

Light Water Reactor Sustainability Program

FY 2017 Summary Report on Industrial and Regulatory Engagement Activities



September 2017

U.S. Department of Energy

Office of Nuclear Energy

DISCLAIMER

This information was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness, of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trade mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

FY 2017 Summary Report on Industrial and Regulatory Engagement Activities

Ken Thomas

September 2017

**Idaho National Laboratory
Light Water Reactor Sustainability Program
Idaho Falls, Idaho 83415**

<http://www.inl.gov>

**Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517**

Executive Summary

The Advanced Instrumentation, Information, and Control (II&C) Systems Technologies Pathway of the Light Water Reactor Sustainability (LWRS) Program conducts a vigorous engagement strategy with the U.S. nuclear power industry, including the nuclear operating companies, major support organizations, the Nuclear Regulatory Commission (NRC), and suppliers. The goal of this engagement strategy is to develop a shared vision and common understanding across the nuclear industry of the need for II&C modernization, the performance improvement that can be attained, and the opportunities for collaboration to enact this vision.

In FY 2017, the vision, strategy, and project work was communicated to a number of key organizations, including the major industry support organizations, and a number of important industry conferences that are attended by leaders in nuclear plant instrumentation and controls as well as human performance and process improvement.

This report presents the specific engagement activities that occurred in FY 2017 to promote awareness and participation by the nuclear power industry in the activities of the II&C Pathway.

Acknowledgements

Industrial and regulatory engagement is a shared activity among the research staff of the LWRS Program II&C Pathway, involving all of those who interact with utility collaborators, industry support groups, industry suppliers, Nuclear Regulatory Commission staff, and other industry stakeholders. In particular, the author would like to thank the following staff members who were instrumental in making this engagement highly effective during FY 2017: Dr. Bruce Hallbert, Jacques Hugo, Johanna Oxstrand, Katya Le Blanc, Dr. Ronald Boring, Shawn St. Germain, Jeffrey Joe, Gordon Clefton, Dr. Vivek Agarwal, Dr. Andrei Gribok, Dr. Ahmad Al Rashdan, Dr. Tom Ulrich, Dr. Roger Lew, Casey Kovesdi, Zachary Spielman, Brandon Rice, Kirk Fitzgerald, and Jeff Einerson,

Table of Contents

Executive Summary.....	iii
Acknowledgements	iv
Acronyms	vii
1. Introduction	1
2. Nuclear Utility Engagement.....	1
2.1 Utility Working Group.....	1
2.2 External Review of the II&C Pathway Research Activities	3
2.3 Duke Energy	4
2.4 Arizona Public Service.....	4
2.5 SCANA.....	6
2.6 Exelon Nuclear.....	6
2.7 Xcel Energy.....	7
2.8 Luminant Energy/Utilities Service Alliance	7
2.9 American Electric Power	8
2.10 Nebraska Public Power District	8
3. Collaboration with Major Industry Support Groups.....	8
3.1 Electric Power Research Institute	8
3.2 Nuclear Energy Institute	9
3.3 Institute of Nuclear Power Operations.....	10
4. General Industry Meetings and Conferences.....	10
4.1 10th International Topical Meeting on Nuclear Plant Information, Control, and Human-Machine Interface Technologies (NPIC & HMIT 2017).....	10
4.2 2015 INPO Digital Workshop.....	11
4.3 2015 Procedure Professional Association Workshop	11
4.4 2015 NITSL Workshop.....	11
4.5 Nuclear Plant Digitalization Conference	11
4.6 2015 ANS Utility Working Conference.....	12
5. Meetings with Suppliers	12
5.1 AREVA.....	12
5.2 Atkins & AMMI.....	12
5.3 CHAMPS	13
5.4 Westinghouse Electric Corporation	13
5.5 Net Axiom.....	13

5.6	Devonway	13
5.7	GSE	13
6.	Regulatory Engagement	13
6.1	Informal Discussions with NRC I&C Managers	13
6.2	Informal Communications with the NRC	14
7.	International.....	14
7.1	KAERI	14
7.2	IFE Halden Reactor Project	14
8.	Other Communications.....	15
8.1	American Nuclear Society Nuclear News.....	15
8.2	LWRS Newsletters.....	15
9.	References	15

List of Tables

Table 1	FY 2017 Collaborating Utilities.....	2
Table 2	FY 2107 Published Reports	2

Acronyms

ASR	alkali-silica reaction
AWP	automated work package
BCMW	Business Case Methodology Workbook
CRADA	Cooperative Research And Development Agreement
CNO	chief nuclear officer
DCS	distributed control system
DOE	Department of Energy
EdF	Electricité de France
EPRI	Electric Power Research Institute
FAT	factory acceptance test
FPGA	Programmable Gate Arrays
HFEP	Human Factors Engineering Program
HFEPF	Human Factors Engineering Program Plan
HRP	Halden Reactor Project
HSI	human-system interface
HSSL	Human System Simulation Laboratory
I-NERI	International Nuclear Energy Research Initiative
I&C	instrumentation and control
II&C	Instrumentation, Information and Control
INPO	Institute of Nuclear Power Operations
IRT	Issues Resolution Team
ISA	International Society of Automation
JITT	Just-In-Time Training

