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REGULATORY FRAMEWORK GAP ASSESSMENT FOR THE USE OF ARTIFICIAL INTELLIGENCE IN NUCLEAR APPLICATIONS

Manuscript Completed: October 2024

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ABSTRACT

To enhance the U.S. Nuclear Regulatory Commission (NRC) staff's readiness for the potential use of artificial intelligence (AI) technologies in NRC-regulated activities, the NRC tasked the Center for Nuclear Waste Regulatory Analyses at Southwest Research Institute® with examining whether the current NRC regulatory framework allows for the potential use of AI systems and, in particular, if regulatory guides (RGs) provide adequate guidance to support NRC evaluations of AI technologies. This report does not, however, identify if specific additional regulatory requirements might be needed to ensure the safe and secure use of AI in nuclear applications. The project, referred to as the AI Regulatory Gap Analysis (AIRGA), examined NRC regulations and in more detail evaluated 517 RGs of ten broad divisions. Potential gaps were identified in fewer than 100 RGs. These potential gaps were classified into eight types:

(i) Implied manual actions
(ii) Special computations
(iii) Preoperational and initial testing programs that may omit AI
(iv) Habitability conditions under autonomous operations
(v) Periodic testing, monitoring, surveillance and reporting
(vi) Software for critical applications
(vii) Radiation safety support
(viii) Miscellaneous: training and human factors engineering

NRC regulations associated with the RGs deemed with gaps were examined afterwards for potential conflicts with the use of AI technologies. It is acknowledged that the AIRGA was not a holistic review but an initial analysis, and that additional regulations and guidance documents may contain gaps or language inconsistent with the use of AI technologies. Accordingly, the NRC may wish to consider follow-on activities to evaluate application-specific gaps; perform future research to address gaps identified in this report; or examine regulations and the regulatory framework in more detail.

For the subset of RGs with potential gaps, the associated regulations at 10 CFR were examined in more detail and found adequate to regulate the use of AI technologies with a few exceptions. The exceptions are related to statements in the regulations calling for explicit actions by humans, when those actions could be potentially executed by AI systems, for example, computer vision for surveillance. Broad questions were identified regarding the regulations of nuclear power plants that require the continuous presence of operators in the control room. For example, if the NRC were to allow a portion of or all operations at an NRC-regulated facility to be operated by AI systems, should operators be required to be present for operations they are not actively involved with?

Based on the results of the analysis, it is recommended that the NRC develop general guides addressing cross-cutting issues associated with potential gaps, such as software development with AI systems, and use of AI technologies in special computations. Standards by professional organizations related to AI were examined to identify if mature standards exist that could be considered for endorsement by NRC; however, no practical standards were identified readily addressing potential gaps. Regarding software development in general (independently of AI), existing software development guides and standards by the Institute of Electrical and Electronic Engineers (IEEE) seem adequate for software with AI. However, expanded guidance is needed in topics related to the quality and quantity of data for machine learning, validation and verification (V&V) activities and documentation of software with AI technologies, and systematic

fail-safe design (e.g., how to address anticipated potential errors by AI systems). If AI is used in special computations, additional guidance may address the types of additional analyses and special documentation to enhance confidence in those computations. Work by the Federal Aviation Administration and the Food and Drug Administration could be examined to learn how these organizations are approaching regulation of AI technologies.

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ACKNOWLEDGEMENTS

This report was prepared to document work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA®) for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. 31310023D0005, for Task Order No. 31310023F0062. The activities reported here were performed on behalf of the NRC Office of Nuclear Regulatory Research. This project highly benefited from discussions with M. Dennis, L. Betancourt, A. Hathaway, N. Tehrani, A. Valiaveedu, and S. Haq of NRC. Appreciation is extended to A. Ramos for assistance in preparation of the report.

All CNWRA-generated original data contained in this report meet the quality assurance (QA) requirements described in the CNWRA QA Manual.

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DISCLAIMER

ABBREVIATIONS AND ACRONYMS

ADAMS	Agencywide Documents Access and Management System
AI	artificial intelligence
AIRGA	AI Regulatory Gap Analysis
API	Application programming interface
ARSO	Associate Radiation Safety Officer
CAP	Corrective Action Program
CFR	*Code of Federal Regulations*
CV	computer vision
DQA	data quality assessment
EIS	environmental impact statements
EPA	Environmental Protection Agency
FAA	U.S. Federal Aviation Administration
FDA	U.S. Food and Drug Administration
GDC	General Design Criterion
HFE	Human Factors Engineering
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IoT	Internet of Things
ISO	International Organization for Standardization
ITU	International Telecommunications Union
JTC	Joint Technical Committee
LLMs	large language models
MLaaS	machine learning as a service
ML	machine learning
NLP	natural language processing

NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
QA	quality assurance
RG	regulatory guide
RMF	Risk Management Framework
ROP	Reactor Oversight Process
RSO	Radiation Safety Officer
SC	Standards Committee
SOP	standard operating procedure
SRP	Standard Review Plan
SSCs	structures, systems, and components
TC	Technical Committee
V&V	validation and verification
W3C	World Wide Web Consortium
XAI	eXplainable Artificial Intelligent
XLIFF	Localisation Interchange File Format
XML	eXtensible Markup Language

1 INTRODUCTION

Artificial intelligence (AI) technologies require special consideration for their safe use in U.S. Nuclear Regulatory Commission (NRC)-regulated activities. In anticipation of such use of AI technologies, this project examined whether the reviewed NRC regulations and guidance allow for the potential use of AI technologies and, if so, whether the reviewed regulations and guidance are flexible and adequate for AI. This report does not, however, identify if specific additional regulatory requirements might be needed to ensure the safe and secure use of AI in nuclear applications. This project contributes to Strategic Goal 1, Ensure NRC Readiness for Regulatory Decision-Making, of the NRC Artificial Intelligence Strategic Plan, NUREG-2261 (NRC 2023a). The regulatory framework assessment scope included NRC regulations of Title 10 of the *Code of Federal Regulations* (10 CFR) Parts 1 to 171 (NRC 2024a), and 517 regulatory guides (RGs) in all NRC divisions (NRC 2024b), plus a few selected NUREG and industry standards cited by the RGs, and a few selected industry standards directly referenced in regulations.[1] The resulting analysis is referred to as the AI Regulatory Gap Analysis (AIRGA).

Initial AIRGA efforts focused on screening NRC regulations in 10 CFR for potential issues, regarding uses of AI technologies consistent with examples described in Section 2.2. Due to time and fundings constraints, however, the authors shifted to a practical approach to execute the project. RGs contain guidance and identify requirements, and they are frequently more detailed than regulations. To narrow down the scope of the project, the analysis first examined whether RGs contained potential gaps or details inconsistent with the use of AI. Then the analysis examined the NRC regulations, cited by the subset of RGs with potential gaps, for potential conflicts with the use of AI technologies. It is acknowledged that this gap analysis, as implemented, was not a holistic review but an initial analysis, and that additional regulations and guidance documents may exist with gaps or language inconsistent with the use of AI technologies. Given this, the NRC may wish to consider follow-on activities to evaluate application-specific gaps; perform future research to address the gaps identified in this report; or examine regulations and the regulatory framework in more detail.

The AIRGA was executed in three broad tasks, depicted in Figure 1-1, aimed at identifying examples of uses of AI technologies, examining the adequacy of guidance in RGs of uses of AI, and examining regulations associated with the subset of RGs deemed with potential gaps. The tasks of the AIRGA are summarized in the following paragraphs.

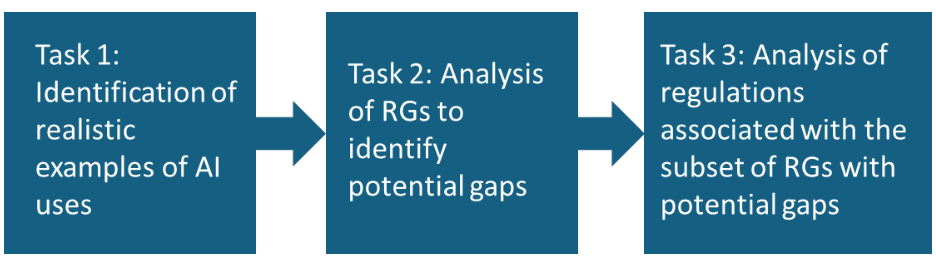

Figure 1-1. Broad tasks of the AI Regulatory Gap Analysis

[1] The NRC regulatory framework also includes guidance to the staff, for example, standard review plans such as NUREG-0800. The standard review plans were not included in the scope of this project.

The first broad task of the AIRGA was familiarization with examples of proposed uses of AI in nuclear applications and other uses of nuclear materials. NUREG/CR-7294, "Exploring Advanced Computational Tools and Techniques with Artificial Intelligence and Machine Learning in Operating Nuclear Plants" (Ma, et al. 2022), provides examples in the context of operating nuclear power plants. In addition, numerous examples have been presented in the Data Science and AI Regulatory Applications Workshops organized by the NRC (NRC 2023b). Those examples and generalized or extrapolated examples provide a realistic frame for potential uses of AI in the short term.

The second broad task of the AIRGA was identifying whether AI technologies could be used within the scope of active RGs, considering examples identified in the first task. If AI technologies could be used, the flexibility of the RG was further examined to see if it permitted those AI uses, as well as to evaluate the RG's adequacy to support evaluation of AI technologies. In this second step potential shortcomings referred to as potential gaps in the RGs were identified.

The third broad task of the AIRGA was examining the NRC regulatory requirements of the RGs with potential gaps identified during the second task. This allowed an assessment of whether any potential shortcoming or gap in the RG directly arose from the underlying regulatory requirements. The AIRGA was documented in a Microsoft® Excel® file that includes notes for each of the 517 RGs. Only a summary of those notes is included in this report and appendices.

This project also examined standards in AI developed by professional organizations, with the objective to identify mature and practical standards that could address potential gaps in RGs. A section of this report was aimed at examining standards, including standards under development.

This report is organized by the following sections. Section 1 is an introduction that provides the basis for and general scope of the analysis. Section 2 is a background section that describes AI technology and terminology, examples of AI uses in nuclear applications, general AI technology risks, and risk management frameworks for the development of AI. Section 3 describes the approach to execute the AIRGA and results of the AIRGA. Section 4 examines AI related standards. Section 5 summarizes the conclusions of the AIRGA. References are provided in Section 6. Three appendices document relevant notes on RGs with and without potential gaps, and on potential gaps in the applicable regulations.

2 GENERAL AI TECHNOLOGY CONSIDERATIONS

This section describes broad considerations of AI technologies. It includes a brief presentation of broad AI terms used in this report and examples of potential uses of AI technologies in the nuclear field as a general frame for the AIRGA. The section concludes with a broad identification of AI systems risks and a description of the Risk Management Framework (RMF) and development of trustworthy AI proposed by the National Institute of Standards and Technology (NIST 2023).

2.1 Terminology

Several definitions exist on AI and no attempt is made here to provide an overarching definition. The reader is referred to a definition of AI in the NRC AI Strategic Plan (NRC 2023a). Additional descriptions of AI techniques in the context of nuclear applications are provided in NUREG/CR-7294 "Exploring Advanced Computational Tools and Techniques with Artificial Intelligence and Machine Learning in Operating Nuclear Plants" (Ma, et al. 2022), the Data Science and AI Regulatory Applications Workshops (NRC 2023b), and a DOE report on computer vision considerations (Rashdan, et al. 2021). For the purpose of developing a basic terminology for this report, Figure 2-1 displays a Venn diagram of AI technologies. The term AI includes machine learning (ML), which refers to a special type of AI that relies on example data to adjust numeric parameters to design a mathematical function. The adjustment process is referred to as *machine learning*, with two main types of learning: supervised and unsupervised.[2] Supervised learning is used when the example data include {input, output} pairs, and unsupervised learning is typically selected to identify data patterns, data similarities, and data clusters. Supervised learning generally involves minimizing the error of a function over the example data space. After the learning stage, the mathematical function with adjusted parameters is used to predict outputs associated with new inputs.

[2] The reader is referred to other summary documents for discussions of other types of learning like semi-supervised learning and reinforcement learning, for example in (Rashdan, et al 2021).

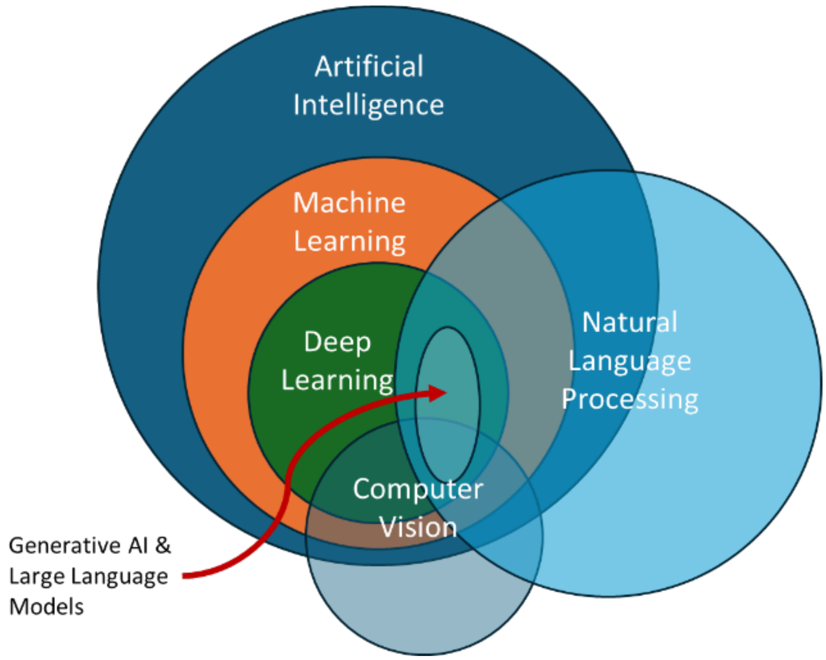

Figure 2-1. Venn diagram of AI technologies

The most common functions in ML are called artificial neural networks or neural networks for short. A typical neural network includes three layers: (i) an input layer, (ii) a hidden layer, and (iii) an output layer. Each layer has many parameters with values that are adjusted during the ML process. More complex neural networks, with four or more layers, are called *deep* neural networks, with the word *deep* describing a vertical diagram representing a long network. A DOE report on computer vision considerations (Rashdan, et al. 2021) briefly describes types of deep neural networks like convolutional, recurrent, and long short-term memory neural networks. Deep neural networks commonly have thousands, millions, and even billions of adjustable parameters. Training of these networks during the ML process has been facilitated by fast computers with high memory capacity and modern parallel computing methods. The training process of deep neural networks is called *deep learning*. Again, the word *deep* merely indicates that the corresponding neural network is complex, with many adjustable parameters. The most important recent advances in AI, such as computer vision, large language models (LLMs), and generative AI, include deep neural networks and deep learning algorithms. Although algorithms that can be considered AI are diverse, the most practical and widely used algorithms generally have neural networks and deep neural networks as central components. The most interesting examples in NUREG/CR-7294 (Ma, et al. 2022) and the Data Science and AI Regulatory Applications Workshops (NRC 2023b) also include neural networks. We used the term AI in general in this report, without specifying any technique; however, it is likely that any deployed AI technology in an NRC-regulated activity will include artificial neural networks and machine learning algorithms.

