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Revision 1

Light Water Reactor Sustainability Program

Summary Report on Industrial and Regulatory Engagement Activities

September 2013

U.S. Department of Energy

Office of Nuclear Energy

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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 obtained, and the opportunities for collaboration to enact this vision.

The primary means of engaging the nuclear operating companies is through a Utility Working Group (UWG), composed of utility representatives that participate in formal meetings and monthly phone calls to provide input on nuclear plant needs and priorities for II&C technologies. Two UWG Special Interest Group meetings were held during the year for the UWG. The first was a joint meeting hosted by the Electric Power Research Institute (EPRI) entitled "Workshop on New Capabilities for Nuclear Plant Productivity Improvement" held in Charlotte, NC, on May 23-24. The second was a meeting hosted by the Tennessee Valley Authority (TVA), held at the Bellefonte Nuclear Station in Scottsboro, AL on June 11-12, 2013, and entitled " Highly-Integrated Control Room Special Interest Group Meeting. The 2013 UWG Summer Meeting was held in Idaho Falls, Idaho, August 20-22, which was a joint meeting with the EPRI's Strategy Group on Performance Improvement through Advanced Technology. The annual summer meeting featured presentations and demonstrations of the technologies that were developed by the II&C Pathway during FY 2013.

Eleven technical and project reports were delivered to the UWG during FY 2013, reflecting the work of the II&C Pathway pilot projects during the year. Distribution of these reports is one of the primary means of transferring to the nuclear industry the knowledge and experience gained during the development of advanced II&C technologies in support of LWR sustainability.

Direct discussions on pilot project involvement were held with Duke Energy, Arizona Public Service, and Southen Nuclear. Discussions were also held on the pathway goals and activities with major industry support organizations during FY 2102, including the Institute of Nuclear Power Operations (INPO), the Nuclear Information Technology Strategic Leadership (NITSL), the Nuclear Energy Institute (NEI), and EPRI.

The Advanced II&C Pathway work was presented at six major industry conferences and meetings during FY2013.

Project communications in the forms of email (with project activity information) and telephone conversations were conducted with the I&C Branch Chief in the NRC's Office of Nuclear Reactor Regulation (NRR). In addition, informal discussions were held with key NRC managers at industry conferences. These meetings provided the opportunity for NRC staff to hear presentations on the research and development activities of the II&C Pathway.

In the international area, discussions were held with Electricite' de France (EdF) concerning possible collaboration in the area of cyber security for nuclear power plant digital technologies.

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Acronyms

AOCC	Advanced Outage Control Center
DCS	distributed control system
EdF	Electricité de France
EPRI	Electric Power Research Institute
FPGA	Field Programmable Gate Arrays
HRP	Halden Reactor Project
HSI	human-system interface
II&C	Instrumentation, Information and Control
INPO	Institute of Nuclear Power Operations
IRT	Issues Resolution Team
ISA	International Society of Automation
LWRS	Light Water Reactor Sustainability
NEI	Nuclear Energy Institute
NITSL	Nuclear Information Technology Strategic Leadership
NRC	Nuclear Regulatory Commission
NRR	Nuclear Reactor Regulation
R&D	research and development
TVA	Tennessee Valley Authority
UWG	Utility Working Group

1. Introduction

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 2013, the vision, strategy, and project work was communicated to a number of key organizations, including the Advanced II&C Utility Working Group, 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 paper presents the specific engagement activities that occurred in FY 2013 to promote awareness and participation by the nuclear power industry in the activities of the II&C Pathway. In addition, copies of presentations for selected industry meetings are provided in the appendices.

2. Utility Working Group

2.1 Background and Purpose

The Advanced II&C Systems Technologies Pathway sponsors a Utility Working Group (UWG) to define and host a series of pilot projects that together will enable significant plant performance gains and minimize operating costs in support of the long-term sustainability of the LWR fleet. At this time, the UWG consists of 13 leading U.S. nuclear utilities, representing over 70% of the U.S. LWR fleet. Additional membership will be pursued for the UWG with the goal of involving every U.S. nuclear operating fleet in the program.

The UWG is directly involved in defining the objectives and research activities of this pathway. The research is conducted within a set of defined pilot projects that develop digital technologies to address the specific II&C modernization needs within the plant II&C systems and operational processes. Criteria have been developed for identifying, prioritizing, and selecting potential advanced II&C pilot projects performed by II&C Pathway.

UWG members serve as host utilities for the pilot projects when their internal performance improvement objectives align with the goals of a particular pilot project. The pilot project hosts make their facilities available for the research and development (R&D) activities and allows other nuclear utilities to observe the technology demonstrations. Host utilities regularly make presentations in key industry technical meetings to describe their motivations and efforts in the pilot projects and to communicate important findings to the industry.

To allow utilities to focus on specific pilot projects of interest, the UWG sponsors special interest groups in two broad areas: 1) control room modernization and 2) work process and human performance improvement through digital technologies. The purpose of the special interest groups is to provide a means of focused engagement for utilities around the technologies

of their particular interests and to provide a forum for peer review of the technologies developed within the special interest group areas.

2.2 Membership

The nuclear utilities participating in the UWG during FY 2013were:

1. Arizona Public Service
2. Constellation Energy
3. Duke Energy (including the recently-merged Progress Energy)
4. Entergy
5. Exelon Nuclear
6. First Energy Nuclear Operating Company
7. Luminant
8. Pacific Gas & Electric
9. Southern California Edison
10. Southern Nuclear
11. South Texas Project
12. Tennessee Valley Authority
13. Xcel Energy

In addition, the Electric Power Research Institute (EPRI) and the IFE Halden Reactor Project (HRP) were full participants in the UWG, as well as development partners in the pilot projects.

2.3 Long-Term II&C Systems Technologies Future Vision and Strategy

An update to the *Long-Term Instrumentation, Information, and Control Systems Technologies Future Vision and Strategy (INL/EXT 11-24154 Rev. 2)* was published in February of 2013. This is a comprehensive description of the II&C modernization strategy and the related pilot projects. The document reflects the needs and priorities as expressed by the UWG in the August, 2012 meeting. It also provides the background on why the II&C Pathway research is needed and it discusses certain drivers for II&C automation in the nuclear power industry.

The Future Vision and Strategy document provides detailed descriptions of the 20 pilot projects that compose the current research scope. The performance improvement and modernization needs are presented for each of the pilot projects, along with descriptions of what technologies will be produced. This document has been widely distributed among the UWG, industry support organizations, and other interested parties. It is available on the INL LWRS web site for access.

The Future Vision and Strategy document will be continually updated as refinements are made to the scope and schedule of the II&C Pathway research program as modified from time to time based on utility priorities and available project funding.

2.4 Special Interest Group Meeting – May 23-24

A Workshop on New Capabilities for Nuclear Plant Productivity Improvement was held at EPRI-Charlotte on May 23-24. There were about 25 attendees at the meeting, representing a number of utilities and research organizations. The meeting format consisted of presentations and roundtable discussions in four areas: 1) Future Plant Worker, 2) Future Plant Control Center, 3) Future Plant Work Automation, and 4) Integrated Operations. Presentations were made on behalf of the LWRS Program in the areas of computer-based procedures, advanced outage control centers, on-line monitoring, and plant work automation.

EPRI presented their development work in the area of electronic work packages. Also, OECD Halden Reactor Project presented work that they have conducted in the area of integrated operations, which is a collection of technologies that enable virtual collaboration over distance.

The agenda for the meeting is found in Appendix A.

2.5 Special Interest Group Meeting – June 11-12

A Utility Working Group (UWG) Special Interest Group meeting on highly-integrated control rooms was held at the Bellefonte Nuclear Plant near Scottsboro, AL. The meeting included 20 attendees associated with the UWG along with host participants from TVA and AREVA. The purpose of the meeting was to review the I&C and control room modernization efforts at Bellefonte as part of TVA's restart of this deferred nuclear plant project from the 1980's. The I&C system for Bellefonte was described as an all-digital design incorporating the use of Field Programmable Gate Arrays (FPGAs) for safety system actuations. A full-scale mock-up of the main control room was demonstrated, which features a completely digital design with a 26 foot wide large display that is located in front of the operator and shift manager consoles.

Other agenda topics included a discussion by the UWG on the applicability of the Bellefonte control room concept to operating LWR nuclear plants, a Halden presentation on integrated system validation techniques for nuclear plant control rooms, the ongoing II&C pilot project with Duke Energy on control room human factors, and the development of the DOE Human Systems Simulation Laboratory reconfigurable hybrid control room simulator at INL.

The agenda for the meeting is found in Appendix B.

2.6 2013 Summer UWG Meeting – August 20-22

The 2013 Summer Utility Working Group (UWG) Meeting was held August 20-22 at the Idaho National Laboratory in Idaho Falls, ID. The purpose of the meeting was to provide a forum to present and discuss the II&C research program work conducted during FY 2013, and to provide an opportunity for researchers and utility representatives to discuss nuclear plant requirements for technology development in support of II&C modernization and performance improvement.

This meeting was jointly held with the Electric Power Research Institute (EPRI) Strategy Group for Productivity Improvements through Advanced Technology. OECD Halden Reactor Project (HRP) also participated in the meeting. There were a total of 35 attendees, including

utility representatives from Duke Energy, Southern Nuclear, Constellation Energy, and Arizona Public Service.

The meeting featured presentations and demonstrations on the current II&C Pathway pilot projects, including the Advanced Outage Control Center, Computer-Based Procedures, On-line Monitoring, and Incorporating Digital Upgrades in an Analog Control Room.

EPRI presented their current efforts in technology development for nuclear power plants, which included human system interface (HSI), virtual models to support knowledge elicitation and transfer, visualization and simulation, computer-assisted training, and other related development topics. Also, EPRI presented their current work to update and expand the EPRI Human Factors Engineering Guidelines. EPRI has proposed collaboration with the II&C research program in the update of these guidelines, so that the results of the pilot project work involving control room upgrades would be included.

Presentations were made by the OECD Halden Reactor Project (HRP) on integrated system validation for control room upgrade based on their experience in conducting studies with reactor operators. HRP also presented a summary of operator studies conducted in their PWR simulator in 2012 in which U.S. crews were introduced to advanced control room technologies.

There were several demonstrations conducted by the II&C Pathway in the Human Systems Simulation Laboratory, including nuclear plant outage technologies, use of the simulator in conducting human factors engineering studies, and a prototype Computerized Operator Support System which is an operator advisory system for time-critical plant transients. Members of the UWG were provided opportunities for hands-on use of the pilot project technologies.

Representatives of the INL Cyber Security staff provided two presentations. The first was an overview of the recently-completed update of the report *Cyber Security Considerations for the Light Water Reactor Sustainability Program*. The second was a presentation on the ever-evolving cyber threat and how it is being practically addressed.

At the end of the meeting, feedback and comments were solicited from the Utility Working Group in terms of current project priorities and potential unaddressed utility priorities. This feedback will be included in the continuing refinement of the long-term vision and strategy for the II&C research program.

The agenda for the meeting is found in Appendix C.

2.7 Monthly UWG Conference Calls

A monthly conference call was held with the UWG every first Tuesday of the months in FY 2013, to communicate ongoing status of the pilot projects, to discuss project deliverables, communicate UWG and industry meeting information, and to provide information on the overall II&C Pathway. The UWG members were able to ask questions about the specific technologies being developed as well as provide their own ideas on how to make them more useful to the industry. The calls also served as a forum for UWG members to share information among themselves related to their own II&C needs and plans.

2.8 Distribution of Project Deliverables to the UWG

Research pathway and pilot project deliverables have been distributed to the UWG as they have become available throughout FY 2013, as follows:

1.	Online Monitoring Technical Basis and Analysis Framework for Emergency Diesel Generators—Interim Report for FY 2013	INL/EXT-12-27754
2.	Evaluation of Revised Computer-Based Procedure System Prototype	INL/EXT-13-28226
3.	Long-Term Instrumentation, Information, and Control Systems Technologies Future Vision and Strategy, Revision 2	INL/EXT 11-24154
4.	Digital Full-Scope Simulation of a Conventional Nuclear Power Plant Control Room, Phase 2: Installation of a Reconfigurable Simulator to Support Nuclear Plant Sustainability	INL/EXT-13-28432
5.	Installation of Halden Reactor Project Digital Interface Prototypes in the Human Systems Simulation Laboratory	INL/EXT-13-29039
6.	Cyber Security Considerations in Support of the Light Water Reactor Sustainability Program, Revision 2	INL/LTD-12-27315
7.	Development of Methodologies for Technology Deployment for Advanced Outage Control Centers that Improve Outage Coordination, Problem Resolution and Outage Risk Management	INL/EXT-13-29934
8.	A Reference Plan for Control Room Modernization: Planning and Analysis Phase	INL/EXT-13-30109
9.	Summary Report on Industrial and Regulatory Engagement Activities, Revision 1	INL/MIS-12-27161
10.	Computer-Based Procedures for Field Workers: Results From Three Evaluation Studies	INL/EXT-13-30183
11.	Demonstration of Online Monitoring for Generator Step-up Transformers and Emergency Diesel Generators	INL/EXT-13-30155

3. Meetings with Individual Nuclear Utilities

3.1 Duke Energy Catawba Nuclear Station

A meeting was held at Duke Energy's Catawba Nuclear Station on November 14, 2012, to discuss the continuing pilot project work there in the area of mobile work technologies and

computer-based procedures. Key participants in the meeting were Mr. Greg Robison, Duke Project Manager for the pilot project, and Mr. Tom Waicosky, Operations Training and technical lead for the pilot project. A brief meeting was also held with the Catawba Site Vice-President, Mr. Kelvin Henderson, who expressed support for the effort and a desire for continuing involvement in the pilot project technologies development and deployment. Mr. Henderson further stated that he would like Catawba to remain at the forefront of the industry in technology implementation for performance improvement.

The meeting resulted in confirming the mutual goals of the pilot project and the interests of Catawba in mobile worker technologies for human performance improvement. Catawba has since indicated that they would support a limited production application of the computer-based procedure prototype as a first step in actual adoption of the technology into site work processes.

3.2 Arizona Public Service Palo Verde Nuclear Generating Station

A meeting was held at the Palo Verde Nuclear Generating Station on December 4, 2012, with Mr. Michael Grigsby, Assistant Plant Manager, to discuss site requirements and priorities in outage management. The meeting was held in conjunction with a site visit for initial information acquisition for the Advanced Outage Control Center (AOCC) pilot project, for which Palo Verde has agreed to be the host demonstration site.

During the visit, additional meetings were held with other site organizations, including Information Technology, Outage Management, and Engineering, as well as several representatives of the site's Issues Resolution Team (IRT) from various organizations. The context of these discussions was the station's current Process and Technology Strategy, and in particular how the pilot project activities could be complementary to their concepts of "Worker of the Future" and "Leader of the Future." These concepts include emphasis on mobile workers, document access, and integration of work process information – all elements of the AOCC pilot project.

In all, the meetings produced good alignment between the pilot project deliverables and the performance improvement objectives of the station. Subsequent interactions with the station have confirmed the mutual benefits of this pilot project host arrangement at Palo Verde.

3.3 Duke Energy Harris Nuclear Station

A meeting was held on December 14, 2012, at Duke Energy's Harris Nuclear Plant with Mr. Matt Gibson, Technical Manager, and Mr. Paul Hunton, Project Manager, for their fleet control room modernization project, which includes the Harris, Brunswick, and Robinson nuclear power plants. Several other Harris and fleet-level staff members attended the meeting. The purpose of the meeting was to confirm the role of the pilot project activities in conducting human factors engineering activities for near-term control room upgrades for the turbine control system and the plant process computer. It was recognized that there was a mutually-beneficial interest in the pilot project to provide human factors engineering guidance for these control room upgrade activities and to be able to transfer this experience and knowledge to the industry in the form of project technical reports.

The meeting also served as a planning and status session for the required project deliverables. Certain technical issues related to the capabilities of the DOE Human Systems Simulation Laboratory were discussed regarding support of future phases of the pilot project. There was also discussion of how the pilot project activities should be conducted in order that regulatory requirements were addressed. The meeting resulted in a detailed understanding of how the pilot project activities could be conducted in a complementary manner with the Duke Energy control room modernization project to produce an industry reference program for control room human factors engineering.

3.4 Southern Nuclear

A meeting with Southern Nuclear was held on June 12, 2013 in Scottsboro Alabama, concerning possible collaboration on a control room upgrade strategy. Southern Nuclear is implementing distributed control system (DCS) technology in their three operating nuclear plants – the Hatch, Farley, and Vogtle Nuclear Stations. They are considering the development of a parallel strategy for upgrading their control rooms as the DCS modifications are implemented over time. Southern Nuclear is also constructing a new nuclear plant based on the Westinghouse AP-1000 plant, which will have a fully-integrated control room. Long-term, it would be beneficial to Southern Nuclear to have as uniform a concept of operations as possible across their fleet as a result of any control room upgrades they elect to implement for the operating stations.

