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Summary Report on Industrial and Regulatory Engagement Activities

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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 semi-annual meetings and monthly phone calls to provide input on nuclear plant needs and priorities for II&C technologies. The UWG held two 3-day meetings in FY2012. The 2012 Winter Meeting was held in Phoenix, Arizona, March 14-16, hosted by Arizona Public Service (Palo Verde Nuclear Generating Station). The 2012 Summer Meeting was held in Idaho Falls, Idaho, August 21-23, which was a joint meeting with the Electric Power Research Institute Strategy Group on Performance Improvement through Advanced Technology.

Seven major technical reports were delivered to the UWG reflecting the work of the pilot projects during the year. Five additional reports from this year's scope of work will be completed by the end of this fiscal year and will be delivered to the UWG shortly thereafter.

Discussions were 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 the Electric Power Research Institute (EPRI).

Although no formal meetings were held with the NRC in FY 2012, key managers of the NRC were in attendance at several industry conference presentations on the Advanced II&C research pathway. These meetings provided the opportunity for informal discussions with these NRC managers and plans were made to have formal meetings with the NRC staff in FY 2013.

The Advanced II&C research pathway work was presented at eight major industry conferences and meetings during FY2012. In addition, the work was shared in two international engagements, one through the U.S. – Argentina Bilateral Energy Working Group and the other through a meeting with Electricite' de France (EdF) arranged by EPRI. The latter engagement resulted in an offer from EdF for collaboration on nuclear plant digital applications for performance improvement.

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Acronyms

ANS	American Nuclear Society
BEWG	Bilateral Energy Working Group
BWR	boiling water reactor
CAES	Center for Advanced Educational Studies
EdF	Electricité de France
EDG	emergency diesel generators
EMC	Electro-Magnetic Compatibility
EPRI	Electric Power Research Institute
GSU	generator set-up
HPRCT	Human, Performance, Root Cause, and Trending
HRP	Halden Reactor Project
HSI	human-system interface
HSSL	human-systems simulation laboratory
I/ITSEC	Interservice/Industry Training, Simulation, and Education Conference
II&C	Instrumentation, Information and Control
INPO	Institute of Nuclear Power Operations
LWRS	Light Water Reactor Sustainability
NEI	Nuclear Energy Institute
NITSL	Nuclear Information Technology Strategic Leadership
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission
OCC	outage control center
OLM	on-line monitoring

PLiM	Nuclear Power Plant Life Management
PWR	pressure water reactor
R&D	research and development
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 2012, 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 2012 to promote awareness and participation by the nuclear power industry. In addition, the presentation material 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 intent to involve 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 a set of 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 this pathway.

UWG members serve as host utilities for the pathway pilot projects when their internal performance improvement objectives align with the goals of a particular pilot project. The pilot project host will make its facilities available for the research and development (R&D) activities and allow 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 four special interest groups in the areas of outage safety and efficiency, human performance improvement for NPP field workers, computer-based procedures, and control room modernization. The purpose of the special interest groups is to provide a means of direct

engagement for utilities and provide the means of broad peer review of the technologies developed by the research program.

2.2 Membership

The nuclear utilities currently participating in the UWG are as follows:

1. Arizona Public Service
2. Constellation Energy
3. Duke Energy
4. Entergy
5. Exelon Nuclear
6. Luminant
7. Pacific Gas & Electric
8. Progress Energy (recently merged with Duke Energy)
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) are full participants in the UWG, as well as development partners in the pilot projects. EPRI sponsors an Advisory Group on Productivity Improvement through Advanced Technology, for which there is cross-participation for utilities, including a joint meeting with the UWG in August of 2012.

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

The *Long-Term Instrumentation, Information, and Control Systems Technologies Future Vision and Strategy (INL/EXT 11-24154)* was published in February of 2012 as a comprehensive description of the II&C modernization strategy and description of the related pilot projects. The document reflects the needs and priorities as expressed by the UWG in the September, 2011 meeting. It also provides the background for why the pathway research is needed and the 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 have been defined to date. The performance improvement and modernization needs are presented for each of the pilot projects, along with a description of what technologies the project will produce. The document has been widely distributed among the UWG, industry support organizations, and other interested parties. It is available on the 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 research pathway as modified from time to time based on utility priorities and available project funding. The next update of the document will be in FY 2013 2nd Quarter.

2.4 2012 Winter UWG Meeting – March 14-16

The UWG held the 2012 Winter Meeting in Phoenix, Arizona, hosted by Arizona Public Service, and more specifically the UWG members from the Palo Verde Nuclear Generating Station. The meeting was held at the Hilton Garden Inn in Avondale.

The theme of this meeting was to hear from the UWG members as to their plans and needs for II&C modernization. Presentations were made by Progress Energy, Duke Energy, Exelon Nuclear, Southern Nuclear, Tennessee Valley Authority, Constellation Energy, and Arizona Public Service. This input was very valuable in assessing the priorities of the Future Vision and Strategy document, which was found to be in close agreement. An open discussion was held on the Future Vision and Strategy document to ensure alignment with the plans of the participating utilities.

In addition, presentations were made by the INL Principal Investigators for the current pilot projects, describing the scope and schedule of the projects, technology developments, demonstration activities, and project deliverables. These presentations included the Advanced Outage Coordination, Mobile Technologies for NPP Field Workers, Computer-Based Procedures, Control Room Modernization, and On-Line Monitoring. Presentations were also made on key aspects of the research pathway, including the development of the Human Systems Simulation Laboratory and the development of a cyber security evaluation program for the pilot projects.

The final segment of the meeting was a half-day session for the Special Interest Groups. Four such groups met to discuss ongoing plans and developments as follows: 1) Outage Safety and Efficiency, 2) Human Performance for NPP Field Workers, 3) Control Room Modernization, and 4) Computer-Based Procedures.

The agenda for the meeting is found in Attachment A.

2.5 2012 Summer UWG Meeting – August 21-23

The 2012 Summer UWG Meeting was held in Idaho Falls, Idaho, August 21 – 23, as a joint meeting with the EPRI Advisory Group on Productivity Improvement through Advanced Technology. The meeting was held at the Hilton Garden Inn in Idaho Falls and at the INL Center for Advanced Engineering Studies (CAES) for two sessions on control room simulation.

The meeting presentations featured work by EPRI and LWRS in improving plant performance while modernizing II&C systems. EPRI presented work that they have conducted in the areas of human-system interface (HSI), decision management, real-time outage decision support, virtual reality for control room upgrades, virtual models to support knowledge elicitation and presentation, computer-based maintenance training, and radiation visualization for work planning.

INL Principal Investigators made presentations on the upcoming FY 2013 planned pilot projects of Advanced Outage Control Center, Automated Work Packages, Computer-Based Procedures, Control Room Modernization, Advanced Alarm Systems, and On-Line Monitoring for Active Components (jointly presented with EPRI).

IFE Halden Reactor Project (HRP) made a presentation on Advanced Design Concepts, outlining the many new concepts that HRP has developed for control room modernization and improved operator performance.

The UWG traveled to the INL CAES facility to observe two control room simulations. One demonstrated the use of bench board-style, touch panel control boards as a new tool to conduct control room and operator performance studies. This introduced to the UWG the control room development and simulation equipment that has been purchased and will soon be installed in the HSSL of a total of 15 benchboard panels.

The other demonstration was of the HRP BWR and PWR simulators, providing the UWG with the opportunity to see how a highly-integrated control room uses advanced information displays, integrated computer-based procedures, state-based alarms, and newly-developed techniques to enhance operator situational awareness.

Other presentations included a very informative overview of digital licensing topics by EPRI and two presentations on cyber security – one dealing with technologies used in the pilot projects and the other a tutorial on the latest techniques of how cyber adversaries are able to defeat defenses and take over control systems.

Addressing the Future Vision and Strategy document, a presentation was made on the future pilot projects (those starting beyond FY 2013) to provide a detailed understanding of the scope and deliverables. A prioritization survey was administered to the group on the relative priorities of these projects and the results will be made available to the UWG in a future conference call. Finally, the UWG discussed future priorities as well as emerging digital technologies of interest.

The agenda for the meeting is found in Attachment B.

2.6 Monthly UWG Conference Calls

A monthly conference call has been held with the UWG every first Tuesday of the months in FY 2012. The call is used to communicate ongoing status of the pilot projects, discussion of project deliverables, opportunities to observe pilot project demonstrations, and communicate UWG meeting information.

While all members cannot participate in each call due to schedule conflicts and emergent plant issues, the feedback from the UWG has been to continue calls on a monthly basis. For those that can participate, it provides an opportunity to stay informed about project developments on a frequent basis. The calls have also served as a forum for UWG members to share information among themselves related to their own II&C needs and plans.

2.7 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 2012, as follows:

1.	Long-Term Instrumentation, Information, and Control Systems Technologies Future Vision and Strategy	INL/EXT 11-24154
2.	Advanced Instrumentation, Information and Control (II&C) Research and Development Facility Build-out and Project Execution of LWRS II&C Pilot Project 3	INL/MIS-12-25139
3.	Computer-Based Procedures for Field Workers in Nuclear Power: Development of a Model of Procedure Usage and Identification of Requirements	INL/EXT-12-25671
4.	Advanced Outage and Control Center: Strategies for Nuclear Plant Outage Work Status Capabilities	INL/EXT-12-26197
5.	Digital Full-Scope Mockup of a Conventional Nuclear Power Plant Control Room, Phase 1: Installation of a Utility Simulator at the Idaho National Laboratory	INL/EXT-12-26367
6.	Resolving Emergent Issues during Nuclear Plant Outages	INL/MIS-12-26413
7.	Applying Human Factors Evaluation and Design Guidance to a Nuclear Power Plant Digital Control System	INL/EXT-12-26787

3. Meetings with Individual Nuclear Utilities

3.1 Duke Energy Catawba Nuclear Station

A meeting was held on February 6, 2012, with the Duke Project Manager for the Human Performance Pilot Project (Mr. Greg Robison) at the Catawba Nuclear Station (Rock Hill, South Carolina) in conjunction with a major demonstration of technology developed under the project. Discussions pertained to Duke's ongoing involvement in the pilot projects in view of the corporate merger with Progress Energy and a significant change in station leadership at Catawba (new Site Vice President and Station Manager). It was noted that there was good support for the pilot project activities in the Operations Training organization and that there was not concern about being able to continue. On this basis, Duke was prepared to host the next pilot project in the Human Performance Improvement for NPP Field Workers enabling area, that of Advanced Work Packages. Duke will also continue to support the work in Computer-Based Procedures, serving as a technical advisor on requirements.

3.2 Exelon Nuclear Corporate Office

A meeting was held on February 28, 2012, with Mr. Keith Moser, Exelon Nuclear Director of Innovation, at the Exelon Nuclear Corporate Office in Warrenville, IL. The purpose of the meeting was to discuss the recent pilot project demonstration on outage process improvement and to discuss Exelon's interests in the continuation of the pilot project. It was noted that in spite of a number of difficulties encountered during the demonstration (emergent plant problems, union member participation concerns), the results were very positive and proved to the satisfaction of Exelon management that the concepts were sound and scalable. In regard to future development, Mr. Moser stated that Exelon would now like to pursue a production implementation of the pilot project technology focused on radiation survey mapping. Therefore,

they would not be inclined to follow-on with the next pilot project in the Outage Safety and Efficiency enabling area, that of an Advanced Outage Control Center (OCC), in that they did not have the funding and management backing for development work in this particular area. Subsequent to this discussion, Arizona Public Service (Palo Verde Nuclear Generating Station) agreed to be the host utility for the OCC pilot project.) Exelon will continue to support the Utility Working Group and potentially host demonstrations in the process and human performance technology developments.

3.3 Exelon Nuclear Braidwood Nuclear Station

A meeting was held at Exelon's Braidwood Nuclear Station (Braidwood, IL) on February 29, 2012, to discuss their potential interest in hosting an on-line monitoring (OLM) pilot project for emergency diesel generators (EDG). The meeting was arranged by EPRI, which has lead for the OLM pilot projects under the Advanced II&C research pathway. Braidwood has an advanced diesel instrumentation package with data going to their Plant Information server, making access by the pilot project application relatively straightforward. The discussions were held with the station lead engineer for EDGs and the corporate lead engineer for component monitoring. There was agreement to pursue this project pending approval by Exelon corporate and Braidwood station management. This approval was subsequently obtained and Exelon is now serving as the host for this pilot project.