2.2 Examples of AI in Nuclear Applications

AI uses in nuclear power plants documented in NUREG/CR-7294 (Ma, et al. 2022) (Ma, et al. 2022) are presented here to frame potential uses of AI technologies. Additional examples were selected from the NRC's Data Science and AI Regulatory Applications Public Workshops (NRC 2023b). These examples were generalized and extrapolated to cover a broad range of applications in NRC-regulated activities. The examples are applicable to the following broad use classifications:

- Special computations
- Testing, monitoring, surveillance, and reporting
- Training and control
- Digital advisors

2.2.1 Special Computations

AI techniques can be used to support special computations. If abundant data are available, for example, from laboratory and field tests, operational records, monitoring, and high-fidelity computer models, machine learning can be used to build AI models and functions, to predict or forecast the response of a system to new situations. The accuracy of the AI model prediction is dependent on factors such as (i) the regularity of data patterns, (ii) the density and coverage of the example data to identify those patterns, (iii) the quality of the example data including how well data represent the real system context, and (iv) the similarity of a new situation to the example data. The following are examples from NUREG/CR-7294 (Ma, et al. 2022) of AI techniques proposed to support special computations:

- Compute the reliability of structures, systems, components (SSCs), and remaining useful life of SSCs, which can be used, for example, as inputs to probabilistic risk analysis models and to develop optimal preventive maintenance strategies
- Quantify human reliability and analyze human performance
- Develop metamodels of high-resolution physics models such as fire dynamics and core dynamics, as efficient stand-alone models or coupled with digital twins
- Analyze external hazards such as seismic events, tornadoes, flooding from historical records
- Identify and characterize radioactive contaminants in the environment, with direct application to the examination of events such as Chernobyl and Fukushima

Results from computations using AI models could provide input to safety analyses and plans such as preventive maintenance or recommendations for severe accident mitigation procedures. AI models may require special validation and verification (V&V) efforts to develop confidence in AI-model outputs.

Many examples in the NRC Data Science and AI Regulatory Applications Workshops (NRC 2023b) to date are related to natural language processing (NLP) and LLMs and information extraction and synthesis to support engineering analyses. LLMs may be used to efficiently extract information from extensive databases of documents, such as the following:

- Records of operational experience
- Maintenance records
- Work orders
- Incident reports
- Regulatory filings
- Condition reports
- Condition logs and entries that are part of the Reactor Oversight Process (ROP) and Corrective Action Program (CAP)
- User's manuals, standard operating procedures, equipment specifications, and technical specifications for operation

At the NRC Data Science and AI Regulatory Applications Workshops (NRC 2023b), NLP and LLMs were explored as tools to examine extensive written records and to efficiently extract information. This information extraction technique could be used to support computation of numerical metrics, such as failure frequency rates of components, for example, based on maintenance records and work orders. Other examples considered LLMs to support investigations in areas such as human reliability and human performance, component reliability, site conditions, site evolution, and historical trends. NRC is exploring NLP to examine records and documents produced in past projects to predict resource requirements for new tasks. Additional examples of NLP and LLM uses include screening and prioritization of CAP reports, performing CAP trending analyses, and executing efficient queries to extract information relevant to addressing specific questions. Queries, for example, could be used to support internal and external inspections and audits or general data gathering for engineering analyses.

2.2.2 Testing, Monitoring, Surveillance, and Reporting

Monitoring equipment, sensors, cameras, and drones yield data that may be interpreted by AI systems to assess the state of a component or a system. Reports may be automatically produced when specific conditions are satisfied, like radiation levels exceeding thresholds. The following are examples of AI uses.

- Non-destructive evaluation: AI identifies flaws or degradation of components
- Monitoring radiation levels: AI interprets information from radiation monitors to assess deviations or exceedance of action levels or other limits
- Cybersecurity: AI identifies operation anomalies to signal cyberattacks, with further actions to stop or mitigate the attack
- Physical security: computer vision systems detect physical intrusions

- Materials accountancy: AI tracks location and inventories of radioactive sources and radioactive material

- Online monitoring: sensors and non-destructive evaluation techniques supply information to AI systems to monitor the health of online (i.e., active) components

- Fault detection, diagnosis, and mitigation: AI detects faults and reaches a diagnosis based on direct or indirect information; AI triggers mitigation actions or provides recommendations to operators

- Accident detection and mitigation: AI detects signatures of accidents or abnormal operation

- Remote surveys, for example, in support of uranium recovery or materials decommissioning programs: smart automatic surveys are deployed with the support of AI systems; survey outputs are interpreted by AI systems

Examples from NRC Data Science and AI Regulatory Applications Workshops (NRC 2023b) included using natural language generation and LLMs for automatic production of incident reports, CAP reports, periodic performance reports, and more complex documents such as environmental impact statements (EIS). Several entities are developing LLMs specialized in nuclear terminology, trained on the millions of documents hosted in the NRC document management system known as Agencywide Documents Access and Management System (ADAMS) (energynews 2024). LLMs could be used, for example, to help collect documents to support inspections and audits. In response to incidents and special conditions, LLMs might be used to generate automatic reports consistent with timeframes and schedules set by the regulation.

2.2.3 Operations and Training

AI may be used to attain different levels of operational autonomy, from the component level to the full facility operation. AI may also be used to train nuclear facility operators under regular and anomalous conditions.[3] The following are examples of potential uses of AI in operations and training:

- Support of operations: AI provides recommendations based, for example, on state variables of a facility, protocols, user manuals, and past performance

- Autonomous operation especially in cases where human response time and accuracy may be insufficient, under dangerous conditions for humans, or in remote locations

[3] Using AI for licensed operator training and examination could potentially impact NUREG-1021, “Operator Licensing Examination Standards for Power Reactors,” which establishes policies, procedures, and practices for examining licensees and applicants for reactor operator and senior reactor operator licenses at power reactor facilities.

- SSC operation and control optimization: AI operates specific structures, systems, components

- Support operator attention: AI monitors the level of attention of operators

- Digital twins support control of components: digital twins are combined with AI systems to regulate the performance of components

- Training systems: digital twins and simulators with AI provide hands on experience of system response under normal conditions and abnormal states of a facility

- Information extraction: LLMs could be used by trainees and operators to find information from standard operating procedure (SOPs) and user manuals

2.2.4 Digital Advisors

A digital advisor is defined in this report as a computer system with information that can be queried with keyboard or voice input. The information output by the digital advisor could be in the form of written text and other audiovisual information. Digital advisors could incorporate LLMs to efficiently extract information from SOPs, user's manuals, technical specifications for operation, licensing documents, operational records, regulations, and guidance. Digital advisors could also read indicators of the state of the facility from sensors, digital twins, and performance monitoring equipment to provide recommendations to an operator. Digital advisors could operate in dynamic mode and, for example, accept queries to help diagnose facility problems and identify optimal mitigations.

Digital advisors could synthesize information from NRC regulations, Environmental Protection Agency (EPA) regulations, state regulations, and operating procedures, to help radiation safety officers and technicians. A digital advisor may recommend courses of action addressing conditions based on worker dose and emission monitoring, consistent with relevant regulations. A digital advisor may also prepare required reports and notifications when special situations arise, like radiation levels, accumulated doses, or emissions above thresholds.

2.3 General AI Technology Risks

This section lists examples of risks of AI technologies, as identified by the NIST AI Risk Management Framework (AI RMF) (NIST 2023). These risks were considered during the review of the RGs as part of the AIRGA.

2.3.1 Machine-learning Systems

- The accuracy of ML systems strongly depends on the quality of the training data; the source data may be voluminous and have a complex structure—potentially introducing inaccuracies when information is extracted to assemble training datasets.

- The data used to train an AI system may not be a true or appropriate representation of the context or intended use of the AI system, and the ground truth may either not exist or not be available.

- Datasets used to train AI systems may become detached from their original and intended context or may become outdated relative to the deployment context.

2.3.2 Deep-neural Networks and Pre-trained Models

- AI systems can be large and complex (many systems contain billions of parameters) making understanding the underlying bases for predictions difficult.

- It is difficult to predict failure modes of large-scale pre-trained[4] models.

- The opacity of complex AI designs creates concerns about reproducibility, including whether predictions are reproducible by different and independent AI systems.

- Using pre-trained models can advance research and improve performance, but it can also increase levels of uncertainty and cause issues with scientific validity, and reproducibility.

- Unanticipated risks may exist with third-party AI technologies, transfer learning[5], and off-label use where AI systems may be trained for decision-making outside an organization's security controls or trained in one domain and then adjusted for another with unanticipated consequences.

2.3.3 Adaptive Learning

- Adaptive AI (an AI system that dynamically learns new patterns over time) is especially prone to data, model, and concept drift.

- Adaptive AI systems may overfit to local optimal solutions when multiple objectives with tradeoffs are not properly considered.

2.3.4 Generative AI

- Generative AI (generative AI such as LLMs is an AI system capable of generating information such as images, text, computer code, music in response to prompts) poses new risks that are difficult to anticipate.

- Ownership of information produced by generative AI systems is not well defined.

- The control of information with generative AI is questionable.

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[4] A *pre-trained* model is an imported model trained elsewhere for a different application.

[5] *Transfer learning* is selecting parts of a pre-trained artificial neural network for a different application, and complementing those parts with a small number of additional layers with trainable inputs that are optimized to achieve specific outputs. Transfer learning can significantly expedite model training.

- Information obtained using generative AI may not be accurate and fully reproducible.

2.3.5 General Risks

- AI systems may require more frequent maintenance and triggers for conducting corrective maintenance due to data, model, or concept drift.
- AI software testing standards are underdeveloped and not broadly accepted and used. It is difficult to document AI-based practices to the standard expected of traditionally engineered software.
- It is difficult to perform regular testing of software with AI technologies, and to define what to test.
- It can be difficult to predict or detect side effects of AI-based systems.
- AI poses special security concerns related to evasion, model extraction, membership inference, availability, or other machine learning attacks; AI may enable different software security abuses.

2.4 Risk Management and Trustworthy AI

The NIST AI RMF (NIST 2023) advocates for the development of an AI risk management program to support development of trustworthy AI systems. The NIST AI RMF is not officially endorsed by the NRC. However, in this project, NIST recommendations were examined to identify practical and systematic aspects of risk management to consider generally in the AIRGA.

2.4.1 NIST AI RMF Risk Management Program

The NIST AI RMF includes elements referred to as Govern, Map, Measure, and Manage. The Govern element of the AI RMF is a central element driving the AI risk management program. The Govern element is intended to promote and cultivate a culture of risk management. The Map element is aimed at defining a context, and identification of risks (i.e., what can happen?) within that context. In the Measure element the identified risks are analyzed and tracked. In the Manage element, the risks are prioritized and acted upon based on a projected impact. These elements of the NIST AI RMF are practical and actionable and can support the development of trustworthy AI systems.

It is noted that RG 1.168 titled *Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants* describes an acceptable method to comply with regulations with respect to verification, validation, reviews, and audits for digital computer software used in safety systems of nuclear power plants. The RG endorses Institute of Electrical and Electronic Engineers (IEEE) Standard 1012-2004 (IEEE 2005). The standard recommends classifying software in 4 levels, with higher testing requirements for levels 3 and 4. The standard calls for a criticality, hazard, security, and risk analysis. The standard also includes identification of mitigation alternatives in case of software malfunction. The IEEE standard already incorporates elements of the risk management framework advocated by NIST and is also applicable to guide development of software with AI technologies. The standard may need supplements to address issues specific to AI, for example input data quality, incorporating best practices on AI validation and verification, and systematic fail-safe design.

2.4.2 Trustworthy AI Attributes

The NIST AI RMF recommends development of *trustworthy AI* as a strategy to manage the risk of AI technologies (NIST 2023). Per the AI RMF, the trustworthy AI strategy includes the following attributes

- Valid and reliable
- Safe
- Secure and resilient
- Accountable and transparent
- Explainable and interpretable
- Privacy enhanced
- Fair with harmful bias managed

Those attributes are briefly summarized to derive practical considerations for the AIRGA inspired by the NIST AI RMF. As previously stated, the NIST AI RMF (NIST 2023) is not officially endorsed by the NRC

2.4.2.1 Valid and Reliable

In the NIST definition, validation refers to demonstrating that software requirements for a specific intended use or application have been fulfilled, through documentation of testing. Reliability refers to the ability of a system to perform as required, without failure, for a given interval or under given conditions. There are additional attributes embedded in valid and reliable, such as accuracy, and robustness or generalizability. Robustness or generalizability is defined as the ability of a system to maintain its level of performance under a variety of circumstances. This is particularly important for AI applications; and it implies that performance should be demonstrated under expected and unexpected settings. Salient considerations related to the Valid and Reliable attribute in the context of the AIRGA include the following:

- Special computations using AI technologies may be subject to quality controls such as peer reviews and transparency and traceability. Are standard methods to document and control computations sufficient for computations using AI technologies?

- Are standard quality assurance software development frameworks sufficient to control the development of software incorporating AI technologies?

- Is there any difference in validation considerations for software with AI technologies actively used in facility operations versus software for other activities (e.g., siting, design, decommissioning)?

2.4.2.2 Safe

The NIST strategy indicates AI systems should not lead to a state in which human life, health, property, or the environment is endangered. The NIST AI RMF states that safe operation of AI systems is improved through

- Responsible design, development, and deployment practices.
- Clear information to deployers on responsible use of the system.
- Responsible decision-making by deployers and end users.
- Explanations and documentation of risks based on empirical evidence of incidents.

Responsible design, development, and deployment practices calls for a risk analysis of the AI system, including examinations of “what can go wrong?” and “what are the consequences?” together with strategies to address and mitigate error or misfunction. Salient considerations for the AIRGA on the Safe attribute are related to whether the NRC regulatory framework requires

- Rigorous simulation and in-domain testing of software and hardware.
- Examination of potential misfunction of technologies.
- Real-time monitoring of technology performance.
- The ability to shut down, modify, or allow human intervention into computer systems that deviate from intended or expected functionality.

2.4.2.3 Secure and Resilient

The NIST strategy indicates AI systems that can maintain confidentiality, integrity, and availability through protection mechanisms that prevent unauthorized access and use are considered *secure*. NIST defines AI systems to be *resilient* if they can withstand unexpected adverse events or unexpected changes in their environment or use, or if they can maintain their functions and structure in the face of internal and external change and degrade safely when this is necessary. Resilience is related to *robustness* (Section 2.4.2.1) but is broader because it encompasses unexpected or adversarial use (or abuse or misuse) of the model or data.

Cybersecurity guidelines apply to the development of systems incorporating AI technologies. RG 5.71 titled Cyber Security Programs for Nuclear Power Reactors describes an approach to meet regulatory requirements of 10 CFR 73.54, “Protection of Digital Computer and Communication Systems and Networks.” This RG describes methods for establishing a cybersecurity program at a commercial nuclear power plant to comply with regulations for adequately protecting digital computer and communication systems and networks against cyberattacks, up to and including the design-basis threat as described in 10 CFR 73.1. This RG also provides guidance on the development of a cybersecurity plan and provides examples of included security controls. RG 5.71 was published in 2023, and it includes modern recommendations applicable to development and deployment of software with AI technologies. Other RGs related to cybersecurity are RG 5.74 titled Managing the Safety/Security Interface, RG 5.83 titled Cyber Security Event Notifications, and RG 1.152 titled Criteria for Use of Computers in Safety Systems of Nuclear Power Plants. These existing RGs address recommendations related to the Secure and Resilient attribute; therefore, no further examination of cybersecurity issues was conducted for this project.

2.4.2.4 Accountable and Transparent

In the NIST strategy, *transparency* reflects the extent to which information about an AI system and its outputs is available to individuals interacting with such a system. Meaningful transparency provides access to appropriate levels of information based on the stage of the AI lifecycle. This access to information is tailored to the role or knowledge of AI actors or individuals interacting with or using the AI system. In the NIST framework, a high level of transparency is needed to attain accountability. Transparency spans design decisions and data selection for the ML process, the structure of the model, its intended use cases, and how and when deployment, post-deployment, or end user decisions were made and by whom.

