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Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Study to Investigate a U.S. Digital Instrumentation and Control and Human-Machine Interface Test Facility

L. J. Bond
A. Schur
D. L. Brenchley

March 2008

Prepared for the U.S. Nuclear Regulatory Commission
under NRC Job Code N6465
via Contract DE-AC05-76RL01830
with the U.S. Department of Energy

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Executive Summary

The increasing use of digital instrumentation and controls and the related human interactions with such systems in nuclear power generating and fuel cycle facilities have introduced new potential benefits to enhance plant safety. However, these developments and technological benefits are presenting some new regulatory challenges. Currently, the U.S. Nuclear Regulatory Commission (NRC) addresses these challenges by analyzing their scope, impact, and potential adverse plant interactions, and then conducting research on significant safety-related issues identified through this analysis. Often, such analyses and research efforts are performed under contracts that the NRC establishes with commercial entities, U.S. Department of Energy (DOE) national laboratories, universities, and international research facilities. However, there may be advantages to alternative approaches that can leverage capabilities and expertise within the wider digital instrumentation and controls and human-machine interfaces (DI&C/HMI) community.

The NRC contracted with the Pacific Northwest National Laboratory (PNNL) to perform a survey and assist in conducting public workshops to review the current and future technical issues in the area of DI&C/HMI, to identify the capabilities that exist and assess the need for a facility or facilities, and report overarching principles that should be considered for the success of any of the conceptual approaches identified. The study comprised three main elements: a survey of capabilities that employed web-based materials; telephone interviews and site visits; and two workshops. These efforts were initiated to address the questions posed by COMPBL-07-0001, "Staff Requirements – Development of a U.S. Digital Instrumentation and Human-Machine Interface Test Facility." The questions posited by the Commission are:

- What potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include industries outside the nuclear industry?
- If nuclear industry participated, how could conflict of interest issues be addressed?
- Do examples of similar facilities currently exist and, if so, what can be learned from their successes and challenges?
- What siting options are most viable (e.g., universities where integration with graduate studies might be encouraged, national laboratories, etc.), taking both cost and ease of technical information exchange into account?
- To what extent could such a facility be designed to be reconfigurable to the expected variety of plant control room and HMI designs?
- To what extent could such a facility be designed to also be used as an advanced reactor training simulator for NRC staff?
- What impediments, if any, to information sharing among participants and to external stakeholders might exist?
- What could be the benefits, or adverse impact, to existing and established international collaborative activities in this area?
- What could be the NRC's legal, budgetary, and oversight role?

The first workshop was held in Atlanta, Georgia, on September 6–7, 2007. A group of 53 DI&C/HMI experts gathered to review current and future issues, necessary capabilities to address these issues, and gaps that may exist in current capabilities. Options for future research and testing capabilities were also discussed. The second workshop was held in Rockville, Maryland, on September 11, 2007 with 45 participants. The workshop attendees were charged to provide inputs on funding, participation, and site options, especially for the options developed at the September 6–7 Atlanta workshop. The key insights from the information gathered during the study are given in this report.

Current U.S. and International Capabilities in the DI&C/HMI Area

This study demonstrated that the U.S. has a robust DI&C/HMI community with capabilities for performing research and development (R&D) across the full spectrum of needs from *sensors to systems* in DI&C and related HMI topics. The community in the U.S. dedicated to nuclear-related DI&C/HMI issues is a small part of this larger community and has more *limited capabilities.*

Many test-bed capabilities are available in the U.S. supporting a variety of DI&C/HMI technologies, but most are not primarily designed to address the specific needs of the nuclear power industry. However, the various capabilities, such as those within the U.S. aerospace community, used for both crew training and fly-by-wire system development, could potentially contribute to meeting many of the *current* gaps in the nuclear domain. Universities and DOE's national laboratories offer many testing capabilities that could address specific nuclear issues. The assessment of capabilities reported is based on the data collected in the course of this study, which was limited in both scope and duration. It includes data provided in responses from organizations who participated in the study. These capabilities are best considered as illustrative of what is available and should not be considered as a comprehensive tabulation.

The nuclear industry indicated that the capabilities, systems, and infrastructure available to them are probably adequate to support design, testing, and building of systems needed to deliver advanced light water reactors (ALWRs) (2010-15 delivery) and for which a combined construction and operation license (COL) will be sought in the next 5 years.

The nuclear-focused DI&C/HMI research community is depleted but "pockets" of expertise remain and it is seeking to re-emerge to support U.S. needs as nuclear technology is again considered. Providing people with needed expertise and experience may present the largest challenge in nuclear–related DI&C in the United States. There is much analog experience, but there is now a need for technology transition, familiarization with digital technologies, and providing more nuclear-focused experience for the wider DI&C community. Capabilities in terms of both staff and facilities were identified at vendor facilities, DOE national laboratories, and universities, some of which are currently focused on meeting NRC needs.

Current and Future Testing and Research Needs in the Area of DI&C/HMI

Participants in the workshops determined that there is not a one-size-fits-all solution to addressing technical challenges, nor is there one solution that provides all the needed facilities and capabilities. The distinct needs of particular communities also directly affect the form of the solution provided for that industry. For example, the facilities and capabilities that are needed by the NRC to solely address regulatory research focused on advanced light-water reactors (ALWRs) are much more limited than those needed by a wider nuclear or multi-industry group that is looking years or decades into the future to address advanced concepts in both DI&C and HMI. Capabilities and needs can be considered as 1) those needed to support retrofits to existing legacy systems in the existing nuclear power plant fleet; 2) those needed to support ALWRs that are expected to submit COL applications in the next 5 years; 3) advanced nuclear power concepts looking at Gen III^{+} and GEN IV; and 4) the diverse range of current once-through fuel cycle, closed fuel cycle, and long-term storage systems that all will involve DI&C/HMI issues.

The need to develop technical bases for enhanced DI&C/HMI review guidance was identified, covering many significant DI&C and HMI areas. These inputs were grouped and are reported under the general headings:

- Cyber Security
- Diversity & Defense-in-Depth
- Risk-Informing Digital Instrumentation and Controls
- Digital Systems Communications
- Control Room and Beyond Control Room
- Human Factors
  - Role of Personnel and Automation
  - Staffing and Training
  - Normal Operations Management
  - HFE Methods and Tools
- Fuel Cycle Facilities
- Validation (software, etc.)
- Advanced Monitoring/Diagnostics
- Advanced Sensors
- General Issues

It is anticipated that nuclear power plants of the future may be both distributed and multi-modular, and that reactors will potentially be part of an interconnected grid system controlled remotely from a central location for daily operations and other activities such as maintenance and diagnostics. New paradigms of operations, metrics, and methodologies for assessment will need to be developed to provide design and assessment guidance that promote safe and timely operations for the full range of human-in-the-loop activities in these new environments. Some areas of research that are critical include human-computer interactions, workload, situation awareness, decision-making, coordination practices among staff, use of paper and computerized procedures, multi-modular and integrated operation, and information sharing.

Preferred Business Model To Meet Future Needs

The options considered ranged from status quo through to multi-sponsor and multi-use consortia operating an integrated test facility, with both NRC and wider focused research agendas. Examples of centers and consortia that operated in various modes across the possible spectrum of options were identified and both pros and cons discussed. The single NRC-funded new facility was viewed as providing support for regulatory research with the highest level of NRC control and minimal conflict of interest issues. However, such a structure would have highest initial and operating costs for the NRC, present challenges in attracting needed staff from the limited pool of expertise in the United States, and present the greatest challenge in ensuring longer-term base funding. There was also only very limited interest in possible participation by industry, and other organizations represented, in this option.

The workshops demonstrated that there was general agreement that the preferred option for addressing future testing and research capabilities should involve a centralized program office at a hub and a distributed network of facilities (satellites). This approach would enable NRC to reach out to other groups and build stronger ties. Collaboration was felt to be compelling in that it opens up access to a vast array of specialized facilities operated by highly trained people who have experience in addressing DI&C/HMI issues. This approach could leverage currently available capabilities and expertise (both within current nuclear-focused communities and in the wider DI&C/HMI community), minimize initial costs, and give opportunities for immediate engagement by those wishing to participate while providing the flexibility for preparing for the future. Such a network also has the potential to form a core for establishing national education activity, which is needed to address nuclear expertise requirements. Part of this solution could be to continue to reach out to the international community and find additional opportunities to coordinate with other industries and other countries, and to establish consortia. Worldwide collaboration is compelling, as this is a positive way to benefit from the advances in nuclear power plants and operations that have occurred outside the United States over the past 25 years. Such an approach offers several options for providing access to digital control room simulators, which are needed both for staff familiarization training and in research studies. New capabilities, if needed, should be developed at either the hub or a satellite, as appropriate. This option also would minimize disruption to current programs during a transition period.

Abbreviations and Acronyms

ALWR	advanced light-water reactor
COI	conflict of interest
COL	construction and operation license
CPAC	Center for Process Analytical Chemistry
DI&C/HMI	digital instrumentation and controls and human-machine interfaces
DOE	U.S. Department of Energy
EIOC	Electricity Infrastructure Operations Center
GNEP	Global Nuclear Energy Partnership
HFE	human factors engineering
ICHMI	instrumentation, control, and human-machine interface
INL	Idaho National Laboratory
I/U CRC	Industry-University Cooperative Research Center
NASA	National Aeronautics and Space Administration
NRC	U.S. Nuclear Regulatory Commission
NSF	National Science Foundation
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
R&D	research and development

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1.0 Introduction

The increasing use of digital instrumentation and controls and the related human interactions with such systems in nuclear power generating and fuel cycle facilities have introduced new potential benefits to enhance plant safety. However, these developments and technological benefits are presenting some new regulatory challenges. Currently, the U.S. Nuclear Regulatory Commission (NRC) addresses these challenges by analyzing their scope, impact, and potential adverse plant interactions, and then conducting research on significant safety-related issues identified through this analysis. Often, such analyses and research efforts are performed under contracts that the NRC establishes with commercial entities, U.S. Department of Energy (DOE) national laboratories, universities, and international research facilities. However, there may be advantages to alternative approaches that can leverage capabilities and expertise within the wider digital instrumentation and controls and human-machine interfaces (DI&C/HMI) community.

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- What potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include industries outside the nuclear industry?
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- What impediments, if any, to information sharing among participants and to external stakeholders might exist?
- What could be the benefits, or adverse impact, to existing and established international collaborative activities in this area?
- What could be the NRC's legal, budgetary, and oversight role?

2.0 Description of Study

This report was developed to support the NRC review of current DI&C/HMI research capabilities and assess the need for a test facility or facilities, and conceptual approaches to meet NRC's regulatory research needs. The study comprised three main elements: a web-based survey of capabilities that employed web-based materials; telephone interviews and site visits; and two workshops. The full range of technological elements encompassed within a DI&C/HMI system is illustrated in Figure 2.1.

A diverse group of approximately 80 individuals was engaged to provide significant input through either interviews or workshop participation. This group was self-selected from among more than 250 people representing 50 different organizations that were contacted. These individuals included representatives from academia, DOE national laboratories, the National Aeronautics and Space Administration (NASA), and the military; industry experts responsible for developing DI&C/HMI for other safety critical systems; and I&C system and nuclear power plant vendors. A total of 32 interviews were conducted—20 telephone interviews and 12 face-to-face interviews. Further, three site visits to U.S. test and research facilities with capabilities that could address some NRC identified needs were conducted. A questionnaire was used as the means to systematically capture information. For both workshops, there was representation of approximately one-third nuclear and DIC industry, one-third academia, and one-third from DOE national laboratories. Fifty-three participants attended the first workshop, and 45 attended the second. Of the latter 45, about one-third had also participated in the first workshop.

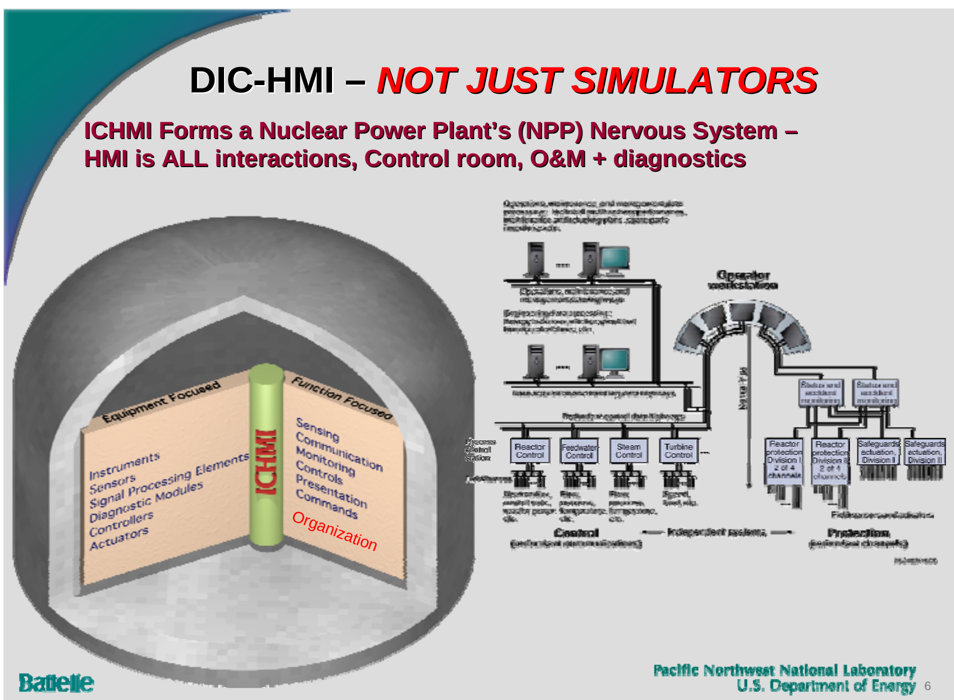

Figure 2.1. Range of Elements Encompassed Within DI&C/HMI Systems

The first workshop was held in Atlanta on September 6–7, 2007. DI&C/HMI experts gathered to review current and future issues, necessary capabilities to address these issues, and gaps that may exist in current capabilities. Options for future research and testing capabilities were also discussed. The second workshop was held in Rockville, Maryland, on September 11, 2007. Experts attending the workshop were charged to provide inputs on funding, participation, and site options, especially for the options developed at the September 6–7 Atlanta workshop. Details about the workshops conducted are provided in Appendices A through DD.

2.1 Current U.S. and International Capabilities in the DI&C/HMI Area

To evaluate the research needs and available capabilities, it became clear that as a precursor to any final assessment, it is necessary to decide if the need is to support 1) "regulatory" research," as required needed by the NRC, or 2) a wider nuclear or DI&C/HNMI community agenda. This study sought to review the needs for the wider agenda and the subset that forms the requirements for supporting regulatory research.

Many test-bed capabilities are available in the United States that support a variety of DI&C/HMI technologies, but most are not designed to primarily address the specific needs of the nuclear power industry. However, the results of their efforts could contribute to meeting the *current* gaps in the nuclear domain. In each research area, capabilities were identified. Universities and DOE's national laboratories offer many testing capabilities that could address specific nuclear issues. For example, sensors for harsh environments; in this case, capabilities exist at Oak Ridge National Laboratory (ORNL), The Ohio State University, and the University of Tennessee. Researchers at PNNL also are looking at sensors for harsh environments, for both nuclear power and process industry applications. The assessment of capabilities reported is based on the data collected in the course of this study, which was limited in both scope and duration. It includes data provided in responses from organizations who participated in the study. These capabilities are best considered as illustrative of what is available and should not be considered as a comprehensive tabulation. Some illustrative examples include

- ORNL's capabilities in prototype testing, analysis, and fabrication at its Electronics Design Labs, lab facilities for environmental stress testing, an advanced communication lab, and a Space Reactor Technology Lab
- Idaho National Laboratory (INL) at its Human System Simulation Laboratory is building human performance and human-machine interface evaluation capabilities.
- PNNL has an Environmental Molecular Science Laboratory user facility supporting both onsite and remote activities. PNNL also has a virtual research laboratory and the Electricity Infrastructure Operations Center (EIOC), which is a test bed for evaluating electrical power infrastructures, tools, and human operations.
- Internationally, there are many centers of note such as the Halden Reactor Project in Norway and IBM's new Global Research Center in France.
- In industry, there are numerous companies with expertise, such as Lockheed's Center for Innovation in Norfolk, Virginia, which is a central reconfigurable facility capable of testing configurations onsite and performing distributed testing with centers that are geographically dispersed. General Dynamics offers many simulation capabilities supporting defense industry needs.

- NASA also is a potential resource. Much could be leveraged from their applied experience in remote missions such as Mars and ground operations in support of space station and shuttle missions.
- The petrochemical industry has numerous facilities supporting DI&C and HMI. These facilities cover the complete production cycle from extraction, to transportation and refining, and then refined product distribution. For example, there are simulators for both extraction and pipeline systems, as well as for supertanker crew training.

Further capabilities also exist in the United States within the wider DI&C/HMI community; for example, in the aerospace community, for both crew training and fly-by-wire system development, and within the high-speed rail sector.

2.2 Current and Future Testing and Research Needs in the Area of DI&C/HMI

Those participating in the workshops determined that there is not a one-size-fits-all solution to addressing technical challenges, nor is there one solution to the needed facilities and capabilities. The needs of the particular community also directly affect the solution for that industry. For example, the facilities and capabilities that are needed by the NRC to solely address regulatory research focused on advanced light water reactors (ALWRs) are much more limited than those needed by a wider nuclear or multi-industry group that is looking years or decades into the future to address advanced concepts in both DI&C and HMI. Capabilities and needs can be considered as 1) those needed to support retrofits to existing legacy systems in the existing nuclear power plant fleet; 2) those needed to support ALWRs that are expected to submit combined construction and operation license (COL) applications in the next 5 years; 3) advanced nuclear power concepts looking at Gen III$^+$ and GEN IV; and 4) the diverse range of current once-through fuel cycle, closed fuel cycle, and long-term storage systems that all will involve DI&C/HMI issues.

Based on the limited review of the technical gaps and current capabilities, it was determined that capabilities probably exist to meet most short-term industry needs (current to 3 years) somewhere in the United States. However, the NRC may need to adopt new approaches so as to be able to use some of these capabilities for development of regulatory guidance and to investigate the associated technical bases for new ALWRs systems and legacy plant control room retrofits. For supporting longer-term research and development (R&D) for advanced reactors (Gen IV, Global Nuclear Energy Partnership [GNEP], etc.), and both front- and back-end fuel cycle facilities, fewer capabilities exist.

The need to develop a technical basis for enhanced DI&C/HMI review guidance was identified, covering many significant DI&C and HMI areas. These inputs were grouped and reported under the general headings of

- Diversity & Defense-in-Depth
- Cyber Security
- Risk-Informing Digital Instrumentation and Controls
- Digital Systems Communications
- Control Room and Beyond Control Room, Human Factors
- Human Factors
  - Role of Personnel and Automation

  - Staffing and Training
  - Normal Operations Management
  - Human Factors Engineering (HFE) Methods and Tools
- Validation (software, etc.)
- Fuel Cycle Facilites
- Advanced Monitoring/Diagnostics
- Advanced Sensors
- General Issues.

When the facilities needed to support the detailed technical topics identified in the general areas identified above were reviewed, the workshop attendees considered that to support delivery of ALWRs in the United States, the only capability potentially not available to support NRC regulatory research was a reconfigurable digital control room simulator. However, vendors do have some capabilities in this area that are specific to particular plant designs. In this context, it was recognized that for HMI research, operator availability for testing must be considered as well as the facility itself. There was also a discussion of the need for a full-scope (from sensors to displays) DI&C test bed dedicated to research applications. The vendor community indicated that their facilities may be able to fulfill this need for ALWRs.

The very limited current university programs that focus on safety critical DI&C/HMI or nuclear DI&C/HMI are not sufficient to meet existing and future R&D needs. Capabilities in terms of both staff and facilities were identified at most DOE national laboratories, some of which are focused on meeting NRC needs. These capabilities can potentially be deployed to meet needs in both the HMI and DI&C areas.

It is anticipated that nuclear power plants of the future may be both distributed and multi-modular, and that reactors will potentially be part of an interconnected grid system controlled remotely from a central location for daily operations and other activities such as maintenance and diagnostics. New paradigms of operations, metrics, and methodologies for assessment will need to be developed to provide design and assessment guidance that promotes safe and timely operations for the full range of human-in-the-loop activities in these new environments. Some areas of research that are critical include human-computer interactions, workload, situation awareness, decision-making, coordination practices among staff, use of paper and computerized procedures, multi-modular and integrated operation, new measures, methods, and tools; and information sharing. Findings from these efforts should be transitioned into practice in areas such as new methods and tools for assessing designs and auditing; identifying and defining personnel roles and responsibilities, staffing, and training; and normal operations management.

3.0 Answers to SRM Questions

The major comments and insights derived from the study are grouped in this section, following the SRM question to which they seem to most closely align. Critical to addressing the various questions was felt to be the definition of a research agenda: the narrower needs of NRC regulatory research activities give significantly different answers to the needs for the wide nuclear power R&D community and those that engage the even wider US DI&C/HMI community. There are also differences in both time scales and groupings of technology, which again drive the research agenda used to define research needs.

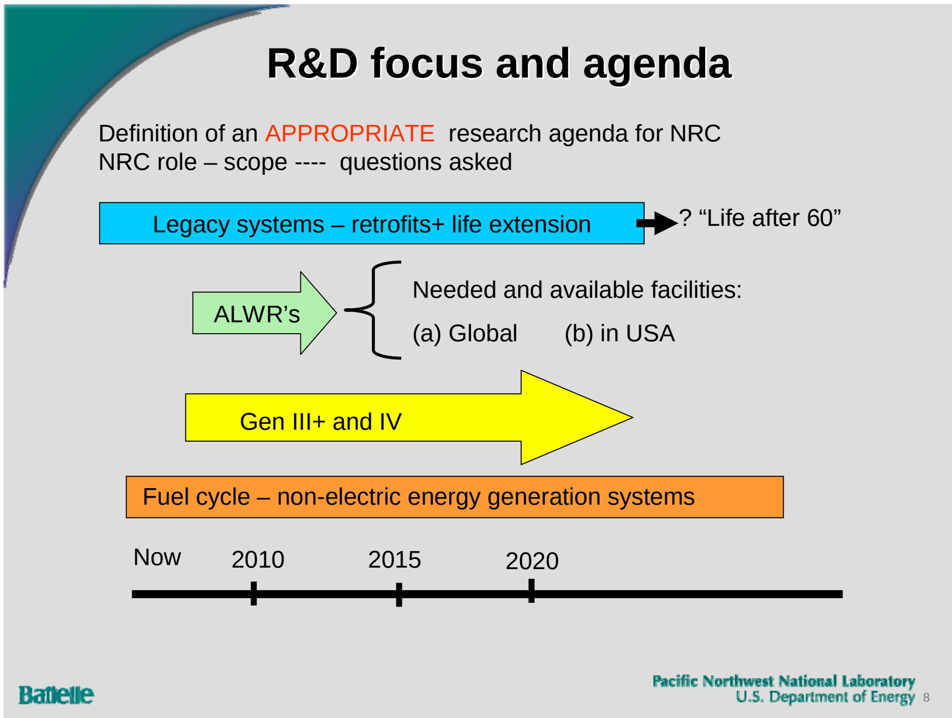

Figure 3.1. Main Themes Defining a Research Agenda and Associated Time Lines

3.1 What Potential Participants Might Be Interested in Joint Participation, Collaboration, and Funding of Such a Facility, and to What Extent Might This Include Industries Outside the Nuclear Industry?

There is a robust DI&C/HMI community within the United States. The non-nuclear focus areas have well-established capabilities and technical communities that support specific major industry needs (e.g., aerospace), and federal agencies (e.g., NASA, the U.S. Department of Defense, the U.S. Air Force, and the U.S. Department of Transportation) have significant capabilities and facilities. These groups have well-established professional meetings, professional oversight, and other forums. In responding to questions, organizations outside the nuclear community expressed little interest in participating in any conceptual NRC-facilitated DI&C/HMI facility, regardless of its configuration or capabilities.

Within the nuclear vendor community, it was reported that they feel that they have the facilities they need to support delivery of ALWRs for which COLs are currently being sought (delivery ~ 2015). Looking toward longer-term needs (i.e., Gen III$^+$ and Gen IV), some expressed interest in some form of collaborative partnership or consortium but preferably with non-NRC leadership (which was linked to a potential solution to conflict-of-interest [COI] issues). There is interest within the R&D community (principally academia and DOE national laboratories) in participation and providing access to capabilities through a network or consortium.

It was stated that for individuals to be motivated to participate, there must be compelling value statements from NRC, DOE, industry, universities, and others. The benefits must be obvious and real, and processes must be established that do not bring increased regulatory challenges to both vendors and operators. The most likely partnership from which the NRC could gain was felt to be through collaborating with DOE. DOE's national laboratories have valuable facilities and many subject matter experts. There are fewer potential COI and other issues to be addressed by NRC, and participants felt that NRC should pursue enhanced collaboration with DOE.

Industry, in general, expressed the view that it is not interested in formalized long-term collaboration; representatives indicated that they did not feel there is anything of value in it for them. They already have facilities and associations that provide the capabilities they need. They support NRC in moving forward to address DI&C/HMI issues, but they do not believe that access to a new facility would give them access to capabilities and answers to research questions that they are not already getting from their own programs. However, they indicated that they might be interested in collaborating with NRC and others on some very well-defined, focused topics, including those associated with Gen III^+ and Gen IV systems. This would be an interaction that would be developed on a case-by-case basis.

While universities are not going to be funding partners, they are interested in being collaborative research partners. They have a track record of successfully addressing NRC-type issues. There are a number of very successful models for university based research centers and national centers of excellence.

Other government agencies such as NASA have extensive facilities that may be potentially available. They have built and used these facilities to address the technical issues for their own applications. They have also begun to address the same issues that NRC will need to address, such as HMI issues in distributed systems and virtual reality interactions to support maintenance and diagnostics, and they have research simulators (with infrastructure) to investigate new HMI paradigms of operations. Specific relationships will need to be investigated to determine suitability and availability, particularly if there is excess capacity at facilities that would be available to or appropriate to address NRC's regulatory issues.

3.2 If Nuclear Industry Participated, How Could Conflict-of-Interest Issues Be Addressed?

Various operational/management models used in centers and consortia, including government agency-industry partnerships ,exist and do successfully handle organizational COI issues, at least with regard to interactions between universities, industry, DOE laboratories, and many other government agencies. The various examples of university-industry, and DOE national laboratory-industry consortia and collaborative centers do successfully address organizational COI issues, although not from a regulatory standpoint. To minimize organizational COI issues, although there was no clear consensus, a number of organizations expressed a preference for third-party rather than NRC leadership. Because industry would seem to prefer to be involved case-by-case, the organizational COI issue would need to be addressed for each instance. Collaboration could be expected to occur only if there were mutual interests in the research and mutual benefit to all participants, including industry.

3.3 Do Examples of Similar Facilities Currently Exist and, If So, What Can Be Learned from Their Successes and Challenges?

Many capabilities exist at DI&C and HMI facilities and within large organizations (e.g., NASA). These capabilities are geographically dispersed. The best example of a facility focused on DI&C/HMI in the nuclear arena is the Halden Reactor Project in Norway. This facility has a reactor and a range of reconfigurable control room simulators that support nuclear and other energy sectors, with a particular focus on DI&C/HMI, fuel, and materials topics.

The issue of DI&C/HMI has been addressed in a number of other technical communities; for example, avionics systems in aircraft, spacecraft systems, military vehicles, train-cab systems, and others. The U.S. NRC nuclear power community was stated as being at least 15 years (and, by some said, significantly further) behind the times in addressing DI&C/HMI issues. Very active communities in other fields and numerous test facilities are in place. Some of these have been identified. However, the extent to which the facilities that exist in other technical communities could be available to NRC and suitable for addressing regulatory research issues needs to be investigated further.

3.4 What Siting Options Are Most Viable (e.g., universities where integration with graduate studies might be encouraged, national laboratories), Taking Both Cost and Ease of Technical Information Exchange into Account?

The options considered ranged from status quo through to multi-sponsor and multi-use consortia operating an integrated test facility, with both NRC and wider focused research agendas. Examples of centers and consortia that operated in various modes across the possible spectrum of options were identified, and both pros and cons discussed.

The single NRC-funded new facility was viewed as providing support for regulatory research with the highest level of NRC control and minimal conflict-of-interest issues. However, such a structure would have the highest initial and operating costs for the NRC, present challenges in attracting needed staff from the limited pool of expertise in the United States, and present the greatest challenge in ensuring longer-term base funding. There was also only very limited interest in possible participation by industry and other organizations represented, in this option.

The workshops demonstrated that there was general agreement that the preferred option for addressing future testing and research capabilities should involve a centralized program office at a hub and a distributed network of facilities (satellites). This approach would enable NRC to reach out to other groups and build stronger ties. Collaboration was felt to be compelling, in that it opens up access to a vast array of specialized facilities operated by highly trained people who have experience in addressing DI&C/HMI issues. This approach could leverage currently available capabilities and expertise (both within current nuclear-focused communities and in the wider DI&C/HMI community), minimize initial costs, and give opportunities for immediate engagement by those wishing to participate while providing the flexibility for preparing for the future. Such a network also has the potential to form a core for establishing national education activity, which is needed to address nuclear expertise requirements. Part of this solution could be to continue to reach out to the international community and find additional opportunities to coordinate with other industries and other countries, and to establish consortia. Worldwide collaboration is compelling, as this is a positive way to benefit from the advances in nuclear power plants and operations that have occurred outside the United States over the past 25 years. Such an approach offers several options for providing access to digital control room simulators, which are needed both for staff familiarization training and in research studies. New capabilities, if needed, should be developed at either the hub or a satellite, as appropriate. This option also would minimize disruption to current programs during a transition period.

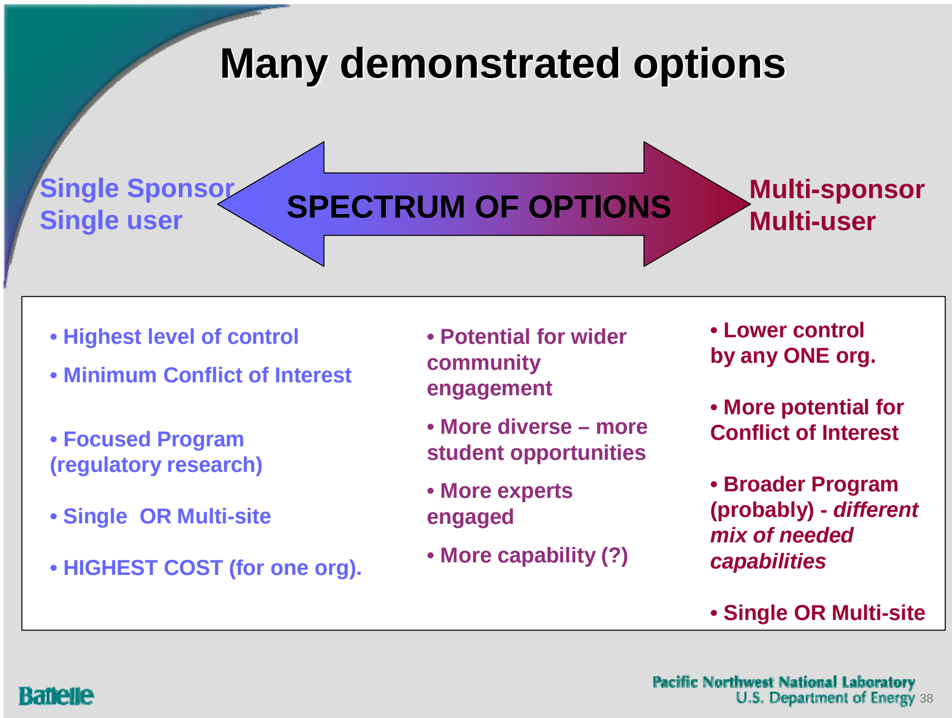

Figure 3.2. Spectrum of Options Covering a Single Facility to a Multi-Sponsor, Multi-Site/Multi-Sponsor Entity

In this scenario, many current capabilities would be used. For this approach to work, participants strongly suggested the need for a well-defined research agenda and a coordinated program plan with short-, mid-, and long-term time frames specified. Dispersion makes use of existing facilities while allowing for new integrated centralized facilities to meet technical capability needs. For the most part, DI&C research can be addressed through multiple dispersed facilities. Conversely, significant elements of HMI research need to be centralized with facilities and staff in the same location. However, modern networking capabilities may provide opportunities for new models of operations to be used to study HMI interactions using geographically dispersed investigators. NASA is beginning to study distributed interactions using configurations that are geographically distributed (e.g., Mars Mission). Industry has resources to tap as well, such as Statoil Hydro (a leader in off-shore oil), and Lockheed's Center for Innovation in Norfolk, Virginia. While Boeing (Everett Washington) was not responsive to participating in this study at this point in time, its DI&C/HMI simulation capabilities should be considered a valuable resource. There is potentially a lot of knowledge to be gained and used about how Boeing sets up and maintains its reconfigurable infrastructure for DI&C/HMI testing and how Boeing performs knowledge management.

With National Science Foundation (NSF) support, the Industry/University Cooperative Research (I/U CRC) Program has resulted in more than 60 centers covering a diverse range of science and engineering centers with universities. In some cases, these have developed in partnership with the DOE. In all cases, a range of industrial sponsors participates in the center, with representatives forming a board that defines the research direction and assesses performance. Such centers have been successful in producing graduates who, in many cases, are hired by the sponsoring companies and organizations. An example of a center that has matured from the program and been sustained for more than 20 years is the Center for Process Analytical Chemistry (CPAC), University of Washington, Seattle, which addresses instrumentation and measurement needs for various process industries. A second example of an I/U CRC is the NDE Center, at the Iowa State University, which has close interaction with the DOE Ames Laboratory. The activities that became this center have provided much of the “science base” for what has become quantitative nondestructive evaluation. It was initially a DARPA–US Air Force activity, more than 30 years ago and became the focus for a peer-reviewed journal, a major annual meeting (the Review of Progress in QNDE, for which the proceedings are now published by the American Institute of Physics), and an international network of centers.

In the area of nuclear I&C, the Idaho National Laboratory has sponsored the Ohio State University Academic Center for Excellence in Instrumentation and Control in Advanced Systems. This entity is still being defined. The primary FY 2006 activity of the INL/OSU Academic Center for Excellence in Instrumentation and Control (I&C) in Advanced Systems was to provide leadership and support for an ICHMI Working Group. The objective of the working group was to develop a roadmap that addresses instrumentation, control, and human machine interface (ICHMI) challenges that need to be overcome to further expand nuclear energy in the United States. The ICHMI Working Group is comprises 10 experts in I&C and human factors representing three national laboratories, two universities, EPRI, NRC, and an I&C vendor.

The hub and satellite models exist in several forms within the DOE system. One example that brings together the various types of organization is the Regional Carbon Sequestration Partnerships. The central program leadership is provided through the National Energy Technology Laboratory (DOE-FE), and there are seven regional consortia, each addressing a defined research agenda, that bring together a group of partners with complementary capabilities. For example, the Big Sky Carbon Sequestration Partnership, which is led by the Montana State University, brings together universities and research institutions (including DOE national laboratories), industry, and international partners with private organizations and public entities at both the state and federal level. University engagement has the potential to address the identified need for the next-generation workforce. Whichever sites or capabilities are engaged, it was felt that best practices should be employed to ensure the highest-quality research and engagement of the brightest and best, thereby expanding the technical community in addressing the research needs for both NRC and the wider community.

Attendees discussed the desired characteristics for any of the options, including the operation of a facility and its management. They emphasized the importance of considering capabilities needed for a facility in the context of its organizational structure, such as being a not-for-profit entity (a 501(c3) charitable organization), a limited liability company, or a department within NRC, and the agenda being addressed. Defining the mission with long-term grand challenges needs to be articulated for achieving longevity and sustainability of the needed capabilities.

3.5 To What Extent Could Such a Facility Be Designed To Be Reconfigurable to the Expected Variety of Plant Control Room and HMI Designs?

In looking at needs, there are competing constraints: for technology familiarization and research, particularly for HMI research, some form of flexibility in configuration is needed. For more site- or vendor-specific training and site- or system-specific HMI research and training, a fixed configuration is needed. To address the wider HMI simulator needs, it is critical that any new digital control room simulator facility for research be designed to be reconfigurable. The DI&C/HMI test facilities must have the flexibility to support multiple users and be quickly reconfigurable to address key domains such as different plant designs, plant control protection systems, and new technology for integration for all generations of plants. Three types of capabilities were identified: testing hardware and software/integration, hardware and software research, and regulatory human factors research.

The reconfiguration capability should go beyond simulators; it should be able to accommodate evolution of new DI&C technologies going from the sensors to the system level, such as for the testing of new infrastructures that integrate capabilities between distributed systems that include all interactions, control rooms, operations and maintenance (O&M), and diagnostics, and linkages to field operations, i.e., events and operations that occur outside the main control room. An integrated reconfigurable facility is also desirable for component, software, and integration testing.

However, it was felt by contributors that no one facility can address all of NRC's research needs across the spectrum of DI&C/HMI topics that were identified. There are also scheduling issues with respect to availability that can be expect to be encountered, should research be limited to a single or even a few sites, that could be expected to slow progress in the research. In research, it was considered to be essential to have access to current or recently retired plant operators.

3.6 To What Extent Could Such a Facility Be Designed To Also Be Used as an Advanced Reactor Training Simulator for NRC Staff?

A facility could be designed to include capabilities to support reactor simulator training on both full scope and part-task simulators. However, simulators that are designed to meet training needs are very different from research and testing facilities, such as those for testing hardware and software integration, hardware and software research, and regulatory human factors research to study operator response issues. Therefore, it was felt that any reactor training simulator(s) would need to be separate from other simulator capabilities because they need to mimic the actual power plant facility. It was felt that training of NRC staff is very important. NRC staff, in general, needs to be knowledgeable of nuclear plant facilities and operations, as well as the emerging requirements for DI&C and HMI technologies.

There could be a benefit of co-locating a research simulator facility with a training simulator facility so that infrastructure and staff could be shared. Further, those staff in training could also serve as test subjects in some human factors experiments.

3.7 What Impediments, If Any, to Information Sharing Among Participants and to External Stakeholders Might Exist?

It was felt that information sharing will be an issue. Access to systems with proprietary information, particularly in a university environment where students would have access, was seen as presenting potential challenges. Technical and organizational issues will limit information sharing among participants and external stakeholders. In developing an integrated center of some form technologically, four areas were seen as being of critical importance: infrastructure for data/knowledge management; hardening of software and hardware; cyber security; and organization, business models, and management.

Infrastructure capabilities for data/knowledge management: These are needed to facilitate interoperability and data/information sharing among all users. From a systems viewpoint, the following areas should be addressed: common platform suites, common software architecture(s), and common data structures. Collectively, easy access should be provided to the research data and its manipulation by researchers for their specific purposes.

Impact of hardening software and hardware to meet required seismic and electromagnetic standards: Meeting these requirements in a test facility could impact the timeliness and extent of deployment of facility capabilities in terms of functionality and interoperability between components and stakeholder organizations.

Cyber security: All aspects of a single or distributed nuclear facility, from software, hardware, and network communications to the physical and culture environment, are vulnerable to threats that range from exploitation by the malicious to misconfiguration brought about by unusable interfaces for all expected users. A structure and operating model needs to be established that promotes a broad range of secure information sharing, especially in the expected distributed nature of nuclear power plants of the future and in the context of a distributed test and research facility. Some of these open science issues are beginning to be addressed by DOE (2007), and details are given in a Report for the Cyber Security Research Needs for Open Science Workshop, July 23–24, 2007.

Organization, business models, and management: These will impact information sharing among participants. Policies and practices that address intellectual property, sharing of proprietary information, organizational COIs, and NRC access to data will need to be addressed. There are many good models of partnership between industry and government/federal agencies, such as the collaborative models put in place by the National Science Foundation (e.g., Industry-University Cooperative Research Centers [I/U CRC)], DOE's Environmental Molecular Science Laboratory user facility (DOE, Richland, Washington); and the Halden Reactor Project (Norway's research center that serves an international community comprising government agencies and private industry under the auspices of the Organization for Economic Development and Cooperation). Another factor to consider is the need to retain separation of NRC oversight and vendor/licensee implementation roles. Attention will need to be given also to security policies that can be applied consistently to both facility operation and information sharing. Often, diverse independent agencies have their own security standards, resulting in heterogeneous and often conflicting policies that impede information sharing.

Shared research would mean shared results. Those who agreed to the shared research agenda would also be agreeing to the way information was shared. COI issues would be handled by having all parties that want to participate sign nondisclosure statements or set up appropriate organizational partitions to avoid bias and COI.

3.8 What Could Be the Benefits, or Adverse Impact, to Existing and Established International Collaborative Activities in this Area?

There are advantages in developing U.S. capabilities, but increasingly the United States is part of a global enterprise. It was felt that collaborators will need to find a way that has commonality across entities to protect infrastructures from intentional malicious harm and user error. Establishing a network was seen as a way to reduce duplication of capabilities, thereby freeing up resources for research and migrating relevant breakthroughs into approved applications. A well-integrated program, based on a multi-organization research agenda (including clearly identified goals and longer-term grand challenges), can have significant impact and needs to be complemented by a process/strategy to migrate relevant breakthroughs into the field. It was considered that the preferred model of a hub-and-spoke system with a well-integrated program of activities has the ability to leverage existing international partnerships, such as those with the Halden Reactor Project. It was also considered that the hub-and-spoke system would draw in resources and expertise from other fields and focus it on the nuclear industry.

3.9 What Could Be the NRC's Legal, Budgetary, and Oversight Role?

Concerns were expressed regarding the relationship between NRC, in its regulatory role, and any others in a collaborative research structure. It was suggested that NRC's legal, budgetary, and oversight role could be that of a collaborative participant that funds existing facilities and promotes the development of specialized facilities necessary to address nuclear-related issues in DI&C/HMI. Providing a "neutral" site for program leadership was seen as one way to minimize COI and other relationship issues. However, the NRC staff indicated that there has been extensive cooperation in the past, and a model for NRC participation exists.

