefit of the nuclear power industry. Again, the Pathway sincerely appreciates the willingness of the NEI Digital I&C Working Group and the NRC to serve in the role of the external review panel and for the efforts of those who provided their ratings, comments, and suggestions for additional research.

## 10. REFERENCES

- 
- [1] Light Water Reactor Sustainability Program Integrated Program Plan, INL/EXT-11-23452 Revision 6, Idaho National Laboratory, 2015P
  - [2] Lybeck, N., Thomas, K., Plant Modernization Technical Program Plan for FY 2019, INL/EXT 13 28055
  - [3] Thomas, K., First of a Kind Control Room Modernization Project Plan, INL/EXT-16-38026, Idaho National Laboratory, 2016
  - [4] Thomas, K., Scarola, K., Strategy for Implementation of Safety Related Digital I&C Systems, INL/EXT 18 45683, Idaho National Laboratory, 2018
  - [5] Nuclear Regulatory Commission, Integrated Action Plan to Modernize Digital Instrumentation and Controls Regulatory Infrastructure, Revision 1, ML17102B307, March, 2017

**Appendix A**  
**Meeting Agenda**



# Appendix A

## Meeting Agenda



### NEI-NRC Meeting Idaho National Laboratory October 16-17, 2018

**Tuesday, October 16, 2018**

**Energy Innovation Laboratory (EIL) Meeting Center, 775 University Blvd, Idaho Falls, ID  
(Rooms A110-A114)**

| Time       | Subject   | Speaker                  |
|------------|---|--------------------------|
| 7:30 a.m.  | Badging – Willow Creek Building<br>1995 Fremont Avenue, Idaho Falls, ID | C. Primer                |
| 8:00 a.m.  | Welcome and Meeting Purpose   | B. Hallbert              |
| 8:15 a.m.  | LWRS/Plant Modernization Overview                                       | B. Hallbert, C<br>Primer |
| 9:00 a.m.  | Control Room Modernization Overview                                     | J. Joe                   |
| 10:00 a.m. | Break   |                          |
| 10:15 a.m. | I&C Modernization/Business Case   | K. Thomas                |
| 11:15 a.m. | Risk-Informed Methods for CCF   | R. Szilard               |
| 12:15 p.m. | Working Lunch – Regulatory Implications for LWRS Research               | K. Thomas                |
| 1:00 p.m.  | On-Line Monitoring and Plant Automation                                 | V. Agarwal               |
| 2:00 p.m.  | Advanced Applications and Process Automation                            | S. St.Germain            |
| 3:00 p.m.  | Break   |                          |
| 3:15 p.m.  | Plant Modernization Research Plan/Feedback                              | K. Thomas                |
| 5:00 p.m.  | Adjourn   |                          |
| 6:00 p.m.  | No-Host Dinner – Location/Address TBD                                   |                          |



## NEI-NRC Meeting Idaho National Laboratory October 16-17, 2018

**Wednesday, October 17, 2018**

**Energy Innovation Laboratory Meeting (EIL) Center, 775 University Blvd, Idaho Falls, ID (Room C203)**

| Time       | Subject  | Speaker         |
|------------|--|-----------------|
| 8:00 a.m.  | Mobile Worker and Plant Technologies                                     | K. Thomas       |
| 9:00 a.m.  | Control Room Simulator – Hands-On Demos                                  | R. Hill, J. Joe |
| 10:00 a.m. | Tour of Computer Assisted Virtual Environment (CAVE) for Control Room VR | R. Hill         |
| 11:00 a.m. | Prepare for Site Tour – Pick up box lunch                                | K. Thomas       |
| 11:30 a.m. | Depart EIL / Working Lunch (Box lunch on bus)                            |                 |
|            | EBR-I Historic Site  |                 |
|            | Advanced Test Reactor  |                 |
|            | Materials & Fuels Complex (Hot Cells)                                    |                 |
| 5:30 p.m.  | Arrive at EIL - Adjourn  |                 |