The meeting included representatives from IFE Halden as another potential party to the collaboration. It was determined that there is mutual interest in Southern Nuclear participating in the pilot project on Incorporating Digital Upgrades in an Analog Control Room. Southern Nuclear's near term interest is in obtaining a current-state 3-D model of one of their control rooms using Halden's CREATE software. In addition, they are interested in investigating the design and human factors aspects of control room upgrades using the HSSL reconfigurable simulator. Planning discussions are continuing on possible collaboration in FY 2014 depending on available funding.

4. Meetings with Major Industry Support Groups

4.1 Institute of Nuclear Power Operations

The Institute of Nuclear Power Operations (INPO)is the key nuclear power industry organization that ensures that nuclear operations and support activities are conducted with the highest standards of excellence and that continuous improvement is a constant focus of nuclear plant management and staff. Digital technology is recognized by INPO as both a highly-promising opportunity for performance improvement as well as something of a challenge to to ensure that the unique aspects of this technology are properly managed. In the past several years, INPO has devoted an increasing portion of its focus and resources on digital technology implementation.

A telephone conference was held with the INPO on March 21, 2013, with Mr. Bill Nowicki and Mr. Doug Kinsman. Mr. Nowicki is the INPO lead person for digital I&C technology and is assisted in this role by Mr. Kinsman. The purpose of the call was to explore

potential coordination of efforts in applying digital technology to control rooms and plant activities. The result of this call was to confirm that there were mutual interests in coordinating these types of industry engagement activities. INPO accepted an invitation to attend the Highly-Integrated Control Room Special Interest Group meeting held at Bellefonte Nuclear Station in June (refer to Section 2.5) to learn more about the pilot project activities for control room upgrades.

Informal meetings with INPO were conducted at the Special Interest Group meeting at the Bellefonte Nuclear Station in June, in which they expressed continuing interest in learning more about the pilot project activities and coordinating respective efforts. A second conference call was held with Mr. Bill Nowicki on July 1, 2013, in which he proposed a series of possible collaborative actions as follows:

- Developing a memorandum of understanding to formalize the collaboration.
- Conducting periodic conference calls between INPO and the II&C research program.
- Collaborating in the area of cyber security for digital applications in nuclear power plants.
- Granting access to the II&C Pathway for the INPO Nuclear Community on-line forum for digital issues for the II&C research program.
- Conducting a future II&C Pathway presentation at INPO for Engineering and Operations representatives.
- Making II&C research program technical reports available to utilities through the INPO web page.
- Presenting the work of the II&C research program at the next INPO Digital Workshop in June, 2014.
- Including INPO participation in any future II&C Highly-Integrated Control Room Special Interest Group meetings.

It was agreed that these potential collaboration opportunities would be mutually-beneficial and they will be explored in FY 2014 as project funding allows.

4.2 Nuclear Energy Institute (NEI)

The Nuclear Energy Institute (NEI) is the nuclear industry support organization that collectively represents the nuclear utilities on licensing and regulatory matters before the NRC. Specifically, NEI has a long history of assisting the industry in regulatory issues for I&C and control room human factors.

On May 8, 2013, a conference call was held with Mr. Gordon Clefton, Program Manager for instrumentation and control of the NEI to provide an update on the ongoing activities of the II&C research program. The control room modernization pilot project was discussed in view of current and future regulatory requirements and guidance in the area of human factors. A concern was noted on a specific potential regulatory issue in which a series of minor control room upgrades conducted under 10 CFR 50.59 (no license amendment required) could be construed to require a license amendment when considered in aggregate. Another area of regulatory

uncertainty is what would constitute an acceptable graded approach to human factors engineering for control room upgrades. It was concluded that there are no current discussions ongoing with the NRC for either of these issues. The II&C Pathway and NEI will continue to discuss these topics periodically and will determine if at some point the nuclear plant licensees are interested in some collective efforts to engage the NRC in resolving these issues.

4.3 Electric Power Research Institute

A meeting was held at the Electric Power Research Institute (EPRI) in Charlotte, North Carolina, on October 10, 2013, to discuss the topic of a comprehensive digital architecture for the many I&C modernization and performance improvement digital technologies expected in the future. EPRI was represented by Mr. Joseph Naser, Mr. Randy May, and Ms. Sherri Bernhoft. Mr. May has conducted related research for EPRI and published a report entitled "Structure for Living Requirements Repository for Long-Term Operation of a Nuclear Power Plant." Among other outcomes, this research has developed a process modeling methodology that could be used to derive the architecture requirements of an integrated digital information environment capable of supporting the expected II&C Pathway technologies. The purpose of the meeting was to explore collaboration opportunities associated with the future II&C pilot project entitled "Digital Architecture for an Automated Plant." It was determined that such collaboration would be mutually-beneficial and will be further considered at the time this pilot project is initiated.

In 2012, EPRI agreed to publish guidelines for each of the areas of enabling capabilities, incorporating the technical reports on the various technologies produced under each of the pilot projects for the respective areas. EPRI will use their standard methods and utility interfaces to develop the guidelines and validate them with the nuclear industry. Joint milestones with EPRI for these guidelines are listed in the *DOE-NE Light Water Reactor Sustainability Program and EPRI Long Term Operations Program – Joint Research and Development Plan* (INL/EXT-12-24562). The schedule for these milestones were revised in February of 2013 in consultation with EPRI to reflect changes to the schedule of pilot projects based on allocated funding for FY 2013.

On August 19, 2013, a meeting was held with EPRI to discuss an opportunity to collaborate in providing human factors engineering guidance for the LWR fleet. EPRI proposed that the II&C Pathway contribute its recent experience in control room human factors engineering to a revision of the EPRI document *Human Factors Guidance for Control Room and Digital Human-System Interface Design and Modification: Guidelines for Planning, Specification, Design, Licensing, Implementation, Training, Operation, and Maintenance" (EPRI TR 1010042)*. This document is considered to be the foremost reference document for nuclear plant operators in addressing control room human factors. It was last revised in 2005 and does not include more recent experience in industry experience in control room human factors.

It was agreed that the technical report published in September, 2013, entitled *A Reference Plan for Control Room Modernization: Planning and Analysis Phase*, would be provided to EPRI for this purpose, along with ongoing consultation during the revision of the EPRI guidelines document. This report was produced under the Incorporating Digital Upgrades in an Analog Control Room pilot project and reflects the general experience and knowledge gained in the control room upgrade work with Duke Energy. This planned collaboration represents a significant opportunity for the work of this II&C pilot project to be made widely available to the

LWR fleet for use in their control room upgrades. It will be a first contribution to the II&C Pathway/EPRI common milestone due in 2016 - Publish Interim Guidelines to Implement Technologies for a Hybrid Control Room.

5. Regulatory Engagement

5.1 Informal Discussions with NRC I&C Managers

Communications through email and telephone were conducted with Mr. John Thorp, NRR I&C Branch Chief during the course of the year, with project information provided as requested. Informal discussions were held with Mr. Thorp at the ANS Utility Working Conference in August, 2013 on a possible II&C Pathway presentation for the I&C Branch when warranted in the future.

Informal discussions were held with Mr. Russell Felts, Deputy Director of the NRC's Cyber Security Directorate at the ANS Utility Working Conference regarding the NRC's approach to wireless hand-held digital technologies with respect to regulatory requirements stated in 10 CFR 73.54 and related NRC Regulatory Guide 5.71.

5.2 Other Communication Opportunities with the NRC

NRC staff members were in attendance during II&C Pathway presentations at the ISA POWID Symposium in Orlando, FL (June, 2013), and the the ANS Utility Working Conference in Hollywood, FL (August, 2013), and had opportunity to hear presentations on the II&C Pathway and the specific activities of the pilot projects. NRC staff directed several questions to the II&C Pathway representatives in the question and answer session of the ANS Utility Working Conference session.

6. General Industry Meetings and Conferences

6.1 Human Factors and Ergonomic Society's 56th Annual Meeting

A presentation of the research paper *A Model of Operator Interaction with Field Procedures: Insights for Computer-Based Procedures* was made in the Accident Analysis, Risk Assessment, and Human Reliability session of the Human Factors and Ergonomic Society's 56th annual meeting, October 23, 2012, Boston, MA. The human factors and ergonomic society's mission is to promote the discovery and exchange of knowledge concerning the characteristics of human beings that are applicable to the design of systems and devices of all kinds. The Society furthers serious consideration of knowledge about the assignment of appropriate functions for humans and machines, whether people serve as operators, maintainers, or users in the system. And, it advocates systematic use of such knowledge to achieve compatibility in the design of interactive systems of people, machines, and environments to ensure their effectiveness, safety,

and ease of performance. The 56th annual meeting was attended by more than 1,450 society members and nonmembers from the United States and around the world.

The II&C Pathway presentation is found in Appendix D.

6.2 Nuclear Long Term Operations & Upgrades Conference

A presentation was made on behalf of the II&C Pathway at the Nuclear Long Term Operations & Upgrades Conference in Charlotte, NC on May 22,2013, on the II&C Pathway pilot projects and in particular the work involving on-line monitoring. This conference addressed the broad spectrum of plant ageing issues that must be resolved for LWR sustainability, and included presentations from several other LWRS Pathways. The meeting was attended by over 40 representatives of utilities, suppliers, and research organizations.

The II&C Pathway presentation is found in Appendix E.

6.3 2013 ISA POWID Symposium

The II&C Pathway research program was presented at the International Society of Automation (ISA) POWID meeting held in Orlando, FL on June 3-5, 2013. POWID is the ISA's annual meeting dedicated to power plant I&C issues. The presentation included an overview and results of all of the pilot projects to-date, and how these projects support the long-term vision for addressing sustainability issues with the current operating nuclear plants. The presentation also described how these new technologies held potential for operational performance improvement for the LWR fleet. The II&C Pathway representative participated in a panel discussion at the meeting on the topic of advancements for nuclear instrumentation and control. Audience questions indicated a high interest in the development activities of the II&C Pathway.

The II&C Pathway presentation is found in Appendix F.

6.4 24th Annual Procedure Symposium – Procedure Professionals Association

A presentation on the accomplishments and results from the first two evaluation studies conducted in the LWRS Computer-Based Procedure project was made at the general session of the Nuclear Procedure Professional Association annual symposium on June 25, 2013, in St. Petersburg, FL. This organization promotes the development of nuclear utility procedure standards and the exchange of information among procedure development professionals to increase reliability, improve performance, and ensure the safe and efficient operation of nuclear facilities. The conference was attended by 81 utility and industry professionals working in the area of nuclear facility procedures. Several attendees expressed interest in collaborating with the computer-based procedure project specifically and the Utility Working Group in general.

The II&C Pathway presentation is found in Appendix G.

6.5 2013 NITSL Workshop

The LWRS II&C Pathway was presented at the Nuclear Information Technology Strategic Leadership (NITSL) Workshop held in Detroit, MI on July 16-17, 2013. The NITSL organization is an association of the commercial nuclear plant Information Technology managers and staff. As a designated INPO Topical Area, NITSL provides a forum for leadership and strategic guidance for the consistent and efficient application and support of information technologies, including the business and plant systems supporting the US nuclear power plants and industry in general. The presentation was part of the meeting plenary session with approximately 270 participants in attendance. There was substantial interest in the developments of the pilot projects and the related efforts in cyber security. As a result of the meeting, NITSL's Infrastructure and Application (I&A) Committee has requested a benchmarking trip to INL in February of 2014, to learn more about the research and development activities of the II&C Pathway. Twelve utility members of the Committee are expected to attend.

The II&C Pathway presentation is found in Appendix H.

6.6 2013 ANS Utility Working Conference

The II&C Pathway organized and chaired a dedicated session at the ANS Utility Working Conference in Hollywood, FL on August 12-14, 2013. This session was part of a conference track on Cyber Security/Digital I&C/Long-Term Operations. The conference was attended by utility staff for operating nuclear plants, as well as representatives of nuclear equipment and services suppliers, government, research organizations, and nuclear industry support organizations. Presentations were made by INL representatives on the overall program long-term vision and strategy, the computer-based procedures pilot project, and the on-line monitoring pilot projects. The session was well-attended and there was considerable interest in the work as indicated by the number of audience questions for the presenters. Several new contacts were made for future project communications.

The II&C Pathway presentation is found in Appendix I.

7. International Information Exchange

7.1 Potential Collaboration with Electricite' de France (EdF)

In late FY 2012, Electricite' de France (EdF) proposed collaboration with II&C Pathway in the area of mobile technologies for nuclear plant field workers. This was intended to be part of a larger collaborative agreement that also involved the Electric Power Research Institute (EPRI) and the OECD Halden Reactor Project (HRP), both of which EdF is affiliated.

Discussions concerning this proposal were conducted at various times in FY 2013 with Mr. Patrick Morilhat, Program Director for I&C and Plant Performance, and Mr. Francois Dionis, Research Engineer, both in the EdF Research and Development organization. In January, Mr. Morilhat stated that he wanted to discuss potential development projects with EPRI before proposing specific collaboration ideas with the II&C Pathway. In June, Mr. Morilhat

stated that EdF's collaboration interests were now in the area of cyber security, and that Mr. David Bateman, Cyber Security Group Chief, would be the lead contact for them.

Mr. David Bateman attended the 2013 Utility Working Group meeting in Idaho Falls, ID, August 20-22, 2013, as the representative of EdF. Mr. Bateman participated in separate discussions with the II&C Pathway and representatives of the INL Cyber Security organization. Based on these discussions, EdF will consider various types of possible collaboration in the cyber security area and will propose to the II&C Pathway their ideas on mutually-beneficial collaboration.

Appendix A

Agenda for the Special Interest Group Meeting - Workshop on New Capabilities for Nuclear Plant Productivity Improvement

Workshop on New Capabilities for Nuclear Plant Productivity Improvement

May 23-24, 2013

EPRI Charlotte Office
1300 West WT Harris Blvd
Charlotte, NC 28262

Workshop Focus: Developments are well-underway to bring new capabilities into the nuclear plant work environment, such as hand-held and wearable technologies for plant workers, computer-based procedures, automated work packages, advanced control centers, and technologies for plant asset management. The focus of the workshop will be on human performance and productivity improvement. The workshop will feature presentations and roundtable discussions of current developments by leading research organizations, including EPRI, the DOE Light Water Reactor Sustainability (LWRS) Program, and the Halden Reactor Project (HRP).

Who Should Attend: Nuclear utility staff involved or interested in human performance improvement, work process improvement, staff productivity gains, nuclear work activity automation, nuclear plant information technology implementation, advanced plant support concepts, and fleet-wide asset management.

Thursday, May 23

8:00 AM – 8:30 AM

Overview of Workshop & Introductions

8:30 AM – 10:00 AM

Future Plant Worker – Topics include hand-held and wearable technologies, component identification technologies, human performance improvement, computer-based procedures, automated work packages, real-time plant information, real-time remote collaboration, and augmented reality.