KAERI	Korea Atomic Energy Research Institute
KNHP	Korea Hydro and Nuclear Power
LTO	Long Term Operations
LWRS	Light Water Reactor Sustainability
NDA	non-disclosure agreement
NEI	Nuclear Energy Institute
NEWPER	Nuclear Electronic Work Packages – Enterprise Requirements
NITSL	Nuclear Information Technology Strategic Leadership
NPIC-HMIT	Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technology
NRC	Nuclear Regulatory Commission
NRR	Nuclear Reactor Regulation
OCC	outage control center
OSTI	Office of Scientific and Technical Information
OTT	Office of Technology Transitions
PPA	Procedure Professionals Association
PVNGS	Palo Verde Nuclear Generating Station
R&D	research and development
SWIL	software-in-the-loop
SwRI	Southwest Research Institute
TCS	turbine control system
USA	Utilities Service Alliance
UWC	Utility Working Conference
UWG	Utility Working Group

1. Introduction

The Advanced Instrumentation, Information, and Control (II&C) Systems Technologies Pathway of the U.S. Department of Energy (DOE) Light Water Reactor Sustainability (LWRS) Program conducts a vigorous engagement strategy with the U.S. nuclear power industry, including the nuclear operating companies, major support organizations, the Nuclear Regulatory Commission (NRC), and nuclear industry suppliers. [1] The goal of this engagement strategy is to develop a shared vision and common understanding across the nuclear industry of the need for II&C modernization, the performance improvement that can be attained, and the opportunities for collaboration to enact this vision.

During FY 2017, the activities of the II&C Pathway were communicated to a number of key nuclear industry organizations, including nuclear utilities, the major industry support organizations, and a number of important industry conferences that are attended by leaders in nuclear plant instrumentation and controls as well as human performance and process improvement.

This report presents the specific engagement activities that occurred in FY 2017 to promote awareness and participation by the nuclear power industry in the activities of the II&C Pathway.

All dates in this report refer to FY 2017 (October 2017 – September 2017) unless otherwise noted.

2. Nuclear Utility Engagement

2.1 Utility Working Group

The II&C Pathway conducts a variety of engagement activities with U.S. nuclear utilities through collaboration in pilot projects, individual meetings on digital technology requirements, and distribution of project reports and other project products. The nuclear utilities that are engaged with the II&C Pathway in one capacity or another are collectively referred to as the Utility Working Group. Over the course of the II&C Pathway, this has included the following utilities:

1. Arizona Public Service
2. Dominion
3. Duke Energy
4. Entergy
5. Exelon Nuclear
6. First Energy Nuclear Operating Company
7. Luminant
8. NextEra
9. Pacific Gas & Electric
10. Public Service Electric and Gas
11. Southern Nuclear
12. South Texas Project
13. Tennessee Valley Authority
14. Xcel Energy

During FY 2017, the primary means of engaging utilities was through focused areas of interest consisting of automated work packages, outage improvement, control room modernization, and on-line monitoring. In many cases, this consisted of their direct involvement in the technology development projects of the II&C Pathway or their expressed interest to learn more about these projects. In this manner, the utilities were engaged in their desired area of development. In addition, it promoted

association and cooperation among utilities with similar technical interests. The utilities who served as project collaborators in the II&C Pathway research activities during FY 2017 are listed in the following table.

Table 1 FY 2017 Collaborating Utilities

Nuclear Utility	Automated Work Packages	Outage Improvement	Control Room Modernization	On-Line Monitoring
Arizona Public Service	X	X	X	
Duke Energy			X	
Exelon Nuclear			X	
Luminant				X
Southern Nuclear		X	X	
Xcel	X			
Cooper Nuclear Station		X	X	

In addition to these utilities who directly participate as pilot project collaborators, other utilities participated in conference calls, direct discussions, and industry meetings within the major focus areas.

Project reports are distributed to the Utility Working Group on an annual basis at the completion of the fiscal year as indicated in the table below. The next such distribution will be in October of 2017 and will use report access services provided by the Office of Scientific and Technical Information (OSTI). This distribution is in addition to the reports that are distributed during the year to interested utilities and other industry stakeholders on a request-basis.

Table 2 FY 2107 Published Reports

	Report Title	Publication No.
1.	Automated Work Package: Radio Frequency Identification, Bluetooth Beacons, and Video Applications in the Nuclear Power Industry.	INL/EXT-17-43264
2.	Technologies for Detecting Interactions between Current Plant Configuration States and Component Manipulations Directed by In-Use Procedures.	INL/EXT-17-43234
3.	Interrogation of Alkali-Silica Reaction Degraded Concrete Samples using Acoustic and Thermal Techniques to Support Development of a Structural Health Monitoring Framework	INL/EXT-17-41852 Revision 1
4.	Potential to Extend the Range of Established Online Monitoring Technologies, Such as Guided Waves in Nuclear Power Plant Systems	INL/EXT-17-43242

5.	Seamless Digital Environment – Data Analytics Case Study	INL/EXT-17-42918
6.	Human-System Interface Design Requirements	INL/LTD-17-41278
7.	Control Room Modernization Business Case Framework	INL/LTD-17-41292
8.	Human Factors Engineering Program Plan for Palo Verde Nuclear Generating Station’s Control Room Modernization Project	INL/LTD-17-41292
9.	Nuclear Power Plant Digital Modernization: Business Case Benefits Quantification.	INL/LTD 17 42941
10.	Prototype Design, Analysis, and Results for a Liquid Radiological Waste Control Room	INL/EXT-17-43226
11.	Analog, Digital, or Enhanced Human-System Interfaces? Results of an Operator-in-the-Loop Study on Main Control Room Modernization for a Nuclear Power Plant.	INL/EXT-17-43188
12.	Evaluation of Control Room Interface Designs to Support Modernization in Nuclear Power Plants	INL/EXT-17-43250
13.	Preliminary Human Factors Evaluation of Control System Upgrades for the Byron and Braidwood Nuclear Power Stations	INL/EXT-16-40705
14.	Human Factors Engineering Aspects of Modifications in Control Room Modernization	INL/EXT-17-42190
15.	Development of an Initial Business Case Framework for Fleet-Based Control Room Modernization	INL/EXT-17-42604
16.	Results from a Preliminary Dynamic Operator Workshop on Control Room Modernization Activities for Braidwood Unit 1	INL/LTD-17-43205
17.	Monitoring, Modeling, and Diagnosis of Alkali-Silica Reaction in Small Concrete Samples	INL/EXT-15-36683