Per the NIST AI RMF, the role of AI developers and deployers should be considered when seeking accountability for the outcomes of AI systems. When consequences are severe, AI actors should consider proportionally and proactively adjusting their transparency and accountability practices. NIST states that maintaining organizational practices and governing structures for harm reduction, like risk management, can foster more accountable systems.

In the NRC regulations, accountability is assigned to licensees, and the accountability attribute was only broadly considered while executing the AIRGA. Transparency considerations are embedded in the following attribute of Explainable and Interpretable and are considered therein.

2.4.2.5 Explainable and Interpretable

Explainability in the NIST strategy refers to a representation of the mechanisms underlying an AI system operation, whereas interpretability refers to the meaning of the AI system output in the context of their designed functional purposes. NIST states that perceptions of negative risk stem from a lack of ability to make sense of, or contextualize, system output appropriately. Explainable and interpretable AI systems offer information that helps end users understand the purposes and potential impact of an AI system.

In the NIST strategy, transparency, explainability, and interpretability are distinct characteristics that support each other. Transparency can answer the question of "what happened" in the system. Explainability can answer the question of "how" a decision was made in the system. Interpretability can answer the question of "why" a decision was made by the system and its meaning or context to the user.

Explainable systems facilitate debugging and monitoring, as well as auditing and control. Explainability and interpretability are heavily dependent on transparency: transparency of data sources for ML, transparency of computation algorithms, and transparency of information use within the AI system. Transparency is a requirement for explainability and interpretability.

Attaining explainability for AI systems appears challenging, especially for complex algorithms and deep neural network architectures with millions of parameters, as stated in Section 2.3. The NRC regulatory framework, including 10 CFR Part 50, Appendix B "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," in general calls for control of information as well as auditability, but not explicit explainability. NRC staff may explore details of technologies and analyses through audits, as needed. The explainability attribute was considered during the AIRGA, but only in broad terms. The main consideration for the AIRGA was exploring if the regulatory framework explicitly calls for explainability, thus potentially imposing special requirements on AI systems.

2.4.2.6 Privacy-Enhanced

Privacy in the NIST strategy refers generally to the norms and practices that support safeguarding human autonomy, identity, and dignity. NIST states that privacy-enhancing technologies for AI, as well as data minimizing methods such as de-identification and aggregation for certain model outputs, can support design for privacy-enhanced AI systems.

The examples in NUREG/CR-7294 (Ma, et al. 2022) and in the NRC Data Science and AI Regulatory Applications Workshops (NRC 2023b) are not related to data mining for personal information. Because NRC regulation and guidance do not specifically address personal privacy, the Privacy-Enhanced attribute was only broadly considered during the AIRGA, without specific questions to be addressed.

2.4.2.7 Fair – with Harmful Bias Managed

Fairness in AI in the NIST strategy includes concerns for equality and equity by addressing issues such as harmful bias and discrimination. There is no clear connection of AI use examples in NUREG/CR-7294 (Ma, et al. 2022) and in the NRC Data Science and AI Regulatory Applications Workshops (NRC 2023b) to harmful bias. AI systems could potentially be used in projects related to environmental justice and siting. For example, siting decisions by an AI system could be biased against vulnerable communities. It is difficult to identify other examples where AI systems could yield harmful bias within the context of NRC-regulated activities. Because NRC regulation and guidance do not specifically address equality, equity, and bias, this attribute was only broadly considered during the AIRGA, without specific questions to be addressed.

3 AI REGULATORY GAP ANALYSIS

3.1 AI Regulatory Gap Analysis Methodology

The AIRGA was executed to evaluate the NRC regulatory framework to enhance the NRC staff's readiness for the potential use of AI technologies in NRC-regulated activities. The analysis examined RGs and underlying NRC regulations at Title 10 of the *Code of Federal Regulations* (10 CFR). The AI use examples, AI technology risks, and the NIST AI RMF (NIST 2023) summarized in Section 2.4 were considered while performing the AIRGA. Initial efforts focused on screening NRC regulations for potential issues regarding uses of AI technologies consistent with examples described in Section 2.2. Due to time and fundings constraints, the authors shifted to a practical approach to execute the project. RGs contain guidance and identify requirements, and they are frequently more detailed than regulations. To narrow down the scope of the gap search, the analysis first examined whether RGs contained potential gaps or details inconsistent with the use of AI. The analysis then examined NRC regulations cited by the subset of RGs with potential gaps, for potential conflicts with the use of AI technologies. For that reason, the information is presented in this section starting first with the RGs and then the NRC regulations.

In summary, the AIRGA was executed in three specific steps:

- Screening RGs
- Analyzing screened-in RGs to identify RGs with potential gaps
- Examining regulations associated with RGs deemed with potential gaps for potential conflicts with the use of AI technologies.

3.1.1 Screening and Analysis of Regulatory Guides

The first step of the AIRGA was screening RGs. The complete set of RGs is available online at the NRC website (NRC 2024b). The RGs are numbered with suffixes from 1 to 10, covering 10 divisions:

1. Power Reactors
2. Research and Test Reactors
3. Fuels and Materials Facilities
4. Environmental and Siting
5. Materials and Plant Protection
6. Products
7. Transportation
8. Occupational Health
9. Antitrust and Financial Review
10. General

As of July 2024, NRC has published 517 RGs (NRC 2024b). Of those, 372 are active; the remaining 145 RGs have been withdrawn with the most recent withdrawal on January 25, 2024.

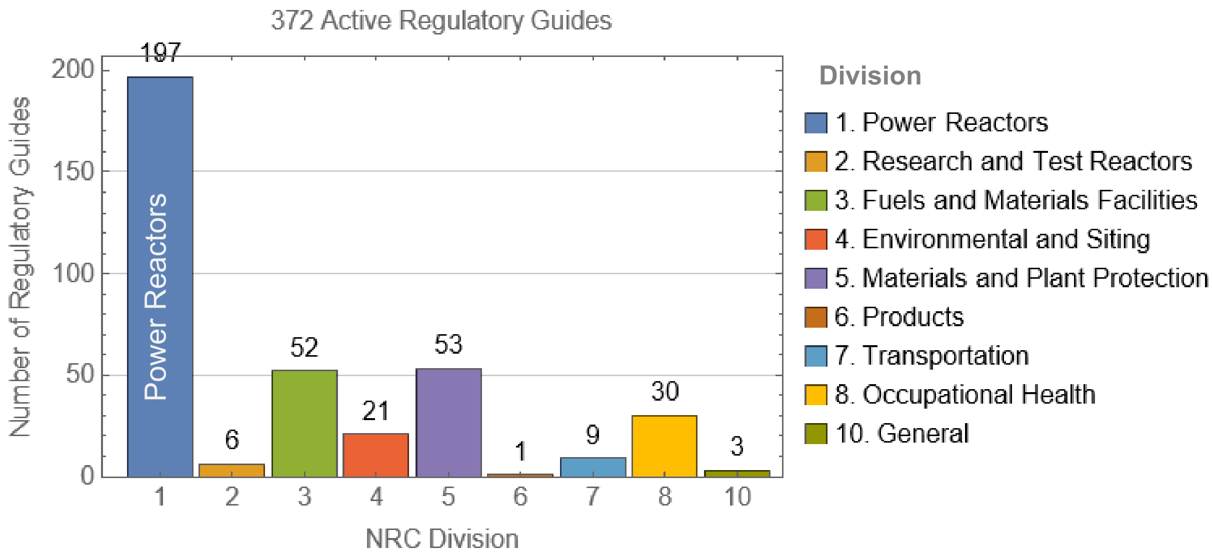

Figure 3-1. Number of regulatory guides by NRC division

All RGs under division 9, Antitrust and Financial Review, have been withdrawn. Figure 3-2 is a bar chart with a count of active RGs by NRC division. Sixteen RGs were not examined in this project for different reasons. Six RGs are draft and have not been declared "final" since 2017 (RGs 1.222, 1.223, 1.224, 1.228, 1.229, and 2.7), one draft RG was discontinued (RG 5.85), and nine RGs are not publicly available because they are labeled "classified" and contain security-related information (RGs 1.214, 5.54, 5.66, 5.69, 5.70, 5.76, 5.78, 5.81, 7.13).

The analysis of RGs was based on seeking answers to three questions. Considering the examples in Section 2.2 of this report, the following question was posed for each RG:

Q0: *Can AI technologies be used within the scope of the RG?*

If the answer to Q0 was no, then the RG was screened out or excluded from further consideration. If the answer to Q0 was yes, the RG was labeled as "screened in," and the following two questions were posed:

Q1: *Is the RG flexible to allow use of AI?*

Q2: *Does the RG provide adequate guidance to evaluate the use of AI?*

If the answer to either Q1 or Q2 was no, the analysis concluded the RG had a potential gap for supporting the evaluation of AI technologies. An Excel file was used to record the RG screening, whether a potential gap was identified for the RG, and notes detailing aspects of the potential gap. A flow diagram of the screening process for RGs is displayed in Figure 3-2.

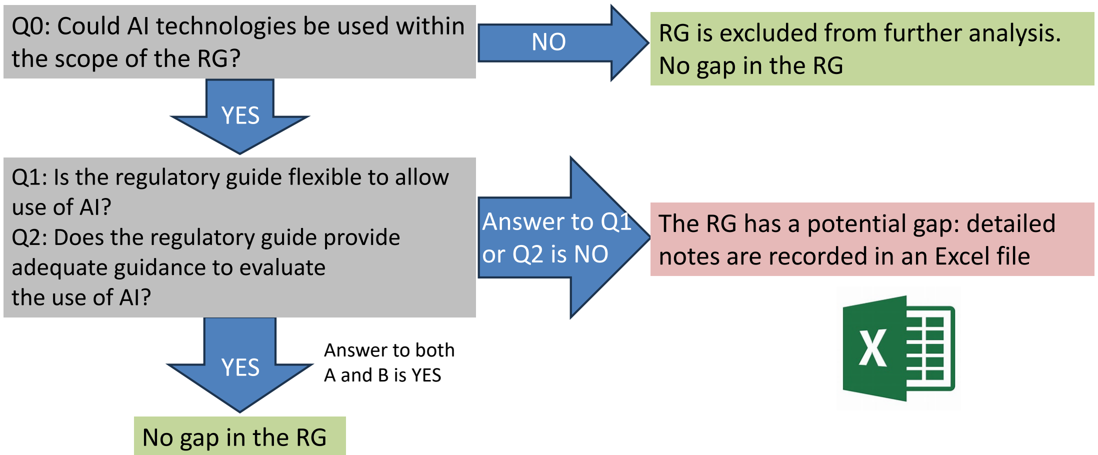

Figure 3-2. Flow diagram of the screening process for regulatory guides

After excluding the 16 RGs from the active 372 RGs, a total of 257 RGs were screened out based on no-answers to question Q0. In broad terms the screened-out RGs:

- Specify physical requirements or construction and deployment approaches
- Define personnel training standards
- Define very specific assumptions and analytical and computational methods
- Specify a level of reliability and robustness of specific components
- Define how to qualify equipment to withstand environmental challenges
- Define physical limits for operation
- Define specific approaches to protect certain structures
- Address programmatic needs such as development of emergency plans, financial plans, and decommissioning plans
- Are general in nature and would not benefit from specific discussion of AI

The analysis concluded the scope of these 257 RGs was independent of AI technologies and screened out. For guides that define specific analytical and computational methods, it was considered unlikely that alternative AI methods would be adopted, because the standard methods are accepted and tested (e.g., analytical methods to define stress levels of structures), or because the recommended methods in the guides are intended to standardize the analyses. Examples of standardized analyses include air dispersion calculations of radioactive releases; human dose calculations; and computation of the effects of explosions near nuclear facilities.

A total of 99 RGs were screened-in for further examination. From this set, based on answers to questions Q1 and Q2, the analysis identified 28 RGs with no gaps, and 71 with potential gaps. The results of the screening and analysis process are summarized in the Venn diagram in Figure 3-3.

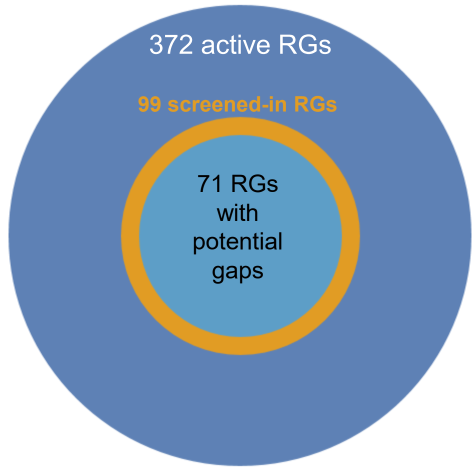

Figure 3-3. Venn diagram showing results of screening and analysis for potential gaps.

Appendix A includes the set of 28 RGs with comments on why those RGs were deemed with no gaps and adequate to support the evaluation of AI technologies. Appendix A includes some examples where the RG may not be sufficient to evaluate AI technologies (i.e., a RG with a no answer to Q2); however, no gap was identified because the use of AI technologies was considered very unlikely within the scope of that RG. For example, well-accepted physics-based computational approaches are unlikely to be replaced with computations based on AI techniques. Additionally, some AI technologies are not readily available, and are unlikely to be developed soon (e.g., AI technologies fully replacing humans welding nuclear components).

Appendix B provides the set of 71 RGs with potential gaps, including detailed comments on the potential gaps. The count of RGs with potential gaps by NRC division is displayed in Figure 3-4.

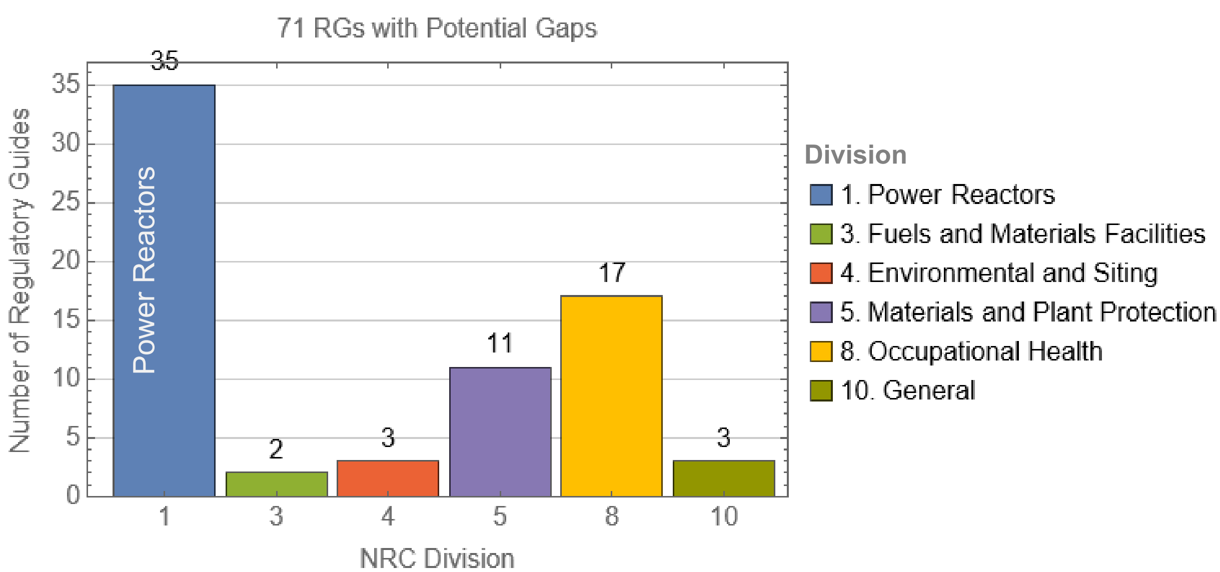

Figure 3-4. Number of regulatory guides with potential gaps by NRC division

3.1.2 Analysis of NRC Regulations

As a next step of the AIRGA, the applicable NRC regulations cited in RGs with potential gaps (71 RGs) were identified. These applicable NRC regulations, from Title 10, Chapter I of the CFR, were examined for potential conflicts with the use of AI technologies, especially related to the potential gaps in the RGs. Only in a relatively small subset of requirements the analysis identified that use of AI technologies could conflict with specific statements in the regulations. Identified issues are discussed in Section 3.3, and Appendix C includes details of the analysis of regulations.