Presentations:

- Computer-Based Procedures — DOE LWRS
- Automated Work Packages — EPRI

- Augmented Reality HRP

10:00 AM – 10:15 AM
Break
10:15 AM – 11:45 AM
Future Plant Worker – Roundtable Discussion
11:45 AM – 12:30 PM
Lunch
12:30 PM – 2:00 PM

Future Control Center – Encompasses Work Execution Centers, Outage Control Centers, Centralized On-Line Monitoring Centers, Management Decision Support Centers, and Emergency Response Facilities (TSC, OSC, EOF). Topics include work and status monitoring, emergent issue resolution, real-time remote collaboration with in-plant workers and other support centers, human performance improvement, decision support technology, social media concepts applied to plant communications, and improved plant risk management.
Presentations:

- Advanced Outage Control Center DOE LWRS
- Outage Management Technologies HRP

2:00 PM – 2:15 PM
Break
2:15 PM – 3:45 PM
Future Control Center – Roundtable Discussion
3:45 PM – 5:00 PM

Future Work Activity Automation – Topics include plant asset management, new technologies for plant workers, and automation of plant work activities.
Presentations:

- Centralized On-Line Monitoring EPRI/ DOE LWRS
- Plant Work Activity Automation DOE LWRS

Friday, May 24

8:00 AM – 9:45 AM

Integrated Operations (IO) – This brings all of the new capabilities together in an innovative concept of operational control and work activity management. IO has been successfully implemented for the Norwegian off-shore oil production industry, enabling many critical functions, including operations, to be conducted on-shore. These concepts are highly applicable to the challenges of nuclear plant activity management, with the promise of substantial improvement in decision making and collaboration among geographically-distributed plant workers and control centers. Topics include real-time remote collaboration, virtual support organization, human factors in collaboration technologies, and collective situational awareness.
Presentations:

- Integrated Operations Concepts HRP
- IO Applied to Outage Management HRP

09:45 AM – 10:00 AM
Break
10:00 AM – 11:30 AM
Integrated Operations – Roundtable Discussion
11:30 AM – 12:00 PM
Workshop Wrap-Up

Appendix B

Agenda for the Highly-Integrated Control Room Special Interest Group Meeting

DOE Advanced Light Water Reactor Sustainability Program
Advanced II&C Utility Working Group

Highly-Integrated Control Room Special Interest Group Meeting

June 11-12, 2013
Bellefonte Nuclear Project

Tuesday, June 11

0800	Welcome and Meeting Overview	Ken Thomas
0815	Introductions	
0830	Plant Tour Reactor Building, Auxiliary Control Room, Main Control Room, Turbine Building, MCR Dynamic Mock-Up	Raymond Williams
1030	I&C Strategies at Bellefonte	Jason Reed
1230	Lunch	
1315	Overview of the Bellefonte HFE design process	Paris Stringfellow
1400	Interactive demo of the MCR mockup	Dominick Logalbo
1445	Break	
1500	Discussion of key challenges in digital MCR design and summary of lessons learned • Use of a physical and dynamic mock-up • Integration with other groups • Challenges with HSI design	Bob Kershner

1600	Discussion – Lessons for the Operating Stations	All
1700	Adjourn	

Wednesday, June 12

0800	Integrated System Validation	Jon Kvalem
0845	INL Human Systems Simulation Laboratory	Ron Boring
0930	Break	
0945	Duke Energy Control Room Upgrades	Matt Gibson
1030	Open Discussion – Industry Needs	
1130	Wrap-Up and Future Plans	Ken Thomas
1145	Adjourn	

Appendix C

Agenda for the 2013 Summer Utility Working Group Meeting

Summer 2013 Joint Meeting of the

- **LWRS Advanced II&C Utility Working Group**
- **EPRI Productivity Improvements through Advanced Technology Strategy Group**

August 20-22, 2013
Idaho National Laboratory
2525 Fremont Ave.
Idaho Falls, ID 83402

EPRI ELECTRIC POWER RESEARCH INSTITUTE

LWRS Light Water Reactor Sustainability

Tuesday, August 20

0800	Badging	
0830	DOE/LWRS Welcome	Bruce Hallbert
0840	EPRI Welcome	Joe Naser
0850	Purpose/Agenda/Participant Introductions	Ken Thomas
0900	Advanced Outage Control Center Prototype Demonstration	Shawn St. Germain
0945	Break	
1000	Advanced Outage Control Center Prototype Demonstration (Cont.)	Shawn St. Germain
1045	On-Line Monitoring Technology Demonstration	Rick Rusaw Nancy Lybeck
1145	Lunch	
1230	Computer-Based Procedure Prototype Demonstration	Johanna Oxstrand

1400	Break	
1415	EPRI Topics/I&C Program	Joe Naser
1530	Halden Reactor Project Experience Report with Control Room Human Factors Studies	Jon Kvalem Gyrd Skranning
1700	Wrap-Up	Ken Thomas

Wednesday, August 21

0800	Integrated Systems Validation	Gyrd Skranning
0930	Break	
0945	Integrated Systems Validation (Cont.)	Gyrd Skranning
1015	EPRI Human Factors Activities	Bob Fink
1115	Duke Control Room Upgrades Program	Matt Gibson Jacques Hugo
1200	Lunch	
1300	Reference Human Factors Engineering Program	Jacques Hugo Ron Boring
1430	Break	
1445	Demonstration of HSSL Reconfigurable Simulator	Ron Boring
1600	Demonstration of Computerized Operator Support System	Ken Thomas Ron Boring
1630	Control Room Pilot Project Scope for FY 2014	Ken Thomas
1700	Wrap-Up	Ken Thomas

Thursday, August 22

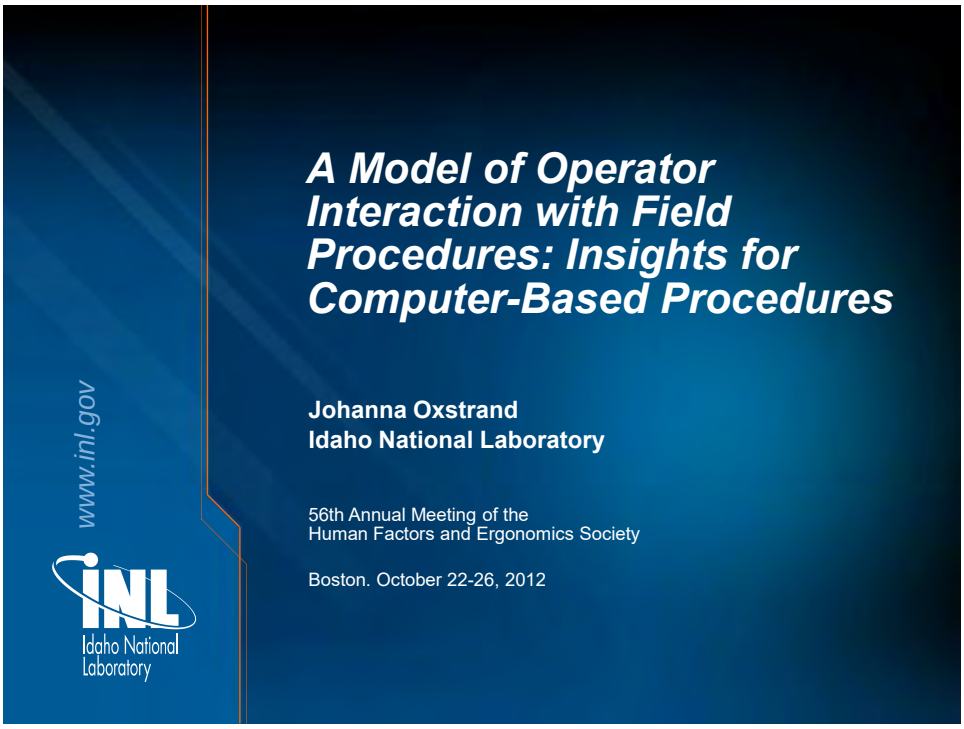
0800	Cyber Security – Current Threat Update	Rob Hoffman
0900	Cyber Security – Pilot Project Report	Bob Anderson
1000	Break	
1000	Industry Engagement Activities	Ken Thomas
1100	Utility Working Group Feedback and Priorities	Ken Thomas
1200	Wrap-Up	Ken Thomas

Afternoon Special Interest Group Meetings (Optional)

1. Human Performance and Process Improvement
2. Control Room Upgrades
3. Cyber Security

Appendix D

Human Factors and Ergonomic Society's 56th Annual Meeting



DOE LWRSP Vision and Program Goals

Vision

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.

Program Goals

- Develop fundamental scientific basis to understand and enable continued long-term operation of existing LWRs.
- Develop technical and operational improvements that contribute to long-term economic viability of existing nuclear power plants.

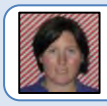
Advanced Instrumentation, Information, and Control (II&C) Systems Technologies

- Address long-term aging and reliability concerns of existing II&C technologies and develop and test new technologies.
- Establish a strategy to implement long-term modernization of II&C systems.
- Develop advanced condition monitoring technologies for reliable plant operation and develop the means to detect and characterize aging degradation processes.

2

Overview

INL CPB Research Team



Johanna Oxstrand
Human Factors Scientist
Software Engineering
Ringhals NPP, Sweden

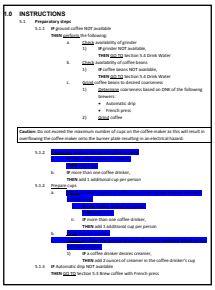
Katya Le Blanc
Human Factors Scientist
Psychology

Research Objectives

- Work with the US Nuclear Power industry to define an industry-wide vision and path forward for implementing CBPs
- Evaluate how to streamline and distill the information in paper-based procedures to increase efficiency, improve the ease of use, and reduce opportunities for errors.

Paper-based Procedures (PBPs) in Nuclear Power

- Used for most planned, abnormal, and emergency activities
- Designed for a wide variety of conditions
- Require manual place-keeping
- Often require managing multiple procedures



Potential Advantages of Computer Based Procedures

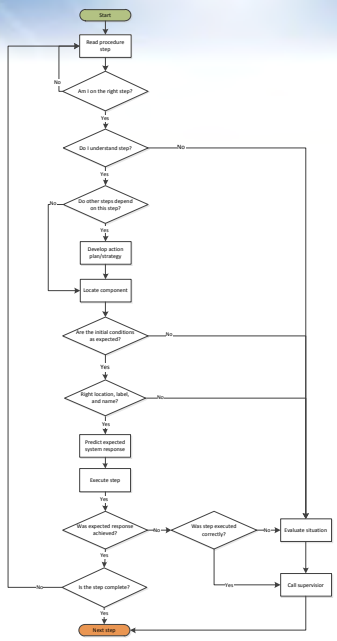
- CBPs are dynamic, so they can potentially reflect actual plant conditions
- CBPs could automatically carry out many tasks, potentially reducing operator workload
- Research on CBPs has existed since the early 1980s, yet no existing US Nuclear Power plant currently use them
- This project focuses on how to implement CBPs for operators in the field (i.e., not in the main control room)
  - May be perceived as less costly and risky
  - Successful demonstration of CBPs in the field may pave the way for CBPs in the main control room

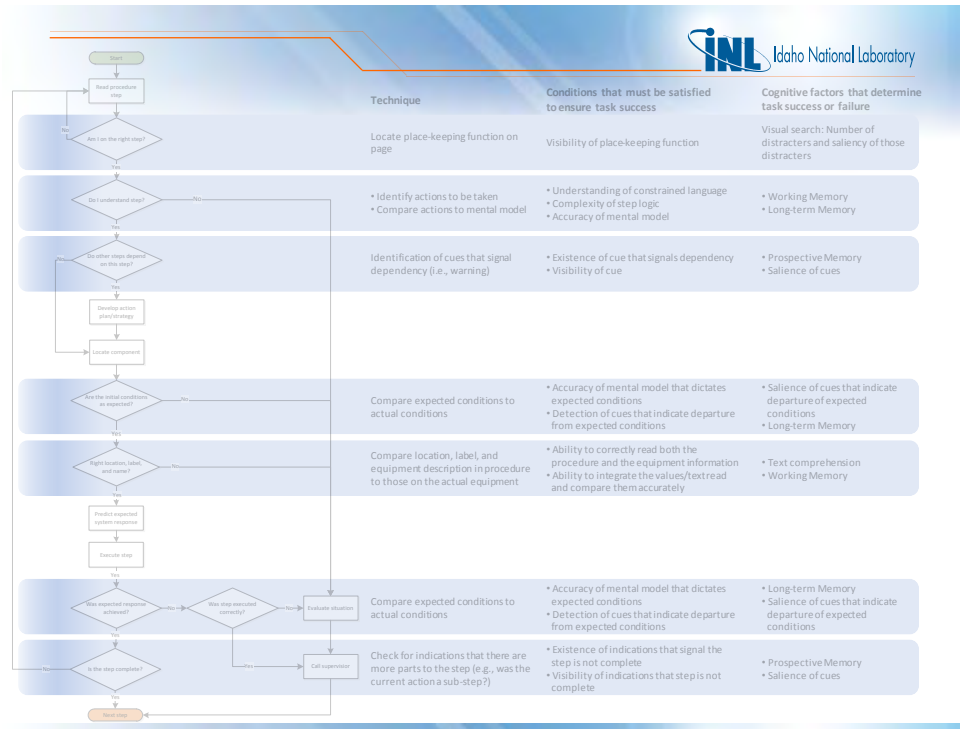
Qualitative Study

- Conducted at a US nuclear power plant over the course of a week
- On-the-Job observation of field operators
  - Researchers followed two operators as the conducted their rounds
- Structured Interviews of Field Operators
  - Researchers interviewed a total of 15 operators and maintenance technicians

Task Flow

- Describes the activities involved in the execution of **one** single procedure step
- We used the task flow and additional input form the interviews to identify potential errors in the procedure following process
- We also identified underlying cognitive mechanisms for some of the errors we identified

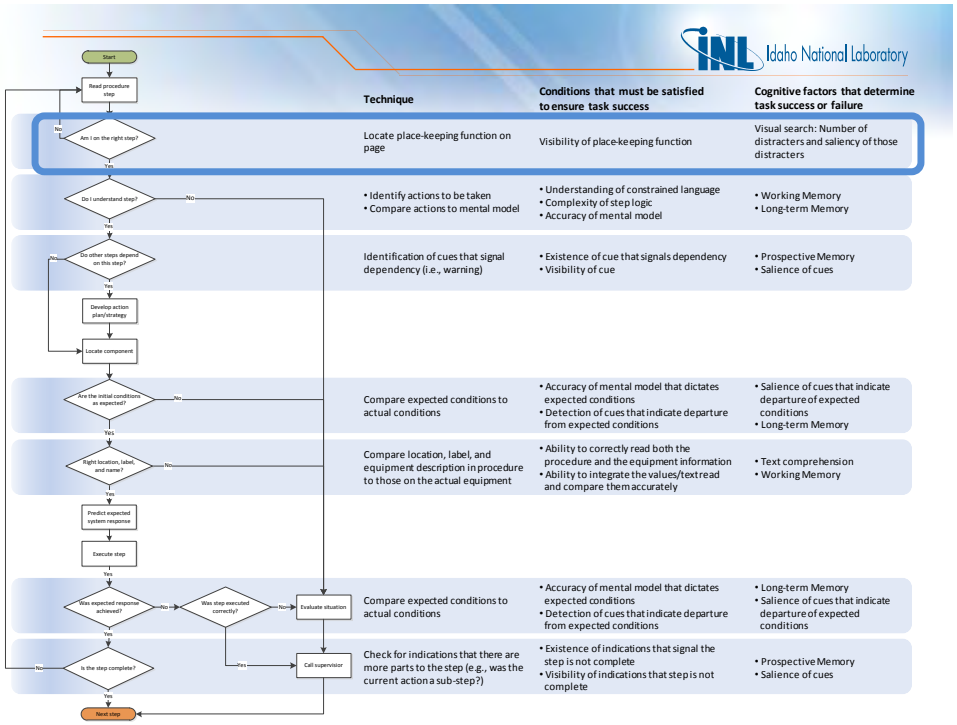




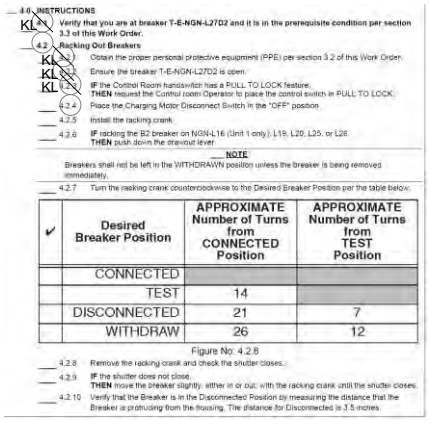
Idaho National Laboratory

Our Approach

- Design a prototype CBP system that enhances operator performance
  - Base CBP design on evaluation of how operators currently use PBPs
  - Design the CBP to support operators, especially where the current use of PBPs is error-prone
  - Empirically validate as many of the assumptions as practical
  - Evaluate the CBP prototype several times before it is finalized
- Provide general guidance on how to implement a CBP



Example of how the Model is used to Design the CBP prototype – Place Keeping



4.0 INSTRUCTIONS

KL Verify that you are at breaker T-E-NGN-L27D2 and it is in the prerequisite condition per section 3.3 of this Work Order.

4.2 Racking Out Breakers

KL Obtain the proper personal protective equipment (PPE) per section 3.2 of this Work Order.

KL Ensure the breaker T-E-NGN-L27D2 is open.

KL IF the Control Room handswitch has a PULL TO LOCK feature,
THEN request the Control room Operator to place the control switch in PULL TO LOCK.

4.2.4 Place the Charging Motor Disconnect Switch in the "OFF" position.

4.2.5 Install the racking crank.

4.2.6 IF racking the B2 breaker on NGN-L16 (Unit 1 only), L19, L20, L25, or L26,
THEN push down the drawout lever.

NOTE
Breakers shall not be left in the WITHDRAWN position unless the breaker is being removed immediately.

4.2.7 Turn the racking crank counterclockwise to the Desired Breaker Position per the table below:

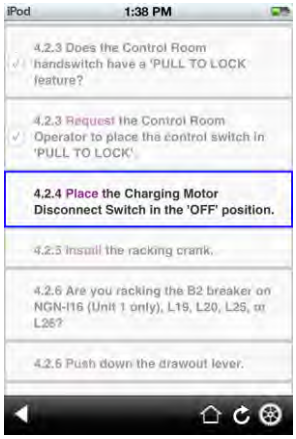
✔	Desired Breaker Position	APPROXIMATE Number of Turns from CONNECTED Position	APPROXIMATE Number of Turns from TEST Position
	CONNECTED		
	TEST	14	
	DISCONNECTED	21	7
	WITHDRAW	26	12

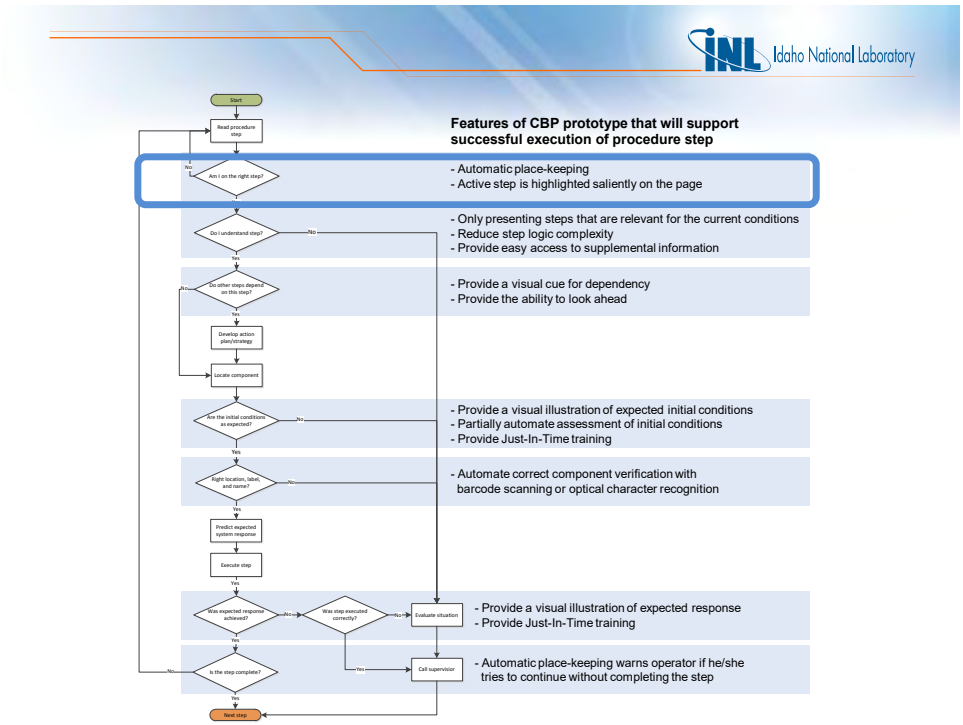
Figure No: 4.2.8

4.2.8 Remove the racking crank and check the shutter closes.

4.2.9 IF the shutter does not close,
THEN move the breaker slightly, either in or out, with the racking crank until the shutter closes.