2.2 External Review of the II&C Pathway Research Activities

To solicit feedback on the topics and results of the ongoing II&C research program, an external review was conducted of the projects to obtain current industry stakeholder feedback. This feedback was documented in the report INL/EXT-16-40568, *Advanced Instrumentation, Information, and Control Systems Technologies Pathway: FY 2016 External Review*, published in November of 2016. 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 August 9-10, 2016, who agreed to serve as the external review panel. The external review consisted of demonstrations in the Human Systems Simulation Laboratory followed by presentations on the II&C research program in general. Written feedback provided by the external review participants indicated 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 also confirmed industry alignment with the priorities, levels of efforts allocated for the research projects, and project schedules.

2.3 Duke Energy

Jeffrey Joe and Ken Thomas held discussions in the June/July timeframe with Paul Hunton of Duke Energy on the restart of control room modernization work that was suspended during FY 2017 due to project delays imposed by Duke. In support of these discussions, reviews were conducted of the previous project reports to confirm that the technical basis of the next phase of work was properly documented. These discussions resulted in the decision to resume the human factors engineering activities in FY 2018, specifically the integrated system validation activities for the Brunswick, Harris, and Robison Nuclear Plants.

2.4 Arizona Public Service

The II&C Pathway is conducting a major project with Arizona Public Service's Palo Verde Nuclear Generating Station (PVNGS) in the area of control room modernization. These research activities are coordinated with PVNGS's Strategic Modernization Program (SMP), which is their comprehensive plan to address obsolescence and reliability issues with their plant I&C systems. Accordingly, a number of contacts were made with during FY 2017 as follows:

- Shawn St. Germain conducted a utility visit at PVNGS to observe outage activities October 17-20. PVNGS continues to deploy and evaluate technology solutions for outage management. During this refueling outage, an outage dashboard was used to evaluate bulk work performance compared to previous outages. PVNGS continues to improve the use of collaboration software for OCC status displays.
- Jacques Hugo and Ron Boring visited PVNGS on November 22nd to discuss the plant's SMP and their end-state vision for the control room. Jacques conducted regular follow-up meetings and discussions during November through March with PVNGS engineering and operations staff at INL, online, and by telephone to verify details of the end-state concept and to collect additional information for the refinement of the existing 3D models of the control room, the development of the end-state concept, and the development of a Human Factors Engineering Program Plan (HFEPP) which was issued as a project report in April. PVNGS had also requested INL to provide guidance for the development of the human-system interface (HSI) for the turbine control system (TCS) and other systems targeted for later upgrade phases. Jacques developed the HSI Style Guide as a companion document to the HFEPP. PVNGS has reviewed and approved the document to be used as a design specification for the development of the TCS HSI by Westinghouse, and also by INL in the development of HSI prototypes during the various control room modernization phases.
- Johanna Oxstrand and Katya Le Blanc conducted a baseline study of the radiological waste control room at PVNGS November 28 through December 1. The purpose of the study was to gain a deeper understanding of current work practices in the radiological waste control room as well as identify areas for improvements.
- Representatives from Palo Verde Nuclear Generating Station (PVNGS) met with team members involved in the main control room modernization activity at INL on January 17-19. The result of the meeting was confirmation of a resource loaded plan for the duration of the project (through FY 2025). Detailed planning for FY 2017 activities was also conducted, resulting in an integrated schedule between INL and PVNGS for development activities, site visits, document reviews, and operator workshops.
- Ron Boring, Tom Ulrich, and Roger Lew traveled to PVNGS on February 12-15 in support of the main control room modernization activity. They met with simulator, operations, and engineering staff to discuss the planned turbine control system upgrade. In the meeting, technical

requirements for the turbine control system were reviewed with the project team, including Westinghouse Electric Corporation, the vendor who will supply the distributed control system for the upgrade. This information was subsequently used to prototype the turbine control system in preparation for the Operator Study of System Overviews conducted at the DOE Human System Simulation Laboratory (HSSL) at INL in August.

