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Revision 0

Digital Environment for Advanced Reactors Workshop

Argonne National Laboratory, Chicago, IL • June 5-6, 2018

GAIN Gateway for Accelerated Innovation in Nuclear

NEI Nuclear Energy Institute

EPRI Electric Power Research Institute

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Digital Environment for Advanced Reactors Workshop

Prepared by Idaho National Laboratory
Office of Nuclear Energy

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EXECUTIVE SUMMARY

On June 5 and 6, 2018, the U.S. Department of Energy (DOE) hosted a workshop to gather input from stakeholders on current challenges associated with design and implementation of digital environments for advanced reactors. The workshop specifically focused on advanced sensors, monitoring, control, and human automation interaction, in addition to the specific technologies needed in these areas to support the deployment of advanced reactors.

This workshop provided a forum for exchange of information on available technologies, ongoing research and development activities, as well as identifying technology gaps needed for advanced reactors. In addition, review of technologies needed to support completion of instrumentation and control systems, operating experience, and lessons learned were provided by the current reactor community. These challenges were considered by the advanced reactor community as they reviewed their relevant design features and the supporting technologies.

The key deliverable from the workshop was to identify gaps between needed and existing technologies. These gaps are captured in this report and are intended to support inform DOE's research priorities decisions.

CONTENTS

ACRONYMS

ANL	Argonne National Laboratory
ASI	Advanced Sensors and Instrumentation
DOE	U.S. Department of Energy
DOE-NE	U.S. Department of Energy Office of Nuclear Energy
EPRI	Electric Power Research Institute
FOA	funding opportunity announcement
GAIN	Gateway for Accelerated Innovation in Nuclear
HTGR	High-Temperature Gas Reactor
I&C	instrumentation and control
INL	Idaho National Laboratory
LWR	light water reactor
LWRS	Light Water Reactor Sustainability
MSR	molten salt reactor
NEET	Nuclear Energy Enabling Technologies
NEI	Nuclear Energy Institute
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
R&D	research and development
RD&D	research, development, and demonstration
SMR	small modular reactor
U.S.	United States
V&V	verification and validation

Digital Environment for Advanced Reactors Workshop

1. INTRODUCTION

The Digital Environment for Advanced Reactors Workshop was sponsored by the United States (U.S.) Department of Energy's (DOE's) Advanced Sensors and Instrumentation (ASI) program through the Gateway for Accelerated Innovation in Nuclear (GAIN), and held June 5–6, 2018, at the Argonne National Laboratory (ANL). The purpose of the workshop was to gather input from stakeholders related to advanced sensors, monitoring, control, and human automation interaction technologies needed to support the deployment of advanced reactors.

DOE Office of Nuclear Energy's (DOE-NE's) mission is to advance U.S. nuclear power in order to meet the nation's energy needs by: (1) enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet; (2) developing an advanced reactor pipeline; and (3) implementing and maintaining the national strategic fuel cycle and supply chain infrastructure.

ASI is one of the program elements of Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development that fosters research and development (R&D) to develop and deploy innovative and advanced instrumentation and control (I&C) capabilities for future nuclear energy systems.

The workshop's stated objective was to provide new reactor communities with a forum for an exchange of information about I&C R&D. The specific focus was on informing the new reactor community of available technologies, operating experience, and lessons learned by current nuclear power plants as they relate to ASI. This was facilitated through presentations (Appendix D), breakout sessions (Appendix B), and member surveys (Appendix C). These activities were supported by members representing the new nuclear reactor community, current nuclear utilities, nuclear vendors, universities, national laboratories, the Electric Power Research Institute (EPRI), the U.S. Nuclear Regulatory Commission (NRC), the Nuclear Energy Institute (NEI), and DOE (Appendix A).

1.1 Federal Investment in Advanced Sensors and Instrumentation Technology

While industry is likely to invest in applied research programs that are directed toward enhancing operations or in developing incremental improvements, industry is unlikely to invest significantly in research programs that focus on longer-term or higher-risk high-reward efforts. Federal R&D investment in the early stages of science and technology innovation will be essential to stocking the pipeline of ideas, materials, devices, and processes contributing to energy innovation. The public role is particularly important in early stage R&D and early maturation of the technology, followed by a transition to primarily private sector activity.

Additionally, because research necessary for nuclear power plant long-term operation is of a broad nature that provides benefits to the entire industry as well as the entire nation, it is unlikely that a single company will make the necessary investment on its own. Government cost-sharing and involvement is required to promote the necessary programs that are of crucial, long-term strategic importance. Nuclear research, development, and demonstration (RD&D) should also consider and address economic competitiveness essential to currently operating plants, the enabling of new plant construction, and U.S. competiveness in global markets.

Although, most research will take years to provide products to the nuclear community, it was emphasized during the workshop that RD&D needs to be conducted with a near-term benefit, especially in cases where that RD&D is already available but faces barriers and/or obstacles to implement. To that end, information obtained from this workshop has been captured and is being used to identify gaps between existing and needed capabilities by the advanced reactor community and to establish DOE research priorities. These DOE activities could include planned solicitations, cost-shared R&D, and pilot projects through private-public partnerships.

1.2 Process for Report Development and Report Content

This workshop report is largely technology-specific rather than program-specific, and represents a joint effort among DOE, national laboratories, and the nuclear industry to facilitate strong stakeholder engagement. The goal is to provide recommendations to DOE-NE for future budget planning by establishing a detailed list of RD&D needs or recommendations. In the discussions, the workshop participants recognized that a good deal of the RD&D on these issues was already underway. However, it was important to develop a comprehensive list for longer-term consideration. This report and its recommendations will therefore provide insight to DOE-NE for future NEET ASI RD&D.

1.3 Workshop Overview

The Digital Environment for Advanced Reactors Workshop was held June 5–6, 2018, at ANL. The event was jointly sponsored by DOE, GAIN, EPRI, and NEI, and was by invitation only. The workshop targeted nuclear community members actively working in areas related to advanced sensors, monitoring, control, and human automation interaction technologies, and was designed to facilitate discussions and capture information as they relate to the challenges and gaps in technologies to support the development of advanced reactors and the advancement of new technologies for the current fleet of light water reactors (LWRs). The workshop also provided a forum for industry to discuss what capabilities and information they would like to have for future nuclear plants and served as a means to exchange information about ongoing R&D projects and programs in sensors and instrumentation to support the next generation of nuclear plants.

1.3.1 Workshop Introductions

The workshop was facilitated by Suibel Schuppner, the DOE-NE NEET ASI Program Manager, and Craig Primer, the NEET ASI National Technical Director. The kickoff and workshop overview was provided by Tom Miller, Director of the DOE-NE Office of Accelerated Innovation. During that kickoff, the Presidential and Departmental Nuclear Energy Priorities were reviewed and the commitment to nuclear R&D was reinforced. In addition to the nuclear relevance discussion, a review of DOE-NE’s mission and strategic plan to support these objectives was conducted. A review of relevant funding opportunities announcements (FOAs) by DOE-NE were provided. These opportunities include the U.S. Industry Opportunities for Advanced Nuclear Technology Development FOA (DE-FOA-0001817), the NE Industry Vouchers, the Consolidated Innovative Nuclear Research FOA, and the Small Business Innovation Research and Small Business Technology Transfer FOA. These FOAs can be found through the GAIN.inl.gov and the NEUP.gov websites. The scope and objectives of this workshop were reinforced and a challenge was given: “Why not the future now?”

1.3.2 Industry Experience

Leveraging this idea, John Connelly, Steven Lopez, and Paul Tobin provided an industry perspective on the “Vision of Future I&C Systems.” Connelly, the Senior Engineering Manager at Exelon Nuclear, presented information describing the financial pressures being experienced by the current nuclear fleet and explained the importance of digital technology to help address improved process efficiency and system performance reliability, which are critical elements to help overcome the financial burdens associated with poorly designed or antiquated technologies. This also included a review of the regulatory challenges associated with upgrading systems and what Exelon has done to standardize its engineering processes.

Lopez, an EPRI Senior Technical Leader, then provided an overview of recent I&C research conducted for their current fleet. This included a discussion on EPRI's vision of plant modernization, the key enablers to support that transformation, and the functional areas it would address. Key programs and products that were available through EPRI were also highlighted, which include plant monitoring recommendations, distributed antenna system design, standard digital system design process, cybersecurity technical assessment methodology, and a discussion regarding how to get more information from EPRI in those areas.