Attendees felt that for any activity to be successful, NRC and potentially others need to commit an increased funding base for DI&C and HMI and to look toward long-term research. It was felt that when others see NRC making investments, they will be encouraged to do the same.

3.10 Some Overarching Observations

Irrespective of the option selected, some overarching observations were made. There was a strong feeling that the activities in DI&C/HMI could benefit from the NRC establishing a DI&C/HMI Advisory Committee to provide access to leaders in the field and to provide some external review and validation of the program. It was felt that a process potentially involving the National Academies "decadal review" process could be used to review, refine, and prioritize the research agenda, particularly if a wider community agenda is considered and identification of intermediate goals and longer-term technology challenges is considered. In whatever option was selected, it was felt that partnerships and a consortium to leverage DOE national laboratories, universities, and industry capabilities would provide maximum impact, particularly given the very limited numbers of people with demonstrated expertise and the resources within the U.S. DI&C-HMI community focused on nuclear issues.

Two models for effective wider research community engagement were considered. In the first, the wider community engaged with the NRC and the nuclear community and, in the second, the nuclear community engaged the wider community through its established professional fora, including workshops, meetings and peer reviewed literature. Given the much longer history of DI&C/HMI consideration in other technical fields, such as aerospace, in which some major meeting series have a 26-year history, it was felt that the joining-them rather than the them-joining-us model was more likely to be productive in achieving wider community engagement.

The study's specific findings can serve as a basis to build a systematic framework to establish both a strategic and tactical roadmap to address the challenge of establishing testing capabilities (facilities) in the United States. Many strengths exist today in the DI&C/HMI community, and entities have capabilities that they are willing to make available, which could serve as a starting point for building a strong technology base. There is also agreement about the approach for governance—a distributed model that provides strong leadership to satellites with diverse expertise that includes the international community.

Some attendees suggested that to facilitate such developments, new policies should be considered by NRC and for it to serve as an enabler so as to create and sustain a U.S.-based test and research capability.

Workshop attendees indicated that NRC staff may benefit from more training/education on the full life cycle of digital systems and from hands-on training to enhance their own capabilities. There may be some advantages to co-locating any new digital reactor training simulators and research simulators to defray costs. It was noted that research simulators must be reconfigurable, whereas plant-specific training simulators must replicate a constant and referenced facility configuration.

3.11 Preferred Option

The preferred options for meeting the research needs, selected from a much longer list that ranged from a single facility–single user to a multi-sponsor–multi-user option, was a system based on a hub-and-spoke (or satellite) model. Such a concept can be implemented in a spectrum of forms, with many choices depending on the research agenda finally selected and the range of partners who are engaged. In this scenario, many current capabilities would be used. For this approach to work, participants strongly suggested the need for a well-defined research agenda and a coordinated program plan with short-, mid-, and long-term timeframes specified. This approach makes optimal use of existing dispersed facilities and technological expertise while still developing some capabilities that will lead to the development of certain centralized facilities. NRC would be a collaborator but not in sole charge of new centralized facilities. A contractor could operate the center/facilities. This third party would provide oversight/programmatic direction but would not have any vested interested in outcomes. A board of stakeholders (NRC, DOE, industry, universities, and others) would provide funding and direction to the R&D base program. Research results would be shared. Individual participants could also fund R&D specific to their needs, in which case the results would be held as proprietary. In short, there must be a process for securing information and handling intellectual property issues.

Such a model would include a program office and could involve a new integrated centralized facility. New facilities would be developed at the hub or at one or more satellites as appropriate. This concept would work to build on current practice, with NRC continuing its present approach of using a number of different facilities on a case-by-case basis. It was agreed that for the success of such an approach there must be clear definition of the center's mission and articulation of the research challenges. Three types of needed capabilities were identified: testing hardware and software/integration; hardware and software research; and human factors regulatory research. There was general agreement that the facility should provide *more* than simulators—it should consider all aspects for DI&C/HMI—all interactions, control rooms, operations and maintenance, and diagnostics. It was felt that benefit could be gained from what others have done outside the field of nuclear power. For example, the robust DI&C/HMI community in the United States and capabilities for R&D cover *sensors to systems* in DI&C and related HMI (e.g., aerospace).

Various conceptual funding options were discussed at the second workshop; however, no collaborative funding partners were identified. It was felt that the NRC needs to develop a plan for the path forward to implement the hub and spoke model. This plan starts with the clearly stated DI&C and HMI regulatory issues to be addressed and then builds a collaborative network to address these in phases using existing facilities and new future facilities. The plan must show understanding about what is unique, either in regard to the research needs or potential research capability suppliers. The plan would specifically list the desired collaborative participants to address each regulatory issue. Such a plan would also be the basis for justification of any new centralized facilities, if needed to address unique research issues. NRC can justify new facilities, even if there are existing facilities at NASA and elsewhere, if these facilities are inadequate because of lack of interest, availability, flexibility, and other factors.

4.0 Conclusion

This study found that the United States has a robust DI&C/HMI community with capabilities for performing R&D across the full spectrum of needs from sensors to systems in DI&C and related HMI. The U.S. community dedicated to nuclear-related DI&C/HMI regulatory research is smaller and has little leverage over technology developments in this area.

The nuclear industry has capabilities, systems, and infrastructure that are adequate to support the design, testing, and building of ALWRs. The nuclear DI&C/HMI research community is depleted but is seeking to re-emerge to support U.S. needs. Much of the R&D capability is focused on longer-term research (i.e., Gen III^{+} and IV). Nuclear power DI&C/HMI R&D has been limited in large measure by the recent limited funding, but "pockets" of expertise remain. Making available the people with expertise and experience may present the largest challenge in nuclear–related digital instrumentation and controls and human factors (in the United States). There is much analogue experience, but there is now a need for technology transition, familiarization with digital technologies, and more nuclear-focused experience.

The workshops demonstrated that there was general agreement that the preferred option for addressing future testing and research capabilities should involve a centralized program office at a hub and a distributed network of facilities (satellites). This approach could leverage currently available capabilities and expertise (both within current nuclear-focused communities and the wider DI&C/HMI community), minimize initial costs, and give opportunities for immediate engagement by those wishing to participate. This option also would minimize disruption to current programs during a transition period. New capabilities, if needed, should be developed at either the hub or a satellite, as appropriate. This hub and satellite option most effectively uses the currently available capabilities while providing the flexibility for preparing for the future. Part of the solution must be to continue to reach out to the international community and find additional opportunities to coordinate with other industries, other countries, and consortia.

It is anticipated that nuclear power plants of the future may be both distributed and multi-modular, and reactors will potentially be part of an interconnected grid system controlled remotely from a central location for daily operations and other activities such as maintenance and diagnostics. New paradigms of operations, metrics, and methodologies for assessment will need to be developed to provide design and assessment guidance that promote safe and timely operations for the full range of human-in-the-loop activities in these new environments. Some areas of research that are critical include human–computer-interactions, workload, situation awareness, decision making, coordinating practices among staff, use of paper and computerized procedures, and information sharing.

To meet the identified challenges, rather than thinking in terms of "catching up," the research agenda should be "looking ahead" for both technologies and governance for an effective and sustainable research capability. Additionally, NRC DI&C/HMI research plans can be improved by seeking and developing approaches to leverage expertise and technical solutions found in other domains that are outside the nuclear domain and yet, by their nature, are safety–critical, such as in the petrochemical, transportation, aerospace, and bio-waste management areas.

In the path forward, NRC DI&C/HMI research efforts should seek collaboration in the larger DI&C community and build stronger ties. This will result in healthy collaboration and more useful answers to regulatory issues. Collaboration is compelling because it opens NRC to a vast array of specialized facilities operated by highly trained people who have experience in addressing DI&C/HMI issues. Worldwide collaboration is compelling as this is a positive way to benefit from the advances in nuclear power plants and operations that have occurred outside of the U.S. over the past 25 years.

5.0 Reference

DOE. 2007. *Report of the Cyber Security Research Needs for Open Science Workshop – July 23-24, 2007*. PNNL-16971, sponsored by the DOE Office of Science in cooperation with the Office of Electricity and Energy Reliability. Available at http://www.sc.doe.gov/ascr/Misc/CSWorkshopFinalReport.pdf

Appendix A

Invitation to Attend Digital Instrumentation & Control (DI&C) – Human-Machine Interface (HMI) Test Facility Workshops

MM DD, 2007

SUBJECT: Invitation to Attend Digital Instrumentation &Control (DIC) – Human-Machine Interface (HMI) Test Facility Workshops

Dear Ms McCraw,

The increasing use of digital instrumentation, controls, and human interactions with these systems in nuclear generating and fuel cycle facilities has brought new regulatory challenges along with the benefits for improved plant safety. Currently, the NRC addresses these challenges by identifying the scope, impact and potential adverse plant interactions that are presented by these challenges and then conducting research on each identified topical safety issue arising from this analysis. Often, the research and analysis is performed through the establishment of different contracts with commercial entities, national laboratories, universities and international research facilities. There may be advantages to establishing a single, integrated center of expertise in the digital instrumentation and control and human-machine interface (DIC&HMI) areas. This center of expertise may be valuable to other federal agencies as well as the NRC.

The Commission has requested that the NRC staff conduct public workshops concerning approaches for an integrated digital instrumentation and control and human-machine interface (DIC&HMI) test facility in the United States. The NRC invites stakeholders with existing capabilities, as well as others who may be interested in participating, such as national laboratories, universities, other federal agencies, research and development centers and vendors, to participate in these workshops.

The workshops will seek to develop a consensus in the technical community on a set of over-arching principles that should be met for the success of any conceptual approaches discussed. The workshop will seek to develop a set of viable concepts for such a facility, with corresponding potential benefits and challenges for each concept. Options may include relying on current facilities, upgrading current facilities or developing a single, integrated facility. It is necessary to determine the number of organizations within the community that are interested in each option.

We are seeking your attendance and input at workshops. The first of these workshops will be technical workshop held in Atlanta, Georgia September 6th and 7th. The second is a business focused workshop to be held in Washington DC September 11th. You can obtain full information about these workshops including accommodation at our website: http://nrc-test-facility.pnl.gov/

We look forward to your participation in the workshops. Please forward this invitation to others you think would wish to participate in NRC's test facility study.

Sincerely yours,
Leonard J. Bond, Ph.D., Laboratory Fellow
Applied Physics & Material Characterization Sciences
National Security Directorate
Pacific Northwest National Laboratory
P.O. Box 999, Mail Stop K5-26
Richland, WA 99352
Tel: (509) 372 4172
E-mail: leonard.Bond@pnl.gov

Appendix B

Invitees to NRC Workshops

Invitees to NRC Workshop (Updated 8/21/2007)

Last Name	First Name	Organization	City	ST	Tel	Email
Abdel-Khalik	Said	GIT School of Mechcanical Engineering	Atlanta	GA	404-894-3719	said.abelkhalik@me.gatech.edu
Akers-McDowell	Karen	Nuclear Assurance	Phoenix	AZ	623-393-5659	karen.akers-mcdowell@aps.com
Albright	Kevin	General Electric Company	Wilmington	NC	910-602-1724	kevin.albright@ge.com
Aldemir	Tunc	Ohio State University	Columbus	OH	614-292-8519	aldemir.1@osu.edu
Alvarado	rossnyev	MPR Associates	alexandria	VA	703-519-0406	ralvarado@mpr.com
Arbuckle	John	Energy Northwest	Richland	WA	509-377-4601	jdarbuckle@energy-northwest.com
Armentrout	Jeffrey	Lackland Air Force Base	Lackland AFB	TX		jeffrey.armentrout@lackland.af.mil
Ayers	Tim	Meade Electric	McCook	IL	708-588-2511	tayers@meadeelctric.com
Bedesem	Peter	Pacific Gas and Electric Company	Avila Beach	CA	805-545-4097	pwb2@pge.com
Belchik	George	AmerenUE - Callaway Plant	Fulton	MO	573-676-8205	gnbelchik@cal.ameren.com
Bennett-Boyd	Shauna	Georgia Institute of Technology	Atlanta	GA	404-894-3718	shauna.boyd@me.gatech.edu
Bennion	John	Idaho State University	Pocatello	ID	208-282-3351	jbennion@isu.edu
Berg	Oivind	Halden Reactor Project	Norway		011-47-69-21-22-71	
Bevard	Bruce	Oak Ridge National Laboratory				bevardbb@ornl.gov
Blessing	David	Lockheed Martin			571-309-8185	david.l.blessing@lmco.com
Bobek	Leo	University of Massachusetts-Lowell				Leo_Bobek@umi.edu
Bolia	Robert S	Air Force Research Laboratory	Wright-Patterson AFB	OH		robert.bolia@wpafb.af.mil
Bolin	Debbie	Catawba Nuclear	York	SC	803-831-3680	DJBolin@duke-Energy.com
Bourham	Mohamed	North Carolina State University	Raleigh	NC		bourham@ncsu.edu
Bouts	Robert	USEC	Piketon	OH	740-897-2991	boutsrr@ports.usec.com
Branch	Kristi	Battelle/Pacific Northwest National Laboratory	Seattle	WA	206-528-3336	kristi.branch@pnl.gov
Brenizer	Jack	Pennsylvania State University				jsbnuc@engr.psu.edu
Brewer	Carl	Ameren Services	St. Louis	MO	314-554-4480	cbrewer@ameren.com
Briber	Robert	University of Maryland				rbriber@umd.edu
Brown	Gilbert	University of Massachusetts	Lowell	MA		Gilbert_Brown@uml.edu
Brown	Ken	INVENSYS				angelika.john@ips.invensys.com
Burgess	Karen	Duke Energy	Mount Holly	NC	803-831-3310	ksburges@duke-energy.com
Burzynski	Mark	AREVA			434-832-4695	Mark.Burzynski@aeva.com
Busch	Robert	University of New Mexico	Albuquerque	NM	505-277-8027	busch@unm.edu
Butterworth	Henry	Nuclear Management Company	Hudson	WI	715-377-3415	henry.butterworth@nmcco.com
Cambron	Tim	Southern Company	Birmingham	AL	205-992-7276	tcambron@southernco.com
Carroll	Tommie E	Duke Energy	Seneca	SC		tecarrol@duke-energy.com
Chase	Don	Scientech				dchase@scientech.com
Chrysler	Susan	Texas Transportation Institute	College Station	TX	979-862-3938	s-chrysler@tamu.edu
Clark	Jeff	Progress Energy Florida	St. Petersburg	FL	727-820-5475	jeff.clark@pgnmail.com
Cleary	Virginia	Sandia National Laboratory				
Clements	Michelle	DTE Energy	Petersburg	MI	734-586-4883	clementsm@dteenergy.com

Invitees to NRC Workshop (Updated 8/21/2007)

Last Name	First Name	Organization	City	ST	Tel	Email
Cochrane	Linda	STPNOC	Wadsworth	TX	361-972-4506	lscochrane@stpegs.com
Cooley	Dana	SeaState Group, inc.	Hockessin	DE	302-584-3591	seastate@verizon.net
Corcoran	William R.	Nuclear Safety Review Concepts Corp.	Windsor	CT	860-285-8779	William.R.Corcoran@1959.USNA.com
Corona	Kimberley	PG&E	Avila Beach	CA	805-545-4524	klcp@pge.com
Corradini	Michael L	University of Wisconsin	Madison	WI		corradin@engr.wisc.edu
Crissman	Keith	Constellation Energy	Lusby	MD	410-495-6543	Keith.Crissman@constellation.com
Davis	Stephen	The Excellence Engine, LLC	Fulton	NY	315-532-4742	steve.davis@excellence-engine.com
De Laurentis	Daniel	Purdue University				ddelaure@purdue.edu
Desmond	Raymond	HF E Areva NP	Charlotte	NC	704-805-2104	desmondraymond@bellsouth.net
DeWeese	R	MPR Associates				rdeweese@mpr.com
Dezfuli	Homayoon	NASA				hdezfuli@nasa.gov
DiFiore	Amanda	Volpe National Transportation Systems Center	Cambridge	MA	617-494-2138	DiFioreA@volpe.dot.gov
Dodds	H.L.	University of Tennessee, Knoxville	Knoxville	TN	865-974-2525	utne@utk.edu
Dorning	John	University of Virginia	Charlottesville	VA	434-924-7237	jjd3r@virginia.edu
Doze	Clay	Ameren Services	St. Louis	MO	314-957-3319	cdoze@ameren.com
Dudenhoeffer	Don	Idaho National Laboratory				donald.dudenhoeffer@inl.gov
Dunn	William L	Kansas State University	Manhattan	Ks	785-532-5628	dunn@mne.ksu.edu
Durue	Leigh	Constellation Energy	Lycoming	NY	315-349-2210	liegh.derue@constellation.com
Edwards	Robert	Pennsylvania State University				RMENUC@engr.psu.edu
Elks	Carl	University of Virginia			434-982-2114	cre4g@virginia.edu
Erin	Larry	Westinghouse			412-374-6456	erinie@westinghouse.com
Ferguson	Dale	NASA Marshall Space Flight Center	Huntsville	AL	256-544-8316	Dale.C.Ferguson@nasa.gov
Fisher	Rob	Fisher IT, Inc.	Huntersville	NC	802-233-0760	rob@fisherit.com
Fleitz	John	FirstEnergy Nuclear	Oak Harbor	OH	419-321-7819	jwfleitz@firstenergycorp.com
Foote	Richard	Westinghouse	Columbia	SC	803-647-3729	footerl@westinghouse.com
Forck	Fred	4konsulting	Jefferson City	MO	573-645-8854	fforck@embarqmail.com
Ford	Michael	BWXT Pantex	Amarillo	TX	806-477-5727	mford@pantex.com
Fuld	Bob	WEC	Unionville	CT	860-712-0333	fuld@sbcglobal.net
Fulgham	Julia	University of New Mexico	Albuquerque	NM	505-277-5431	jfulghum@unm.edu
Gallogly	Kay	The 42 Group, LLC	Newark	DE	302-369-8859	kaygallogly@42llc.com
Garcia	Humberto	Idaho National Laboratory				Humberto.Garcia@inl.gov
Garrity	Tom	Pacific Gas and Electric	Avila Beach	CA	805-545-4855	txg6@pge.com
Gears	Gerry	Department of Energy				gerald.gears@nuclear.energy.gov
Germain	Jeff	Constellation Energy	Ontario	NY	585-771-3876	jeffrey.germain@constellation.com
Gillan	Douglas	North Carolina State University			919-515-1715	djgillan@ced1.coe.ncsu.edu
Givin	Robert J.	Energy Northwest	Richland	WA	509-372-5678	rjgivin@energy-northwest.com
Glines	Neil	Pacific Gas & Electric Co.	Avila Beach	CA	805 595-7545	nglines@sbcglobal.net

Invitees to NRC Workshop (Updated 8/21/2007)						
Last Name	**First Name**	**Organization**	**City**	**ST**	**Tel**	**Email**
Golay	Michael	Massachusetts Institute of Technology		MA	617-253-5824	golay@mit.edu
Graf	Tim	Pacific Gas & Electric	Avila Beach	CA	805-545-3983	TAG3@pge.com
Graf	Arnold	Areva				arnold.graf@areva.com
Gruzinski	Ken	FENOC - Perry Nuclear Power Plant	Perry	OH	440-280-5989	gruzinskik@firstenergycorp.com
Haber	Sonja	HPA	New York	NY	212-874-6520	sbhaber@hpacorp.com
Haghighat	Ali	University of Florida				haghighat@ufl.edu
Hallbert	Bruce	Idaho National Laboratory				Bruce.Hallbert@inl.gov
Haynesworth	Tracy	Southern California Edison - SONGS	San Clemente	CA	949-368-3113	tracy.haynesworth@sce.com
Hefler	J	Altransolutions				jhefler@altransolutions.com
Heitzman	Jarrett	PPL	Berwick	PA	570-542-3212	jsheitzman@pplweb.com
Heller	Daniel	Lockheed Martin				daniel.j.heller@lmco.com
Henneberger	Mark	Navel Reactors			202-781-6249	mark.henneberger@navy.mil
Higgins	James	Brookhaven National Laboratory				higgins@bnl.gov
Hills	Jason	Sandia National Laboratory				
Hines	Wes	University of Tennessee				jhines2@utk.edu
Hochreiter	Larry	Pennsylvania State University				LEHNUC@engr.psu.edu
Hogan	Steve	Ameren/UE	Fulton	MO	573-676-4198	sphogan@cal.ameren.com
Holcomb	David	Oak Ridge National Laboratory				holcombde@ornl.gov
Holloway	Geoffrey	Exelon Energy Delivery	Oakbrook Terrace	IL	630-437-2273	geoffrey.holloway@exeloncorp.com
Hutchings	Karen	INPO	Atlanta	GA	770-644-8355	hutchingsks@inpo.org
Jamshidi	Mo	University of Texas, San Antonio	San Antonio	TX		moj@wacong.org
Janes	Mike	Sandia National Laboratory				mejanes@sandia.gov
Jennings	Karen	FPL - St. Lucie Nuclear Plant	Jensen Beach	FL	772-467-7454	karen_jennings@fpl.com
Johnson	Chuck	TVA	hixson	TN	423-774-2800	ecjohnson@tva.gov
Johnson	Barry J	University of Virginia				bwj@virginia.edu
Johnson	Gary	Lawrence Livermore National Lab				johnson27@llnl.gov
Jonas	Kathy	Duke Energy Corp	York	SC	803 831-4274	kljonas@duke-energy.com
Jones	Jeffrey M	AREVA			704-805-2695	Jeffrey.Jones@areva.com
Kennedy	Edward	CH2M HILL Hanford	Richland	WA	509-376-0533	Edward_E_Kennedy@rl.gov
Kester	Rick	Lockheed Martin			570-803-2581	rick.kester@lmco.com
Khalil	Hussein	Argonne National Laboratory				hkhalil@anl.gov
Kimray	Larry	Duke Energy / CNS	York	-	803-831-3327	lrkimray@duke-energy.com
Klapproth	James L	GE Nuclear			910-675-6626	james.klapproth@ge.com
Klein	Andrew C	Oregon State University	Corvallis	OR		kleina@ne.orst.edu
Krahenbuhl	Melinda	University of Utah	Salt Lake City	UT	801-581-4188	mpk@nuclear.utah.edu
Kriesel	Thomas	INPO	Atlanta	GA	770-644-8355	hutchingsks@inpo.org

Invitees to NRC Workshop (Updated 8/21/2007)						
Last Name	**First Name**	**Organization**	**City**	**ST**	**Tel**	**Email**
Kumar	Arvind	University of Missouri	Rolla	MO	573-341-4747	kumar@umr.edu
Lake	Frederic	WD Associates	Norman	OK	717-880-2711	fdlake@teamwd.com
Landsberger	Sheldon	University of Texas	Austin	TX	512-232-2467	s.landsberger@mail.utexas.edu
LaPoint	Michael	Constellation Energy	Lycoming	NY	315-349-2210	michael.lapoint@constellation.com
Laughery	Ron	Alion Science and Technology	Boulder	CO	303-442-6947	ron@laugherys.com
Lee	Jaime M	Walter Reed Army Institute of Research	Silver Springs	MD		jaime.lee@na.amedd.army.mil
Libra	Rick	Exelon Corporation				Rick.Libra@exeloncorp.com
Lord	Jim	Southern Company Generation	Juliette	GA	478-993-3904	jmlord@southernco.com
Lowe	Brian D	National Institute for Occupational Safety & Health	Cincinnati	OH		blowe@cdc.gov
Lundberg	Johan	Westinghouse				Johan.lundberg@se.westinghouse.com
Lyon	Cathie	PG&E	Avila Beach	CA	805.545.4734	CLS1@PGE.COM
Malcom	Scott	Atomic Energy of Canada	Mississauga Ontario Canada		905-823-9040	malcolms@aecl.ca
Maple	Amanda Maple	Pacific Gas and Electric	Avila Beach	CA	805-545-4743	armb@pge.com
Martin	Jack	Luminant	Glen Rose	TX	254-897-6321	Jack.Martin@Luminant.com
Martin	William	University of Michigan		MI	734-764-5534	wrm@umich.edu
Martinez-Guridi	Gerarado	Brookhaven National Laboratory				martinez@bnl.gov
Matera	Dawn	PSEG Nuclear	Hancocks Bridge	NJ	856-339-1752	Dawn.Matera@pseg.com
May	Gary	Georgia Tech				gary.may@3ce.gatech.edu
McCandless	Jeffrey	NASA Ames Research Center	Moffett Field	CA	650-604-1162	jmccandless@mail.arc.nasa.gov
McDowell	Jim	Performance Improvement	Phoenix	AZ	623-393-5668	james.mcdowell@aps.com
Meter	Len	Invensys				Leonid.meter@ips.invensys.com
Middleton	Bobby	Sandia National Laboratory				
Miller	Don	Ohio State University	Columbus	OH	614-292-7979	miller.68@osu.eu
Miller	Thomas P	Office of Nuclear Power Technology	Germantown	MD	301-903-0180	tom.miller@nuclear.energy.gov
Miller	William	University of Missouri, Columbia	Columbia	MO	543-882-9692	MillerW@missouri.edu
Moore	John	First Energy Corp	Wall	PA	724-682-7189	moorerd@firstenergycorp.com
Morrison	Jeffrey G	Space & Naval Warfare Systems Command	San Diego	CA	619-553-9070	Jmorriso@spawar.navy.mil
Murray	Joe	Invensys			989-374-1858	joseph.murray@ips.invensys.com
Muschara	Tony	INPO	Atlanta	GA	770-644-8355	muscharatm@inpo.org
Narvell	Rick	NTSB	Washington	DC	202-314-6422	narvelr@ntsb.gov
Naser	Joseph	EPRI	Palo Alto	CA	650-855-2107	jnaser@epri.com
Northcutt	Timothy	Westinghouse Electric Company	Columbia	SC	803-647-3465	northctb@westinghouse.com
O'Bryan	Steve	Lockheed Martin			817-296-6333	Stephen.f.obryan@lmco.com
O'Hara	John	Brookhaven National Laboratory				ohara@bnl.gov

Invitees to NRC Workshop (Updated 8/21/2007)						
Last Name	**First Name**	**Organization**	**City**	**ST**	**Tel**	**Email**
Orwe	Fridtjov	Halden Reactor Project			011-47-69-21-23-47	
Osmonson	Thomas	Exelon Nuclear	Morris, Il	-	815-416-3648	tom.osmonson@exeloncorp.com
Over	Christopher	PG&E	Paso Robles	CA	805-545-4813	cno2@pge.com
Overman	Chris	Nebraska Public Power District	Kearney	NE	308-238-5216	cmoverm@nppd.com
Paradies	Mark	System Improvements, Inc.	Knoxville	TN	865-539-2139	mark@taproot.com
Peavy	Joel J	General Atomics	San Diego	CA	858-455-4734	Joel.Peavy@gat.com
Pericci	John	Lockheed Martin			570-803-2623	john.pericci@lmco.com
Petrowski	Michael	PSEG Nuclear, LLC	Pennsville	NJ	856-339-5425	Michael.petrowski@pseg.com
Philips	Laurence	Sandia National Laboratory				lrphill@sandia.gov
Pirus	Dominique	Electricite de France	Villeurbanne Cedex France			dominique.pirus@edf.fr
Planchon	H. Peter	Idaho National Laboratory	Idaho Falls	ID	208-526-3268	pete.planchon@inl.gov
Plott	Christopher	Alion Science & Technology	Boulder	CO	303-442-6947 x124	cplott@alionscience.com
Poeppel	Roger	Argonne National Laboratory				poeppel@anl.gov
Poston	John	Texas A&M Universtiy	College Station	TX	979-845-4161	j-poston@tamu.edu
Prinzel	Lawrence	NASA Langley Research Center	Hampton	VA	757-864-2277	lawrence.j.prinzel@nasa.gov
Quinn	Edward	Longenecker & Assoc.	Dana Point	CA	949-632-1369	tedquinn@cox.net
Quinn	Ted	GE Nuclear			910-602-1768	edward.quinn@ge.com
Rahnema	Farzard	Georgia Institute of Technology	Atlanta	GA	404-894-3731	farzad.rahnema@nre.gatech.edu
Rankin	Greg	Exelon Nuclear	Cordova	IL	309-227-2717	gregory.rankin@exeloncorp.com
Raptis	Paul	Argonne National Laboratory				raptis@anl.gov
Regan	Thomas	University of Massachusetts-Lowell				Thomas_Regan@umi.edu
Robinson	Charlie	Invensys				Charlie.robinson@ips.invensys.com
Rochau	Gary	Sandia National Laboratory				
Ross-Flanigan	Nancy	Univ of Michigan Transportations Research Inst	Ann Arbor	MI	734-647-1853	rossflan@umich.edu
Rowe	Chester	The Excellence Engine LLC	Oswego	NY	315-591-2159	chet.rowe@excellence-engine.com
Sands	Belinda	Exelon	Forked River	-	609-971-2566	Belinda.Sands@exeloncorp.com
Scarola	Ken	Mitsubishi			412-612-1192	kenscarola@nuclear automation.com
Schroeder	David	FAA Civil Aerospace Medical Institute	Oklahoma City	OK	405-954-6825	David.Schroeder@faa.gov
Scott	Clayton	Invensys				clayton, scott@ips.invensys.com
Seamans	Steve	Westinghouse			412-374-2206	seamans@westinghouse.com
Sebacher	Stephanie	AmerenUE	Fulton	MO	573-676-6124	shsebacher@cal.ameren.com
Seidl	Ron	Energy Northwest	Richland	WA	509-377-2226	rvseidl@energy-northwest.com
Seong	Seung-Hwan	Korea Atomic Energy Research Institute	Daejeon Republic of Korea		82 42 868 8244	shseong@kaeri.re.kr
Seymour	Mark	Southern Nuclear	Waynesboro	GA	706-826-3484	meseymou@southernco.com
Shack	Bill	Argonne National Laboratory				wjshack@anl.gov

Invitees to NRC Workshop (Updated 8/21/2007)						
Last Name	**First Name**	**Organization**	**City**	**ST**	**Tel**	**Email**
Shahkarami	Amir	Exelon			630-853-8829	amir.shahkarami@exceloncorp.com
Slone	Sandra	AREVA				
Smidts	Carol	Ohio State University				csmidts@umd.edu
Snapp	Nicholas	Scientech	Dunedin	FL	727-669-3025	nsnapp@scientech.com
Snyder	Dale	FPL Energy Seabrook Station	Seabrook	NH	603-773-7357	dale_snyder@fpl.com
Spitz	henry	University of Cincinnati	Cincinnati	OH	513-556-2003	henry.spitz@uc.edu
Spurgin	Anthony	Consultant	San Diego	CA	619-295-0836	a-jspurgin@cox.net
Starkey	Robert	Areva NP, Inc.	Lynchburg	VA	+49 9131 189 2742	robert.starkey@areva.com
Stetson	David	Pacific Gas & Electric Co.	Avila Beach	CA	805-545-4523	das1@pge.com
Stubbins	James F	University of Illinois	Urbana	IL		jstubbin@uiuc.edu
Summers	John	INPO/First Energy	Akron	OH	330-384-4511	jsummers@firstenergycorp.com
Sword	Jeffrey	Exelon	Philadelphia	PA	215-841-5877	jeffrey.sword@exeloncorp.com
Tank	Mark	Wolf Creek Nuclear Operating Corporation	Burlington	KS	620-364-8831 ext 8125	matank@wcnoc.com
Tasick	George	Entergy - FitzPatrick	Manlius	NY	315-349-6572	gtasick@entergy.com
Techau	Susan	Exelon Nuclear	Warrenville	IL	630-657-2904	susan.techau@exeloncorp.com
Terrell	John Michael	Southern Company Generation	Juliette	GA	478-993-3689	jmterrel@southernco.com
Thole	Karen	Pennsylvania State University	University Park	PA	814-865-2519	KThole@psu.edu
Thompson	Randy	Wolf Creek	Waverly	KS	620-364-8831	rathomp@wcnoc.com
Thompson	Bruce	Ames Laboratory & Center				rbthomps@iastate.edu
Titus	Jeremy	Constellation Energy	Lycoming	NY	315-349-2210	jeremy.titus@constellation.com
Tonkinson	Tyrone	Simple Approach, Inc.	Bloomsburg	PA	570-407-2553	ttonkinson@digital-link.net
Tsoukalas	Lefteri H	Purdue University	W Lafayette	IN		tsoukala@ecn.purdue.edu
Turinsky	Paul	North Carolina State University				turinsky@unity.ncsu.edu
Upadhyaya	Belle	University of Tennessee		TN		bupadhya@utk.edu
Vaglia	David	Westinghouse Electric Company				vagliadj@westinghouse.com
Vincek	Vincent	Florida Power & Light	Jensen Beach	FL	772-465-3550x3063	Vincent_Vincek@fpl.com
Vujic	Jasmina	University of California-Berkeley	Berkeley	CA	510-642-5107	ahn@nuc.berkeley.edu
Wagner	Rick	Areva	Charlotte	NC	704-617-0543	rick.wagner@areva.com
Waltar	Alan	Pacific Northwest National Lab	Richland	WA	509-375-4565	alan.waltar@pnl.gov
Wary	Scott	PPL Susquehanna	Berwick	PA	570-542-1737	wswary@pplweb.com
Watts	Humphrey	Carnegie Mellon				watts@sei.cmu.edu
Wei	Tim	Rensselaer Polytechnic Institute	Troy	NY	518-276-6351	weit@rpi.edu
Welty	Chuck	Electrical Power Research Institute			650-855-2821	cwelty@epri.com
Werchen	Paul	Air Force Research Laboratory	Brooks City Base	TX	210-536-6325	paul.werchan@brooks.af.mil
Werner	Ruth	Sandia National Laboratory				
White	John	University of Massachusetts-Lowell				John_White@umi.edu
Whitmer	Ben	STPNOC	Wadsworth	TX	361-972-7449	blwhitmer@stpegs.com
Wiesnack	Wolfgang	Halden			011-47-69-21-23-47	wolfgang.wiesenack@hrp.no
Williams	Ron	University of Virginia				rdw@virginia.edu

Invitees to NRC Workshop (Updated 8/21/2007)

Last Name	First Name	Organization	City	ST	Tel	Email
Woessner	Patricia	Exelon - Byron	Byron	IL	815-406-2796	patrica.woessner@exeloncorp.com
Wood	Richard	Oak Ridge National Laboratory				woodrt@ornl.gov
Woolford	Barbara J	NASA Johnson Space Center	Houston	TX	281-483-3701	bwoolfor@ems.jsc.nasa.gov
Wu	George X	Renssaeler Polytechnic Institute	Troy	NY	518-276-4014	xug2@rpi.edu
Wuokko	Dale	FirstEnergy Corp.	Oak Harbor	OH	419-321-7120	drwuokko@firstenergycorp.com
Wyant	Francis	Sandia National Laboratory				fjwyant@sandia.gov
Young	Robert	Ameren Services	St. Louis	MO	314-554-2695	ryoung3@ameren.com
Young	Terry	Duke Energy	Seneca	SC	864-885-3615	twyoung@duke-energy.com
Zuppinger	William	Westinghouse	Wexford	PA	412-374-4647	zuppinwl@westinghouse.com

Appendix C

Attendance List from Web Sign-up

Atlanta	Washing-ton DC	Name	Title	Email	Organization	Occupation	Phone	Permis-sion
TRUE	TRUE	Aldemir, Tunc	Dr.	aldemir.1@osu.edu	The Ohio State University	Professor	614-292-4627	TRUE
TRUE	TRUE	Anikanov, Sergey	Dr.	anikanss@westinghouse.com	Westinghouse	Technical Lead, AP1000 Plant Computer	412-215-6585	TRUE
TRUE	TRUE	Arnholt, Brian	Mr.	brian.arnholt@ge.com	General Electric	Technical Leader	540-387-7125	TRUE
TRUE	TRUE	Ashok, Pradeepkumar	Dr.	pradeepkumar@mail.utexas.edu	The University of Texas at Austin	Program Manager / Research Scientist	5124713039	TRUE
TRUE	TRUE	Blessing, David		david.l.blessing@lmco.com	Lockheed Martin	Systems Engineer	571-309-0185	TRUE
FALSE	TRUE	Burr, Janice		janice.burr@ge.com	GE Energy	Engineer	540-387-8913	TRUE
TRUE	TRUE	Clefton, Gordon	Mr.	gac@nei.org	NEI	Snr Project Manager	202-739-8086	TRUE
TRUE	TRUE	Danneels, Jeffrey	Mr.	jjdanne@sandia.gov	Sandia National Labs	Manager	505-284-3897	TRUE
TRUE	TRUE	Edwards, Robert	Dr.	rmenuc@engr.psu.edu	Penn State	Professor	814-865-0037	TRUE
FALSE	TRUE	Elks, Carl	Dr.	cre4g@virginia.edu	University of Virginia	Principle Scientist	434-982-2114	TRUE
TRUE	TRUE	Fanner, Rodney J.	Mr.	rjf2@nrc.gov	NRC	Reactor Eng. Inspector	404-562-4638	FALSE
TRUE	TRUE	Griffin, James	Mr.	jpg1@nrc.gov	USNRC	Sr Simulator Engineer	423 855-6516	TRUE
TRUE	TRUE	Haghighat, Alireza	Dr.	haghighat@ufl.edu	University of Florida	Professor and Chair	352-392-1401	TRUE
TRUE	TRUE	Hashemian, Hash	Mr.	hash@ams-corp.com	AMS	President	865-691-1756	TRUE
FALSE	TRUE	Heller, Daniel	Mr.	daniel.j.heller@lmco.com	Lockheed Martin	General Manager	570-803-2200	TRUE
TRUE	FALSE	Jamshidi, Mo	Dr.	moj@wacong.org	University of Texas, San Antonio	Lutcher Brown Endowed Chaired Professor	210 458 7074	TRUE
TRUE	TRUE	Johnson, Barry	Dr.	bwj@virginia.edu	University of Virginia	Professor	434-924-7623	TRUE
FALSE	TRUE	Kawanago, Shinji	Mr.	shinji_kawanago@mnes-us.com	MNES	Manager	703-908-8054	TRUE
TRUE	TRUE	Keithline, Kimberly	Mrs.	kak@nei.org	Nuclear Energy Institute	nuclear engineer	202-739-8105	TRUE
TRUE	TRUE	Kester, Richard	Mr.	rick.kester@lmco.com	Lockheed Martin MFC	Manager, I&C	570-803-2581	TRUE
TRUE	TRUE	Legenski, Ed	Mr.	edward.legenski@worleyparsons.com	The WorleyParsons Group	Principal Engineer	610-855-2931	TRUE
TRUE	TRUE	Murray, Joseph	Mr.	Joseph.Murray@IPS.Invensys.com	Invensys Process Systems	Nuclear Program Manager	949-374-1858	TRUE
TRUE	TRUE	Naser, Joseph	Dr.	jnaser@epri.com	EPRI	Manager, I&C	650-855-2107	TRUE
TRUE	TRUE	O'Hara, John	Dr.	ohara@bnl.gov	BNL	Research Scientist	631 344-3638	TRUE
TRUE	TRUE	Plott, Christopher	Mr.	cplott@alionscience.com	Alion Science & Technology	HF Engineer	303-442-6947 x1	TRUE
FALSE	TRUE	Poeppel, Roger	Dr.	poeppel@anl.gov	Argonne National Laboratory	Senior Engineer	630 252 5118	TRUE

Atlanta	Washing-ton DC	Name	Title	Email	Organization	Occupation	Phone	Permis-sion
TRUE	TRUE	Pryor, Mitch	Dr.	mpryor@mail.utexas.edu	University of Texas at Austin	Program Manager, Robotics Research Group	512 471 5182	TRUE
TRUE	TRUE	Quinn, Francis	Mr.	fmquinn@STPEGS.COM	STP 3 & 4	I&C and HF Consulting Engineer	301-962-6265	TRUE
FALSE	TRUE	Raptis, Apostolos (Paul)	Dr.	raptis@anl.gov	Argonne National Laboratory	Dept. Mgr./Sr. Electrica Engineer	630-252-5930	TRUE
TRUE	TRUE	Rodriguez, Reinaldo	Mr.	rrr1@nrc.gov	NRC Region 2	Reactor Inspector	404-562-4498	TRUE
TRUE	TRUE	Smidts, Carol	Dr.	csmidts@umd.edu	University of Maryland	Professor	301-4057314	TRUE
TRUE	TRUE	Sun, Xiaodong	Dr.	sun.200@osu.edu	The Ohio State University	Assistant Professor	614-247-7646	TRUE
TRUE	TRUE	Utsumi, Masafumi	Mr.	masafumi_utsumi@mhi.co.jp	Mitsubishi Heavy Industries Ltd.	Engineering Manager	-3390	TRUE
TRUE	TRUE	Vaglia, David	Mr.	vagliadj@westinghouse.com	Westinghouse Electric Company	Engineer	412-374-6513	TRUE
TRUE	TRUE	Wyant, Francis	Mr.	fjwyant@sandia.gov	Sandia National Laboratories	Engineer	505-844-5682	TRUE

Appendix D

U.S. Nuclear Regulatory Commission
U.S. Digital Instrumentation and Control and Human-Machine Interface Workshop
Doc. 7590-01-P

[7590-01-P]

U.S. NUCLEAR REGULATORY COMMISSION

U.S. Digital Instrumentation and Control

and Human-Machine Interface Workshop

AGENCY: U.S. Nuclear Regulatory Commission

ACTION: Opportunity to provide input concerning digital instrumentation and control and human-machine interface test and research in the United States.

SUMMARY: The increasing use of digital instrumentation and controls, and the growing prevalence of human interactions with such systems, in nuclear generating and fuel cycle facilities have introduced new regulatory challenges along with the potential benefit of improved plant safety. Currently, the U.S. Nuclear Regulatory Commission (NRC) addresses these challenges by analyzing their scope, impact, and potential adverse plant interactions, and then conducting research on each safety-related topical issue identified through this analysis. Often, such analyses and research are performed under contracts that the NRC establishes with commercial entities, national laboratories, universities, and international research facilities. However, there may be advantages to alternative approaches such as establishing a single, integrated test facility with expertise in the areas of digital instrumentation and controls and human-machine interfaces (DIC&HMI).