3.4 Progress Energy Harris Nuclear Plant

A meeting was held at the Progress Energy corporate office in Raleigh, NC, on April 12, 2012, to discuss the possibility of Harris Nuclear Plant being the host site for an OLM demonstration for generator step-up (GSU) transformers. Harris was a particularly good candidate because they were in the process of replacing their GSU transformers, which will enable the capture of baseline information for these replacement components. In addition, the transformers will have more instrumentation than is normally found on older installations. The meeting was arranged by EPRI, which has lead for OLM pilot projects under the Advanced II&C research pathway. The discussions included the asset management leads for Progress, as well as other Progress individuals who have experience in component performance monitoring. Progress agreed to pursue this idea with their management, and subsequently obtained approval to host the pilot project.

3.5 Progress Energy Corporate Office

A meeting was held at the Progress Energy corporate office in Raleigh, NC, on September 18, 2012, to discuss the work of the LWRS pilot project in the area of human factors engineeering for control room modernization. Specifically, the meeting focused on the plant II&C upgrades that Progress is making at their Brunswick and Harris Nuclear Plants for the turbine control systems and plant computers. Progress has entered into a funds-in Cooperative Research & Development Agreement with LWRS under the pilot project Incorporating Digital Upgrades in an Analog Control Room. In conducting this development work, LWRS has teamed with IFE Halden Reactor Project (HRP) and Lew Hanes, an independent human factors consultant. The purpose of the meeting was to develop plans and requirements for upcoming

simulator workshops to be held in the INL Human Systems Simulation Laboratory (HSSL) in October and November of 2012.

4. Meetings with Major Industry Support Groups

4.1 Institute of Nuclear Power Operations

On January 20, 2012, a webcast was held with the Institute of Nuclear Power Operations (INPO) to present the goals, objectives, and activities of the Advanced II&C research pathway. INPO was represented by Engineering senior managers. INL was represented by the Director for the II&C pathway and the lead for Industry and Regulatory Engagement. The project was presented in detail, discussing in particular the pilot projects that were in progress with the nuclear utility hosts. INPO discussed their short-term objectives of improving the quality of engineering activities for digital implementation. It was agreed that there was common interest in the application of digital technology and how that impacted station performance expectations. INPO stated that they were in the process of enhancing their support for standards of excellence for digital systems implementation. Both parties agreed to continue to exchange information and look for opportunities for collaboration where advantageous.

A second opportunity to brief INPO on the project occurred at the EPRI I&C Technical Integration Committee meeting in Atlanta, GA, on August 27, 2012. INPO is a member of this committee, represented by the INPO lead for digital systems, who was appointed to this new position subsequent to the webcast held in January. This gave INPO an understanding of the progress of the pilot projects in FY 2012 and the planned work for FY 2013, especially in the area of control room modernization.

4.2 Nuclear Information Technology Strategic Leadership

A webcast was held with the Nuclear Information Technology Strategic Leadership (NITSL) – Integration and Application Committee on April 12, 2012. NITSL is an organization sponsored by INPO and made up of the nuclear IT managers from the nuclear utilities. Its purpose is to provide consistent industry guidance and leadership on IT issues affecting the operating plants. It is sponsored by INPO and for important issues, receives direction from the Chief Nuclear Officers of the nuclear utilities, facilited as a group by the Nuclear Energy Institute.

The Advanced II&C research pathway and activities was presented to the committee members, with emphasis on the technologies being developed under the current pilot projects. There was considerable interest in this work and how it might fit with initiatives that the individual utilities were pursuing to improve plant performance. Subsequent to this webcast, NITSL invited the pathway to make a presentation at its annual general meeting for all NITSL committees (July 2013) as part of the opening session. NITSL also inquired about the possibility of establishing a formal relationship with the research pathway. Follow-up discussions will be held on this idea.

4.3 Nuclear Energy Institute

On August 1, 2012, a meeting was held with the Nuclear Energy Institute (NEI) to provide an understanding of the research program and to identify initial opportunities for cooperation in NPP digital implementation. Representing NEI was Mr. Gordon Clefton, Program Manager for instrumentation and control, who also handles the interface with the NRC on II&C issues, on behalf of the nuclear power industry. NEI was appreciative of the update on the Advanced II&C research activities and pilot projects. NEI would like continuing updates on the progress, especially where there might be regulatory issues associated with the introduction of new digital technologies into plant applications. In such cases, there might be opportunities to pursue regulatory analysis and guidance prior to implementation. Also, NEI suggested that we have an update on the pathway work in one of the periodic interface meetings that NEI holds with the NRC on II&C issues.

4.4 Electric Power Research Institute

The Advanced II&C research pathway objectives and activities were presented at the EPRI Nuclear Power Council – I&C Integration Committee Meeting in Atlanta on August 27, 2012. Although EPRI is a full-participant in the research pathway and a member of the Utility Working Group, there had, up to this point, been no opportunity to brief this committee on the pilot project activities. This committee is composed of utility leaders in II&C functions for the operating fleet, in addition to representatives from NEI and INPO. Its purpose is to provide guidance to EPRI regarding utility needs and priorities for development in the II&C area. The presentation also highlighted the collaboration that is occurring with EPRI in support of the Utility Working Group and for the on-line monitoring pilot projects. The presentation was well-received with a number of good questions and comments.

5. Regulatory Engagement

5.1 Informal Discussions with NRC I&C Managers

There were no formal meetings held with the NRC in FY 2012 for discussions of the Advanced II&C research pathway. However, informal discussions occurred with two key NRC I&C managers during the ANS I&C Workshop held in conjunction with the 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies in San Diego on July 22, 2012. Both the Advanced II&C pathway and the NRC were presenters in this workshop, and therefore, there was opportunity to hear of each other's R&D activities. During the course of the meeting, discussions were held with Mr. John Thorp, NRR I&C Branch Chief, and Mr. Russell Sydnor, RES I&C Branch Chief, on the control room and human factors work the pathway is doing with host utilities. It was agreed that a briefing for NRC staff would be held in FY 2013 on the technologies that are being developed and whether they are addressed by the current regulatory guidance. In addition, Mr. Thorp stated that he would invite the pathway to be a presenter in the 2013 Regulatory Information Conference (March, 2013 in Washington, DC) as part of the I&C track.

5.2 Other Communication Opportunities with the NRC

NRC managers and staff attended a session in the 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies in San Diego on July 22, 2012, in which the pathway presented a paper on the research activities in the various pilot projects that address operations and maintenance activities. This provided the opportunity for them to hear specific details about the technologies that are being developed for NPP field workers, outage improvement, and control room modernization.

The NRC participated in the LWRS FY-13 Budget Planning Meeting held on August 1, 2012, in Washington, DC. In this meeting, Mr. Gene Carpenter, Primary NRC contact for LWRS, had opportunity to hear the FY 2013 technical plan for the Advanced II&C pathway.

6. General Industry Meetings and Conferences

6.1 EPRI Strategy Group on Productivity Improvement through Advanced Technology

The EPRI Strategy Group on Productivity Improvement through Advanced Technology met on November 29 – December 1, 2012, in Orlando, FL. The meeting was hosted by Lockheed Martin. The Strategy Group is composed of nuclear utility representatives that have responsibility for technology improvements for their nuclear operations. The Advanced II&C pathway is invited to attend the meetings of this group as part of the collaboration with EPRI. As such, this provided an opportunity to give this group an update on the work of the pathway. The meeting also provided the opportunity to tour the Lockheed simulation technology facilities and hear presentations on their work with the nuclear power industry. Specifically, this facility is working with General Electric to design an advanced control room for the Advanced Boiling Water Reactor. As part of the meeting, a side trip was also taken to the annual I/ITSEC trade show in the Orlando Convention Center. This is the world's largest trade show on simulation technology for military and aviation requirements, and provided an opportunity to see the state-of-the-art technologies for similar needs as found in nuclear power – flight control simulation, heads-up displays, decision support systems, logistics simulators, computer-based training, mobile and "wearable" technologies for support personnel, etc.

The pathway presentation is found in Appendix C.

6.2 Third International Conference on Nuclear Power Plant Life Management

A paper was published as part of the proceedings for the Third International Conference on Nuclear Power Plant Life Management (PLiM) entitled "Future Vision for Instrumentation, Information, and Control Modernization." The conference was held in Salt Lake City, May 14 – 17, 2012. A poster by the same title was presented in the poster sessions held daily throughout the meeting. The Advanced II&C pathway was also responsible for chairing a session on I&C Modernization, which provided an opportunity for discussion and exchange of ideas with other organizations involved in these types of activities. Two other papers were presented during the conference by Principal Investigators for the pilot projects: 1) "Development of an End-State

Vision for Incorporating Digital Controls and Operator Interface Design into Control Room Modernization" and 2) "An Assessment of Integrated Health Management Frameworks."

The pathway presentation is found in Appendix D.

6.3 Human Performance, Root Cause, and Trending Annual Workshop

The Human Performance, Root Cause, and Trending (HPRCT) Annual Workshop was held in Jackson, WY, on June 18 – 22, 2012. The workshop was attended by over 90 human performance and root cause professionals from a number of industries, including nuclear utilities and related consultants. The Advanced II&C pathway made two presentations at the workshop as follows: 1) Advanced Outage Control Centers, and 2) Integrating Human Performance in Wireless Technology – A Case Study. There was considerable interest in the work of the pathway on the part of the workshop attendees and the workshop provided an opportunity for the involved pilot project Principle Investigators to benchmark with other industries.

6.4 24th Annual Procedure Symposium – Procedure Professionals Association

A presentation on the Advanced II&C R&D program and the work on Computer-Based Procedures pilot project was made at the general session of the 2012 Nuclear Procedure Professional Association meeting, June 19, 2012 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 96 utility and industry professionals working in the area of nuclear facility procedures. Several attendees expressed interest in potentially joining the Utility Working Group.

The pathway presentation is found in Appendix E.

6.5 ANS Digital Instrumentation and Control Workshop

A presentation was made on the Advanced II&C Systems Technologies research pathway at the ANS I&C Workshop held in conjunction with the 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies in San Diego, July 22, 2012. The presentation focused on the pilot project work in control room modernization with utility partners of Southern California Edison and Progress Energy. It described ongoing work in optimized human-system interfaces for main control boards and in the development of a reference Human Factors Engineering Plan for use by utilities to develop their internal human factors program for control board modernization. The presentation further described the build-out of the Human Systems Simulation Laboratory (HSSL), which will be the host facility for development and validation of concepts for hybrid and fully-integrated control rooms.

The pathway presentation is found in Appendix F.

6.6 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies

A paper was presented at the 8th International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human Machine Interface Technologies in San Diego, July 23 – 26, 2012, entitled "Business Drivers for Nuclear Plant Operations and Maintenance Automation." This paper focused on the many opportunities to improve human performance and process efficiency in the critical areas of nuclear plant operations and maintenance. It described the pilot projects that are producing these technologies. The session was well attended and there were a number of excellent questions during the general Q&A period directed to the II&C pathway, indicating significant interest on the part of industry in the concepts presented.

Several other papers from the Advanced II&C pathway were presented as follows: 1) Commercial Utility Perspectives on Nuclear Power Plant Control Room Modernization, 2) Model of Procedure Usage – Results from a Qualitative Study to Inform Design of Computer-Based Procedures, 3) Integrating Human Performance into Technology, 4) Beyond Integrated System Validation: Use of a Control Room Training Simulator for Proof-of-Concept Interface Development, 5) Technology Integration Initiative in Support of Outage Management, and 6) Considerations for the Treatment of Computerized Procedures in Human Reliability Analysis.

The pathway presentation is found in Appendix G.

6.7 Westinghouse Outage Optimization Workshop

The Westinghouse Outage Optimization Workshop was held in Las Vegas, NV on July 29 – August 1, 2012. The attendees were largely composed of the nuclear utility outage directors and support staff. The focus of the meeting was outage performance improvement from a variety of perspectives. Westinghouse contacted the Advanced II&C pathway upon hearing about the Advanced Outage Coordination pilot project and requested that the work be presented at the workshop. The pathway made a presentation entitled "Outage Control Center Command and Control Technology," which included a live demonstration of the technologies that were used in the Exelon Bryon Nuclear Station pilot project demonstration in February, 2012. Ovalpath Corporation, who was contracted by the pathway to provide real-time collaboration technology for the Byron pilot project, supported the demonstration at the workshop at their own expense.