- Ken Thomas visited PVNGS on February 28 – March 2 to conduct interviews for the project work on quantification of control room modernization benefits. Assisting in the visit was a Ken Scarola of Nuclear Automation Engineering, LLC. Representatives of Engineering, Operations, Maintenance, Projects, and Senior Management participated in the interviews. A number of data sets were collected that relate to how the site activities will be improved by the I&C and control room upgrades, including operational activities, maintenance and testing activities, plant system issue resolution efforts, etc. This information was evaluated for cost savings and other performance improvement as the basis of a business case for the modernization project.
- Aaron Bly conducted a data analytics workshop at PVNGS as a part of the digital architecture project March 27-30. The information obtained in this workshop was used to develop a project report and two industry conference presentations.
- Shawn St. Germain visited Palo Verde during March 28-30 to discuss an upcoming pilot demonstration of computer vision technology conducted by Arizona State University through the NEUP program. Additionally, outage documents were collected to support new research into methods to improve outage risk management.
- Tom Ulrich, Casey Kovesdi, and Zach Spielman visited PVNGS on April 29 participate in to the Just-In-Time Training (JITT) for the turbine startup during the Spring 2017 refueling outage. The JITT provided the opportunity to meet with Palo Verde instructors and operators to discuss scenarios related to the Operator Study of System Overviews for the turbine control system held at INL in August.
- Ken Thomas provided guidance in July on use of business case technology developed under business case projects conducted in the past several years. Specifically, Palo Verde used the Business Case Methodology Workbook (BCMw) for automated work packages in support of their internal justification to implement this type of technology. This represented the first usage of the BCMw undertaken by a utility that was not part of a formal I&C Pathway project.
- Casey Kovesdi and Zach Spielman conducted a dynamic workshop for the liquid radiological waste control room at PVNGS, July 30- Aug 3. Fourteen field operators participated in the workshop, including all four of the radiological waste operators at PVNGS.
- Ken Thomas traveled to PVNGS on August 1-3 to conduct a site review of the findings of the control room modernization business case quantification research. Assisting in the visit was Ken Scarola of Nuclear Automation Engineering, LLC. The purpose of the visit was to meet with plant managers and staff to confirm the magnitude of cost savings that could be derived from the implementation of various control room technologies. The PVNGS staff endorsed the findings of the research and provided additional insights on how the savings could be realized. This information was incorporated into the project report, which was issued on August 17.
- An Operator Study of System Overviews was conducted with a three-person reactor operator crew in the HSSL at INL in August, 2017. The study was focused on the human factors improvements recommended for the TCS digital upgrade as part of the PVNGS control room modernization and featured a benchmark comparison of three variants of a TCS: the existing analog TCS, a proposed standalone digital TCS with two displays, and the digital TCS with the addition of a third display consisting of a system overview screen. TCS prototypes were

developed at INL to allow evaluation of operator performance and preferences during realistic turbine scenarios in the full-scope simulator. The study revealed that completion of turbine startup was several minutes faster with the digital TCS variants than with the conventional analog TCS. This study provided compelling evidence that the new digital TCS was used successfully by the operators without extensive training or rewriting of the operating procedures, suggesting high usability for the digital TCS design.

2.5 SCANA

Ken Thomas held discussions with Ed Greco of SCANA (VC Summer Nuclear Station Unit 1) on a possible collaboration in the area of automated work packages in January. After some discussion among their senior managers, SCANA decided they could not support the work at this time due to other issues they were dealing with, but would be open to such a collaboration in the future. On that basis, the project team in this area began discussions with Xcel Energy, leading to their role in this project work as described in Section 2.7.

Jacques Hugo, Ron Boring, and Ken Thomas provided consultation to SCANA over several months (March – June) as part of the engineering work for the AP1000 plants being constructed near Jenkinsville, South Carolina, as the VC Summer Nuclear Station Units 2 & 3. The plant Safety Analysis Report developed by Westinghouse Electric Corporation stated requirements for a Human Factors Engineering Program (HFEP). SCANA had begun to develop this document and was referred to INL by the Electric Power Research Institute (EPRI) for support in this development. Having conducted similar work for other nuclear projects, Jacques Hugo reviewed the documentation and provided extensive guidance to SCANA. Specific recommendations included the development of a graded approach to the definition of the required human factors activities to ensure compliance with NUREG-0711 expectations and easy integration with systems engineering work.

2.6 Exelon Nuclear

The II&C Pathway is conducting research with Exelon Nuclear in the area of fleet-based control room modernization and had the following interactions in FY 2017:

- LWRs researchers attended Exelon's software-in-the-loop (SWIL) test at Westinghouse Electric Corporation in Cranberry Township, PA, on March 13-15. The purpose in attending was to observe and learn about the functionality and the design of the human system interface of the Westinghouse Ovation distributed control system.
- LWRs researchers participated in the factory acceptance test (FAT) of the Braidwood Ovation digital control system at Westinghouse with Exelon collaborators on July 13-14.
- Exelon and LWRs researchers conducted a workshop in the HSSL from August 28 to September 1. The purpose of the workshop was to perform a human factors engineering review of the digital control system being developed for the non-safety related I&C for the nuclear steam supply systems that are being upgraded at Exelon's Braidwood and Byron Nuclear Generating Stations.
- Bruce Hallbert and Ken Thomas conducted ongoing discussions with John Connelly, Exelon Capital Projects Manager, during the July – August time frame on potential collaboration for full modernization of a nuclear power plant. This work scope is currently under development with further meetings planned in the fall.
- In addition to these meetings, weekly status calls were held with the Exelon project staff to coordinate work activities and to discuss technical developments.

2.7 Xcel Energy

The LWRS Program developed a Cooperative Research and Development Agreement (CRADA) with Xcel Energy Inc. to collaborate on an automated work package (AWP) effort during FY 2017. The scope was to develop and evaluate an initial set of advanced automated work package capabilities including radio frequency identification, Bluetooth beacons, and video monitoring and recording for:

1. materials tools and equipment tracking at foreign material exclusion zones and verification of their proper use,
2. location identification and location driven automatic actions and warnings, and
3. video remote concurrences, just-in-time training, peer reviews and quality assurance.

There was continuous engagement of Xcel during FY 2017 through bi-weekly conference call meetings and a visit to Xcel in Minneapolis, Minnesota, in August. The purpose of the visit was to conduct a user study to evaluate the potential and feasibility of the selected set of automation capabilities in improving the current work process in nuclear power plants. The study was attended by participants from various work areas at Xcel. The participants ranged from senior directors to craft. The findings of the study concluded that the three evaluated technologies are feasible and highly beneficial to the nuclear power industry.