The NRC is conducting public workshops to review the current and future technical issues in the area of digital instrumentation and control and human-machine interface (I&C and HMI), to identify the capabilities that a facility or facilities would need to have to support their resolution. The workshop will review the capabilities of current facilities and consider lessons

learned from their operation. Based on this information a set of options will be developed. Toward that end, the NRC invites stakeholders including those with existing capabilities, as well as others who may be interested in participating (such as national laboratories, universities, other Federal agencies, research and development centers, and vendors), to participate in the workshops. The workshops will seek to develop a consensus in the technical community regarding a set of overarching principles that should be met to ensure the success of any conceptual approaches discussed. Options may include relying on current facilities; upgrading current facilities; or developing a single, integrated facility. In addition, it is necessary to determine the number of organizations within the community that are interested in each option.

Interested parties should note that the staff is working with Pacific Northwest National Laboratory, to develop additional information on experiences that other similar facilities have had, in order to learn from their successes and challenges.

DISCUSSION: The NRC will hold two workshops to engage potentially interested stakeholders. The first workshop will be held on September 6–7, 2007, at the Clarion Hotel at Atlanta International Airport, which is located at 5010 Old National Highway in Atlanta, Georgia. This initial workshop will review, at a conceptual level the current and future technical issues in the area of digital instrumentation and control and human-machine interface (I&C and HMI) and will identify the capabilities that a facility or facilities would need to have to support their resolution. The workshop will review the capabilities of current facilities and consider lessons learned from their operation. Based on this information the workshop will develop a set of options for establishing additional capabilities, if needed, or ways to integrate current capabilities in a manner that creates synergies and efficiencies to support current and future needs of the technical community in the digital I&C and HMI areas.

The second workshop will be held on September 11, 2007, at the Hilton Washington DC/Rockville Executive Meeting Center, which is located at 1750 Rockville Pike in Rockville, Maryland. This workshop will use information gathered at the Atlanta workshop regarding the additional capabilities (if any) that the community requires to address current and future Digital Instrumentation and Control (I&C) and Human Machine Interface (HMI) issues and the facility options available to perform this work. The workshop will discuss at a conceptual level how each of the facility options could be managed. These management issues include potential participants, funding arrangements, conflict of interest (COI) considerations, and siting. Additional information about both workshops can be obtained at http://nrc-test-facility.pnl.gov.

Additionally, to promote the efficiency and effectiveness of these workshops, the NRC invites interested stakeholders to provide comments in the following areas:

(1) Which potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include participants outside the nuclear industry?

(2) If the nuclear industry participates, how could conflict-of-interest issues be addressed?

(3) Do similar facilities currently exist and, if so, what can be learned from their successes and challenges?

(4) What siting options would be most viable (e.g., universities where integration with graduate studies might be encouraged, national laboratories, etc.), considering both cost and ease of technical information exchange?

(5) To what extent could such a facility be designed to be reconfigurable to the expected variety of plant control room and HMI designs?

(6) To what extent could such a facility be designed to also be used as an advanced reactor training simulator for NRC staff?

(7) What impediments, if any, might exist to limit information sharing among participants and external stakeholders?

(8) What could be the benefits, or adverse impacts, of existing and established international collaborative activities in this area?

(9) What could be the NRC's legal, budgetary, and oversight role?

(10) Would stakeholders potentially be interested in the establishment of a facility that would serve as a national technical center of excellence to support a wide range of agencies and industries that have needs and interests in the rapidly advancing areas of instrumentation and controls, digital safety systems, and human-machine interfaces?

The workshop results and public comments received, along with other information developed as a result of the staff's discussions with interested stakeholders, will be used to support NRC decision making on this subject

AVAILABILITY AND DATES: Additional information is available through the NRC Test Facility Working Group Web page, at http://nrc-test-facility.pnl.gov. Comments would be most helpful if received by September 30, 2007.

COMMENT PROCEDURES: The NRC staff encourages and welcomes stakeholder participation in the workshops, as well as submittal of related comments and suggestions from interested parties. Personal information, such as your name, address, telephone number, e-mail address, etc., will not be removed from your submission.

You may submit comments by any of the following methods:

- Mail comments to Leonard Bond, Ph.D, Pacific Northwest National Laboratory, P.O. Box 999, Mail Stop K5-26, Richland, WA 99352.
- Provide comments on-line at http://nrc-test-facility.pnl.gov.
- Email comments to Leonard.Bond@pnl.gov.

CONTACT INFORMATION: General questions regarding this study or the related workshops should be addressed to Steven A. Arndt at (301) 415-6502 or by email to SAA@nrc.gov.

Dated at Rockville, Maryland, this _____ day of ___________, 2007.

For the U.S. Nuclear Regulatory Commission.

____
Brian W. Sheron, Director,
Office of Nuclear Regulatory Research

D.6

Appendix E

Attendance List – September 6–7, 2007

NRC MEETING September 6 & 7, 2007 - Atlanta, GA

NAME	ORGANIZATION	PHONE NO.	EMAIL
Aldemir, Tunc	Ohio State University	614-292-4627	aldemir@osu.edu
Arndt, Steve	Nuclear Regulatory Commission	301-415-6502	SAA@nrc.gov
Arnholt, Brian	General Electric	540-387-7125	brian.arnholt@ge.com
Ashok, Pradeepkumar	University of Texas, Austin	512-413-1797	pradeepkumar@mail.utexas.edu
Belavadi,Varadaraja	Washington Group International	609-720-2166	varadaraja.belavadi@wgint.com
Benhardt, Herbert C.	Washington Group International	803-208-1508	carl.benhardt@wsms.com
Blessing, David	Lockheed Martin	571-309-0185	david.blessing@lmco.com
Bond, Leonard	Pacific Northwest National Laboratory	509-372-4172	leonard.bond@pnl.gov
Brenchley, David	Pacific Northwest National Laboratory	509-375-6515	Dr.B@pnl.gov
Clefton, Gordon	Nuclear Energy Institute (NEI)	202-739-8086	gac@nei.org
Danneels, Jeff	Sandia National Laboratory	505-284-3897	jjdanne@sandia.gov
Dudenhoeffer, Jeff	Idaho National Laboratory	208-526-0700	donald.dudenhoeffer@inl.gov
Dunn, Michael	AREVA	704-805-2178	michael.dunn@areva.com
Edwards, Robert	Penn State	814-865-0037	rmenul@engr.psu.edu
Elks, Carl R.	University of Virginia	434-982-2114	cre4g@virginia.edu
Fanner, Rodney J.	Nuclear Regulatory Commission	404-562-4638	rjfz@nrc.gov
Golay, Michael	Massachusetts Institute of Technology	617-253-5824	golay@mit.edu
Gran, Bjorn A.	IFE/Halden Reactor Project	47-69212395	bjornag@hrp.no
Griffen, James	Nuclear Regulatory Commission	423-855-6518	jpg@nrc.gov
Haghighat, Alireza	University of Florida	352-392-1401 x306	haghighat@ufl.edu
Hallbert, Bruce	Idaho National Laboratory	208-526-9867	bruce.halbert@inl.gov
Hashemian, Hash	AMS	865-691-1756	hash@ams-corp.com
Holcomb, David	Oakridge National Laboratory	865-576-7889	holcombde@ornl.gov
Hutchings, Karin	INPO	770-644-8784	hutchings@inpo.org
Jamshidi, Mo	University of Texas	210-458-7074	moj@wacong.org
Johnson, Barry W.	University of Virginia	434-924-7623	bwj@virginia.edu
Johnson, Michael R.	Nuclear Regulatory Commission	301-415-0774	mrj@nrc.gov
Keithline, Kimberly A.	Nuclear Energy Institute (NEI)	202-468-6673	kak@nei.org
Kester, Richard	Lockheed Martin	570-803-2581	rick.kester@lmco.com
Legenski, Ed	The WorleyParsons Group	610-855-2931	edward.legenski@worleyparsons.com
Libra, Rick	Exelon	610-765-5873	rick.libra@exelonxorp.com
Mays, Gary	Oakridge National Laboratory	865-574-0394	maysst@ornl.gov
Murray, Joseph	Invensys Process Systems	949-374-1858	joseph.murray@ips.invensys.com
Naser, Joseph	Electrical Power Research Institute	650-855-2107	jnaser@epri.com
O'Hara, John	Brookhaven National Laboratory	631-344-3638	ohara@bnl.gov
Owre, Fridtjov	IFE/Halden Reactor Project	47-69212354	fridtjov@hrp.no

NRC MEETING September 6 & 7, 2007 - Atlanta, GA

NAME	ORGANIZATION	PHONE NO.	EMAIL
Persensky, Julious	Nuclear Regulatory Commission	301-415-6759	jjp2@nrc.gov
Plott, Christopher	Alion Science & Technology	303-442-6947 x124	cplott@alionscience.com
Quinn, Francis M.	South Project Electric Generating Station	301-963-6265	fmquinn@stpegs.com
Quinn, Ted	Longenecker & Associates	949-632-1369	tedquinn@lox.net
Raptis, A.C.(Paul)	Argonne National Laboratory	630-252-3862	raptis@anl.gov
Rodriguez, Reinaldo	Nuclear Regulatory Commission	404-562-4498	rrrl@nrc.gov
Schur, Anne	Pacific Northwest National Laboratory	614-247-7646	sun.200@osu.edu
Skeen, David	Nuclear Regulatory Commission	301-415-1990	dls@nrc.gov
Smidts, Carol	University of Maryland	301-405-7314	csmidts@umd.edu
Summers, John	First Energy Nuclear Operating Company	330-612-0052	jsummers@firstenergycorp.com
Sydnor, Russell	Nuclear Regulatory Commission	301-415-7510	rbs1@nrc.gov
Uhle, Jennifer	Nuclear Regulatory Commission	301-415-5686	jlu@nrc.gov
Utsumi, Masafumi	Mitsubishi Heavy Industries	81-78-672-2721	masafumi_utsumi@mhl.co.jp
Vaglia, David J.	Westinghouse Electric Company	412-374-6513	vagliadj@westinghouse.com
Vail, Beth	Washington Group International	803-502-9701	beth.vail@wsms.com
Wood, Richard	Oakridge National Laboratory	865-574-5578	woodrt@ornl.gov
Wyant, Francis	Sandia National Laboratories	505-844-5682	fjwyant@sandia.gov

Appendix F

Agenda – September 6–7, 2007

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

Agenda: September 6-7, 2007
Atlanta, Georgia

http://nrc-test-facility.pnl.gov/

Room: Azalea II & III, unless otherwise specified

Thursday, September 6

Time	Topic	Speaker
7:00	Registration	
8:00	Welcome	Steven Arndt, NRC
8:10	Logistics for Sessions	David Brenchley, PNNL
8:15	Opening remarks	David Skeen representing Chairman Dale Klein
8:30	Opening remarks	Michael Johnson, Deputy Director, Office of Nuclear Regulatory Research
8:40	Opening remarks from other stakeholders	
8:50	Review of current and future technical needs	Steven Arndt, NRC
9:15	Public Comments	
9:30	Break	
9:45	Review of existing capabilities	Leonard Bond, PNNL
10:30	Open discussion on technical issues that need to be solved and what capabilities are needed to support resolution of these issues	David Brenchley, PNNL
11:30	Instructions to Focus Groups	Steven Arndt, NRC
12:00	Lunch (on your own)	
1:00	Focus Group Work: Technical issues and needed capabilities in breakout rooms	
3:00	Group Reports	
4:00	Discussion- Finding common ground on technical issues and needed capabilities; identify gaps	David Brenchley, PNNL
5:00	Day Two Instructions to Focus Groups	Steven Arndt, NRC
5:30	Adjourn	

Friday, September 7

Time	Topic	Speaker
8:00	Overview of Day 1 Results, Q&A	Steven Arndt, NRC
8:30	Open discussion of potential options that would provide the needed capabilities to support identified needs	David Brenchley, PNNL
9:00	Focus Group Work: Identify potential options/models	
11:00	Group Reports	
12:00	Lunch (on your own)	
1:00	Discussion- Finding common ground on potential options/models; identify gaps	David Brenchley, PNNL
2:00	Identifying Competing Issues	David Brenchley, PNNL
3:30	Public comments	
3:45	Create storyboard of results for presentation to workshop B	David Brenchley, PNNL
4:00	Closing Comments & Thank You	Steven Arndt, NRC
5:00	Adjourn	

Appendix G

Welcome and Opening Remarks

Presentation by
Steven Arndt
September 6, 2007

Welcome and Opening Remarks

September 6, 2007

Steven Arndt
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research
(301-415-6502, saa@nrc.gov)

Meeting Logistics

- **Purpose of the Meeting**
- **Background**
- **Sign-In Sheet/Registration**
- **Public Meeting Feedback Forms**
- **Introductions**
- **Agenda**
- **Opportunity for public to comment/ask questions**

Meeting Objects

- **Objectives**
  - This workshop will review and identify current and future technical issues in the area of digital instrumentation and control and human-machine interface (I&C and HMI) technology
  - Identify the capabilities that a current of future, facility or facilities would need to have to support their resolution
  - Review the capabilities of current facilities and consider lessons learned from their operation
  - Based on this information, the workshop will develop a set of options to develop additional capabilities, if needed, or ways to integrate current capabilities in a manner that creates synergies and efficiencies to support current and future needs of the technical community in the digital I&C and HMI areas.

Meeting Objects

Projected outcomes

- A consensus, at a conceptual level, of what current and future technical issues will need to be addressed,
- What capabilities are needed to address them and
- A set of potential concepts for developing the needed capabilities. The potential options will range from continued use of current facilities to a new stand alone integrated facility and will include corresponding potential benefits and challenges.

Background

- **SRM-COMPBL-07-0001**
  - ***Conduct a workshop*** **to gather information needed to develop a set of high level conceptual requirements and approaches and draft recommendations on the potential test facility;**
  - ***Provide a Commission paper*** **that provides recommendations on how and where to processed with the establishment of a test facility, including recommendations on legal, budgetary and oversight roles. The commission paper would need to address at a minimum the nine questions raised in the SRM.**
- **In addition to the issues raised in the SRM a number of other issues will need to be reviewed**
  - **What are the current and future testing and research needs**
  - **What capabilities do we need to support their resolution of the testing and research needs**
  - **How would we coordinate our efforts with other stakeholders**

SRM Questions

- **SRM-COMPBL-07-0001**
  - **What potential participants might be interested in joint participation, collaboration and funding**
  - **If the nuclear industry participates how could COI issues be addressed**
  - **What can be learned from similar facilities**
  - **What are the siting options**
  - **To what extent could the facility be reconfigurable**
  - **To what extent could the facility be used as an advance reactor training simulator for NRC staff**
  - **What impediment would there be with sharing information**
  - **What could be the benefits or impact on our established international collaborative activities in this area**
  - **What could be the NRC's legal budgetary and oversight role**

Meeting Logistics

- Purpose of the Meeting
- Background
- Sign-In Sheet/Registration
- Public Meeting Feedback Forms
- Introductions
- Agenda
- Opportunity for public to comment/ask questions

Thursday Agenda

- 7:00 Registration
- 8:00 Welcome, Steven Arndt, NRC
- 8:10 Logistics for Sessions, David Brenchley, PNNL
- 8:15 Opening remarks, David Skeen representing Chairman Dale Klein
- 8:30 Opening remarks Michael Johnson, Deputy Director, Office of Nuclear Regulatory Research
- 8:40 Opening remarks from other stakeholders
- 8:50 Review of current and future technical needs, Steven Arndt, NRC
- 9:15 Public Comments
- 9:30 Break
- 9:45 Review of existing capabilities, Leonard Bond, PNNL
- 10:30 Open discussion on technical issues that need to be solved and what capabilities are needed to support resolution of these issues, David Brenchley, PNNL
- 11:30 Instructions to Focus Groups Steven Arndt, NRC
- 12:00 Lunch (on your own)
- 1:00 Focus Group Work: Technical issues and needed capabilities in breakout rooms
- 3:00 Group Reports
- 4:00 Discussion- Finding common ground on technical issues and needed capabilities; identify gaps, David Brenchley, PNNL
- 5:00 Day Two Instructions to Focus Groups, Steven Arndt, NRC
- 5:30 Adjourn

8

Friday Agenda

- 7:00 Registration
- 8:00 Overview of Day 1 Results, Q&A, Steven Arndt, NRC
- 8:30 Open discussion of potential options that would provide the needed capabilities to support identified needs, David Brenchley, PNNL
- 9:00 Focus Group Work: Identify potential options/models
- 11:00 Group Reports
- 12:00 Lunch (on your own)
- 1:00 Discussion- Finding common ground on potential options/models; identify gaps, David Brenchley, PNNL
- 2:00 Identifying Competing Issues, David Brenchley, PNNL
- 3:30 Public comments
- 3:45 Create storyboard of results for presentation to Washington workshop, David Brenchley, PNNL
- 4:00 Closing Comments & Thank You, Steven Arndt, NRC
- 5:00 Adjourn

Meeting Logistics

- Purpose of the Meeting
- Background
- Sign-In Sheet/Registration
- Public Meeting Feedback Forms
- Introductions
- Agenda
- Opportunity for public to comment/ask questions

Appendix H

Michael Johnson’s Opening Remarks for the NRC’s Public Meeting on Digital Instrumentation & Control and Human-Machine Interface Test and Research Needs

Michael Johnson's Opening Remarks for the NRC's Public Meeting on Digital Instrumentation & Control and Human-Machine Interface Test and Research Needs

Atlanta, Georgia, USA
September 6, 2007

As Deputy Director of the Office of Nuclear Regulatory Research for the U.S. Nuclear Regulatory Commission — your host for this workshop — I am delighted to welcome you here today. We are pleased to have you participate in this important forum to share your views and experiences. Our goal for this workshop is to discuss current and future needs in the area of digital instrumentation & control and human-machine interface technology, identify current capabilities, and explore options for developing additional capabilities if needed (including integrating current capabilities).

The dynamic areas of Digital I&/C and human machine interface have long been important to the NRC, and they are currently receiving heightened attention. This is because both the NRC and the industry need to prepare for the licensing of new reactors, and upgrades of existing facilities, using technologies that have not previously been widely used in U.S. nuclear power plants. As many of you know, the NRC has been working with the nuclear industry on a number of specific technical issues, as part of our Digital I&C Steering Committee and Task Working Groups, which were formed earlier this year. In particular, these issues include digital system diversity and defense-in-depth, as well as digital system risk analysis and cyber-security. Other issues include digital system communications and human factors aspects of control room design.
In addition, we are considering related issues, including digital systems in non-reactor applications (such as fuel cycle facilities), as well as issues related to the digital system licensing process.

The NRC's short-term initiatives in these areas include the ongoing efforts by the Task Working Groups to develop "interim staff guidance" to provide regulatory stability for licensees, as well as digital I&C and HMI vendors. In the longer-term, the regulatory positions developed by the Task Working Groups will be incorporated into the agency's updated regulatory guides and other guidance documents. Of course, as you well know, additional work may be needed after the agency issues the interim guidance, and a number of other issues may arise as the technologies evolve.

The NRC has an active research program to improve the common understanding of the issues in this rapidly changing area, and enhance our regulatory processes. In conducting this program, one of our strategic goals is to ensure that our actions are effective, efficient, realistic, and timely.
Toward that end, our research in the digital I&C and HMI areas involves a variety of U.S. and international facilities. This collaboration supports the effective, efficient, realistic, and timely development of technical information, tools, analysis methods, and regulatory guidance. Together, these products support the regulatory efforts of the NRC's various

program offices, as well as the industry and other agency stakeholders. In particular, our research is currently focused on emerging issues related to the agency's regulatory and licensing functions; including such issues as:

- evaluation and development of diversity and defense-in-depth strategies for digital systems,
- development of technical bases for regulatory review of field programmable gate arrays (FPGAs),
- evaluation of digital communication strategies,
- review of electromagnetic and radio-frequency interference issues at nuclear facilities,
- cyber-security research,
- digital system risk and reliability research,
- evaluation of advanced control room designs, including soft controls, computerized procedures, operator workload, and so forth,
- advanced diagnostics, prognostics, and online monitoring,
- development and review of digital systems failure databases, and
- reviews of emerging technologies

To support this work, we draw upon the expertise of a broad spectrum of research organizations and facilities. In particular, these include Ohio State University, the University of Tennessee, the University of Maryland, and other major universities. They also include Brookhaven National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and other national laboratories administered by the U.S. Department of Energy.

Additionally because digital I&C and HMI are important around the world, international cooperation benefits everyone involved. The NRC has long been interested and active in the international nuclear safety arena. In fact, for the past 10 years, we have been particularly interested and active in international research in the area of digital systems safety. We believe that interacting with international research organizations and regulatory agencies helps the NRC to develop and refine our regulatory guidance and policy, while gaining valuable experience from our international partners.

The NRC also engages international research facilities and programs to conduct our research. Key examples include the Halden Reactor Project, which involves extensive research in the areas of digital systems safety and human factors aspects of control room design. Additionally, the NRC's research relies on an international cooperative program that provides access to research and data from the international community. In particular, the NRC has been very active in the database project, known as Computer-Based Systems Important to Safety (COMPSIS), sponsored by the Organization for

Economic Cooperation and Development (OECD), which is gathering much-needed digital failure data. The NRC is also the lead organization for a new activity that will begin shortly under the auspices of the Working Group on Risk, within the Committee on the Safety of Nuclear Installations (CSNI) established by the OECD Nuclear Energy Agency. This working group will make recommendations regarding current methods and information sources used for quantitative evaluation of digital system reliability for PRA applications. The working group will also identify, where appropriate, the additional efforts that would be needed to improve digital system reliability assessments.

Finally, when appropriate to support our research in the digital I&C and HMI areas, the NRC engages in collaborative efforts with other Federal agencies, including the National Aeronautics and Space Administration (NASA) and the Naval Reactors Program. These collaborative efforts also involve industry research organizations, such as the Electric Power Research Institute (EPRI).

This extensive research framework sets the stage for today's workshop, which is part of our ongoing efforts to ensure that our research activities are effective, efficient, realistic, and timely. The objective of this workshop is to give our stakeholders an opportunity to provide input into our ongoing review of current and emerging issues that we may encounter in the digital I&C and HMI areas.

In so doing, you will help us review the capabilities of current facilities and consider lessons learned from their operation. Based on this input, we will then identify options for developing additional capabilities, if needed, or integrating current capabilities to support the current and future needs of the nuclear industry in the digital I&C and HMI areas.

In addition, based on your input, we will host a subsequent workshop in Washington, DC, on September 11, to discuss, at a conceptual level, the management issues associated with various options. Specifically, these issues include potential participants, funding arrangements, conflict-of-interest (COI) considerations, and siting.

The NRC intends to continue working with all of our stakeholders to conduct and maintain appropriate cooperative research and testing programs, where possible. In so doing, our goals are to leverage our limited resources and work with stakeholders to enable the safe use of digital I&C and HMI technologies.

Along these lines, I invite members of the research and testing communities to consider working directly with the NRC, as part of a sabbatical or through other arrangements. In addition, to the obvious benefits this would provide to the NRC's research programs and to the researcher (who would gain insights regarding how we develop our regulatory research products), it would promote closer working relationships between the NRC and other research organizations.

We are fortunate that many of the industry's leading experts are with us here today. Consequently, I believe that this workshop will give us all a unique opportunity to learn from each other and generate interesting and fruitful discussions regarding current and emerging issues and the research capabilities we will need to resolve them. Again, I thank you all for participating in this important forum.

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Appendix I

Current and Future Needs in the Digital Instrumentation and Control and Human Machine Interface Area

Presentation by
Steven Arndt
September 6, 2007

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Current and Future Needs in the Digital Instrumentation and Control and Human Machine Interface Area

September 6, 2007

Steven Arndt
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research
(301-415-6502, saa@nrc.gov)

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Background

- **In the 1997 NAS report "Digital Instrumentation and Control Systems in Nuclear Power Plants: Safety and Reliability Issues" the review committee identified a number of key areas**
- **NRC reviewed the 1997 NAS report recommendations and I&C vendor development efforts at that time and develop research NRC Research Plan for Digital I&C for FY 2001-2004 (SECY-01-0155)**
- **NRC updated the research plan as "NRC Digital System Research Plan FY 2005 – FY 2009"**
- **During this time frame the NRC has also developed research program plans for Human Machine Interface research**

Background

- Since the NAS review in 1997 there have been a number of changes to digital I&C and HMI technology
  - New technology now being used in the nuclear arena
  - Technology that has been used widely in non-nuclear applications is now moving into the nuclear arena
  - Continuing need to improve review process
- New drives
  - New reactors
  - Extensive use of digital systems in fuel cycle facilities
  - Updating of current plant Digital I&C and HMI
  - Advanced reactor programs
    - DOE Technology Roadmap: Instrumentation, Control, and Human-Machine Interface to support DOE Advanced Nuclear Energy Programs, March 2007.

Background

- November 8, 2006 Commission Meeting
- Digital I&C Steering Committee
- Task Working Groups
  - TWG #1: Cyber Security
  - TWG #2: Diversity and Defense-in-Depth
  - TWG #3: Risk-Informing Digital I&C
  - TWG #4: Highly-Integrated Control Room–Communications
  - TWG #5: Highly-Integrated Control Room–Human Factors
  - TWG #6: Licensing Process
  - TWG #7: Fuel Cycle Facilities
- Addressing most important short term issues

CURRENT RESEARCH

- In the Digital I&C area structured to include the most important research areas needed to support the program offices
  - Systems Aspects of Digital Technology
  - Software Quality Assurance
  - Risk Assessment of Digital I&C Systems
  - Security Aspects of Digital Systems
  - Emerging Digital Technology and Applications
  - Advanced Nuclear Power Plant Digital Systems
- In the HMI area research is being done in the areas of
  - Fatigue
  - Workload
  - Safety Culture
  - Effects of automation
  - Effects of degraded digital I&C
  - Computerized procedures
  - Changes in concepts of operation

How an Issue Becomes a Need

- Technology that has been used widely in non-nuclear applications is now moving into the nuclear arena. We need to be able to prepare more effectively
  - For example, Field Programmable Gate Arrays (FPGAs)
    - Have been in use for more than 15 years
    - NRC found out that vendors were planning to use them in nuclear safety systems 3-4 years ago
    - NRC started research on them last year
    - Application using them this year
- Some needs only become apparent as new technologies or methods are discussed or reviewed
  - Defensive measures effectiveness in improving digital system reliability including fault tolerant features, etc.

How an Issue Becomes a Need

- Some needs only become apparent as new techniques are used to solve new issues
  - Priority Logic Modules have been used in other industries for some time, but only recently to solve new digital I&C issues in the nuclear industry
- Continuing need to improve review process
  - Current software review process, does provide an method for assuring software quality but is not as effective, efficient or predictable as we would like
  - Other industries use more review tools or are involve earlier in the software development process
  - Unlike some industries NRC does not conduct independent validation and verifications or testing

Issues

- Human Machine Interface/Human Factors
  - Minimum Inventory
  - Procedures
  - Manual Operator Actions
  - Soft Controls
  - Emergency Response Capability
  - Graded Approach to HF
  - Role of Personnel
  - Uses of Plant-referenced Simulator
  - Degraded Digital I&C
  - Safe Shutdown Capability
  - HFE of Security Control Stations
  - HFE of Advisory Systems
  - Simulation and Aggressive Control Room Modernization

Issues

- **Digital I&C**
  - Improved diversity and defense-in-depth strategies
  - Network security and reliability assessment methods
  - Cyber security assessment methods
  - Security assessment methods for EM vulnerability
  - Improved digital system risk assessment methods
  - More effective methods for evaluating new design concepts
  - More effective methods for communication strategies
  - More effective methods for the review of both COTS and system specific operating systems and code generation tools
  - Better methods for evaluation software quality and reliability
  - Additional technical bases for review of emerging technologies
    - FPGAs
    - On-line Monitoring
    - Smart transmitters
    - Self testing methods
    - Advanced Instrumentation

Summary

- On of the objectives of this workshop is to identify current and future technical issues and needs in the area of digital instrumentation and control and human-machine interface (I&C and HMI) technology
- There are a number of different ways how technical issues become research or testing needs
- The NRC has in place the means to review current and future applications in the area of digital I&C and HMI, but there are a number of areas that we can and should continue to improve our processes

Appendix J

Preliminary Review of Existing DIC & HMI Facilities and Capabilities

Presented by
Leonard J. Bond
September 6–7, 2007

Preliminary

Review of existing DIC & HMI facilities and capabilities

Leonard J. Bond, Anne Schur
and David Brenchley
Pacific Northwest National Laboratory

September 6-7, 2007

Battelle

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Outline

- Scope and methodology
  - DI&C - Digital Instrumentation and Controls
  - HMI/HMS – Human-Machine Interface / Systems
- Community Information (survey results)
  - Vendors
  - DOE Laboratories
  - Academia
  - Research organizations
  - Wider community
- Options for meeting NRC & community DI&C – HMI needs
- Summary

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Study Scope

- Survey of existing (U.S.) facilities with similar potential capabilities
  - Capabilities in design, conducting, operating, maintaining test and research in digital I&C and/or HMI/HMS issues
  - Use of facilities, user base, staffing levels, funding methodology, construction costs, annual operating and O&M costs.
  - Options for operating models

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Study Methodology

- Identification of organizations
  - Knowledge of community
  - Web search
  - Previous NRC studies (e.g. HF circa 2002)
  - Key stake holders identified – with NRC
- Telephone and face-to-face interviews
- Web site questions
- Limited site visits (*due to time constraints*)
- Federal Register announcement
- September workshops
  - Invitations to participate and contribute

- Total of more than 75 organizations identified
  - Vendors, organizations (EPRI,NEI etc), DOE Labs, universities
  - Total of more than 30 contacted
- Total of more than 20 Interviews
  - Telephone
  - Interviews – face-to-face 7 at IEEE Meeting CA (Aug 26-30)
  - Two Site visits
- Information gathering to continue until September 30, 2007
  - http://nrc-test-facility.pnl.gov/

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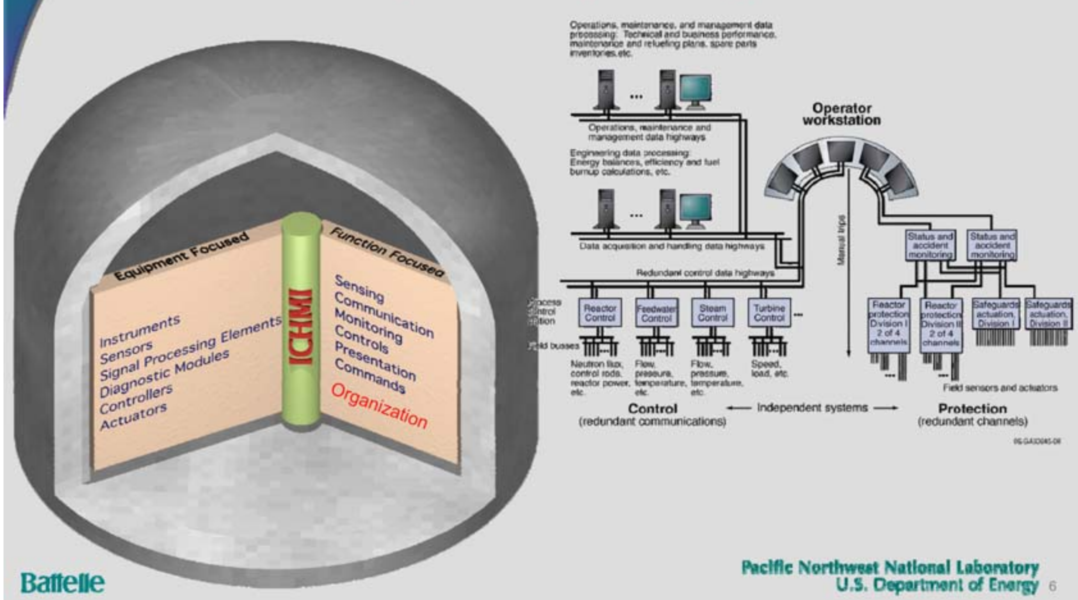
U.S. Department of Energy 4

Information to Gather

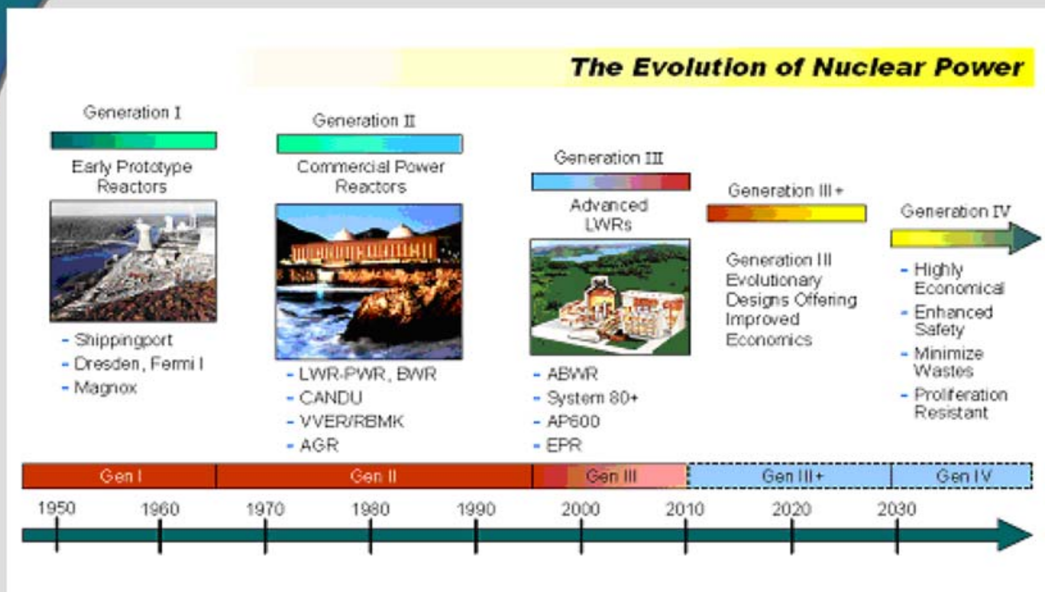
- Identify and investigate scope and conceptual design attributes of other U.S. facilities
  - National laboratories, universities, military installations, other government agencies and industry capabilities.
- Survey existing facilities
  - Designing, conducting, operating, maintaining test and research facility in digital I&C and/or HMI/HMS
  - Issues/concerns to be resolved
  - Types of research done?
- Develop draft survey results for NRC
  - Staffing, user base, funding methodology, facility construction costs, annual, operation and maintenance
- Type of facility/purpose: research, training, engineering development
- Owner & User Base, Funding, Management
- Operational capabilities & infrastructure support. What can it do for NRC and what can't it do for NRC?
- Strengths and Limitations

DIC-HMI – *MORE THAN SIMULATORS*

ICHMI Forms a Nuclear Power Plant's (NPP) Nervous System –
HMI is ALL interactions, Control room, O&M + diagnostics



Time-line Issue



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Community Information

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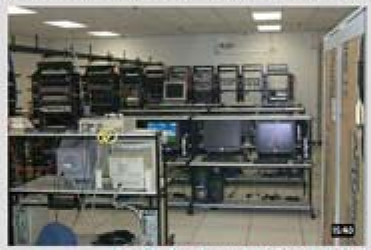
Vendor Community – "NP2010/ALWR's"

- Vendors have facilities
- Systems developed
  - Architectures and designs
  - Simulators being developed
- Design/Development R&D not required
  - Anything now too late for 2010/15… only possible to impact "edges"
- Nuclear I&C just a small part of process systems market

AP-1000 Control Room Simulator
Westinghouse Energy Center, PA



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Some Vendor Concerns

- Concerns relating to possible "Center" implementation
  - Ensuring cyber security
  - Protection of vendor proprietary information
  - Expertise comes from doing
  - Take vendor class – then hire an expert in particular system
  - Center would have "non-qualified systems" (NPP have qualified systems)
  - Cost and utilization
  - Scope of activities – more than just a simulator?
- Loss of experienced staff
- Platform experts are at the vendors
- Need tools to make people more efficient – tools to find info (cross train)
- Nuclear needs to join the wider I&C Community
  - Why are we (or think we are) so different!
- Costs of a single center –technology rate of change, lock into aging capabilities
- Consider innovative options – networks (virtual center)
- Digital I&C already deployed – e.g. Sizewell
- As a community focus for research on Gen IV (post 2020)
- Keep research and training on simulators separate.
- Center effort - Potential to slow existing NRC activities

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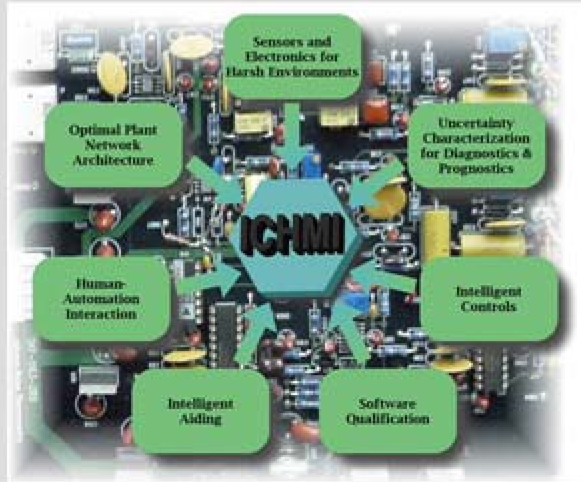
Longer Term Needs (Vendors)

- Research needed to support advanced reactor concepts
  - E.g. GNEP and Gen IV concepts
- HMI – display, interactions, information management and workforce aids.
- O&M DI&C issues



DOE Laboratories – I&C/DI&C

- Advanced Control Test and Operations (ACTO) facility: DOE-NE (ORNL). Operated until early '90's
  - Human resources remain – equipment *aged out*
  - *75% of nuclear expertise in DOE labs could retire in 5 years**
- All major DOE laboratories have I&C, sensors, measurements, communications laboratories
  - Sensors for harsh, environments, communication, monitoring, controls, diagnostics & prognostics
  - Much more capability than that focused to meet nuclear power program needs
- Dedicated test facilities – limited (aging/aged out)

*Wogman, et.al (2005) *J. Rad.& Nuclear Chemistry* 263 (1) 137-143.

DOE Laboratories – Human Factors

- **Six DOE labs have history of HF – HMI Research**
  - BNL, INL, LLNL, LANL, ORNL and PNNL
- Brookhaven
  - Historically 90% of work in this area for NRC. HMI studies, new needs assessments for advanced reactors
- Idaho
  - Advanced R&D Plant Simulator (expansion in progress), human performance simulation and modeling
- Lawrence Livermore
  - Historically performed extensive studies for NRC including nuclear medical research. Have numerous part-task simulators and virtual image simulator
- Los Alamos
  - Have performed studies for NRC. Strong capabilities in PRA, HRA, organizational factors, and VR
- Oakridge
  - Historically performed studies for NRC, EPRI and DOT. Strengths: operator and maintainer modeling. Have access to operators from the facilities that is part of their laboratory.
- Pacific Northwest (and Battelle/Seattle)
  - Electricity Infrastructure Operations Center (EIOC): Experiments and usability testing; visualization concepts for grid operations, situation awareness, HMI designs, performance measures. New needs assessments.

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DOE Laboratories

- *Examples* of new, upgraded emerging capabilities and facilities
  - INL – I&C initiatives, SCADA test bed, "vendor systems"
    - GNEP and other programs may fund new capabilities
  - PNNL's Electricity Infrastructure Operations Center
  - DOE-NE Advanced Test Reactor (Transition to user facility)
  - ORNL - Digital I&C and test & evaluation facilities + HIFA, Spallation Neutron Source

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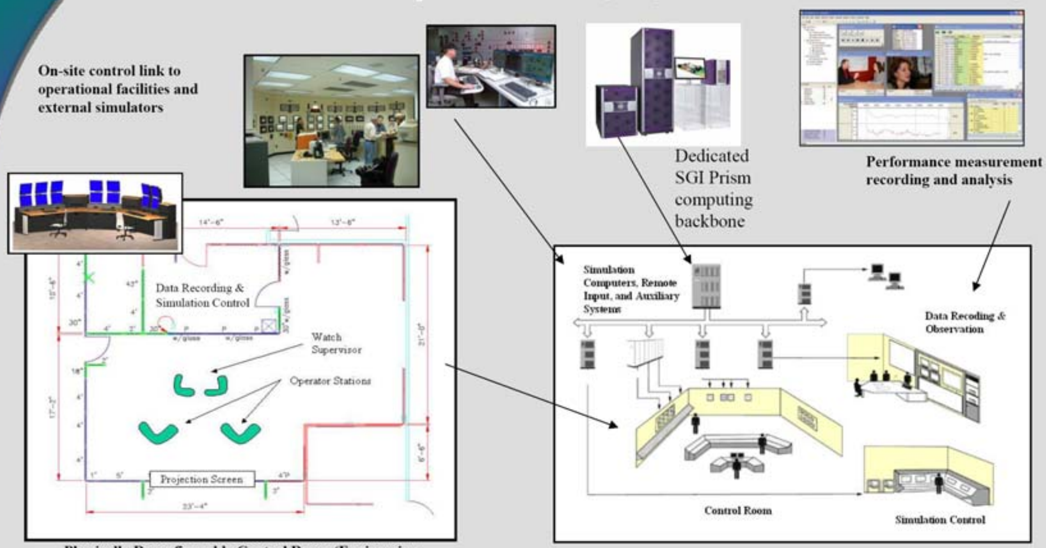
Example of New Capability: INL Human System Simulation Lab Expansion (expected GNEP funded)



Physically Reconfigurable Control Room (Engineering Research Office Building – Idaho Falls

Distributed Reconfigurable Simulation Architecture

Academia

- University nuclear I&C – HMI community
  - Small – limited funding
  - Some commercial systems at different sites
- Examples of some activities & facilities
  - Digital I&C for research reactor – U. Florida.
  - U. Tenn. – seeking to upgrade PWR simulator to DIC
  - Penn state ESBWR – low-pressure test facility
  - Ohio State University Academic Center for Excellence in Instrumentation and Control in Advanced Systems (sponsored by INL)

US Academic community

Research interests cover: Sensors, systems, communication, software, diagnostics

26 Research Reactors in U.S. Universities

Academia

- Numerous centers and groups working in DI&C – HMI topics
- Many groups working in non-nuclear applications – Examples:
  - Center for Manufacturing and Automation (USC – UCLA et al.)
  - Center for Advanced Communications (Villanova)
  - Center for wireless information networks (Rutgers)
  - Measurement and control engineering center (U. Tenn. + ORNL)
  - Center for Design of Analog-Digital Integrated Circuits (CDADIC) Washington State University (lead institution)
  - NAS Industry-University CRC Program (60+ center – current or past members of programs)

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Government Research & Development: (HF &/or DI&C)

- NASA.... Experience in distributed simulations, DI&C research and operations for hardware and software where researchers and instruments are geographically dispersed on earth and interplanetary.
- Department of Defense (Several sites and organizations)
  - Air force ... simulators and systems
  - Navy and army organizations
- Federal Aviation Administration
- Transportation – FHA, Rail - human factors (HF) orgs.
- NRC – Training Center Chattanooga
- Naval Reactors

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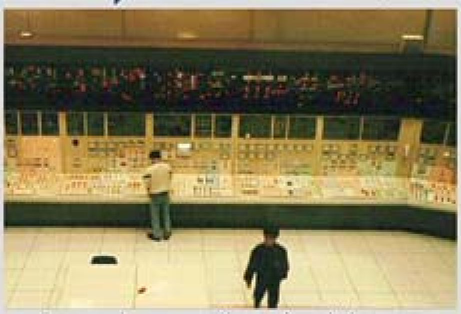
Training Simulators

Simulators required for NRC staff familiarization *(Not for formal operator training):* systems different for each "type" and for each new reactor or family of reactors.