Finally, Tobin, the Rolls Royce Executive Vice President for Nuclear Digital Services, wrapped up the industry presentations with a review of his company's capabilities and a futuristic vision of where it is headed. Among the key information provided from his presentation was the importance of seamless information integration to support improved monitoring and maintenance cost performance. The desire is to get to a fully integrated supply chain lifecycle. This new business model would provide dynamic plant data to remote support centers that would monitor equipment, support maintenance, and enable work control activities virtually.

1.3.3 Advanced Reactor Type Overview

The focus of the conversation then changed to new reactor design and the challenges faced by the design community associated with specific reactor types. These included overviews and challenges that were presented by new reactor design experts representing four unique advanced reactor types: (1) molten salt reactors; (2) fast reactors; (3) high-temperature gas reactors; and (4) LWR Small Modular Reactors (SMRs). the presenters were asked to include answers to the following:

1. Briefly describe the I&C design basis and any unique I&C features of your reactor/I&C concept.
2. What are the operating conditions (operational and environmental) that set the qualification criteria for the sensors and other I&C field components?
3. What new sensors, actuators, and communications technologies are needed beyond what is available today as qualified, commercial products?
4. What advances in protection, control, and monitoring systems are needed to support the normal operations and response to unanticipated and beyond design basis events?
5. What sensors and monitoring capabilities are proposed to provide early detection in plant components and structures degradation?
6. What control room and/or operational concepts are being considered that are beyond what has been previously licensed and deployed?
7. Describe what administrative and work control automation you would like to have available to use in advanced reactors.

Dr. Matthew Lish from Flibe presented an overview of general design and unique operating characteristics of the molten salt reactor (MSR). The presentation included a discussion of the unresolved challenges facing the MSR designer with regard to monitoring and controls. These included:

- substantially autonomous/remote operation
- salt redox monitoring/control

- instruments and actuators that can handle very harsh reactor conditions (e.g., high-dose, high-temperature, high-flow)
- in-core instruments
- gaseous fission product and tritium leak detection/monitoring.

Greg Doba, a senior controls engineer from General Electric, then led a Fast Reactor overview, including a discussion on its unique I&C design. He highlighted that based on the inherent safety of the Fast Reactor design, SCRAMs are not required for safety, nor is 1E power required. However, some I&C challenges due to the high radiation levels remain, which include:

- ways to remotely and non-invasively measure elemental and isotopic composition
- instruments and actuators that can handle very harsh reactor conditions (e.g., high-dose, high-temperature, high-flow)
- high-temperature neutron flux detectors
- high-radiation robotics.

Farshid Shahrokhi, the Framatome High-Temperature Gas Reactor (HTGR) Director, provided a similar overview of the HTGR characteristics and the I&C challenges associated with its design, which included:

- advanced robotics
- enhanced refueling system
- remote monitoring.

Brian Arnholt, the NuScale Safety I&C Engineering Supervisor, completed the advanced reactor overviews with a presentation on the LWR concept. The unique approach of coupling multiple reactors through one control room provided unique challenges with regards to licensing and advanced human-system interface layouts, including:

- testing and qualification of sensor applications in unique environments
- managing evolving cyber security threats.

1.3.4 Instrumentation and Control Technology Requirements Input Break-Out Sessions

Having reviewed current industry experience and new reactor design challenges, the workshop participants then began participating in break-out sessions in four specific areas:

1. Sensors and Communications.
2. Controls, Protection, and Monitoring.
3. Online Monitoring & Diagnostics.
4. Concept of Operations/Control Rooms.

Each of the break-out sessions reviewed these issues as they relate to the specific area of focus:

1. Technology Overview/Scope.
2. Summary of Pre-Meeting Survey Input.
3. Summary of Break-Out Sessions Input by Reactor Type:

a. Technology Requirements (Technical and Environmental).

b. Commercially-Available Technology.

c. Industry Proprietary Developments (Complete, In-Progress, and Future).

d. Needs for DOE-Sponsored Research.

4. Common Development Needs among Reactor Types.

5. Desired Enabling Technology (Beyond Current Requirements).

6. General Questions and Discussion Specific to the Area.

1.3.5 Break-Out Session Report

At the completion of the break-out sessions, the facilitators reviewed the comments and captured what they considered to best represent what the participants thought were the most important areas or challenges facing the new reactor I&C design efforts. These were presented at the workshop on Day 2 to ensure alignment between the facilitators and the workshop participants before finalizing what was considered to be the highest priorities for future R&D. Along with capturing the overall challenges, a survey was created to solicit feedback to better understand where there might be unique challenges for individual new reactor types, as well as what was considered to be crosscutting. The results are captured in Appendix C.

1.3.6 Insight from Light Water Reactor Sustainability, Nuclear Energy Institute, and Nuclear Regulatory Commission

At the completion of the break-out session report, several organizations provided their perspectives on the challenges facing the existing and advance reactor communities. Ian Jung of the NRC Chief Instrumentation, Controls, and Electronics Engineering Branch, Division of Engineering and Infrastructure Office of New Reactors, provided information on NRC's Instrumentation and Controls Safety-Focused Review Initiative. Ken Thomas of the Light Water Reactor Sustainability (LWRS) Program talked about the initiatives and current activities supporting the DOE-sponsored program that is tasked with ensuring long-term sustainability of the LWR fleet through technology modernization, automation, and advanced applications. Finally, NEI's Jason Remer presented key initiatives and challenges driving the activities within his organization.

2. RECOMMENDATIONS

The GAIN Workshop identified the following areas as high importance for future RD&D. A detailed list of RD&D suggestions are provided in Appendix C. The results of the workshop breakout session challenges went through a ranking process and should provide insight into how the items generally ranked among the workshop participants. Future discussions and investigation into these items could provide information that would support a change in these priorities or their emphasis.

The results are broken into the four workshop focus areas and represent what were considered to be the top challenges in each category. Note that in general, many of the RD&D ideas are applicable to both new advanced reactor plants and currently operating ones:

<u>Sensors and Communication</u>:

- Developing nuclear standards for qualification of nuclear energy radiation-hardened sensors and electronics.
- Creating a high-temperature fission chamber.
- Including internal flowrate measurement in integrated designs.
- Building a facility for qualification and accelerated lifetime testing at representative environmental conditions, especially radiation.

<u>Control, Protection, and Monitoring</u>:

- Developing methods to demonstrate that passive safety systems are sufficient to address licensing requirements regarding cybersecurity, common cause failure, and design basis accidents.
- Providing radiation-hardening of digital-based electronic components.
- Obtaining a process to optimize software verification and validation (V&V) with a focus on targeting high impact areas.

<u>Online Monitoring and Diagnostics</u>:

- Integrating predictive analytics with business processes.
- Developing a methodology for beneficial sensor selection/grading (probably based on risk) and optimal placement by taking both cost and risk into consideration.
- Creating smart multimodal measurements, such as a self-calibrating, longer lasting, single instrument that can give more than one parameter on a single penetration, as well as optical requirements and distributed sensing capabilities.

<u>Concept of Operations/Control Rooms</u>:

- Developing a guidance for reduced staffing and/or autonomous operation, including gaining full credit for passively safe systems.
- Creating a technical basis for minimal control rooms (e.g., remote operations or single workstation or laptop).

2.1 Prioritized RD&D Recommendations

1. Developing state-of-the-art advanced control rooms, controls systems, and plant protection technology systems. Applicants should:
    a. reduce I&C testing and V&V efforts associated with fulfilling current licensing requirements for cybersecurity, common cause failure, and design basis accidents through methods that would credit passive safety features instead.
    b. provide radiation-hardening of digital-based electronic components, such as programmable logic controllers and field-programmable gate arrays.
    c. create a technical basis for reduced staffing and/or autonomous operation in minimal control rooms (e.g., remote operations or single workstation).
2. Developing advanced online monitoring systems for nuclear plant operation and maintenance. Applicants should:
    a. demonstrate an optimal balance between cost and plant performance for achieving reliability, availability, maintainability, and security.
    b. integrate predictive analytics and risk-informed condition monitoring with business process applications, which would enable a transformational approach to supply chain and asset management.
3. Developing new sensors and instrumentation to support improved plant control and data analytics applications. Applicants should:
    a. demonstrate advanced instrumentation and communication of data that can be located in high-temperature, high-radiation reactor cores.
    b. upgrade smart multimodal measurement devices that can measure multiple parameters simultaneously.