3.2 Results of Analysis of Regulatory Guides

The AIRGA applied to the RGs identified 71 RGs with potential gaps. To synthesize information, the potential gaps were classified into eight categories:

- Gap 1: Implied Manual Actions
- Gap 2: Special Computations
- Gap 3: Preoperational and Initial Testing Programs May Omit AI
- Gap 4: Habitability Conditions under Autonomous Operations
- Gap 5: Periodic Testing, Monitoring, and Reporting
- Gap 6: Software for Safety-Related Applications
- Gap 7: Radiation Safety Support
- Gap 8: Miscellaneous: Training and Human Factors Engineering

These eight categories are summarized in the following subsections, including tables with the list of RGs corresponding to the potential gap. Some RGs are representative of several gap categories; no effort was made to classify RGs into unique gap categories. The list of types or categories of gaps follows a chronological order in which they were identified.

RGs related to “Changes, Tests, and Experiments” (RG 1.187, 2.8, 3.72, and 5.74) include criteria to allow licensees to introduce changes to a facility without requiring NRC approval. One potential issue considered in the analysis was whether current RGs might permit deployment of AI technologies without proper NRC approval. RGs 1.187, 2.8, 3.72, and 5.74 were examined and found to contain criteria that would trigger a detailed evaluation of AI technologies; thus, no gaps were identified in these RGs (see Appendix A).

3.2.1 Gap 1: Implied Manual Actions

This potential gap refers to statements in RGs implying manual actions by humans. Operators and technicians are implicitly referred in the RG to take an action or perform a task. AI technologies offer alternatives to execute those potential actions without human intervention. Use of AI technologies would potentially conflict with statements in RGs; however, it is acknowledged that RGs provide guidance that itself is not mandatory. In few instances, wording in RGs calling for manual actions directly follows from NRC regulatory requirements. The list of RGs related to the potential Gap 1 are listed in Table 3-1. Detailed notes on each of these RGs are provided in Appendix B.

Table 3-1. Regulatory guides related to Gap 1: Implied Manual Actions

RG Number	Title
1.7	Control of Combustible Gas Concentrations in Containment
1.114	Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit
1.141	Containment Isolation Provisions for Fluid Systems
1.147	Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1
1.149	Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, and Applicant Experience Requirements
1.189	Fire Protection for Nuclear Power Plants
1.205	Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants
5.7	Entry/Exit Control for Protected Areas, Vital Areas, and Material Access Areas
5.44	Perimeter Intrusion Alarm Systems

3.2.2 Gap 2: Special Computations

As stated in Section 2.2.1, AI techniques can be used in support of special computations, particularly when databases exist that could be used for ML. Considering the types of applications described in Section 2.2.1, it was deemed likely that AI techniques could be used for computations within the scope of several RGs. In general, the guidance was considered insufficient to evaluate computations using AI techniques and this constitutes the potential gap.

Table 3-2. Regulatory guides related to Gap 2: Special Computations

RG Number	Title
1.59	Design Basis Floods for Nuclear Power Plants
1.60	Design Response Spectra for Seismic Design of Nuclear Power Plants
1.76	Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants
1.157	Best-Estimate Calculations of Emergency Core Cooling System Performance
1.198	Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites
1.200	Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities
1.203	Transient and Accident Analysis Methods
1.245	Preparing Probabilistic Fracture Mechanics (PFM) Submittals
1.247	TRIAL - Acceptability of Probabilistic Risk Assessment Results for Non-Light Water Reactor Risk-Informed Activities
3.27	Nondestructive Examination of Welds in the Liners of Concrete Barriers in Fuel Reprocessing Plants
3.76	Implementation of Aging Management Requirements for Spent Fuel Storage Renewals
5.11	Nondestructive Assay of Special Nuclear Material Contained in Scrap and Waste
5.21	Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry
5.23	In Situ Assay of Plutonium Residual Holdup

Table 3-2. Regulatory guides related to Gap 2: Special Computations

RG Number	Title
5.37	In Situ Assay of Enriched Uranium Residual Holdup
5.38	Nondestructive Assay of High-Enrichment Uranium Fuel Plates by Gamma Ray Spectrometry
10.4	Guide for the Preparation of Applications for Licenses to Process Source Material

Many RGs call for computations citing standard methods. During the AIRGA, it was deemed unlikely AI techniques would be considered when traditional techniques are well accepted and may be more practical. In those cases, the RG was screened out and no gap was identified. Regarding screened-in RGs with potential gaps, in most instances the underlying NRC regulations are general and considered broadly applicable to regulating the use of AI technologies. However, in a few cases the applicable regulations were explicit about the types of acceptable models and computations, thus implicitly restricting the use of AI technologies. Those regulations are summarized in Section 3.3 and in Appendix C.

3.2.3 Gap 3: Preoperational and Initial Testing Programs May Omit AI

RGs addressing preoperational and initial testing programs recommend specific systems to be tested prior to facility operation and as part of the initial testing program before launching a facility. If AI systems are used in safety systems, it is expected those systems would need to be fully tested, including tests of software malfunction and fail-safe design, with consideration of special risks such as those described in Section 2.3. It is acknowledged that comprehensive verification and validation testing of software in general is addressed in RG 1.168, “Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants.” AI systems may require additional pre-operational testing to address robustness attributes (e.g., performance under challenges) to complement the criticality, risk, hazard, and security analyses called for by RG 1.168. Regardless of whether AI systems are used in safety or non-safety systems, AI systems should be thoroughly tested from a cybersecurity standpoint. The RGs related to preoperational and initial testing are listed in Table 3-3.

Table 3-3. Regulatory guides related to Gap 3: Preoperational and Initial Testing Programs May Omit AI

RG Number	Title
1.68	Initial Test Programs for Water-Cooled Nuclear Power Plants
1.68.2	Initial Startup Test Program to Demonstrate Remote Shutdown Capability for Water-Cooled Nuclear Power Plants
1.79	Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors
1.79.1	Initial Test Program of Emergency Core Cooling Systems for New Boiling-Water Reactors

The applicable regulations of the RGs in Table 3-3 were found adequate to regulate AI technologies.

3.2.4 Gap 4: Habitability Conditions Under Autonomous Operations

Several RGs describe acceptable methods for ensuring habitable conditions in nuclear power plant control rooms under normal and accident situations. This includes, for example, maintaining low radiation fields, clean air, and enough oxygen in a control room. Methods for ensuring habitability are in general also sufficient to protect critical equipment. If AI systems could be used to achieve different levels of autonomous operation up to full autonomy, habitability guidance could be possibly refocused on recommendations to protect equipment. Facilities may be designed with remote controls, and it may be necessary to consider protecting the connectivity and interfacing between the facility and the control room, under normal and accident conditions.

RGs address specific NRC requirements; for example, General Design Criterion 19 of Appendix A of 10 CFR Part 50 requires a control room with adequate radiation protection for human occupancy. The RGs address human occupancy under radiation, chemical, and fire hazards. RGs listed in Table 3-4 are related to Gap 4.

Table 3-4. Regulatory guides related to Gap 4: Habitability Conditions Under Autonomous Operations

RG Number	Title
1.78	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release
1.189	Fire Protection for Nuclear Power Plants
1.196	Control Room Habitability at Light-Water Nuclear Power Reactors

The following relevant questions were identified related to RGs in Table 3-4 and to their applicable regulations:

- Which actions traditionally executed by operators would be permissible to be conducted by AI systems?
- If autonomous AI operation were allowed, should human operators be present if they are not actively participating in facility operation? Would it be permissible for operators to merely oversee actions by AI systems?
- Regulations include requirements that certain automatic equipment should also allow for manual control. Should requirements like these be imposed on AI systems used in safety systems and control systems?
- What kind of protection should be required for autonomous control systems located in the facility, and for communication systems to control facilities located elsewhere?

3.2.5 Gap 5: Periodic Testing, Monitoring, Surveillance, and Reporting

Several RGs call for periodic testing, surveillance, monitoring, and reporting of conditions. Developments in AI in non-destructive evaluation and computer vision in surveillance, suggest it would be feasible using AI in many testing, monitoring, and surveillance programs addressed in RGs. Several RGs call for periodic reports, incident reports, and reports when certain conditions are established. Large language models could be used to automatically prepare and publish those reports. General guidance may be needed to evaluate the proper use of AI technologies. It is noted that there is overlap of this gap with Gap 1. Gap 1 addresses manual actions in general, while Gap 5 is related to manual actions for periodic testing, monitoring, and surveillance. This is the gap category with the longest list of RGs identified in this project. The RGs associated with this potential gap are listed in Table 3-5.

Table 3-5. Regulatory guides related to Gap 5: Periodic Testing, Monitoring, Surveillance, and Reporting

RG Number	Title
1.7	Control of Combustible Gas Concentrations in Containment
1.9	Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants
1.21	Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste
1.90	Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons
1.118	Periodic Testing of Electric Power and Protection Systems
1.129	Maintenance, Testing, and Replacement of Vented Lead-Acid Storage Batteries for Production and Utilization Facilities
1.141	Containment Isolation Provisions for Fluid Systems
1.147	Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1
1.205	Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants
1.246	Acceptability of ASME Code, Section XI, Division 2, Requirements for RIM Programs for NPPs, for Non-LWRs
3.27	Nondestructive Examination of Welds in the Liners of Concrete Barriers in Fuel Reprocessing Plants
3.76	Implementation of Aging Management Requirements for Spent Fuel Storage Renewals
4.1	Radiological Environmental Monitoring for Nuclear Power Plants
4.14	Radiological Effluent and Environmental Monitoring at Uranium Mills
4.16	Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants
5.7	Entry/Exit Control for Protected Areas, Vital Areas, and Material Access Areas
5.11	Nondestructive Assay of Special Nuclear Material Contained in Scrap and Waste
5.21	Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry
5.23	In Situ Assay of Plutonium Residual Holdup

Table 3-5. Regulatory guides related to Gap 5: Periodic Testing, Monitoring, Surveillance, and Reporting

RG Number	Title
5.27	Special Nuclear Material Doorway Monitors
5.37	In Situ Assay of Enriched Uranium Residual Holdup
5.38	Nondestructive Assay of High-Enrichment Uranium Fuel Plates by Gamma Ray Spectrometry
5.41	Shipping, Receiving, and Internal Transfer of Special Nuclear Material at Fuel Cycle Facilities
5.44	Perimeter Intrusion Alarm Systems
5.71	Cyber Security Programs for Nuclear Power Reactors
8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable
8.10	Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable
8.11	Applications of Bioassay for Uranium
8.15	Acceptable Programs for Respiratory Protection
8.18	Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be as Low as Reasonably Achievable
8.19	Occupational Radiation Dose Assessment in Light-Water Reactor Power Plants - Design Stage Man-Rem Estimates
8.20	Applications of Bioassay for Radioiodine
8.22	Bioassay at Uranium Mills
8.25	Air Sampling in the Workplace
8.26	Applications of Bioassay for Fission and Activation Products
8.31	Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable
8.32	Criteria for Establishing a Tritium Bioassay Program
8.34	Monitoring Criteria and Methods to Calculate Occupational Radiation Doses
8.36	Radiation Dose to the Embryo/Fetus
8.37	ALARA Levels for Effluents from Materials Facilities
8.38	Control of Access to High and Very High Radiation Areas of Nuclear Plants
10.2	Guidance to Academic Institutions Applying for Specific Byproduct Material Licenses of Limited Scope
10.3	Guide for the Preparation of Applications for Special Nuclear Material Licenses of Less than Critical Mass Quantities
10.4	Guide for the Preparation of Applications for Licenses to Process Source Material

In general, the analysis found the NRC regulations addressed by the RGs in Table 3-5 were broadly applicable to regulating the use of AI technologies. However, in a few cases the analysis found that regulations call for monitoring and surveillance by humans, such as video surveillance, thus implicitly restricting the use of computer vision, for example. With respect to periodic reporting, the regulations do not state how the reports should be produced; thus, it appears LLMs could be used to produce reports without conflicting with the NRC regulations. It is the responsibility of licensees and applicants to ensure the quality and accuracy of information provided to the NRC. This project did not attempt to identify if specific additional requirements, such as additional reporting requirements for AI-generated reports, might be needed to ensure the safe and secure use of AI in nuclear applications.

3.2.6 Gap 6: Software for Critical Applications

RGs related to software development, control, and procurement for safety-related applications were examined and deemed adequate to be applied to software including AI. However, complementary guidance may be needed to address some risks identified in Section 2.3 of this report, and this defines a potential gap for the related RGs, listed in Table 3-6. The reader is referred to detailed comments for each RG in Appendix B.

Table 3-6. Regulatory guides related to Gap 6: Software for Critical Applications

RG Number	Title
1.168	Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants
1.169	Configuration Management Plans for Digital Computer Software Used in Safety Systems of Nuclear Power Plants
1.171	Software Unit Testing for Digital Computer Software Used in Safety Systems of Nuclear Power Plants
1.172	Software Requirement Specifications for Digital Computer Software and Complex Electronics Used in Safety Systems of Nuclear Power Plants
1.173	Developing Software Life Cycle Processes for Digital Computer Software Used in Safety Systems of Nuclear Power Plants
1.231	Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Safety-Related Applications for Nuclear Power Plants
5.71	Cyber Security Programs for Nuclear Power Reactors

RG 1.168 describes a method for complying with regulations regarding verification, validation, reviews, and audits for digital computer software used in safety systems of nuclear power plants, and it endorses IEEE Std 1012-2004 (IEEE 2005). The IEEE standard seems appropriate to guide the development and deployment of software with AI technologies and consistent with recommendations in the NIST AI RMF (NIST 2023). The IEEE standard is discussed in detail in Section 4.1.1. Supplemental guidance may be needed to address data quality and quantity for ML, to define best practices in the validation and verification of AI technologies, and to address fail-safe design.

RG 1.231 may also need special consideration because it defines additional testing of software procured from commercial vendors. For example, if the commercial vendor has an active QA program abiding by 10 CFR Part 50, Appendix B, then RG 1.231 allows for software to be more readily procured and deployed. However, it is not clear that 10 CFR Part 50, Appendix B QA programs sufficiently address the AI risks summarized in Section 2.3 of this report. Thus, it may be appropriate to develop general guidance for the development of software with AI technologies that could also be adopted by commercial vendors.

In general, the NRC regulations addressed by the RGs in Table 3-6 were found to be broadly applicable to regulating the use of AI technologies and no issues were identified.