**Appendix B**  
**Meeting Attendance**



# Appendix B

## Meeting Attendance



### NEI-NRC Meeting Idaho National Laboratory October 16-17, 2018

#### Energy Innovation Laboratory (EIL) Meeting Center, 775 University Blvd, Idaho Falls, ID

|                |             |                             |
|----------------|-------------|-----------------------------|
| Steele         | Fred        | Energy Northwest            |
| King           | Ronald      | EPRI                        |
| Connelly       | John        | Exelon                      |
| Howard         | Angie       | Howard – Johnson Associates |
| Agarwal        | Vivek       | INL                         |
| Barnard        | Cathy       | INL                         |
| Cleifton       | Gordon      | INL                         |
| Hallbert       | Bruce       | INL                         |
| Hill           | Rachael     | INL                         |
| Joe            | Jeffrey     | INL                         |
| Krynicky       | Teresa      | INL                         |
| Primer         | Craig       | INL                         |
| Spielman       | Zachary     | INL                         |
| St. Germain    | Shawn       | INL                         |
| Szillard       | Ronaldo     | INL                         |
| Thomas         | Ken         | INL                         |
| Ulrich         | Thomas      | INL                         |
| Anderson       | Victoria    | Nuclear Energy Institute    |
| Remer          | Jason       | Nuclear Energy Institute    |
| Rosko          | William     | Rolls-Royce                 |
| Hahn           | Alison      | U. S. DOE -NE5              |
| Akhavannik     | Huda        | U. S. NRC                   |
| Ashcraft       | Joseph      | U. S. NRC                   |
| Basturescu     | Sergiu      | U. S. NRC                   |
| Benner         | Eric        | U. S. NRC                   |
| Dittman        | Bernard     | U. S. NRC                   |
| Halverson      | Derek       | U. S. NRC                   |
| Kalathiveettil | Dawnmathews | U. S. NRC                   |
| Li             | Ming        | U. S. NRC                   |
| Zhao           | Jack        | U. S. NRC                   |



**NEI-NRC Meeting (Tour)  
Idaho National Laboratory  
October 17, 2018**

**INL Site Tour – EBR-1 Historic Site, Adv. Test Reactor, Materials & Fuels Complex (Hot Cells)**

|                |             |                          |
|----------------|-------------|--------------------------|
| Steele         | Fred        | Energy Northwest         |
| Steele         | Phyllis     | Energy Northwest         |
| King           | Ronald      | EPRI                     |
| Connelly       | John        | Exelon                   |
| Cleifton       | Gordon      | INL                      |
| Thomas         | Ken         | INL                      |
| Weeks          | Ryan        | INL                      |
| Remer          | Jason       | Nuclear Energy Institute |
| Rosko          | William     | Rolls-Royce              |
| Akhavannik     | Huda        | U.S. NRC                 |
| Ashcraft       | Joseph      | U.S. NRC                 |
| Basturescu     | Sergiu      | U.S. NRC                 |
| Benner         | Eric        | U.S. NRC                 |
| Dittman        | Bernard     | U.S. NRC                 |
| Halverson      | Derek       | U.S. NRC                 |
| Kalathiveettil | Dawnmathews | U.S. NRC                 |
| Li             | Ming        | U.S. NRC                 |
| Zhao           | Jack        | U.S. NRC                 |

**Appendix C**  
**External Review Survey Form**



# Appendix C

## External Review Survey Form

DOE Light Water Reactor Sustainability (LWRS) Program  
Plant Modernization Pathway

NEI-NRC Joint Meeting at INL – Program Feedback  
October 16, 2018

Please provide feedback on the current research areas based on the needs and priorities of the current nuclear operating fleet.

Name (optional): \_\_\_\_\_

Organization (optional): \_\_\_\_\_

Organization Type:

Utility \_\_\_ Industry Support Organization \_\_\_ Supplier \_\_\_ NRC \_\_\_ Other \_\_\_  
(Check One)

Perspectives:

For industry, please respond from the perspective of how this research and development will contribute to modernization of nuclear plant I&C infrastructure and resultant O&M cost savings.

For the NRC, please respond from the perspective of how this research and development will inform the staff of key characteristics and technical considerations of these technologies.

### Control Room Modernization

Value: (Circle one)

5            4            3            2            1  
High Value                      Medium Value                      Low Value

Comments:

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**Timeframe of Need:** (Circle One)

5            4            3            2            1

Now

Next 5 Years

Next 10 Years

Comments:

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## **I&C Modernization**

**Value:** (Circle one)

5            4            3            2            1

High Value

Medium Value

Low Value

Comments:

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**Timeframe of Need:** (Circle One)

5            4            3            2            1

Now

Next 5 Years

Next 10 Years

Comments:

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## Risk-Informed Methods

Value: (Circle One)

5            4            3            2            1

High Value

Medium Value

Low Value

Comments:

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Timeframe of Need: (Circle One)

5            4            3            2            1

Now

Next 5 Years

Next 10 Years

Comments:

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## Online Monitoring and Plant Automation

Value: (Circle One)

5            4            3            2            1

High Value

Medium Value

Low Value

Comments:

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Timeframe of Need: (Circle One)

5            4            3            2            1

Now

Next 5 Years

Next 10 Years

Comments:

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## Advanced Applications and Process Automation

**Value:** (Circle One)

5            4            3            2            1

High Value

Medium Value

Low Value

Comments:

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**Timeframe of Need:** (Circle One)

5            4            3            2            1

Now

Next 5 Years

Next 10 Years

Comments:

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General Comments on the Plant Modernization Pathway Program:

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Additional Technology Research Needed:

Topic: \_\_\_\_\_

Brief Description:

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Topic: \_\_\_\_\_

Brief Description:

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Topic: \_\_\_\_\_

Brief Description:

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