4.2.10 Verify that the Breaker is in the Disconnected Position by measuring the distance that the Breaker is protruding from the housing. The distance for Disconnected is 3.5 inches.





Evaluation Study – Palo Verde, August 2012

- Objective: Demonstrate a prototype in a as simple context as possible to get focused feedback on the design of the user interface
- A simple procedure and scenario were selected
- 13 participants conducted the scenario with both the CBP prototype and the PBP (order was counterbalanced)
- The user interface design was evaluated

Results From Evaluation Study

- Operators were able to perform the procedure using the CBP prototype with minimal training.
- Context-sensitivity and reduced step logic complexity were perceived as desirable features
- Several specific improvements to the user interface were identified

Johanna.Oxstrand@inl.gov and Katya.LeBlanc@inl.gov

Appendix E

Nuclear Long Term Operations & Upgrades Conference

Advanced Instrumentation, Information, and Control Systems Technologies

Ken Thomas
Idaho National Laboratory

Nuclear Long Term Operations
and Upgrades Conference
Charlotte, NC
May 22, 2013

Light Water Reactor Sustainability R&D Program

Two-Fold Challenge of Sustainability

- Aging issues that could be life-limiting to the LWR fleet must be successfully resolved from a technical and regulatory standpoint. These issues primarily concern the large components and structures in a nuclear plant that would be difficult or cost-prohibitive to replace.
- The business model must remain competitive even while absorbing the cost of investments in technologies to ensure extended life of these critical plant components and structures.

So, the challenge of II&C modernization is implement digital upgrades in a manner that improves the competitiveness of the plant business model.

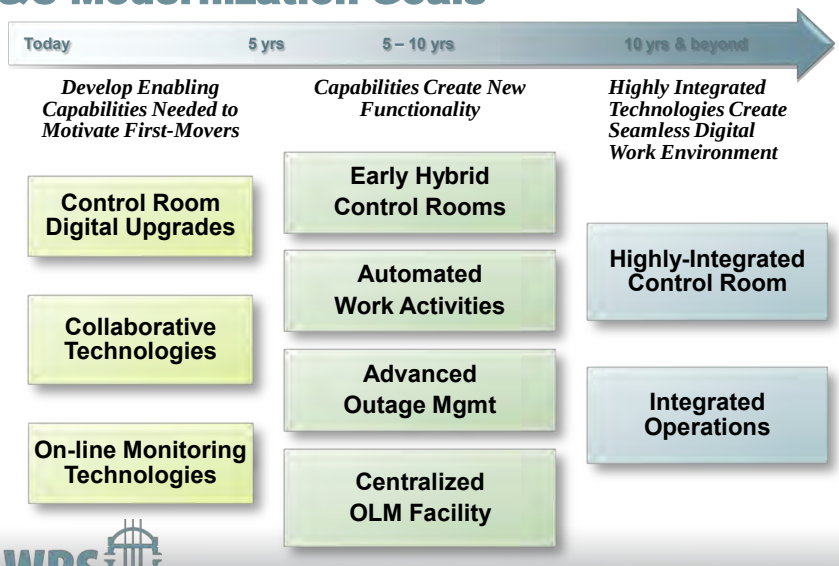
For Wide-Scale II&C Modernization:

- Avoid settling for "like for like" system replacements that do not leverage the benefits of digital technology
- Implement digital technology in a manner that enables significant business process improvement
- Capture inherent benefits regarding nuclear safety, improved productivity, improved job satisfaction, reduced human error, reduced dose, and improved asset management.
- Transform the NPP operating model from one that is labor-centric to one that is technology-centric.

Transforming the NPP Operating Model with Digital Technology

- Integrating plant systems, plant processes, and plant workers
- Demonstrating and validating new technologies and operational concepts at host nuclear plants
- Providing guidance for NPP implementation
- Communicating results to nuclear power stakeholders

II&C Modernization Goals



Utility Working Group

- 14 nuclear utility fleets represented.
- Advises the program on utility requirements and development plans for II&C modernization.
- Serves as host sites for demonstration projects when matching near term development objectives are identified.
- EPRI and Halden Reactor Project are key development partners

Centralized On-Line Monitoring

Joint Project with EPRI (Richard Rusaw, EPRI Project Manager)

- real-time assessment and monitoring of important plant SSCs
- development of diagnostic and prognostic models
- prognostic models are concerned with “remaining useful life”
- validation of the EPRI-developed OLM software (*Fleet-wide Prognostic and Health Management (FW-PHM) Suite)*.

Initial pilot projects are focused on active components

- emergency diesel generators
- large power transformers

In 2015, focus will shift to critical large passive structures and components

- biggest impact on NPP long-term sustainability
- will leverage development of suitable sensor and NDE technology

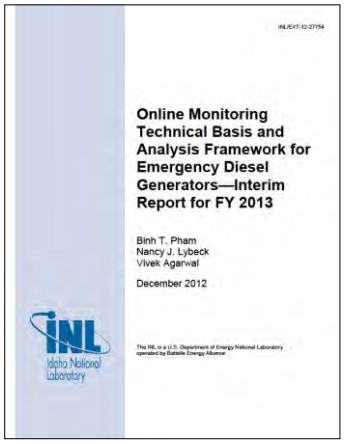
Centralized OLM is an important element of NPP work activity automation.

Centralized On-Line Monitoring

Working with Exelon at the Braidwood Nuclear Station to develop an OLM for emergency diesel generators.

Diagnostic Model Scope:

- Excessive piston wear
- Improper valve timing
- Fuel pump failure
- Unresponsive governor
- Intermittent control signal to the governor
- Intermittent magnetic pickup signal
- Diesel engine fuel injector – improper fuel injection
- Lubricating oil pump – Low Lubricating oil pressure
- Jacket water pump – Low jacket water pressure
- Voltage regulator – Voltage regulating system malfunction

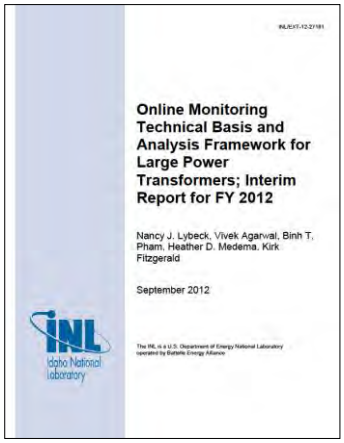


Centralized On-Line Monitoring

Working with Progress Energy at the Harris Nuclear Plant to develop an OLM for large power transformers.

Diagnostic Models Developed:

- Loss of bushing insulation dielectric strength
- Displaced core winding
  - Insulating oil
  - Acidity
  - Contamination
- Dielectric strength degradation
- Insulating oil pump motor loss of performance
- Paper insulation degradation
- Gas Ratios
  - Doernenburg ratios
  - Rogers ratios
  - Oxygen/Nitrogen ratio
  - Acetylene/Hydrogen ratio
- Acoustic signals



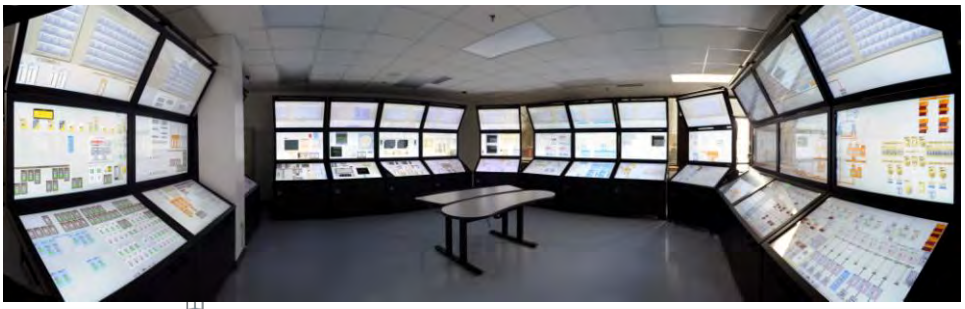
Human Systems Simulation Laboratory (HSSL)

- Reconfigurable full-scale simulator for control room upgrade evaluations
- Supports rapid prototyping - new designs may be iterated and tested to ensure they maintain and even enhance operator performance.
- Can serve as a standard test bed for control room modernization across the industry.
- Uses the same thermal-hydraulic and physically simulated plant models as NPP training simulators
- Can conduct the required evaluation elements of NUREG 0700 and 0711
- Can measure human performance and collect related data.

Human Systems Simulation Laboratory

Uses 15 bench board-style panels (glass-top touch-sensitive) that together can mimic a full NPP control room with dynamic simulation. These panels can be arranged in various configurations to mimic the layout of currently-operating NPPs.

New technologies can be mixed with these touch panels to simulate future hybrid control rooms as a mixture of traditional bench boards and new large displays.



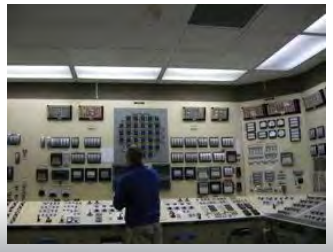
Incorporating Digital Upgrades in an Analog Control Room

Conducting control room upgrade studies with two nuclear utilities, using the HSSL and their on-site training simulators.

Work is focused on opportunities for improved operator interfaces enabled by the implementation of digital distributed control systems (DCS).

September 2013 Report to be Published:

Reference Human Factors Engineering Plan for an optimized, human-factored control board layout for integrating digital operator interface screens with analog controls and indicators.



Collaborating with EPRI in developing activities and publications

LWRS Light Water Reactor Sustainability

12

Computer-Based Procedures

Working with Duke Energy and Arizona Public Service in a series of demonstrations of a CBP prototype to improve human performance and productivity in NPPs. Testing a procedure step model that was developed earlier in the pilot project.

Results to date have led to refinements in how information is presented to a procedure user to improve human performance.

Will conduct a field study at the Palo Verde Nuclear Generating Station in July, as the final study for field based procedures. In FY 2014 the focus will turn to control room procedures.

The project results to date will be presented to the nuclear industry's Procedure Professionals Association annual symposium in June. This meeting is attended by the procedure managers from most of the nuclear fleets.

LWRS Light Water Reactor Sustainability

13

Mobile Technologies for NPP Field Workers

- Emphasis is on NPP field worker human performance and productivity
- Uses hand-held or wearable technologies
- Real-time collaboration with distant parties
- Correct component identification
- Embedded work processes
- Real-time work status sent to Work Control Center
- Real-time retrieval of needed information – OE, drawings, manuals, training material, etc.
- Future development in:
  - automated work packages
  - augmented reality

LWRS Light Water Reactor Sustainability

14

Advanced Outage Control Center

- Have developed advanced outage management technologies with two utility partners
- Leverages the mobile technologies for NPP field workers together with the collaborative technologies for control centers
- Current focus in on an Advanced Outage Control Center, with the following capabilities.
  - Real Time Collaboration for Emergent Issues
  - Improved Communication of Outage Status Out of the OCC
  - Improved Communication of Discovered Conditions to the OCC
  - Real-Time Work Status
  - Automatic Pending Support Notifications
  - Real-Time Requirements Monitor

LWRS Light Water Reactor Sustainability

15


In summary…..
Shift the digital approach from a replacement strategy to a modernization strategy
Integrate plant systems, work processes, and human performance
Leverage the wide spectrum of new technologies and innovations
Transform our business to achieve significant performance improvement
www.inl.gov
INL
Idaho National Laboratory

Appendix F

2013 ISA POWID Symposium

Advanced Instrumentation, Information, and Control Systems Technologies

Ken Thomas
Idaho National Laboratory

ISA POWID Symposium 2013
Orlando, FL
June 3, 2013

Light Water Reactor Sustainability R&D Program

DOE LWRSP Vision and Program Goals

Vision

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.

Program Goals

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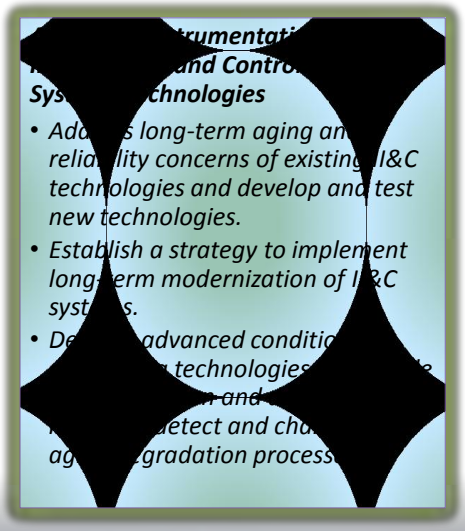

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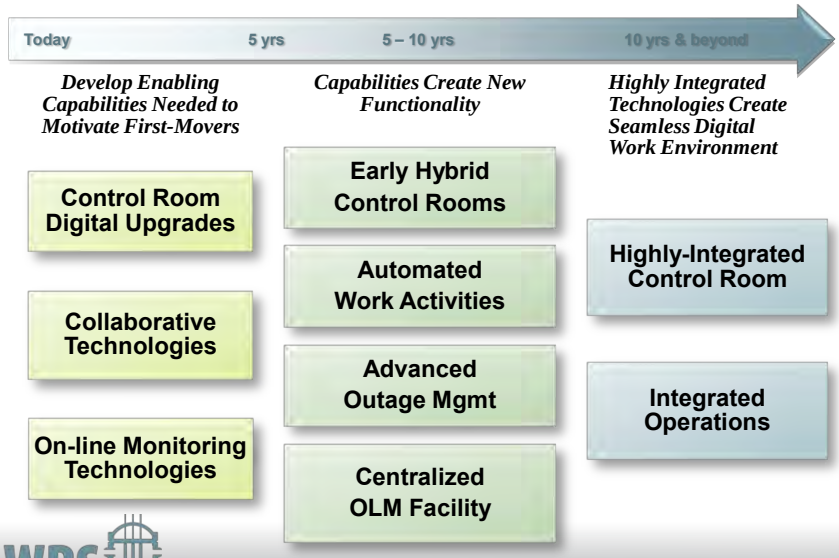
II&C Modernization Goals



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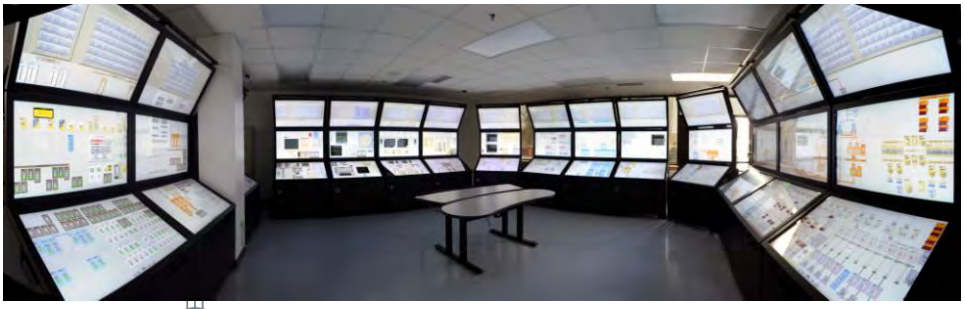
- Serves as host sites for demonstration projects when matching near term development objectives are identified.
- EPRI and Halden Reactor Project are key development partners

Human Systems Simulation Laboratory (HSSL)

Uses 15 bench board-style panels (glass-top touch-sensitive) that together can mimic a full NPP control room with dynamic simulation.

New technologies can be mixed with these touch panels to simulate future hybrid control rooms as a mixture of traditional bench boards and large displays.