Each industry has its own capabilities.



Current generation simulator

Photo J. Gonyeau

New AP-1000 Simulator

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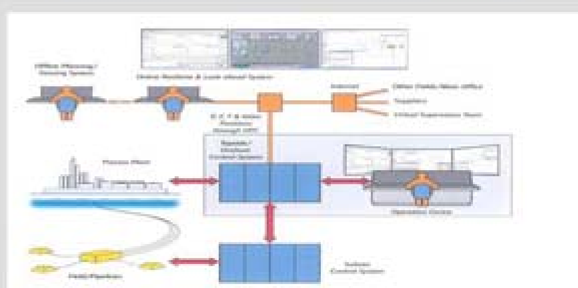
Dynamic Simulator – Process Instrumentation & Control Engineering

- EXAMPLES:
- D-SPICE
  - Kongsberg
- Process & Control
- Training
- Production management
- Hanford – WTP
  - Simulator $2M
  - I&C System $13M



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Examples of Training Simulators

- Coal fired control room simulator *

- "soft simulator"*

*EMPOWER training

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Large Experiment Control Rooms

- National Ignition Facility
- Fermilab
- Spallation Neutron Source
- Other?

NIF – Control Room

Fermilab
CDF Experiment

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Site Visits

- PNNL EIOC – act as test-bed for questions
  - visit to EIOC
- INL
  - Human Factors & Digital I&C Evaluation Facility
  - SCADA Test Bed
- (2-3) Locations TBD
- Early identification of potential locations to visit is essential

Electricity Infrastructure Operations Center

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National SCADA Test Bed Program (INL)

- Sponsored by DOE Office of Electricity and Energy Assurance
- Mission is… ***to support industry and government in ensuring the security of the Nation's energy infrastructure***
- Closely integrated with related DOE and Department of Homeland Security programs
- **Teaming with other National Laboratories**
- **Teaming with industry (CRADAs)**

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Experience Outside the US

- Halden Project
- Japan/Asia
  - Test Simulator for advanced instrumentation - KAERI
- Europe – NEW (July '07) IBM Global Center of Excellence for Nuclear Power
  - IBM + vendor software applications focus
  - $10 million investment
  - Located near ITER
  - 10,000 Sq feet

Halden Project

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Halden Project

MTO-labs 2007

- Scope
  - (i) HMI and (ii) fuels & materials
  - 50 year history – international research program (17 members countries)
    - US include EPRI, NRC, Westinghouse
  - 3rd generation man-machine lab became operational 2005
  - Operates around 3-year research programs
  - Reconfigurable facilities
  - Not just nuclear – oil and gas + air traffic control

View of Hammlab

STATOIL Snøhvit facility

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USA NPP-Focused DI&C – HMI Communities

Modest size US community in nuclear power I&C (DI&C – HMI) recent meetings

JOINT 8TH IEEE CONFERENCE ON HUMAN FACTORS AND POWER PLANTS AND

13TH ANNUAL CONFERENCE ON HUMAN PERFORMANCE / ROOT CAUSE / TRENDING /

OPERATING EXPERIENCE / SELF ASSESSMENT

- Next meeting April 2009

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Wider Research Community

Vibrant DI&C & HMI Communities in USA

Examples of Meetings and conferences

- IEEE/AIAA 26th Digital Avionics Systems Conf (DASC) – Dallas, TX
- **CICINDI-2007 8th International Conference on Control, Virtual Instrumentation, and Digital Systems November 4 to 9, 2007, Mexico City, Mexico**
- **18th ISA POWID/EPRI Controls & Instrumentation Conference, *The Pathway to Power Automation for the 2010 Decade,* June 8th – 13 2008 - Phoenix, Arizona**

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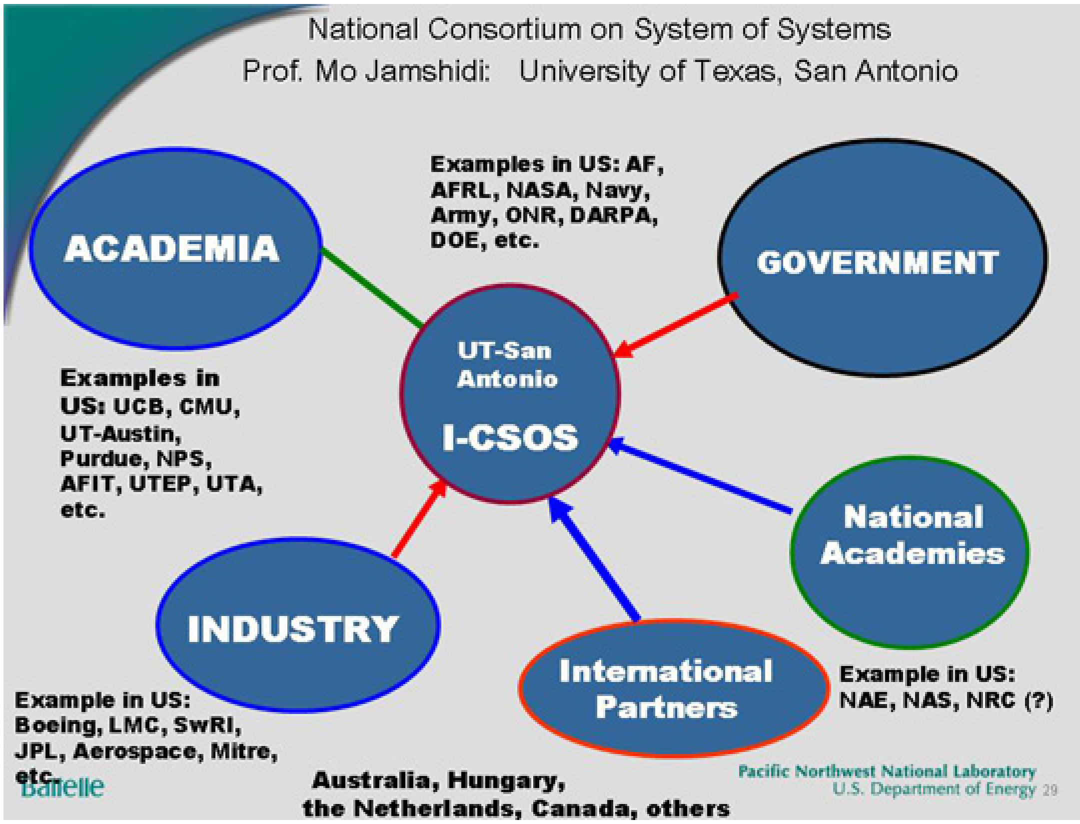

Facilities/Capabilities - SUMMARY

- Robust digital I&C HMI community in USA
- Capabilities for R&D – *sensors to systems* in DI&C and related HMI (e.g. aero-space)
- HOWEVER – capabilities in USA dedicated to NUCLEAR related DI&C – HMI issues limited
  - Industry has capabilities, systems and infrastructure
  - Research community depleted – re-emerging (or trying)
  - Nuclear Power DI&C-HMI R&D – funding has been limited
- "pockets" of expertise remain
- People -"aging community" (particularly in nuclear R&D)
- Integrated facility –other areas??? Are they effective….

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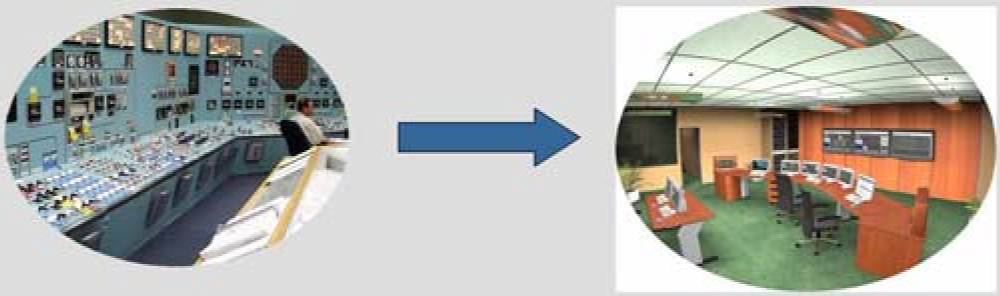
OPTIONS FOR MEETING NRC DI&C – HMI REGULATORY RESEARCH AND WIDER NUCLEAR POWER COMMUNITY NEEDS



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Research Vision

- Develop a community-wide research agenda
  - DI&C-HMI Science/Advisory Committee (National Academies?)
  - Decadal research review (National Academies – define long term needs) – NRC, DOE, NEI et al
  - Peer review proposals and programs
- New capabilities are emerging (need to support/foster)
- Perform needed research through "consortium"
  - Virtual network – some central "Project Office"

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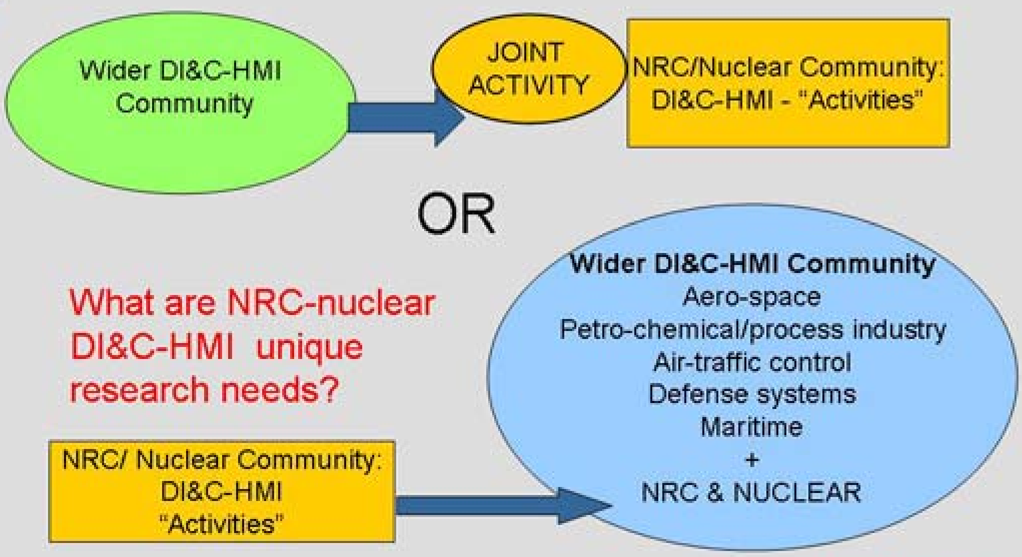
Research Vision… con't.

- EPRI model for research – few facilities
  - USE BEST AVAILABLE (University, DOE Lab, etc.)
- Some form of Consortium or network generating most interest in responding community:
  - Establish a DI&C – HMI "project/program office" to coordinate/manage and INTEGRATE activities
  - Needs to be ONE FRONT DOOR and one web site for the "program"
  - Cf. – Big Sky Consortium – Carbon Sequestration etc. (or other example)

Two Possible Models for DI&C-HMI Community Interactions and Engagement



No New Facility (Option #A)

- Seek to continue to improve current NRC approach
  - Use universities, DOE Labs, research organizations
- Provide integrated NRC DI&C-HMI activity (program office?)
  - Establish a DI&C-HMI Science Committee Advisory
  - National Academy Decadal Review to review and/or refine (prioritize) research agenda
  - Seek partnerships – "Consortium" to leverage DOE, industry and academic capabilities

New Facility – NRC Lead Role

- NRC Stand-Alone (Option #B)
  - Owned and operated by NRC
- NRC/DOE Partnership (Option #C)
  - Owned and operated by NRC & DOE as partners
- Government (NRC & DOE)/Industry Partnership (Option #D)
  - Could be with industrial nuclear power plant consortium
  - Government owned – contractor operated

National User Facility: Center of Excellence DI&C - HMI

- NRC User Facility (DOE – Office of Science model) (Option #E)

Operated by one organization but available to all qualified users on a 'fee basis.'

What is the expected use rate for NRC regulatory research?

If NRC can use 100% of the time then why would you want to have a user facility and then not be able to use it when you needed it?

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Center of Excellence Model

- National Center - Contractor operated; could be national laboratory, university (Option #F)
- NSF (or similar) Industry-University Cooperative Research Center (Option #G)
- Consortium (several models): (Option #H) Industry/University/Government cooperative research.

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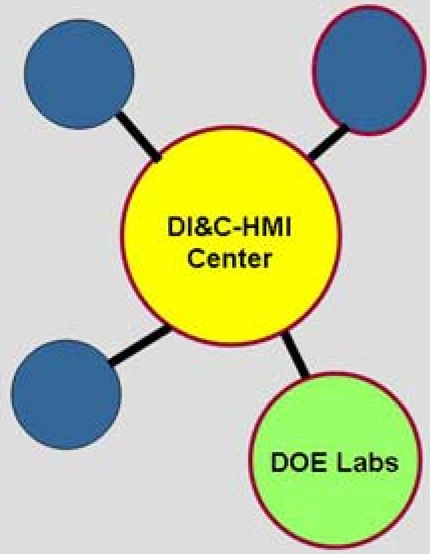
Distributed Center Approach (Option #I)

- Establish a project or program office
- Leverage best available facilities
- Leverage established expertise
- Coordinate and integrate activity for maximum impact
- Defined research agenda – use peer review, steering/advisory groups



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- HOWEVER – capabilities in USA dedicated to NUCLEAR related DI&C – HMI issues *limited*
  - Vendors/Industry has capabilities, systems and infrastructure
    - Support design, test, build
  - Research community *depleted* – re-emerging (or trying)
  - Nuclear Power DI&C-HMI R&D – funding has been limited
- "pockets" of expertise remain
- People – in nuclear related I&C (in USA) – analogue experience – need for technology transition

SUMMARY - cont

- Large organizations (e.g. NASA, Lockheed Martin) have expertise
- Professional community – with nuclear expertise needs to expand to capture wide DI&C – HMI capabilities
- New facilities being developed (e.g.) :
  - Fed. Railroad Administration – Cab Technology Integration Laboratory (SOW – May, 2007)
  - IBM Global Center of Excellence for Nuclear Power – France
- Longer term - Need more innovative DI&C -HMI research

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Some Consortium and Center Issues

- Proprietary information
  - How to handle in research consortium or university?
- Computer security (Cyber security)
- Non-qualified systems used in research
  - Potential impacts on plants is "issue" identified
    - Relationship between research & regulated systems
- Qualified staff – loss of expertise
  - Lack of new generation
  - Need to engage a wider community.

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Appendix K

Open Discussion Summary: Technical Issues for Workshop September 6–7, 2007

DIC/HMI Workshop

September 6-7, 2007
Atlanta, Georgia

Open Discussion Summary: Technical Issues
(raw data)

(R.T. Wood) Common Cause Failure Diversity

(Jim Griffin) Security of Network

(Don Dudenhoefer) Developing methods and tools for technology neutral evaluation of new DIC and HMI concepts.

(Tunc Aldemir) Risk modeling

(A.C. Raptis) What about wireless data transmission

(M. Golay) Removal of barriers to digital technology

(M. Golay) Software quality/reliability

(M. Golay) Cyber security/safety

(M. Golay) Digital complexity and quality control

(M. Golay) Expansion of score

(FJ Wyant) How will DIC/HMI test facility be made flexible enough to support multiple user needs?

(Ed Legenski) "DIC" also implies fieldbus protocols such as Foundation Fieldbus and PROFIBUS. Will these be considered?

(Fridtjov Orwe) Digital Control Rooms: Large Screen Display Design for current and future plants. Used for what? Dynamic and/or interactive?

(Pradeepkumar Ashok) How to quantify effectiveness of HMI that is developed. Whare the metrics?

(A.C. Raptis) National Facility for sensor validation as well as overall system validation

(Bruce Halbert) Multi-unit control room integration and associated regulatory issues

(Ted Quinn) What is the regulatory basis, if any, in development of new simulator? IAU regulation 1.149; 10CFR 50.55.46; ANS 3.5

(John Summers) Post mod testing demonstrates system will perform function 100% of the time needed.

(Brian Arnholt) Managing & keeping up with advances in technology. Example: computer systems & hardware, displays, etc.

(B.A. Gran) To be specific with respect to 1) safety related DIC/HMI, 2) non-safety DIC/HMI, or 3) both (integrated as in some other industries)

(Mike Dunn)Timeline for NRC review/approval versus technology development.

(Ali Haghighat) Funding

(Carl Benhardt) Control room discipline.

(Carl Benhardt) Flexibility of control

(Carl Benhardt) Hard panels to flat screens.

(Carl Benhardt) Operator can rearrange control room.

(Dave Vaglia) How to address multiple/different mission of future plants: 1) hydrogen generation, 2) process steam for toher uses, 3) electricity production.

(Carl Benhardt) Facility Mode Issues: 1) know mode status, 2) reactor facility, 3) chem. Plant facility or systems. Determining for HIS.

(Kimberly Keither line) What safety functions need an automatic diverse actuation system?

(R.T. Wood) Fault coverage. Testing and analysis protocols and techniques.

(Masafumi Utsumi) System reliability; estimation include CCF.

(C. Smidts) Validation of Software reliability/safety quantification methods for the digital I&C system.

(Ali Haghighat) Hands on training.

(John Summers) Humans reacting to a digital fault respond consistently (independent of experience).

(Dave Vaglia) How can one generic research facility that will be reconfigured address different plant designs and different plant control and protection systems?

(Hash Hashemian) Sensors must get more attention in the digital I&C picture.

(Barry Johnson) Reliability. Safety assessment of integrated hardware/software systems. Key work is integrated. Complexity. Quantitative.

(Carl Elks) The quantitative assess of dependable system—emerging and future digital I&D.

(R. T. Wood) Life Cycle Maintainability. Rapid obsolescence of digital technology.

(Chris Plott) What representation to operators best support DIC?

(Bruce Hallbert)Determination of adequate staffing levels for main control room.

(John O'hara) The best integration or best mix of human and automation resources to achieve safe and efficient operation.

(John O'hara) Determining a set of performance measures and criteria for the evaluation of human-machine systems..can it be standardized?

(Jim Friffin) Standardization: 1) reinventing the wheel each time and 2) reducing review time.

(Don Dudenhoeffer) Human Perforamnce/system validation for procedure response requirements with new technologies.

(Jennifer Uhle) Initial presentation affecting operator response.

(Ted Quinn) Importance of hands-on simulator as parrot of training new staff.

(Barry Johnson) Incremental validation and verification. Being able to focus and limit V & V when changes are made yet ensure effectiveness.

(David Holcom) Configuration control of development tools-versions of FPGA software tool sets.

(F. Wyant) No representation from NNR or NRO at this workshop to provide perspective of licensing issues and timing of the DIC-HMI test facility to COL applications.

(Joseph Naser) Acceptance of computerized support systems for operators where (it) could impact safety.

(Joe Murray) Training of new staff on R&D safety principles in digital systems.

(RT Wood) Harmonization of International Standards.

(RT Wood) Transition of Decision capabilities/responsibilities from human to machine. Multi-unit plants near autonomy.

(Carl Benhardt) Cross cultural issues in control room design. Japan/France/US/GB

(David Blessing) Does there need to be an analogues backup display for selectee safety paramenters?

Procedures and technologies to support protection growing cyber security concerns. (Don Dudenhoeffer)

(David Holcomb) Credit for lessons learned in other industies—new technology. Have higher hurdles than existing ones.

(Chris Plott) How do we qualify 'representative' users for HMI testing for prototype/early versions of technologies/.

(John Summers) Culture. Remember nuclear is different, so what works elsewhere may not be adequate for nuclear.

(C. Smidts) Testing tools for quality assurance and/or development of SW in the digital system.

(Russ Sydnor) Secure network. Designs for safety critical systems.

How to best develop/engage next generation of engineers and scientists.

(David Blessing) Does ability to remotely monitor plant data detract from operator responsibility?

(F. Owre) The digital control room; integrated system validation. What kind of acceptance criteria should be provided?

(Jay Persensky) Maintenance of systems.

(M. Golay) Standards for health monitoring and advice operator support, task management, integrated oversight.

(M. Golay) Cost benefit evaluation, methods for judging digital innovation

(Barry Johnson) Complete system modeling and simulation: I&C, plant, human, etc

(Joseph Naser) Acceptance of use of part scope and other simulation capabilities as well as full scope simulators especially for upgrades

(Brian Arnholt) How to avoid common trap on information overload to the operator

(Joseph Naser) Acceptance a) reduce number of MCR operators and b) control of multiple units from a centralized location

(A.C. Raptis) Physics based probabilistic models for sensors and systems in general that will continuously be updated by sensor data that eventually might contribute to predicts sensor/system status

(Pradeepkumar Ashok) Decision making framework that makes up the visualization software

(Frank Quinn) Forget "catch-up" (40 years behind) and try to get ahead

(Frank Quinn) We are more worried about "converting" older stuff versus training youngsters

((F. Orwe, Halden) Issue: Integrate computerized procedures – should they be text oriented and/or integrated in the control displays

((F. Orwe, Halden) Issue: How to perform(?) on-line monitoring by means of software

(R.T. Wood) Characterize uncertainty I models and diagnostics

(John O'Hara) Management of logic into systems to enable operators to maintain gobal situation awareness and do troubleshooting in a computer-based CR with 100 or hundreds of displays

(R.T. Wood) Objective software quality/dependability metrics, what constitutes necessary and efficient?

Monitoring who does(?) and how are plants monitored remotely

(Karen Hutchings) How to integrate the use of human performance effort prevention tools and digital controls

(Frank Quinn) What happened to K-reator at Savannah River? (effort digital I&C u/g and 90s) EMACS – 10 mioles away

(Masafumi Utsumi) What is the nuclear specific requirements for DIC?

Appendix L

Open Discussion Summary: Capabilities for Workshop September 6–7, 2007

DIC/HMI Workshop

September 6-7, 2007
Atlanta, Georgia

Open Discussion Summary: Capabilities

(Frank Quinn) Learn to share and learn to borrow

(Gordon Clifton) Capability to provide reports of successful application of DI&C (Lessons learned, op experience, etc)

(F.J. Wyant, SNL) Interact- contract with experts from outside nuclear industry to access their solutions to similar issues

(Tunc Aldemir) Development of smart/context-based testing methodologies

(C. Smidts) Reporting of existing Sn code (+doc +…dev history+ operating system experience)+ platforms. or benchmark codes

(R.T. Wood) Benchmark efforts to demonstrate/confirm/compare components/methods/testing regimes

(Hash Hashemain) Sample rate of digital I&C

(Hash Hashemain) High sampling rates are needed for on-line diagnostics of performance of digital I7C equipment

(Halden Project) One capability needed… to have test facility that can address both the safety aspects of DIC and (its influence on the HMI's and) the operation in the control room

(Ted Quinn) Integrate part-task simulator PNRT-TNSK digital simulator into the NRC training program

(John Summer) Expertise in analyzing digital/human events of consequence to verify corrective actions solve the root cause

(Brian Arnholt) Effective means of vendors gov't industry to share information without compromising intellectual property

(David Holcomb) Continuously revise NPIC &HMI best practices

(Rick Libra) To solve: Need clear <u>ownership</u> of the I&C issue to assure accountability and support of resolution

(Rick Libra) To solve: The use of systematic problem solving methods and clear management process AND access to the solutions by all parties

(Don Dudenhoeffer) Prioritize list of objectives and a systematic execution plan/timeline focusing on the nuclear industry

(Brian Arnholt) Benchmark and data gathering from non-nuclear process industries using digital I&C technology

Capability to resolve large screen display design for future reactors

- a mixed group of process experts HIS designs and computer scientists
- simulator facility to test out ideas and build prototype
- access to operations to use test designs as they progress

(Kimberly Keithline) The ability to visualize and understand how operators would respond to an accident concurrent with digital common cause failure

(Chris Plott) Models of subsystem including humans that can be used for early integration testing

(John Summers) Using system approach towards defining training needs associated expertise to develop the resulting framing

(Carl Benhardt) The capability of the NRC to make a firm statement that the methodology provided in NUREG 0800/0711 will not be shortcut for the convenience of industry

[Barry Johnson] Multi-disciplinary research: technologies, applications

(Barry Johnson) Applied research:

- Real systems
- Real applications
- Industry
- University
- Government

(R.T. Wood) Systematic execution of research analysis, evaluation, confirmation

(R.T. Wood) Optimized coordinated efforts rather than spotty critical-path/funding driven by coverage issues

(R.T. Wood) Simulation tool/hardware-in-loop testing capabilities resources

(M. Golay)Formalization of NRC of mechanisms for creation of unsafe conditions and statement of acceptance criteria

(Frank Quinn) Stop thinking that radation is more dangerous than chemical and biological agents (and natural phenomena)

A design for verification and validation mindset from the outset – emphasis of the scientific process

(Al Haghighat) Employ hands-on training and workforce for reactors for design and construction of digital I&C

(Barry Johnson) Workforce and development: EE, CS, ME, that understand nuclear technology and systems engineering

(David Holcomb) Facility capable of license capability by demonstration of advanced technologies (-how will wireless be performed?)

(Russell Sydnor) Improved integration of DIC-HMI design and regulatory resolution, e.g. do diversity and defense in depth aspects actually impede operation?

Catalog of current capability for DIC HMI test, R&D support expertise. [Russell Sydnor, NRC/RES]

Appendix M

Focus Group Instructions, September 6, 2007

Focus Group Instructions

September 6: 1:00 – 3:00 pm

FOCUS GROUP ASSIGNMENTS

1) Identify DIC & HMI technical issues that need to be addressed &
2) Define the type capabilities that are needed to address these issues.

FOCUS GROUP LOCATIONS

Group #1: Dogwood Room
Facilitator: Jay Persensky, NRC

Group #2: Topiary Room
Facilitator: Ted Quinn, GE

Group #3: The Palms Room
Facilitator: Joe Naser, EPRI

Group #4: The Board Room
Facilitator: Mike Golay, MIT

Group #5: Azalea II & III
Facilitator: Chris Plott, Alion Science & Technology

FOCUS GROUP PROCESS

The group facilitator will help the group address the questions below and keep things moving. Work at a 'high level." Don't get into the details. Short, concise inputs please; no long dissertations.

Use the flipchart pad and markers to record ideas, comments and results. Use 45 minutes to identify a list of technical issues (should include regulatory issues, but not be limited to regulatory issues) that need to be addressed. Similarly use 45 minutes to identify the required test and/or research capabilities to address such issues. Finally use 30 min to summarize your results. Prepare flipcharts to put on the wall <u>and</u> prepare a power point presentation that can be used to report to the total group.

A memory stick will be provided for each group. This stick contains some key documents that you may wish to use in your deliberations. Please save your power point presentations on the memory stick. We will collect the memory sticks from each of the groups at the end of the workshop.

3M flipcharts and colored markers will be provided to each group. Make legible summary charts for the presentation you give to the larger group. These charts will remain posted on the wall.

1) <u>DIC & HMI TECHNICAL ISSUES</u> (45 min)

What are the technical regulatory issues that need to be addressed? Make a list of technical issues. Then decide the type of issue and who should address it. Consider:

- DIC versus HMI
- Short-term versus long-term
- Regulatory versus industry

Do not worry about current capabilities at this point, focus on issues that need to be looked and resolved.

2) REQUIRED CAPABILITES FOR TEST FACILITY (45 min)

Address the questions below. Focus on capabilities that must be available to address technical DIC & HMI regulatory issues.

- How should technical regulatory issues be solved? Could more testing done earlier in the life cycle improve the regulatory process?
- What capabilities are needed to address the questions/issues identified?
- What type of facility could provide these capabilities?
- What are the advantages to an integrated test and research facility? Could these capabilities be made available on other ways?
- To what extent should a facility be designed to be reconfigurable to expected variety of plant control room and HMI designs? (SRM Question #5)
- To what extent should a facility be designed to also be used as an advanced reactor-training simulator for NRC staff? (SRM Question #6)

3) FOCUS GROUP REPORT (30 min)

Prepare summary flipcharts of your work and power point slides for the presentation of your results. Write your Group # on each page. The flipcharts will be posted on the wall so that we can compare findings across the five Focus Groups. The slides will make it easier to report to the larger group.

- Use one or more slides to summarize the technical DIC & HMI issues, especially regulatory ones that need to be addressed.
- Use one or more slides to summarize the capabilities that are needed to address the technical DIC & HMI issues.

NRC Workshop Website: http://nrc-test-facility.pnl.gov/

Appendix N

Focus Group – Activities and Output for September 6, 2007

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 6th Focus Group Activity:

Identify Technical Issues & Define Needed Capabilities

Group #1
Facilitator: Jay Persensky, NRC

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DIC & HMI Technical Issues

- Dogwood Group Report-Out
- 9 people in the group
- Determine DIC & HMI research needs and how they can be met. Can existing facilities be used or are new facilities needed?
- Many topics identified needing Research, Development, or a combination of both.
- Examples of areas of research: Software reliability; Sensors; Failure Modes of digital systems; HMI (particular topical areas)

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Dogwood Group (2 of 3)

- Examples of Development: Speed of obsolescence; level of surveillance/testing (i.e., self-testing/calibrating sensors, smart sensors & sensor networks, etc.); cross-training (i.e., NRC, vendors, universities, national/international Labs).
- Capabilities:
- HMI needs full scope/scale physical test facilities augmented with part-task/scale simulation capabilities (e.g., VR, human-system models)
- DIC needs full scope testing facilities and modular desktop engineering scale capabilities (e.g., MATLAB / SIMULINK)

Dogwood Group (3 of 3)

Recommendations

- Recommend using existing capabilities and emerging capabilities vs. develop on own. Develop NRC/Industry/Lab/Academia coordinated research program. Government sponsored, industry-funded, University implemented.
- Short term (Gen 3+ up to 2016): use vendor simulators to do application-specific data generation.
- Long term and generic issues (e.g., Gen IV) recommend use of modular, reconfigurable physical facilities.

DIC & HMI Required Capabilities
Thursday, September 6
Focus Group #1

- HMI: Modular reconfigurable full-scope simulator with human performance measurement capability
- Access to qualified operators
- DIC: Modular reconfigurable full-scope test facility
- Funding
- Outside industries—bench mark
- Operating experience
- Coordinate research by an industry-government consortium. Government sponsored. Industry funded and university implemented.
- Short term (GEN 3+): use vendor simulators
- Long term (GEN 4): MRFSS test facility
- Unified research plan

DIC & HMI Technical Issues
Thursday, September 6
Focus Group #1

- Data storms
- New failure modes
- Credit for self-testing
- Defense in Depth
- Level of Surveillance testing
- Speed of obsolescence
- Life cycle planning
- Regulatory adaptability
- Cross training   Industry ⇔ Government
- Use of VR to reduce costs of facility
- Safety to non-safety interface
- Sensors development
- Sampling rates
- Backup systems
- Digital buss technology for process transmitters i.e. speed & sensitivity
- Integrated operations
- Alarm prioritization
- Complexity management
- Level of automations
- Computerized procedures
- Training vs research
- Interface with screens
- Sensors to screen signal
- Software reliability/system reliability
- Use of digital operational experience
- Human reliability --- Life Cycle Risk Analysis
- Methods/metrics/standards
- Maintain situation awareness
- Embedded training
- Human mitigation of software
- What does operator need to know
- Degradation of I & C
- On-line monitoring

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 6th Focus Group Activity:

Identify Technical Issues & Define Needed Capabilities

Group #2
Facilitator: Ted Quinn, GE

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DIC & HMI Technical Issues (1a)

- Resolve common cause failure/ common mode failure regulatory issue, by demonstration, to understand end result
- Cyber Security; QA; testing, scanning, vulnerability and penetration
- Electronic communications between safety and non-safety and between safety
- Tools we use today for personnel error reduction need to be validated or create new tools
- Do defenses for event prevention (line of defensibility) transfer from analog world to digital world?

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DIC & HMI Technical Issues (1b)

- Inherent complexity of highly automated highly integrated control room
- Inaccurate or incomplete operator mental model
  - Mode confusion by interaction of operator to the machine
  - Lack of/ limited situational awareness of the operator (out-of-the-loop)
  - Behavioral change – not to touch & let computer do it instead
- Keep operator out of "knowledge-based error mode"

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DIC & HMI Technical Issues (1c)

- Lack of consistent technical understanding of digital I&C -HMI, depth and breadth across all NRC
- On-line diagnostics and remote plant monitoring
- Wireless technology deployment
- Advanced sensors
- Managing obsolescence and replacement of digital systems

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Capabilities Needed (2a)

- NRC must have capability to adequately review, to assess, make recommendations, identify deficiencies

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Capabilities Needed (2b)

- Demonstrate adequate diversity of digital I&C while subject to CCF (including the relative merits of acceptability of various methods)
- Demonstrate defensive measures under various challenges
- Demonstrate non-interference between various non-safety and safety systems and cross-channel communications
- Validate that the right Human error prevention tools can be used in the right situations to get the right results, in the automated digital I&C –HMI control room

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Capabilities Needed (2c)

- Capability to validate that the right defense in depth methodology (engineering controls, administrative, management and cultural)
- To develop “best practices” to reduce or eliminate mode confusion
- To develop “best practices” to keep the operators in tune with the plant dynamics (in-the-loop); cover internal and external operational experience review
- Capability to train whoever (I&C techs, operators) to understand using an actual simulation and demonstrate consistent new behavior

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Capabilities Needed (2d)

- NRC familiarization training; capability to demonstrate full aspects of the plant (extends beyond the control room; on-line monitoring) for digital I&C
- Demonstrate that the test-bed is adaptable, reconfigurable, and evolve-able in response to new and emerging digital I&C technologies

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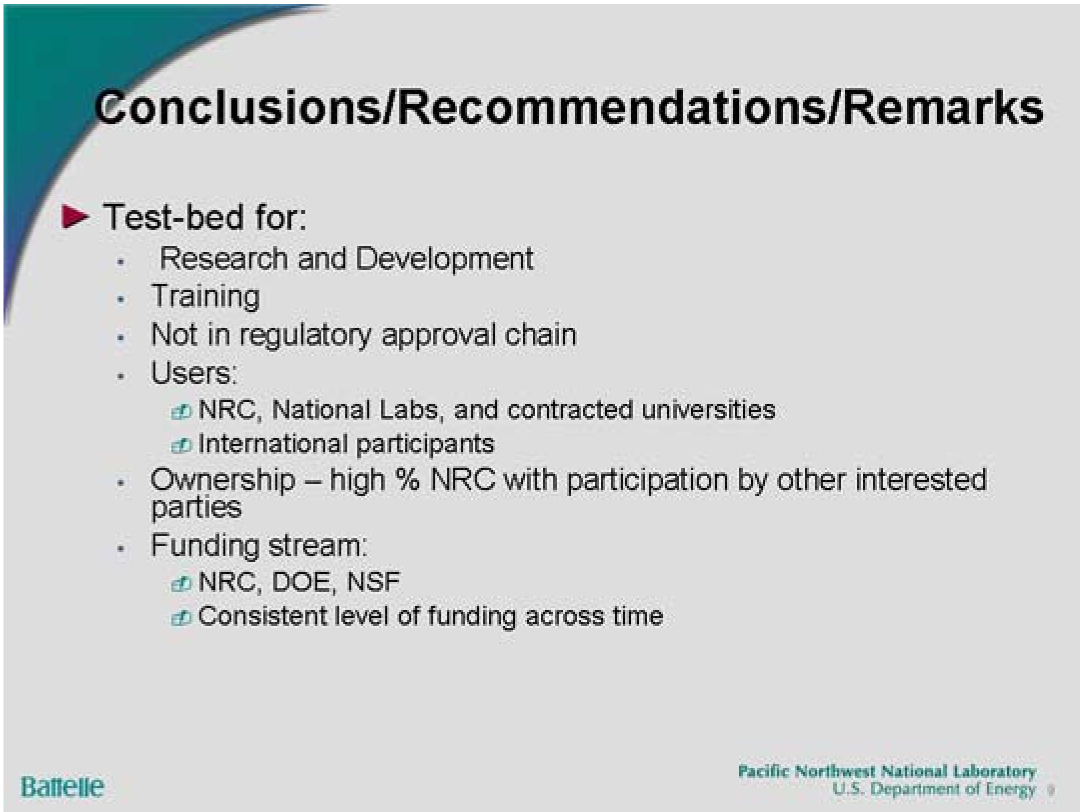
Conclusions/Recommendations/Remarks
Test-bed for:
Research and Development
Training
Not in regulatory approval chain
Users:
NRC, National Labs, and contracted universities
International participants
Ownership – high % NRC with participation by other interested parties
Funding stream:
NRC, DOE, NSF
Consistent level of funding across time
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DIC & HMI Required Capabilities
Thursday, September 6
Focus Group #2

- Demonstrate adequacy of diversity of I&C systems while subject to CCF**.**
- Cyber security
- Demonstrate non-interference between NS & S and cross channel communications
- Capability to validate tools that are being used
- Capacity to validate the defense in depth method that has been use.
- To develop best practices to reduce or eliminate mode confusion.
- To develop best practices to help operations in loop & cover internal and external OE.
- Capacity to do familiarization training on a simulator
- Ability to demonstrate digital I&C, online monitoring, wireless.

DIC & HMI Technical Issues
Thursday, September 6
Focus Group #2

- Assessing capabilities of emerging I & C.
- Need capability to review, assess, and make recommendations
    - Identify violations
    - Integral to the regulatory process

- Solid knowledge base
- Resolve CCF – regulatory issue by demonstration
- Cyber Security
    - Testing
    - QA
- Electronic communication –protocols
- Tools we use today need to be validated or create new ones to achieve error reduction.
- Defenses transferred to digital.
- Inherent complexity of programmable digital system.
- Situation Awareness—what should be happening? Driving or passenger?
- Behavioral change—not to touch and let the computer do it.
- Bottom line—stay away from knowledge-based error mode.
- Lack of consistent technical understanding of ICHMI—breadth and depth across all of NRC
- On-line digital remote plant monitors
- Wireless deployment
- Advanced sensors
- Maintaining old system—overcome obsolescence.

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 6th Focus Group Activity:

Identify Technical Issues & Define Needed Capabilities

Group #3
Facilitator: Joe Naser, EPRI

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DIC & HMI Technical Issues

- Work force
- Computerized procedures
- Transparent automation
- Validation
- Wireless
- Information overload
- Situation awareness
- Human reliability
- Solve Gen 3, Gen 3+, Gen 4 issues?