The presentation was well-received with many questions and positive comments. Westinghouse invited the pathway to provide a follow-up presentation at next year's workshop. In addition, Westinghouse is working on a new outage concept called "Flawless Fueling" and expressed interest in collaborating with the pathway.

6.8 2012 ANS Utility Working Conference

The Advanced II&C pathway organized and chaired a session at the ANS Utility Working Conference in Hollywood, FL, on August 7, 2012, entitled Strategies for Using Advanced II&C and Information Technologies to Modernize Plant Processes for LTO. In this session, three presentations were made: 1) Advanced Digital Technology for Nuclear Power Plants (INL), 2) Technology for Nuclear Plant Human Performance Improvement (Duke Energy), and 3) Improving Work Processes for Nuclear Plants (Exelon Nuclear). This

conference session served as an opportunity for the utility project managers of two of the pilot projects to present the development work from their perspectives. There was a large attendance for this session and many questions, indicating the interest in the work of this pathway. Following the session, there were several requests from participants for direct information, and expressions of interest for further discussions by two high profile nuclear II&C providers – Invensys and Doosan Heavy Industries.

The pathway presentation is found in Appendix H.

7. International Information Exchange

7.1 U.S. – Argentina: Bilateral Energy Working Group

The Advanced II&C pathway, at the request of the Department of Energy, participates in the U.S. – Argentina: Bilateral Energy Working Group (BEWG) which is concerned with civilian reactor life sustainability. The Advanced II&C pathway is designated as the primary contact for the U.S. in matters pertaining to I&C, and as such, works with a counterpart at the Argentina Comisión Nacional de Energía Atómica. For FY 2012, this effort has been limited to providing information to Argentina on requested topics, including the long-term strategy for II&C modernization. In response, they were provided a copy of the *Long-Term Instrumentation, Information, and Control Systems Technologies Future Vision and Strategy (INL/EXT 11-24154).* They also requested and were provided information on the Oak Ridge National Laboratory Electro-Magnetic Compatibility (EMC) Laboratory. No information has been obtained from Argentina on these topics. They have also requested U.S. participation in an IAEA-sponsored workshop on Digital Systems in NPPs, On Line Monitoring, and Wireless System Implementation to be held in Buenos Aires, Argentina, in November, 2012.

7.2 EPRI – EdF Meeting on Productivity Improvement through Advanced Technology

The EPRI Strategy Group on Productivity Improvement through Advanced Technology held a meeting April 23-24, 2012, hosted by Electricite' de France (EdF) at their research facility in Chatou, France. The Advanced II&C pathway participates in this EPRI Strategy Group and was asked to make a presentation on the pathway work, specifically providing an overview of the 20 pilot projects that are underway or planned, and the technologies that will be developed

This meeting provided the opportunity to understand EdF's approach in developing advanced II&C technologies and to incorporate these perspectives and ideas into the pathway's Future Vision and Strategy. It also provided an opportunity to obtain feedback from EdF on our own approach and how their experience in these same application areas should be factored into our development plans. Specific agenda topics of common interest were advanced outage management, advanced outage control room design, information displays, communications technology for field operators, reduced operator workload with simulation tools, and advanced worker training.

Participation in this technical conference provided the experience, approach, and lessons-learned of EdF in this regard and this information will be factored into the Advanced II&C pilot

project plans. As a result of this meeting, EdF has proposed collaboration with the Advanced II&C pathway on common development interests. This is now under consideration.

The pathway presentation is found in Appendix I.

Appendix A

Agenda for the 2012 Utility Working Group Winter Meeting

Light Water Reactor Sustainability Program
Advanced II&C Technologies Utility Working Group
2012 Winter Meeting

March 14-16, 2012
Phoenix, AZ

March 14, 2012 Hilton Garden Inn Phoenix/Avondale
11460 W. Hilton Way
Avondale, AZ 85323 623-882-3351

Time	Topic	Speaker
0800	Palo Verde Welcome	John Hesser VP of Nuclear Engineering
0815	Idaho National Laboratory Welcome	Bruce Hallbert
0830	Introduction of Meeting Participants	Ken Thomas
0845	Progress Energy I&C Upgrade Strategy	Matt Gibson
0930	Break	
1000	Southern Nuclear I&C Strategy	Ray Herb
1045	TVA Bellefonte I&C Strategy	Alvin Hinson
1200	Lunch	
1300	Constellation I&C Strategy	Gary Ly
1345	Palo Verde “Worker of the Future”	Gary Shanker Bruce Gordon
1430	Break	
1500	Palo Verde XML Based Procedures	Carlos Williams
1545	Palo Verde I&C Strategy	Scott Burns
1630	On-Line Monitoring Pilot Projects	Rick Rusaw
1715	Wrap-Up	Ken Thomas
1730	Adjourn	

Light Water Reactor Sustainability Program
Advanced II&C Technologies Utility Working Group
2012 Winter Meeting

March 14-16, 2012
Phoenix, AZ

March 15, 2012 Hilton Garden Inn Phoenix/Avondale
11460 W. Hilton Way
Avondale, AZ 85323 623-882-3351

Time	Topic	Speaker
0800	Long-Term II&C Modernization Future Vision and Strategy	Ken Thomas
0930	Break	
1000	Cross-Check on Utility Requirements vs. Future Vision	All
1030	Cyber Security for Pilot Project Technologies	Bob Anderson Rob Hoffman
1200	Lunch	
1300	Human Systems Simulation Laboratory (HSSL)	Jacques Hugo
1345	2012 Project Scope – Highly-Integrated Control Room	Ron Boring
1430	Break	
1500	2012 Project Scope – Outage Safety and Efficiency	Greg Weatherby
1545	2012 Project Scope – Human Performance	Ron Farris
1630	2012 Project Scope – Computer-Based Procedures	Johanna Oxstrand
1715	Wrap-Up	Ken Thomas
1730	Adjourn	

Light Water Reactor Sustainability Program
Advanced II&C Technologies Utility Working Group
2012 Winter Meeting

March 14-16, 2012
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Avondale, AZ 85323 623-882-3351

Time	Topic	Speaker
0700	Special Interest Groups (SIGs) – Breakout Meetings • Outage Safety and Efficiency Keith Moser, Greg Weatherby • Human Performance for NPP Field Workers Greg Robison, Ron Farris • Highly-Integrated Control Room Gerry Wyatt, Ron Boring • Computer-Based Procedures Bill Russell, Johanna Oxstrand	All
0900	Break	
0930	Special Interest Groups – Breakout Meetings Continued	All
1130	Working Lunch – SIG Reports	
1230	Adjourn	

Appendix B

Agenda for the 2012 Utility Working Group Summer Meeting

Summer 2012 Joint Meeting of the

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

August 21-23, 2012
Hilton Garden Inn
Idaho Falls, ID 83402

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

LWRS Light Water Reactor Sustainability

Tuesday, August 21

0800	DOE/LWRS Welcome	Rich Reister Kathy McCarthy
0815	Purpose/Agenda/Participant Introductions	Bruce Hallbert Ken Thomas
0835	EPRI Welcome	Joe Naser
0845	Overview of EPRI Productivity Developments	Joe Naser
0930	Break	
0945	EPRI Radiation Visualization Development	Phung Tran
1045	New Technologies for Plant Operations at EdF	Francois Dionis
1130	Lunch	
1300	Mobile Solutions for Field Operations at EdF	Francois Dionis
1345	Advanced Outage Control Center Pilot Project	Greg Weatherby
1430	Break	
1445	Automated Work Package Pilot Project	Ron Farris
1530	Computer-Based Procedure Pilot Project	Johanna Oxstrand Katya Le Blanc
1615	On-Line Monitoring (OLM) Pilot Projects	Rick Rusaw Nancy Lybeck Vivek Agarwal
1700	Wrap-Up	Ken Thomas

Summer 2012 Joint Meeting of the

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

August 21-23, 2012
Hilton Garden Inn
Idaho Falls, ID 83402

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

LWRS Light Water Reactor Sustainability

Wednesday, August 22

0800	Advanced II&C Development Program Status and Future Projects	Ken Thomas
0930	Break	
1000	Control Room Upgrade Strategy	Ron Boring
1130	Lunch	
1300	Advanced Design Concepts	Jon Kvalem
1430	Travel to INL Simulator	
1500	Demonstration of Control Room Simulation	Tony Magi
1600	Demonstration of Hammlab Simulator	Christer Nihlwing
1700	Travel to Hilton Garden Inn/Adjourn	

Summer 2012 Joint Meeting of the

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

August 21-23, 2012
Hilton Garden Inn
Idaho Falls, ID 83402

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Thursday, August 23

0800	Digital Licensing Issues	Ray Torok
0900	Cyber Security Evaluation of Initial Pilot Projects	Rita Wells
0945	Break	
1000	Cyber Security Tutorial	Jason Larsen Rob Hoffman
1045	Technology Trends – What will be possible?	All
1130	Lunch	
1300	Advanced II&C Vision/Strategy – Priorities Discussion	All
1400	Wrap-Up	Ken Thomas
1415	Adjourn	

Appendix C

Advanced Instrumentation, Information, and control Systems Technologies R&D Program

Advanced Instrumentation, Information, and Control Systems Technologies

R&D Program

Ken Thomas
Idaho National Laboratory

www.inl.gov

Idaho National Laboratory

Advanced II&C Systems Technologies

Technologies for and demonstrations of highly integrated control and display technologies that address long-term objectives of nuclear power plant operation, including the following:

- Fleet-wide management of asset information to support integrated operations
- Improved visualization and use of information to support decision-making and actions
- Greater automation of functions and availability of operator support systems to improve efficiencies and reduce errors

LWRS Light Water Reactor Sustainability

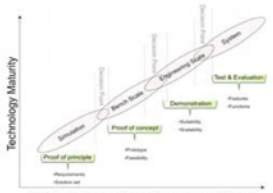
Science Based Approach

Approach
- Transformation of plant functions
- Development of enabling technologies
- Demonstration before deployment

Addresses
- Ingrained limiting paradigms
- Technology obsolescence
- Future workforce
- Human error

End-State Vision
- NPP modernization and renewal
- Extended plant life with sustainable operating model
- Enhanced nuclear safety
- Reduced staffing & O&M costs

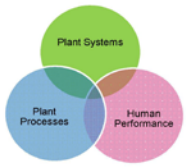
Applied Research Model



System and Data Qualification Requirements

Engaging the Nuclear Power Industry

- Research and development of near-term beneficial technologies while building the digital work environment of the future
- Integrating plant systems, plant processes, and human performance
- In-kind contribution from industry – time, expenses, plant access, plant expertise, reference documents, and other resources (e.g. simulator)
- Industry hosts the technology demonstration and effectiveness assessments
- INL provides research & associated technologies, training & implementation, and research reports
- INL facilitates industry-wide adoption of new capabilities



Utility Working Group

Exelon. · Edison · Entergy · aps · Constellation Energy · STP · Southern Company · PG&E · Progress Energy · TVA · Luminant · Duke Energy · INL · EPRI

Special Interest Groups

- Industry Focus Groups for
  - Control Room Modernization
  - Human performance
  - Computer-based Procedures
  - Outage Safety and Efficiency
- Opportunity to network with industry colleagues involved in I&C strategy
- Opportunity to shape an industry-consensus end-state vision
- Opportunity to visit participating utilities (nuclear stations) involved in these developments
- Opportunity to participate in pilot projects, if desired

Human Systems Simulation Laboratory

- *Reconfigurable Control Room Simulator*
- *Virtual Reality Cave*

Technology Building Blocks for a Future Digital Environment

- Heads-up information displays
- Wireless streaming of information & video
- Computer-based procedures
- Component status identification (bar code, RFID)
- Smart Board – large interactive display devices
- Wireless component position indicators
- Alarm management and display technology
- On-Line monitoring systems

2

Long-Term I&C Modernization Strategy

Objective: To significantly reduce the technical, financial, and regulatory risk of I&C modernization by demonstrating the new technologies and operational concepts in an actual NPP setting.

There are two things that differentiate this program:

1. The technologies are actually demonstrated in NPPs under controlled circumstances to validate them.
2. The HSSL provides an advanced simulation facility to validate concepts that cannot practically be demonstrated in a NPP until they are validated (e.g. control room changes).

I&C Modernization vs. Replacement

I&C Replacement Strategy: More common strategy of "like-for-like" replacements of legacy I&C systems, which deliberately restricts the beneficial use of inherent digital capabilities in order to minimize the impact on the "operating infrastructure," consisting of plant procedures, training, operator familiarity, design basis, and licensing basis. While this strategy resolves the immediate reliability and obsolescence concerns, it does not create a platform for business innovation. It generally adds to the cost of operating the plant in that the replacement systems require new sets of skills, spare parts, vendor support, etc., without off-setting business improvement.