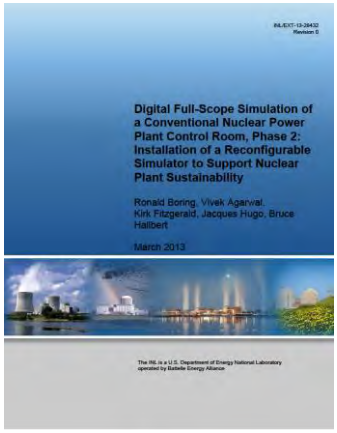
HSSL Reconfigurable Simulator

- Supports rapid prototyping - new designs may be iterated and tested to ensure they maintain and even enhance operator performance.
- Uses the same thermal-hydraulic and physically simulated plant models as NPP training simulators
- Can conduct the required evaluation elements of NUREG 0700 and 0711
- Can measure human performance and collect related data.

HSSL Report

Digital Full-Scope Simulation of a Conventional Nuclear Power Plant Control Room, Phase 2: Installation of a Reconfigurable Simulator to Support Nuclear Plant Sustainability

- Describes the unique capabilities of a full-scale, glass-top simulator for LWR conventional control rooms.
- Describes how it can be reconfigured between multiple plants using different simulation software.
- Describes the types of human factors studies that can be conducted with the glass-top simulator.
- Describes in detail how the simulator facility can be used for Function Analysis/Allocation and Task Analysis, in support of NRC NUREG-0711 requirements.



LWRS Light Water Reactor Sustainability

10

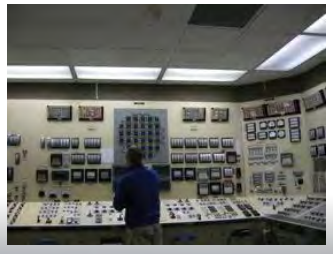
Incorporating Digital Upgrades in an Analog Control Room

Conducting control room upgrade studies with two nuclear utilities, using the HSSL and their on-site training simulators.

September 2013 Report to be published:

Reference Human Factors Engineering Plan for an optimized, human-factored control board layout for integrating digital operator interface screens with analog controls and indicators.

Collaborating with EPRI in development activities and publications



LWRS Light Water Reactor Sustainability

11

Computer-Based Procedures

Working with Duke Energy and Arizona Public Service in a series of demonstrations of a CBP prototype to improve human performance and productivity in NPPs. Testing a procedure step model that was developed earlier in the pilot project.

Results to date have led to refinements in how information is presented to a procedure user to improve human performance.

Will conduct a field study at the Palo Verde Nuclear Generating Station in July, as the final study for field based procedures. In FY 2014 the focus will turn to control room procedures.

LWRS Light Water Reactor Sustainability

12

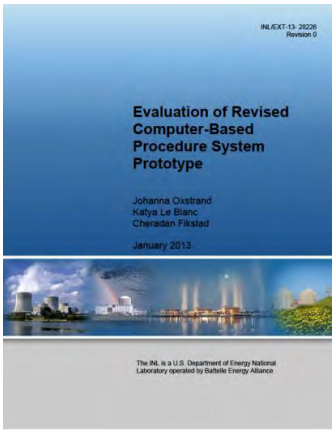
Computer-Based Procedures - Reports

January 2013 Report:

Evaluation of Revised Computer-Based Procedure System Prototype (INL/EXT-13-28226)

September 2013 Report to be published:

Complete evaluation of final LWRS II&C Computer-Based Procedure prototype for field workers



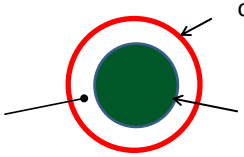
LWRS Light Water Reactor Sustainability

13

Computerized Operator Support System

Automatic Protective Actions vs. Procedure-Based Operator Control Actions

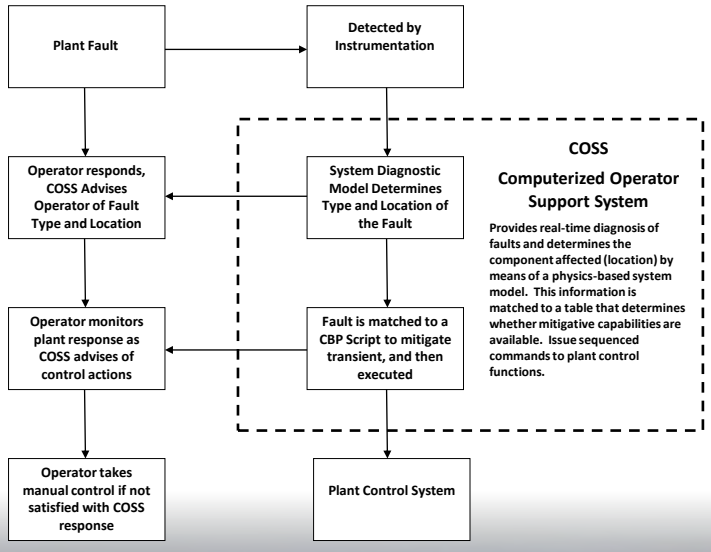
Plant safety envelope maintained by Protection System; independent of Control System



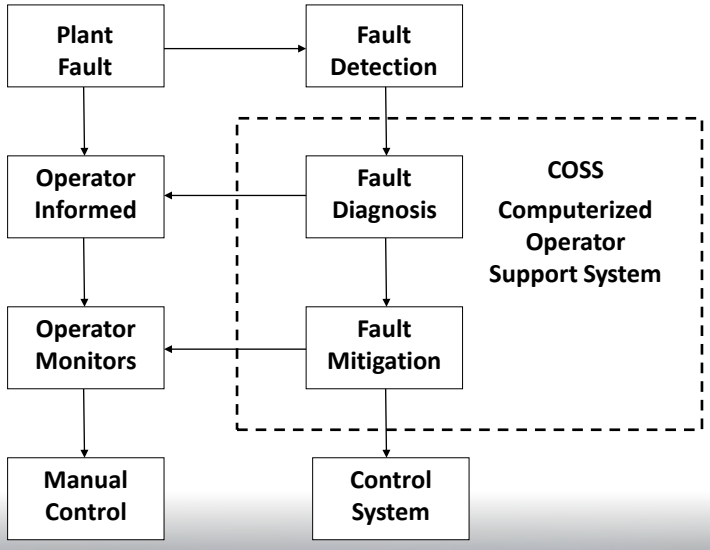
Region of encroachment on Protection System during upsets

Normal plant operating region maintained by Control System

Computerized Operator Support System



Computerized Operator Support System



16

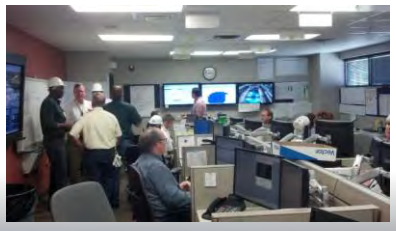
Mobile Technologies for NPP Field Workers

- Emphasis is on NPP field worker human performance and productivity
- Uses hand-held or wearable technologies
- Real-time collaboration with distant parties
- Correct component identification
- Embedded work processes
- Real-time work status sent to Work Control Center
- Real-time retrieval of needed information – OE, drawings, manuals, training material, etc.

17

Advanced Outage Control Center

- Leverages the mobile technologies for NPP field workers together with the collaborative technologies for control centers
- Current focus is on an Advanced Outage Control Center:
  - Real Time Collaboration for Emergent Issues
  - Real-Time Work Status
  - Improved Communication of Outage Status
  - Automatic Pending Support Notifications
  - Real-Time Requirements Monitor



LWRS Light Water Reactor Sustainability

18

Centralized On-Line Monitoring

- Joint Project with EPRI (Richard Rusaw, EPRI Project Manager)
  - real-time assessment and monitoring of important plant SSCs
  - development of diagnostic and prognostic models
  - prognostic models are concerned with “remaining useful life”
  - validation of the EPRI-developed OLM software (*Fleet-wide Prognostic and Health Management (FW-PHM) Suite)*.
- Initial pilot projects are focused on active components
  - Emergency Diesel Generators – Braidwood Nuclear Station
  - Large Power Transformers – Harris Nuclear Plant
- In 2015, focus will shift to critical large passive structures and components
  - biggest impact on NPP long-term sustainability
  - will leverage development of sensor and NDE technology

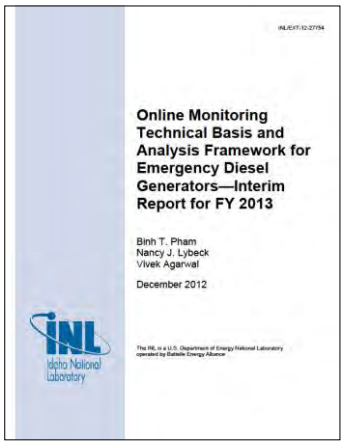
LWRS Light Water Reactor Sustainability

19

OLM – Emergency Diesel Generators

Diagnostic Model Scope:

- Excessive piston wear
- Improper valve timing
- Fuel pump failure
- Unresponsive governor
- Intermittent control signal to the governor
- Intermittent magnetic pickup signal
- Diesel engine fuel injector – improper fuel injection
- Lubricating oil pump – Low Lubricating oil pressure
- Jacket water pump – Low jacket water pressure
- Voltage regulating system malfunction

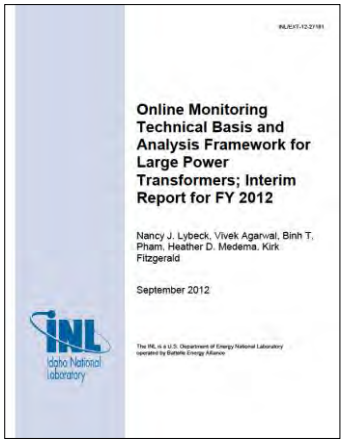


OLM – Large Power Transformers

Working with Progress Energy to develop an OLM for large power transformers.

Diagnostic Models Developed:

- Loss of bushing insulation dielectric strength
- Displaced core winding
  - Insulating oil
  - Acidity
  - Contamination
- Dielectric strength degradation
- Insulating oil pump motor loss of performance
- Paper insulation degradation
- Gas Ratios
- Acoustic signals




In summary…..
Shift the digital approach from a replacement strategy to a modernization strategy
Integrate plant systems, work processes, and human performance
Leverage the wide spectrum of new technologies and innovations
Transform our business to achieve significant performance improvement
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INL
Idaho National Laboratory

Appendix G

24th Annual Procedure Symposium – Procedure Professionals Association

DOE LWRS Vision and Program Goals

Vision

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.

Program Goals

- Develop fundamental scientific basis to understand and enable continued long-term operation of existing LWRs.
- Develop technical and operational improvements that contribute to long-term economic viability of existing nuclear power plants.

Advanced Instrumentation, Information, and Control (II&C) Systems Technologies

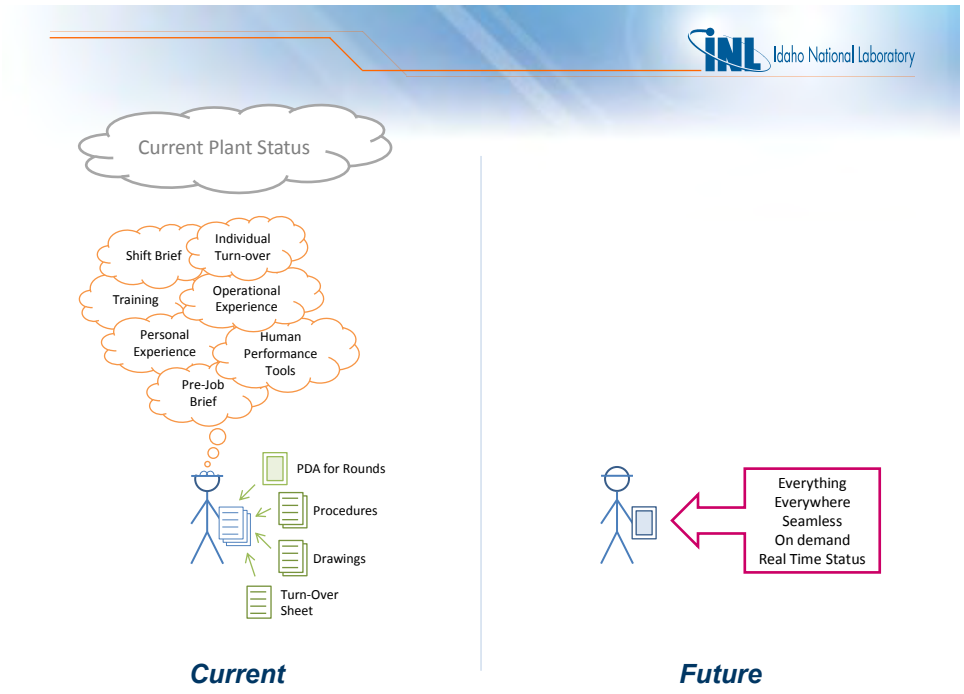
- Address long-term aging and reliability concerns of existing II&C technologies and develop and test new technologies.
- Establish a strategy to implement long-term modernization of II&C systems.
- Develop advanced condition monitoring technologies for reliable plant operation and develop the means to detect and characterize aging degradation processes.

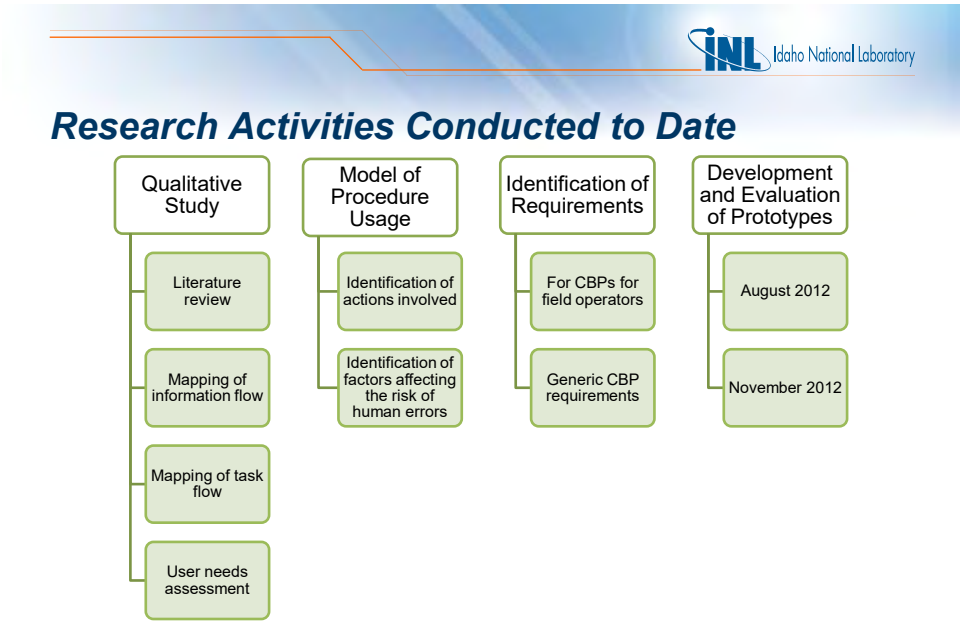
2

Computer-Based Procedure Research Effort

Research Objectives

- Define design requirements for computer-based procedures (CBPs) to ensure improvement.
- Evaluate how to streamline and distill the information in the PBP and to make use of the advantages of dynamic presentation to:
  - Increase efficiency,
  - Improve the ease of use, and
  - Reduce opportunities for errors.
  - Incorporate HU Tools into the normal flow of the procedure.
- Support the industry to build a business case
- We do **NOT** look at how to display PBPs on an electronic device (e.g., pdf with hyperlinks).


Idaho National Laboratory
Current Plant Status
Shift Brief
Individual Turn-over
Training
Operational Experience
Personal Experience
Human Performance Tools
Pre-Job Brief
PDA for Rounds
Procedures
Drawings
Turn-Over Sheet
Everything
Everywhere
Seamless
On demand
Real Time Status
Current
Future


Idaho National Laboratory
Research Activities Conducted to Date
Qualitative Study
Literature review
Mapping of information flow
Mapping of task flow
User needs assessment
Model of Procedure Usage
Identification of actions involved
Identification of factors affecting the risk of human errors
Identification of Requirements
For CBPs for field operators
Generic CBP requirements
Development and Evaluation of Prototypes
August 2012
November 2012

What has previous research and our own effort taught us so far.

DESCRIPTION OF FUNCTIONS

Recap From This Morning

- Top 5 Traps :
  - Field Decisions
  - Difficulty
  - Vagueness and Misleading Information
  - Multiple Embedded Actions

Thank you, Rob Fisher!