3. CHALLENGES

The workshop captured significant input on the current challenges facing nuclear industry in the U.S., above and beyond what the specific focus area was, but still important to capture. They include:

- historically low natural gas prices, resulting in markets where existing or new nuclear reactors cannot profitably compete.
- adverse market conditions that undervalue the unique attributes of nuclear energy, such as:
  - Federal and State mandates for renewable generation, which obscure the real operating costs.
  - transmission constraints, which require power plants to pay a congestion charge to move their power onto the grid.
  - market designs that do not compensate dispatchable baseload nuclear plants for the value they provide to the grid.
- rising nuclear operations and maintenance costs.
- aging equipment (obsolescence).
- increasing need for flexible power operations.
- cooling water availability challenges.
- regulatory demands and cumulative impacts of new regulatory requirements.
- lack of public understanding and acceptance of nuclear power.
- used nuclear fuel disposition, primarily in its impact on public understanding and acceptance of nuclear energy’s important role in national energy policy.
- workforce issues, such as staffing for the future, training, attrition/retention, “new to nuclear” workers.

4. CONCLUSION

One of the key goals of the DOE-NE ASI program is to ensure new advanced reactors remain competitive using unique technologies and processes. While RD&D can contribute to the reduction/elimination of many of the challenges listed above, many of these challenges are policy-related, but RD&D can inform and help change/shape policy. The specific information captured and presentations addressing these challenges provided during the workshop can be seen on the GAIN website located at: **https://gain.inl.gov/SitePages/Workshops.aspx**. Information obtained from this workshop has been captured in this report and is being used to identify gaps between existing and needed capabilities by the advanced reactors community and to establish research priorities by DOE. These activities could include planned solicitations, cost-shared R&D, and pilot projects through private-public partnerships.

Appendix A
Workshop Attendees

Workshop Presenters:

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Appendix B
Breakout Session Feedback Notes

This appendix has the information presented to the workshop participants capturing the discussions as it relates to each breakout session topic:

Advanced Reactor Type Overviews

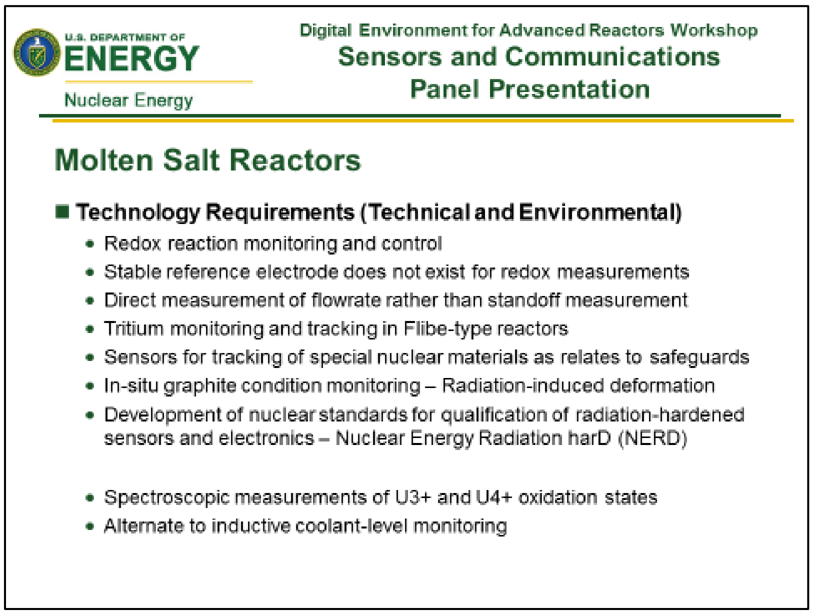

Figure 1. Slide 1 Sensors and Communications Panel Presentation.

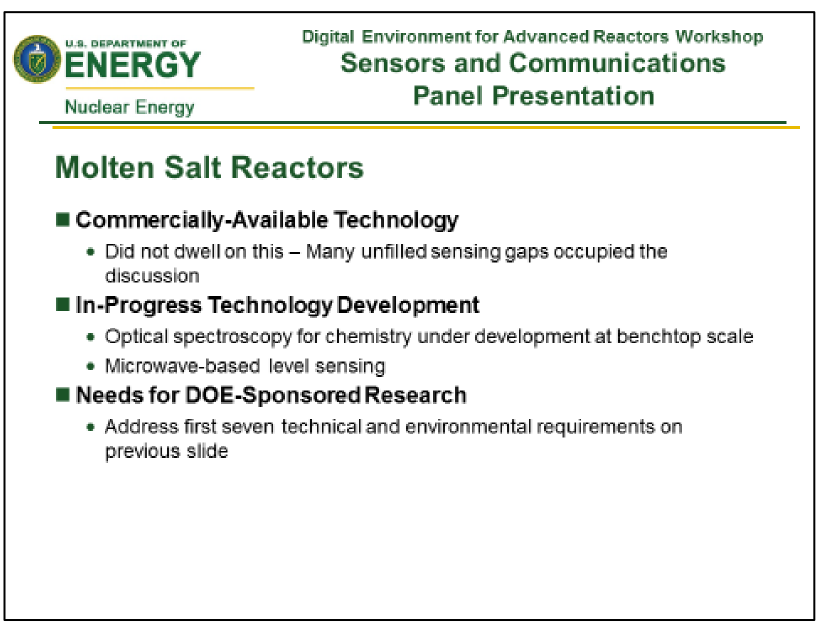

Figure 2. Slide 2 Sensors and Communications Panel Presentation.

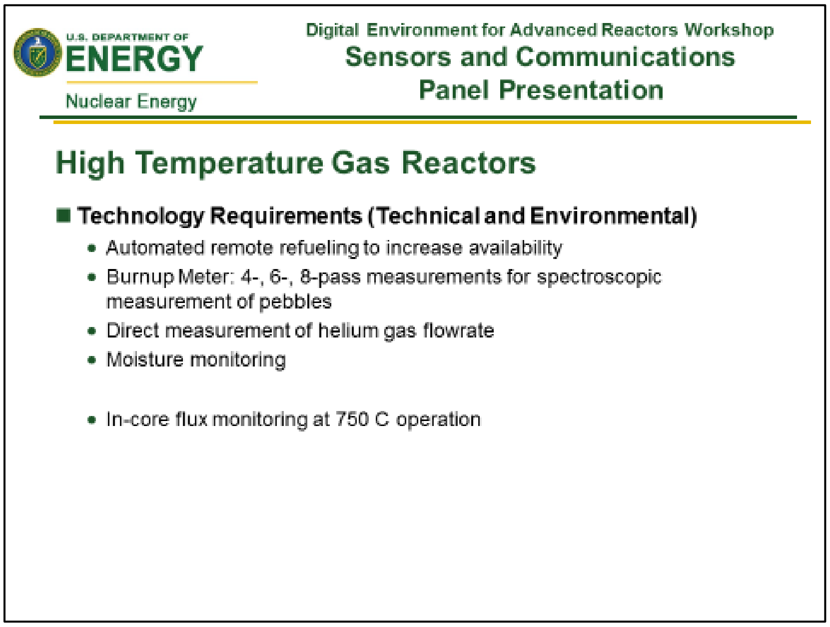

Figure 3. Slide 3 Sensors and Communications Panel Presentation.