I&C Modernization Strategy: Future strategy to implement digital technology in a manner that transforms the NPP operating model with business innovation while addressing the reliability and obsolescence concerns of the legacy I&C systems. This strategy has been successfully employed in many business sectors to improve quality of operations while reducing costs. It generally follows the pattern of reducing reliance on human skill while automating tasks and augmenting human performance and oversight with technology. When used to transform the operating model, digital technology has been a cost reducer.

Long-Term I&C Modernization Strategy

- Identify the business innovations and underlying technologies that will address the challenges of the future business environment.
- Sponsor and engage a Utility Working Group composed of I&C and business innovation leaders from the nuclear utilities to advise the research program on nuclear plant requirements and to serve as a peer review group for developed technologies and related business innovations.
- Conduct pilot projects at host nuclear plants to demonstrate and validate the business innovations and associated technologies, thereby reducing the risk of full-scale implementation by nuclear utilities.
- Develop laboratory facilities, such as the Human Systems Simulation Laboratory, to conduct program-related research and to demonstrate technologies and concepts that cannot be implemented at host nuclear plants until they are proven and validated.
- Develop and validate the overall plant information architecture that integrates these technologies into a seamless digital environment that supports the new operating model.

Long-Term I&C Modernization Strategy

- Communicate the work of this research program to all stakeholders, particularly the senior executives of the nuclear industry.
- Engage the major industry support organizations of EPRI, INPO, and NEI to ensure coordination of efforts and collaboration on development where beneficial.
- Maintain open communications with the NRC regarding the regulatory acceptability of the technologies and associated operational concepts.
- Engage the supplier community in providing commercial products for the demonstrated technologies in support of the desired business innovations.
- Develop a business case for the new nuclear plant operating model by extrapolating projected savings from the technologies and operational concepts demonstrated in the pilot projects. Validate these projected savings with multiple utilities.

Highly-Integrated Control Room

Pilot Projects

- Incorporating Digital Upgrades in an Analog Control Room
- Advanced Alarm Systems
- Computer-Based Procedures
- Computerized Operator Support System (COSS)
- Future Concepts of Operation

Highly-Integrated Control Room

Pilot Project No:	A1 **Title:**	Incorporating Digital Upgrades in an Analog Control Room	
Purpose:	To develop HFE guidance for implementation of a hybrid and fully integrated control room as new digital technologies and operator interface systems are introduced into a traditional control room.		
Scope:	Install the host utility's plant simulator and control room layout in the INL HSSL, conduct human factors studies on function and layout options for incorporation of new digital technology and develop associated guidance		
Deliverables:	End-state vision for incorporating digital controls and operator interface design into a traditional analog control room, control board and control room layout optimization guidelines based on HFE principles, and standardized operator interface screens based on HFE principles.		
Schedule:	October 2011 to September 2016	**Cost:**	TBD
Host Utility:	Southern California Edison	**Project Status:**	Planned

Highly-Integrated Control Room

Pilot Project No:	A2 **Title:**	Advanced Alarm Systems	
Purpose:	To improve operator performance in an event or plant transient by prioritizing alarms within the context of plant state and operating mode.		
Scope:	Development of candidate alarm display concepts, human factors evaluations of candidate systems in HSSL, and development of a requirements specification for an advanced alarm system.		
Deliverables:	Guideline standard for advanced alarm management system in a nuclear plant control room and methodology for integrating diverse alarms and annunciators across all systems and digital platforms.		
Schedule:	October 2012 to September 2014	**Cost:**	TBD
Host Utility:	Southern California Edison	**Project Status:**	Planned

SONGS Control Room Modernization Pilot Project

Develop first principles of control room design management that will help establish the technical basis for the design of new hybrid Control Room systems at SONGS and other power plants

- End-State Vision and Strategy for Control Room Modification – including a needs analysis and a long-term work plan.
- Proof-of-Concept HSI Screen - Develop and evaluate digital replacement displays for single panel/system at SONGS and

Highly-Integrated Control Room

Pilot Projects

- Incorporating Digital Upgrades in an Analog Control Room
- Advanced Alarm Systems
- Control Room Computer-Based Procedures
- Computerized Operator Support System (COSS)
- Future Concepts of Operation

Highly-Integrated Control Room

Pilot Project No:	A3 **Title:**	Control Room Computer-Based Procedures	
Purpose:	To improve operator performance by the use of CBPs in plant operational activities.		
Scope:	Working with the host utility's CBP development project to provide HFE studies regarding the procedure presentations, structure, and underlying software system to ensure that human error traps are not created.		
Deliverables:	A HFE analysis of the host utility's CBP approach and structure, associated data taken in the host utility's simulator in trial CBP usage, and a CBP implementation guideline for industry adoption.		
Schedule:	October 2011 to July 2013	**Cost:**	TBD
Host Utility:	South Texas Project	**Project Status:**	Planned

Computer-Based Procedures

- Conduct a baseline study to identify current work practices and human error rates, i.e. to identify procedure related issues to be addressed within the. This includes identification of appropriate level of automation in the procedures.
- Define design and functional requirements and specifications
- Develop prototypes and demonstration computer-based procedures
- Set up small-scale computer-based procedure solution at utility
- Conduct user tests and data collection at the utility. Compare results to baseline study to measure improvements

Potential Features of Computer-Based Procedures

- Integration with real-time plant data and system status
- Time monitoring for time-critical actions
- Detection of undesirable interactions
- State-based and mode sensitive context
- Sequencing of steps and other procedures (workflows)
- Place-keeping
- Seamless transitions to other procedures
- Computational aids and validation of results
- Embedded job aids – reference material, training material, and operating experience reports
- Automatic information insertion and verification of plant response

Potential Features of Computer-Based Procedures (continued)

- Remote concurrences and authorizations
- Soft controls – platform for the future "highly automated" plant
- Real-time task status
- Real-time risk assessment

Highly-Integrated Control Room

Pilot Projects

- Incorporating Digital Upgrades in an Analog Control Room
- Advanced Alarm Systems
- Computer-Based Procedures
- Computerized Operator Support System (COSS)
- Future Concepts of Operation

High-Automated Plant

Pilot Projects

- Digital Architecture for a Highly-Automated Plant
- Automating Manually-Performed Plant Activities
- Advanced Plant Control Automation
- Advanced Plant Control Algorithms

Human Performance Improvement for NPP Field Workers

Pilot Projects

- Mobile Technologies for NPP Field Workers
- Automated Work Packages
- Augmented Reality for NPP Field Workers

Human Performance Improvement for NPP Field Workers

Pilot Project No:	C1	**Title:**	Mobile Technologies for NPP Field Workers
Purpose:	To improve performance of NPP field workers by replacing paper-based activities with technology-based activities, thereby reducing human error, improving productivity, and providing real-time information links to work processes and control centers. In addition, by maximizing the "collective situational awareness" of the entire plant, these technological advancements will greatly improve critical decision making at all levels.		
Scope:	Assemble an array of mobile technologies that constitute a platform for field activities in a NPP, apply these technologies to initial applications of safety tagging and valve line-up verifications, develop a prototype computer-based procedure capability for field activities, conduct related human factors evaluations, and provide guidance for a fleetwide scale up of the technologies.		
Deliverables:	Prototype technologies, human factors evaluations of the technologies in use in the host utility NPP field activities, and guidance for fleetwide scale-up of the technologies.		
Schedule:	January 2011 to September 2012	**Cost:**	TBD
Host Utility:	Duke Energy	**Project Status:**	In progress

Human Performance Improvement for NPP Field Workers

Pilot Projects

- Mobile Technologies for NPP Field Workers
- Automated Work Packages
- Augmented Reality for NPP Field Workers

Integrated Operations*

Pilot Projects

- Advanced OLM Facility
- Virtual Plant Support Organization
- Management Decision Support Center

* Halden Reactor Project Concept

Outage Safety and Efficiency

Pilot Projects

- Advanced Outage Coordination
- Advanced Outage Control Center
- Outage Risk Management Improvement

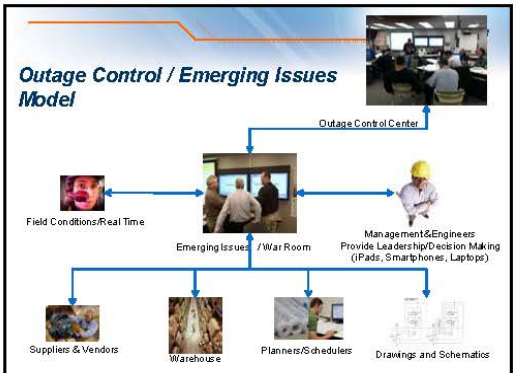
Outage Safety and Efficiency

Pilot Project No:	E1	**Title:**	Advanced Outage Coordination
Purpose:	To improve outage performance by introducing technologies that facilitate communications, coordination, and collaboration in obtaining critical activity status, managing the enormous flow of information through the OCC, and resolving emergent problems in an efficient and effective manner.		
Scope:	Determine technology needs for outage coordination improvement, prototype technologies, implement technologies in the control centers of a host utility NPP for use in refueling outages, conduct associated technical and human factors studies, and develop a guidelines document for industry implementation.		
Deliverables:	Prototype technologies and guidelines document for industry implementation.		
Schedule:	FY 2010 to FY 2012	**Cost:**	TBD
Host Utility:	Exelon Nuclear	**Status**	In progress

Advanced Outage Coordination

- Conducted at Exelon's Byron Nuclear Station in the March and September 2011 refueling outages
- Project scope is real-time communications and collaboration between the Outage Control Center (OCC) and the Work Execution Center (WEC), using large interactive displays that share information remotely
- The new display technology is used to manage fast-moving issues such as schedule threats, new priorities, and immediate support needs
- Project has been successful in improving communications and coordinating control centers.
- 2012 Scope:
  - Control of Equipment and Status
  - Real-Time Work Status
  - Emergent Issue Resolution

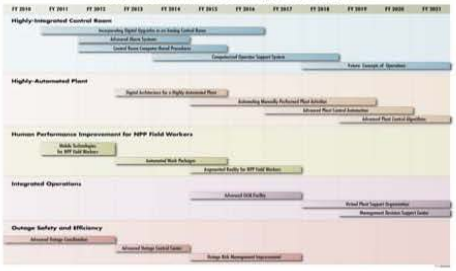
Outage Control / Emerging Issues Model



Outage Safety and Efficiency

Pilot Projects

- Advanced Outage Coordination
- Advanced Outage Control Center
- Outage Risk Management Improvement



Appendix E

Future Vision for Instrumentation, Information, and Control Modernization

Future Vision for Instrumentation, Information, and Control Modernization

Ken Thomas, Idaho National Laboratory

Introduction

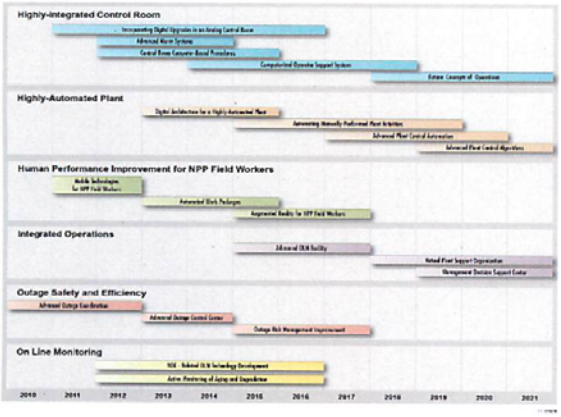
Unlike most other safety-critical industries, the nuclear power industry has not used digital technology to innovate its business model and transform risk-significant activities from mostly manual operations to use of automation. This is due to in large part to the tremendous investment in the current operating infrastructure and the need for a research program that manages the risk of this transformation. A Future Vision of a transformed nuclear plant operating model based on an integrated digital environment has been developed as part of the Advanced Instrumentation, Information, and Control (II&C) research pathway, under the Light Water Reactor (LWR) Sustainability Program.

Method

Data Collection: A Utility Working Group has provided information on current challenges for modernizing II&C systems, desired technologies to improve II&C reliability, opportunities for plant performance improvement, and priorities for development.

Development of an Industry Consensus Future Vision and Strategy: to build a seamless digital environment that integrates plant systems, plant processes, and plant workers (human performance); thereby enhancing nuclear safety, increasing productivity, and improving overall plant performance.