Recap From This Morning

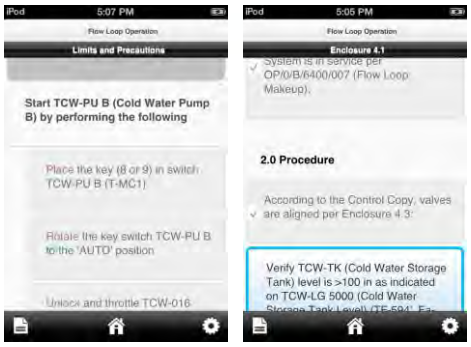
- Top 5 Traps:
  - Field Decisions
  - Difficulty
  - Vagueness and Misleading Information
  - Multiple Embedded Actions

- How we address these:
  - Step Presentation
  - Dynamic Context Sensitivity
  - Simplified Step Logic
  - Place-Keeping
  - Verifications

Step Presentation

- Highlight important information
- Embedded job aids
- Computational aids and validation of result
- Ability to look ahead
- Seamless transitions

- Single step vs Overview
  - To improve readability we tried single step. Based on feedback we changed to execute from overview.
- Present N/A'd steps at all times?
  - Controversy: show steps always vs showing on demand/request

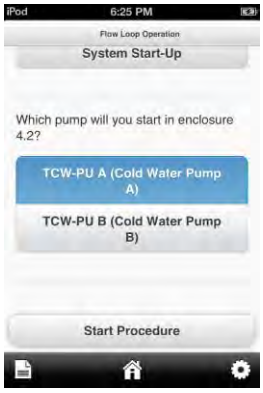


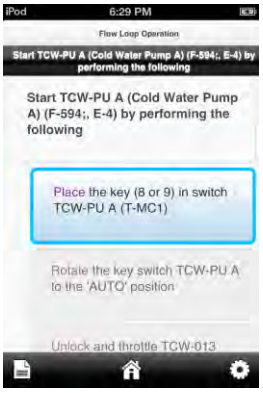
Example Procedure

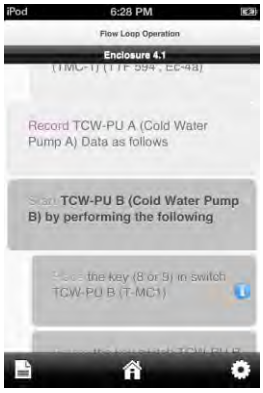
_____ _____	2.3	Open TCW-010 (Cold Water Storage Tank Outlet Isol) (TF-594', Fa-4)
_____	2.4	IF starting TCW-PU A (Cold Water Pump A) (F-594', E-4) perform the following
_____	2.4.1	Place the key (8, or 9) in switch TCW-PU A (T-MC1)
_____	2.4.2	Rotate the key switch TCW-PU A to the "AUTO" position
_____	2.4.3	Unlock and throttle TCW-013 (Cold Water Pump A Disch Throttle) (TTF 594', Ec-4a)) to obtain 50-60% on TCW-P5010 (Cold Water Pump A Disch Flow) (TMC-1) (TTF 594', Ec-5)
_____	2.5	IF starting TCW-PU B Cold Water pump B perform the following
_____	2.5.1	Place the key (8, or 9) in switch TCW-PU B (T-MC1)
_____	2.5.2	Rotate the key switch TCW-PU B to the "AUTO" position
_____	2.5.3	Unlock and throttle TCW-016 (Cold Water Pump B Disch Throttle) (TTF 594', Ec-4a)) to obtain 50-60% on TCW-P5020 (Cold Water Pump B Disch Flow) (TMC-1) (TTF 594', Ec-4a)
_____	2.6	IF started on step 2.4 record TCW-PU A (Cold Water Pump A) data as follows.

- TCW PG 5010 Cold Water Pump A Suction Pressure _____psig
- TCW PG 5020 Cold Water Pump A Disch Pressure _____psig
- TCW P 5010 Cold Water Pump A Disch Flow _____%
- TCW P 5000 TCW-PU A from T-TBOX0907 ammeter _____amps

Dynamic Context-Sensitivity



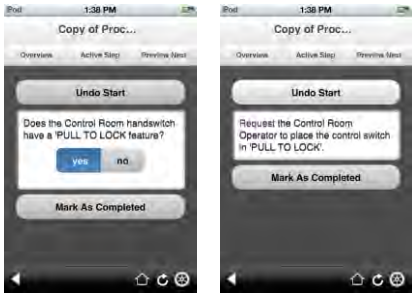




- Only present the relevant steps based on User input, Plant State, Operation Mode, or other procedures in use

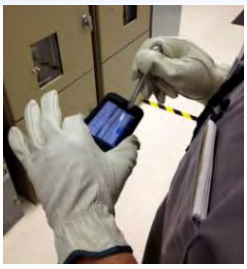
Simplified Step Logic

- Why?
  - Conditional statements (If/Then, When/Then, etc) put the burden of evaluation on the field worker
- How?
  - Ask simple questions (Yes or No, Pump A or Pump B)
  - Based on input from the field worker or from a plant database, present the appropriate path through the procedure



Place-Keeping

- Why?
  - Conducting steps out of sequence or omitting a step are two deviations we need to consider
  - Circle before reading step – unnatural behavior
- How?
  - Current step is clearly indicated
  - Steps can't be conducted out of sequence
  - CBPS provides information regarding path through procedure (decisions made)
  - Continuously applicable steps are clearly indicated
  - Field worker always has the option to stop work and contact supervisor.



Place-Keeping

4.0 INSTRUCTIONS

Precondition Verifications

Verify that you are at breaker T-E-NGN-L27D2.

Ensure that the prerequisite conditions per section 3.3 of this work order are met.

4.3 Racking Out Breakers

Obtain the proper personal protective equipment (PPE) per section 3.2 of this Work Order.

Ensure the breaker T-E-NGN-L27D2 is open.

IF the Control Room handswitch has a PULL TO LOCK feature,
THEN request the Control room Operator to place the control switch in PULL TO LOCK.

Place the Charging Motor Disconnect Switch in the "OFF" position.

4.2.5 Install the racking crank.

4.2.6 IF racking the B2 breaker on NGN-L16 (Unit 1 only), L19, L20, L25, or L26,
THEN push down the drawout lever.

NOTE

Breakers shall not be left in the WITHDRAWN position unless the breaker is being removed immediately.

4.2.7 Turn the racking crank counterclockwise to the Desired Breaker Position per the table below:

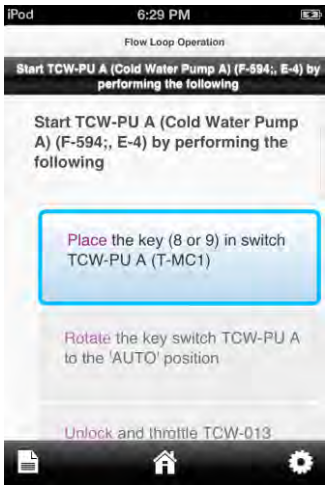
✔	Desired Breaker Position	APPROXIMATE Number of Turns from CONNECTED Position	APPROXIMATE Number of Turns from TEST Position
	CONNECTED		
	TEST	14	
	DISCONNECTED	21	7
	WITHDRAW	26	12

Figure No: 4.2.8

4.2.8 Remove the racking crank and check the shutter closes.

4.2.9 IF the shutter does not close,
THEN move the breaker slightly, either in or out, with the racking crank until the shutter closes.

4.2.10 Verify that the Breaker is in the Disconnected Position by measuring the distance that the Breaker is protruding from the housing. The distance for Disconnected is 3.5 inches.



Correct Component Verification

- Why?
  - Manipulating the wrong component is identified as an important deviation.
- How?
  - Use the CBPS to verify correct component
    - Barcodes
    - Optical character recognition (OCR)
    - Manual input

Verifications

- Independent verification
  - Notify user when IV is needed.
  - Assign and notify personnel to conduct IV.
  - Review video/photo or visit the work site.
- Concurrent verifications
  - Other user logs in and sign off on the step.

Other Functions Considered

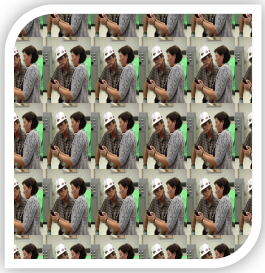
- Soft controls
  - Deemed N/A for field procedures
    - Most equipment can't be operated remotely (even in advanced plants)
    - Maybe applicable for MCR CBPs
- Real-time task status
  - If access to wifi, one can know where the operator is in the procedure at any given time
- Automatic information insertion and verification of plant response

How we test and evaluate our concepts.

EVALUATION STUDIES

Evaluation Study – General Process

- Pre-Job Brief and Two Minute Drill
- Training on CBP system
- Conduct scenario
  - Paper-based procedure
  - Computer-based procedure
- We measure
  - Deviation from specified path
  - Performance time
  - Workload (NASA TLX)
  - Usability of device and interface

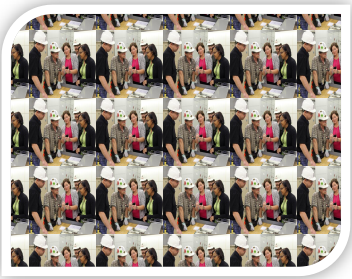


Evaluation Study #1 – Palo Verde, August 2012

- Objective:
  - Demonstrate a prototype in a as simple context as possible to get focused feedback on the design of the user interface
- A simple procedure and scenario
- 13 participants
- The user interface design was evaluated in terms of usability, acceptability, and potential increased process efficiency

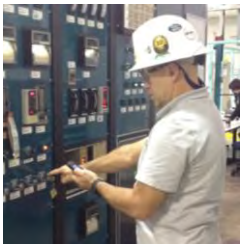
Study #1 - Result

- Context sensitivity is a highly desirable feature
  - 100% of participants reported that only seeing the relevant steps was an improvement
  - 100% of participants preferred the simplified step logic
- Presenting procedures on a small device is a challenge
  - The "single step" view may reduce awareness of where you are in the procedure
  - The single step mode is not necessary on larger devices
  - The iPod device may be too small for many applications of CBPs
- The user interaction can be simplified by automatically activating the next step when previous one is marked complete



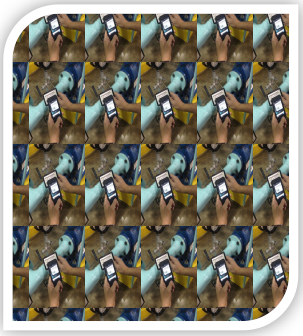
Evaluation Study #2 – Catawba, November 2012

- Objective:
  - Evaluate whether the modification improved usability of the prototype.
  - Provide quantitative performance data that could be used to compare CBP and PBP usage.
- 10 participants
- Performed a scenario in the Flow Loop facility
- The user interface design was evaluated



Study #2 - Result

- Results indicate that CBPs may be effective in enhancing human performance.
- Fewer overall deviations when the procedure was executed using the CBP than with the PBP.
  - A greater number of non-recovered deviations when the procedure was executed using the PBP.
  - CBP may help operators to catch potential errors and prevent them.
- Results also indicate that operators are highly likely to readily accept CBPs.
  - The majority of participants reported that they preferred the CBP over PBPs,
  - They rated the CBP as highly usable,
  - They unanimously preferred the dynamic context-sensitivity of CBPs to static PBPs.



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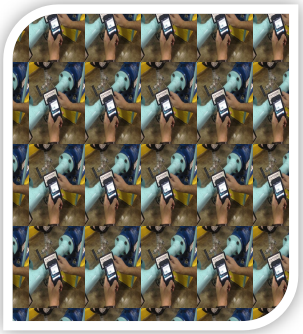
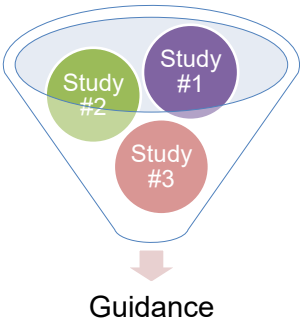


What we will do and what the end-result of all the studies will be.

PATH FORWARD

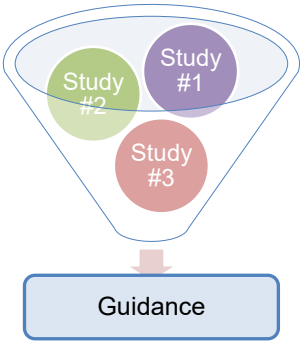
Why All These Evaluation Studies? (Study 1-3)

- Need to understand the reality of how procedures are used in order to know how to best improve the process.
  - The result from the research should be tailored to the nuclear industry's needs.
  - Need to collect both qualitative and quantitative data to ensure that the procedure usage process is indeed improved.
  - Many iterations provides opportunity to evaluate details and ensure a more complete and accurate guidance.
- The results of the three studies will be synthesized to provide guidance on:
  - How to effectively design the user interface of a CBP system for field operators.
  - What implications the human factors specifications have for the underlying data structure and the procedure content.



Validation Study (Study 4)

- Validate the newly developed Guidance.
  - Develop a final prototype based on Guidance document.
- To be evaluated/validated at a nuclear utility
  - Activity in the plant (not training lab).
  - Non-safety related system.
  - Frequently conducted activity.
  - Data collected automatically while the procedure is performed.
  - The utility will have the prototype for about 3 months.



The Great Migration

- Ground work needed
  - Standardize procedure content across organizations
    - MNT, Field Ops/AO, Chemistry, etc. they all use procedures even tough we like to call them different things.
  - Logic must be identified and specified
    - E.g., basis within procedure to where to branch
- Encoding procedures – A tool to
  - Transfer existing PBPs to a data structure,
  - Enter new data, and
  - Compose CBPs.
- How do we get started?
  - Design Guidance
  - Data Structure
  - Procedure Writer's Guides

We look forward to future collaboration endeavors!

Johanna.Oxstrand@inl.gov and Katya.LeBlanc@inl.gov

Appendix H

2013 NITSL Workshop

Advanced Instrumentation, Information, and Control Systems Technologies

Ken Thomas
Idaho National Laboratory

2013 NITSL Workshop
Detroit, MI
July 16, 2013

Light Water Reactor Sustainability R&D Program

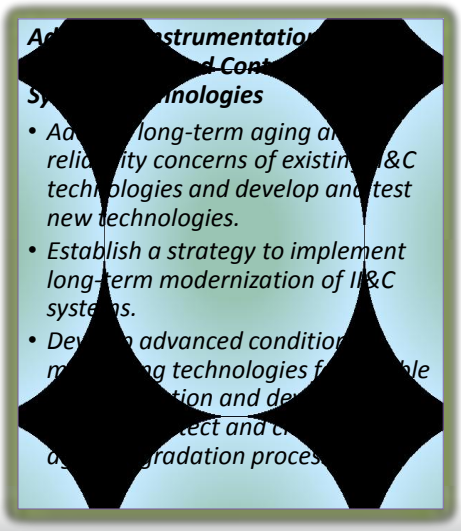
DOE LWRSP Vision and Program Goals

Vision

- Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.

Program Goals

- Develop fundamental scientific basis to understand and enable continued long-term operation of existing LWRs.
- Develop technical and operational improvements that contribute to long-term economic viability of existing nuclear power plants.



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So, the challenge of II&C modernization is to implement digital upgrades in a manner that improves the competitiveness of the plant business model.

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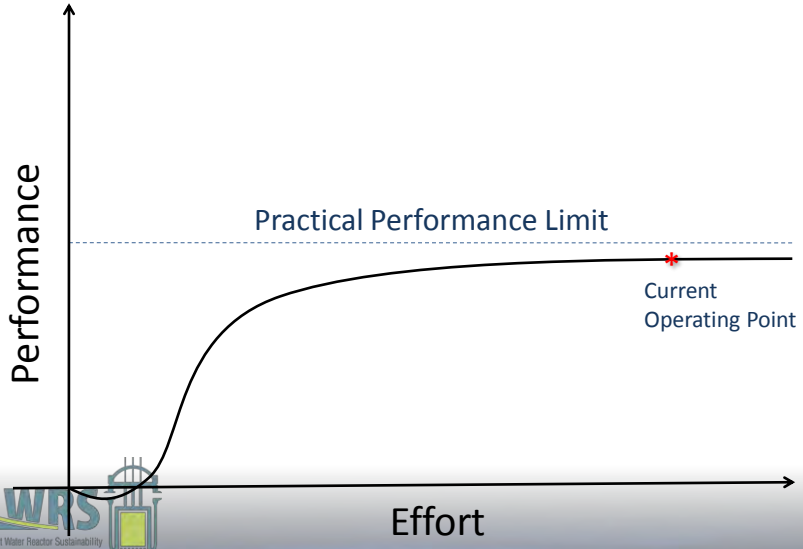
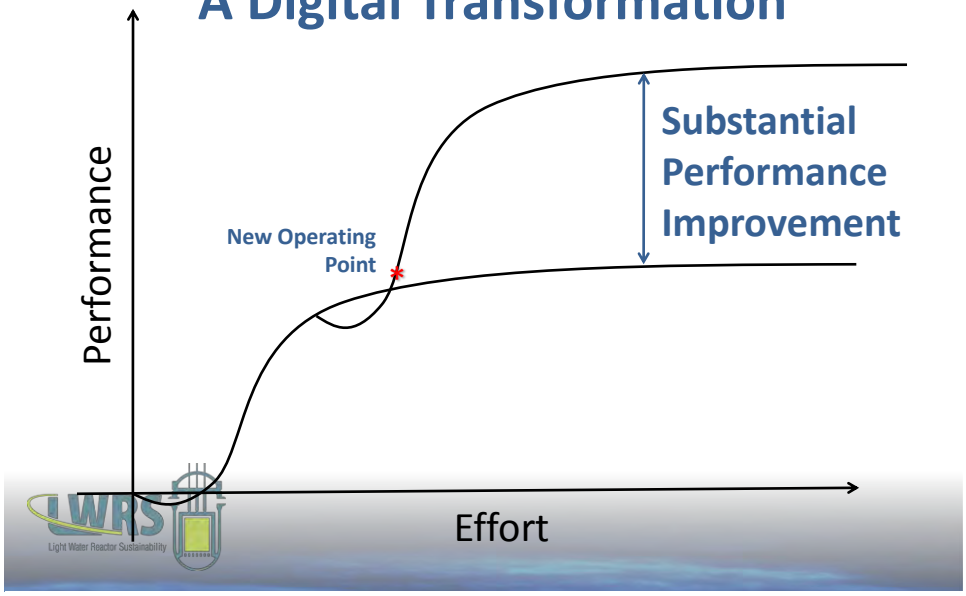
Challenge for Sustainability