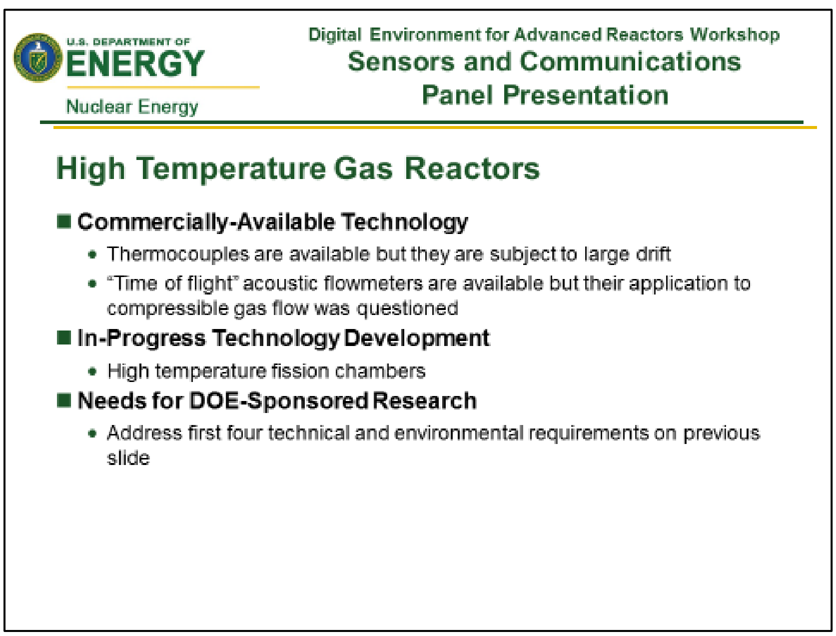

Figure 4. Slide 4 Sensors and Communications Panel Presentation.

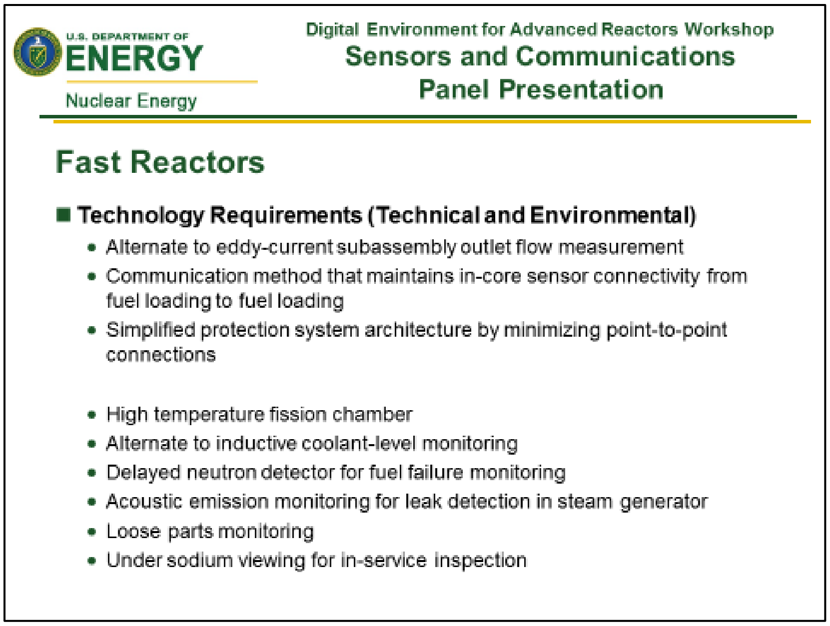

Figure 5. Slide 5 Sensors and Communications Panel Presentation.

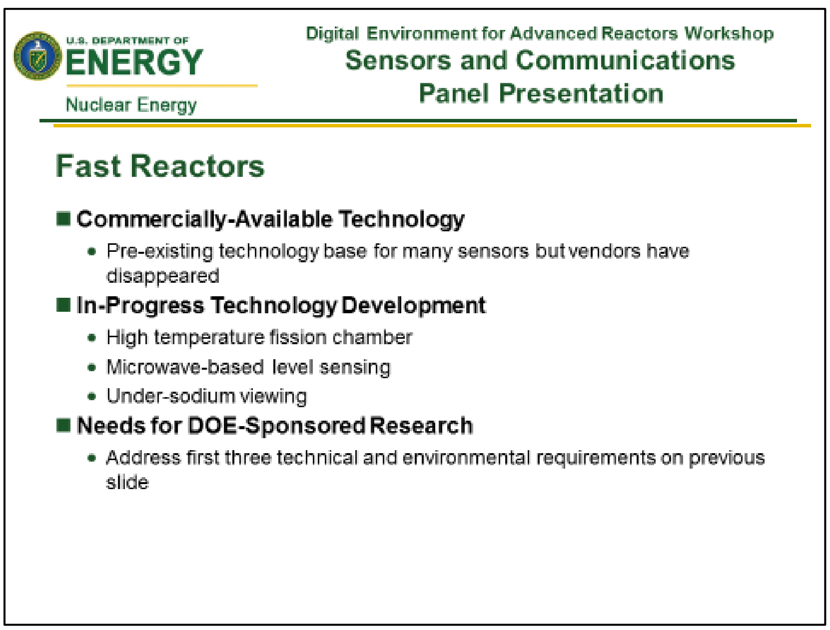

Figure 6. Slide 6 Sensors and Communications Panel Presentation.

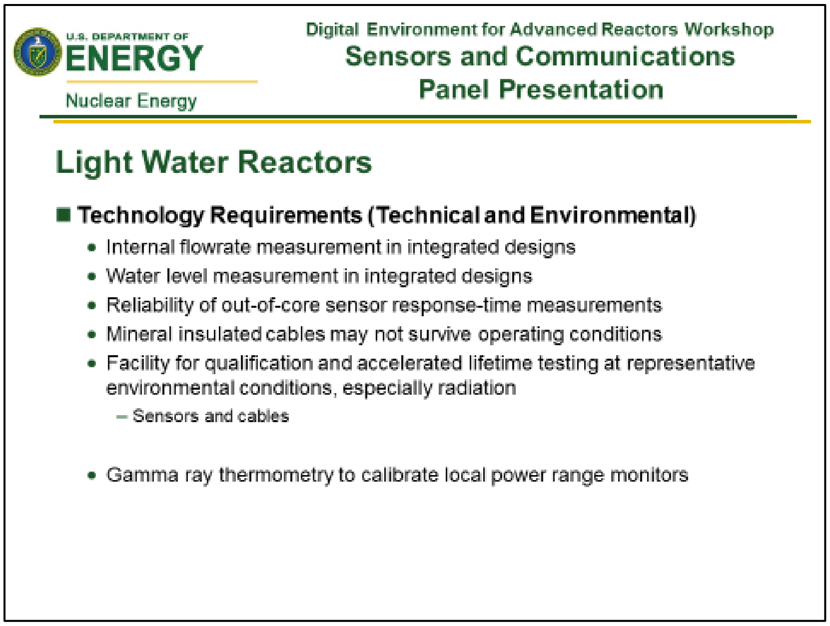

Figure 7. Slide 7 Sensors and Communications Panel Presentation.

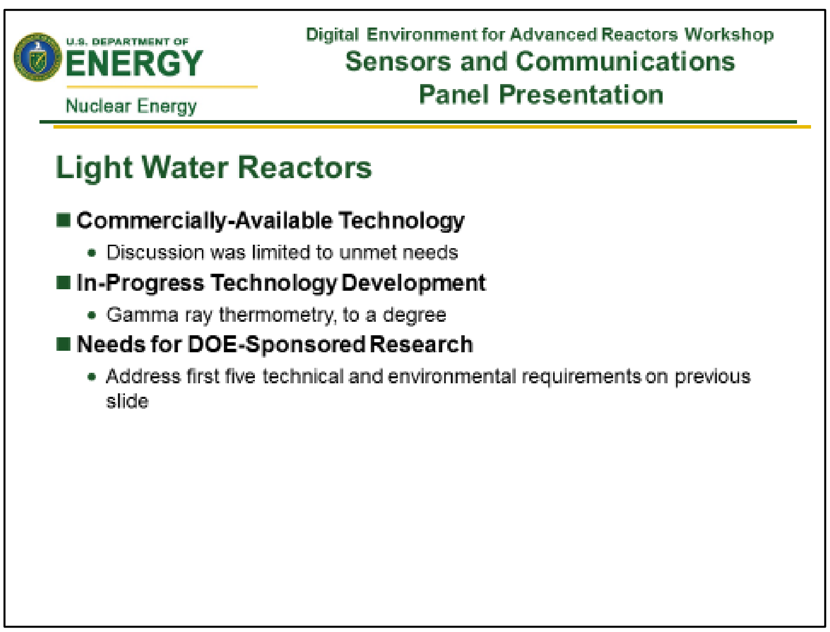

Figure 8. Slide 7 Sensors and Communications Panel Presentation.