Conduct of Pilot Projects: conducted at host utilities as the means for industry to collectively integrate new technologies into nuclear plant work activities one at a time, spread over many plants and utilities, to the benefit of all. The pilot projects introduce new digital technologies into the nuclear plant operating environment to demonstrate and validate them for eventual production usage. In turn, the pilot project technologies serve as the



Vision

Results

The initial pilot projects have confirmed that the expected benefits can indeed be demonstrated by the pilot projects and that the underlying technologies can together comprise a network of capabilities that will fulfill the expectations of the future vision.

1. Based on a science-based approach to research, development, and demonstration activities, host utilities are willing to introduce digital technologies into their work methods, in some cases, in the live plant environment for purposes of evaluating and refining the technologies for eventual production usage.
2. Human performance can be improved by the introduction of well-developed digital technologies as supported by direct measurement and participant surveys.
3. Plant support processes can be made substantially more efficient with digital technologies that automatically communicate information to other parties, and update data bases and project status documents in the background as the worker conducts plant work activities.
4. Models of plant functions, such as procedure usage, are highly useful in capturing the requirements of complex nuclear plant activities and expectations.

Conclusions

1. The project has been successful in pursuing what has been an illusive endeavour for the nuclear power industry – the modernization of the LWR fleet II&C systems. The success is due to the project method; that is, to engage the industry in a research and development effort that provides near-term benefit while building a seamless digital platform that integrates plant I&C systems, plant work processes, and plant workers.
2. The initial pilot projects have confirmed that this level of benefit is obtainable and the technologies are recognized by the operating utilities to have substantial benefit. The project will serve to reduce the risk and uncertainty in the implementation of these technologies and will ultimately provide a roadmap for wide-spread II&C modernization for the LWR fleet.

Appendix E

Computer-Based Procedures for Nuclear Power Plants

DOE Light Water Reactor Sustainability

Computer-Based Procedures for Nuclear Power Plants

Ken Thomas
Idaho National Laboratory

24th Annual Procedure Symposium
Procedure Professionals Association
St. Petersburg, FL
June 19-21, 2012

www.inl.gov

INL Idaho National Laboratory

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.

INL Idaho National Laboratory

Future Vision and Modernization Strategy

- Reduce the technical, financial, and regulatory risk of upgrading the aging II&C systems to support extended plant life beyond 60 years, thereby ensuring that legacy analog II&C systems are not life-limiting issues for the LWR fleet
- Transform the NPP operating model, integrating plant systems, plant processes, and plant workers
- Develop a seamless digital environment
- that encompasses all aspects of plant operations and support
- Provide the technological foundation to improve plant performance and addresses the challenges of the future business environment

INL Idaho National Laboratory

Performance Improvement: Broad Outcomes

- II&C systems provide enhanced, accurate, and dependable plant control functions and operator information, thereby resolving the aging and reliability concerns of their predecessor legacy analog systems.
- The margins of nuclear safety are increased by the inherent reliability and precision of digital technology.
- Worker productivity is substantially enhanced through the automation of manual tasks, improvements in communications and coordination, and the immediate availability of utility and industry experts through real-time distance collaboration.
- Human performance is greatly improved through advanced worker technologies and automated processes.
- Radiation dose is minimized by reductions in the time and effort to conduct plant activities in radiation areas, and through new capabilities for workers to visualize radiation fields in their work areas using augmented reality technologies.
- Plant cost performance is improved through increased capacity factors and reduced operating costs.

Modernization Strategy: Objectives

- Identify the business innovations and underlying technologies that enable II&C modernization and address the challenges of the future business environment.
- Sponsor and engage a Utility Working Group (UWG) composed of II&C and business innovation leaders from the nuclear utilities to advise the research program on nuclear plant requirements and to serve as a peer review group for developed technologies and related business innovations.
- Conduct pilot projects at host nuclear plants (members of the UWG) to demonstrate and validate the business innovations and associated technologies, thereby reducing the risk of full-scale implementation by nuclear utilities.
- Develop laboratory facilities, such as the Human Systems Simulation Laboratory (HSSL), to conduct program-related research and to demonstrate technologies and concepts that cannot be implemented at host nuclear plants until they are proven and validated.
- Develop and validate the overall plant information architecture that integrates these technologies into a seamless digital environment that supports the new operating model.

Modernization Strategy: Objectives (cont.)

- Communicate the work of this research program to all stakeholders, particularly decision makers for plant life extension beyond 60 years.
- Engage the major industry support organizations of EPRI, INPO, and NEI to ensure coordination of efforts and collaboration on development where beneficial.
- Maintain open communications with the U.S. Nuclear Regulatory Commission (NRC) regarding the regulatory acceptability of the technologies and associated operational concepts.
- Engage the supplier community in promoting the development of commercial products for the demonstrated technologies supporting the desired business innovations.
- Develop a business case for the transformed nuclear plant operating model by extrapolating projected savings from the technologies and operational concepts demonstrated in the pilot projects. Validate these projected savings with multiple utilities.

Engaging the nuclear utilities

- Research and development of near-term beneficial technologies while building the digital work environment of the future
- Utilities hosts the technology demonstration and effectiveness assessments
- INL provides research & associated technologies, training & implementation, and research reports
- INL facilitates industry-wide adoption of new capabilities
- Utilities provide in-kind contribution – time, expenses, plant access, plant expertise, reference documents, and other resources (e.g. simulator)
- The Utility Working Group develops a consensus future vision for digital transformation, prioritizes the developments, and provides a peer review of the project results

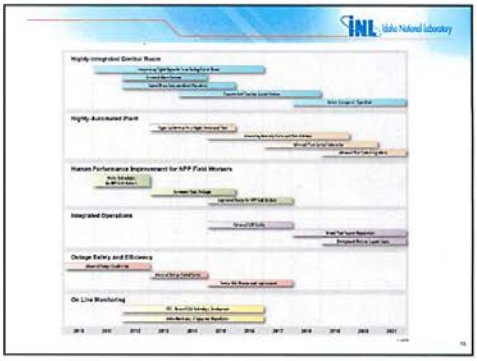
LWRS Light Water Reactor Sustainability

Utility Working Group

Exelon. · EDISON · Entergy · aps · Constellation Energy · STP · SOUTHERN COMPANY · PG&E · Progress Energy · TVA · Duke Energy. · Luminant · INL · EPRI

Special Interest Groups

- Industry Focus Groups for:
  - Control Room Modernization
  - Outage Safety and Efficiency
  - Human Performance Improvement for NPP Field Workers
  - Computer-based Procedures
- Opportunity to network with industry colleagues involved in I&C strategy
- Opportunity to shape an industry-consensus end-state vision
- Opportunity to visit participating utilities (nuclear stations) involved in these developments
- Opportunity to participate in pilot projects, if desired
- Additional Special Interest Groups will be formed as new areas of development are undertaken



Overview of Computer-Based Procedure Project

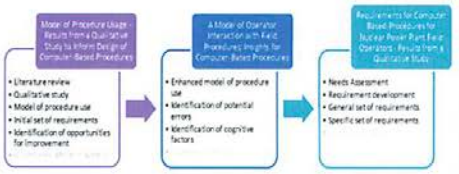
INL CPB Research Team

Research Objectives

- Define requirements for computer-based procedures (CBPs) to ensure an improvement compared to current paper-based procedures (PBPs).
- Evaluate how to streamline and distill the information in the PBP to increase efficiency, improve the ease of use, and reduce opportunities for errors.
- The research effort does not focus on how to display PBPs on an electronic device

FY12 Research Activities

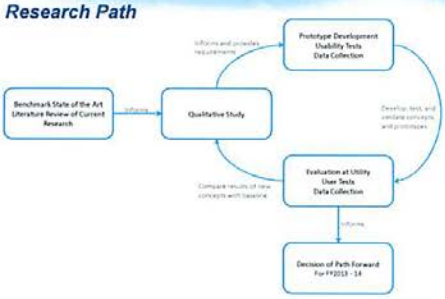
Progression of Research Activities



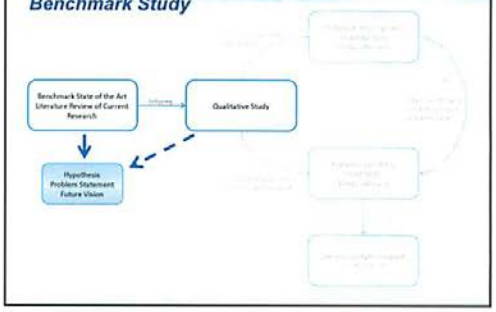
Related Pilot Project Research Papers

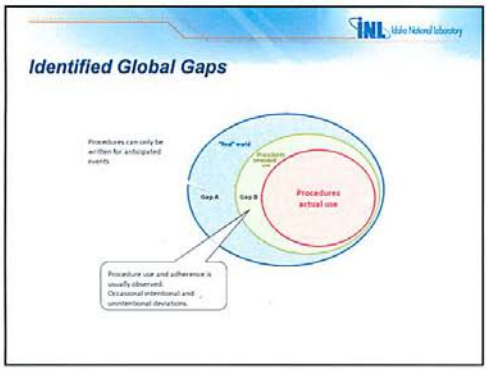
- Model of Procedure Usage - Results from a Qualitative Study to Inform Design of Computer-Based Procedures
  8th International Conference On Nuclear Plant Instrumentation, Control, And Human-Machine Interface Technologies (ANS NPIC & HMIT 2012)
- A Model of Operator Interaction with Field Procedures: Insights for Computer-Based Procedures
  Human Factors and Ergonomic Society 56th Annual Meeting (HFES 2012)
- Requirements for Computer Based-Procedures for Nuclear Power Plant Field Operators - Results from a Qualitative Study
  3rd International Conference on NPP Life Management for Long Term Operations (IAEA PLIM 2012)

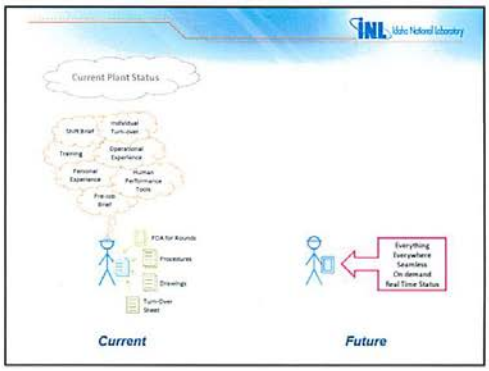
Research Path

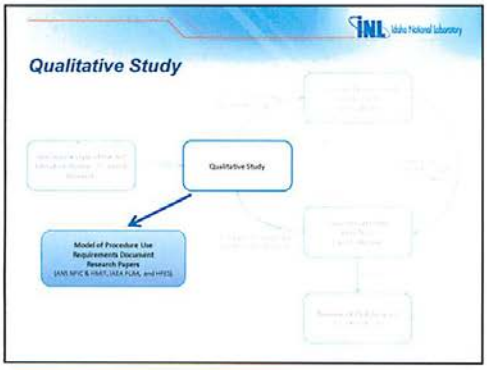


Benchmark Study




Identified Global Gaps
Procedures can only be written for anticipated events.
"Real" world
Procedures intended use
Gap A
Gap B
Procedures actual use
Procedure use and adherence is usually observed. Occasional intentional and unintentional deviations.