3.2.7 Gap 7: Radiation Safety Support

This potential gap is related to digital advisors discussed in Section 2.2.4. It is envisioned there may be commercial incentives to make extensive use of large language models (LLMs) and other AI technologies to support activities traditionally assigned to radiation safety professionals and technicians. As stated in Section 2.2.4, digital advisors could keep track of relevant federal and state regulations, keep track of monitoring programs, recommend courses of action, and write required periodic reports. However, relevant RGs include wording implying specific activities and tasks can only be executed by certified professionals, and not by AI systems. The wording in RGs in some cases mirror the underlying NRC requirements. The RGs associated with this potential gap are listed in Table 3-7.

Table 3-7. Regulatory guides related to Gap 7: Radiation Safety Support

RG Number	Title
8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable
8.10	Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable
8.11	Applications of Bioassay for Uranium
8.15	Acceptable Programs for Respiratory Protection
8.18	Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be as Low as Reasonably Achievable
8.20	Applications of Bioassay for Radioiodine
8.22	Bioassay at Uranium Mills
8.25	Air Sampling in the Workplace
8.26	Applications of Bioassay for Fission and Activation Products
8.31	Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable
8.32	Criteria for Establishing a Tritium Bioassay Program
8.34	Monitoring Criteria and Methods to Calculate Occupational Radiation Doses
8.35	Planned Special Exposures
8.36	Radiation Dose to the Embryo/Fetus
8.38	Control of Access to High and Very High Radiation Areas of Nuclear Plants
10.4	Guide for the Preparation of Applications for Licenses to Process Source Material

3.2.8 Gap 8: Miscellaneous: Training and Human Factors Engineering

The miscellaneous gap was associated with unique issues (there is only one RG for each issue) described in the following paragraphs. The RGs associated with this potential gap are listed in Table 3-8.

Table 3-8. Regulatory guides related to Gap 8: Miscellaneous: Training and Human Factors Engineering

RG Number	Title
1.149	Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, and Applicant Experience Requirements
1.206	Applications for Nuclear Power Plants

RG 1.149, “Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, and Applicant Experience Requirements,” concerns simulators used for training operators and senior operators. If AI systems were successfully used in nuclear power plants, the role of operators may change. It is unclear, if such circumstances were allowed, if training programs should be updated to include only controls operated by humans, and if AI systems should include handover switches to operators under special circumstances. The scope of training programs may require examination in light of functions and actions by AI systems.

The analysis found RG 1.206 “Applications for Nuclear Power Plants,” which describes the content of applications, is independent of AI technologies. However, RG 1.206 also addresses human factors engineering (HFE) by citing the Standard Review Plan (SRP), NUREG-0800 (NRC 2023c). HFE is addressed in Section 14.3.9, “Human Factors Engineering—Inspections, Tests, Analyses, and Acceptance Criteria” of the SRP. Special consideration should be given to Human Factors Engineering (HFE) if remote operation of nuclear facilities is considered a viable option, which may or may not include AI systems. It is not clear the guidance and the SRP are sufficient to evaluate the use of HFE for safe deployment of AI technologies. The potential gap is related to whether traditional HFE is adequate to address AI technologies.

3.3 Results of Analysis of NRC Regulations

During early stages of the AIRGA, NRC regulations were initially screened by systematically applying pre-defined screening criteria to each Part of Title 10, Chapter I of the CFR. NRC regulations were screened-in if they were applicable to potential uses of AI technologies like the examples in Section 2.2 in the context of NRC-regulated activities. If there is no perceived potential use of AI technology in the NRC regulated activity, then the regulation was screened out. Regulations that solely apply to how NRC administers its own activities in exercising its regulatory functions or statutory obligations were screened out. For example, 10 CFR Part 1, “Statement of organization and general information” provides general information about the NRC; 10 CFR Part 4, “Nondiscrimination in Federally assisted programs or activities receiving Federal financial assistance from the Commission” and 10 CFR Part 5, “Nondiscrimination on the basis of sex in education programs or activities receiving Federal financial assistance” applies to NRC funded programs and activities. These parts were screened out.

The NRC regulations that were screened in were predominantly related to licensing, oversight, and decommissioning in the various NRC program areas including power reactors, materials, and radioactive waste. This includes power and non-power reactors, nuclear fuel cycle and uranium recovery facilities, and materials used in a variety of activities including medical diagnosis and therapy, medical and biological research, academic training and research, industrial gauges, nondestructive testing, production of radiopharmaceuticals, and fabrication of commercial products. The NRC regulations addressing waste management licensing include high-level waste repository licensing and low-level radioactive waste disposal facility licensing. Other regulations that were screened in address requirements that apply across many program areas or to broad activities including transportation, radiation protection, worker notification, and requirements for the conduct of hearings.

The NRC regulations that were screened out were predominantly administrative or other requirements that applied to NRC or NRC staff (e.g., how NRC operates as a federal agency). A smaller subset of the requirements that were screened out did not have an obvious nexus to the use of AI technologies. Examples of requirements applicable to the NRC or NRC staff include requirements pertaining to NRC organization, non-discrimination in federal programs, NRC advisory committees, NRC public records, NRC staff security clearances, NRC payment of legal fees, liability claims, and access authorization for classified information. Requirements with no clear nexus to AI technology included narrow trespassing requirements, fee determinations, patents, and requirements applicable to specific facilities that are no longer operating[6].

To focus project resources and streamline the analysis, the detailed analysis of regulations concentrated on identifying if potential gaps in the RGs arise from statements in the applicable regulations. Only a small subject of the regulations evaluated had text that was found to potentially conflict with the use of AI technologies. Table 3-9 summarizes regulations with some text potentially in conflict with the use of AI technologies. Extended notes are provided in Appendix C. Both the Table 3-9 and Appendix C are sorted by the RG number. The complete list of applicable regulations for each of the RGs in Table 3-9 is included in Appendix C. Table 3-9 only includes regulations with some text that could be interpreted to be in conflict with the use of AI technologies. The section symbol § in Tables 3-9 and 3-10 is used to avoid repetition because all cited sections are within Title 10 of the CFR.

Table 3-9. Regulations with limited text potentially conflicting with uses of AI.

RG No.	Gap Type.	Regulation and comment
1.78	4	Part 50 Appendix A General Design Criterion (GDC) 19: different criteria could be set to protect critical equipment.
1.114	1	§50.54(k): operators must be always present in the control room. Part 50 Appendix A GDC 19: the only executors of actions are operators. §50.54(m)(2)(iii): operators are in the facility to execute actions.
1.157	2	§50.46: physical models are required. Part 50 Appendix K: physical models are required.
1.189	4	Part 50 Appendix A GDC 19: implies habitability requirements under fires.
1.196	4	Part 50 Appendix A GDC 19: implies habitability requirements under fires.
1.203	2	§50.46: physical models are required. Part 50 Appendix K: physical models are required.
1.245	1, 2, 5	§50.55a(a)(1)(iv) lists ASME codes of Operation and Maintenance of Nuclear Power Plants. The operation and maintenance ASME codes refer to the role of human operators, implicitly limiting the scope of AI systems (Gap 1). However, the list of ASME codes in §50.55a(a)(1)(iv) is extensive and those codes were not examined in this project in detail.

[6] With respect to non-existent facilities, such as NRC licensed reprocessing facilities, this report did not specifically consider portions of the regulation that may be applicable to entities in pre-application discussions for future design, construction or operation.

Table 3-9. Regulations with limited text potentially conflicting with uses of AI.

RG No.	Gap Type.	Regulation and comment
		§50.61, §50.61a – these regulations refer to explicit fracture toughness models (Gap 2). The following standards are referenced in Part 50 Appendix H “Reactor Vessel Material Surveillance Program Requirements (i) ASTM E 185–73, (ii) ASTM E 185–79, (iii) ASTM E 185–82. The standards set actions by humans for surveillance of vessels (Gap 5). However, those ASTM standards were not examined in detail in the current project.
5.27	1, 5	§73.46(d)(9), §73.46(d)(10), §73.46(d)(11), §73.46(d)(13): regulations refer to human actions (Gap 1). §73.46(e)(3) refers to monitored television by humans for surveillance (Gap 5). §73.46(e)(9) refers to human observation (Gap 5). §73.60(b) refers to physical searches, but the wording also allows searches by alternative methods.
5.44	5	73.46(e)(3) refers to monitored television by humans for surveillance (Gap 5).
8.8	7	§20.1601(a)(2) refers to “a supervisor” being present. §20.1601(f) refers to "personnel" being present.
8.10	7	20.1601(f) refers to "personnel" being present.
8.18	7	§20.1601(a)(2) refers to "a supervisor" being present. §20.1601(f) refers to "personnel" being present. §35.24(e) and §35.24(f) pertain to the establishment of a Radiation Safety Officer and Radiation Safety Committee, functions of which are executed by humans. §35.50 describes qualifications of a Radiation Safety Officer (RSO) and Associate Radiation Safety Officer (ARSO) establishing those functions executed by humans. §35.59 addresses recentness of training for all "individuals." §35.2067(b) stipulates including the name of the individual who performed the inventory.
8.25	7	§20.1501(d) requires dosimeters processed by humans. §20.2103(b) concerns record retention, limiting the possibility of generating information on the fly later by LLMs. Relevant information should be captured and preserved as records at the time a decision is made.
8.26	7	§20.2103(b) (same comment as RG 8.25).
8.32	7	§20.2103(b) (same comment as RG 8.25).
8.34	7	§20.1501(d) requires dosimeters processed by humans. §20.2103(b) (same note than RG 8.25).
8.38	7	§20.1601(a)(2) refers to "a supervisor" being present. §20.1601(f) refers to "personnel" being present.
10.3	7	§70.62(c)(2) requires qualifications of integrated safety analysis team members. §70.74 requires reports be made by a knowledgeable licensee representative.
10.4	7	The RG 10.4 broadly refers most notably to requirements at Part 20. See the comments for RG 8.8, 8.10, 8.18, 8.25, 8.26. 8.32, and 8.38.

Table 3-10 is a summary of regulations with some text potentially in conflict with uses of AI technologies. The Table 3-10 is sorted by the Gap Types, without reference to RGs.

Table 3-10. Regulations with limited text potentially conflicting with uses of AI organized by Gap Type.

Gap Type	Comment	Regulations
1	The regulations imply manual actions are executed by humans. There may be interest by the industry to deploy AI systems to execute those actions.	§50.54(m)(2)(iii) §50.54(k) §50.55a(a)(1)(iv) Part 50 GCD 19 §73.46(d)(9) §73.46(d)(10) §73.46(d)(11) §73.46(d)(13)
2	AI techniques could be used to support special computations; however, the regulations call for methods, such as physics-based models, limiting the possibility of using AI techniques.	§50.46 §50.61 §50.61a Part 50 Appendix K
4	The regulations state habitability requirements in the control room. Consideration should be given to pertinent protection requirements in case of varying levels of autonomous control supported by AI technologies.	Part 50 Appendix A GDC 19
5	The regulations call for monitoring and surveillance programs, with wording implying manual or human actions. There may be interest by the industry to deploy AI systems to execute those actions.	Part 50 Appendix H §73.46(e)(3) §73.46(e)(9) §73.60(b)
7	The regulation explicitly sets responsibilities certain type of personnel with occupational health protection responsibilities, like Radiation Safety Officers (RSOs) and Associate Radiation Safety Officers (ARSOs). Requirements at §35.50 set qualifications and credentials for an RSO and ARSO. Therefore, the regulation implicitly states that those responsibilities cannot be executed by AI systems, limiting the role of digital advisors (see Section 2.2.4). However, using AI digital advisors in a support role would not conflict with regulatory requirements.	§20.1501(d) §20.1601(a)(2) §20.1601(f) §20.2103(b) §35.24(e) §35.24(f) §35.59 §70.62(c)(2) §70.74

It is highlighted that §50.54(k) and §50.54(m)(2)(iii) call for the presence of a licensed operator or licensed senior operator in the control room at all times. It is implicit that those individuals are in the control room to operate the facility. It is not clear from the regulations which actions traditionally executed by operators would be permissible for AI systems. Is it permissible for a human operator to take a passive role to merely overview actions by AI systems? Should operators be present if they are not actively participating in operation?

Regulations at §20.2103(b) require the licensee to retain records until the Commission terminates the license, including records of the results of surveys to determine the dose from external sources; records of the results of measurements and calculations used to determine individual intakes of radioactive material and used in the assessment of internal dose; records showing the results of air sampling, surveys, and bioassays; and records of the results of measurements and calculations used to evaluate the release of radioactive effluents to the environment. Requirements at §20.2103(b) do not forbid the use of AI technology like LLMs for report production; however, they implicitly limit how the technology can be used. For example, if AI technology and LLMs were used to process monitoring data, conduct calculations, or produce reports used in demonstrating compliance with Part 20 requirements or license conditions, then that information should be captured as fixed records at the time of use, rather than be reproducible from system queries of raw data or recalculations at a later time.

In general, there are risks related to the accuracy of information generated by AI systems such as LLMs, and the reproducibility and control of information (Section 2.3.4). When reports and documents are required in the regulation, the regulation does not state how those reports and documents should be prepared and produced. However, the regulation, for example at Part 13, is clear that licensees and applicants are responsible for the accuracy of information submitted to the NRC. Part 13 establishes administrative procedures for imposing civil penalties and assessments against persons who make, submit, or present, or cause to be made, submitted, or presented, false, fictitious, or fraudulent claims or written statements to authorities or to their agents. Licensees and applicants are ultimately responsible for information provided to NRC.

3.4 Discussion of AIRGA Results

The main potential for regulatory conflicts with AI technologies lies in regulations that explicitly or implicitly state actions by humans, which could be alternatively executed by AI systems. In general, most regulatory requirements do not state the role of humans, only that actions should be completed, without specifying how; this is why only a very small set of regulations is listed in Table 3-10.

Regarding AI techniques in special computations, in general the regulations do not specify methods to execute computations, with a few exceptions. The exceptions, related to Gap 2 in Table 3-9 and Table 3-10, correspond to modeling the emergency core cooling system in nuclear reactors and fracture toughness models. In those cases, the regulations call for physics-based models satisfying special attributes. In most other computations required in the regulations, there is flexibility to use AI techniques. The licensees and applicants should demonstrate that results of computations using AI techniques are sound and valid.

Regarding the gap analysis of the RGs, several RGs were identified with potential gaps. It is understood that RGs document methods acceptable to NRC staff, however, licensees can use other methods if they provide acceptable bases. Nonetheless, guidance may be needed to assist NRC staff consistently evaluate safe uses of AI technologies. Rather than explicitly introducing AI statements in many RGs to address potential gaps, it may be more practical to consider developing new RGs that could address cross-cutting issues. The following were identified as relevant examples of cross-cutting issues.

RGs for software development and deployment provide guidelines that are also applicable to software with AI technologies. However, RGs and software development standards may need to be extended to recognize special features of AI systems. Machine learning algorithms require abundant data, raising questions on (i) data quality, (ii) data representation of a range of conditions and multiple states of the system, and (iii) data sufficiency for ML. There are unique attributes of AI technologies that draw attention to issues related to systematic testing and level of documentation of verification, validation, and AI system confidence activities. As discussed in Section 2.3, there is always a possibility of anomalous outputs by AI systems. Thus, there is a need for systematic fail-safe design, including (i) active identification of inputs very different than data used during the model development and ML stage, (ii) active identification of anomalous outputs, and (iii) approaches to mitigate or correct errors and avoid their propagation.

More immediate use of AI could be in support of special computations. AI algorithms including ML are readily available in commercial and open-source software. It is not too difficult to use data to train an artificial neural network of predefined structure, and compute predictions to new inputs with the trained neural network. General guidance is needed on how to evaluate computations using AI technologies, and the level of supporting documentation needed for those computations. As stated in the previous paragraph, some confidence in the predictions stems from the quality of the data used for ML, and whether trends exist in the data that could be synthesized by an AI system. A standard approach in ML is setting aside data for verification, making sure that the prediction error in the verification dataset is similar to the error in the training dataset. For example, a small error in the training dataset and big error in the verification dataset is an indicator of overfitting and poor generalization of the network to new conditions. Recommendations from AI practitioners are needed on additional systematic approaches and data analyses that would enhance confidence in predictions, which could be captured in general guidance.