Panel Presentation

Protection, Control, and Monitoring Requirements Presentation

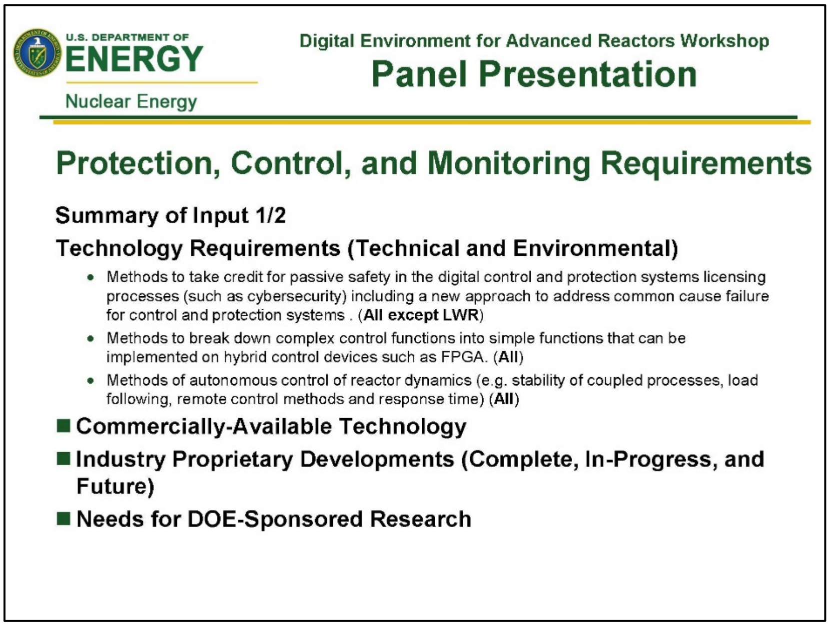

Figure 9. Slide 1 Protection, Control, and Monitoring Requirements Presentation.

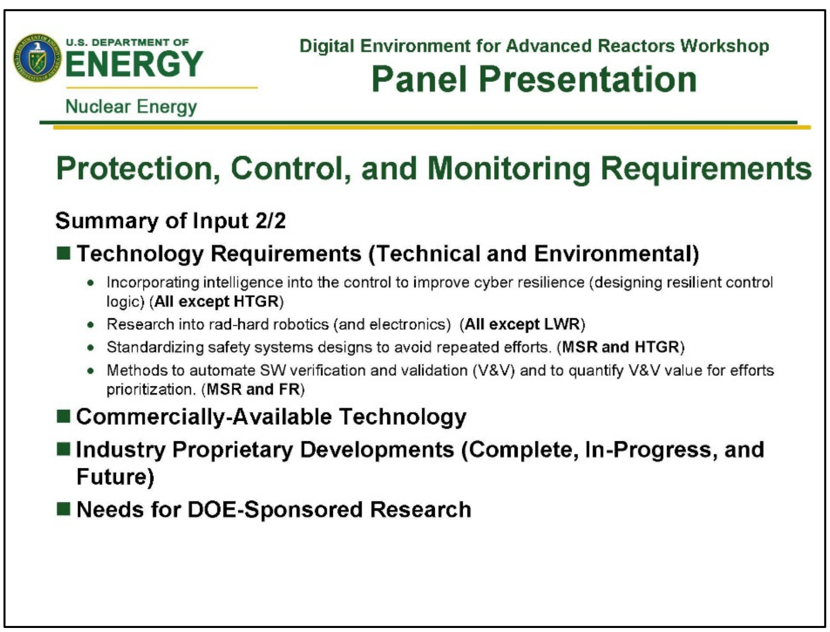

Figure 10. Slide 2 Protection, Control, and Monitoring Requirements Presentation.

Online Monitoring & Diagnostics and Prognostics Presentation

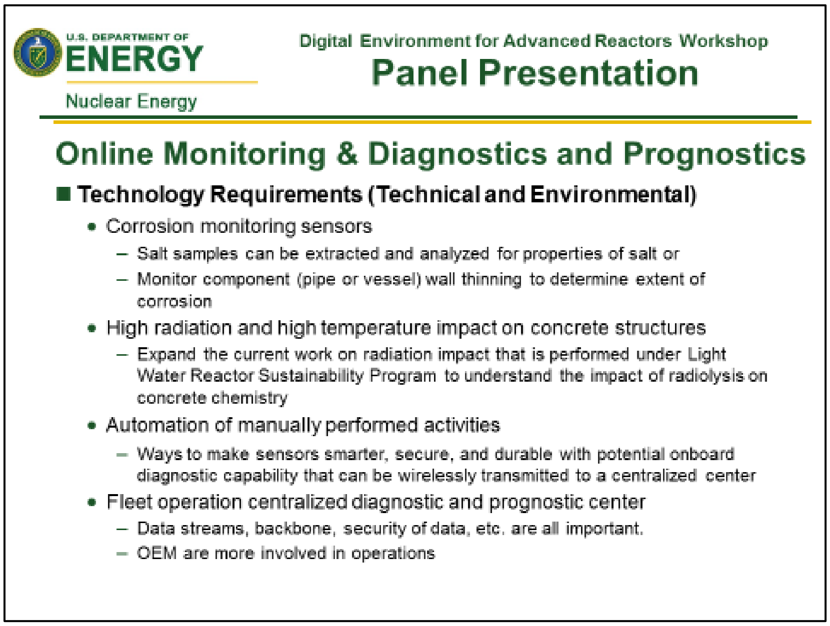

Figure 11. Slide 1 Online Monitoring & Diagnostics and Prognostics Presentation.

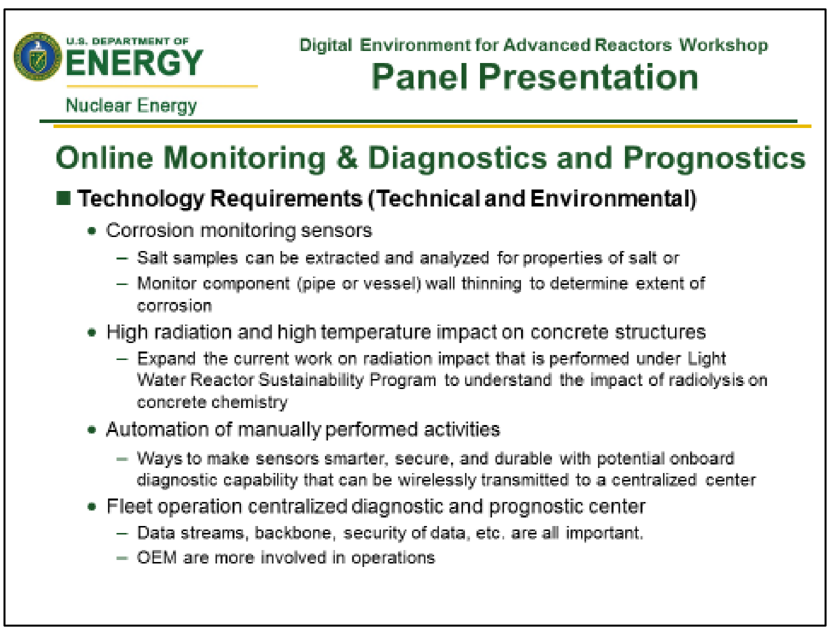

Figure 12. Slide 2 Online Monitoring & Diagnostics and Prognostics Presentation.