2.8 Luminant Energy/Utilities Service Alliance

Ken Thomas and Bruce Hallbert met with the Board of Directors of the Utilities Service Alliance (USA) at the Luminant Energy corporate office in Dallas, TX on February 7-8. USA is an organization that provides services and conducts joint improvement projects for its utility members, which includes the following nuclear plants: Columbia, Comanche Peak, Cook, Cooper, Fermi, Ft. Calhoun, Monticello, Prairie Island, South Texas Project, and Susquehanna. The Board of Directors was represented in this meeting by four Chief Nuclear Officers, the President/CEO of USA, and other USA leadership. Discussions were held on a potential collaboration with DOE on a fleet-based plant monitoring center.

Bruce Hallbert and Ken Thomas had a follow up meeting with Luminant, USA, EPRI, and representatives of other nuclear operating companies (First Energy, Dominion, and Entergy) on May 11-12 at the Luminant corporate office to discuss the proposed centralized monitoring function for USA, with the possibility of these other companies participating through the Nuclear Energy Institute's Delivering the Nuclear Promise Initiative. Several common objectives between this industry group and the II&C Pathway pilot projects were identified and discussed. The result of the meeting was a series of scheduled activities through the summer months to determine interest and support levels of the DOE/LWRS Program and the chief nuclear officers (CNOs) of these nuclear utilities.

Related to these project development efforts, Ken Thomas worked with Luminant representatives during April to develop a business case study plan for the proposed collaboration, entitled *Centralized Monitoring Program - Business Case Plan*. The report described the scope, schedule, and budget-grade cost estimate for a potential business case on centralized on-line monitoring function for a large fleet. It was prepared in association with ongoing discussions with Luminant Energy, the Utilities Service Alliance (USA), and EPRI. This business case study would be part of a larger project proposed by Luminant to set up a centralized monitoring function for USA similar to the one that Luminant operates for its own plants. The business case would conduct studies at three representative USA nuclear plants and extrapolate the expected cost savings over the entire fleet.

2.9 American Electric Power

Shawn St. Germain conducted a utility visit at American Electric Power's DC Cook Nuclear Station October 11-14 to observe outage activities, evaluate their use of the Syntempo software application, and to present LWRs research in outage improvement. DC Cook expressed interest in improving outage control center (OCC) communications and possibly participating in future II&C Pathway research activities. However, no definite collaboration plans have been established at this time.

2.10 Nebraska Public Power District

In April, Shawn St. Germain and Jacques Hugo visited Chris Pelchat, Nuclear Projects Department Manager at the Nebraska Public Power District Cooper Nuclear Station in Brownville, NE to advise on the upgrade of their OCC (which included the Technical Support Center and Operations Support Center). During the visit, several potential human factors enhancements and improvements to the layout of the center were identified. It was proposed to develop a 3D model of the proposed layout, but since the modifications would be relatively simple, it was decided to develop only 2D layout drawings. These drawings were reviewed by Cooper station and approved for further refinement by the engineering team.

In addition to the control room upgrade, the INL team also discussed the previous work done on improvement of OCCs, including the development of OneNote templates and the prototype Outage Information Dashboard. Cooper expressed interest in both innovations and subsequently requested INL to provide a copy of the Dashboard software to use in conjunction with their existing Syntempo system. This is currently being arranged, while negotiations to commercialize the software are being conducted by the INL Technology Deployment department.

3. Collaboration with Major Industry Support Groups

3.1 Electric Power Research Institute

The Electric Power Research Institute (EPRI) is a key partner for the II&C Pathway, with collaboration made possible through a Memorandum of Understanding adopted in 2010 that links the Department of Energy Light Water Reactor Sustainability Program with the EPRI Long Term Operations (LTO) Program. [2] Since that time, EPRI and the II&C Pathway have collaborated on a number of technology developments, as well as jointly sponsoring meetings and other industry collaboration opportunities. The relationship with EPRI is particularly beneficial to the II&C Pathway because of EPRI's research activities, staff expertise, and extensive relationship with utility staff in plant functions that are related to the technology research activities. Periodic phone calls are held with the II&C Pathway leadership and the Senior Program Manager and key staff for the EPRI I&C research.

As one specific project during FY 2017, The II&C Pathway and EPRI are collaborating to improve guided wave technology as a means to inspect nuclear plant secondary system piping. EPRI participates in development of technologies for this project as a technical advisor. They provide expert review of project plans, project results, and project reports. EPRI also performs the development of their own technical approaches and share data collected from existing on-line monitoring technologies. In addition, EPRI facilitates utility and industry engagement through their network of utility contacts and sponsored industry meetings. EPRI facilitated transfer of guided wave data and technical documentation from Southwest Research Institute (SwRI) to INL. Currently, EPRI and Southwest Research Institute (SwRI) are working on a non-disclosure (NDA) agreement to make SwRI's proprietary data conversion software available to INL at no cost.

The II&C Pathway is also conducting research in on-line monitoring of concrete structures, and in particular, the detection of alkali-silica reaction (ASR). Vivek Agarwal periodically updates Ms. Maria Guimaraes of EPRI about important research highlights on the structural health monitoring research performed at INL and Vanderbilt University, providing to her the recent published milestone report and presentations. Vivek Agarwal and Bruce P. Hallbert organized a webinar on the online monitoring of concrete structures in nuclear power plants on September 18. In the webinar, Nuclear Energy University Program funded research led by University of Nebraska-Lincoln was presented. The purpose of the webinar was to understand the research progress and path forward. Ms. Maria Guimaraes attended the webinar, serving as an industrial advisor to INL on this project. She is also associated with concrete non-destructive evaluation work at EPRI and is aware of experimental setup at University of Tennessee-Knoxville built in collaboration with Oak Ridge National Laboratory.