4 STANDARDS FOR AI TECHNOLOGIES

This section examines software development standards, to identify practical standards that could fulfill potential needs identified after the AI Regulatory Gap Analysis (AIRGA) documented in Section 3. The examination includes developed standards, standards under development, and activities by committees and working groups towards the development of standards.

4.1 Published Standards Related to AI Technologies

Several standards were examined to identify whether professional standards could be considered for endorsement by NRC to complement existing software development practices and standards referred in RGs. The Institute of Electrical and Electronic Engineers (IEEE) has published standards, draft standards, and recommended practices related to AI technologies (IEEE 2024a):

- **2841-2022**: Recommended Practice for Framework and Process for Deep Learning Evaluation
- **2894**: Approved Draft Guide for an Architectural Framework for Explainable Artificial Intelligence
- **2937-2023**: Standard for Performance Benchmarking for Artificial Intelligence Server Systems
- **3129**: Standard for Robustness Testing and Evaluation of Artificial Intelligence (AI)-based Image Recognition Service
- **3168**: Approved Draft Standard for Robustness Evaluation Test Methods for a Natural Language Processing Service that uses Machine Learning

AI standards published by the ISO/IEC include (ISO 2024a):

- **23894:2023**: Artificial intelligence — Guidance on risk management
- **42001:2023**: Artificial intelligence — Management system

The following subsections discuss traditional software verification and validation, AI specific standards in the previous bullets, and data quality standards.

4.1.1 Traditional Software Verification and Validation

IEEE Standard 1012-2004 Software Verification and Validation (V&V) applies to systems, software, and hardware being developed, maintained, or reused. This standard is endorsed by RG 1.168 for V&V of computer software used in safety systems in nuclear power plants. The IEEE standard is general, and it can also be used to control development of software incorporating AI technologies for critical applications. For that reason, this standard is summarized and examined.

V&V processes discussed in IEEE Std 1012-2004 include the analysis, evaluation, review, inspection, assessment, and testing of products. V&V may be performed at the level of the system, software element, or hardware element, or on any combination of these. V&V may also be performed on an element of a system, including a subsystem. The V&V process includes several steps:

- Planning: Develop a plan for the V&V process, defining objectives, scope, resources, schedule, and deliverables.
- Requirements Review: Analyze software requirements documents to verify that they are correct, unambiguous, testable, and complete. Ensure that requirements satisfy user needs and comply with applicable standards and regulations.
- Test Plan Development: Create a detailed test plan that outlines the testing strategy, test cases, test scenarios, test data, pass/fail criteria, and resource allocation.
- Unit Testing: Perform unit tests to validate individual components or modules of the software. This stage focuses on verifying that code adheres to design specifications and does not contain defects.
- Integration Testing: Validate the interactions between software components and subsystems. Test the integration of third-party libraries, hardware devices, and other dependencies.
- System Testing: Verify that the software functions correctly in the target environment and fulfills all specified requirements. System testing should simulate real-world conditions and stress the software to expose potential weaknesses.
- Acceptance Testing: Confirm that the software meets user acceptance criteria and is ready for production deployment. User acceptance testing may involve end-users, subject matter experts, or other stakeholders who evaluate the software under actual usage conditions.
- Regression Testing: Periodically retest the software after modifications, bug fixes, or updates to ensure that previously validated functionality remains intact.
- Release Management: Manage the release cycle, coordinating software delivery, installation, configuration, and post-release support.
- Maintenance: Maintain and enhance the software throughout its lifecycle, addressing bugs, vulnerabilities, and feature requests. Use feedback loops and continuous improvement strategies to refine the V&V process over time.

The IEEE standard recommends classifying software in 4 levels, with higher testing requirements for levels 3 and 4. The standard recommends developing a hazard, security, and risk analysis of the software. The hazard analysis addresses “what can go wrong?” The IEEE recommends the hazard/risk analysis is applied at various levels, including hardware interface and system interface. The standard calls for examining performance of the software at boundaries (e.g., data, interfaces) and under stress conditions. In other words, the standard recommends software testing under extreme conditions, extreme combinations of inputs, as well as interactions with other software and hardware. The standard also includes identification of mitigation alternatives in case of software errors. The scope of IEEE Std 1012-2004 is thorough and can guide the development and deployment of software incorporating AI technologies. However, complementary standards may be needed to address special features and risks of AI systems. For example, AI systems of interest for potential use in NRC-regulated activities are data-driven and data dependent, and criteria may be needed to evaluate the quality of the initial database used to design the AI system. Guidance may be needed on the accuracy of the database (e.g., do the data represent the actual system? Are there transcription and scale errors?). Guidance may be needed to examine the coverage of the database compared to the range of system conditions and states (e.g., do data cover the different states of the system?), and the data quantity (e.g., are there enough examples of the different states of the system in the database?).

The IEEE standard already calls to examine software performance under extreme and stress conditions. However, it may be necessary to explicitly call for examination of software performance to rare inputs at the boundaries of the database, as well as to inputs well outside of the database. As noted in Section 3.4, systematic fail-safe design and approaches may need to be defined to handle anomalous inputs and anomalous outputs of an AI system.

4.1.2 Framework and Process for Deep Learning Evaluation

Of the standards specifically related to AI technologies, IEEE Standard 2841-2022 is a Recommended Practice with practical and actionable statements. IEEE Standard 2841-2022 defines an "assessment index" system which considers the algorithm and code implementation, the target function, the training data and adversarial examples, the hardware and software dependencies, and the environmental data. It defines the assessment process at four stages: the demand phase, the design phase, the implementation phase, and the operation phase. The IEEE Standard 2841-2022 provides general recommendations; however, IEEE Standard 1012-2004 on validation and verification is a more focused standard to guide the development of software incorporating AI technologies for critical applications. The Standard 2841-2022 does not readily include practical elements related to the initial database quality and quantity, type of systematic testing pertinent to the AI technology, and systematic fail-safe design.

4.1.3 Data Quality Assessment

Because the AI systems are generally reliant on data, standards regarding data quality assessment (DQA) were also reviewed for practical advice. DQA is a systematic process to assess the strengths and weaknesses of a dataset, and to inform users of the 'health' of the data. The assessment in general focuses on the validity, reliability, integrity, and timeliness of the data. The International Telecommunications Union (ITU) published Recommendation ITU-T Y.3602 defining functional requirements for data provenance (ITU 2022). ISO published standards relevant to DQA in ISO 8000 Parts 61, 62, 64, and 82. Those ISO 8000 Parts were examined to determine whether the guidance could be used to evaluate the quality of an information database used to design an AI system. To adhere to ISO 8000, organizations perform DQA as a multi-stage process involving seven steps, each with its own activities and deliverables.

- Defining Quality Criteria: Establish criteria for what constitutes high-quality data, such as accuracy, completeness, timeliness, relevance, consistency, and uniqueness.
- Data Profiling: Examine the dataset to identify patterns, inconsistencies, missing values, duplicates, and anomalies. This step often involves statistical techniques and automated tools to quickly scan large volumes of data.
- Data Cleaning: Correct errors and inconsistencies found during data profiling, such as fixing typos, filling in missing values, removing duplicates, and resolving conflicting records.
- Validation: Verify the corrected data against external sources or reference data sets to confirm accuracy and completeness.
- Monitoring: Implement ongoing monitoring processes to track data quality over time and detect changes or degradations in data quality.
- Reporting: Document findings, recommendations, and improvements resulting from the data quality assessment process. Share this report with appropriate stakeholders and maintain a record of actions taken to improve data quality.

- Continuous Improvement: Regularly review and update data quality assessment procedures to incorporate new insights, evolving business needs, and emerging technology capabilities.

The recommendations in ISO 8000 could be used to evaluate the quality management of an information database used to design an AI system. The ISO 8000 addresses issues related to data quality, including accuracy and context relevance. However, the standard does not provide direct guidance for evaluating the data variety (e.g., are there examples of the multiple conditions and states of the system?), and data sufficiency and density (e.g., are there enough examples for each of the states of the system?).

4.2 Standards for AI Technologies Under Development

Many professional organizations include efforts, subcommittees and working groups, to examine AI topics and potentially develop standards. Some salient committees are described in the following paragraphs, including references to websites for details.

ISO/IEC JTC 1/SC 42 - Artificial Intelligence: This Joint Technical Committee (JTC) 1 under the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) oversees AI standardization work globally. The Standards Committee (SC) 42 scope covers general principles and concepts, terminology, methodologies, ethical issues, requirements engineering, interoperability, security, testing, and evaluation (ISO 2024b). Several working groups are dedicated to specific topics like foundational standards, computational approaches, computer vision, natural language processing, machine learning, robotics, and automotive systems.

IEEE SA AI Ethics and Governance Committee: IEEE Standards Association established the AI Ethics and Governance Committee to develop guidelines addressing the ethical and societal impacts of AI (IEEE 2024b). The committee promotes transparency, fairness, accountability, privacy, and human wellbeing through consensus-driven standards. Examples of projects of the committee include the Ethically Aligned Design recommendations and the Model Process for Addressing Ethical Concerns during System Design.

ITU-T Study Group 13 – Future Networks: Under the auspices of the International Telecommunication Union (ITU) of the United Nations, the Study Group 13 works on future communication networks with a focus on cloud computing and trusted network infrastructures (ITU 2024a). Study Group 13 developed recommendations for cloud computing requirements for machine learning as a service (MLaaS), including functional requirements for MLaaS to identify functionalities such as machine learning data pre-processing, ML model training, and ML model testing (ITU 2024b).

OASIS XLIFF Technical Committee: The OASIS eXtensible Markup Language (XML) Localisation Interchange File Format (XLIFF) Technical Committee (TC) creates open standards for handling localized content in software applications (OASIS OPEN 2024). One ongoing project involves leveraging AI techniques to streamline translation memory matching, linguistic validation, and automated text classification tasks.

The Open Group Open FAIR Certification Program: The Open Group developed the Open FAIR approach to quantitatively analyze risk using Bayesian probability theory (The Open GROUP 2024). With support from experts in cybersecurity, financial modeling, actuarial sciences, and statistics, they provide guidance on identifying potential threats, estimating likelihood, assessing vulnerabilities, and calculating expected loss due to adverse events affecting AI systems.

W3C Web of Things (WoT) Interest Group: As part of the World Wide Web Consortium (W3C), the WoT Interest Group explores ways to integrate Internet of Things (IoT) devices into web architectures (W3C 2024). By defining common vocabularies and semantic models, it intends to facilitate interaction among heterogeneous devices, platforms, and services, and interoperability in AI systems including cloud environments.

The efforts by these different groups are broad, in some cases with abundant online documents. It may be pertinent to further examine documentation produced by these groups to identify literature with practical guidelines. Detailed examination of those documents was outside the scope of this project.

The IEEE Standards Association includes numerous standards under development (IEEE 2024c). A selected set of standards are listed in the following bullets, which could address stated needs regarding data quality and quantity, systematic V&V of AI systems, and systematic fail-safe design. Draft documents of those standards and recommended practices are not publicly available:

- **P2976**: Standard for XAI - eXplainable Artificial Intelligence - for Achieving Clarity and Interoperability of AI Systems Design
- **P3110**: Standard for Computer Vision (CV) – Technical Requirements for Algorithms Application Programming Interfaces (APIs) of Deep Learning Framework
- **P3157**: Recommended Practice for Vulnerability Test for Machine Learning Models for Computer Vision Applications
- **P3193**: Recommended Practice on Large-scale Pre-trained Deep Learning Model Application Framework
- **P3347**: Standard for Description Schemas for Neural Network Architectures
- **P3350**: Recommended Practice for Improving Generalizability of Artificial Intelligence for Medical Imaging
- **P3395**: Standard for the Implementation of Safeguards, Controls, and Preventive Techniques for Artificial Intelligence (AI) Models
- **P3396**: Recommended Practice for Defining and Evaluating Artificial Intelligence (AI) Risk, Safety, Trustworthiness, and Responsibility
- **P3403**: Recommended Practice on Data Processing for Training Large Language Models
- **P3419**: Standard for Large Language Model Evaluation
- **P3429**: Recommended Practices for Levels of Artificial Intelligence Generated Content Technologies
- **P3378**: Standard for Framework and Process for Large-Scale Deep Learning Model Evaluation
- **P7018**: Standard for Security and Trustworthiness Requirements in Generative Pretrained Artificial Intelligence (AI) Models

4.3 Observations on Developed Standards and Standards Under Development

The first step towards standardizing development of AI systems is to establish a common understanding of the requirements of the systems and unifying terminology around those requirements. A number of developed and draft standards specific to AI systems are highly focused on this first step: comprehensively describing the desirable AI traits and developing terminologies and defining concepts. Despite the growing interest in establishing standards for the development, deployment, and use of AI systems; there are no widely accepted or universally adopted standards. Existing standards typically cover areas such as ethics, safety, transparency, and explainability. They aim to provide a common framework for developers, users, and regulators to assess and compare AI system performance and trustworthiness; but it is difficult to derive practical guidance from those standards. There is a rapid pace of AI innovation, and developing and updating standards that are accepted and used by the professional community will remain a challenge. Keeping track of activities by working groups and draft standard development will also be a challenge, because the efforts are many and widespread. In Section 3.4 specific needs were identified to address gaps by the AIRGA, namely guidance on data quality and quantity, systematic testing of AI systems, and fail-safe design. There are currently no published standards with comprehensive and mature guidance on those topics.

5 CONCLUSIONS

This project, referred to as the AI Regulatory Gap Analysis (AIRGA), examined whether the current NRC regulatory framework allows for the potential use of AI systems and, in particular, if the RGs provide adequate guidance to support NRC evaluations of AI technologies. This report does not, however, identify if specific additional regulatory requirements might be needed to ensure the safe and secure use of AI in nuclear applications. The AIRGA was executed in three tasks aimed at identifying examples of uses of AI technologies, examining the adequacy of guidance in reviewed RGs, and examining regulations associated with the subset of RGs deemed with potential gaps. Of the 517 RGs initially reviewed, potential gaps were identified in fewer than 100 RGs. In most cases, it was concluded that the NRC regulations associated with the RGs were adequate to regulate AI technologies.

Initial AIRGA efforts focused on screening NRC regulations in 10 CFR for potential issues regarding uses of AI technologies consistent with examples described in Section 2.2. Due to time and fundings constraints, however, the authors shifted to a practical approach to execute the project. RGs contain guidance and identify requirements, and they are frequently more detailed than regulations. To narrow down the scope of the search of gaps, the analysis first examined whether RGs contained potential gaps or details inconsistent with the use of AI technologies. Then the analysis examined the NRC regulations cited by the subset of RGs deemed with potential gaps for potential conflicts with the use of AI technologies. It is acknowledged that this gap analysis is not a holistic review, but an initial effort, and that additional regulations and guidance documents may exist containing gaps or language inconsistent with the use of AI technologies. Given this, the NRC may wish to consider follow-on activities to evaluate application-specific gaps; perform future research to address the gaps identified in this report; or examine in more detail regulations and the regulatory framework.