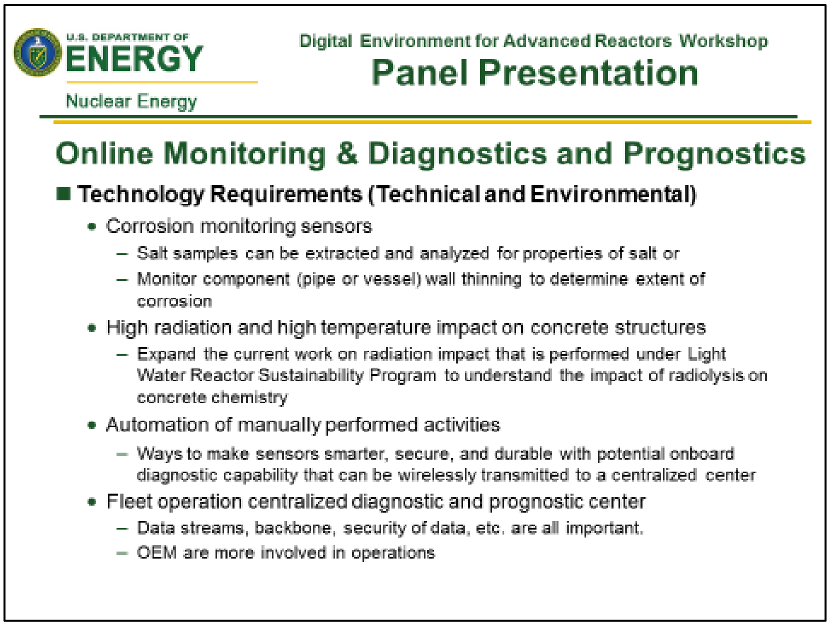

Figure 13. Slide 3 Online Monitoring & Diagnostics and Prognostics Presentation.

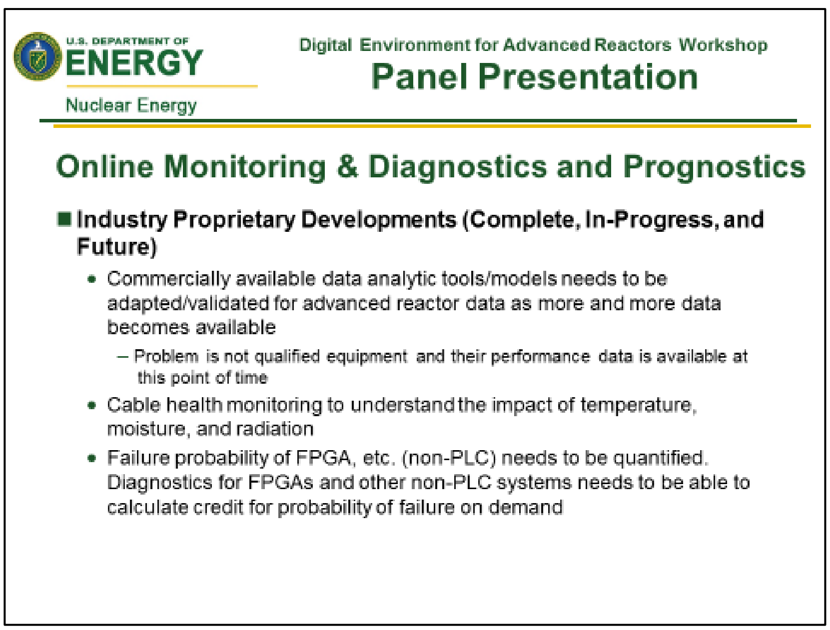

Figure 14. Slide 4 Online Monitoring & Diagnostics and Prognostics Presentation.

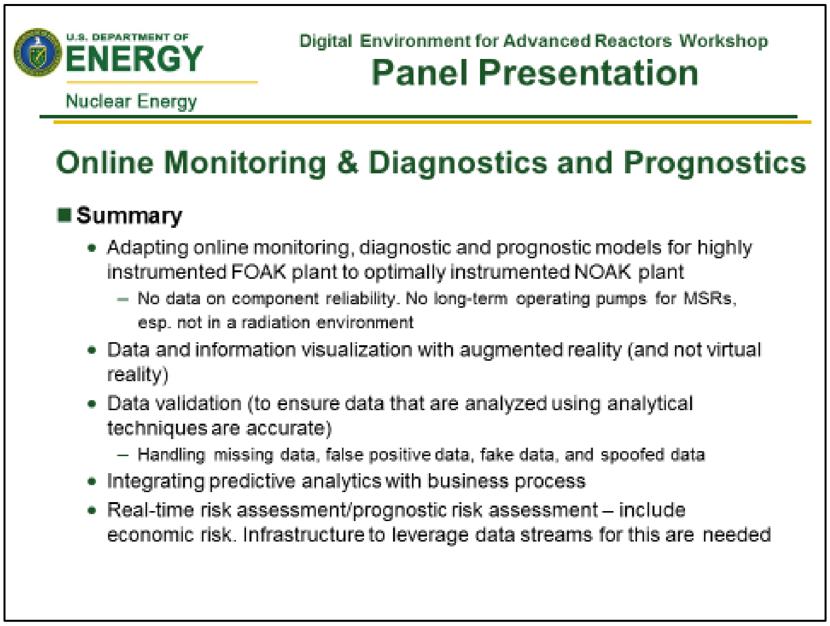

Figure 15. Slide 5 Online Monitoring & Diagnostics and Prognostics Presentation.

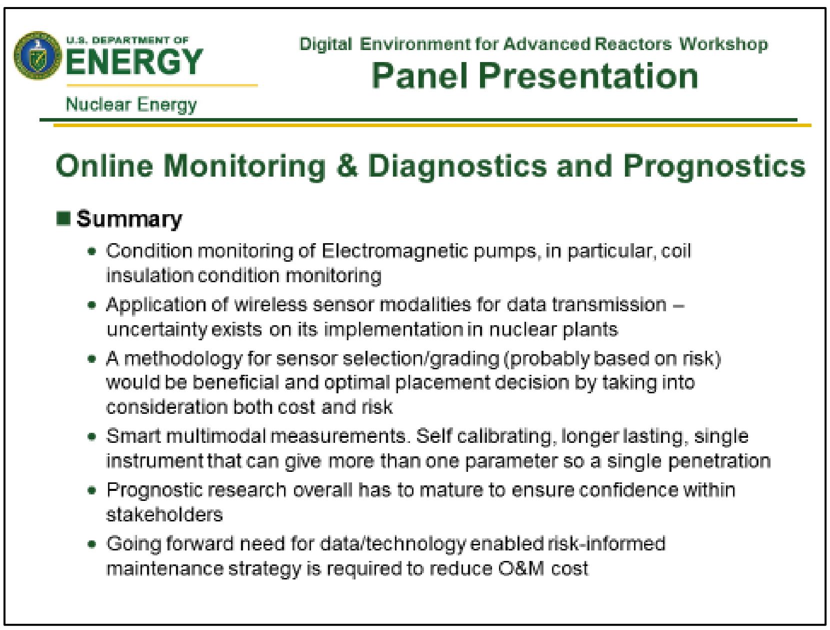

Figure 16. Slide 6 Online Monitoring & Diagnostics and Prognostics Presentation.

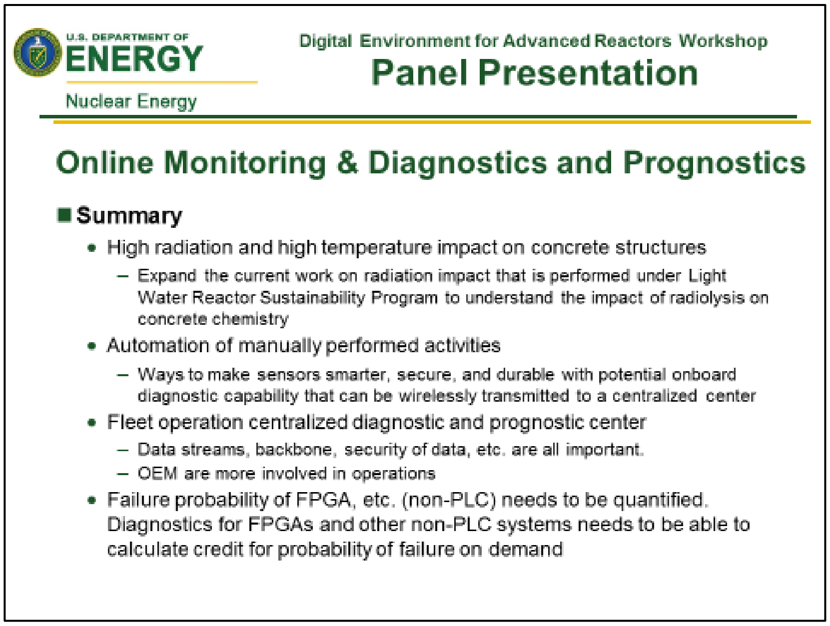

Figure 17. Slide 7 Online Monitoring & Diagnostics and Prognostics Presentation.