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DIC & HMI Technical Issues

- New instrumentation
- Operator role / plant design
- Supervisory control
- Control centers for non generation facilities
- Smart sensors in hazardous environments
- Sensor information network
- On-line monitoring early fault detection, diagnostics, prognostics
- Configuration control

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DIC & HMI Technical Issues

- Generic criteria for evaluation of technologies
- Digital obsolescence strategy
- Remote monitoring and advisory capability
- Cyber security

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Capabilities Needed

- Accessibility to wide range of staff, users, test subjects
- Training methods
- Validation methods
- Multi-purpose and configurable simulation capability
- Data collection and storage facilities
- Data evaluation and analysis tools
- Ability to collect, exchange and distribute information
- Standardize data format

Capabilities Needed

- Data access management
- Collaborative virtual environment
- Adequate physical infrastructure / flexibility
- Centralized management of facility
- Strategic plans for 3-5 years
- Simulator functions to challenge performance shape factors
- Consistency in operation to compare results with others

Capabilities Needed

- Include hardware in the loop (even remotely)
- Multiple external facilities for test

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Conclusions/Recommendations/Remarks

- We have identified several issues and capabilities for consideration

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DIC & HMI Required Capabilities

Thursday, September 6
Focus Group #3

- Access to wide range of
    - Technical staff
    - Users
    - Test subjects
- Training methods
- Validation methods
- Multipurpose and configurable simulation capability
- Data collection and storage facilities
- Data analysis and evaluation tools
- Ability to collect, exchange and distribute information
- Replay real transients
- Data access management (IT)
- Collaborative virtual environment
- Adequate physical infrastructure/flexibility\
- Centralized management of facilities
- Strategic plans for E.C. (3 -5 years)
- Capabilities to handle large screen displays and a large number of work stations.
- Simulator functions to challenge PSFs
- Simulator limitations
- Consistency in operation
    - To exchange information w/ E.C. Halden
- Sustained programmatic support
- External review board
- Sustained baseline of operation
- Include H.W. in the loop.
- Multiple experimental facilities for testing (net)

DIC & HMI Technical Issues

Thursday, September 6

Focus Group #3

- Work force
- Computerized procedures
- Transparent automation
- Automation level
- Validation
    - Sensors, communication network
    - HMI, operator aids
    - Integrated system validation
    - Risk informed
- Wireless
    - Data transmission
    - Wearable equipment
- Information overload
    - visualization technology
- Situation awareness
    - Out of the work performance problems
- Acceptability of operator aids
- Human reliability
- Solve Gen III, III+, IV issues?
- Availability vs Reliability
- New Instrumentation
    - Passive plant designs
    - GEN IV designs
- "Inherently Safe Designs"
- Human intervention before design intention
- Operator role/plant design
- Supervisory control over:
    - Multiple processes
    - Multiple module control
- Control Centers for distributed non-generation (furl, waste…) utility-like processes
- Smart sensors in hazard environments
- Sensor information network
- On-line monitoring, diagnostics and prognostics, early fault detection
- Configuration control
    - 3rd part SW
- Generic criteria for evaluation of technologies.
- Handling of legacy DBs.
- Additional skills to do the job in the control room
    - Computer skills
- Cultural change
    - Young generation with new skills
- Digital obsolescence strategy
- Remote monitoring and advisory
- Cyber security

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 6th Focus Group Activity:

Identify Technical Issues & Define Needed Capabilities

Group #4
Facilitator: Mike Golay, MIT
et al.
The Board Room

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DIC&HMI Technical Issues That Inhibit Regulatory Acceptance

- TWG High Priority Issues
- Ability of regulator to maintain current technological capabilities
- Ability of regulator to assess complexity, determine the consequences, and limit complexity to allowable envelop [establish metrics, demonstrate/confirm effective approaches]

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DIC&HMI Technical Issues That Inhibit Regulatory Acceptance (cont)

- TWG High Priority Issues
  - Cyber Security
  - Diversity and Defense-in-Depth
  - Risk Informing Review of Digital Technology
  - Highly Integrated Control Room – Communications
  - Highly Integrated Control Room – Human Factors

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Desired Capabilities of DIC&HMI Test Facility Can Support Issue Resolution

Should Facility be purely nuclear?

[Coordinate/collaborate with Process Industry?]

- Address TWG issues [i.e., resolve uncertainties, demonstrate/characterize performance]
- Create research/expert community with integration and coordination
- Provide needed, timely information to staff
- Use nuclear and non-nuclear drivers [simulation (plant, systems, interfaces), test loops, test chambers, research reactor]
- Easily reconfigured HMI capabilities [test-bed with necessary flexibility and fidelity]

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Conclusions/Recommendations/Remarks

- Test Facility can enable more effective introduction of DIC&HMI Technologies but must be pursued in a way that does not distract from current NRC efforts

  DIC&HMI TF focus is Research, Development, & DEMONSTRATION
  - Research capabilities can be established and available to nuclear power stakeholders
  - R&D products (e.g., concepts, methods, algorithms, prototypes) can be proven/benchmarked
  - Technology transfer from other application domains can be investigated and validated for nuclear power suitability
  - Implementation and performance issues can be identified and evaluated
  - Uncertainty can be resolved and unnecessary conservatism addressed

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DIC & HMI Required Capabilities

Thursday, September 6
Focus Group #4

- Should a facility be purely nuclear? Could team with process industry.
- Address TWG issues.
- Create research/expert community with integration and coordination.
- Provide needed, timely information to staff
- Use nuclear and non-nuclear drivers
- Easily reconfigured HMI capabilities.

DIC & HMI Technical Issues

Thursday, September 6
Focus Group #4

- TWG List (11/8/06)
- Ability of regulator to maintain current technological capabilities
- Ability of regulator to limit complexity to allowable envelope.

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 6th Focus Group Activity:

Identify Technical Issues & Define Needed Capabilities

Group #5

Facilitator: Chris Plott, Alion Science & Technology

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DIC & HMI Technical Issues

- From an I&C perspective, any test facility appears to be too late for the next set of plants (i.e., 1-8 years) to be licensed.
- Should support a Gen 3+ (8+ year) capapbility
- There is a need for near term solutions
- Need for independent test capability
- Need to retain separation of NRC oversight (what) and vendor/licensee implementation (how)
- Need to support NRC test, research, and training needs concurrently
- NRC needs advanced reactor training capability for all phases of the plant life cycle

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DIC & HMI Technical Issues

- Need to support new technology integration for all generations of plants
- Need versatility/flexibility for accommodating different technologies
- We don't fully understand all of the gaps for supporting R&D, test, and training
- Need for mechanisms to manage intellectual property
- How will a multi-sponsor facility support the sponsors diverse needs?

Capabilities Needed

- A distributed capability can be implemented in the near-term to evolve into a longer-term integrated capability (group consensus on this)
- Engineer to allow for flexibility in technology integration and plant representation
  - Need robust simulation of specific plant behavior
  - Need to be able to support multiple plant types
- Need to balance complexity/flexibility with cost/responsiveness

Capabilities Needed

- Need capability to obtain and process operating experience from international nuclear industry, test facilities, and other related industries
- Need to be able to prioritize and manage conflicting goals between R&D, test, and training activities
- NRC training capability is critical and should
  - Complement current capabilities
  - Not compete with R&D and testing activities
- Need to support NRC field staff for new construction and testing
- Need to support translation of facility outputs into regulatory guidance and industry feedback

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Conclusions/Recommendations/Remarks

- (intentionally left blank)

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DIC & HMI Required Capabilities
Thursday, September 6
Focus Group #5

- A distributed capability could be implemented near term to evolve in the long term integrated capability (general consensus0
- Need robust simulation of specific plant behavior
- Need to be able to support multiple plant types
- Need capability to get and process OE from international and other industries. Ditto for test facilities.
- Need to be able to prioritize and manage conflicting goals between R&R, test, and training.
- Need to support NRC field staff for new construction and test.
- Need to support translation of facility outputs into regulatory guidance and industry feedback.
- Over engineer to allow for flexibility in technology integration and plant representation.
- Need to balance complexity/flexibility with cost/responsiveness.
- NRC training capability is critical and should a) complement current capabilities and b) not compete with R&D tests.

DIC & HMI Technical Issues
Thursday, September 6
Focus Group #5

- Any test facility appears to be too late for next set of plants to be licensed.
- The need for nearer term solutions.
- Need to retain separation of NRC oversight and vendor implementation
- How will a multi-sponsor facility support their diverse needs. Should support a Gen 3+ test capability (8+ years)
- Need to support NRC test, research, and training needs currently.
- Need to support new technology integration for all generations of plants.
- Need for independent test capability.
- Need versatility/flexibility for accommodating different technologies.
- NRC needs advanced reactor training capability for all phases of plant life cycle.
- We don't fully under all of the gaps for supporting R&D, test, and training.
- Need for mechanisms to manage IP.

<u>Recommendations</u>

Short-Term (1 – 8 years)

- Establish test facility (I&C) to cover testing, licensing, V&V
- Work with Human Factors specialists to develop a basic (simple) HMI

Long Term (> 8 years)

- Have test facility to also encompass research, training, simulation
- Improve HMI to next level? Perhaps virtual reality.

Appendix O

Open Discussion Summary: Capabilities for Workshop September 6–7, 2007

DIC/HMI Workshop

September 6-7, 2007
Atlanta, Georgia

Open Discussion Summary: Capabilities

Cyber-Security (TWG#1)
-

Diversity and Defense-in-Depth (TWG#2)
-

Risk-Informing Digital (TWG#3)
-
Highly Integrated Control Room-Communications (TWG#4)
-

Highly Integrated Control-Human Room - Factors (TWG#5)

(John Summer) Expertise in analyzing digital/human events of consequence to verify corrective actions solve the root cause

Capability to resolve large screen display design for future reactors
- a mixed group of process experts HIS designs and computer scientists
- simulator facility to test out ideas and build prototype
- access to operations to use test designs as they progress

(Kimberly Keithline) The ability to visualize and understand how operators would respond to an accident concurrent with digital common cause failure

(Chris Plott) Models of subsystem including humans that can be used for early integration testing

Fuel Cycle Facility (TWG#7)

Validation (Software) (#8)
(C. Smidts) Reporting of existing Sn code (+doc +…dev history+ operating system experience)+ platforms. or benchmark codes

Advanced Monitoring (#9)
(Tunc Aldemir) Development of smart/context-based testing methodologies

(Hash Hashemain) Sample rate of digital I&C

(Hash Hashemain) High sampling rates are needed for on-line diagnostics of performance of digital I7C equipment

Catch-All (#10)
(David Holcombe) Continuously revise NPIC &HMI best practices

(Barry Johnson) Applied research:
- Real systems
- Real applications
- Industry
- University
- Government

(David Holcomb) Facility capable of license capability by demonstration of advanced technologies (-how will wireless be performed?)

Evaluation Methods and Tools (#11)
(R.T. Wood) Benchmark efforts to demonstrate/confirm/compare components/methods/testing regimes

(Ted Quinn) Integrate part-task simulator PNRT-TNSK digital simulator into the NRC training program

(Brian Arnholt) Benchmark and data gathering from non-nuclear process industries using digital I&C technology

(R.T. Wood) Systematic execution of research analysis, evaluation, confirmation

(R.T. Wood) Simulation tool/hardware-in-loop testing capabilities resources

A design for verification and validation mindset from the outset – emphasis of the scientific process

(Rick Libra) To solve: The use of systematic problem solving methods and clear management process AND access to the solutions by all parties

Policy/Organization (#12)

(Frank Quinn) Learn to share and learn to borrow

(F.J. Wyant, SNL) Interact- contract with experts from outside nuclear industry to access their solutions to similar issues

(Brian Arnholt) Effective means of vendors gov't industry to share information without compromising intellectual property

(Halden Project) One capability needed… to have test facility that can address both the safety aspects of DIC and (its influence on the HMI's and) the operation in the control room

(Rick Libra) To solve: Need clear <u>ownership</u> of the I&C issue to assure accountability and support of resolution

(Don Dudenhoeffer) Prioritize list of objectives and a systematic execution plan/timeline focusing on the nuclear industry

(John Summers) Using system approach towards defining training needs associated expertise to develop the resulting framing

(Carl Benhardt) The capability of the NRC to make a firm statement that the methodology provided in NUREG 0800/0711 will not be shortcut for the convenience of industry

(Barry Johnson) Multi-disciplinary research: technologies, applications

(R.T. Wood) Optimized coordinated efforts rather than spotty critical-path/funding driven by coverage issues

(M. Golay) Formalization of NRC of mechanisms for creation of unsafe conditions and statement of acceptance criteria

(Frank Quinn) Stop thinking that radation is more dangerous than chemical and biological agents (and natural phenomena)

(Al Haghighat) Employ hands-on training and workforce for reactors for design and construction of digital I&C

(Barry Johnson) Workforce and development: EE, CS, ME, that understand nuclear technology and systems engineering

(Russell Sydnor) Improved integration of DIC-HMI design and regulatory issue resolution, e.g. do diversity and defense in depth aspects of actually impede operation

Reporting (#13)
(Gordon Clifton) Capability to provide reports of successful application of DI&C (Lessons learned, op experience, etc)

(Russell Sydnor, NRC/RES) Catalog of current capability for DIC HMI test, R&D support expertise.

Appendix P

Overview of Day 1 Results, Q&A

Presented by
Steven Arndt
September 7, 2007

Overview of Day 1 Results, Q&A

September 7, 2007

Steven Arndt
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research
(301-415-6502, saa@nrc.gov)

Progress Made

- Very good opening remarks from several speakers
- Review of current and future technical needs
- Review of existing capabilities, Leonard Bond, PNNL
- Development of technical issues that need to be solved
- Development of capabilities are needed to support resolution of these issues
- Large amount of common ground on technical issues and needed capabilities

Summary in General Session and Working Groups Issues

- Large number of issues that fall into
  - Cyber Security
  - Diversity & Defense-in-Depth
  - Risk-Informing Digital I&C
  - Digital Systems Communications
  - Control Room and beyond control room, human factors
  - Fuel cycle Facilities
  - Validation (software etc.)
  - Advanced Monitoring/Diagnostics
  - Advanced Sensors
  - General Issues
- A number of these issues

Summary in General Session and Working Groups Issues

Cyber Security

- Need to understand hoe to design digital system so that the security of they have secure network.
- Need to developments to assess both cyber security and safety and designs that can provide both capabilities.
- Better technologies, tools and procedures to help assess the level of digital systems to cyber security concerns in the presents of growing cyber security concerns.

Some of these issues are being currently address at current DOE facilities

Summary in General Session and Working Groups Issues

Diversity & Defense-in-Depth

- Need for better common cause failure (diversity) review criteria
- Better decision criteria for determining if there is a need for analogue backup display for selected safety parameters?
- Need for a better way to determine what safety functions need an automatic diverse actuation system?
- The ability to visualize and understand how operators would respond to an accident concurrent with digital common cause failure
- Resolve common cause failure/ common mode failure regulatory issue, by demonstration, to understand end result

Short term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities

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Summary in General Session and Working Groups Issues

Risk-Informing Digital I&C

- Need for digital system risk modeling capability
- Need for software quality/reliability
- Need for physics based probabilistic models for sensors and systems in general that will continuously be updated by sensor data that eventually might contribute to predicts sensor/system status
- System reliability modeling methods. Need for better ways of estimating CCF. Better safety assessment methods for integrated hardware/software systems.
- Human reliability
- How do we measure/quantity defensive measures? Do defenses for event prevention (line of defensibility) transfer from analog world to digital world?

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

Summary in General Session and Working Groups Issues

Digital Systems Communications

- Criteria for use of wireless data transmission for safety applications
- Review criteria for large screen display designs for current and future plants, particularly if the can/should be dynamic and/or interactive
- Multi-unit control room integration and associated regulatory issues
- Electronic communications between safety and non-safety and between safety
- Better understanding of protocols such as foundation fieldbus and PROFIBUS.

Short term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities, but additional capabilities may be needed

Summary in General Session and Working Groups Issues

Control Room and beyond control room, human factors

- How should the regulatory basis for new simulators be changes (if at all) Regulation Guide 1.149; 10CFR 50.55.46; ANS 3.5
- What will be the acceptance criteria for computerized support systems for operators where [it] could impact safety
- What kind of displays and representations on control screens best integrates with the requirements of digital systems? How should this feedback be accomplished?
- How should integrate computerized procedures be implemented? Should they be text oriented and/or integrated in the control displays
- Transition of decision capabilities/responsibilities from human to machine. Multi-unit plants near autonomy.
- How to quantify effectiveness of HMI that is developed. What are the metrics?

Summary in General Session and Working Groups Issues

Control Room and beyond control room, human factors

- How will operators behave in a new control room, should they be able to reconfigure the control room? How flexible should the control room be? Control room discipline.
- Humans reacting to a digital fault respond consistently (independent of experience).
- What will be the best integration or best mix of human and automation resources to achieve safe and efficient operation?
- How does the initial presentation or choose of standard screens affecting operator response
- Does ability to remotely monitor plant data detract from operator responsibility?
- How to avoid common trap on information overload to the operator

Summary in General Session and Working Groups Issues

Control Room and beyond control room, human factors

- How do you management the logic in systems to enable operators to maintain global situation awareness and do troubleshooting in a computer-based CR with 100 or hundreds of displays
- How to integrate the use of human performance effort prevention tools and digital controls
- Determining a set of performance measures and criteria for the evaluation of human-machine systems.....can it be standardized?
- Human Performance/system validation for procedure response requirements with new technologies.
- The digital control room; integrated system validation. What kind of acceptance criteria should be provided?
- Acceptance of use of part scope and other simulation capabilities as well as full scope simulators especially for upgrades
- Acceptance a) reduce number of MCR operators and b) control of multiple units from a centralized location

Summary in General Session and Working Groups Issues

Control Room and beyond control room, human factors

- Inherent complexity of highly automated highly integrated control room
- Inaccurate or incomplete operator mental model
  - Mode confusion by interaction of operator to the machine
  - Lack of/ limited situational awareness of the operator (out-of-the-loop)
  - Behavioral change – not to touch & let computer do it instead
- Keep operator out of "knowledge-based error mode"
- Cross cultural issues in control room design. Japan/France/US/GB

Short term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities, but additional capabilities (research simulator) may be needed

Summary in General Session and Working Groups Issues

Fuel cycle Facilities

- What criteria should be established to support digital I&C and HMI for multiple/different mission of future plants: 1) hydrogen generation, 2) process steam for other uses, 3) electricity production.
- How should different facility modes of operations be implemented (monitoring mode status, operative reactor facility, Chem. Plant facility or systems)? How should the HMI be designed?
- In the fuel cycle facilities rapid obsolescence of digital technology will be an even bigger issues because of the use of COTS. How do you manage this?
- Control centers for non generation facilities

This work is not currently being address at current university and DOE facilities, additional capabilities may be needed

Summary in General Session and Working Groups Issues

Validation (software etc.)

- Need for methods and tools for technology neutral (performance based) evaluation of new DIC and HMI concepts.
- Need for digital complexity and quality control modeling
- Need for better post modification testing. Models for testing to system perform
- Managing & keeping up with advances in technology. Example: computer systems & hardware, displays, etc.
- Better test and analysis protocols and techniques. Means for crediting these tests in regulatory reviews
- Better ways to validate software reliability/safety quantification methods for the digital I&C system.
- The quantitative assess of dependable system—emerging and future digital I&D.
- How can the industry use incremental validation and verification?

Summary in General Session and Working Groups Issues

Validation (software etc.)

- How can the industry use incremental validation and verification? Being able to focus and limit V & V when changes are made yet ensure effectiveness.
- Objective software quality/dependability metrics, what constitutes necessary and efficient?

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

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Summary in General Session and Working Groups Issues

Advanced Monitoring/Diagnostics

- Configuration control of development tools-versions of FPGA software tool sets.
- On-line diagnostics and remote plant monitoring
- Early fault detection, diagnostics, prognosis
- Issue: How to perform(?) on-line monitoring by means of software
- Monitoring who does(?) and how are plants monitored remotely?
- Standards for health monitoring and advice operator support, task management, integrated oversight
- Characterize uncertainty in models and diagnostics

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

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Protecting People and the Environment

Summary in General Session and Working Groups Issues

Advanced Sensors

- Should sensors get more attention in the digital I&C picture. How do you monitor, validate performance, etc.
- Smart sensors in hazardous environments
- Information on new instrumentation to support GENP, NGNP, and other new systems with new requirements
- Sensor information network
- Better sensor validation as well as overall system validation

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

U.S.NRC UNITED STATES NUCLEAR REGULATORY COMMISSION Protecting People and the Environment

Summary in General Session and Working Groups Issues

General Issues

- Removal of barriers to digital technology
- Generic criteria for evaluation of technologies
- Need to support new technology integration for all generations of plants, Need versatility/flexibility for accommodating different technologies
- How do you develop better cost benefit evaluation, methods for judging digital innovation.
- Credit for lessons learned in other industries—new technology. Have higher hurdles than existing ones.
- Digital obsolescence strategy, how do you manage a much more rapid digital system life cycle?
- How will DIC/HMI test facility be made flexible enough to support multiple user needs?

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Summary in General Session and Working Groups Issues

General Issues

- How can one generic research facility that will be reconfigured address different plant designs and different plant control and protection systems?
- Improved International coordination/cooperation
  - Harmonization of International Standards.
- Development of better/more complete training
  - Hands on training
  - Advanced reactor training capability for all phases of the plant life cycle
  - Determination of adequate staffing levels for main control room.
  - Importance of hands-on simulator as parrot of training new staff.
  - How to best develop/engage next generation of engineers and scientists. Training of new staff on R&D safety principles in digital systems.

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Summary in General Session and Working Groups Issues

General Issues

- Lack of consistent technical understanding of digital I&C -HMI, depth and breadth across all NRC
- How do you provide continued funding to support long term development of research and test capabilities
- Forget "catch-up" (40 years behind) and try to get ahead
- Need to retain separation of NRC oversight (what) and vendor/licensee implementation (how)

Appendix Q

Focus Group Instructions, September 7, 2007

Focus Group Instructions

September 7   9:00 – 11:00 am

FOCUS GROUP ASSIGNMENTS

1) Identify options/models for a DIC & HMI integrated test facility capability &
2) Note the advantages/limitations of each option/model.

FOCUS GROUP LOCATIONS

Group #1: Dogwood Room
Facilitator: Jay Persensky, NRC

Group #2: Topiary Room
Facilitator: Ted Quinn, GE

Group #3: The Palms Room
Facilitator: Joe Naser, EPRI

Group #4: The Board Room
Facilitator: Mike Golay, MIT

Group #5: Azalea II & III
Facilitator: Chris Plott, Alion Science & Technology

FOCUS GROUP PROCESS

The group facilitator will help the group address the questions below and keep things moving. Work at a 'high level." Don't get into the details. Short, concise inputs please; no long dissertations.

Use the flipchart pad and markers to record ideas, comments and results. Use 45 minutes to identify a list of options/models that could accomplish the testing and research. Similarly use 45 minutes to identify the advantages/limitations of each model. Finally use 30 min to summarize your results. Prepare flipcharts to put on the wall <u>and</u> prepare a power point presentation that can be used to report to the total group.

A memory stick will be provided for each group. This stick contains some key documents that you may wish to use in your deliberations. Please save your power point presentations on the memory stick. We will collect the memory sticks from each of the groups at the end of the workshop.

3M flipcharts and colored markers will be provided to each group. Make legible summary charts for the presentation you give to the larger group. These charts will remain posted on the wall.

1) <u>IDENTIFY OPTIONS/MODELS</u> (45 min)

What kind of approach could accomplish the research? Identify at least 2 or 3 options/models for research and briefly note the main attributes of each. Build your own options/models or pick from some suggested by others: 1) No New Facility (NRC enhances what it does), 2) NRC Stand Alone Facility, 3) NRC/DOE Partnership, 4) Government (NRC & DOE)/Industry Partnership, 5) User Facility Approach under NRC management, 6) Center of Excellence Approach, 7) University Consortium Model, 8) Distributed Center Approach, and others. Address the following questions as you consider these options/models:

1. What potential participants might be interested in joint participation, collaboration, and funding these research and test capabilites, and to what extend might this include industries outside the nuclear industry? (SRM #1)
2. Do examples of similar facilities currently exist and, if so, what can be learned from their successes and challenges? (SRM #3)
3. What site options are most viable (e.g. universities where integration with graduate studies might be encouraged, national laboratories, etc.), taking both cost and ease of technical information exchange into account? (SRM #4)

<u>LIST ADVANTAGES/LIMITATIONS FOR EACH OPTION/MODEL</u> (45 min)

For each of the models identified in the first part, list the advantages and limitations.

<u>FOCUS GROUP REPORT</u> (30 min)

Prepare summary flipcharts of your work <u>and</u> power point slides for the presentation of your results. Write your Group # on each page. The flipcharts will be posted on the wall so that we can compare findings across the five Focus Groups. The slides will make it easier to report to the larger group.

- Use one or more slides to summarize the options, basic attributes and advantages/limitations.

NRC Workshop Website: http://nrc-test-facility.pnl.gov/

Appendix R

Option Evaluations

Group # 1 Options Evaluation

OPTION A: NO NEW FACILITY

Advantages

- No additional costs or locations
- Continuity of on-going efforts
- Ability to leverage existing capability
- Quicker response
- Competition

Disadvantages

-
- Limited coordination
- Lack of unifying plan
- Competition—sharing
- Inability to get quality information; no collaboratioin
- Inability to respond quickly to emerging need

OPTION B: INTEGRATED NRC LEAD

Advantages

- Meet long term needs
- NRC/own prioritization
- Ability to react to emerging needs
- Security
- Critical mass
- Openness
- Co-location for collaboration

Disadvantages

- High cost
- Need to relocate
- Staffing
- Single facility can't meet all needs
- Difficulty with proprietary equipment etc.
- Could disrupt existing work
- Regulator is impediment to full disclosure
- Lack of access to innovative technology
- Openness

OPTION I: DISTRIBUTED - CONSORTIUM

Advantages

- Have to have unifying plan
- Need for business model for cooperation
- Focus on long-term needs
- Lower costs—leveraging costs
- Less relocation
- Technical experts and technology co-located
- Continuity of on-going efforts
- Centers of Excellence (global)

Disadvantages

- Unifying plan not available yet
- Prioritization to meet various sponsors competing needs
- Hard to focus on emerging needs
- Need for new or modified technology
- Limited collaboration among staff
- Lack of critical mass
- Need for New facility to meet gaps

OPTION DOGWOOD:

Option I as government sponsored, industry funded and university/laboratory implemented.

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 7th Focus Group Activity:

Identify Options/Models for DIC & HMI Integrated Test Facility and Note Advantages/Limitations

Group #1
Facilitator: Jay Persensky, NRC

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Options/Models Considered

- Dogwood Group Considered Four Options:
  - Option A: No New Facility
  - Option B: NRC Led-Integrated Facility
  - Option I: Distributed Consortium
  - New Facility?

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Option A: No New Facility Advantages

- No Additional Costs or Facility Needs
- Maintain Continuity and Momentum of Ongoing Efforts
- Ability to Leverage Existing Capabilities
- Quicker Response Time
- Competition

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Option A: No New Facility Disadvantages

- Limited Coordination of Ongoing Work
- Lack of a Unifying Program or Plan
- Competition: Lack of Information Sharing
- Inability to React Quickly to Emergent Needs

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Option B: NRC Led-Integrated Facility Advantages

- Meet Long-term Needs
- NRC Establishes Priorities
- Ability to React to Emerging Needs
- Ability to Maintain Security of Facility
- Critical Mass within NRC (staffing)

Option B: NRC Led-Integrated Facility Disadvantages

- High Cost
- Need to Acquire/Relocate Facility Staff
- Single Facility Cannot Meet All Needs
- Regulator is Impediment to Full Disclosure
- Lack of Access to Advanced Technology Being Developed by Vendors
- A Single Facility Cannot Meet All Needs
- Difficulty with Proprietary Information

Option I: Distributed Consortium Advantages

- Need to Have Unifying Plan
- Need for Business Model for Cooperation
- Ability to Focus on Long-term Needs
- Leveraging Costs
- Keep Technical Experts Close to Technology
- Maintain Continuity of Ongoing Efforts
- Global Centers of Excellence Model

Option I: Distributed Consortium Disadvantages

- Prioritization of Meeting Competing Needs
- Hard to Focus on Emerging Needs
- Consensus for New or Modified Technology
- Lack of Critical Mass
- Limited Collaboration Among Experts
- Need for New Facility to Meet All Needs

Option Dogwood: ?

- ??? (intentionally left blank)

Conclusions/Recommendations/Remarks

- Group Consensus is a Global Distributed Consortium
  - Able to bridge gap and leverage existing capabilities and future needs
    - Government Sponsored
    - Industry Funded
    - University/Lab Implemented
  - Requires New Facility Capabilities to Address All Needs
- Best Options Carry Staffing Issues
  - Developing/training new staff
  - Relocation of people

Conclusions/Recommendations/Remarks

- Development of University Programs to Address Staffing and Qualification Issues
  - Specialized Post-Graduate Programs
  - Need for Operators as Test Subjects

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Group #2 Options Evaluation

Option C: New Integrated Facility NRC/DOE Partnership

Pros	**Cons**
#1 Easy to do “security” research	#1 Less “leading edge” access for security research
#2 & #4 Centralized research fac. and provides best location for D3 model testing and validation	#2 High $ because not cost shared by users
#3 Ease of multi-disciplinary research	#3 “Reduced knowledge sharing
#5 Centralized facility for HMI/HIS research	#5 Vulnerability to federal budget appropriations (start-up & continuation)
#8a Integrated with the physical control room #8b Better security of plants reliability data	#8a “Reserved licensee participation, at the L’s site
#9 Highly customized facility best mated to user’s need	-
#10 OJT & TPE (&DLA) – Practical hands-on training	-

Option E: National User Facility “Center for Excellence” NRC User Facility (DOE-Office of Science model)

Pros	**Cons**
#1 With controls in place, good access to security related info	#1 Rigorous controls required to be in place prior to doing security research
#2a Centralize research fac. Provides best location for D3 model testing and validation #2b Reduced federal $ for start-up & O&M costs	#2a “Conflicted” vendor involvement -
#3 Ease of multidisciplinary research	#3 Reduced knowledge sharing
#5 Centralized facility for HMI/HIS research	#5 Less vulnerable to budget appropriations
#8 Acceptance of licensee participation, (when testing advanced monitoring, etc) at the L’s site	-
#10 Practical hands-on training	-

Option I: Distributed/Consortium

Pros	**Cons**
#1 Most access to cutting edge security	#1 Least access to clearance related info
#2 Access to world-wide expertise	#2a Limited vendor involvement, unless at their site #2b Export control issues
#3 Greater knowledge sharing	#3 Harder to co-ordinate multi-disciplinary research
#5 Least vulnerable to specific budget appropriations (NASAG, IAEA.CRIEPI)	#5a Hard to distribute the (MCR) activity across numerous sites #5b Challenge of fiscal year distribution by consensus
#9 Pre-existing facilities for harsh environment sensor development & testing (can save $)	#10 Distance learning challenges

HYBRID – 'ICE' Model

• Hub and spoke hybrid

• Incorporate "Pros," minimize "Cons"

• Need a primary owner

• Funding may be a significant challenge

• Centralize facilities
where necessary and all others

• Decentralized where possible

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 7th Focus Group Activity:

Identify Options/Models for DIC & HMI Integrated Test Facility and Note Advantages/Limitations

Group #2
Facilitator: Ted Quinn, GE

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Options/Models Considered

- ☐NRC/DOE Partnership
- Office of Science or NSF Model
- Distributed Center/Consortium
- Hub and Spoke

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Option C—New Integrated Facility

NRC/DOE Partnership

	Pro:	Cons:
Cyber Security	Easy to do security research	Less *leading edge* access
D^3 & Communications	Provides central research facility - best for D3 model validation & testing	High $ - not shared by users
Risk Informed	Ease of multi-disciplinary research	Reduced knowledge sharing
Control Room & Human Factors	Centralized facility	Vulnerable to budget appropriations (start-up and operations)
Fuel Cycle Facilities	DOE facility required	
Validation	neutral	
Advanced Monitoring/Diagnostics	Integrated with physical control room. Better security of plant reliability data.	Reserved licensee participation at their site
Sensors	Highly customized capabilities	New facilities more expensive
General	Practical hands on training - experiential learning	

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Option E—National User Facility

Office of Science or NSF Model

	Pro:	Cons:
Cyber Security	With strong controls, good security access	Rigorous controls required
D^3 & Communications	Provides central research facility - best for D3 model validation & testing Reduced federal expenditure	*Conflicted* vendor involvement
Risk Informed	Ease of multi-disciplinary research	Reduced knowledge sharing
Control Room & Human Factors	Centralized facility	Less vulnerable to budget vagaries
Fuel Cycle Facilities		
Validation	neutral	
Advanced Monitoring/Diagnostics	Ease of licensee participation at their site	
Sensors		
General	Practical hands on training - experiential learning	

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Option I—Distributed Center/Consortium

	Pro:	Cons:
Cyber Security	Most access to cutting edge security	Least access to clearance related information
D^3 & Communications	Access to world wide expertise	Limited vendor involvement, unless at their site. Export control issues
Risk Informed	Greater knowledge base	Hard to coordinate multidisciplinary research
Control Room & Human Factors	Least vulnerable to specific budget appropriations (NSAG, IAEA, CRIEPI)	Hard to distribute the (MCR) activity across numerous sites
Fuel Cycle Facilities	Not practical	
Validation	neutral	
Advanced Monitoring/Diagnostics	Ease of licensee participation at their site	
Sensors	Pre existing harsh environment facilities lower cost	
General		Distance learning challenges

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New Option—Hub and Spoke (Hybrid)

- Incorporate the pros and minimize the cons of all of the options
- Need a primary owner
  - Funding significant challenge
- Centralize where necessary - decentralize as possible

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Options/Models Considered (cont. 1c)

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Advantages/Limitations of Each Option/Model Considered

- (intentionally left blank)

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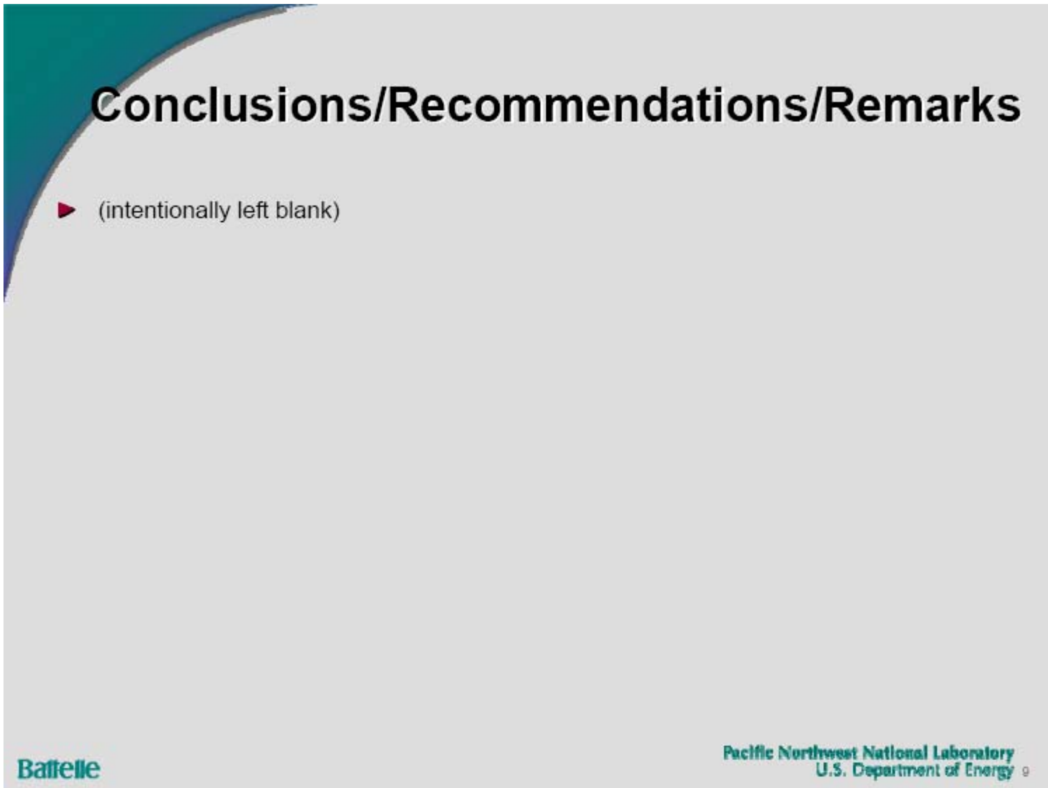
Conclusions/Recommendations/Remarks
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Group #3 Options Evaluation

Option D: Pros

√ • Halden has demonstrated working model
√ • Complete control over resources
√ • Leveraging other funding programs
√ • Reuse of government assets
√ • Ownership and control of "your own" infrastructure
√ • Consistency of staff (?)
√ • Consistency of research
√ • Focus of research
√ • Data and information management in control/security

Option D: Cons

√ • Flexibility research
√ • Access to expertise (National)
• Higher operating cost
• Consistency of Staff Member
• Less flexibility funding
√ • Longer to implement new facility
• Staff building

Option I: Pros

√ • Takes maximum advantage of existing national capabilities
• Fastest start-up
• Quickest way to access existing resources
√ • Experience from other industry
• Tie up other industry labs
• Common use of simulator resources (over net)
√ • Minimum capital cost
√ • Minimum operating cost
√ • Flexible and expandability, scalability
• Larger resource pool
• More diverse
• Greater industry/ext.org involvement
• Broader political support (?)
√ • Modern infrastructure
√ • Sustainability
• Greater utilization of universities, labs, and industry near to satellites

Option I: Cons

- Lack of dedicated infrastructure
- Competition for resources
- Competing priorities
- Center does not control satellites
- Challenge -> maintaining consistency of research

√ • Methods (exchange of data) across satellites
- Less political support (?)

Option I: Challenges

√ • Communication and Satellite infrastructure
√ • Increased coordination efforts
√ • Centralized leadership (Authority vs satellites)
√ • Maintain focus and team spirit across central and satellites
- Security
- Additional admin burden

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 7th Focus Group Activity:

Identify Options/Models for DIC & HMI Integrated Test Facility and Note Advantages/Limitations

Group #3
Facilitator: Joe Naser, EPRI

New Integrated Facility

- D. Government (NRC & DOE) / Industry Partnership

D. Government (NRC & DOE) / Industry Partnership Pros

- Halden has demonstrated working model
- Complete control over resources
- Leveraging other funding programs
- Reuse of government assets
- Ownership and control "your own" infrastructure
- Consistency of staff (?)
- Consistency of research methods
- Focus of research
- Data and infrastructure management in control / security

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D. Government (NRC & DOE) / Industry Partnership Cons

- **Flexibility in research**
- **Access to expertise (national)**
- Higher initial capital costs
- Higher operating costs
- Consistency of staff?
- Less flexibility in funding
- **Longer to implement new facility**
- Staff building

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National User Facility

- F. National Center – Contractor Operated at Laboratory or University
- Not of Interest

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F. National Center – Contractor Operated at Laboratory or University

- Not of interest

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Distributed Center Approach

- I. Distributed Center Approach

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I. Distributed Center Approach: Pros

- **Takes maximum advantage of existing capabilities**
- Fastest start-up
- Quickest way to access existing resources
- **Experience from other industry**
- Tie into other industry resources
- Common use of simulator resources (over net)
- **Minimum capital cost**
- **Minimum operating cost**
- **Flexibility, expandability, scalability**

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I. Distributed Center Approach: Pros

- **Larger resource pool**
- **More diverse resource pool**
- Greater industry / external organizations
- Broader political support (?)
- **Modern infrastructure**
- **Sustainability**
- Greater utilization of universities, labs, industry near to satellites

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I. Distributed Center Approach Cons

- Lack of dedicated infrastructure
- Competition for resources
- Competing priorities
- Center does not control the satellites
- Less political support (?)

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New Option

- Combination of A and D

I. Distributed Center Approach Challenges

- **Maintaining consistency of research methods (exchange of data) across satellites**
- **Communication and satellite infrastructure**
- **Increased coordination efforts**
- **Centralized leadership (authority vs. satellites)**
- **Maintain focus and team spirit across central and satellites**
- Security
- Additional administrative burden

Conclusions/Recommendations/Remarks

- (intentionally left blank)

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Group #4 Options Evaluation

Option C: NRC-DOE Partnership New Facility (Monolithic)

Assumptions:
NRC-DOE recapture AEC fellowship

Pros:
- Existing Univ-Lab relationships
- Potential to pull together
- Direct focus highest level of expertise on critical issues
- Secure environment
- New structure => firewall between Reg. Res & Tech Dev
- Easier integration of DIC-HMI

Cons:
- Innovation inhibited? [Univ. lead; Industry part. Near term]
- Start-up of new facility -> [infrastructure] - + delay
- No clear industry involvement
- Political
- Blurs line between Reg-Promoter
- No Univ leadership

Option G: Industry-University Research Center

Pros:
- Existing model
- Cross cut with other industries
- Expand expert community [grad students; dept university]
- Political
- Existing Univ. Research
- Facilities Base Industry involvement

Cons:
- Focus too narrow? [nuclear industry]
- Short term funding [5 years]
- Security/IP [challenge]
- Political
- DOE labs typically excluded
- Basic research focus
- Broad competition
- Current HRA/HF activity @ national labs
- Role of International organizations?
- More difficult to address regulatory issues

Option I: Distributed Center

Assumptions:
• Many facilities/labs exist and can engaged

Pros:
• Broadened focus beyond strictly regulatory
• Draws from all stakeholders
• Effective use of resources
• Fast start/early returns
• Exiting models [HJRP]
• Buy-in more direct (no external permission)
• Can draw from other industries/agencies more readily
• Coordinated focus
• Integrated access to findings/research
• Regulatory insulation through intermediary board
• Cost effective leverages exiting funding
• Avoid duplication
• Engage international community

Cons:
• Independence?
• Narrow focus
• Security/IP?
• Maintain focus
• Resource competition
• Facility gaps [vendor facilities?]
• Culture/turf issues

Other
Tech integrator active participant?
Independent LLC?

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 7th Focus Group Activity:

Identify Options/Models for DIC&HMI Integrated Test Facility and Note Advantages/Limitations

Group #4
Facilitator: Richard Wood, ORNL
et al.
The Board Room

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Option C – Pros and Cons
NRC-DOE Partnership for New Facility

- Pros
  - Existing university-national laboratory relationships
  - Potential to pull together highest level of expertise
  - Direct focus on critical issues
  - Secure environment
  - New structure – firewall between regulatory research and technical development
  - Easier integration of Digital I&C and HMI

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Option C – Pros and Cons
NRC-DOE Partnership for New Facility

- Cons
  - Innovation inhibited?
  - Startup of new facility
  - No clear industry involvement
  - Political
  - Blurs line between regulator and promoter
  - No university leadership
  - Duplication
  - Sustained cost for dedicated staff (relocate/hire→feed)

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Option G – Pros and Cons
Industry-University Cooperative Research Center

- Pros
  - Existing model
  - Cross cut with other industries
  - Expand expert community
  - Political
  - Existing university research base
  - Facilitates industry involvement
  - Leverage existing NSF Industry-University Cooperative Research Centers on relevant technical focus areas
  - Stimulate innovation

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Option G – Pros and Cons
Industry-University Cooperative Research Center

- **Cons**
  - Focus too narrow?
  - Short term funding
  - Security/IP challenges
  - Political
  - DOE labs typically excluded
  - Basic research focus
  - Broad competition
  - Current HRA/HF activity at national labs
  - More difficult to address regulatory issues
  - Role of international organizations?