A common type of gap is related to statements in the RGs specifying actions by humans, when those actions could also be executed by AI systems (Gap 1). Some of those human actions are related to testing, monitoring, and surveillance (Gap 5). In a small proportion of RGs, the human actions referred to in the RGs are directly called by applicable regulatory requirements, like humans performing video surveillance, physical searches, and escort functions. A second common type of gap in RGs concerns the use of AI in special computations, because there is no AI-specific guidance on how to evaluate those computations. In general, the applicable regulations do not state how to execute computations (with few exceptions like required physics-based models of the emergency core cooling system and fracture toughness models) and they were found adequate to regulate the use of AI in required computations.

Regulations at 10 CFR §50.54(k) and §50.54(m)(2)(iii) call for the continuous presence of a licensed operator or licensed senior operator in the control room in nuclear power plants. 10 CFR Part 50 Appendix A General Design Criterion (GDC) 19 requires, in part, that a control room be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions, and to maintain the nuclear power plant in a safe condition under accident conditions. The term "actions can be taken" is interpreted as actions by anyone, human or computer. However, since the presence of human operators in the control room is required, it can also be interpreted that the only executors of actions in the control room are operators (consistent with their training and certification requirements). In principle, it may be technically possible for AI systems to execute actions of operators, with the range and scope of possible actions by AI systems expanding with time as the AI technology evolves. This technical possibility raises several potential regulatory questions, such as the following.

- Which operator actions would be permissible to be conducted by AI systems?
- If autonomous AI operation were allowed, should human operators be present if they are not actively participating in facility operation? Would it be permissible for operators to merely oversee actions by AI systems?
- Regulations include requirements that certain automatic equipment should also allow for manual control. Should requirements like these be imposed on AI systems used in safety systems and control systems?
- What kind of protection should be required for autonomous control systems located in the facility, and for communication systems to control facilities located elsewhere?

Potential conflicts with the use of AI technologies were found in a small subset of the regulations evaluated. In general, regulations are stated in broad terms with impersonal actions (regulations only require actions to be completed but not how to execute those actions) and were deemed adequate to regulate the use of AI technologies. However, there are broad questions to consider, such as those in the previous bullets.

Potential gaps were identified in fewer than 100 RGs, classified as eight types of gaps, namely (i) implied manual actions, (ii) special computations, (iii) preoperational and initial testing programs may omit AI, (iv) habitability conditions under autonomous operations, (v) periodic testing, monitoring, surveillance and reporting, (vi) software for critical applications, (vii) radiation safety support, and (viii) miscellaneous: training and human factors engineering. Rather than revising RGs to explicitly incorporate statements mentioning AI technologies to address potential gaps, developing general guidance for cross cutting issues is recommended.

Standards by professional organizations on AI were examined to identify if practical and mature standards exist that could be endorsed by NRC. However, no practical AI standards were identified readily addressing the potential gaps.

Regarding traditional software development, existing guidance and Institute of Electrical and Electronic Engineers (IEEE) standards seem adequate to support the development and deployment of software with AI technologies. However, complementary guidance may be needed to address specific features and risks of AI systems. For example, guidance is needed on data variety and quantity used for machine learning (ML). Data quality standards at selected Parts of ISO 8000 focus on data accuracy, data context, and data management, but do not address questions related to data variety and quantity such as (i) how well data capture the possible range of conditions and states of a system and (ii) how much data coverage of the range of conditions and states of a system is sufficient for ML purposes. Guidance is also needed on the type of systematic testing and documentation that would provide confidence in responses by AI systems, including responses to rare inputs and inputs that differ substantially from the information in the ML database. The IEEE standards for traditional software development and software validation and verification (V&V), such as IEEE Standard 1012-2004, incorporate risk management recommendations, with graded approaches to V&V depending on critical uses of the software, formal risk assessments evaluating scenarios in which the software could be in error or misperform, and solutions to mitigate those errors. AI systems are known to potentially produce erroneous outputs especially for inputs that are very different than in the original ML database, and guidance for systematic fail-safe design would complement the existing risk management framework of the IEEE standards. With respect to special computations using AI techniques, guidance may be needed on the type of activities and documentation prepared by licensees and applicants to enhance confidence in those computations, including analyses of data to prepare for the ML stage.

Developing the recommended guidance may be complicated without a reference application. An initial pilot program could be considered, for example, that evaluates computations using AI techniques to inform the development of approaches to testing and documentation to enhance confidence in outputs of AI computations. This suggestion is consistent with Task 5.1 of the NRC AI Strategic Plan (NRC 2023d). Examining solutions by other regulated industries is also recommended. For example, the Federal Aviation Administration (FAA) regulates the safety of aircraft, and the FAA may be doing work to address safety issues regarding the potential use of AI to control aircraft and aircraft traffic. The Food and Drug Administration (FDA) regulates medical devices. Computer vision has been explored to support examination of medical images such as x-rays, microscopic images of tissues, magnetic resonance imaging, and computer tomography scans. AI techniques can also support diagnosis by synthesizing individual biometrics, medical notes, and medical literature. It would be informative to examine how these regulated industries are approaching safe incorporation of AI, including the information acceptable to regulators to demonstrate safe use and deployment of AI technologies. This suggestion is consistent with Task 5.3 of the NRC AI Strategic Plan (NRC 2023d).

In summary, the report authors provide the following recommendations to the NRC staff:

1. Develop guidance on data quality for ML purposes, including aspects of accuracy, context, data management, data variety, and data quantity.

2. Develop guidance on the type of systematic testing and documentation needed to enhance confidence in responses by AI systems, with emphasis on rare and extreme inputs.

3. Develop guidance on systematic fail-safe design, including active detection of inputs different than in the ML database, active detection of anomalous responses by AI systems, and mitigation of errors by AI systems.

4. Develop guidance on the types of testing and documentation needed to enhance confidence in computations and predictions that use AI techniques.

5. Examine work by the FDA and FAA to regulate AI, to yield insights useful in developing the guidance described in recommendations 1 to 4.

6. Deploy a pilot program aimed at evaluating computations by an existing licensee using AI technologies, to yield recommendations relevant to recommendation 4.

6 REFERENCES

energynews. 2024. *Atomic Canyon and ORNL develop revolutionary nuclear AI.* https://energynews.pro/en/atomic-canyon-and-ornl-develop-revolutionary-nuclear-ai/.

IEEE. 2005. *1012-2004 - IEEE Standard for Software Verification and Validation.* Institute of Electrical and Electronic Engineers, IEEE. doi:10.1109/IEEESTD.2005.96278.

—. 2024c. *Artificial Intelligence Standards Committee.* https://sagroups.ieee.org/ai-sc/active-pars/.

—. 2024a. *Artificial Intelligence Standards Committee, Standards.* https://sagroups.ieee.org/ai-sc/standards/.

—. 2024b. *IEEE GET Program, GET Program for AI Ethics and Governance Standards.* https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=93.

ISO. 2024a. *ISO: Global standards for trusted goods and services.* https://www.iso.org/home.html.

—. 2024b. *SO/IEC JTC 1/SC 42 Artificial Intelligence.* https://www.iso.org/committee/6794475.html.

ITU. 2024b. *Cloud computing - Functional requirements for machine learning as a service.* https://www.itu.int/itu-t/workprog/wp_item.aspx?isn=14484.

ITU. 2022. *ITU-T Y.3602: Big data – Functional requirements for data provenance.* International Telecommunication Union. https://www.itu.int/ITU-T/recommendations/rec.aspx?rec=15074.

—. 2024a. *Study Group 13 at a glance.* https://www.itu.int/en/ITU-T/about/groups/Pages/sg13.aspx.

Ma, Z., H. Bao, S. Zhang, M. Xian, and A. Mack. 2022. *NUREG/CR-7294: Exploring Advanced Computational Tools and Techniques with Artificial Intelligence and Machine Learning in Operating Nuclear Plants.* Washington DC: U. S. Nuclear Regulatory Commission. https://www.nrc.gov/docs/ML2204/ML22042A662.pdf.

NIST. 2023. *Artificial Intelligence Risk Management Framework (AI RMF 1.0).* Washington DC: National Institute of Standards and Technology. doi:10.6028/NIST.AI.100-1.

NRC. 2023b. *Data Science and Artificial Intelligence Regulatory Applications Workshops.* U. S. Nuclear Reglatory Commission. Accessed 2023. https://www.nrc.gov/public-involve/conference-symposia/data-science-ai-reg-workshops.html.

—. 2024a. *NRC Regulations Title 10, Code of Federal Regulations.* U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/doc-collections/cfr/index.html.

—. 2024b. *NRC Regulatory Guides.* U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/doc-collections/reg-guides/index.html.

NRC. 2023c. *NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition.* Washington DC: U.S. Nuclear Regulatory Commission. https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/index.html.

NRC. 2023a. *NUREG-2261: Artificial Intelligence Strategic Plan, Fiscal Years 2023-2027.* Washington DC: U. S. Nuclear Regulatory Commission. https://www.nrc.gov/docs/ML2313/ML23132A305.pdf.

NRC. 2023d. *Project Plan for the U.S. Nuclear Regulatory Commission Artificial Intelligence Strategic Plan Fiscal Years 2023–2027, Revision 0.* Washington DC: U.S. Nuclear Regulatory Commission. https://www.nrc.gov/docs/ML2323/ML23236A279.pdf.

OASIS OPEN. 2024. *OASIS XML Localisation Interchange File Format (XLIFF) TC.* https://groups.oasis-open.org/communities/tc-community-home2?CommunityKey=3d0f1f56-8477-4b53-9b14-018dc7d3eecf.

Rashdan, Ahmad Al, Roman Shaffer, Edward L. Quinn, Michael Bailey, Ronald Jarrett, and Kellen M. Giraud. 2021. *Considerations regarding the Use of Computer Vision Machine Learning in Safety-Related or Risk-Significant Applications in Nuclear Power Plants.* U.S. Department of Energy. https://inldigitallibrary.inl.gov/sites/STI/STI/Sort_69687.pdf.

The Open GROUP. 2024. *Open FAIR™ Certification Program.* https://www.opengroup.org/certifications/openfair.

W3C. 2024. *W3C WoT – Interest Group.* https://www.w3.org/WoT/ig/.

APPENDIX A: SCREENED-IN REGULATORY GUIDES WITH NO GAPS

This appendix includes the set of screened-in regulatory guides (RGs) with no gaps. The screened-in RGs are those with a yes response to the question

Q0: *Can AI technologies be used within the scope of the RG?*

For those RGs with a yes question to Q0, the questions Q1 and Q2 were posed in the analysis:

Q1: *Is the RG flexible to allow use of AI?*

Q2: *Does the RG provide adequate guidance to evaluate the use of AI?*

A no answer to either of these questions would identify a potential gap; otherwise, the analysis concluded the RG had no gap. The RGs with potential gaps are included in Appendix B. For some RGs in this appendix, the answer to Q1 or Q2 was “no”; however, the analysis concluded the RG had no gap, because the use of AI was considered unlikely within the scope of the RG, as explained in the Comment column.

RG	Title	Q1	Q2	Comment
1.20	Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing	Yes	No, but unlikely use of AI	This guide describes acceptable methods and procedures when developing a comprehensive vibration assessment program (CVAP) for reactor internals during preoperational and startup testing. The scope of this RG covers boiling water reactor (BWR) and pressurized water reactor (PWR) reactor internals, and small modular reactor (SMR) reactor internals. **The guide describes a comprehensive (analytic and testing) program to evaluate vibrations (structural, hydraulic, and acoustic). In principle AI could be used in the analytic part of the program; for example, to identify vibration modes and frequencies, especially since abundant analyses and testing data may be available to train AI systems. However, it seems unlikely that non-mechanistic analyses would be accepted to replace traditional, physics-based, approaches.**
1.45	Guidance on Monitoring and Responding to Reactor Coolant System Leakage	Yes	Yes	This guide describes acceptable methods for use in implementing the regulatory requirements regarding selecting reactor coolant leakage detection systems, monitoring for leakage, and responding to leakage. This guide applies to light-water-cooled reactors. **The guidance recommends monitoring leakage of the reactor coolant system (RCS) and suggests methods and techniques. However, the guidance recognizes that leakage detection methods are indirect and that multiple signals should be interpreted to conclude leakage existence, to identify the location, and to establish leak rates. It may be feasible to use an AI system to interpret diverse information (e.g., level of tanks and sumps, radioactivity in air, atmospheric pressure and humidity, condensate rates from air coolers) for that aim. The guidance is flexible to permit investigation and deployment of AI systems. There is no evident gap in the guidance. It might be necessary to state that AI systems may be used to supply complementary information in leak detection programs and not the sole method the plant relies on to detect leakage.**
1.47	Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems	Yes	No, but unlikely use of AI	This guide describes an acceptable method for use in regulatory compliance with respect to a bypassed and inoperable status indication for nuclear power plant safety systems. The guide calls for computer indicators highlighting that specific safety systems are bypassed or not operable by design due, for example, to maintenance, inspection, and periodic testing. The indicators should also announce when the safety functions are back in service. **The guide is modern, and accounts for digital and computer-based instrumentation and controls. The guide endorses IEEE Std 603-1991, with supplements**. It is implicit that bypass and inoperable status indicators are intended for a human operator, and not for an AI system. It is not evident how AI technologies could be used in the bypass or inoperable status indicators, and it is concluded this guidance would not be affected AI technologies.
1.52	Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere	Yes	No, but unlikely use of AI	This guide provides an acceptable method to implement Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” as it applies to the design, inspection, and testing of air filtration and iodine adsorption units of engineered-safety-feature (ESF) atmosphere cleanup systems in light-water-cooled nuclear power plants. For the purposes of this guide, ESF atmosphere cleanup systems are those systems that are credited in the licensee’s current design-basis accident (DBA) analysis, as described in the safety analysis report (SAR). This guide addresses ESF atmosphere cleanup

RG	Title	Q1	Q2	Comment
	Cleanup Systems in Light-Water-Cooled Nuclear Power Plants			systems, including the various components and ductwork, in the postulated DBA environment. **Guidance is provided for air cleaning systems for post-accident conditions. It is noted that some air filtration functions are aimed, for example, to keep the air in the control room clean for operators. Thus, the guidance implicitly assumes humans are present and need clean air to operate facilities. It is unclear how AI systems could be used in filtration systems. At this time, use of AI in air cleaning systems is considered unlikely.**
1.57	Design Limits and Loading Combinations for Metal Primary Reactor Containment System Components	Yes	No, but unlikely use of AI	This guide describes an acceptable approach for use in designing metal primary reactor containment system components and it provides methods for demonstrating containment structural integrity. **The guide relies on testing, materials properties, and analyses. The recommended analyses are physics-based such as nonlinear finite element. It appears unlikely that something other than well established and accepted methods to define limit loads will be considered.**
1.61	Damping Values for Seismic Design of Nuclear Power Plants	Yes	No, but unlikely use of AI	This guide provides guidance on acceptable damping values for use in the seismic response analysis of seismic Category I nuclear power plant structures, systems, and components (SSCs). The specified damping values are intended for elastic dynamic seismic analysis where energy dissipation is accounted for by viscous damping. The guidance describes specific approaches to account for damping dissipating energy in seismic analyses. If analyses were to account for damping, the guidance defines an acceptable approach to incorporate damping**. It is most unlikely that the damping analyses will use AI methods.**
1.62	Manual Initiation of Protective Actions	Yes	Yes	This guide describes an acceptable method for use in complying with regulations with respect to the means for manual initiation of protective actions provided (1) by otherwise automatically initiated safety systems or (2) as a method diverse from automatic initiation. The means for manual initiation of protective actions provided by otherwise automatically initiated safety systems serves a safety-related function to complete all credited protective actions for the safety system as required by IEEE Std 603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations,” and the correction sheet, dated January 30, 1995. The diverse means for manual initiation should satisfy Point 4 of Branch Technical Position (BTP) 7-19, “Guidance for Evaluation of Diversity and Defense-In-Depth in Digital Computer-Based Instrumentation and Control Systems,” of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” issued March 2007. Although protective actions can be initiated automatically (including digital and computer controls, which could encompass AI systems), the guide calls for additional manual initiation of protective actions, provided certain requirements are satisfied. **If AI was used, AI should also allow manual initiation.** **The regulation calls to ensure manual initiation of protective actions for redundancy and**