Concepts of Operations/Control Room Presentation

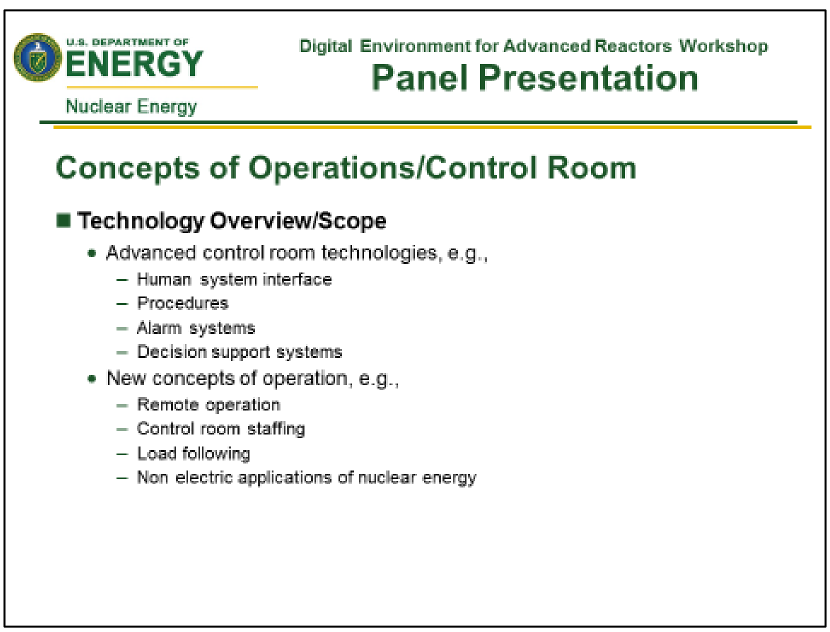

Figure 18. Slide 1 Concepts of Operations/Control Room Presentation.

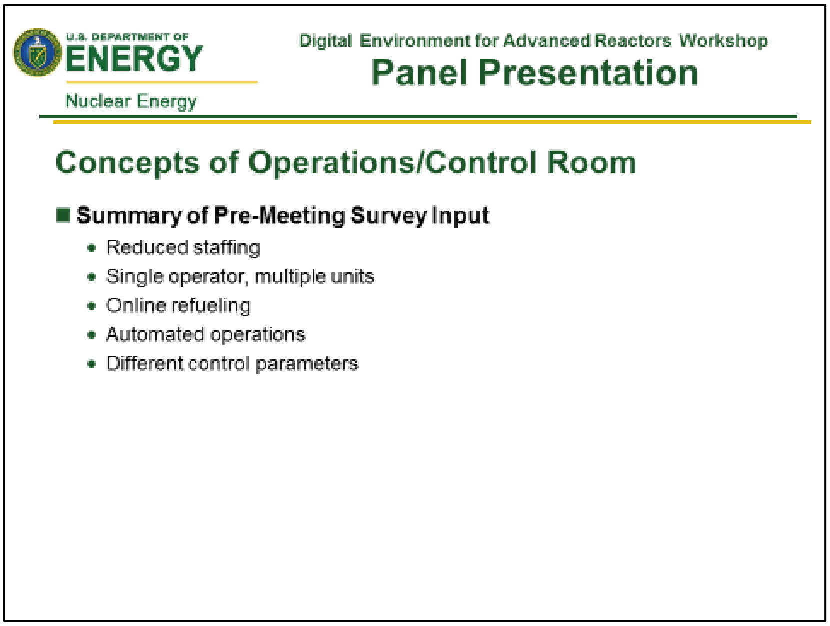

Figure 19. Slide 2 Concepts of Operations/Control Room Presentation.

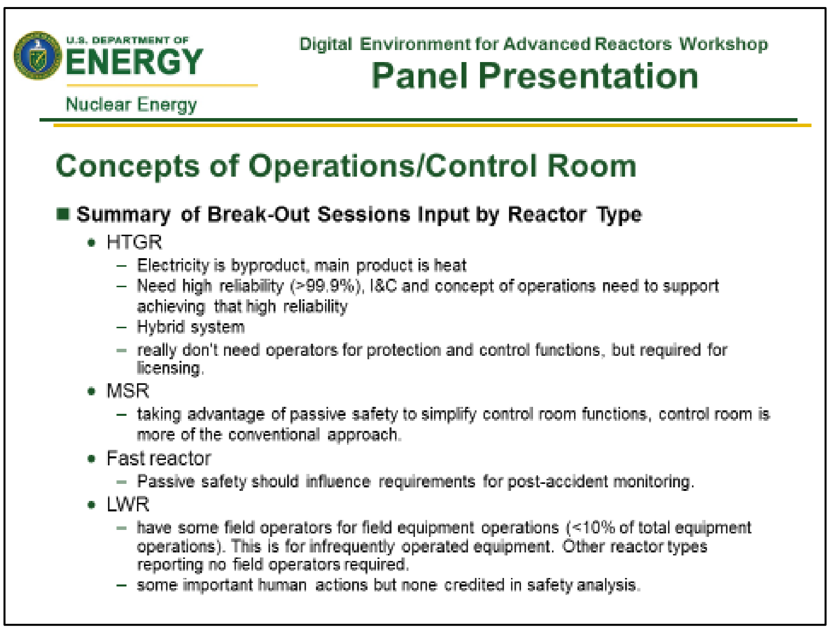

Figure 20. Slide 3 Concepts of Operations/Control Room Presentation.

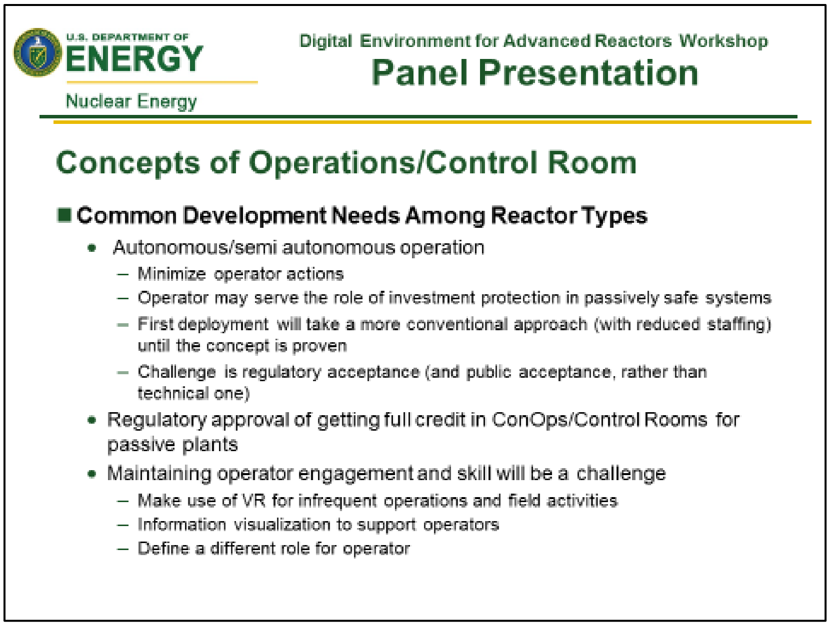

Figure 21. Slide 4 Concepts of Operations/Control Room Presentation.

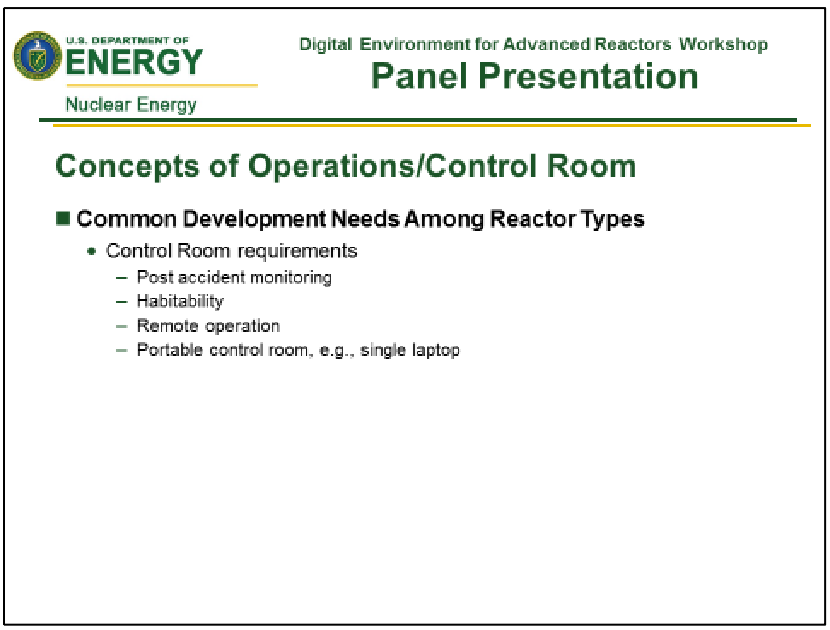

Figure 22. Slide 5 Concepts of Operations/Control Room Presentation.