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Option I – Pros and Cons
Distributed Center

- **Pros**
  - Draws from all stakeholders
  - Effective use of resources
  - Fast start/early returns
  - Existing models
  - Buy-in more direct – no external permission
  - Can draw from other industries/agencies more readily
  - Coordinated focus
  - Integrated access to findings/resources
  - Regulatory insulation through intermediary board
  - Cost effect – leverages existing funding
  - Avoid duplication
  - Engage international community
  - Broadened subject beyond strictly regulatory
  - Develop consensus
  - Encourages collaboration

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Option I – Pros and Cons
Distributed Center

- Cons
  - Independence?
  - Security/IP?
  - Limited stakeholder base
  - Resource competition
  - Ability to maintain focus
  - Culture & turf issues
  - Consistency/quality of products
- I-prime includes other industries/agencies/facilities plus technical integrator (Active participant? Independent company? LLC?)

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Conclusions/Recommendations/Remarks

- We like I-squared (I,I)
  - Low startup cost
  - Immediate return
  - Little disruption
  - Leverage existing projects and facilities (build/add as needed over time)
  - Most flexibility
  - Few dedicated staff/facilities but matrix/project access to many subject matter experts (SMEs) and research/test/evaluation resources
  - Incrementally add sponsors/stakeholders/resources

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Group #5 Options Evaluation

OPTION A: NO NEW FACILITY

Pros

- Least costly financially (near term)
- Doesn't insert an additional step in the licensing process
- Preserves relationships with existing providers/capabilities
- Doesn't' divert resources from other NRC programs
- May force NRC to maximize existing relationships/capabilities
- May force NRC to better align/embrace international regulatory agencies/approaches

Cons

- Limits opportunities for synergistic research
- Some issues could not be full addressed due to data limitations
- Miss opportunity for more fully integrated testing, so that you could miss unexpected/unknown interactions or failure modes
- Remain dependent on international capabilities and their limited availability
- Limits US's ability to catch up technologically
- May provide better long term financial benefits
- May miss interaction opportunities with other regulatory agencies because of lack of focus on this area

OPTION H: CENTERS OF EXCELLENCE-CONSORTIUM

Pros

- Broad dissemination of results
- Leveraging of knowledge/capabilities across stakeholders
- Greater incentives (survival) to build and maintain user base
- "One stop shopping" for users.
- Fosters a more creative environment
- Fosters relationships with similar facilities across domains
- Fosters international collaboration
- Makes best capabilities available
- Potential to bring benefits of centralized location and consortium together
- Provides better internship/education opportunities
- Enables tailoring of research to specific issues

Cons

- Can't maintain capabilities outside active user funding—need some base funding
- Intellectual property management issues
- Full cost recovery, so small users may not be able to afford without base funding

- NRC needs to get into the cue with other users
- Can't get results in a timely anner
- Governance complexity
- More difficult to leverage results between experiments/studies

OPTION I: DISTRIBUTED - CONSORTIUM

Pros

- Quick start up
- Gets best capability for issue
- No single point failure of system (assuming some duplication of capability)
- Lower start up cost
- No need to pay for capability when not in use
- Keeps larger community engaged due to diversity of participants
- Ca n support multiple research areas at the same time
- Allows for greater budgeting flexibility for NRC
- Immediate utilization of facilities where the capital investments have already been made

Cons

- Funding/partner management could be cumbersome
- Conflict management among partners
- Limited to available capabilities
- Lower incentives for participation
- Lower incentives to develop new capabilities
- Loss of synergies due to distributed participants
- Additional resources may be required to address security issues

OPTION X: PHASED APPROACH

- Sustain current programs (OPTION A) initially
- Kick off an OPTION I program as soon as it can be funded
- Have a migration plan to a centralized facility. NRC funded and led for nuclear specific, and user for more general DIC & HMI
- Establish a joint international research planning capability

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

September 7th Focus Group 5 Activity:

Identify Options/Models for DIC & HMI Integrated Test Facility and Note Advantages/Limitations

Group #5
Facilitator: Chris Plott, Alion Science & Technology

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Option A: No New Facility

- Pros
  - Least costly in the near-term
  - Doesn't insert an additional step in the licensing process
  - Preserves relationships with existing providers/capabilities
  - Does not divert resources from other NRC programs
  - May force NRC to maximize existing relationships/capabilities
  - May force NRC better align/embrace international regulatory agencies/approaches

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Option A: No New Facility

- Cons
  - Limits opportunities for synergistic research
  - Some issues could not be fully addressed due to data limitations
  - Miss opportunity for more fully integrated testing, so that you could miss unexpected/unknown interactions or failure modes
  - Remain dependent on International capabilities and their limited availability
  - Limits US ability to catch up technologically
  - May provide better long-term financial benefits
  - May miss interaction opportunities with other regulatory agencies because of lack of focus on this area

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Option H: Center of Excellence-Consortium

- Definition
  - One physical location multiple partners provide capabilities funded by users
  - All facility costs provided by facility users
- Pros
  - Broad dissemination of results
  - Leveraging of knowledge/capabilities across stake holders
  - Greater incentives to build and maintain user base (survival)
  - "One-stop shopping" for users
  - Foster a more creative environment
  - Fosters relationships with similar facilities across industrial domains
  - Fosters international collaboration

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Option H: Center of Excellence-Consortium

- Pros (Continued)
  - Makes best capabilities available
  - Potential to bring benefits of central location and consortium together
  - Provides better internship/educational opportunities
  - Enables tailoring of research to specific issues
- Cons
  - Can't maintain capabilities outside active user funding (need some base funding)
  - Intellectual property management issues

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Option H: Center of Excellence-Consortium

- Cons (Continued)
  - Full cost recovery – so small user may not be able to afford without base funding
  - NRC needs to get into the cue with other users (may not get results in a timely manner)
  - Governance complexity
  - More difficult to leverage results between experiments/studies

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Option I: Distrubuted Consortium

- Pros
  - Quick start-up
  - Gets best capability for issues
  - No single point failure of system (assuming some duplication of capabilities exists)
  - Lower start-up costs
  - No need to pay for capabilities when not in use
  - Keeps larger community engaged due to diversity of participants
  - Can support multiple research areas at the same time
  - Allows for greater budgeting flexibility for NRC

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Option I: Distrubuted Consortium

- Pros (continued)
  - Immediate utilization of facilities where the capital investments have already been made
- Cons
  - Potentially limited to available facilities
  - Lower incentives for participation
  - Lower incentives to develop new capabilities
  - Loss of synergies due to distributed participants
  - Additional resources may be required to address security issues

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Option I: Distrubuted Consortium

- Cons (continued)
  - Funding/partner management could be cumbersome
  - Conflict management among partners

Option X: Evolutionary Model

- Initially sustain current programs (Option A)
- Kick-off an Option I program as soon as funding can begin
- Have a migration plan to a centralized facility
  - NRC funded/led for nuclear specific and other users for more general DIC/HMI
- Establish a joint international research planning activity

Appendix S

NRC Workshop Digital Instrumentation and Control (DIC) and Human Machine Interface (HMI) Workshop Part A Summary Report

NRC Workshop Digital Instrumentation and Control (DIC) and Human Machine Interface (HMI) Workshop Part A
Summary Report

At the workshop in Atlanta the assembled Digital I&C and HMI experts reviewed current and future issues, necessary capabilities to address these issues, gaps that may exist in current capabilities. Preferred options for future research and testing capabilities were also discussed. Based on the limited review of the technical gaps, capabilities it was determined that capabilities exist to meet most short term (current to 3 years) needs somewhere in the US. However, Nuclear Regulatory Commission (NRC) needs to more effectively use them for development of regulatory guidance and the associated technical bases for ALWR and control room retrofits. For advanced reactors (Gen IV, GENP, etc.) fewer capabilities exist. The only major missing capability identified was a "research" simulator for regulatory human factors research; however, vendors do have some capabilities in this area. In this area staffing issues (i.e. operator availability for testing) most be considered. There was also a discussion of the need for a full scope (from sensors to displays) digital I&C test bed dedicated to research applications. The vendor community indicated that their facilities could fulfill this need.

The workshop attendees indicated that the NRC staff may benefit from more training/education on the full life cycle of digital systems and hands-on training. There may be some advantages to co-locating new reactor training simulators and research simulators to defray costs. Research simulators must be reconfigurable, whereas training simulators must replicate a constant and referenced facility. Therefore training and research, but they should not rely on the same simulator. The very limited current university programs that focus on safety critical DIC & HMI or nuclear DIC & HM are not sufficient to meet existing and future needs.

There was general agreement that the preferred option for addressing future testing and research capabilities should involve a centralized program office at a hub, and a distributed network of facilities (satellites). Neew capabilities, if needed, would be developed at either a the hub or at a satellite, as appropriate. This hub and satellite option most effectively uses the currently available capabilities while it provides the flexibility for preparing for the future.

Part of the solution must be to continue to reach out to the international community and find additional opportunities to coordinate with other industries, other countries, and consortia.

Appendix T

Attendance List – September 11, 2007

NRC MEETING SEPTEMBER 11, 2007 - Washington, DC

NAME	ORGANIZATION	PHONE NO.	EMAIL
Aldemire, Tunc	Ohio State University	614-292-4627	aldemir.T@osu.edu
Arndt, Steven	NRC/RES	301-415-6502	saa@nrc.gov
Arnholt, Brian	GE	540-387-7125	brian.arnholt@ge.com
Blessing, David	Lockheed Martin	571-309-0185	david.l.blessing@lmco.com
Bond, Leonard	PNNL	509-372-4172	leonard.bond@pnl.gov
Brenchley, David	PNNL	509-375-6515	Dr.B@pnl.gov
Burr, Janice	GE	540-387-8913	janice.Burr@ge.com
Castleman, Pat	NRC	301-415-1750	pic@nrc.com
Crotazu, Rick	NRC	301-415-6010	RXCZ@NRC.gov
Dennis, Tim	ANS	610-767-0979	A243@yahoo.com
Dudenhoeffer, Don	INL	208-526-0700	donald.duderhoetter@inl.gov
Ford, C. David	WGI	609-720-3096	david.ford.@wgint.com
Gears, Gerry	DOE	301-903-2566	gerald.gears@nuclear.energy.gov
Haghighat, Ali	University of Florida	352-392-1401 Ex306	haghighat@ufl.edu
Houghton, Tom	NEI	202-739-8107	tch@nei.org
Hurst, Tim	STP 34	979-845-5068	timH@hursttech.com
Johnson, Barry	UVA	434-924-7623	bwj@virginia.edu
Johnson, Michael	NRC/TTC	301--415-0774	mrj@nrc.gov
Keithline, Kimberly A	NEI	202-739-8105	kak@nei.org
Kester, Richard	Lockhead Martin	570-803-2581	rick.kester@lmcu.com
Klein, Dale	NRC	301-415-6587	DEK1@NRC.gov
Marion, Alex	NEI	202-739-8080	am@nei.org
Mays, Gary	ORNL	865-574-0394	maysgt@ornl.gov
Miller, Mark	NRC/TTC	423-855-6507	msm@nrc.gov
Miller, Tom	DOE	301-903-4517	tom.miller@hq.doe.gov
Murray, Joe	Invesys	949-374-1858	Joseph.Murray@IPS.com
Orive, Fmdtjou	Halden	47-69212354	fridtjov@hrp.no
Owre, Fridtjov	Halden Reactor	47-69212354	fridtjov@hrp.uo
Persensky, J	NRC	301-415-6759	JJP2@NRC.gov
Planchon, H. Peter	INL	208-526-3268	pete.planchon@inl.gov
Plott, Chris		303-412-6947	cplott@qlionscience.com
Poeppel, Roger	ANL	630-252-5118	poeppel@anl.gov
Quinn, Frank	STP 34	301-963-6265	frankq@hursttech.com
Raleigh, Deann	LIS	240-626-9556	draleigh@scient@edu
Raptis, Paul	ANL	630-252-5930	raptis@ano.gov
Schur, Anne	PNNL	509-375-6488	anne.schur@pnl.gov
Simpson, Julie	ORNL	865-576-8130	simpsonss@ornl.gov
Smidts, Carol J	UMD	301-405-7314	csmidts@umd.edu
Sun, Xiaodong	Ohio State University	614-247-7646	sun.200@osu.edu
Sydnor, Russ	NRC	301-415-7510	RBS1@NRC.gov
Szabo, Autumn	NRC	301-415-6587	AXS7@NRC.gov
Utsumi, Masafumi	MHI	81-786722721	masafumi_utsumi@mhi.co.jp
Vaglia, Dave	Westinghouse	412-374-6513	vagliadj@westinghouse.com
Vine, Gary	EPRI	202-293-7347	GVINE@epri.com
Wood, Richard	ORNL	865-574-5578	woodrt@ornl.gov

Appendix U

Welcome and Opening Remarks

Presentation by
Steven Arndt
September 11, 2007

Welcome and Opening Remarks

September 11, 2007

Steven Arndt
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research
(301-415-6502, saa@nrc.gov)

Meeting Logistics

- Purpose of the Meeting
- Background
- Sign-In Sheet/Registration
- Public Meeting Feedback Forms
- Introductions
- Agenda
- Opportunity for public to comment/ask questions

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Workshop Objectives

- **This workshop will discuss**
  - Potential models for working collaboratively to resolve Digital I&C and HMI issues. A set of potential advantages and challenges associated with various participation options will be established.
  - Possible siting options of a facility or facilities. Options may include, but are not limited to use of or enhancing an existing facility or facilities or development of a new facility. Governmental, private and academic facilities will be considered.
  - Possible COI issues, methods to share data among participants, and other management issues associated with each of the participation options identified.
  - Potential cost effectiveness of the various options for performing the required Digital I&C and HMI testing and research.

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Protecting People and the Environment

Projected Outcomes

- The outcomes of this workshop will be a set of potential options for collaboratively performing the required Digital I&C and HMI work.
- Areas to be addressed include siting, funding, participation, methods for data exchange, and other managerial issues.
- Advantages and challenges will be identified for each of the options.

Background

- **SRM-COMPBL-07-0001**
  - *Conduct a workshop* to gather information needed to develop a set of high level conceptual requirements and approaches and draft recommendations on the potential test facility;
  - *Prepare a Commission paper* that provides recommendations on how and where to proceed with the establishment of a test facility, including recommendations on legal, budgetary and oversight roles. The commission paper would need to address at a minimum the nine questions raised in the SRM.
- **In addition to the issues raised in the SRM a number of other issues will need to be reviewed**
  - What are the current and future testing and research needs
  - What capabilities do we need to support resolution of the testing and research needs
  - How would we coordinate our efforts with other stakeholders

SRM Questions

- **SRM-COMPBL-07-0001**
  - What potential participants might be interested in joint participation, collaboration and funding
  - If the nuclear industry participates how could COI issues be addressed
  - What can be learned from similar facilities
  - What are the siting options
  - To what extent could the facility be reconfigurable
  - To what extent could the facility be used as an advance reactor training simulator for NRC staff
  - What impediment would there be with sharing information
  - What could be the benefits or impact on our established international collaborative activities in this area
  - What could be the NRC's legal budgetary and oversight role

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Meeting Logistics

- Purpose of the Meeting
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Protecting People and the Environment

Agenda

- 7:00 Registration
- 8:00 Welcome, Steven Arndt, NRC
- 8:30 Opening remarks, Chairman Dale Klein, NRC
- 9:00 Review of existing capabilities, Leonard Bond, PNNL
- 10:00 Break
- 10:15 Review of technical options/models developed in Atlanta workshop, Steven Arndt, NRC
- 10:45 Open discussion of possible funding/participation options
- 11:30 Input from Public
- 12:00 Lunch (on your own)
- 1:00 Open discussion on siting options/models
- 1:45 Discussion - Finding common ground on funding/participation options and siting options/models
- 2:15 Discussion of challenges to funding/participation models, data availability, COI, etc.
- 3:00 Break
- 3:15 Input from Public
- 3:30 Integration Roll Up
- 4:00 Discussion - Finding common ground on integrated options, needs, technical capabilities, funding/participation, siting options and COI issues
- 4:45 Closing Comments & Thank You
- 5:00 Adjourn

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Meeting Logistics

- Purpose of the Meeting
- Background
- Sign-In Sheet/Registration
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- Introductions
- Agenda
- Opportunity for public to comment/ask questions

Appendix V

Remarks Prepared for NRC Chairman Dale E. Klein

Digital Instrumentation and Control Workshop

Washington, D.C.

September 11, 2007

NRC NEWS

U.S. NUCLEAR REGULATORY COMMISSION
Office of Public Affairs Telephone: 301/415-8200
Washington, D.C. 20555-0001
E-mail: opa@nrc.gov
Site: http://www.nrc.gov

No. 07-043

Remarks Prepared for NRC Chairman Dale E. Klein

Digital Instrumentation and Control Workshop

Washington DC

September 11, 2007

Thank you, I am very pleased to be here.

I understand that you had a very productive workshop in Atlanta last week. I hope today's workshop will provide further insights on how we can ensure that the continuing improvements in Digital Instrumentation and Control (DI&C) technology and Human Machine Interface (HMI) will provide safety benefits to nuclear facilities.

I just returned from a meeting of the American Nuclear Society in Idaho. And now I am getting ready to leave for Europe tomorrow, where I will be attending the annual meeting of the International Atomic Energy Agency. The speech I gave in Idaho, and the one I will be delivering in Vienna, are both on the subject of how the NRC is getting ready to regulate the next generation of reactors. So new technologies—such as DI&C and HMI—are definitely on my mind.

My role here today is not to give a long speech. Instead, I just want to convey a few messages, and thank you for conducting this workshop so that our staff can better understand the issues and help prepare the NRC for future nuclear technology.

I should mention that I am not alone in regarding this as an important topic. My fellow Commissioners are also highly focused on this as a crucial issue for the agency. In fact, this workshop resulted from a proposal advanced earlier this year by Commissioner Lyons, and unanimously approved by the Commission.

The first point I would like to make is this: The future of nuclear power plants is clearly in the direction of DI&C and enhanced HMI… and the NRC needs to begin preparing for these new technologies now if we are going to be able to fulfill our future regulatory responsibilities. Let me put this in perspective by mentioning some of the important developments that are occurring within the NRC.

As you are probably aware, the combination of new technology and changing employee demographics is presenting us with several challenges, which overlap and to some degree exacerbate one another:

Both industry and the NRC are feeling the effects of the aging nuclear workforce. This fact, and the corresponding loss of experienced people, are happening right at the time that industry is prepared to grow—which means that both the utilities and the NRC need to increase the number of employees to handle the increased workload we are all facing. At the NRC, in one two-week pay period early this year, nearly 1000 years of regulatory experience walked out of the agency due to retirements; and that included 560 years of technical experience. I also understand that at last week's workshop it was reported that 75% of the workforce at the Department of Energy's National Labs will be eligible for retirement by 2010.

On the industry side, I believe that Nuclear Energy Institute will soon publish its updated nuclear industry workforce survey. One finding which they have already released is this: roughly 35% of current utility personnel will be eligible for retirement within 5 years. This is not a crisis… yet. But it has the potential to become one.

I should mention that the need for workforce development is not just limited to nuclear engineers, but also includes other engineering and scientific disciplines as well… not to mention the skilled craft workers such as DI&C technicians, electricians, welders, pipe-fitters, mechanics, and others needed to construct and operate the plants.

My second point concerns another challenge we face. Because the growth of the nuclear industry was basically stalled for two decades in the U.S., there has been substantial progress in nuclear technology elsewhere in the world that you as operators, and we as regulators, don't really have experience with. Specifically, while the current fleet of light water reactors were designed and built in the analog electronics era, the next wave of reactors will likely move away from analog toward DI&C—in the short term—and also away from light-water toward advanced reactors over the long term.

What does the combination of all these factors mean? Simply this: our most senior people—the people whose experience and judgment will guide the "Nuclear Renaissance"—are not trained in the technologies that will characterize that Renaissance. Yet, at the same time that we need to prepare for next generation of nuclear technology, we will also need to maintain expertise in existing technologies, because the focus on the safety of the existing fleet must remain paramount. So I am very grateful that you, the experts in DI&C and HMI, are attending this workshop to help us understand the challenges we face, and help us figure out ways of meeting it.

Probably the key concern for us as regulators is understanding how new technologies will maintain the core safety principle of Defense in Depth—which brings me to my final point. We need to have a very clear understanding of how DI&C and HMI systems guarantee diversity, redundancy, and independence.

While the NRC recognizes that DI&C and HMI hold great promise for improving efficiency of plant operations, and can be very beneficial for utility owners, our concern as regulators is always safety first. I know that all of you share this concern, and I recognize that plant operators deal with this issue every day. Even before we started grappling with DI&C, the crucial importance of HMI was underscored by the Three Mile Island accident. Following that event, the NRC required plants to undertake detailed control room design reviews and make human factors improvements to them.

Therefore, we need to work together to understand not only the benefits of these digital systems, but also their possible failure modes, and the means by which these systems can be designed to fulfill the demands of diversity, redundancy, and independence. With these tools, the NRC will have the means to evaluate these new technologies, and uphold our responsibilities for safety and security oversight.

I promised that my remarks would be brief, and since I am always saying that the NRC must be a stable and predictable regulator, I am keeping my word.

Thank you once again for the opportunity to participate in this important conference, and allowing me to share a few thoughts with you. I look forward to hearing about the outcome of this workshop at a later date, and learning more about the issues we all face in the areas of Digital Instrumentation and Control and Human Machine Interface.

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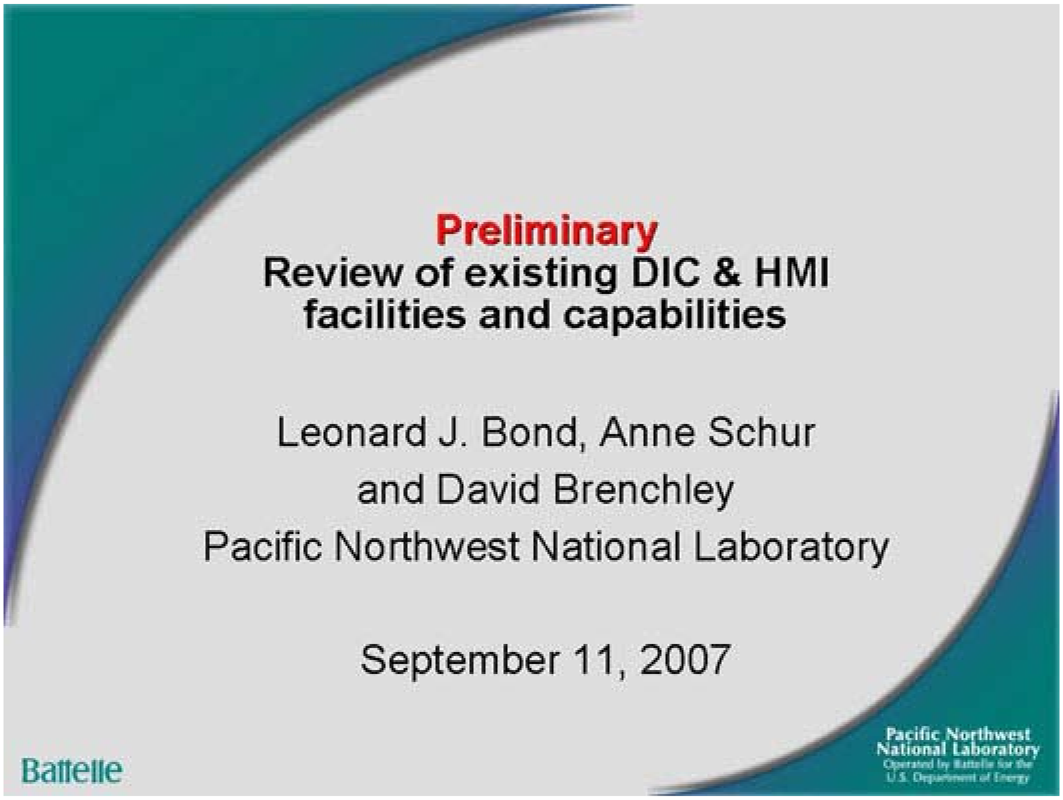
News releases are available through a free *listserv* subscription at the following Web address: http://www.nrc.gov/public-involve/listserver.html. The NRC homepage at www.nrc.gov also offers a SUBSCRIBE link. E-mail notifications are sent to subscribers when news releases are posted to NRC's Web site.

Appendix W

Preliminary Review of Existing DIC & HMI Facilities and Capabilities

Presented by
Leonard J. Bond
September 11, 2007


Preliminary
Review of existing DIC & HMI facilities and capabilities
Leonard J. Bond, Anne Schur
and David Brenchley
Pacific Northwest National Laboratory
September 11, 2007
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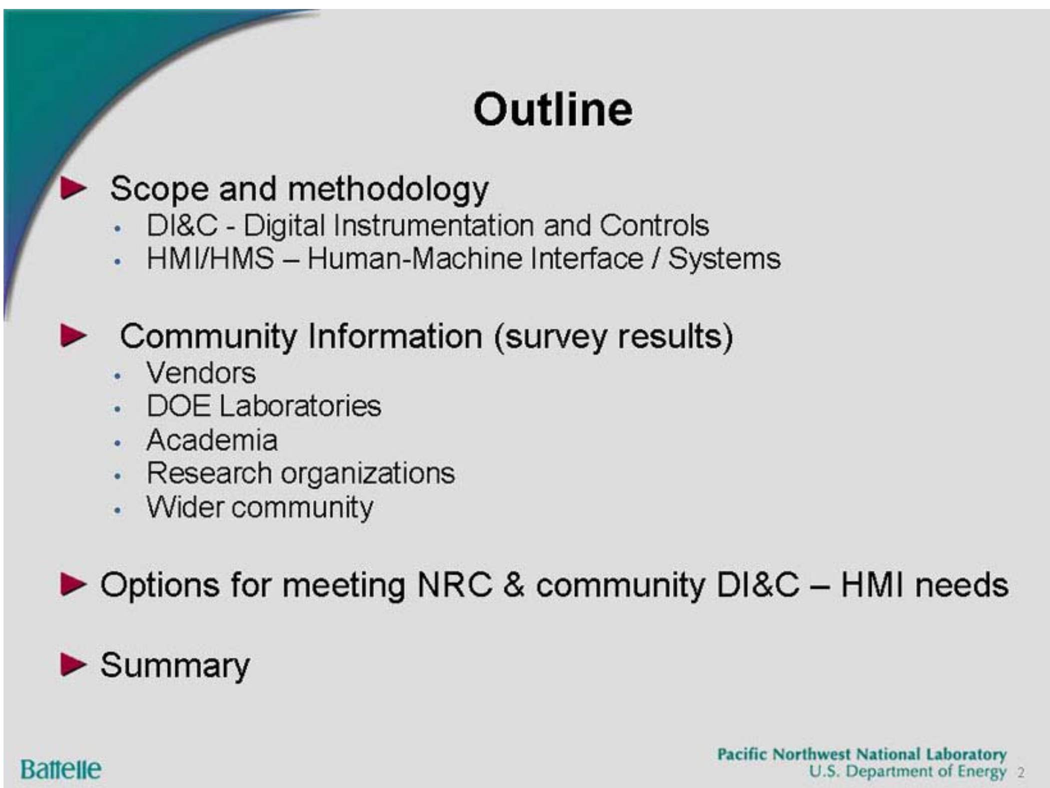
Outline
Scope and methodology
DI&C - Digital Instrumentation and Controls
HMI/HMS – Human-Machine Interface / Systems
Community Information (survey results)
Vendors
DOE Laboratories
Academia
Research organizations
Wider community
Options for meeting NRC & community DI&C – HMI needs
Summary
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Study Scope

- Survey of existing (U.S.) facilities with similar potential capabilities
  - Capabilities in design, conducting, operating, maintaining test and research in digital I&C and/or HMI/HMS issues
  - Use of facilities, user base, staffing levels, funding methodology, construction costs, annual operating and O&M costs.
  - Options for operating models

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Study Methodology

- Identification of organizations
  - Knowledge of community
  - Web search
  - Previous NRC studies (e.g. HF circa 2002)
  - Key stake holders identified – with NRC
- Telephone and face-to-face interviews
- Web site questions
- Limited site visits (*due to time constraints*)
- Federal Register announcement
- September workshops
  - Invitations to participate and contribute

- Total of more than 75 organizations identified
  - Vendors, organizations (EPRI,NEI etc), DOE Labs, universities
  - Total of more than 30 contacted
- Total of more than 27 Interviews
  - Telephone
  - Interviews – face-to-face 7 at IEEE Meeting CA (Aug 26-30)
  - Two Site visits
- Information gathering to continue until September 30, 2007
  - http://nrc-test-facility.pnl.gov/

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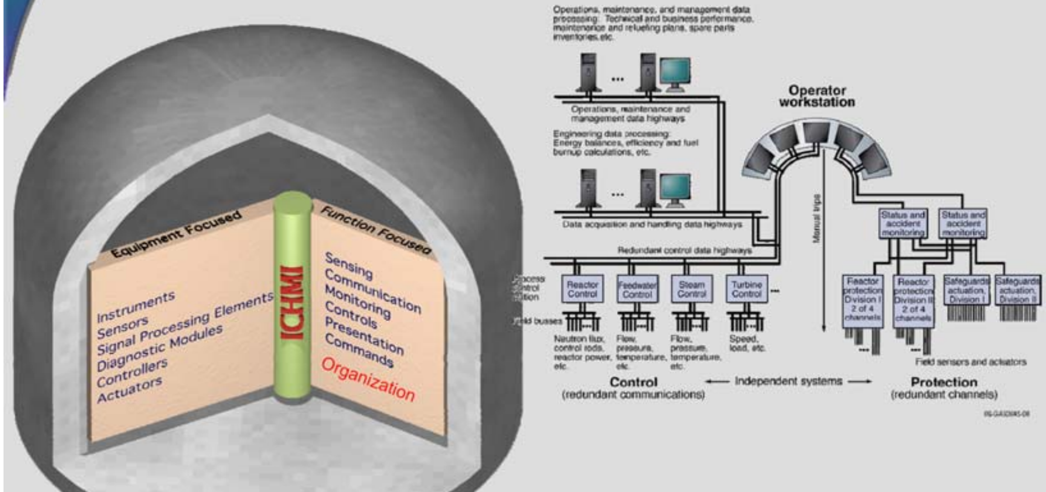
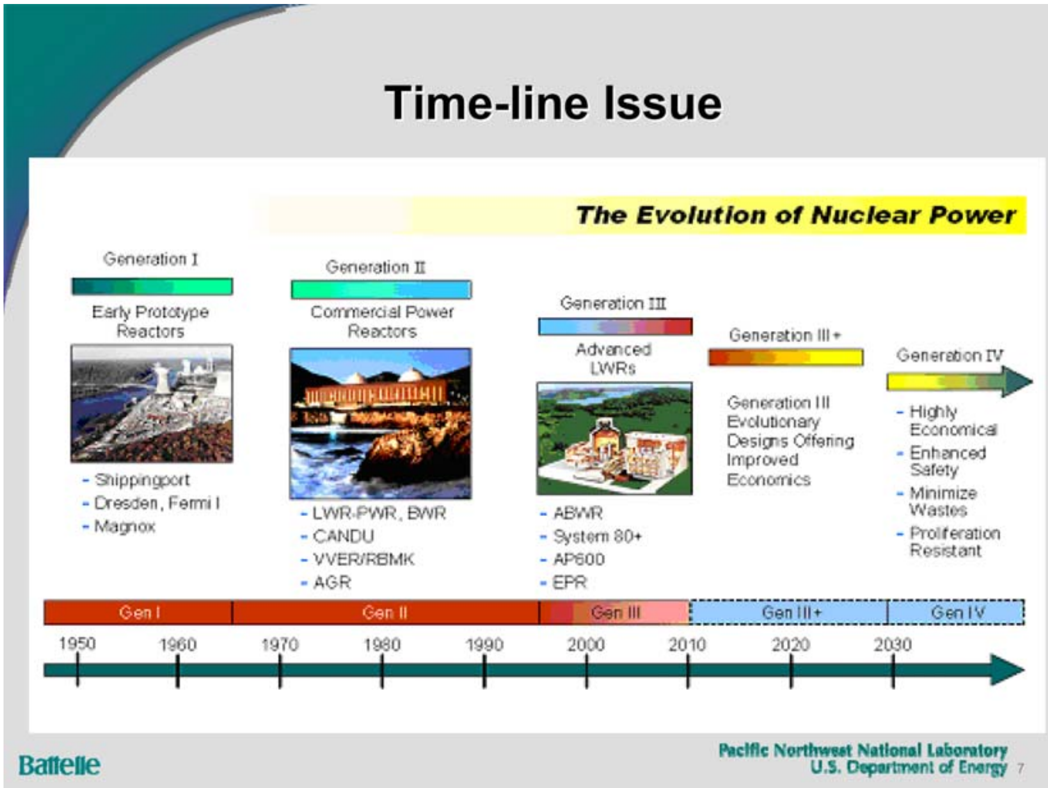
Information to Gather

- Identify and investigate scope and conceptual design attributes of other U.S. facilities
  - National laboratories, universities, military installations, other government agencies and industry capabilities.
- Survey existing facilities
  - Designing, conducting, operating, maintaining test and research facility in digital I&C and/or HMI/HMS
  - Issues/concerns to be resolved
  - Types of research done?
- Develop draft survey results for NRC
  - Staffing, user base, funding methodology, facility construction costs, annual, operation and maintenance
- Type of facility/purpose: research, training, engineering development
- Owner & User Base, Funding, Management
- Operational capabilities & infrastructure support. What can it do for NRC and what can't it do for NRC?
- Strengths and Limitations

DIC-HMI – *MORE THAN SIMULATORS*

ICHMI Forms a Nuclear Power Plant's (NPP) Nervous System –
HMI is ALL interactions, Control room, O&M + diagnostics




Time-line Issue
The Evolution of Nuclear Power
Generation I
Early Prototype Reactors
- Shippingport
- Dresden, Fermi I
- Magnox
Generation II
Commercial Power Reactors
- LWR-PWR, BWR
- CANDU
- VVER/RBMK
- AGR
Generation III
Advanced LWRs
- ABWR
- System 80+
- AP600
- EPR
Generation III+
Generation III Evolutionary Designs Offering Improved Economics
Generation IV
- Highly Economical
- Enhanced Safety
- Minimize Wastes
- Proliferation Resistant
Gen I
Gen II
Gen III
Gen III+
Gen IV
1950
1960
1970
1980
1990
2000
2010
2020
2030
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Community Information
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Vendor Community – "NP2010/ALWR's"

- Vendors have facilities
  - support design, test and development
  - Nuclear I&C just a small part of process systems market
- Systems developed
  - Architectures and designs
  - Simulators being developed
  - Design/Development R&D not required

Any new center/facility too late for 2010/15 needs… only possible to impact "edges"

AP-1000 Control Room Simulator
Westinghouse Energy Center, PA

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Some Vendor Concerns

- Concerns relating to possible "Center" implementation
  - Ensuring cyber security
  - Protection of vendor proprietary information
  - Expertise comes from doing
  - Take vendor class – then hire an expert in particular system
  - Center would have "non-qualified systems" (NPP have qualified systems)
  - Cost and utilization
  - Scope of activities – more than just a simulator?
- Loss of experienced staff
- Platform experts are at the vendors
- Need tools to make people more efficient – tools to find info (cross train)
- Nuclear needs to join the wider I&C Community
  - Why are we (or think we are) so different?
- Consider innovative options – networks (virtual center)
- Costs of a single center –technology rate of change, look into aging issues
- Digital I&C already deployed – e.g. Sizewell
- As a community focus for research should be on Gen IV (post 2020)
- Keep research and training on simulators separate.
- Center effort - Potential to slow existing NRC activities

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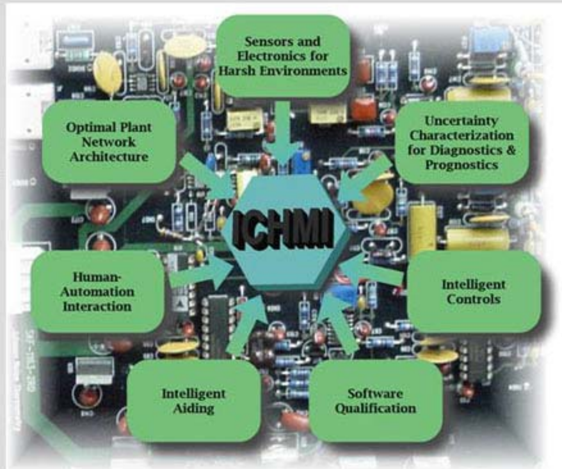
Longer Term Needs (Vendors)

- Research needed to support advanced reactor concepts
  - E.g. GNEP and Gen IV concepts
- HMI – display, interactions, information management and workforce aids.
- O&M DI&C issues



DOE Laboratories – I&C/DI&C

- Advanced Control Test and Operations (ACTO) facility: DOE-NE (ORNL). Operated until early '90's
  - Human resources remain – equipment *aged out*
  - *75% of nuclear expertise in DOE labs could retire within 5 years**
- All major DOE laboratories have I&C, sensors, measurements, communications laboratories
  - Sensors for harsh, environments, communication, monitoring, controls, diagnostics & prognostics
  - Much more capability than that focused to meet nuclear power program needs
- Dedicated test facilities – limited (aging/aged out)

*Wogman, et.al (2005) *J. Rad.& Nuclear Chemistry* 263 (1) 137-143.

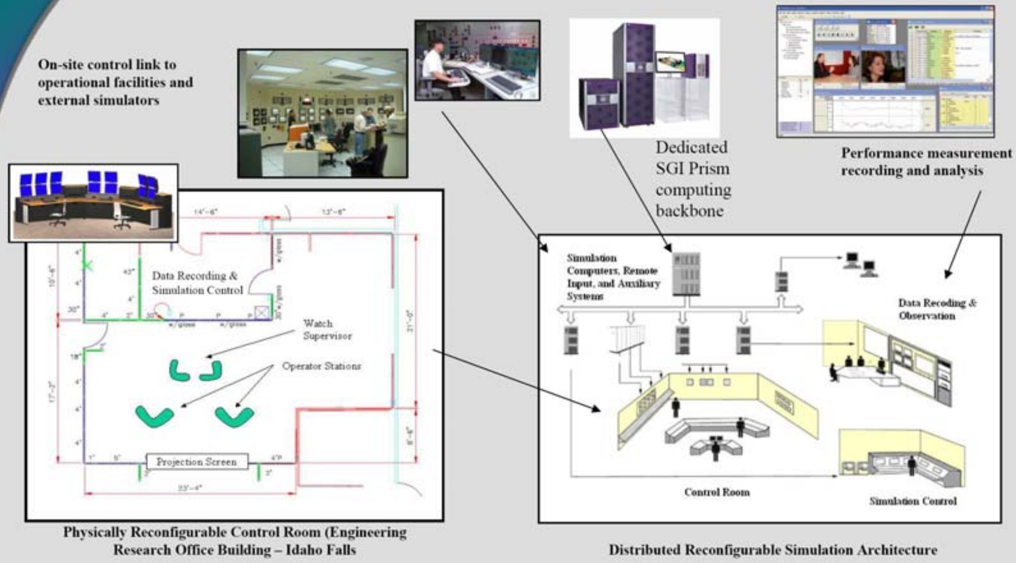
DOE Laboratories – Human Factors

- **Six DOE labs have history of HF – HMI research**
  - BNL, INL, LLNL, LANL, ORNL and PNNL
- Brookhaven
  - Historically 90% of work in this area for NRC. HMI studies, new needs assessments for advanced reactors
- Idaho
  - Advanced R&D Plant Simulator (expansion in progress), human performance simulation and modeling
- Lawrence Livermore
  - Historically performed extensive studies for NRC including nuclear medical research. Have numerous part-task simulators and virtual image simulator
- Los Alamos
  - Have performed studies for NRC. Strong capabilities in PRA, HRA, organizational factors, and VR
- Oakridge
  - Historically performed studies for NRC, EPRI and DOT. Strengths: operator and maintainer modeling. Have access to operators from the facilities that is part of their laboratory.
- Pacific Northwest (and Battelle/Seattle)
  - Electricity Infrastructure Operations Center (EIOC): Experiments and usability testing; visualization concepts for grid operations, situation awareness, HMI designs, performance measures. New needs assessments.

DOE Laboratories

- *Examples* of new, upgraded emerging capabilities and facilities
  - INL – I&C initiatives, SCADA test bed, "vendor systems"
    - GNEP and other programs may fund new capabilities
  - PNNL's Electricity Infrastructure Operations Center
  - DOE-NE Advanced Test Reactor (Transition to user facility)
  - ORNL - Digital I&C and test & evaluation facilities + HIFA, Spallation Neutron Source

Example of New Capability: INL Human System Simulation Lab Expansion (expected GNEP funded)



Academia

- **University nuclear I&C – HMI community**
  - Small – limited funding
  - Some commercial systems at different sites
- **Examples of some activities & facilities**
  - Digital I&C for research reactor – U. Florida.
  - U. Tenn. – seeking to upgrade PWR simulator to DIC
  - Penn state ESBWR – low-pressure test facility
  - Ohio State University Academic Center for Excellence in Instrumentation and Control in Advanced Systems (sponsored by INL)

US Academic community

- Research interests cover: Sensors, systems, communication, software, diagnostics
- 26 Research Reactors in U.S. Universities

Academia

- Numerous centers and groups working in DI&C – HMI topics
- Many groups working in non-nuclear applications – Examples:
  - Center for Manufacturing and Automation (USC – UCLA et al.)
  - Center for Advanced Communications (Villanova)
  - Center for wireless information networks (Rutgers)
  - Measurement and control engineering center (U. Tenn. + ORNL)
  - Center for Design of Analog-Digital Integrated Circuits (CDADIC) Washington State University (lead institution)
  - NAS Industry-University CRC Program (60+ center – current or past members of programs)

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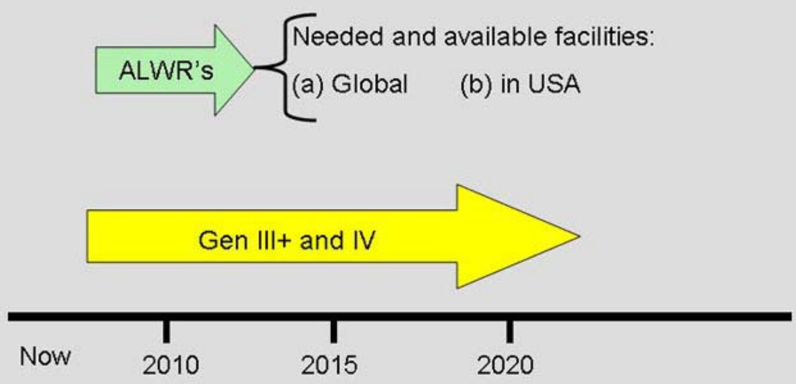
R&D Focus and Agenda



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Government Research & Development: (HF &/or DI&C)

- NASA…. Experience in distributed simulations, DI&C research and operations for hardware and software where researchers and instruments are geographically dispersed on earth and interplanetary.
- Department of Defense (Several sites and organizations)
  - Air force … simulators and systems
  - Navy and army organizations
- Federal Aviation Administration
- Transportation – FHA, Rail - human factors (HF) orgs.
- NRC – Training Center Chattanooga
- Naval Reactors

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Training Simulators

Simulators required for NRC staff familiarization *(Not for formal operator training):* systems different for each "type" and for each new reactor or family of reactors.