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

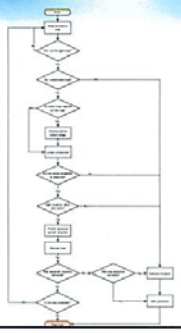

Qualitative Study
Qualitative Study
Model of Procedure Use Requirements Document Research Papers


Method for Qualitative Study
Observations
Interviews
Focus Groups
Information Flow
Task Flow

Information Flow

The Initial Model of Procedure Use

- Describes the activities involved in the execution of one single procedure step
- Based on the result from the Qualitative study

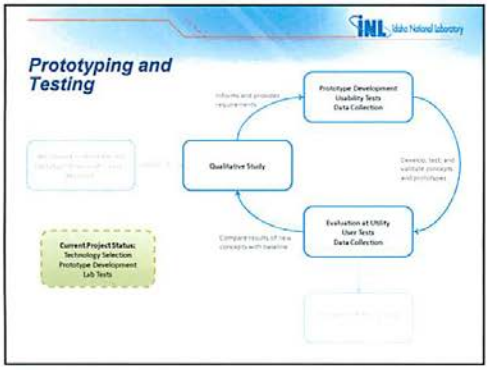


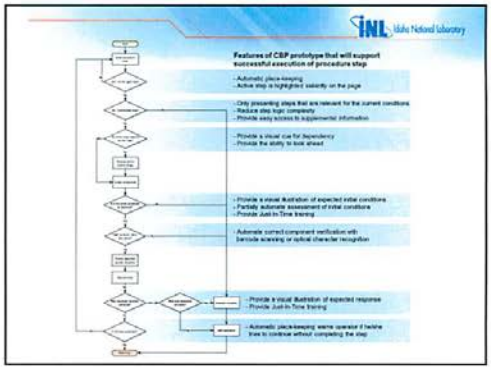
CBP Requirements

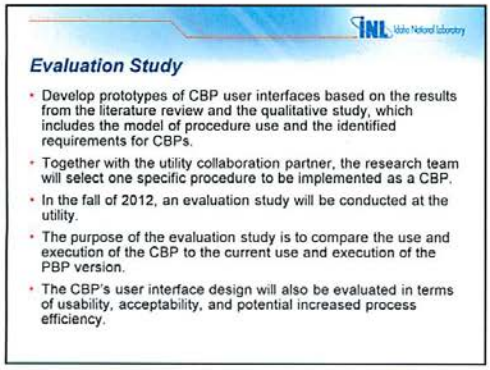
- Guide operators through the logical sequence of the procedure.
- Ease the burden of place-keeping for the operator.
- Make the action steps distinguishable from information gathering steps.
- Alert operator to dependencies between steps.
- Ease the burden of correct component verification for the operator.
- Ease the identification and support assessment of the expected initial conditions.
- Ease the identification and support assessment of the expected plant and equipment response.
- Include functionality that improves communication.

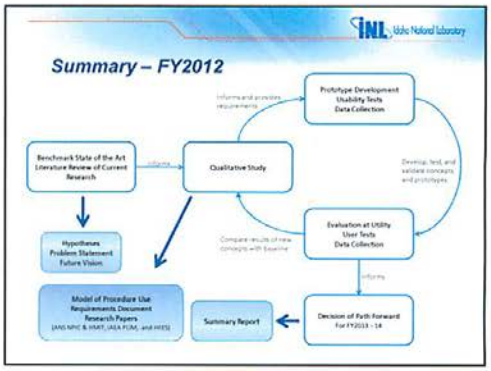
CBP Requirements

- Be designed so that the operator controls the procedure pace.
- Make calculations when the necessary information is available.
- Alert users when procedure steps or conditions have been violated.
- Alert users when conditions require transitioning to another procedure.
- Evaluate step logic when the necessary information is available.
- Be designed so that it is easy for the user to "undo" an unintended or incorrect action (an error of commission).
- Allow the operator to look ahead and back in the procedure.


INL Idaho National Laboratory
Prototyping and Testing
Prototype Development
Usability Tests
Data Collection
Qualitative Study
Evaluation at Utility
User Tests
Data Collection
Current Project Status:
Technology Selection
Prototype Development
Lab Tests


INL Idaho National Laboratory
Features of CBP prototype that will support successful execution of procedure step


INL Idaho National Laboratory
Evaluation Study
• Develop prototypes of CBP user interfaces based on the results from the literature review and the qualitative study, which includes the model of procedure use and the identified requirements for CBPs.
• Together with the utility collaboration partner, the research team will select one specific procedure to be implemented as a CBP.
• In the fall of 2012, an evaluation study will be conducted at the utility.
• The purpose of the evaluation study is to compare the use and execution of the CBP to the current use and execution of the PBP version.
• The CBP's user interface design will also be evaluated in terms of usability, acceptability, and potential increased process efficiency.


INL Idaho National Laboratory
Summary – FY2012
Prototype Development
Usability Tests
Data Collection
Benchmark State of the Art
Literature Review of Current
Research
Qualitative Study
Hypotheses
Problem Statement
Future Vision
Evaluation at Utility
User Tests
Data Collection
Model of Procedure Use
Requirements Document
Research Papers
Summary Report
Decision of Path Forward

Relationship of CBPs and Automated Work Packages

- Automated work packages contain one or more procedures and can control the sequence of work involving multiple procedures.
- Procedures can provide step-by-step status to the work package for work progress monitoring and release of parallel work.
- These capabilities would reside on a common hand-held device (tablet or PDA) and would provide seamless access to all parts of the work package and related documentation.
- Capabilities will be provided to modify the work package on a real-time basis, going through the appropriate change processes, to allow work to proceed when faced with changing conditions or requirements.

Potential Future Requirements

- Time monitoring for time-critical actions
- Detection of undesirable interactions
- State-based and mode sensitive context
- Seamless transitions to other procedures
- Automatic information insertion and verification of plant response
- Remote concurrences and authorizations
- Soft controls – platform for the future "highly automated" plant
- Real-time task status
- Real-time risk assessment

In summary…..

Computer-based procedures are an essential element of the strategy for Human Performance Improvement for NPP Field Workers

Initial qualitative studies have defined models on which to base improvements enabled by technology

Upcoming field demonstrations will be used to confirm the models and human performance improvement

Appendix F

Advanced Instrumentation, Information, and Control Systems Technologies
Digital I&C Workshop

LWRSP

Advanced Instrumentation, Information, and Control Systems Technologies

Digital I&C Workshop
July 22, 2012

Ken Thomas
Idaho National Laboratory

INL Idaho National Laboratory

DOE Light Water Reactor Sustainability Program 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.

INL Idaho National Laboratory

II&C Modernization vs. Replacement

II&C Replacement Strategy: More common strategy of "like-for-like" replacements of legacy II&C systems, which deliberately restricts the beneficial use of inherent digital capabilities in order to minimize the impact on the "operating infrastructure," consisting of plant procedures, training, operator familiarity, design basis, and licensing basis. While this strategy resolves the immediate reliability and system aging concerns, it does not create a platform for business innovation. It generally adds to the cost of operating the plant in that the replacement systems require new sets of skills, spare parts, vendor support, etc., without off-setting business improvement.

II&C Modernization Strategy: Future strategy to implement digital technology in a manner that transforms the nuclear station operating model with business innovation while addressing the reliability and aging concerns of the legacy II&C systems. This strategy has been successfully employed in many business sectors to improve quality of operations while reducing costs. It generally follows the pattern of reducing reliance on human skill while automating tasks and augmenting human performance and oversight with technology. When used to transform the operating model, digital technology has been a cost reducer.

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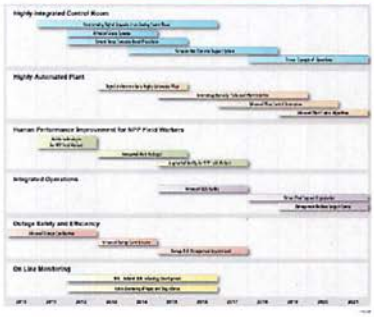
Long-Term II&C Modernization Strategy

To significantly reduce the technical, financial, and regulatory risk of II&C modernization by:

- demonstrating and validating new technologies and operational concepts at host nuclear plants, addressing legacy II&C technology challenges and future business innovation.
- transforming the operating model, integrating plant systems, plant processes, and plant workers.
- providing guidance for full-scale implementation.
- providing Technical Basis Reports to support utility II&C long-term planning, regulatory submittals, and procurement.
- communicating the work of this research program to nuclear power stakeholders.

Utility Working Group

Exelon. · Edison · Entergy · aps · Constellation Energy · STP · Southern Company · TVA · PG&E · Progress Energy · Xcel Energy · Duke Energy · Luminant · INL · ARP · EPRI



Highly-Integrated Control Room

Pilot Projects

- Incorporating Digital Upgrades in an Analog Control Room
- Advanced Alarm Systems
- Computer-Based Procedures
- Computerized Operator Support System (COSS)
- Future Concepts of Operation

INL Human System Simulation Laboratory: Simulator-Based Human Factors Research with Nuclear Power Plant Simulators

Operate multiple NPP simulator models

- PWR, BWR, SMR
- Plant-specific and Generic

Unique capability

- Test design and analysis for human-in-the-loop behavioral and performance testing
- Usability analyses & proof-of-concept tests of existing and emerging Human-System Interaction technologies
- Development of operator-centric requirements
- Perception and cognition experiments (e.g. situation awareness, workload…)

Objectives

- Assess human performance in simulated control rooms
- Develop standard set of human performance measures
- Implement LWRS & SMR simulator models
- Develop technical basis for selection of advanced HSIs
- Develop advanced human factors research tools

2

Origin of the HSSL

- Use of simulators in industry not new
- Accepted as a valid, reliable and cost-effective means to evaluate and validate a large range of issues in many industries: technology & design decisions, operating concepts, human performance, etc.
- All utilities have training simulators – not available for research purposes
- INL's first HSSL launched in 2007 – still evolving to keep pace with state-of-the-art
- Current strategic plan looking 10 years ahead

Mission of the HSSL

To provide a national user facility that supports the DOE and the nuclear energy industry with research-based guidance on the human and technological contributions to system resilience and the performance of nuclear power plant crews under various task and environmental conditions.

What are the "Human Factors"?

Research Process for Control Room Modernization

Step 1

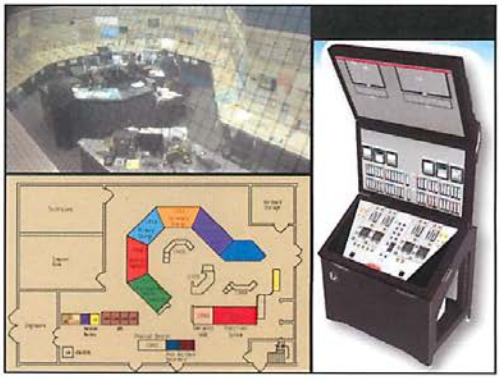
- Translate analog control room to digital representation
- Marry plant control room to INL simulator

Step 2

- Develop a reference Human Factors Engineering Program
- Develop style guides for replacement HSI
- Provide human factors support

Step 3

- Create innovative controls and displays that improve human performance
  - Develop DCS implementation
  - Develop operator support systems including overview displays
- Conduct workshops with plant operators to validate concepts



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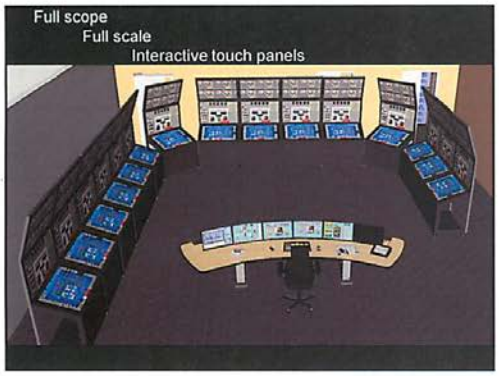
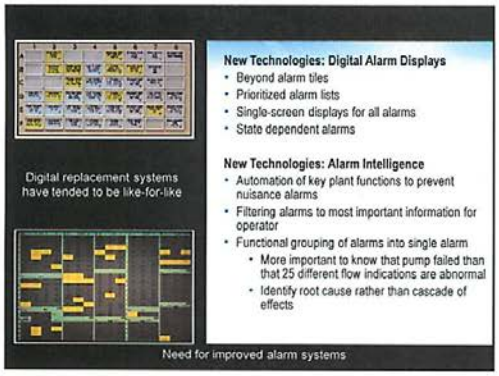

Full scope
Full scale
Interactive touch panels


Digital replacement systems have tended to be like-for-like
New Technologies: Digital Alarm Displays
• Beyond alarm tiles
• Prioritized alarm lists
• Single-screen displays for all alarms
• State dependent alarms
New Technologies: Alarm Intelligence
• Automation of key plant functions to prevent nuisance alarms
• Filtering alarms to most important information for operator
• Functional grouping of alarms into single alarm
• More important to know that pump failed than that 25 different flow indications are abnormal
• Identify root cause rather than cascade of effects
Need for improved alarm systems


In summary…..
Shift the digital approach from a replacement strategy to a modernization strategy
Provide advanced simulation facilities to enable development and validation of advanced control room concepts
Transform traditional control rooms to achieve significant operational improvement
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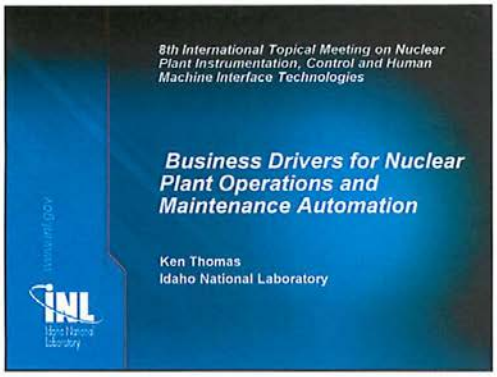
Idaho National Laboratory

4

Appendix G

Business Drivers for Nuclear Plant Operations and Maintenance Automation


8th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies
Business Drivers for Nuclear Plant Operations and Maintenance Automation
Ken Thomas
Idaho National Laboratory
INL
Idaho National Laboratory


INL Idaho National Laboratory
DOE Light Water Reactor Sustainability Program 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.