In the area of automated work package research, Ahmad Al Rashdan conducted conference call meetings with EPRI in December and February, and participated in the Work Planning Users Group Meeting in January. The current project status was presented in a conference meeting at EPRI in April.

Finally Bruce Hallbert participated in the semi-annual EPRI Nuclear Power Council Advisory Meetings – I&C Committee in January and August, providing this important industry support group, as well as the nuclear utilities in attendance, with periodic updates on the work and technology developments of the II&C Pathway. These were important engagements for the II&C Pathway in that they provide formal and informal information exchanges with EPRI senior leadership.

3.2 Nuclear Energy Institute

Ken Thomas and Bruce Hallbert in the Nuclear Energy Institute (NEI) Digital I&C Working Group, the purpose of which is to engage the NRC on certain issues that are considered by industry to be barriers to digital technology implementation for nuclear power plants. This includes periodic meetings and conference calls to work on initiatives to resolve these regulatory barriers.

Ken Thomas participated in a quarterly meeting of the Nuclear Energy Institute (NEI) Digital I&C Working Group, held on October 17-18 at the Westinghouse Electric Company corporate office in Cranberry Township, PA. This working group is made up of nuclear utilities, nuclear suppliers, and industry support groups, and is tasked by the chief nuclear officers of the nuclear utilities to work with the Nuclear Regulatory Commission (NRC) staff to resolve regulatory barriers to digital I&C system implementation. [3] The Working Group reviewed comments and status on several regulatory topics which that were being discussed with the NRC. The most notable issue addressed in the meeting was the regulatory treatment of software common cause failure. Other major topics included the digital I&C licensing process and the criteria for whether a digital I&C design change needs prior NRC review before implementation. The Working Group provided direction and positions on these topics. The NRC staff joined the last part of the meeting for a discussion of these same topics, to ensure a mutual understanding of the positions and status of efforts on both sides. Following this formal part of the meeting, Westinghouse offered tours of their digital I&C technology development and manufacturing facilities (three locations), which included the advanced control room for the AP-1000 nuclear plant.

Ken Thomas held discussions with NEI (Jason Remer) in February 2017 on potential research topics of interest to the industry in resolving digital I&C regulatory barriers. Additional discussions were held with Jason and Bruce Hallbert, which resulted in an agreement to focus on 1) advanced methods to address safety-related digital technology, and 2) development of a seamless digital environment for NPP cost reduction and performance improvement.

3.3 Institute of Nuclear Power Operations

Regular phone calls are held by Ken Thomas with the Institute of Nuclear Power Operations (INPO) to coordinate II&C Pathway developments with the activities and performance guidance of INPO. The primary contact is Bill Nowicki, who is a Senior Evaluator in Engineering and is responsible for coordinating INPO activities for digital I&C upgrades being undertaken by nuclear utilities. Topics of discussions in these calls included INPO's recent findings in the implementation of digital systems, opportunities for big data analytics, and opportunities for INL to participate in INPO assist visits to utilities upgrading their I&C systems.

A presentation on the digital technology developments of the II&C Pathway was provided at the annual INPO Digital Workshop on May 2-3, as described in section 4.2.

4. General Industry Meetings and Conferences

4.1 10th International Topical Meeting on Nuclear Plant Information, Control, and Human-Machine Interface Technologies (NPIC & HMIT 2017)

LWRS researchers presented 18 papers related to this project at the American Nuclear Society Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technology (NPIC-HMIT) conference held in San Francisco June 12-15. Held every two years, the conference is a forum for nuclear instrumentation and control (I&C) and human factors engineering professionals to present their research and development and exchange information on new digital technology for nuclear plant I&C and human factors. It attracts a national and international audience due to the quality of research and development papers that are presented. It is very broad in its coverage of digital, I&C, and human factors topics and therefore covers virtually every aspect of the work of the II&C Pathway. The following is the list of the II&C papers that were presented at the conference. In addition, several staff participated in panel discussions on various topics related to human factors and digital technology.

- A Human Factors Meta Model for U.S. Nuclear Power Plant Control Room Modernization
- A Novel Tool for Improving the Data Collection Process During Control Room Modernization Human-System Interface Testing and Evaluation Activities
- A Review of Human-System Interface Design Issues Observed During Analog-to-Digital and Digital-to-Digital Migrations in U.S. Nuclear Power Plants
- A Human Factors Engineering Process to Support Human-System Interface Design in Control Room Modernization
- Design Themes for Future Hybrid Nuclear Power Plant Control Rooms
- Application of Eye Tracking for Measurement and Evaluation in Human Factors Studies in Control Room Modernization
- A Summary Comparison of Design Evaluation Techniques
- Automated Work Package: Capabilities of the Future
- Migration to a Fully-Integrated Control Room
- A Business Case for Nuclear Plant Control Room Modernization
- Concrete Structural Health Monitoring in Nuclear Power Plants

- Framework for Structural Online Health Monitoring of Aging and Degradation of Secondary Piping Systems Due to Some Aspects of Erosion
- Providing Plant Data Analytics Through A Seamless Digital Environment
- Human Factors Principles in Information Dashboard Design
- Human Factors and Modeling Methods in the Development of Control Room Modernization Concepts
- Implementing Computer-Based Procedures: Thinking Outside the Paper Margins
- Development of Utility Generic Functional Requirements for Electronic Work Packages and Computer-Based Procedures
- Supporting the Industry by Developing a Design Guidance for Computer-Based Procedures for Field Workers

4.2 2015 INPO Digital Workshop

Ken Thomas made a presentation at the 2017 INPO Digital Workshop, held in Atlanta, GA, on May 2-3, entitled INL Update on Advanced I&C Technology Development, highlighting the work of the II&C Pathway with particular emphasis on the control room modernization work. The INPO Digital Workshop is an annual meeting of nuclear plant I&C professionals that provides an opportunity to learn about significant developments potentially benefitting the operating nuclear plants in plant controls and control room upgrades, as well as pertinent licensing and engineering process issues. This workshop was attended by over 80 nuclear utility and nuclear supplier representatives. There was follow up with several attendees seeking reports and technical information relate to the ongoing research work of the II&C Pathway.