→ Each industry has its own capabilities

Current Generation Simulator
Photo J. Gonyeau

New AP-1000 Simulator

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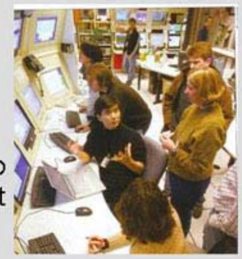
Large Experiment Control Rooms

- National Ignition Facility
- Fermilab
- Spallation Neutron Source
- Other?

NIF – Control Room



Fermilab
CDF Experiment

Site Visits

- PNNL EIOC – act as test-bed for questions
  - visit to EIOC
- INL
  - Human Factors & Digital I&C Evaluation Facility
  - SCADA Test Bed
- (2-3) Locations TBD
- Early identification of potential locations to visit is essential

Electricity Infrastructure Operations Center

National SCADA Test Bed Program (INL)

- Sponsored by DOE Office of Electricity and Energy Assurance
- Mission is… ***to support industry and government in ensuring the security of the Nation's energy infrastructure***
- Closely integrated with related DOE and Department of Homeland Security programs

► **Teaming with other National Laboratories**

► **Teaming with industry (CRADAs)**

Experience Outside the US

► Halden Project

► Japan/Asia
- Test Simulator for advanced instrumentation - KAERI

► Europe – NEW (July '07) IBM Global Center of Excellence for Nuclear Power
- IBM + vendor software applications focus
- $10 million investment
- Located near ITER
- 10,000 Sq feet

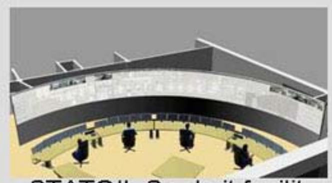
Halden Project

Halden Project

MTO-labs 2007

- Scope
  - (i) HMI and (ii) fuels & materials
  - 50 year history – international research program (17 members countries)
    - US include EPRI, NRC, Westinghouse
  - 3rd generation man-machine lab became operational 2005
  - Operates around 3-year research programs
  - Reconfigurable facilities
  - Not just nuclear – oil and gas + air traffic control

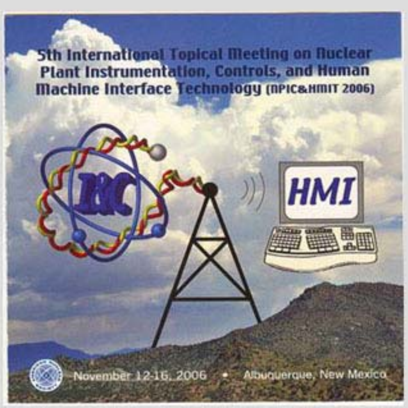
View of Hammlab



STATOIL Snøhvit facility

USA NPP-Focused DI&C – HMI Communities

Modest size US community in nuclear power I&C (DI&C – HMI) recent meetings



JOINT 8TH IEEE CONFERENCE ON HUMAN FACTORS AND POWER PLANTS AND

13TH ANNUAL CONFERENCE ON HUMAN PERFORMANCE / ROOT CAUSE / TRENDING /

OPERATING EXPERIENCE / SELF ASSESSMENT

- Next meeting April 2009

Wider Research Community

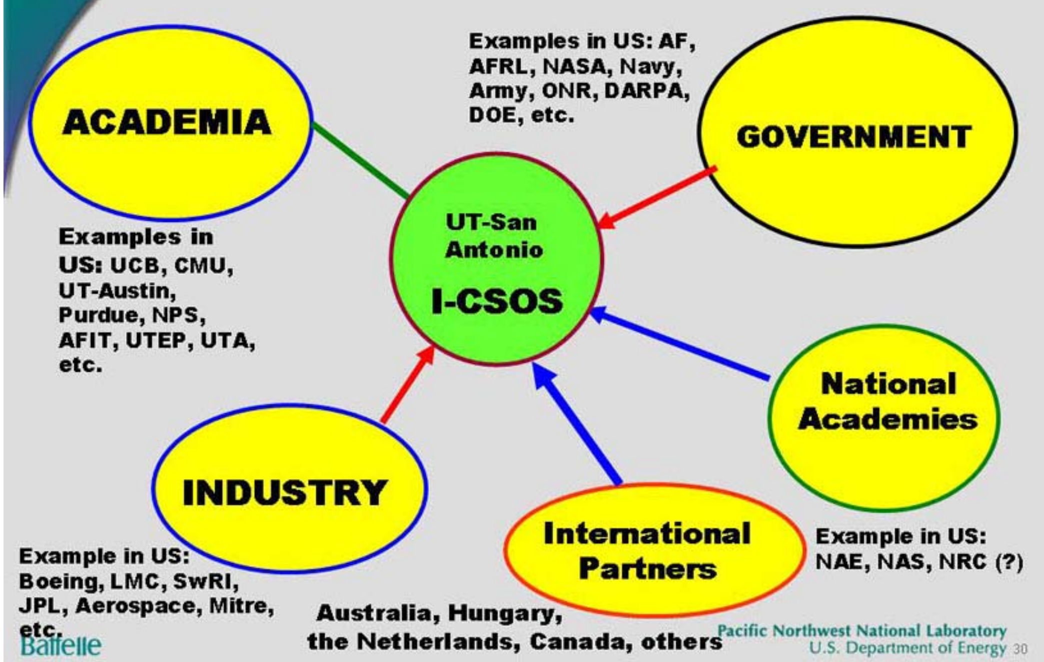
Vibrant DI&C & HMI Communities in USA

Examples of Meetings and conferences

- IEEE/AIAA 26th Digital Avionics Systems Conf (DASC) – Dallas, TX
- **CICINDI-2007 8th International Conference on Control, Virtual Instrumentation, and Digital Systems November 4 to 9, 2007, Mexico City, Mexico**
- **18th ISA POWID/EPRI Controls & Instrumentation Conference, *The Pathway to Power Automation for the 2010 Decade,* June 8th – 13 2008 - Phoenix, Arizona**

National Consortium on System of Systems

Prof. Mo Jamshidi: University of Texas, San Antonio



Facilities/Capabilities - SUMMARY

- Robust digital I&C HMI community in USA
- Capabilities for R&D – *sensors to systems* in DI&C and related HMI (e.g. aero-space)
- Capabilities in USA dedicated to NUCLEAR related DI&C – HMI issues – smaller community - *limited*
  - Industry has capabilities, systems and infrastructure -
    - Probably adequate to support design, test build – focused on ALWR' (2010-15 delivery)
  - Research community depleted – re-emerging (or trying)
    - Much focused on meeting needs of longer term (i.e. Gen III+ & IV)
    - Nuclear Power DI&C-HMI R&D: recent R&D funding limited (DOE & NRC)
    - "pockets" of expertise remain
- People – in nuclear related I&C (in USA) – much analogue experience – need for technology transition – familiarization & more nuclear focused experience

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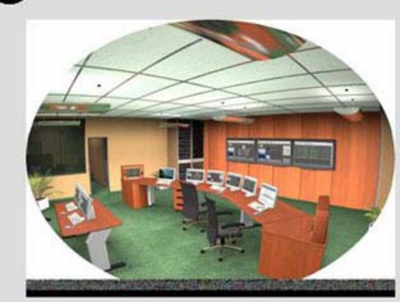
OPTIONS FOR MEETING NRC DI&C – HMI REGULATORY RESEARCH AND WIDER NUCLEAR POWER COMMUNITY NEEDS



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Research Vision

- Develop a community-wide research agenda
  - DI&C-HMI Science/Advisory Committee (National Academies?)
  - Decadal research review (National Academies – define long term needs) – NRC, DOE, NEI et al
  - Peer review proposals and programs
- New capabilities are emerging (need to support/foster)
- Perform needed research through "consortium"
  - Virtual network – some central "Project Office"

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Research Vision… con't.

- EPRI model for research – few facilities
  - USE BEST AVAILABLE (University, DOE Lab, etc.)
- Some form of Consortium or network generating most interest in responding community:
  - Establish a DI&C – HMI "project/program office" to coordinate/manage and INTEGRATE activities
  - Needs to be ONE FRONT DOOR and one web site for the "program"
  - Cf. – Big Sky Consortium – Carbon Sequestration etc. (or other example)

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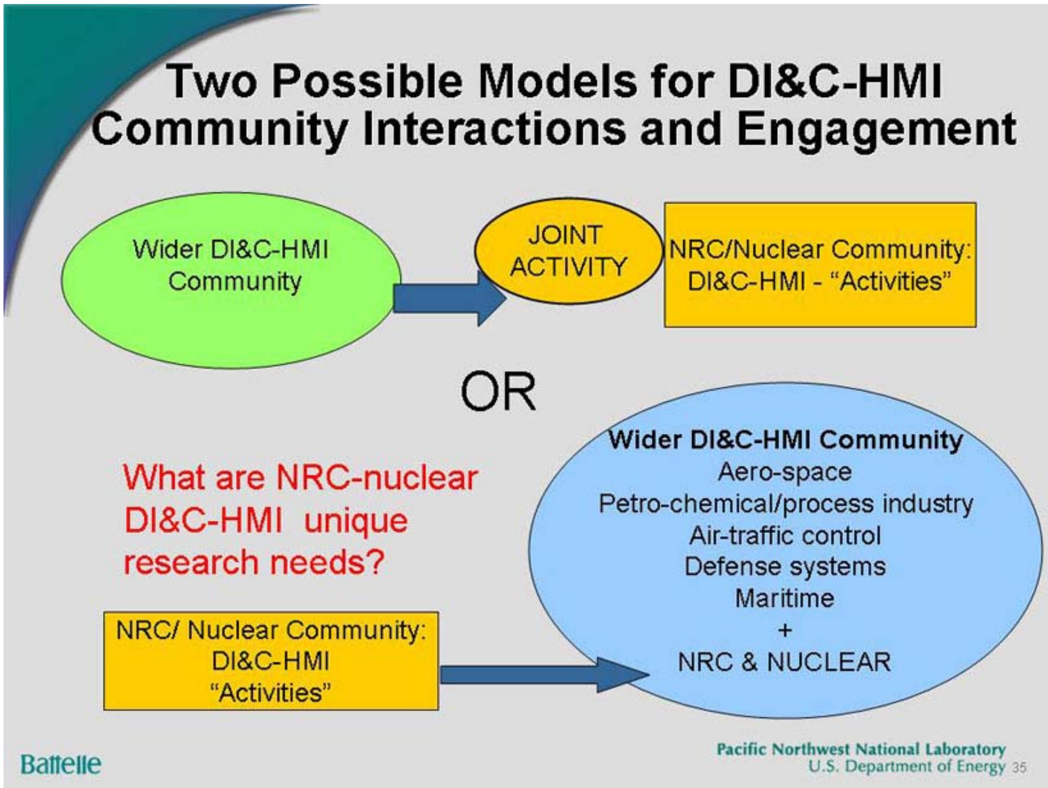
Two Possible Models for DI&C-HMI Community Interactions and Engagement
Wider DI&C-HMI Community
JOINT ACTIVITY
NRC/Nuclear Community: DI&C-HMI - "Activities"
OR
What are NRC-nuclear DI&C-HMI unique research needs?
NRC/ Nuclear Community: DI&C-HMI "Activities"
Wider DI&C-HMI Community
Aero-space
Petro-chemical/process industry
Air-traffic control
Defense systems
Maritime
+
NRC & NUCLEAR
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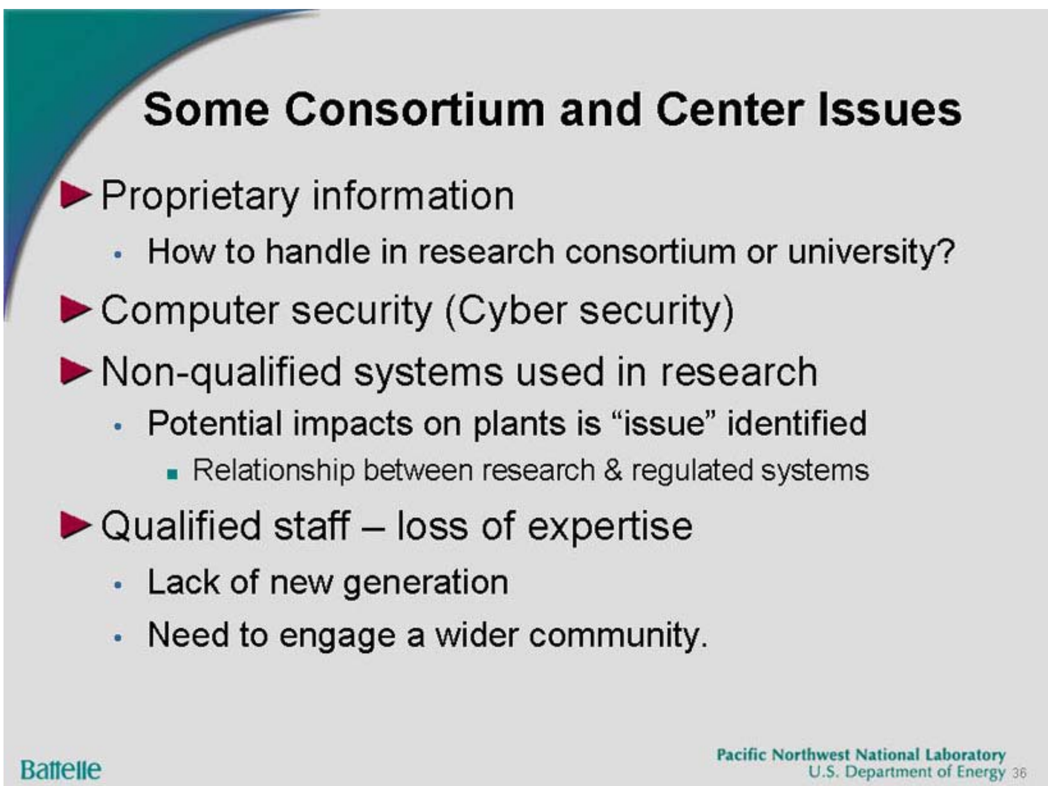
Some Consortium and Center Issues
Proprietary information
How to handle in research consortium or university?
Computer security (Cyber security)
Non-qualified systems used in research
Potential impacts on plants is "issue" identified
Relationship between research & regulated systems
Qualified staff – loss of expertise
Lack of new generation
Need to engage a wider community.
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Many Demonstrated Options

Single Sponsor
Single user

SPECTRUM OF OPTIONS

Multi-sponsor
Multi-user

- Highest level of control
- Minimum Conflict of Interest
- Focused Program (regulatory research)
- Single OR Multi-site
- HIGHEST COST (for one org).

- Potential for wider community engagement
- More diverse – more student opportunities
- More experts engaged
- More capability (?)

- Lower control by any ONE org.
- More potential for Conflict of Interest
- Broader Program (probably) - *different mix of needed capabilities*
- Single OR Multi-site

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No New Facility (Option #a)

- Seek to continue to improve current NRC approach
  - Use universities, DOE Labs, research organizations
- Provide integrated NRC DI&C-HMI activity (program office?)
  - Establish a DI&C-HMI Science Committee Advisory
  - National Academy Decadal Review to review and/or refine (prioritize) research agenda
  - Seek partnerships – "Consortium" to leverage DOE, industry and academic capabilities

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NRC Lead Role & New Facility
NRC Stand-Alone (Option #b)
Owned and operated by NRC
NRC/DOE Partnership (Option #c)
Owned and operated by NRC & DOE as partners
Government (NRC & DOE)/Industry Partnership (Option #d)
Could be with industrial nuclear power plant consortium
Government owned – contractor operated
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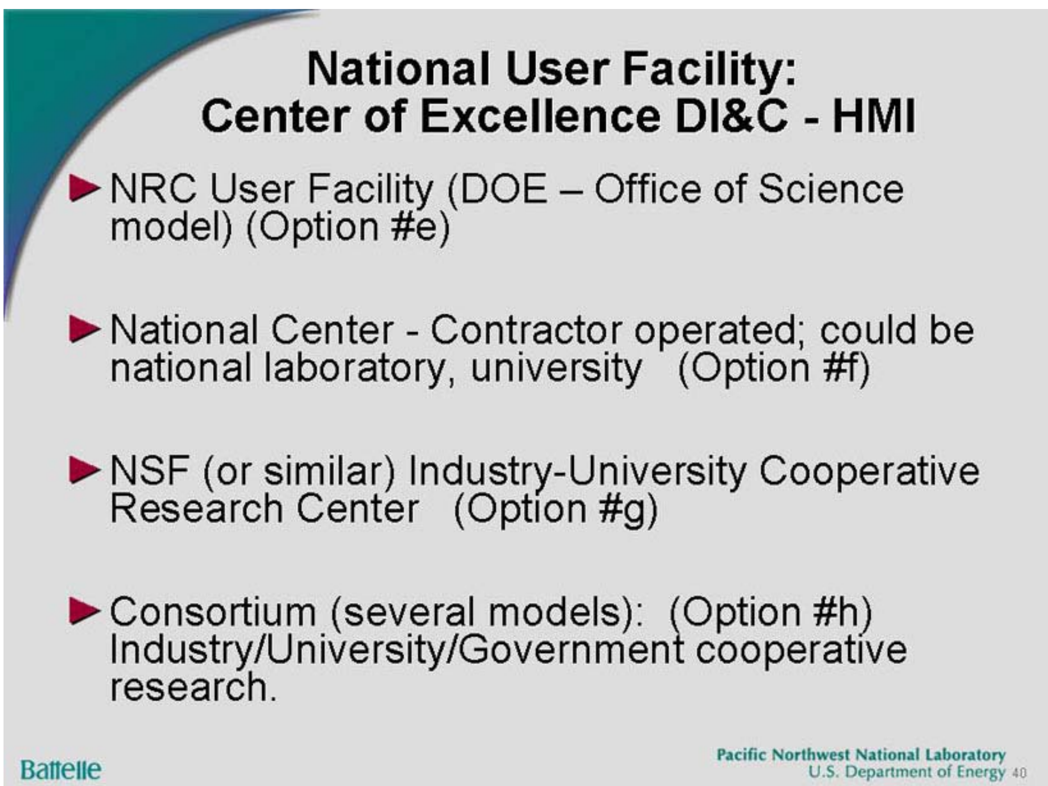
National User Facility:
Center of Excellence DI&C - HMI
NRC User Facility (DOE – Office of Science model) (Option #e)
National Center - Contractor operated; could be national laboratory, university (Option #f)
NSF (or similar) Industry-University Cooperative Research Center (Option #g)
Consortium (several models): (Option #h) Industry/University/Government cooperative research.
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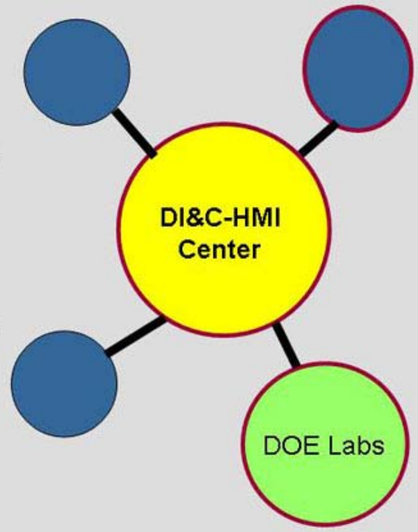
Distributed Center Approach (Option #i)

- Establish a project or program office
- Leverage best available facilities
- Leverage established expertise
- Coordinate and integrate activity for maximum impact
- Defined research agenda – use peer review, steering/advisory groups



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- Capabilities in USA dedicated to NUCLEAR related DI&C – HMI issues *limited*
  - Vendors/Industry has capabilities, systems and infrastructure
    - Support design, test, build
  - Research community *depleted* – re-emerging (or trying)
  - Nuclear Power DI&C-HMI R&D – funding has been limited
- “pockets” of expertise remain
- People – in nuclear related I&C (in USA) – analogue experience – need for technology transition

SUMMARY - cont

- Large organizations (e.g. NASA, Lockheed Martin) have expertise
- Professional community – with nuclear expertise needs to expand to capture wide DI&C – HMI capabilities
- New facilities being developed (e.g.) :
  - Fed. Railroad Administration – Cab Technology Integration Laboratory (SOW – May, 2007)
  - IBM Global Center of Excellence for Nuclear Power – France
- Longer term research agenda - need for more innovative DI&C -HMI research

Project web site

http://nrc-test-facility.pnl.gov/

Appendix X

Review of Technical Options/Models Developed at the Washington Workshop

Presented by
Steven Arndt
September 11, 2007

Review of Technical Options/Models Developed at the Washington Workshop

September 11, 2007

Steven Arndt
Division of Fuel, Engineering & Radiological Research
Office of Nuclear Regulatory Research
(301-415-6502, saa@nrc.gov)

Background

- In the 1997 NAS report "Digital Instrumentation and Control Systems in Nuclear Power Plants: Safety and Reliability Issues" the review committee identified a number of key areas
- NRC reviewed the 1997 NAS report recommendations and I&C vendor development efforts at that time and develop research NRC Research Plan for Digital I&C for FY 2001-2004 (SECY-01-0155)
- NRC updated the research plan as "NRC Digital System Research Plan FY 2005 – FY 2009"
- During this time frame the NRC has also developed research program plans for Human Machine Interface research

Background

- Since the NAS review in 1997 there have been a number of changes to digital I&C and HMI technology
  - New technology now being used in the nuclear arena
  - Technology that has been used widely in non-nuclear applications is now moving into the nuclear arena
  - Continuing need to improve review process
- New drives
  - New reactors
  - Extensive use of digital systems in fuel cycle facilities
  - Updating of current plant Digital I&C and HMI
  - Advanced reactor programs
    - DOE Technology Roadmap: Instrumentation, Control, and Human-Machine Interface to support DOE Advanced Nuclear Energy Programs, March 2007.

Background

- November 8, 2006 Commission Meeting
- Digital I&C Steering Committee
- Task Working Groups
  - TWG #1: Cyber Security
  - TWG #2: Diversity and Defense-in-Depth
  - TWG #3: Risk-Informing Digital I&C
  - TWG #4: Highly-Integrated Control Room–Communications
  - TWG #5: Highly-Integrated Control Room–Human Factors
  - TWG #6: Licensing Process
  - TWG #7: Fuel Cycle Facilities
- Addressing most important short term issues

Current Research

- In the Digital I&C area structured to include the most important research areas needed to support the program offices
  - Systems Aspects of Digital Technology
  - Software Quality Assurance
  - Risk Assessment of Digital I&C Systems
  - Security Aspects of Digital Systems
  - Emerging Digital Technology and Applications
  - Advanced Nuclear Power Plant Digital Systems
- In the HMI area research is being done in the areas of
  - Fatigue
  - Workload
  - Safety Culture
  - Effects of automation
  - Effects of degraded digital I&C
  - Computerized procedures
  - Changes in concepts of operation

How an Issue Becomes a Need

- Technology that has been used widely in non-nuclear applications is now moving into the nuclear arena. We need to be able to prepare more effectively
  - For example, Field Programmable Gate Arrays (FPGAs)
    - Have been in use for more than 15 years
    - NRC found out that vendors were planning to use them in nuclear safety systems 3-4 years ago
    - NRC started research on them last year
    - Application using them this year
- Some needs only become apparent as new technologies or methods are discussed or reviewed
  - Defensive measures effectiveness in improving digital system reliability including fault tolerant features, etc.

How an Issue Becomes a Need

- Some needs only become apparent as new techniques are used to solve new issues
  - Priority Logic Modules have been used in other industries for some time, but only recently to solve new digital I&C issues in the nuclear industry
- Continuing need to improve review process
  - Current software review process, does provide an method for assuring software quality but is not as effective, efficient or predictable as we would like
  - Other industries use more review tools or are involve earlier in the software development process
  - Unlike some industries NRC does not conduct independent validation and verifications or testing

Progress Made at Atlanta Workshop

- Opening remarks from several speakers
- Review of existing capabilities, and lessons learned from successful integrated research and test facilities
- Review of current and future technical needs
- Development of needed capabilities
- Development of options for meeting needs and for improving NRC capability to develop technical basis for regulatory guidance
- Large amount of common ground on technical issues and needed capabilities

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Summary in General Session and Working Groups Issues

- Large number of issues that fell into 10 areas
  - Cyber Security
  - Diversity & Defense-in-Depth
  - Risk-Informing Digital I&C
  - Digital Systems Communications
  - Control Room and beyond control room, human factors
  - Fuel cycle Facilities
  - Validation (software etc.)
  - Advanced Monitoring/Diagnostics
  - Advanced Sensors
  - General Issues

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Possible Options

No New Facility

NRC would continue in its present approach of using a number of different facilities on a case by case basis.

Advantages	Disadvantages
Continuity of on-going efforts	Limited coordination
No additional costs or locations; least costly in the near term	Less opportunity for integrated synergistic research; could miss unexpected/unknown interactions
Ability to leverage existing capability	Limits US's ability to catch up technologically
Quicker response	Could inhibit innovation

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Possible Options

OPTION A: New Integrated Facility

In this option a new integrated facility would be developed to provide the capabilities needed to address the DIC/HMI regulatory issues. It would be a stand-alone facility that is operated by NRC or would be a partnership of NRC, DOE and/or industry.

Advantages	Disadvantages
Ability to focus priorities and effort	Higher cost
Security; easy to do "security" research	Could disrupt existing work
Easier collaboration between DIC & HMI work; ease of multi-disciplinary research	If run by NRC could inhibit industry participation
Provide opportunity for training and testing on full scope of DIC & HMI equipment	Less access to expertise worldwide

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Possible Options

OPTION B: Distributed Center

In this option capabilities/facilities would be dispersed. It assumes the many facilities/labs that exist can be engaged in research and testing. There would be a program office to provide central leadership. Emphasis on coordination and integration is provided through program office rather than physical integration. There is a unifying plan for cooperation. There is a defined research agenda and the use of peer review and steering/advisory groups to guide the research program.

Advantages	Disadvantages
Takes maximum advantage of existing national capabilities and provides for continuity of on-going efforts	Need to prioritize to meet the needs of various sponsors with competing priorities
Can utilize facilities where the capital investments have already been made to minimize capital cost	Funding/partner management could be cumbersome; need to manage conflict among partners
Expandability, flexibility (working across distribution), scalability	Loss of synergies due to distributed participants
Quick start up	Lack of dedicated infrastructure

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Possible Options

OPTION C: Hub Model

In this option NRC would sustain current programs initially. It would immediately kick off an Option B program as soon as it could be funded. Facilities would be centralized where necessary and all others decentralized where possible. Centralized facilities enhance collaboration/integration while not limiting access to other capabilities. Joint international research planning capability would also be a part of this option if appropriate.

Advantages	Disadvantages
Easier model for engaging industry	Need to prioritize to meet the needs of various sponsors with competing needs
Improves collaboration/access	Funding/partner management could be cumbersome; need to manage conflict among partners
Fills the most gaps	Less synergy due to distributed participant
Graded/timed approach that allows getting started quickly	

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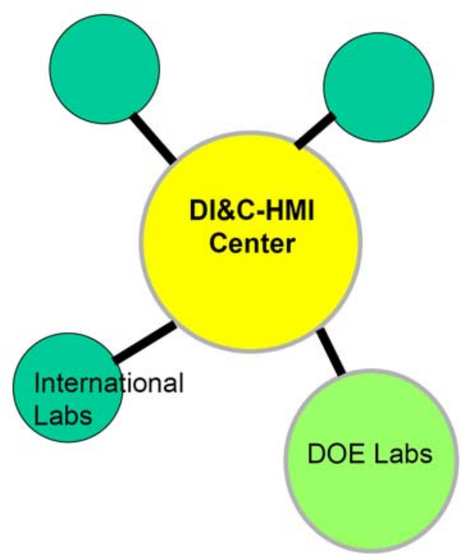
Recommended Option

Option C: Hub Model

- continuing the current approach
- Immediately kick off as a disturbed Center program
- Facilities would be centralized where necessary and all others decentralized where possible
- Centralized facilities enhance collaboration/integration while not limiting access to other capabilities
- Joint international research planning capability would also be a part of this option if appropriate



Summary

- At the workshop in Atlanta the assembled Digital I&C and HMI experts reviewed
  - Current a future issues
  - Needed capabilities to address these issues
  - Gaps that may exist in current capabilities
  - Preferred options would be for future research and testing capabilities
- Technical gaps
  - Generally capabilities exist to meet most short term needs somewhere in the US
  - NRC needs to find better ways to access and use them LWR and ALWR
  - Advanced reactors (Gen IV, GENP, etc.) fewer capabilities exist
  - Major missing capability identified was a "research" simulator
  - Possible needed capability full scope (from sensors to displays) digital I&C test bed
- NRC staff (current and future) need more training/education on the full life cycle of digital systems and hands-on training

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Summary

- There may be some advantages to co-locating new reactor training simulators and research simulators for reasons of sharing overhead, but they should not be the same simulator
- The preferred facility model starts out as continuing the current approach and then moves to a distributed integrated center and then to a distributed center with new capabilities being developed at a single facility
- Part of the solution must be to continue to reach out to the international community and find additional opportunities to participate with other industries, other countries, and other consortia

Appendix Y

Summary DI&C/HMI Technical Issues Discussed on September 6 in General Session and Working Groups (data placed in categories)

Summary DIC/HMI Technical Issues Discussed on September 6th in General Session and Working Groups

(data placed in categories)

1. Cyber Security

- Need to understand how to design digital system so that the security they have and secure network...
- Need to development and to assess both cyber security and safety and designs that can provide both capabilities.
- Better technologies, tools and procedures to help assess the level of digital systems to cyber security concerns in the presence of growing cyber security concerns.

Some of these issues are being currently address at current DOE facilities

DOE has significant capabilities that could be used, but are not being fully used by the nuclear community, because of nuclear specific security and COI issues

2. Diversity & Defense-in-Depth

- Need for better common cause failure (diversity) review criteria
- Better decision criteria for determining if there is a need for analogue backup display for selected safety parameters?
- Need for a better way to determine what safety functions need an automatic diverse actuation system?
- The ability to visualize and understand how operators would respond to an accident concurrent with digital common cause failure
- Resolve common cause failure/ common mode failure regulatory issue, by demonstration, to understand end result

Short-term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities

Access to real system to work on
Knowledge gaps that may require additional investigation
Finding and getting nuclear and non-nuclear data
Find a way to integrating available data

A lot of the facilities are available, but to get the optimal answer a full system evaluation may be needed

Vendors may have many of the capabilities

Some information can be developed with current facilities

3. Risk-Informing Digital I&C

- Need for digital system risk modeling capability
- Need for software quality/reliability
- Need for physics based probabilistic models for sensors and systems in general that will continuously be updated by sensor data that eventually might contribute to predicts sensor/system status
- System reliability modeling methods. Need for better ways of estimating CCF. Better safety assessment methods for integrated hardware/software systems.
- Human reliability
- How do we measure/quantity defensive measures? Do defenses for event prevention (line of defensibility) transfer from analog world to digital world?

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

Testing/data to support quantitative evaluations
Benchmarking on real situations

4. Digital Systems Communications

- Criteria for use of wireless data transmission for safety applications
- Review criteria for large screen display designs for current and future plants, particularly if the can/should be dynamic and/or interactive
- Multi-unit control room integration and associated regulatory issues
- Electronic communications between safety and non-safety and between safety
- Better understanding of protocols such as foundation fieldbus and PROFIBUS.

Short term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities, but additional capabilities may be needed

5. Control Room and beyond control room, human factors

- How should the regulatory basis for new simulators be changes (if at all) Regulation Guide 1.149; 10CFR 50.55.46; ANS 3.5

- What will be the acceptance criteria for computerized support systems for operators where [it] could impact safety
- What kind of displays and representations on control screens best integrates with the requirements of digital systems? How should this feedback be accomplished?
- How should integrate computerized procedures be implemented? Should they be text oriented and/or integrated in the control displays
- Transition of decision capabilities/responsibilities from human to machine. Multi-unit plants near autonomy.
- How to quantify effectiveness of HMI that is developed. What are the metrics?
- How will operators behave in a new control room, should they be able to reconfigure the control room? How flexible should the control room be? Control room discipline.
- Humans reacting to a digital fault respond consistently (independent of experience).
- What will be the best integration or best mix of human and automation resources to achieve safe and efficient operation?
- How does the initial presentation or choose of standard screens affecting operator response
- Does ability to remotely monitor plant data detract from operator responsibility?
- How to avoid common trap on information overload to the operator
- How do you management the logic in systems to enable operators to maintain global situation awareness and do troubleshooting in a computer-based CR with 100 or hundreds of displays
- How to integrate the use of human performance effort prevention tools and digital controls
- Determining a set of performance measures and criteria for the evaluation of human-machine systems…..can it be standardized?
- Human Performance/system validation for procedure response requirements with new technologies.
- The digital control room; integrated system validation. What kind of acceptance criteria should be provided?
- Acceptance of use of part scope and other simulation capabilities as well as full scope simulators especially for upgrades
- Acceptance a) reduce number of MCR operators and b) control of multiple units from a centralized location

- Inherent complexity of highly automated highly integrated control room

- Inaccurate or incomplete operator mental model
  - Mode confusion by interaction of operator to the machine
  - Lack of/ limited situational awareness of the operator (out-of-the-loop)
  - Behavioral change – not to touch & let computer do it instead

- Keep operator out of "knowledge-based error mode"

- Cross cultural issues in control room design. Japan/France/US/GB

Short-term resolutions currently being developed. Longer term research and analysis has been started at current universities and DOE facilities, but additional capabilities (research simulator) may be needed

6. Fuel cycle Facilities

- What criteria should be established to support digital I&C and HMI for multiple/different mission of future plants: 1) hydrogen generation, 2) process steam for other uses, 3) electricity production.

- How should different facility modes of operations be implemented (monitoring mode status, operative reactor facility, Chem. Plant facility or systems)? How should the HMI be designed?

- In the fuel cycle facilities rapid obsolescence of digital technology will be an even bigger issues because of the use of COTS. How do you manage this?

- Control centers for non generation facilities

This work is not currently being address at current university and DOE facilities, additional capabilities may be needed

7. Validation (software etc.)

- Need for methods and tools for technology neutral (performance based) evaluation of new DIC and HMI concepts.

- Need for digital complexity and quality control modeling

- Need for better post modification testing. Models for testing to system perform

- Managing & keeping up with advances in technology. Example: computer systems & hardware, displays, etc.

- Better test and analysis protocols and techniques. Means for crediting these tests in regulatory reviews

- Better ways to validate software reliability/safety quantification methods for the digital I&C system.

- The quantitative assess of dependable system—emerging and future digital I&D.

- How can the industry use incremental validation and verification? Being able to focus and limit V & V when changes are made yet ensure effectiveness.

- Objective software quality/dependability metrics, what constitutes necessary and efficient?

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

8. Advanced Monitoring/Diagnostics

- Configuration control of development tools-versions of FPGA software tool sets.

- On-line diagnostics and remote plant monitoring

- Early fault detection, diagnostics, prognosis

- Issue: How to perform(?) on-line monitoring by means of software

- Monitoring whom does (?) and how are plants monitored remotely?

- Standards for health monitoring and advice operator support, task management, integrated oversight

- Characterize uncertainty in models and diagnostics

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

9. Advanced Sensors

- Should sensors get more attention in the digital I&C picture. How do you monitor, validate performance, etc.

- Smart sensors in hazardous environments

- Information on new instrumentation to support GENP, NGNP, and other new systems with new requirements

- Sensor information network

- Better sensor validation as well as overall system validation

Some of these issues are being currently address at current university and DOE facilities but additional capabilities may be needed

10. General Issues

- Removal of barriers to digital technology

- Generic criteria for evaluation of technologies

- Need to support new technology integration for all generations of plants, Need versatility/flexibility for accommodating different technologies

- How do you develop better cost benefit evaluation, methods for judging digital innovation.

- Credit for lessons learned in other industries—new technology. Have higher hurdles than existing ones.

- Digital obsolescence strategy, how do you manage a much more rapid digital system life cycle?

- How will DIC/HMI test facility be made flexible enough to support multiple user needs?

- How can one generic research facility that will be reconfigured address different plant designs and different plant control and protection systems?

- How do you provide continued funding to support long term development of research and test capabilities

- Improved International coordination/cooperation
    - Harmonization of International Standards.

- Development of better/more complete training
    - Hands on training
    - Advanced reactor training capability for all phases of the plant life cycle
    - Determination of adequate staffing levels for main control room.
    - Importance of hands-on simulator as parrot of training new staff.
    - How to best develop/engage next generation of engineers and scientists.
    - Training of new staff on R&D safety principles in digital systems.

- Lack of consistent technical understanding of digital I&C -HMI, depth and breadth across all NRC

- Forget "catch-up" (40 years behind) and try to get ahead

- Need to retain separation of NRC oversight (what) and vendor/licensee implementation (how)

Appendix Z

Summary DIC/HMI Technical Issues/Needs Discussed at the September 6th and 7th Workshop

Summary DIC/HMI Technical Issues/Needs Discussed at the September 6th and 7th Workshop

1. Cyber Security

There is a need to develop additional technical bases for determining which digital systems architectures for both system and network security is appropriate. Novel families of technologies, tools and procedures are needed to address growing cyber security concerns and to help assess the level of performance with regard to digital systems cyber security performance.

Are there capabilities to support issues: Yes, however some of the capabilities are not in organizations that are currently engaged in nuclear issues.

Who/where: DOE national laboratories and to a minor extent universities. There is extensive work being preformed in support of the Department of Homeland Security. These capabilities include Sandia National Laboratory, Idaho National Laboratory (INL) and Pacific Northwest National Laboratory (PNNL).

Do the capabilities fully support current and future needs: For ALWR's and current plant control room retro-fits – vendors feel yes. For advanced systems and concepts, new capabilities will be developed and technology will need to be transitioned into the nuclear domain.

2. Diversity & Defense-in-Depth

Current short term issues associated with the design of digital safety systems for current plant retro-fits are being developed as part of the NRC Task Working Group and as Interim Staff Guidance. However, it is widely agreed that the proposed guidance is not an optimal long term solution. Issues that need additional work include the need for better common cause failure (diversity) review criteria, better decision criteria for determining what safety parameters need diverse backups, and better ways of determining what safety functions require an automatic diverse actuation system. Additionally, there is a need to develop the ability to better understand how operators would respond to an accident (off-normal event) concurrent with a digital system common cause failure. It is also necessary to show how data from demonstrations or failures cab be used to inform diversity and defense in depth review criteria.

Are there capabilities to support issues: Yes, for short term (supporting ALWR's) with the exception of a research simulator to study operator response issues.

Who/Where: Several Universities and National Labs have capabilities and are supported by NRC, DOE and other industries. These capabilities include Oak Ridge National Laboratory (ORNL), The Ohio State University, University of Virginia, and industry facilities.

Do the capabilities fully support current and future needs: For ALWR and current plant control room retro-fits, yes with the exception of a research simulator to study operator issues; for Gen IV and GENP maybe not, because of need to support diagnostics of new reactor technology.

3. Risk-Informing Digital I&C

There is currently not agreed upon methods for modeling digital systems in current generation PRAs. There are identified needs for digital system risk modeling capability, software quality/reliability assessment tools (and procedures) and better ways for estimating CCF. This work includes development of methods for assessing/quantify defensive measures designed into digital systems, physics based probabilistic models for sensors and systems in general, human reliability, and dynamic reliability modeling methods.

Are there capabilities to support issues: Yes, however there are limited facilities (other than vendor sites) in which to conduct reliability testing of fully integrated digital systems and no research simulator to study operator response issues, in the US.

Who/Where: Several Universities and National Labs have capabilities and are supported by NRC, DOE and other industries. Some of these include The Ohio State University, the University of Maryland, the University of Virginia, Idaho National Laboratory (INL) and Brookhaven National Laboratory (BNL).

Do the capabilities fully support current and future needs: Yes, for ALWR and current plant control room retro-fits. The exception is no a research simulator to study operator issues and capabilities to conduct reliability testing of fully integrated digital systems; for Gen IV and GENP it will depend on how many new digital systems and control room concepts are introduced.

4. Digital Systems Communications

A series of first generation digital I&C communication capabilities are being developed to meet ALWR and current plant control room retro-fits needs. As new approaches and technology are developed such as wireless data transmission for safety applications, additional review criteria and the technical bases to support these will be needed.
A diverse range of new approaches are being developed (priory logic modules, etc.) particularly with regard to advanced concepts. If systems deploying multiple-units with a single control room are proposed, issues of technology integration and associated regulatory issues will need to be addressed. There are open issues associated with communications between safety and non-safety systems and better understanding is required for system communication protocols such as foundation “Fieldbus” and PROFIBUS.

Are there capabilities to support issues: Yes, for first generation system proposed for ALWR’s and current plant control room retro-fits needs. Advanced capability is not yet being developed in all of the current organizations that are engaged in nuclear issues.