INL Idaho National Laboratory
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• providing Technical Basis Reports to support utility II&C long-term planning, regulatory submittals, and procurement.
• communicating the work of this research program to nuclear power stakeholders.
LWRS
Light Water Reactor Sustainability


INL Idaho National Laboratory
Utility Working Group
Exelon.
EDISON
Entergy.
aps
Constellation Energy
SOUTHERN COMPANY
TVA
PG&E
Progress Energy
Xcel Energy
Duke Energy
Luminant
INL
EPRI

1

Key Business Drivers

- Six key business drivers will challenge the current LWR fleets ability to maintain its rate of performance improvement.
- Each of these will call into question the general assumptions of how work is conducted in the nuclear plants.
- They will each point to an expanded role of technology to address these emerging factors.
- Automation of operations and maintenance activities will result in needed performance improvement as a response to the challenge posed by each of the business drivers.

Cost Performance

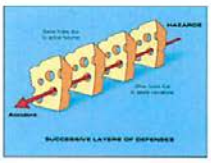
- Other forms of generation (primarily gas).
- Expense of ongoing safety issues.
- Nuclear O&M budgets dominated by labor costs (~70%), typically 10X the number of staff at a comparably-sized coal plant.
- Labor will continue to be a rising cost – but can be somewhat offset by advanced technologies.
- Investment funds for performance improvement needs are getting squeezed by market competition.

Workforce Availability

- Pending retirement wave, more than 25,000 skilled nuclear workers will have to be replaced by 2015.
- Knowledge management is not keeping pace with retirements.
- Replacement worker availability is strained due to a declining technical workforce in the U.S.
- It will be difficult to attract today's digital-immersed workforce into the legacy technologies that dominate the current nuclear fleet.

Human Performance

- Due to low level of plant automation, manual actions still dominate operations.
- Events are prevented by focusing on correct worker behaviors (error prevention) - plus process and organizational layers of defenses are set up to prevent an error becoming an event.
- Still, human error is a significant contributor to and a complicating factor in operational events.
- Technology is greatly under-utilized in preventing human error.



Dose and Rad Waste Reduction

- Great strides in reducing dose relying on ALARA principles
- Automation can greatly reduce "time and distance"
- Automation can reduce rad waste by eliminating unnecessary paper in contaminated areas

Long-Term Asset Management

- Large component aging management is key to long-term sustainability of the operating nuclear fleet.
- New technologies for on-line monitoring of degradation mechanisms are needed to move from periodic to condition-based maintenance and interventions.
- These technologies will require advanced capabilities for diagnostics and prognostics (remaining useful life).

Nuclear Safety

Issue: Maintaining the highest levels of nuclear safety, overcoming event-driven public and political perception of safety (Fukushima)

Automation has broad potential to favorably impact nuclear safety, by addressing equipment reliability, human performance, plant operational stability, and improved accident response capability.

Aggregate Effect of Business Drivers

- Plant cost performance is improved through increased worker productivity and better operating performance.
- Human performance is greatly improved by automating manual activities and elevating the role of plant workers to one of technology oversight.
- Workforce requirements are reduced due to the automation and it will be easier to attract a talented workforce into a work environment that empowers workers with technology.
- Radiation dose is minimized by reductions in the time and effort to conduct plant activities in radiation areas due to task automation, or the elimination of the need for workers to conduct certain activities in radiation fields.
- Plant components will be inherently more reliable and have longer operating lives through the use of on-line monitoring technologies to improve asset management.
- The margins of nuclear safety are increased by the inherent reliability and precision of digital technology.

Transformed Plant Operating Model Based on a Seamless Digital Information Environment

Automation for Operations

- Highly Integrated Control Room
- In-Plant Operations
- Computer-Based Procedures
- Computerized Operator Support Systems

Automation for Maintenance

- Mobile Worker Technologies
- Automated Work Packages
- Automation of Manually-Performed Activities
- On-Line Monitoring

Real-Time Plant Status Control

- Bar Code Component Identification
- Real-Time Work Progress Status
- Remote Verification
- Distance Collaboration

4

Work Process Automation

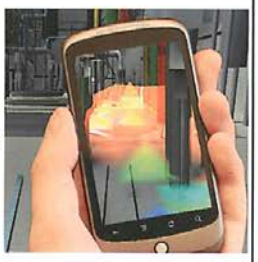
- Mobile Applications
- Real-time status to control centers and managers
- Human error prevention
- Automatic document generation
- Automatic data base updates

Outage Safety and Efficiency

- Advanced Outage Coordination
- Advanced Outage Control Center
- Outage Risk Management Improvement

Augmented Reality

- Ability to visualize invisible and abstract information
- Uses position tracking and device sensors to know the location and view of the field workers
- Useful in such applications as radiation visualization, operational data, and plant safety



Conclusions:

Key Business Drivers will shape the future of nuclear plant operations and maintenance

Automation of activities can substantially mitigate the effects of these business drivers

We can transform our business to achieve significant performance improvement

5

Appendix H

Advanced Digital Technology for Nuclear Power Plants

Light Water Reactor Sustainability Program

Advanced Digital Technology for Nuclear Power Plants

ANS Utility Working Conference
Hollywood, FL August 5-8, 2012

Ken Thomas
Idaho National Laboratory

www.inl.gov

INL Idaho National Laboratory

The Light Water Reactor Sustainability (LWRS) Program is developing the scientific basis to extend existing nuclear power plant operating life beyond the current 60-year licensing period and ensure long-term reliability productivity, safety, and security. The program is conducted in collaboration with national laboratories, universities, industry, and international partners.

Idaho National Laboratory serves as the Technical Integration Office and coordinates the Research and Development (R&D) projects in the following pathways:

- ***Materials Aging and Degradation Assessment***
- ***Advanced Light Water Reactor Fuel***
- ***Instrumentation and Controls***
- ***Risk-Informed Safety Margin Characterization***

INL Idaho National Laboratory

DOE LWRSP Vision and Program Goals

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

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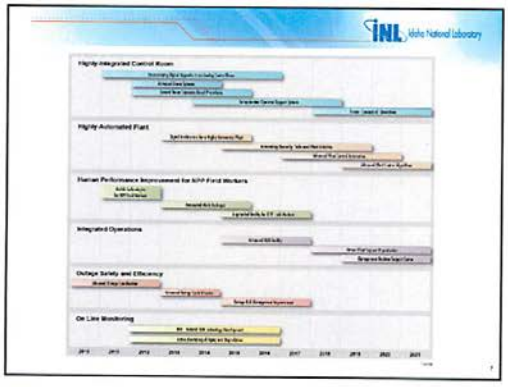

Engaging the nuclear utilities

- Research and development of near-term beneficial technologies while building the digital work environment of the future
- Utilities hosts the technology demonstration and effectiveness assessments
- INL provides research & associated technologies, training & implementation, and research reports
- INL facilitates industry-wide adoption of new capabilities
- Utilities provide in-kind contribution – time, expenses, plant access, plant expertise, reference documents, and other resources (e.g. simulator)
- The Utility Working Group develops a consensus future vision for digital transformation, prioritizes the developments, and provides a peer review of the project results

LWRS
Light Water Reactor Sustainability

2

Utility Working Group

Exelon. · EDISON · Entergy · aps · Constellation Energy · STP · SOUTHERN COMPANY · TVA · PG&E · Progress Energy · Xcel Energy · Duke Energy · Luminant · INL · EPRI

Special Interest Groups

- Industry Focus Groups for
  - Control Room Modernization
  - Human performance
  - Computer-based Procedures
  - Outage Safety and Efficiency
- Opportunity to network with industry colleagues involved in I&C strategy
- Opportunity to shape an industry-consensus end-state vision
- Opportunity to visit participating utilities (nuclear stations) involved in these developments
- Opportunity to participate in pilot projects, if desired

Human Systems Simulation Laboratory

- *Reconfigurable Control Room Simulator*
- *Virtual Reality Cave*

Origin of the HSSL

- Use of simulators in industry not new
- Accepted as a valid, reliable and cost-effective means to evaluate and validate a large range of issues in many industries: technology & design decisions, operating concepts, human performance, etc.
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3

INL Human System Simulation Laboratory:
Simulator-Based Human Factors Research with Nuclear Power Plant Simulators

Operate multiple NPP simulator models
- PWR, BWR, SMR
- Plant-specific and Generic

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- Implement LWRS & SMR simulator models
- Develop technical basis for selection of advanced HSIs
- Develop advanced human factors research tools

What are the "Human Factors"?

INL Idaho National Laboratory

ORGANIZATIONAL FACTORS: Regulatory, training, job design, politics, roles, work organization

ENVIRONMENTAL FACTORS: Noise, heating, lighting, ventilation, radiation

HEALTH FACTORS: stress, headaches musculo-skeletal disorders

COMFORT FACTORS: Seating, equipment, layout

CONSTRAINTS: costs, timescales, budgets, staff, equipment, infrastructure

THE USER (operator): Mental & physical abilities and limitations

PRODUCTIVITY FACTORS: Increase output, quality decrease costs, errors, labor requirements, production time

OPERATOR INTERFACE: Input & output devices, dialogue structures, display objects, navigation …

TASK FACTORS: easy, complex, novel, task allocation, repetitive, monitoring, skills components

SYSTEM FUNCTIONALITY: hardware, software, application

Research Process for Control Room Modernization

INL Idaho National Laboratory

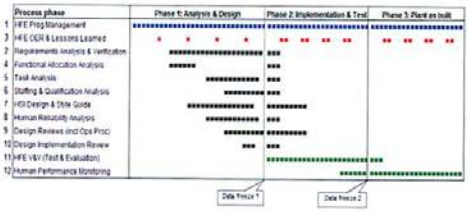
Step 1
- Translate analog control room to digital representation
- Incorporate plant control room to INL simulator

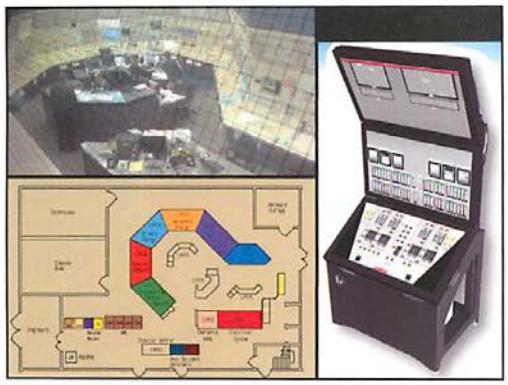
Step 2
- Develop a reference Human Factors Engineering Program
- Develop style guides for replacement HSI
- Provide human factors support

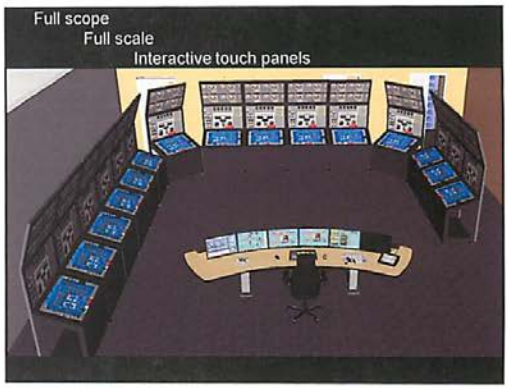
Step 3
- Create innovative controls and displays that improve human performance
  - Develop DCS implementation
  - Develop operator support systems including overview displays
- Conduct workshops with plant operators to validate concepts