4.3 2015 Procedure Professional Association Workshop

Johanna Oxstrand is a member of the Procedure Professionals Association (PPA) steering committee and their procedure standards committee. As a part of these duties Johanna planned and participated at the annual conference in Clearwater, Florida, June 19-22. As a part of the conference, the two main outcomes of the Nuclear Electronic Work Packages – Enterprise Requirements (NEWPER) initiative were discussed; Functional requirements for Basic and Moderate Smart Documents (published in December 2016) and Functional requirements for Advanced and Dynamic Smart Documents. The latter report was published by PPA in August 2017.

4.4 2015 NITSL Workshop

Johanna Oxstrand participated in the annual Nuclear Information Technology Strategic Leadership (NITSL) meeting in San Francisco, July 17-20. Johanna Oxstrand is a member on the Infrastructure and Applications committee. She presented both the results of NEWPER, which was a 2016 NITSL initiative and on Data Analytics and Seamless Digital Environments, which was one of the 2017 initiatives.

4.5 Nuclear Plant Digitalization Conference

Johanna Oxstrand attended the Nuclear Plant Digitalization Conference in Charlotte, NC, November 14-17 where she presented a summary of the control room modernization efforts in the LWRS II&C pathway. The conference focused on solutions to drive safety, reliability and economic performance

through the digitalization of nuclear power plants. Representatives from INPO, EPRI, U.S. nuclear utilities, international nuclear utilities, and vendors participated in the conference.

4.6 2015 ANS Utility Working Conference

Bruce Hallbert and Ken Thomas co-chaired two sessions at the American Nuclear Society Utility Working Conference (UWC), held in Amelia Island, FL, August 7-9. The first session was in the Executive Track, entitled: Technology-Enabled Business Improvement, with presentations by the II&C Pathway, IFE Halden Reactor Project, and Arizona Public Service. Bruce Hallbert presented the II&C Pathway work on a seamless digital environment for nuclear power plants. Lorenzo Slay of PVNGS presented the collaborative work with the II&C Pathway on control room modernization. Rounding out the session, Andreas Bye of the IFE Halden Reactor Project presented their work in the area of integrated operations for off-shore oil production, which holds much promise for application in nuclear power plants.

The second session was in the Innovation Track, entitled: Seamless Digital Environment for Nuclear Power Plants. Ken Thomas presented work on computerized operator support systems. Shawn St. Germain presented the work of the II&C Pathway in outage risk management. Ann Orr of PVNGS presented their work with the II&C Pathway in research and application of technology for data analytics and digital architecture development.

Both sessions were well-attended with good questions and discussion from the audience. In addition, a number of contacts were made during the conference regarding the research work of the II&C Pathway.

5. Meetings with Suppliers

5.1 AREVA

Shawn St. Germain visited AREVA's North American Outage Support Center on November 8th. Shawn presented LWRS activities and observed how AREVA uses a centralized support center to monitor work at multiple utility outages supported by AREVA simultaneously throughout the country. A number of potential areas for collaboration were discussed, but have not been pursued by AREVA at this time.

5.2 Atkins & AMMI

Ken Thomas, Shawn St. Germain, Jacques Hugo, Katya LeBlanc, and Ron Boring, met with Atkins Global and AMMI on potential pilot project collaborations in the areas of outage risk and schedule management at INL on December . Representing Atkins and AMMI were Sean Clark, Director of Business Development for Atkins Global, Keith Began, Manager of Fire Protection and GLASS for Atkins Global, and David Garcia, President, AMMI.

Detailed discussions were held on mutual development interests in these areas. Several information items (reports, papers, etc.) have or will be forwarded as follow-up on the discussions. Following, an NDA was signed between all parties with plans to collaborate on a future pilot.

5.3 CHAMPS

Shawn St. Germain and Jacques Hugo conducted a Go-To-Meeting with Champs Analytics to discuss the advanced outage dashboard and to present ideas for an outage requirements monitor to support improved outage risk management. Follow up on this meeting is continuing.

5.4 Westinghouse Electric Corporation

A non-disclosure agreement with Westinghouse Electric Corporation for the Fleet-Based Control Room Modernization Project was developed to enable participation of the INL pilot project team in an upcoming Westinghouse design exercise for the Exelon control room upgrades.

Ken Thomas provided support to DOE-NE in the evaluation of a proposal from Westinghouse Electric Corporation on the upgrade of their nuclear plant protection system. This included attending a meeting at Westinghouse in Warrendale, PA on March 14 to discuss opportunities to collaborate on the improvement of plant protection systems for light water reactors. A proposal was developed to conduct an preliminary phase of the collaboration, which is likely to be executed in FY 2018.