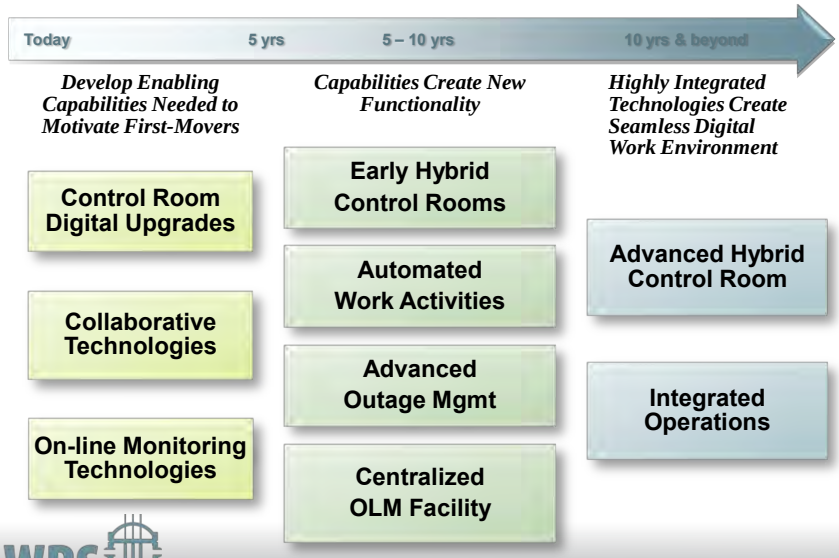
Future Performance Based on A Digital Transformation



Transforming the NPP Operating Model with Digital Technology

- Integrating plant systems, plant processes, and plant workers
- Demonstrating and validating new technologies and operational concepts at host nuclear plants
- Providing guidance for NPP implementation
- Communicating results to nuclear power stakeholders

II&C Modernization Goals



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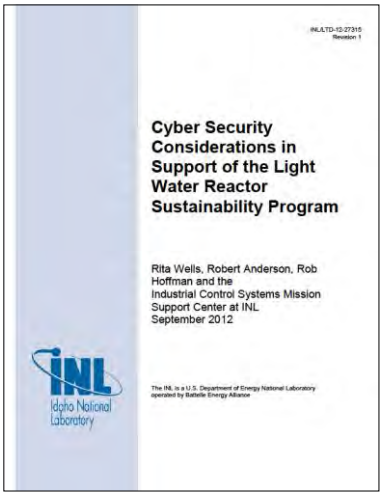

LWRS Light Water Reactor Sustainability

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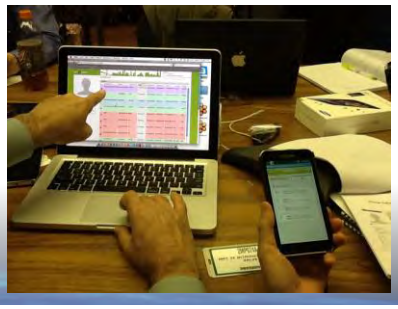

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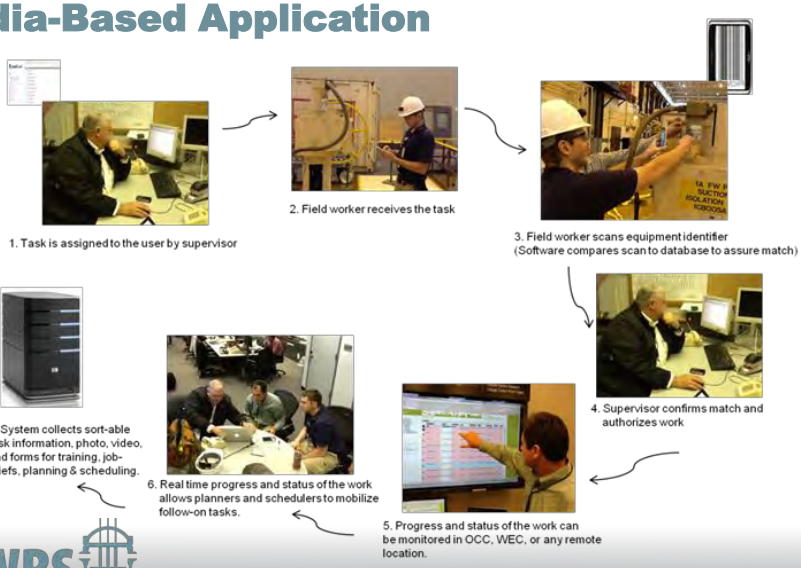


Computer-Based Procedures

- Working with Duke Energy and Arizona Public Service in a series of demonstrations of a CBP prototype to improve human performance and productivity in NPPs.
- Results to date have led to refinements in how information is presented to a procedure user to improve human performance.
- Will conduct a field study at the Palo Verde Nuclear Generating Station in July, as the final study for field based procedures. In FY 2014 the focus will turn to control room procedures.

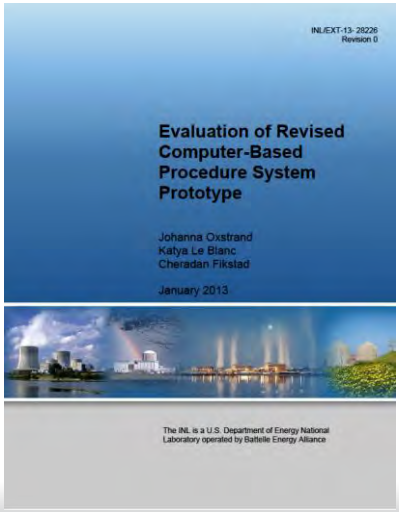
Computer-Based Procedures - Reports

January 2013 Report:

Evaluation of Revised Computer-Based Procedure System Prototype (INL/EXT-13-28226)

September 2013 Report to be published:

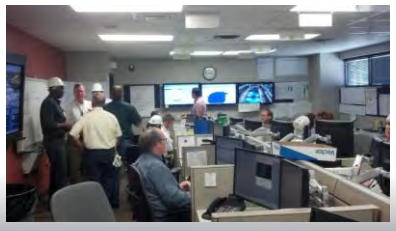
Complete evaluation of final LWRS II&C Computer-Based Procedure prototype for field workers



Advanced Outage Control Center

Focus is on an Advanced Outage Control Center:

- Real Time Collaboration for Emergent Issues
- Real-Time Work Status
- Improved Communication of Outage Status
- Automatic Pending Support Notifications
- Real-Time Requirements Monitor
- Optimized OCC layout
- Technology interface with satellite control centers



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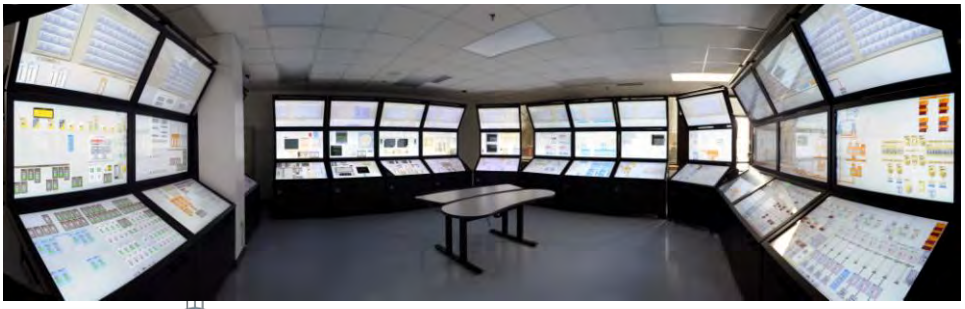

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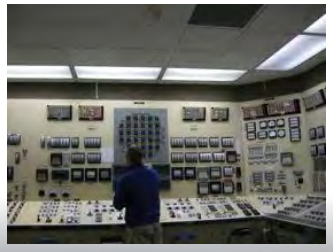

Computerized Operator Support Systems

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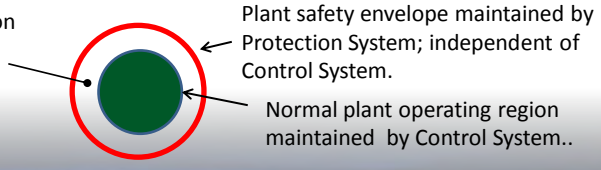

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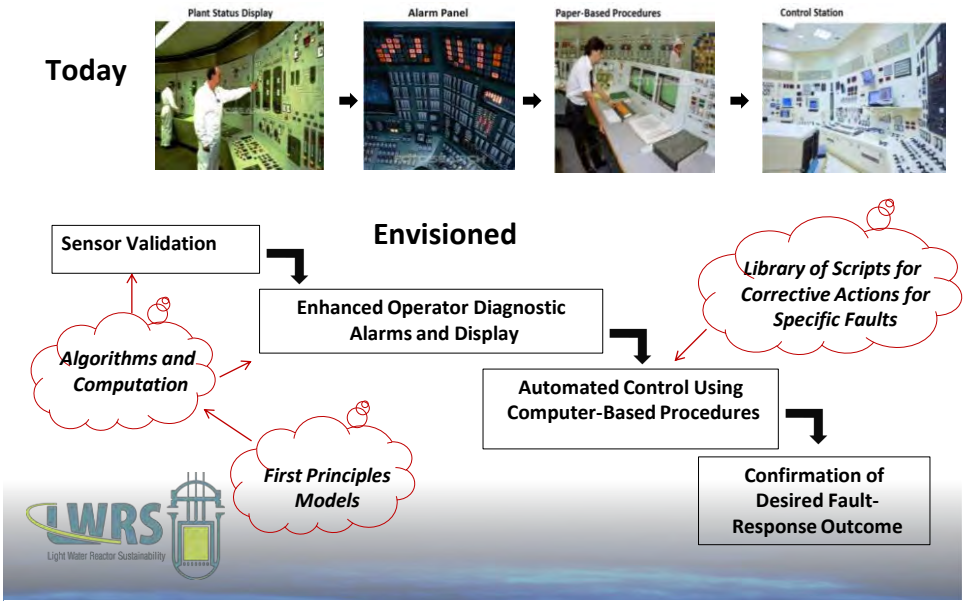

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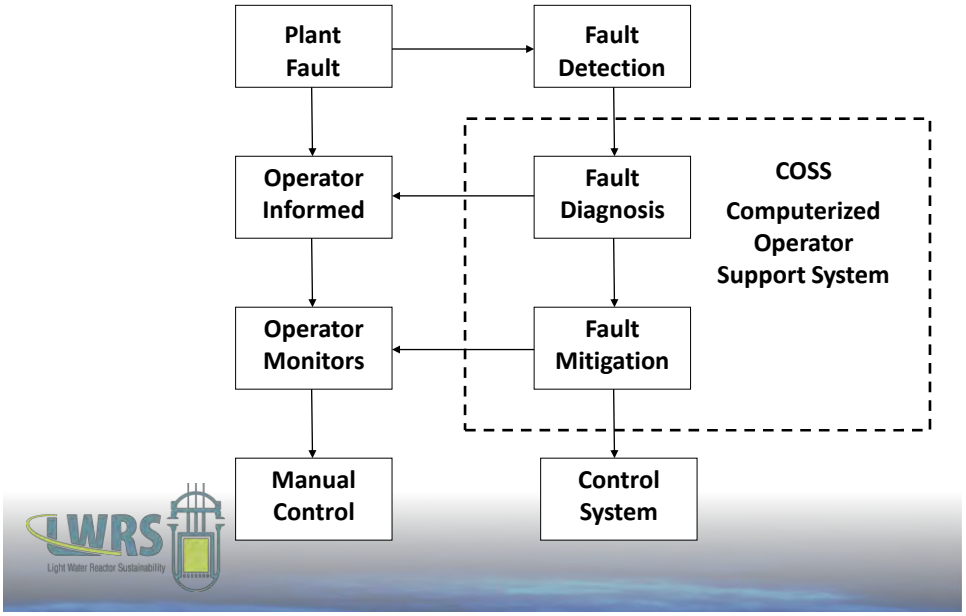


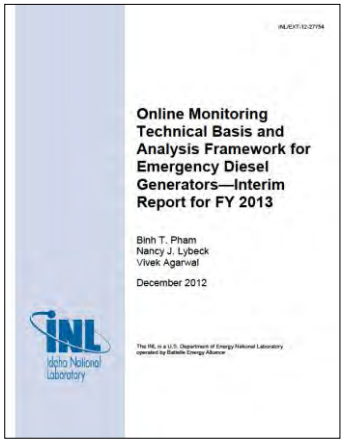
Centralized On-Line Monitoring

- Joint Project with EPRI (Richard Rusaw, EPRI Project Manager)
  - real-time assessment and monitoring of important plant SSCs
  - development of diagnostic and prognostic models
  - prognostic models are concerned with “remaining useful life”
  - validation of the EPRI-developed OLM software (*Fleet-wide Prognostic and Health Management (FW-PHM) Suite)*.
- Initial pilot projects are focused on active components
  - Emergency Diesel Generators – Braidwood Nuclear Station
  - Large Power Transformers – Harris Nuclear Plant
- In 2015, focus will shift to critical large passive structures and components
  - biggest impact on NPP long-term sustainability
  - will leverage development of sensor and NDE technology

OLM – Emergency Diesel Generators

Working with Braidwood Nuclear Station
Diagnostic Model Scope:

- Excessive piston wear
- Improper valve timing
- Fuel pump failure
- Unresponsive governor
- Intermittent magnetic pickup signal
- Diesel engine fuel injector – improper fuel injection
- Lubricating oil pump – Low oil pressure
- Jacket water pump – Low pressure
- Voltage regulating system malfunction

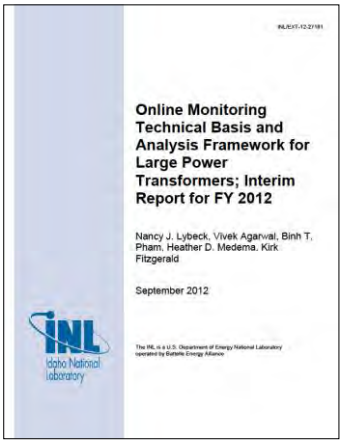


OLM – Large Power Transformers

Working with Progress Energy

Diagnostic Models Developed:

- Loss of bushing insulation dielectric strength
- Displaced core winding
- Dielectric strength degradation
- Insulating oil pump motor loss of performance
- Paper insulation degradation
- Gas Ratios
- Acoustic signals



LWRS Light Water Reactor Sustainability

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www.inl.gov

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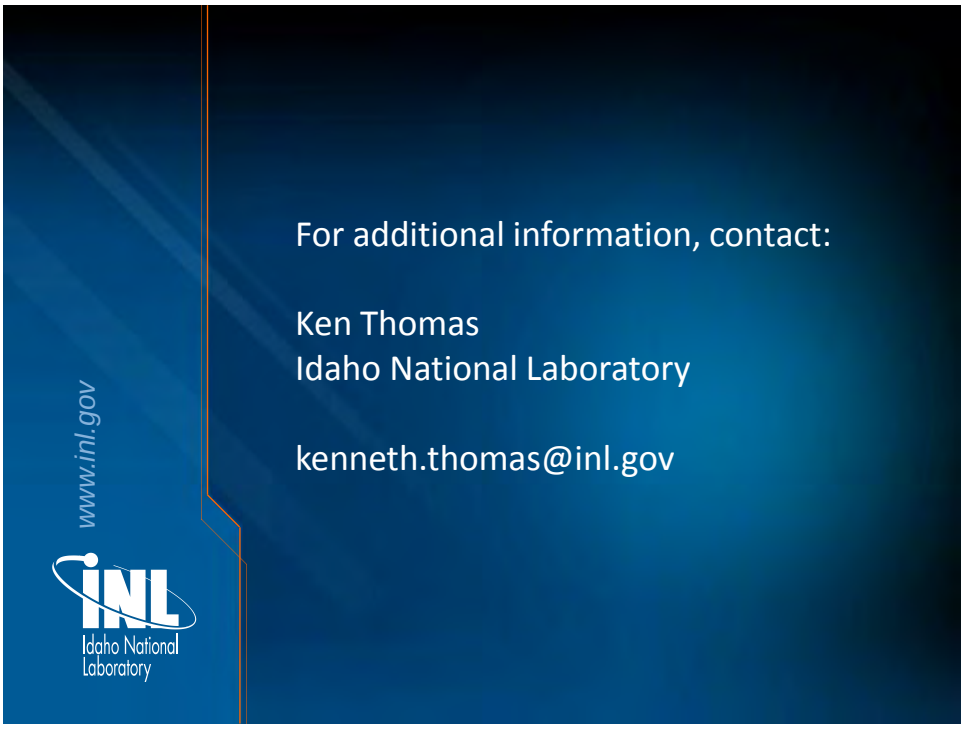
For additional information, contact:
Ken Thomas
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kenneth.thomas@inl.gov
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Appendix I