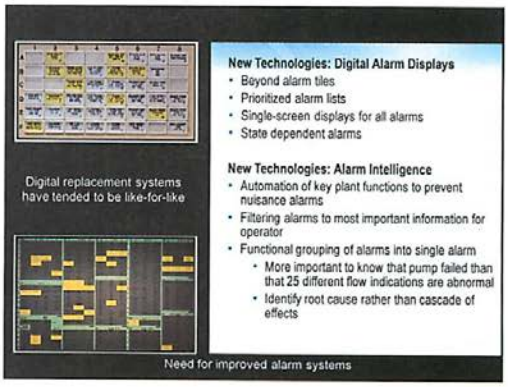
HFE Process Flow Based on NUREG-0711

INL Idaho National Laboratory






Full scope
Full scale
Interactive touch panels


Digital replacement systems have tended to be like-for-like
New Technologies: Digital Alarm Displays
• Beyond alarm tiles
• Prioritized alarm lists
• Single-screen displays for all alarms
• State dependent alarms
New Technologies: Alarm Intelligence
• Automation of key plant functions to prevent nuisance alarms
• Filtering alarms to most important information for operator
• Functional grouping of alarms into single alarm
• More important to know that pump failed than that 25 different flow indications are abnormal
• Identify root cause rather than cascade of effects
Need for improved alarm systems

5


In summary.....
Shift the digital approach from a replacement strategy to a modernization strategy
Provide advanced simulation facilities to enable development and validation of advanced control room concepts
Transform traditional control rooms to achieve significant operational improvement
INL

6

Appendix I

Transforming the Nuclear Power Plant Operating Model with Digital Technology

Transforming the Nuclear Power Plant Operating Model with Digital Technology

Ken Thomas
Idaho National Laboratory

EdF-EPRI-IFE Halden Reactor Project Meeting
Chatou, France
April 23-24, 2012

I&C Replacements with Digital Systems

- Safety-Critical Protection Systems
- Integrated and Local Control Systems
- Monitoring Systems
- Diagnostic Systems
- Plant Information Systems
- Control Room Upgrades
- Component-Level Applications

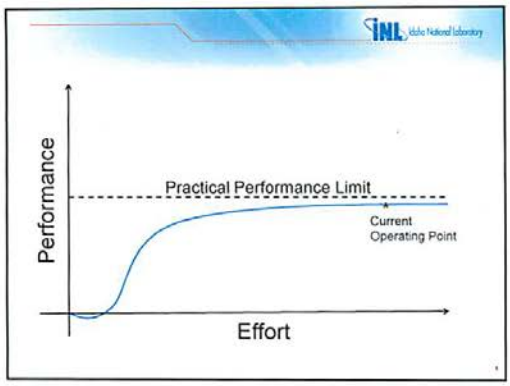
Systems-Based I&C Replacement Strategy

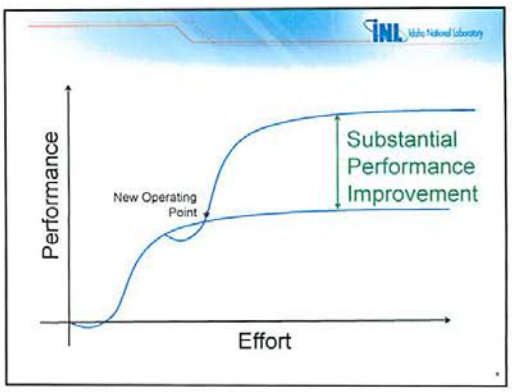
- I&C replacement strategy is driven by obsolescence and reliability issues
- Replacements are typically "like-for-like"
- Digital is not yet contributing significantly to overall plant performance improvement
- The reason is that we are thinking in terms of replacing systems rather transforming our operating model

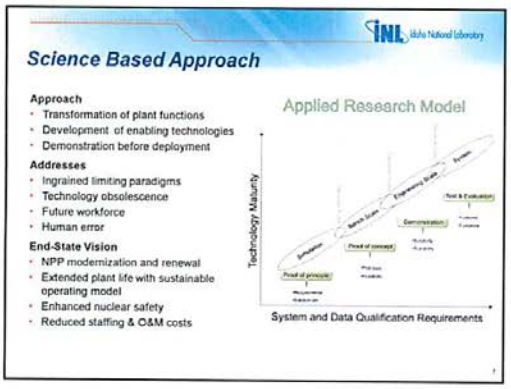
Performance-Based I&C Replacement Strategy

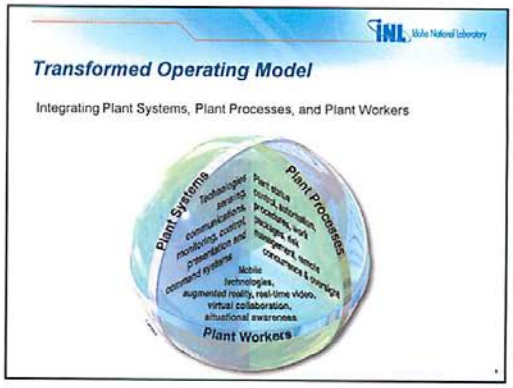
- I&C modernization is considered to be a critical need for the sustainability of the operating nuclear fleet
- Due to short-term operational focus, the US commercial nuclear industry could modernize its legacy I&C systems and still miss the opportunity to transform its operating model
- A national research program is needed to develop the transformative technologies and implementation roadmap for a performance-based I&C replacement strategy

LWRS
Light Water Reactor Sustainability


Performance
Practical Performance Limit
Current
Operating Point
Effort


Performance
New Operating
Point
Substantial
Performance
Improvement
Effort


Science Based Approach
Approach
Transformation of plant functions
Development of enabling technologies
Demonstration before deployment
Addresses
Ingrained limiting paradigms
Technology obsolescence
Future workforce
Human error
End-State Vision
NPP modernization and renewal
Extended plant life with sustainable operating model
Enhanced nuclear safety
Reduced staffing & O&M costs
Applied Research Model
Technology Maturity
System and Data Qualification Requirements


Transformed Operating Model
Integrating Plant Systems, Plant Processes, and Plant Workers
Plant Systems
Plant Processes
Plant Workers
Mobile technologies, augmented reality, real-time video, virtual collaboration, situational awareness

Transformed Operating Model: Broad Outcomes

- II&C systems provide enhanced, accurate, and dependable plant control functions and operator information, thereby resolving the aging and reliability concerns of their predecessor legacy analog systems.
- The margins of nuclear safety are increased by the inherent reliability and precision of digital technology.
- Worker productivity is substantially enhanced through the automation of manual tasks, improvements in communications and coordination, and the immediate availability of utility and industry experts through real-time distance collaboration.
- Human performance is greatly improved through advanced worker technologies and automated processes.
- Radiation dose is minimized by reductions in the time and effort to conduct plant activities in radiation areas, and through new capabilities for workers to visualize radiation fields in their work areas using augmented reality technologies.
- Plant cost performance is improved through increased capacity factors and reduced operating costs.

Modernization Strategy: Objectives

- Identify the business innovations and underlying technologies that enable II&C modernization and address the challenges of the future business environment.
- Sponsor and engage a Utility Working Group (UWG) composed of II&C and business innovation leaders from the nuclear utilities to advise the research program on nuclear plant requirements and to serve as a peer review group for developed technologies and related business innovations.
- Conduct pilot projects at host nuclear plants (members of the UWG) to demonstrate and validate the business innovations and associated technologies, thereby reducing the risk of full-scale implementation by nuclear utilities.
- Develop laboratory facilities, such as the Human Systems Simulation Laboratory (HSSL), to conduct program-related research and to demonstrate technologies and concepts that cannot be implemented at host nuclear plants until they are proven and validated.
- Develop and validate the overall plant information architecture that integrates these technologies into a seamless digital environment that supports the new operating model.

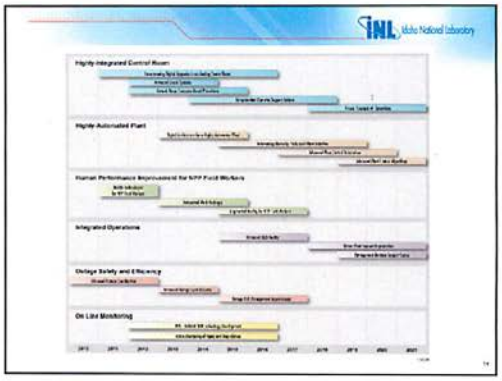
Modernization Strategy: Objectives (cont.)

- Communicate the work of this research program to all stakeholders, particularly decision makers for plant life extension beyond 60 years.
- Engage the major industry support organizations of EPRI, INPO, and NEI to ensure coordination of efforts and collaboration on development where beneficial.
- Maintain open communications with the U.S. Nuclear Regulatory Commission (NRC) regarding the regulatory acceptability of the technologies and associated operational concepts.
- Engage the supplier community in promoting the development of commercial products for the demonstrated technologies supporting the desired business innovations.
- Develop a business case for the transformed nuclear plant operating model by extrapolating projected savings from the technologies and operational concepts demonstrated in the pilot projects. Validate these projected savings with multiple utilities.

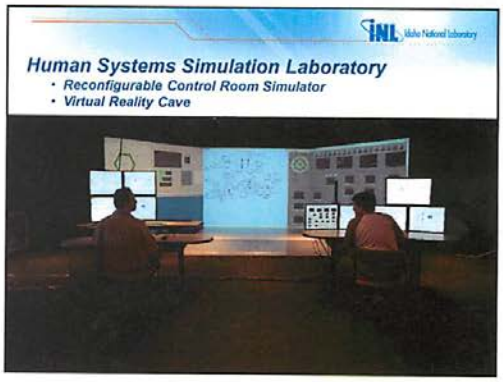
Advanced II&C Utility Working Group

- It assures that the end-state vision for plant modernization is shared by a significant portion of the LWR fleet.
- It assures the near-term technologies are immediately beneficial while they comprise the long-term building blocks of a more comprehensive digital environment.
- It greatly reduces the risk of implementation for any one utility, given that the proven abilities of INL stand behind the soundness of the technologies and that the oversight of the working group provides a competent peer review.
- It allows the utilities to move forward together in transforming their operating model to fully exploit these technologies, providing a transparent process for coordinating efforts with the major industry support organizations of EPRI, INPO, and NEI.
- It increases the likelihood that the technology implementations will receive favorable regulatory reviews due to INL's extensive understanding of the NRC's requirements in the area of digital II&C technology and human factors science.


INL Idaho National Laboratory
Utility Working Group
Exelon.
EDISON
Entergy.
aps
Constellation Energy
STP
SOUTHERN COMPANY
PG&E
Progress Energy
TVA
Duke Energy
Luminant
OPPD
INL Idaho National Laboratory
EPRI ELECTRIC POWER RESEARCH INSTITUTE


INL Idaho National Laboratory
Highly Integrated Control Room
Highly Automated Plant
Integrated Operations
On Line Monitoring


INL Idaho National Laboratory


INL Idaho National Laboratory
Human Systems Simulation Laboratory
• Reconfigurable Control Room Simulator
• Virtual Reality Cave

4

Technology Building Blocks for a Future Digital Environment

- Heads-up information displays
- Wireless streaming of information & video
- Computer-based procedures
- Component status identification (bar code, RFID)
- Smart Board – large interactive display devices
- Wireless component position indicators
- Alarm management and display technology
- On-Line monitoring systems

Highly-Integrated Control Room

- End-State Vision for Modernized Control Room
- Human System Interfaces
- Computer-Based Procedures
- Advanced Alarm Systems
- Operator Support Systems
- Advanced Plant Control Automation

Outage Safety and Efficiency

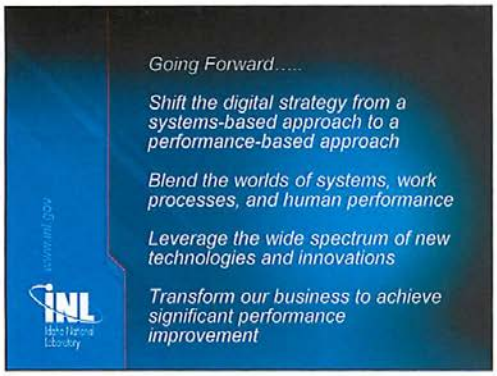
Pilot Projects

- Advanced Outage Coordination
- Advanced Outage Control Center
- Outage Risk Management Improvement

Catawba - Human Performance Improvement for NPP Field Workers

- Targets plant status control, safety tags, and field work processes
- Uses hand-held and hands-free (heads-up) devices to access automated work processes and plant information, using wireless communications
- Uses real-time video streaming and data updates for monitoring, collaboration, and concurrence from remote parties

5


Going Forward.....
Shift the digital strategy from a systems-based approach to a performance-based approach
Blend the worlds of systems, work processes, and human performance
Leverage the wide spectrum of new technologies and innovations
Transform our business to achieve significant performance improvement
INL
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