5.5 Net Axiom

Johanna Oxstrand and Katya Le Blanc received a grant from DOE's Office of Technology Transitions (OTT) to assert copyright on the computer-based procedure software developed as a part of the Computer-Based Procedures for Field Workers project. In August 2017, Johanna and Katya were awarded a grant from OTT to commercialize the computer-based procedure software in partnership with the vendor NextAxiom Inc. The combined value of the grant (DOE and partner's contributions) is \$1.5 million. The commercialization effort will start in FY18.

5.6 Devonway

Johanna Oxstrand was invited to present the topic "How to engage employees through technology - The impact of computer-based procedures" at the DevonWay 8th Continuous Improvement Conference (Ci8) and DevonWay User Group in La Jolla, CA, February 6-9, 2017. The focus of the conference was on strategies for strengthening safety culture and take-home techniques the participants can use in their home organizations. The vast majority of the participants represented U.S. nuclear utilities. In addition, vendors of electronic work management solutions were participating.

5.7 GSE

Sean Fuller, Jay Umholtz, and Sally White from GSE Systems, Inc. visited INL on October 25th to observe GSE Systems equipment being utilized in the HSSL and to discuss potential areas of additional collaboration. II&C Pathway researchers briefed the GSE representatives on their respective LWRS projects and provided a tour and demonstration of the HSSL.

6. Regulatory Engagement

6.1 Informal Discussions with NRC I&C Managers

Bruce Hallbert and Ken Thomas traveled to Washington DC to attend a workshop at the Nuclear Regulatory Commission on the proposed use of safety assurance cases as a form of a submittal for digital

I&C license amendments. This workshop was jointly facilitated by Bruce Hallbert of the II&C Pathway and Jon Kvalem of the IFE Halden Reactor Project. It featured a broad range of domestic and international speakers covering the use of safety assurance cases in nuclear as well as other safety-critical industries. As a result of the workshop, preliminary scoping of future work on safety assurance case has been developed and will be a topic of discussion with Halden and the NRC.

This workshop provided opportunity to inform several NRC managers in I&C regulatory functions of the work of the II&C Pathway, both in formal remarks by Bruce Hallbert to the workshop attendees as well as through informal discussions over the course of the meeting.

6.2 Informal Communications with the NRC

Informal communications were conducted with members of the NRC managers staff during NEI meetings and industry meetings. These provided opportunities to inform the NRC of the relevant work activities of the II&C Pathway and establish lines of communication for further discussions when necessary.

7. International

7.1 KAERI

The Korea Atomic Energy Research Institute (KAERI) is a world leader in nuclear plant development and an important partner of the II&C Pathway in control room human factors research, under the Department of Energy I-NERI R&D Program. In connection with a non-LWRS funding source, INL staff member, Ron Boring, traveled with LWRS AIIC pathway lead, Bruce Hallbert, to visit KAERI and various Korea Hydro and Nuclear Power (KHNP) facilities, including the two new APR1400 units at the Shin Kori site. Bruce Hallbert presented LWRS overviews, and Ron Boring presented overviews of recent control room modernization activities. The visit afforded significant insights to benefit LWRS projects related to advanced control room design and operator performance evaluation.

7.2 IFE Halden Reactor Project

IFE Halden Reactor Project is highly-respected leader in nuclear energy technology, and particularly in the field of control room modernization and nuclear control room operator human performance. The II&C Pathway contracts Halden to perform certain research tasks for the Control Room Modernization Pilot Project. The task for 2017 was to development of information rich displays for a radiological waste control room at a nuclear power plant. The technology developed under this task was delivered to the II&C Pathway in August and a report summarizing the development effort was completed in September.

Shawn St. Germain visited Halden December 5-8 to review the work each organization is currently doing and planned future work related to outage optimization. Plans were made for continued collaboration and cooperation regarding outage management research.

Bruce Hallbert attended the Enlarged Halden Programme Group meeting in September, presenting the current work of the II&C Pathway. Participation in this meeting provided information on current Halden research projects relevant to the work of the II&C Pathway in the areas of outage improvement, online monitoring, control room modernization, and human factors research methodologies. As a member of the Halden Programme Group, the II&C Pathway is able to access the research reports produced by Halden under this program.

8. Other Communications

8.1 American Nuclear Society Nuclear News

A cover story in the June 2017 edition of Nuclear News featured recent work by II&C Pathway under the LWRS program to modernize the main control room at Palo Verde Nuclear Generating Station. The article was distributed in conjunction with the American Nuclear Society Summer Meeting and the embedded Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technology (NPIC-HMIT) conference and received wide visibility in the nuclear industry and research communities. The article was written by Ken Thomas, Ron Boring, Jacques Hugo, and Bruce Hallbert of II&C Pathway.

8.2 LWRS Newsletters

Bruce Hallbert, Ron Boring, Jacques Hugo, and Ken Thomas wrote an article for the February edition, entitled “Control Room Modernization.”

Joseph Campbell wrote an article for the July edition, entitled “Efficient Electronic Procedures in Nuclear Power Plants”

Jeffrey Joe wrote an article for the September edition, entitled “Human Factors Engineering R&D for Control Room Modernization”

9. References

1. Hallbert, Bruce and Thomas, Ken, Advanced Instrumentation, Information, and Control Systems Technologies Technical Program Plan for FY 2017 (INL/EXT-13-28055 Rev. 6), Idaho National Laboratory, September, 2016
2. U.S. Department of Energy, Memorandum of Understanding Between the United States Department of Energy and the Electric Power Research Institute on Light Water Reactor Research Programs, November 1, 2010
3. U.S. Nuclear Regulatory Commission, Integrated Action Plan to Modernize Digital Instrumentation and Control Regulatory Infrastructure Revision 1, March 31, 2017