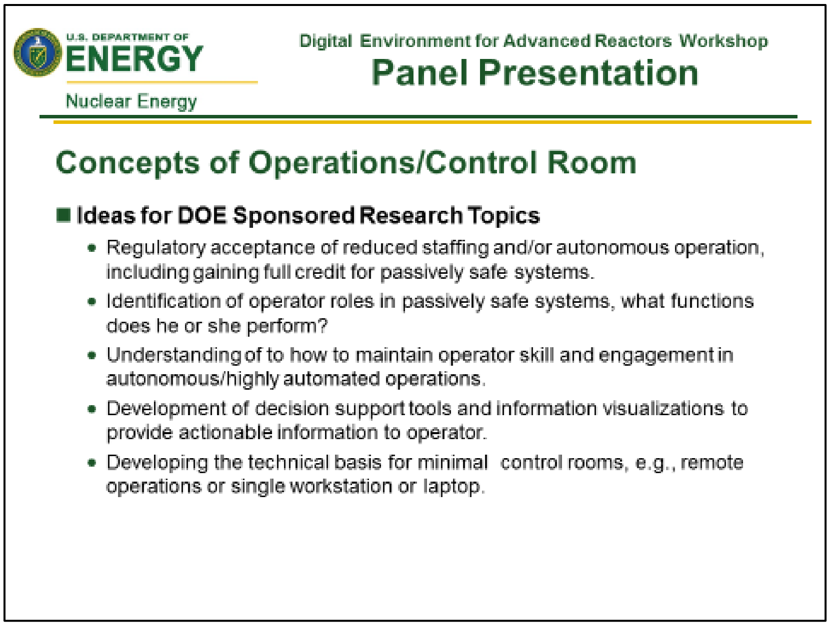

Figure 23. Slide 6 Concepts of Operations/Control Room Presentation.

Appendix C
Survey Results

A survey was conducted at the completion of the breakout session panel review to rank the importance of each of the possible research areas identified during the breakout sessions. In this Appendix the results of the survey are provided. The survey ranking approach asked participants to use a scale of 1 through 10 to indicate least to most important to their areas of interests. One (1) indicating least important and ten (10) most import areas for the Department of Energy to consider funding future research.

Sensors & Communication

Gap Description	Overall Score
Redox reaction monitoring and control (MSR).	5.2
Direct measurement of flowrate rather than standoff measurement (MSR).	5.9
Tritium monitoring and tracking in Flibe-type reactors (MSR).	4.9
Sensors for tracking of special nuclear materials as relates to safeguards (MSR).	5.0
Development of nuclear standards for qualification of radiation-hardened sensors and electronics – Nuclear Energy Radiation harD (NERD) (MSR).	6.4
High temperature fission chamber (Fast Reactors).	6.3
Simplified protection system architecture by minimizing point-to-point connections (Fast Reactor).	4.7
Alternate to eddy-current subassembly outlet flow measurement (Fast Reactor).	4.2
Maintain in-core sensor connectivity from fuel loading to fuel loading (Fast Reactor).	4.2
Improved burnup Meter: 4-, 6-, 8-pass measurements for spectroscopic measurement of pebbles (HTGR).	4.1
Improved direct measurement of helium gas flowrate (HTGR).	4.9
Internal flowrate measurement in integrated designs (LWR).	5.6
Water level measurement in integrated designs (LWR).	5.1
Mineral insulated cables may not survive operating conditions (LWR).	4.9
Facility for qualification and accelerated lifetime testing at representative environmental conditions, especially radiation (LWR).	6.8

Control, Protection, and Monitoring

Gap Description	Overall Score
Methods to demonstrate that passive Safety systems are sufficient to address licensing requirements regarding cybersecurity, common cause failure, and design basis accidents.	6.1
Rad-Hard of Electronics for digital based components.	7.5
Strategy to enable adaptive autonomous control of changing reactor dynamics for stability and reduction of operator role.	5.9
Develop ca concept of safety platform where standardization would benefit the industry.	4.8
Develop a process to optimize the SW verification and validation (V&V) to target high impact parts of the software.	5.9

Online Monitoring & Diagnostics

Gap Description	Overall Score
Adapting online monitoring, diagnostic and prognostic models for highly instrumented FOAK plant to optimally instrumented nth of a kind plant.	6.6
Data and information visualization with augmented reality (and not virtual reality).	3.4
Data validation (to ensure data that is analyzed using analytical techniques is accurate), which includes handling missing data, false positive data, fake data, and spoofed data.	5.1
Integrating predictive analytics with business process.	5.5
Real-time risk assessment/prognostic risk assessment – include economic risk. Infrastructure to leverage data streams for this are needed.	6.0
No data on component reliability. No long-term operating pumps for MSRs, especially not in a radiation environment.	5.3
Condition monitoring of Electromagnetic pumps, in particular, coil insulation condition monitoring.	5.1
Application of wireless sensor modalities for data transmission – uncertainty exists on its implementation in nuclear plants.	6.2
A methodology for sensor selection/grading (probably based on risk) would be beneficial and optimal placement decision by taking into consideration both cost and risk.	5.6
Smart multimodal measurements. Self-calibrating, longer lasting, single instrument that can give more than one parameter so a single penetration -- Optical requirements and distributed sensing.	6.4
Prognostic research overall has to mature to ensure confidence within stakeholders.	5.3
Going forward need for data/technology enabled risk-informed maintenance strategy is required to reduce operations and maintenance cost.	5.7

Gap Description	Overall Score
High radiation and high temperature impact on concrete structures for advanced reactor technologies.	5.3

Concept of Operations/ Control Rooms

Gap Description	Overall Score
Guidance for developing basis for reduced staffing and/or autonomous operation, including gaining full credit for passively safe systems.	7.0
Identification of operator roles in passively safe systems, what functions does he or she perform?	5.2
Understanding of to how to maintain operator skill and engagement in autonomous/highly automated operations.	5.3
Development of decision support tools and information visualizations to provide actionable information to operator.	5.9
Developing the technical basis for minimal control rooms, e.g., remote operations or single workstation or laptop.	6.8

Appendix D
Workshop Presentations

Workshop Presentations are available on the GAIN website at: https://gain.inl.gov/SitePages/Workshops.aspx. These presentations include:

Industry Overview

1. Workshop Goals and Agenda Presentation
2. DOE-NE Overview Presentation – Tom Miller
3. Digital Transformation Presentation – John Connelly
4. Pioneering the Power That Matters Presentation – Paul Tobin
5. Current Fleet I&C Research Presentation – Steven Lopez

Advanced Reactor Type Overview

1. Molten Salt Reactor I&C Agenda – Matthew Lish
2. Fast Reactor Working Group Presentation – Greg Doba
3. High Temperature Gas Reactor – Farshid Shahrokhi
4. Light Water Reactor – Brian Arnholt

Break Out Session

1. Sensor and Communications – Rick Vilim
2. Protection, Control and Monitoring Requirements – Ahmad Al Rashdan
3. Online Monitoring & Diagnostics and Prognostics Presentation – Vivek Agarwal
4. Concepts of Operations/Control Room – Katya LeBlanc

Insight from LWRS, NEI, and NRC

1. Instrumentation and Controls: Safety-Focused Review Initiative – Ian Jung
2. Technology and Regulatory Transformation – Jason Remer
3. Department of Energy Research Perspective – Ken Thomas
4. Summary of Actions and Path Forward