Who/where: Several universities and DOE national laboratories have capabilities and are supported by NRC, DOE and other industries. These capabilities include Oak Ridge National Laboratory, Sandia National Laboratory, Idaho National Laboratory and Pacific Northwest National Laboratory, The Ohio State University, the University of Maryland and the University of Virginia.

Do the capabilities fully support current and future needs: For ALWR's and current plant control room retro-fits, yes. For advanced systems and concepts new capabilities are needed and technology needs to be transitioned into NPP domain.

5. Control Room and beyond control room, human factors

There is a need to develop additional technical bases on which HMI issues can be assessed in the context of new paradigms of operations meeting regulatory needs. Examples are the display hardware meeting reliability requirements, the visual representation of information on large display spaces such as wall mounted type displays, and representing sensor data of inherently complex automated digital systems and their control, computerized support systems and new procedures; and integration or best mix of human and automation resources to achieve safe and efficient operation.

Presently short term issues associated with the design of ALWR digital control rooms current plant retro-fits are being addressed as part of the NRC Task Working Group and as Interim Staff Guidance. However, as new paradigms of operation mature new review methods and human performance–based evaluation criteria will be required as will recommendations for design particularly for both dynamic and interactive modes of operations. It is anticipated that operations will evolve to multi-unit plants operating in near autonomy. This could create a need for new evaluation metrics and design guidance to assess remote monitoring and supervisory control for both operations and maintenance from a centralized location.

Are there capabilities to support issues: Yes, for the short term supporting current designs, new planned near term reactor plants and current plant control room retro-fits. Longer term research and analysis needs, can probably be met, with the exception of an identified need for a research simulator to be used to study operator response issues.

Who/Where: Several Universities and National Labs have capabilities and are supported by NRC, DOE and other industries. NASA, the military, and other agencies, including transportation (e.g. FAA). Other resources that are outside the nuclear domain yet with similar challenges such as those of safety should be tapped. Examples include the petrochemical industry, pharmaceuticals, hazardous waste disposal, and ship control rooms. International centers such as the Halden Project, Norway; IBM Global Center, France; and Japan/Asia should be considered.

Do the capabilities fully support current and future needs: For near term planned plants there are existing capabilities that can be used as resources. A research simulator capability is needed to study operator issues for advanced reactors, Gen IV and GENP.

6. Fuel cycle and other non-reactor Facilities

The fuel cycle for current as well as new designs and concepts is an integral part of the NPP system. Facilities that can potentially require to be licensed need to include all parts of the life cycle from extraction to ultimate disposal and/or reprocessing. Fuel cycle facilities include technologies as diverse as those associated with centrifuges for enrichment, those needed to design, test and fabricate current light water reactor fuels; MOX and advanced and fast reactor fuels for possible Gen IV and possibly GNEP needs. Facilities are also needed to support the back-end of the fuel cycle, including both interim storage and long term disposal, as well as advanced re-cycle concepts. In the fuel cycle facilities rapid obsolescence of digital technology will have even bigger issues because of the use of COTS --- How do you manage this? There is a need to develop guidance to assist in management of this technology lifecycle and its evolution.

The spectrum of potential non-reactor systems is further expanded to support digital I&C and HMI for multiple/different missions of future plants such as: 1) hydrogen generation, 2) process steam for other uses, potentially in combination with 3) electricity production. New approaches for both the design and regulation of systems will probably need to be considered.

Different modes of operations will be implemented to support a wide range of facilities such as power plant/reactor monitoring modes, operating reactor facility, chemical plant, facility or systems. There are open issues with regard to how the HMI elements both will and should be designed. Opportunities exist for implementation of new HMI concepts that will probably require new regulatory guidance.

Are there capabilities to support issues: Yes, for current ALWR fuel. New or upgraded facilities are expected to be needed to support advanced fuel work particularly if new generation fuels go into commercial scale production.

Who/Where: Several National Labs and industry have capabilities to research and support ALWR fuel delivery. DOE has supported AFCI and is now looking towards GNEP. The R&D capabilities include radiological facilities at ORNL, INL, and ANL and PNNL. There are issues regarding taking spent fuel for recycle/reprocessing to and from most DOE sites. A consortium of laboratories is collaborating to support CETE, a pilot scale reprocessing demonstration, at the ORNL. PNNL is heavily engaged in supporting the waste treatment plant (WTP) science and technology needs at the Hanford site. There are also activities at the Savannah River site.

Do the capabilities fully support current and future needs:
New or refurbished facilities will be needed to support anything more than sub-pilot scale demonstrations for closing the fuel cycle. New facilities will be needed if new generation fuels, including those for gas and fast reactors, to go into commercial scale production.

7. Validation (software etc.)

To develop the technical basis needed for regulatory review criteria new tools, systems and sub-systems and approaches are needed for managing and keeping up with advances in technology. For example, in applications involving computer systems and hardware. Such tools are seen as needing to be technology neutral and to utilize performance and reliability based metrics. These metrics need to include quantitative assessment of dependability of emerging and future digital I&C systems.

As systems evolve there is seen to be a need for better post modification testing. This should include models for testing effects/impact of modifications on system performance. Better test and analysis protocols and techniques for software validation are required as well as regulatory means for crediting these tests in reviews.

Are there capabilities to support issues: Yes, for first generation system proposed for ALWR's and retro-fit systems, for legacy plants, but much capability is not in organizations that are currently engaged in nuclear issues.

Who/where: Several universities and DOE national laboratories have activities supported by NRC, including at both the University of Maryland and LLNL. Work for other fields of application is in progress with various agencies including NASA, the Air Force/military (aero-space community) and in the DOE laboratories at PNNL, Sandia, INL and other sites.

Do the capabilities fully support current and future needs: For ALWR's and current plant control room retro-fits, yes. For advanced systems and concepts new capabilities are needed and technology needs to be transitioned into the NPP domain.

8. Advanced Monitoring/Diagnostics

To develop needed technical bases for regulatory review criteria in the areas of advanced monitoring and diagnostics the community will need to be able to develop new standards for system health monitoring, use of data to support operator advice, task management, and integrated oversight, and characterize uncertainty in models and diagnostics.

Advanced monitoring and diagnostics methods are used extensively in other industries but there are only limited applications in nuclear safety systems (Sizewell B) or it is only just now being deployed (in Finland). Research and development for other industries is significantly more advanced. The regulatory framework requires development as monitoring technologies move from on-line monitoring to advanced diagnostics and eventually prognostics and new O&M practices are considered for implementation.

Are there capabilities to support issues: Yes

Who/Where: Several Universities and National Labs have capabilities and are supported by NRC, DOE and other industries. These capabilities include ORNL, ANL and the University of Tennessee in the areas of on-line monitoring, INL in the area of diagnostics and PNNL in the area of prognostics.

Do the capabilities fully support current and future needs: For ALWR and current plant control room retro-fits, yes; for Gen III+, Gen IV and GENP probably not. There is a need to develop, demonstrate and provide guidance to support diagnostics of new reactor technology.

9. Advanced Sensors

Most sensor needs for ALWR's can be met from technologies developed to support legacy systems. As smart systems evolve they are seen as becoming increasingly integral elements in digital I&C – this aspect of the technology for ALWR's does require attention, including from a regulatory perspective.

There is a need to develop the capabilities to understand needs and requirements for Gen III+ and Gen IV systems. New processes and approaches are needed to address sensor monitoring, and performance validation. As systems other than boiling water are used smart sensors will be required for an increasing diverse range of hazardous environments, i.e. high temperature gas and liquid sodium. New sensor network and communication concepts, developed in other fields, can be expected to need to be reviewed for possible NPP application.

Are there capabilities to support issues: Yes, for ALWR's and current fleet retrofits. Research needed for non-water systems and smart sensor systems.

Who/where: NRC not supporting much work in this area. There are several universities and DOE national laboratories with DOE supported activities including ORNL, Ohio State University, University of Tennessee and PNNL looking at sensors for harsh environments for both nuclear power and process industry applications. There has also been work supported by DOE under the ATP program, and Hydrogen programs looking at process industry and hydrogen energy system needs (including to support both fuel cells and other automotive systems).

Do the capabilities fully support current and future needs: For ALWR's and current plant control room retro-fits, yes. For advanced systems and concepts new capabilities are needed and technology needs to be transitioned into NPP domain. High temperature gas sensing and fast reactors have identified gaps in available US testing/harsh environments facilities.

10. General Issues

For successfully creating and sustaining a test and research capability over arching technical and management issues need to be considered.

<u>Technical</u>

There is a need to address how barriers to digital technology can be removed in critical areas. An example is identifying what needs to be changed in technology that currently exists. Another area is determining how DIC/HMI test facilities can have the flexibility needed to support multiple users and be quickly reconfigured to address key domains such as different plant designs, plant control, and protection systems, and new technology for integration for all generation of plants.

As technology will change there is a need to address and manage/regulate issues around obsolescence. Consideration should be given to developing an obsolescence strategy that includes a more rapid digital system lifecycle. As technology will change generic criteria will need to be developed for the evaluation of both the evolving and new technologies. This should include cost benefit evaluation methods for judging the value of digital innovation.

DIC in the nuclear field seems to have a "higher hurdle" than existing analogue technology. New technologies developed outside the nuclear field provide opportunities as resources for lessons learned on similar and in some cases near identical critical issues. These resources should be tapped.

Training is another area that needs attention. This should include development of a better/more complete comprehensive training program covering activities ranging from hands-on for all phases of the plant life cycle to educating next generation engineers and scientists and new NRC staff in fundamentals. Examples of these fundamentals include R&D safety principles in digital systems and key concepts in depth and breath of digital DIC/HMI.

Management

There is a need to develop new implementation and deployment strategies for the USA that thinks in terms of “getting ahead” versus “catching-up”. Within this new paradigm, consideration needs to be given to how to provide continued funding to support long term development of research and testing capabilities and also strengthen international coordination and cooperation. Another factor to consider is the need to retain separation of NRC oversight (what) and vendor/licensee implementation (how) roles.

Appendix AA

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

Options for Funding, Participation & Siting

September 11

NRC Workshop Digital Instrumentation and Control & Human-Machine Interface

US Digital Instrumentation and Control (DIC) and Human-Machine Interface (HMI) Workshop

Options for Funding, Participation & Siting

September 11

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SRM Focus Questions

- **SRM Q #1: What potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include industries outside the nuclear industry?**
- **SRM Q #2: If nuclear industry participate, how could conflict-of-interest issues be addressed?**

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SRM Focus Questions (cont)

- SRM Q #4: What siting options are most viable (e.g. universities where integration with graduate studies might be encouraged, national laboratories, etc.), taking both cost and ease of technical information into account?
- SRM Q # 7: What impediments, if any, to information sharing among participants and to external stakeholders might exist?

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Discussion on Funding/Participation

- SRM Q #1: What potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include industries outside the nuclear industry?
- SRM Q #2: If nuclear industry participate, how could conflict-of-interest issues be addressed?

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Potential Funding/Participation Options

- University
- NRC
- NRC/DOE
- NRC/Industry
- NRC/DOE/Industry
- Other

Discussion on Siting

- SRM Q #4: What siting options are most viable (e.g. universities where integration with graduate studies might be encouraged, national laboratories, etc.), taking both cost and ease of technical information into account?

Potential Siting Options

- NRC
- DOE
- University
- Industry
- Other

Finding Common Ground on Funding, Participation, & Siting Options

What funding, participation & siting options do you think will work for the options below?

- **Option A: New Integrated Facility**
  (Centralized Facility)
- **Option B: Distributed Center**
  (Dispersed facilities with centralized program center)
- **Option C: Hub Model**
  (Centralized facilities where necessary and dispersed facilities where possible. Centralized program center.)

Option A: New Integrated Facility

Centralized Facility

Siting → Funding/ Participation ↓	NRC	DOE	Industry	University	Other
NRC					
NRC/DOE					
NRC/ Industry					
NRC/DOE/ Industry					
Other					
University					

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Option B: Distributed Center

Centralized Program Office

Siting → Funding/ Participation ↓	NRC	DOE	Industry	University	Other
NRC					
Government Agencies					
Government & Industry					
U.S. & Global Partners					
Other					
University					

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Option C: Hub Model

Centralized Program Office & Some Centralized Facilities

Siting → Funding/ Participation ↓	NRC	DOE	Industry	University	Other
NRC					
Government Agencies					
Government & Industry					
U.S. & Global Partners					
Other					
University					

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Option A: New Integrated Facility

Centralized Facility

Siting → Funding/ Participation ↓	NRC	DOE	Industry	University	Other
1 NRC	1			2	
2 NRC/DOE	1	2			
NRC/ Industry					
NRC/DOE/ Industry					
Other					
University					

Example

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Discussion on Impediments

- SRM Q # 7: What impediments, if any, to information sharing among participants and to external stakeholders might exist?

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Option A: New Integrated Facility

Centralized Facility

Roll-up

Siting → Funding/ Participation ↓	NRC		DOE		Industry		University		Other	
	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice
NRC										
NRC/DOE										
NRC/ Industry										
NRC/DOE/ Industry										
Other										
University										

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Option B: Distributed Center

Centralized Facility

Roll-up

Siting → Funding/ Participation ↓	NRC		DOE		Industry		University		Other	
	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice
NRC										
NRC/DOE										
NRC/ Industry										
NRC/DOE/ Industry										
Other										
University										

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Option C: Hub Model

Centralized Facility

Roll-up

Siting → Funding/ Participation ↓	NRC		DOE		Industry		University		Other	
	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice	Choice
NRC										
NRC/DOE										
NRC/ Industry										
NRC/DOE/ Industry										
Other										
University										

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Appendix BB

DIC/HMI Meeting

September 11, 2007, Washington, D.C.

Open Discussion Notes

DIC/HMI Meeting

September 11, 2007   Washington, D.C.

Open Discussion Notes

Funding/Participation

(A. Haghighat) We need to separate activities into two parts:

1. Short term
   - Explore ways to initiate activities to address using existing systems
   - Use existing facilities—involve and redirect
2. Long term
   - Development and advancement of control systems
   - Training of workforce
   - Establishment of Centers of Excellence

(Don Dudenhoeffer, INL) DOE/Industry/NRC/Academia have been working together to develop advanced I&C and HMI research focus. To date, however, the issue has been programmatic funding to support integrated and collaborative project of substance.

Limit 'employment' in the R&D facility to those in the U.S. perhaps with a clearance.

(Pete Planchon) Halden Model covers more than research. Should be able to also fund research independently at same facility.

(Gary Vine) For NRC there is a huge advantage of more collaboration with DOE.

(Chris Plott) Multiple funding sources help to ensure that the research capability is available and sustained.

Two part to issue: 1) Structure of financial and governance and 2) Capital assets infrastructure i.e. what needed? Location(s)? How and who makes investment?

Structure:
- Board of stakeholders…DOE, NRC, Industry
- Providing funding and direction to R&D to base program. Results shared by all.
- Individual R&D would be specifically paid for by individual organizations

(Gary Vine) Collaboration yes but not with NRC in charge. Industry wants to see demonstrated value in being involved.

(Russ Sydnor) Tap into industry and utility funding via the university parts of the Hub model e.g. identify and coordinate and search out industry sponsors for university research to support issue resolution and future talent development.

(Russ Sydnor) Utility participation via collaborative research efforts using utility supplied facility. e.g. mock-up facilities (used for operation and maintenance, technician training) that exist at many utilities.

(Russ Sydnor) Funding model that supports the Hub model—program office identifies 3 year plan. Specific research need in 3 year plan are funded on a user need basis e.g. if research supports NRC regulatory development then NRC funds it. If research supports DOE Gen IV then DOE funds it. Industry funds design basis development research.

(Gary May) The two aspects of funding regarding conducting work at any one facility for both industry and regulatory needs: 1) funds for actual research and 2) funds to have the general capability and infrastructure available to do the research.

(F. Owre) Funding issue—find a formula. NRC needs a larger funding base to commit to long term research. Separate funding and participation. Participation should be available to all major players (NRC, DOE, Industry, Universities). Separate Federal issues (long0term) issues from (short-term) current ones.

How does a near term plant cooperate with a general facility (say to do V & V) and not get entangled with the NRC before the completion of the activities.

(Chris Plott) NRC may need to show they are willing to fund/commit to interest others in invest funding.

Address COI issues by requesting that all parties that want to play sign disclosure or setup appropriate organizational partition to avoid bias or any conflict issues.
Staff exploiting relationships under the EEO program to dedicate more funding

Include vendors and other governmental agencies.

Use unbiased 3rd party to provide oversight/programmatic direction; one who has no vested interest in outcome.

Require a certain amount of $$ per group/entity in order to participate. If $ can't' be given then request resources from the organization.

Make more outreach efforts to other groups. Build stronger relationship ties with others.

(Joe Murray) Industries can't see anything in it for them. They support NRC in moving forward but don't see it would give them answers they are not already getting with their own programs.

Split DOE Program needs (NGNP, GNEP, etc) from commercial industry needs. Funding assistance and industry engagement completely different i.e. industry won't fund very long term work.

(R.T. Wood) Additional thoughts on synergistic coupling of NRC/DOE/Industry/University research need (add to Pete Plancheon's thoughts).

Benefits:

1) Governance—independent body composed of reps from stakeholders with multiple funding sources provides insulation for NRC to reduce perception of mixed regulatory/advocacy role. Also broadened scope enhances innovation and encourages interest by students. Allows next generation staff (NRC & Industry) to experience both side (development and regulation).

2) Hard Infrastructure. Leverages dollars and existing capabilities. Makes extensive range of subject matter experts available to all stake holders. Avoids duplication and reduces potential for conflicting conclusions due to inconsistent data problems.

Governance: NRC needs not primary concern. Sustained funding from multiple sources needed (must secure and retain buy-in). Infrastructure: Competition for resources. Firewalls to protect information and avoid perception of COI..

(Dave Vaglia) Long term coordination desired fro MCR/I&C design beyond present licensing process for plants like AP1000, APWR, ESBWR. Looks like needs for GNGP plants, IRIS, PBMR, Advanced Recycle Reactors. Multiple modular control co-generation/hydrogen/electricity HF on core damage frequency.

(David Vaglia) Vendor concern that existing/agreed to licensing process for plants in design now will be delayed, disrupted. Last time though, many plants were "killed" by being delayed.

Siting Options

(Russ Sydnor) Develop a virtual site to be run by the Hub Model Program Office. The Program office is made up from representatives i.e. NRC/DOE/Universities/Industry/Utilities. The program oversight board contracts an independent site operator to build and operate the virtual site on-line.

(Russ Sydnor) Are there any independent labs that would be interested in bidding on a DIC/HMI facility that would be jointly funded by NRC/DOE/Industry?

(Jay Persensky) Need single site for full-scope simulator for HMI research. Need significant investment in infrastructure for research simulator. Need access to operators.

(Frank Quinn) Minimize staff relocation. Family commitments and housing market considerations.

(Frank Quinn) We need to interest our universities because we can not design and operate all these new plants without significant numbers of new graduates.

(Frank Quinn) Research simulator for human factors will need qualified power plant operators. Limited number. Limited work hours. Credit for requal?

(Don Dudenhoeffer) Programmatic sustainability not only from NRC but from other programs.

(Don Dudenhoeffer) The hub and spoke model does not preclude the utilization of multiple sites. Siting would be required for the central facility.

(Chris Plott) For HMI research and perhaps training a portable option might be worth considering.

(Tim Hurst) Siting at other than universities closes the facilities to the majority of potential users. Facilities have to be at a generic location.

(R.T. Wood) The role of tech. integrator/Program Office/Board of Directors includes acting as single point of contact to facilitate access to center resources/sites. The three options discussed concerning siting the Program Management Board of Directors are: 1) @ NRC HQ, 2) @ facility site that hosts substantial hard infrastructure (likely a national lab), of 3) independent company "technical integrator." Not a research organization.

(R.T. Wood) Case for Action. 1) Clearly articulate DIC & HMI research needs and define explicitly the cost/benefit of inaction/action, 2) ensure more effective use of existing resources (e.g. facilities, testbeds, SMEs), experience (nuclear and non-nuclear, U.S. and international), and knowledge (transition from reactionary approach to visionary/anticipatory approach), 3) Integrate access/use of hardened facilities and people to ensure efficiency in execution soft facilities (HMI/Simulator, testbed, analysis tools, etc.) can be added as needed. [This is the Hub model concept.. Drivers: 1) address knowledge gaps/uncertainties that result in unnecessary conservatism, 2) Infrastructure sustainability. Provide vehicle for experiential training and student (future staff) development through head-on access and research opportunities, respectively. Fully engage broad community for DIC & HMI research (nuclear and non-nuclear, SMEs) and provide access points for other industries.

(A. Haghighat) We should consider forming a consortium of government/industry/university possibly a company with appropriate by-laws and guidelines. The company can have an executive office with an Executive Director. The cost could be handled with fees.

(Tunc Aldmir) Hierarchical type of decentralized administration, e.g. universities form a consortium led by a single institution.

(Chris Plott) Ability to implant cyber security for both security reasons and IP reasons.

(R.T. Wood) Have company to be technical integrator but not owner of research facility.

(R.T. Wood) Regardless of siting options, predictability and consistency of access by stakeholders is essential, with necessary security considerations included.

(F. Owre) Machines can be distributed but people are different. Need to have the right people together.

(Brian Arnholt) Established infrastructure of universities and DOE labs supports the distributed consortium.

Siting discussion is counter productive at this time. Follow process: 1) define needs, 2) list functional requirements to be meet needs, 3) select structure of governance of physical infrastructure then 4) site for infrastructure.

(F. Owre) You need a centralized (or universal) site if your are going to run HF experiments because you need a placer where the following can come together and actually do the work: simulators, HMI, researchers, process experts, and operators.
Digital research can be much more distributed than HMI research because you will initially address HW and SW issues, not people issues. Have one site with neutral operator. Have a program committee which directs the technical program formulation. Fro this there will be R&D people issues and R&D machine issues. The first needs to be centralized with research simulator, operators, process experts and researchers. The second can be distributed to DOE labs, universities and others.

Staffing issue for research simulators. Researchers include (H factors, behaviorial/psychology, and ICT). Need access to operators!! Process experiments define transients, experiments, participating/assisting researchers. Basic technicians. Developers (Systems, HMI, integration).

Consider other governmental labs. Consider commercial entities as well.

Suggested criteria for evaluating sites: accessibility, centrality, secure, expertise, location, staffing, modularity, cost, bias (by audience)

Borrow space at another facility/ university.

<u>Impediments/Challenges</u> (especially with information sharing among participants)

- IP issues
- NRC access to data
- Sharing of proprietary information
- Organizational conflicts of interest
- Take advantage of previous relations to address conflicts of interest
- Must show everyone "What's in it for me."
- Consistent quality of data
- Need restrictions on publication of results?
- Need to look at information sharing procedures used at similar facilities
- Need definition of what is proprietary
- How NRC will use results
- Shared research means shared information
- Don't want to share information with regulators before the proper time.
- Takes tenacious effort to make collaboration work—be ready

<u>What Would Make Us Better in DIC/HMI?</u>

Benchmarking effectiveness of tools against other industries.

Internal and external peer review of work.

External review board.

Increase involvement with organizations that have strong DIC/HMI capabilities.

Be more assertive in building collaborative relationships.

Address challenges with budget associated with emerging issues.

Training for NRC staff to help them understand systems and plants better.

Invest in training of NRC staff.

More cooperation with other safety critical industries.

Resolve generic issues to develop performance based rules.

Use lessons learned from others.

Define review tools for NRC's confirmatory mission.

Know how to apply research to licensing issues.

Know how applicable university type research is to licensing!

Know how to determine if something is applicable. What is the best way to know if something is applicable?

Look at FFRDC.

Better availability of data.

(Gary Vine) Stay within role of doing regulatory research. What is regulatory research? Can't duplicate work? Can't go beyond confirmatory needs? Dine all areas NRC needs additional research.

(Russ Sydnor) Characteristics for improved research:

- Needs identification
- Capability index/catalog
- Improved integration
- Improved critique/assessment of results
- Annual reviews
- How to manage emerging issues
- Flexibility

Desired Characteristics of a Facility/Center

- Better understanding about 1) what is unique, 2) what is out there, 3) what other agencies are doing and 4) what the needs are.
- Process for handling IP issues
- Security of information
- Address R&D for proper time frame.
- Access by users.
- Better leverage of research for teaching and education.
- Designed to promote cooperation and collaboration.
- Ability to leverage with other industries.
- Better coordination between DIC and HMI research plans.
- Knowledge management process. How to aggregate, store, and access distributed information.
- A clearly articulated value proposition for all participants/users. Need to demonstrated long term value.
- Expand on EPRI model to other constituents
- Use multiple funding sources to ensure capabilities are there when you need them.

Appendix CC

US DIC & HMI Workshop: Integration Roll Up

US DIC & HMI Workshop: Integration Roll Up

Leonard J. Bond

Pacific Northwest National Laboratory

September 11, 2007
Draft 3

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SRM Focus Questions

- SRM Q #1: What potential participants might be interested in joint participation, collaboration, and funding of such a facility, and to what extent might this include industries outside the nuclear industry?

- SRM Q #2: If nuclear industry participate, how could conflict-of-interest issues be addressed?

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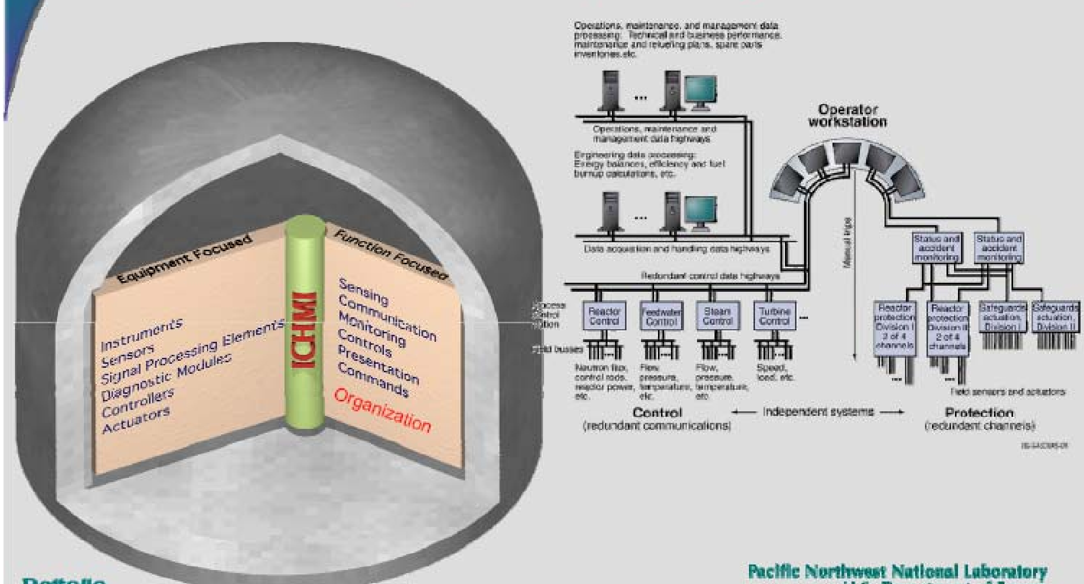
SRM Focus Questions (cont)

- SRM Q #4: What siting options are most viable (e.g. universities where integration with graduate studies might be encouraged, national laboratories, etc.), taking both cost and ease of technical information into account?
- SRM Q # 7: What impediments, if any, to information sharing among participants and to external stakeholders might exist?

DIC-HMI – *MORE THAN SIMULATORS*

**ICHMI Forms a Nuclear Power Plant's (NPP) Nervous System –
HMI is ALL interactions, Control room, O&M + diagnostics**



Facilities/Capabilities - SUMMARY

- Robust digital I&C HMI community in USA
- Capabilities for R&D – *sensors to systems* in DI&C and related HMI (e.g. aero-space)
- Capabilities in USA dedicated to NUCLEAR related DI&C – HMI issues – smaller community - *limited*
  - Industry has capabilities, systems and infrastructure -
    - Probably adequate to support design, test build – focused on ALWR' (2010-15 delivery)
  - Research community depleted – re-emerging (or trying)
    - Much focused on meeting needs of longer term (i.e. Gen III+ & IV)
    - Nuclear Power DI&C-HMI R&D: recent R&D funding limited (DOE & NRC)
    - "pockets" of expertise remain
- People – in nuclear related I&C (in USA) – much analogue experience – need for technology transition – familiarization & more nuclear focused experience

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Summary in General Session and Working Groups Issues

- Large number of issues that fall into:
  - Cyber Security
  - Diversity & Defense-in-Depth
  - Risk-Informing Digital I&C
  - Digital Systems Communications
  - Control Room and beyond control room, human factors
  - Fuel cycle Facilities
  - Validation (software etc.)
  - Advanced Monitoring/Diagnostics
  - Advanced Sensors
  - General Issues

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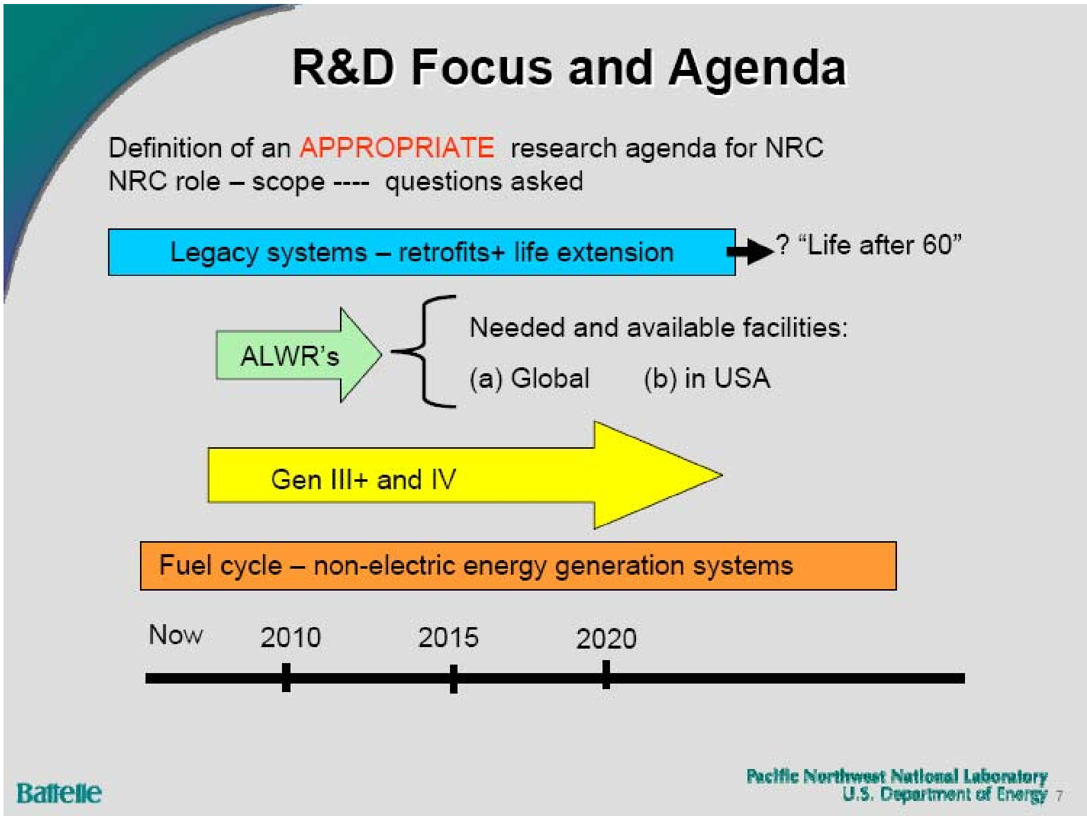
R&D Focus and Agenda
Definition of an APPROPRIATE research agenda for NRC
NRC role – scope ---- questions asked
Legacy systems – retrofits+ life extension
? "Life after 60"
ALWR's
Needed and available facilities:
(a) Global (b) in USA
Gen III+ and IV
Fuel cycle – non-electric energy generation systems
Now
2010
2015
2020
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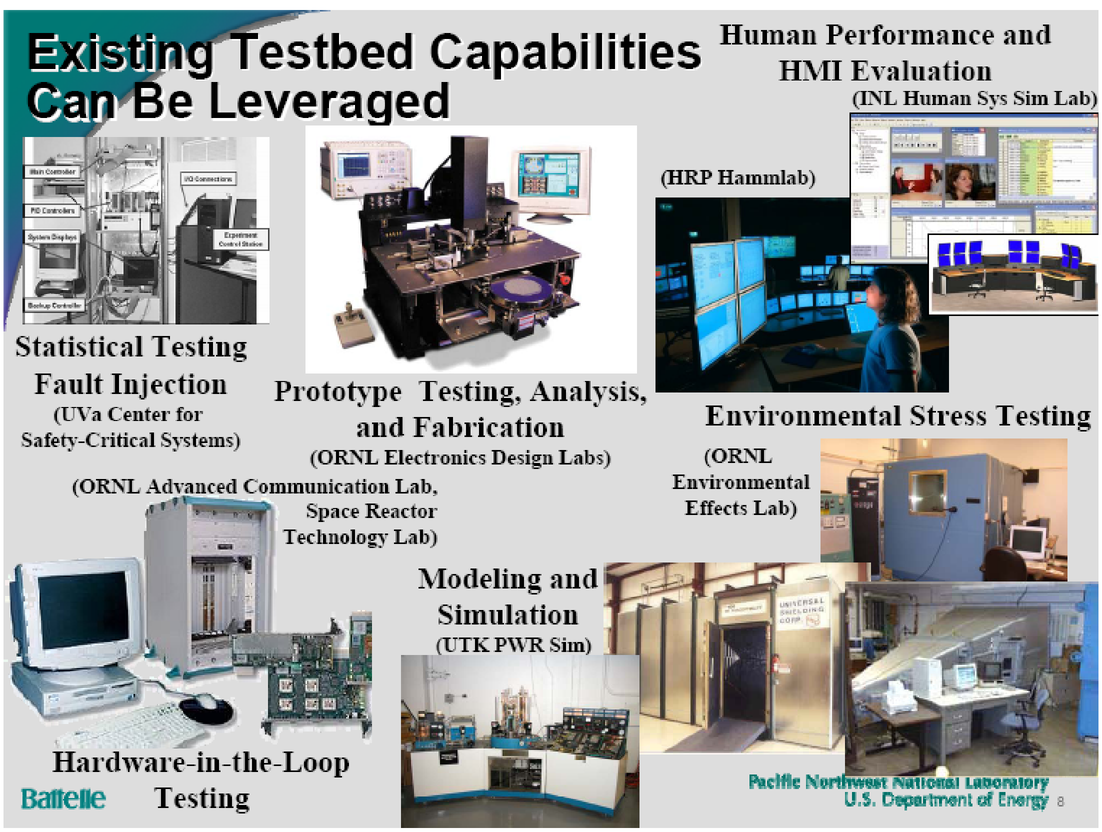
Existing Testbed Capabilities Can Be Leveraged
Human Performance and HMI Evaluation
(INL Human Sys Sim Lab)
(HRP Hammlab)
Statistical Testing
Fault Injection
(UVa Center for Safety-Critical Systems)
Prototype Testing, Analysis, and Fabrication
(ORNL Electronics Design Labs)
Environmental Stress Testing
(ORNL Environmental Effects Lab)
(ORNL Advanced Communication Lab, Space Reactor Technology Lab)
Modeling and Simulation
(UTK PWR Sim)
Hardware-in-the-Loop Testing
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Many Demonstrated Options

Single Sponsor
Single user

SPECTRUM OF OPTIONS

Multi-sponsor
Multi-user

- Highest level of control
- Minimum Conflict of Interest
- Focused Program (regulatory research)
- Single OR Multi-site
- HIGHEST COST (for one org).

- Potential for wider community engagement
- More diverse – more student opportunities
- More experts engaged
- More capability (?)

- Lower control by any ONE org.
- More potential for Conflict of Interest
- Broader Program (probably) - *different mix of needed capabilities*
- Single OR Multi-site

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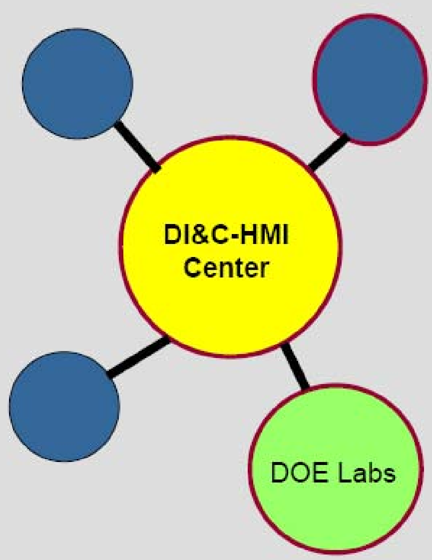
Distributed Center Approach (Option #i)

- Establish a project or program office
- Leverage best available facilities
- Leverage established expertise
- Coordinate and integrate activity for maximum impact
- Defined research agenda – use peer review, steering/advisory groups



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Finding Common Ground on Funding, Participation, & Siting Options

What funding, participation & siting options do you think will work for the options below?

- No new facility – apply continual improvement to current NRC approach (univ., labs etc engaged)
- Option A: New Integrated Facility
  (Centralized Facility)
- Option B: Distributed Center
  (Dispersed facilities with centralized program center)
- Option C: Hub Model
  (Centralized facilities where necessary and dispersed facilities where possible. Centralized program center.)

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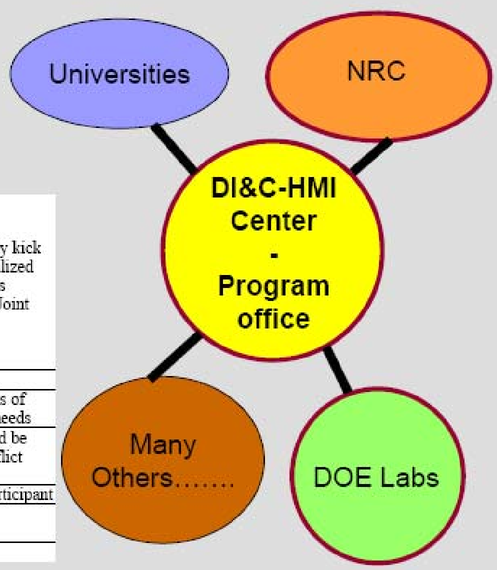
Hub and Spoke

- Fast start
- Maximum access to facilities and talent

OPTION C: Hub Model

In this option NRC would sustain current programs initially. It would immediately kick off an Option B program as soon as it could be funded. Facilities would be centralized where necessary and all others decentralized where possible. Centralized facilities enhance collaboration/integration while not limiting access to other capabilities. Joint international research planning capability would also be a part of this option if appropriate.

Advantages	Disadvantages
Easier model for engaging industry	Need to prioritize to meet the needs of various sponsors with competing needs
Improves collaboration/access	Funding/partner management could be cumbersome; need to manage conflict among partners
Fills the most gaps	Less synergy due to distributed participant
Graded/timed approach that allows getting started quickly	



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Some Key Messages

- Require to have demonstrated needs - research agenda
- Industry may be interested in a defined research program – meeting needs
- NRC role – issues and concerns --- regulator
- DOE – role – directed to provide facilities for NRC –Office of Research
- Consortium – Who plays? NRC participate rather than lead
- People needs – crafts/trades to researchers
  - NRC loss of expertise - ????
- Need to benefit from what others have done
- ????

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Research Simulator

- Qualified staff availability
  - Need mix process experts, operators, techs etc
- Must ensure cyber security and data protection
- Research and training systems – need to be different

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Effective Centers

- Need for a well defined research agenda
  - Community needs/agenda
  - NRC needs and agenda – regulatory research
  - **Define what capabilities needed – and when**
- Need to understand where if and where nuclear is unique
- Lessons learned from other industries
  - E.g. Leverage fossil HF experience
  - Aero-space etc
- Well developed and tested structures and management models
  - 501c3 -- LLC ??? Board?
  - Understand what programs are effective and have impact (DARPA)

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Appendix DD

NRC Workshop Digital Instrumentation and Control (DIC) Human Machine Interface (HMI) Workshop Part A Summary Report: Washington D.C. September 11, 2007

NRC Workshop Digital Instrumentation and Control (DIC) Human Machine Interface (HMI) Workshop Part A Summary Report: Washington DC September 11, 2007

At the workshop in Rockville, Maryland, NRC Chairman Dale Klein confirmed the Commission's commitment to advancing NRC's capabilities for addressing Digital I&C/HMI regulatory issues. Experts attending the workshop were charged to provide inputs on funding, participation and siting options, especially for the preferred options developed at the Atlanta workshop held September 6th and 7th. The preferred options, selected from a much longer list ranging from a single facility- single user to a multi-sponsor-multi-user option, included: 1) A new integrated centralized facility, 2) Enhance current practice and NRC would continue its present approach of using a number of different facilities on a case by case basis, 3) "Hub & Spoke" providing a program office and centralized facilities. New facilities would be developed at the hub or at one or more satellites as appropriate, and 4) A distributed center with a network of satellite facilities coordinated through a centralized program center.

It was agreed that there must be clear definition of the center's mission regardless of whether the center is distributed or a single site. Attendees discussed desired characteristics for the operation of a facility and its management. They emphasized the importance of considering the facility in context of its organization such as 501(c3), LLC, or a department within NRC. Defining the mission with long-term grand challenges needs to be articulated for achieving longevity and sustainability of the needed capabilities.

Three types of needed capabilities were identified; testing hardware and software/integration, hardware and software research, and research for regulatory human factors. There was general agreement that the facility should provide *more* than simulators – it should be considering all paths of the nerve system for DIC/HMI -- ALL interactions, control rooms, O&M and diagnostics.

It was felt that benefit could be gained from what others have done outside the field of nuclear. For example, the robust digital I&C/HMI community in the USA and capabilities for R&D cover *sensors to systems* in DI&C and related HMI (e.g. aero-space).

Many issues and needs were identified and there was general agreement that an understanding about where these fit with respect to how they can be solved now, need research at existing facilities or need research at new facilities. Research is needed to inform NRC and there is a need to demonstrate long term value of a facility, and finding a way to effectively get a head of the game.