2013 ANS Utility Working Conference

Advanced Instrumentation, Information, and Control Systems Technologies: Utility Pilot Projects

Ken Thomas
Idaho National Laboratory

2013 ANS Utility Working Conference
Hollywood, FL
August 12, 2013

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Ad… …strumentatio…
… …d Cont…
Sy… …nologies

- *Ad… …long-term aging a… reli… …ity concerns of existin… …I&C tech…ologies and develop and test new technologies.*
- *Establish a strategy to implement long-term modernization of II&C syste…s.*
- *Dev… …advanced condition… m… …g technologies f… …ble …tion and de… …tect and c… a… …gradation proces…*

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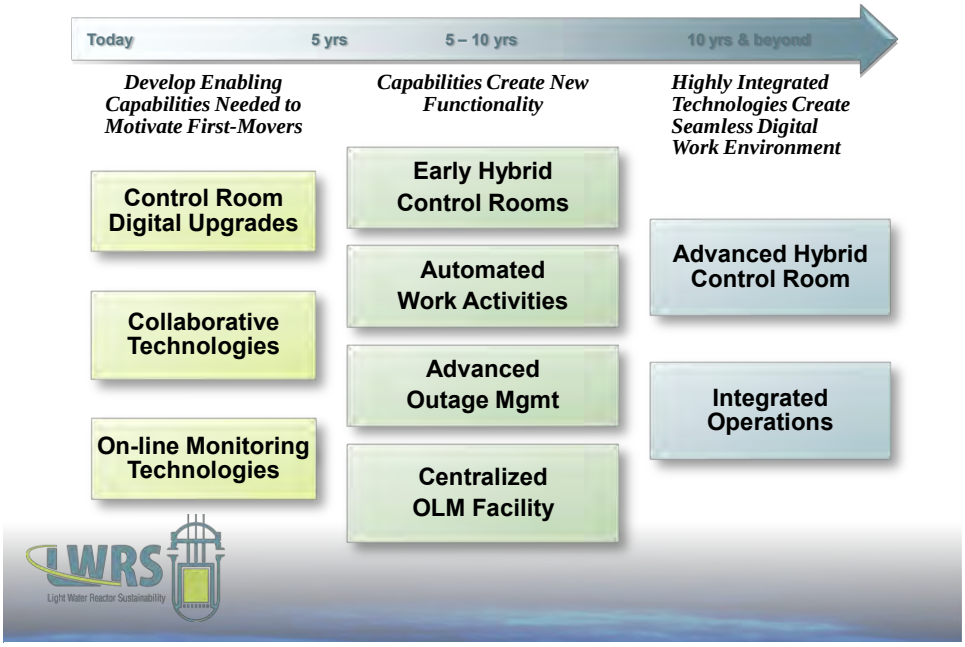

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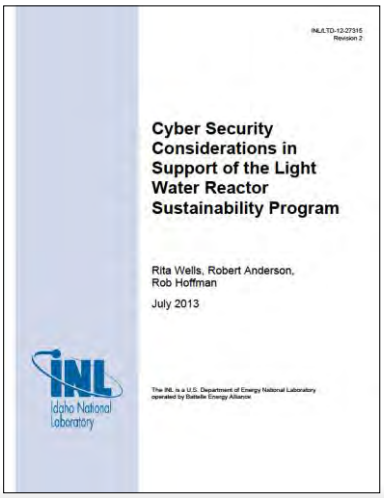

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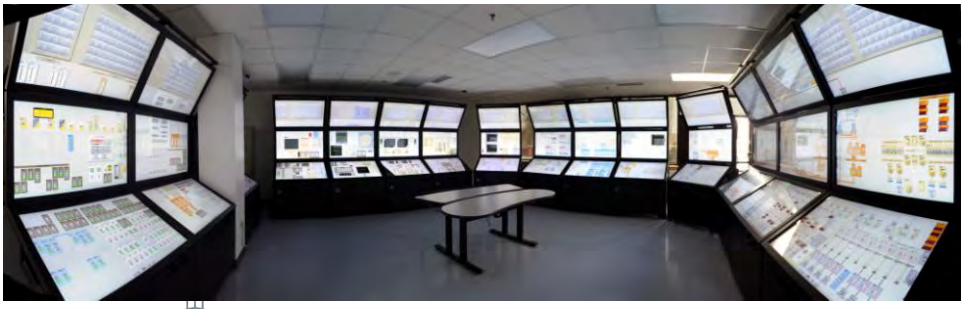

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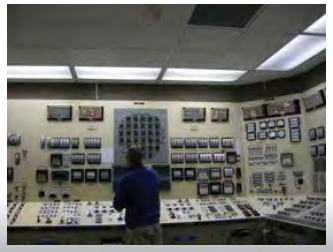

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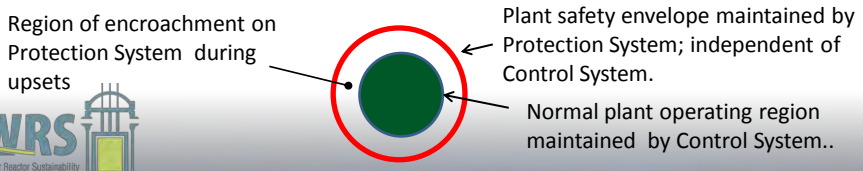

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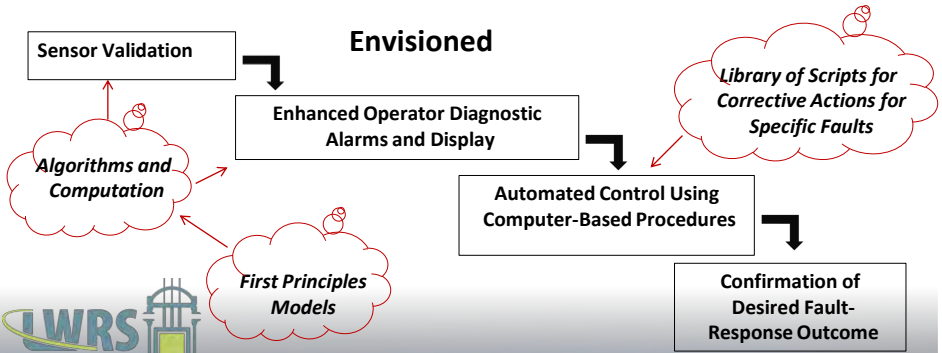

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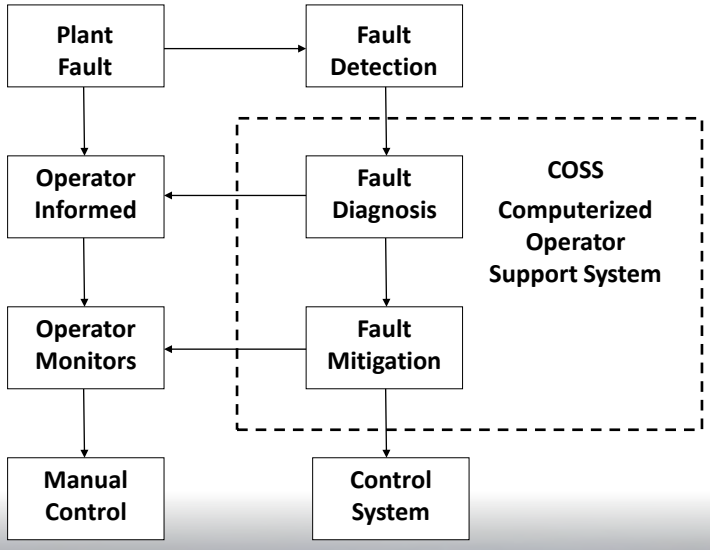

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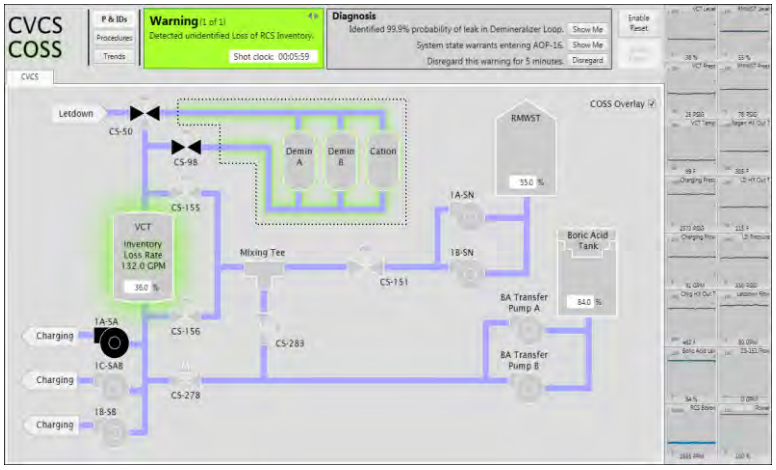

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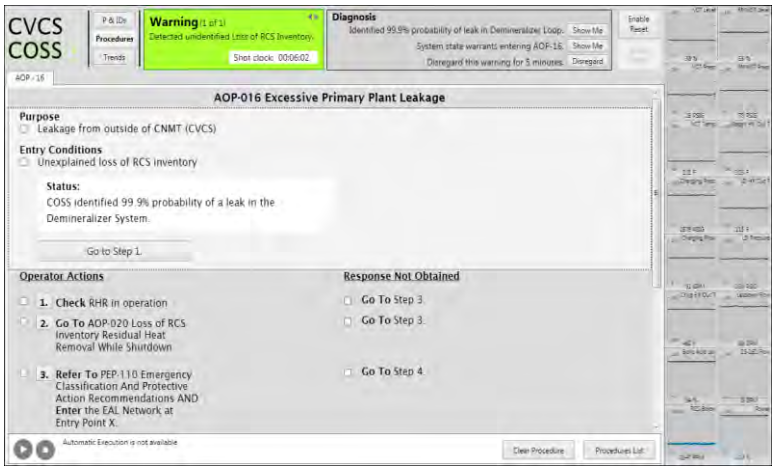

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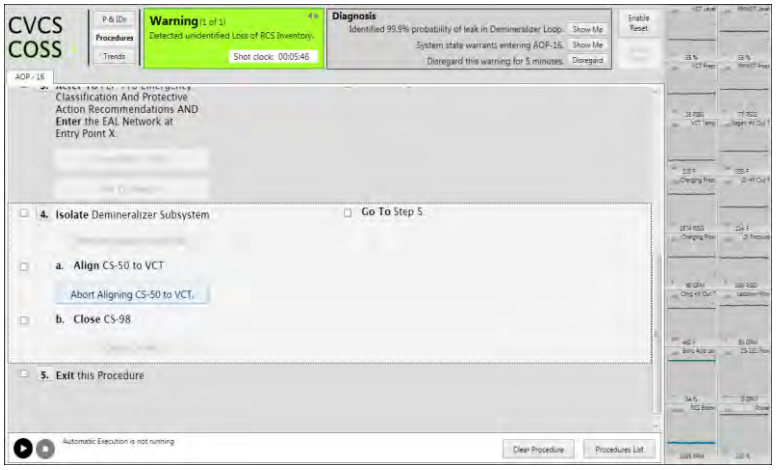

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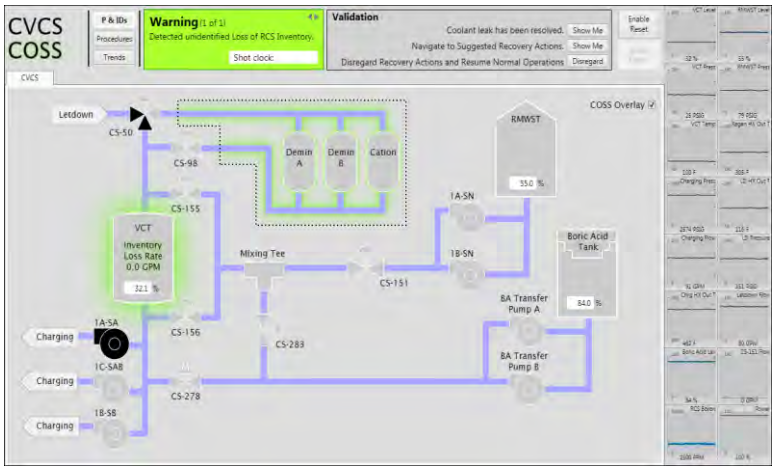

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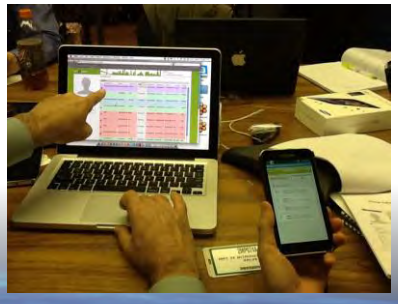

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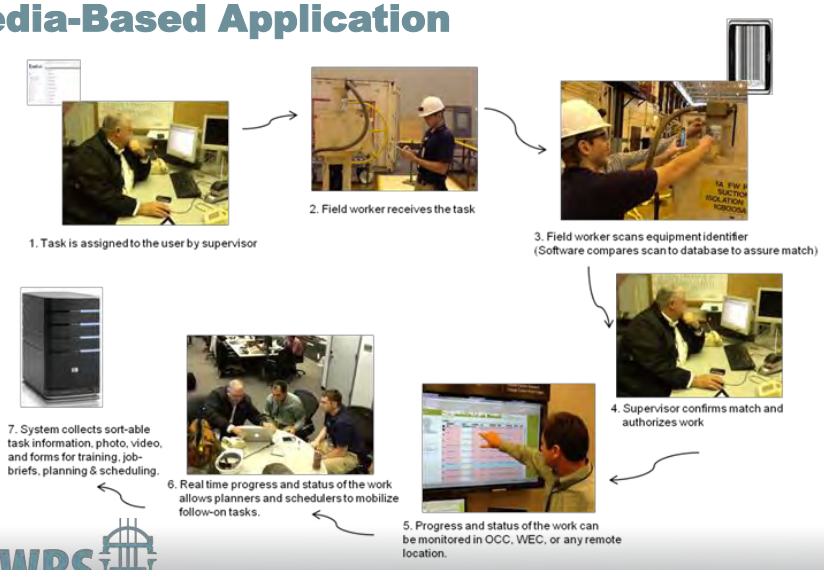

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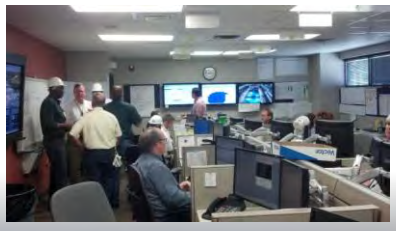


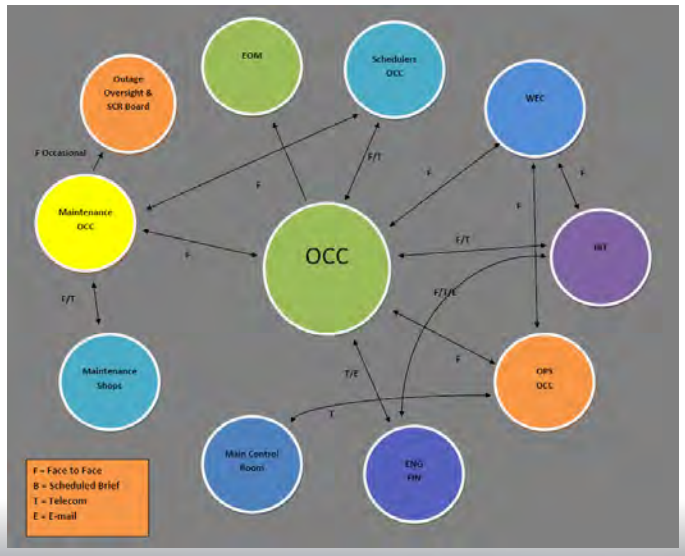
AOCC Project Overview

- Purpose – To improve management of NPP outages through development of an advanced OCC that is specifically designed to maximize the usefulness of communication and collaboration technologies for outage coordination and problem resolution activities.
- Schedule – FY 2013 – 2014
- Utility Partner – Arizona Public Service (APS)
- Key APS Staff
  - Michael Grigsby
  - Carlos Williams
- INL Research Staff
  - Shawn St. Germain
  - Ronald Farris
  - Heather Medema

INL AOCC Implementation Strategy

- Identify Outage Processes that have the Greatest Potential for Improvement
- Evaluate Collaboration/Communication Technology Options That Show Promise For OCC Application
- Analyze the Current Organizational Structure Using Human Factors Methodologies
- Individually Analyze the Application of Technology to Processes on a Limited Scale
- Determine to What Extent Tasks Should be Reallocated Utilizing Technology
- Develop a New Physical OCC Layout Based on Task Reallocation, Technology Integration and Human Factors Considerations
- Analyze the Effectiveness of the New Arrangement and Make the Necessary Adjustments

Communication Map



Concepts for an Optimized OCC Layout

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