RG	Title	Q1	Q2	Comment
				defense-in-depth reasons. Those requirements may remain even under full control by AI systems.
1.68.1	Initial Test Program of Condensate and Feedwater Systems for Light-Water Reactors	Yes	Yes	The guide describes acceptable methods to develop preoperational, initial plant startup, and power ascension tests for light water reactor (LWR) power plant condensate, feedwater (FW), startup feedwater (SFW), auxiliary feedwater (AFW), and emergency feedwater (EFW) systems. It also includes recommended tests for new reactor condensate and FW systems for the advanced boiling water reactor (BWR), economic simplified BWR, U.S. evolutionary power reactor (EPR), U.S. advanced pressurized water reactor (PWR), and advanced passive 1000 (AP1000), including the AFW/EFW systems for the U.S. EPR and the U.S. advanced PWR, as well as tests for active defense-in-depth system functions such as the SFW system in the AP1000 design. The guidance explicitly calls for testing safety-related digital instrumentation and control (I&C) system software logic to follow the guidance in RG 1.171, “Software Unit Testing for Digital Computer Software Used in Safety Systems of Nuclear Power Plants.” **This guidance is applicable to AI systems. No evident gap is identified in RG 1.68.1. RG 1.171 is independently examined.**
1.68.3	Preoperational Testing of Instrument and Control Air Systems	Yes	Yes	The guide describes methods and procedures acceptable to implement preoperational testing of the instrument and control air systems (ICAS) in nuclear power plants. It provides preoperational testing to verify that ICAS and the loads they supply will operate properly at normal system pressures and to ensure the operability of functions important to safety in the event that system pressure is lost, reduced below normal operating level, or increased above the design pressure of the pneumatic system components to the upstream safety valve accumulation pressure. The guidance is specific to preoperational testing of ICAS. There are no gaps related to the used of AI technologies specific to this guidance. **General issues possibly associated to testing of AI controlling systems was noted in the evaluation of RG 1.68.**
1.69	Concrete Radiation Shields and Generic Shield Testing for Nuclear Power Plants	No, but unlikely use of AI	No, but unlikely use of AI	This guide describes a method acceptable to comply with requirements regarding the design and construction of concrete radiation shields in nuclear power plants. The guidance endorses ANSI/ANS-6.4-2006, ACI 349-06, and ACI 349.1R-07 for the construction of radiation shielding structures of hot laboratories, radiochemical plants, experimental facilities, nuclear fuel fabrication plants, and the shielding structures for nuclear power plants, with a few exceptions. The guidance specifies the Monte Carlo technique as an acceptable technique for radiation shielding computations. There is no flexibility for alternative computational methods, for example based on AI technologies. **However, the use of AI systems to perform shielding computations instead of accepted Monte Carlo methods is considered unlikely**.
1.71	Welder Qualification for Areas of Limited Accessibility	No, but unlikely use of AI	No, but unlikely use of AI	This guide describes an acceptable method for implementing requirements regarding the control of welding for nuclear components, as they relate to light-water-cooled and gas-cooled reactors. The focus of the guidance is on welder qualification for areas of limited accessibility. **At this time, it is unlikely that the complex actions executed by human welders would be replaced by AI systems**.

RG	Title	Q1	Q2	Comment
1.72	Spray Pond Piping Made from Fiberglass-Reinforced Thermosetting Resin	No, but unlikely use of AI	No, but unlikely use of AI	This guide describes an acceptable method for implementing requirements regarding the design, fabrication, and testing of fiberglass-reinforced thermo setting resin (RTR) piping for spray pond applications. This guide applies to light-water cooled and gas-cooled reactors. The guide endorses ASME Code Case N-155-l (1792-1) with supplements. As part of the design, analyses should be executed to define challenge stress levels. The accepted computational approaches are specified, without flexibility for alternative computational methods using AI technologies. **It appears unlikely that AI methods would be proposed as a substitute for well accepted design methods**.
1.82	Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident	Yes	No, but unlikely use of AI	The guide describes an acceptable approach to meet the regulatory requirements for sumps and suppression pools that provide water sources for emergency core cooling, containment heat removal, or containment atmosphere cleanup systems. It also provides guidelines for evaluating the adequacy and the availability of the sump or suppression pool for long-term recirculation cooling following a loss-of-coolant accident (LOCA), and the use of containment accident pressure (CAP) in determining the net positive suction head (NPSH) for the emergency core cooling and containment heat removal pumps. This guide applies to both the pressurized-water reactor (PWR) and boiling-water reactor (BWR) types of light-water reactors. **The guidance recommends approaches to examine the robustness of emergency cooling to address a LOCA, considering debris interactions. It is not clear how AI could be used in support of the analysis. In precedent submittals to address Generic Safety Issue 191, the use of correlations for example to compute pressure drops across strainers as a function of debris types and amounts was rejected by the NRC staff. Instead, the approved approach is direct use of experimental data showing that strainers can survive specific debris loads, and assuming strainer failure and core damage whenever loads are outside experimental tests. It is unclear how AI could be used to support this kind of analysis.**
1.96	Design of Main Steam Isolation Valve Leakage Control Systems for Boiling Water Reactor Nuclear Power Plants	Yes	Yes	This guide describes an acceptable basis for implementing General Design Criterion 54 with regard to the design of a leakage control system for the main steam isolation valves of boiling water reactor (BWR) nuclear power plants to ensure that total site radiological effects do not exceed guidelines of 10 CFR Part 100, "Reactor Site Criteria," in the event of a postulated design-basis loss-of-coolant accident (LOCA). **The guide concerns the reliability of the leakage control system (LCS), which could be manually or automatically actuated. The guide recommends instrumentation and circuits necessary for the functioning of the LCS should be designed in accordance with standards applicable to an engineered safety feature.** **RG 1.168 guides the verification and validation of software and interfacing hardware. RG 1.168 includes criticality, hazard, risk, and security assessments. RG 1.168 provides sufficient guidance to examine the risk of software with AI.**
1.127	Inspection of Water-Control Structures Associated with Nuclear Power Plants	Yes	No, but unlikely use of AI	This guide describes an acceptable method for designing water control structures (e.g., dams, slopes, canals, reservoirs, and associated conveyance facilities) such that periodic inspections may be performed. In addition, this guide describes an acceptable inspection and monitoring program for water control structures. Water control structures include those used in the

RG	Title	Q1	Q2	Comment
				emergency cooling water system and those relied upon for flood protection. The guide is intended to facilitate in-service inspection and surveillance programs for dams, slopes, canals, and other water-control structures associated with emergency cooling water systems or flood protection of nuclear power plants. **In this case, it is difficult to envision AI technologies replacing human inspection, surveillance, and patrolling of water-control structures. There is significant variety of structures to be inspected, and many variables to be monitored and interpreted. At this time, it is not credible those functions implemented by humans could be effectively executed by AI systems.**
1.132	Geologic and Geotechnical Site Characterization Investigations for Nuclear Power Plants	Yes	Yes	This guide provides guidance on field investigations for determining the geologic, geotechnical, geophysical, and hydrogeologic characteristics of a prospective site for engineering analysis and design of nuclear power plants. The guide describes for example surface, subsurface investigations, borings and exploratory investigations, sampling rocks and soils, geophysical investigations, groundwater investigations. The guidance is very broad. The main point of the guidance is calling for site specific investigations. **Investigations might be supported by AI technologies; however, the guidance is high-level and expect no need to expand the guidance to address AI methods.**
1.133	Loose-Part Detection Program for the Primary System of Light-Water-Cooled Reactors	Yes	Yes	This guide describes an acceptable method acceptable to detecting a potentially safety-related loose (i.e., disengaged and drifting) part in light-water-cooled reactors during normal operation. This guide also outlines a program that can help licensees to meet the Part 20 criterion that exposures of station personnel to radiation during routine operation of the station will be "as low as is reasonably achievable" (ALARA). The guide is related to a loose-part detection program. Sensors are based on acoustic signals. An alarm should be triggered if a loose part is detected. The detection program triggers alarms, which call for additional investigation to verify and identify the loose part. AI systems might complement a loose-part detection program. **The guide is high-level and expect no need to adjust the scope of the guidance to address AI methods**.
1.137	Fuel Oil Systems for Emergency Power Supplies	Yes	No, but unlikely use of AI	This guide describes accepted updated methods for use in complying with requirements regarding fuel oil systems for safety-related diesel-powered generators and diesel oil-fueled gas turbine generators, including assurance of adequate fuel oil quality. The guidance provided herein may also be applied to the fuel oil systems for nonsafety-related standby power supplies to the extent deemed appropriate to the safety significance of the power supplies. **The guidance addresses fuel oil systems. It is assumed that these systems are manually operated and maintained. There are requirements for periodic maintenance and surveillance, which in principle could be automatized by AI systems. However, at this time this appears an unlikely use of AI systems.**
1.170	Test Documentation for Digital Computer Software Used in Safety Systems of	Yes	Yes	This guide describes an acceptable method for use in complying with regulations with respect to software and system test documentation for digital computer software used in the safety systems of nuclear power plants. This guide endorses IEEE Std. 829-2008, “IEEE Standard for Software and System Test Documentation,” with clarifications and exceptions.

RG	Title	Q1	Q2	Comment
	Nuclear Power Plants			**The guide concerns only records and documentation. The documents in the standard are considered sufficient for AI software. Issues of substance are addressed in RG 1.168 and 1.169.**
1.174	An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis	Yes	Yes	This guide describes an acceptable approach for developing risk-informed applications for a licensing basis change that considers engineering issues and applies risk insights. It provides general guidance concerning analysis of the risk associated with proposed changes in plant design and operation. **The guide concerns risk-informed analyses to support a licensing basis change, in the context of 5 principles, including defense-in-depth and safety margins. AI methods could be used in engineering analyses or to support PRA analyses (e.g., to compute reliability rates of safety components). The guide provides sufficient guidance to execute review of a risk-informed analyses, including those incorporating AI-supported computations**.
1.175	Plant-Specific, Risk-Informed Decisionmaking: Inservice Testing	Yes	Yes	This guide describes an acceptable approach for developing risk-informed inservice testing (RI-IST) programs. It supplements the guidance provided in RG 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis”. This guide describes acceptable methods for using information from a probabilistic risk assessment (PRA) with deterministic engineering information in the development of a RI-IST program to be submitted by a nuclear power plant licensee for review and authorization by the NRC. **The guide concerns changes to an inservice testing program justified based on risk-informed analyses. The potential changes include changing the frequency of testing or testing different equipment. These changes can be supported by PRA and engineering analyses showing that the change would not be risk significant. The engineering analyses and PRA could include AI-supported analyses. AI could also be used to extract relevant information from service and maintenance records. Any AI analysis would have to be properly justified. It is not evident that the guide has gaps regarding use of AI technologies**.
1.177	Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications	Yes	Yes	This guide describes an acceptable approach for developing risk-informed applications for changes to completion times (CTs) and surveillance frequencies (SFs) of plant technical specifications (TS). This RG provides specific guidance for considering engineering issues and using risk information to evaluate nuclear power plant TS changes to CTs and SFs. **The guide concerns changes to CTs and SFs. As the observation in RG 1.175, the changes can be supported by PRA and engineering analyses should that the change can be implemented without significant changes in risk. The engineering analyses and PRA could include AI-supported analyses. AI could also be used to extract relevant information from service and maintenance records. Any AI analysis would have to be properly justified. It is not evident that the guide has gaps regarding use of AI technologies.**

RG	Title	Q1	Q2	Comment
1.178	An Approach for Plant-Specific Risk-Informed Decisionmaking for Inservice Inspection of Piping	Yes	Yes	This guide describes an acceptable approach for developing risk-informed inservice inspection (RI-ISI) programs. This guide describes acceptable methods for using information from a probabilistic risk assessment (PRA) with deterministic engineering information in the development of RI-ISI programs. This guide supplements the guidance provided in RG 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis” and includes precise terminology to ensure that the defense-in-depth philosophy is interpreted and implemented consistently. **The guide concerns ISI for piping. AI methods could be used in the engineering analyses. Empirical data could be used to characterize degradation mechanisms and quantify probabilities of failure. The guide does not provide details on how to execute engineering analyses. Connection is made to the main five principles in RG 1.174. It is not evident the guide needs modification to address AI technologies.**
1.187	Guidance for Implementation of 10 CFR 50.59, Changes, Tests, and Experiments	Yes	Yes	This guide provides licensees with an acceptable method for use in complying with the regulations on the process by which licensees, under certain conditions, may make changes to their facilities and procedures as described in the final safety analysis report (FSAR) (as updated) [also referred to as the updated final safety analysis report (UFSAR)], and conduct tests or experiments not described in the FSAR (as updated) without obtaining a license amendment pursuant to 10 CFR 50.90, “Application for amendment of license, construction permit, or early site permit.” The guide endorses NEI 96-07, Revision 1, with clarifications. **If changes include AI technologies, under which circumstances would complete analyses be triggered? Is it possible for AI technologies to be introduced without sufficient scrutiny? The answer to the last question is NO.** **NEI 96-07, Appendix D, Rev. 1, Supplemental Guidance for Application of 10 CFR 50.59 to Digital Modifications, provides focused application of the 10 CFR 50.59 guidance contained in NEI 96-07, Revision 1, to activities involving digital modifications. The guidance in this appendix applies to 10 CFR 50.59 reviews for both small-scale and large-scale digital modifications: from the simple replacement of an individual analog meter with a microprocessor-based instrument, to a complete replacement of an analog reactor protection system with an integrated digital system. Examples of activities considered to involve a digital modification include computers, computer programs, data (and its presentation), embedded digital devices, software, firmware, hardware, the human-system interface, microprocessors and programmable digital devices. Under that definition, the guidance encompasses software with AI technologies.** **AI technologies potentially introduce changes to human-software interface (HIS), triggering a “Screen In” status. AI technologies could be used in the following tasks (1) monitoring and detection, (2) situation awareness, (3) response planning, and (4) response implementation, also triggering a “Screen In” status. The guide calls to evaluate “creation of new potential failure modes” and AI can introduce artefacts associated with anomalous outputs. In this case the Appendix D guide would trigger a “Screen In” status.**

RG	Title	Q1	Q2	Comment
				After a change is classified as "Screen In," a safety analysis should be developed, potentially examining effects in safety features and safety systems, to be quantified as changes in core damage frequency. Therefore, it is considered that the NEI 96-07, Appendix D, Rev. 1 is sufficiently complete to trigger a thorough analysis prior to the adoption of an AI technology.
1.190	Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence	Yes	No, but unlikely use of AI	This guide provides acceptable state-of-the-art calculations and measurement procedures for determining pressure vessel fluence. This guide is intended to ensure the accuracy and reliability of the fluence determination required by General Design Criteria (GDC) 14, 30, and 31 of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50. The guide describes methods and assumptions acceptable for determining the pressure vessel neutron fluence. These methods are directly applicable to the determination of RT_{NDT} (reference temperature for nil-ductility transition) and RT_{PTS} (reference temperature at the end of the license period). The licensee may propose alternative methods. Alternative methods will be considered on a plant-specific basis, especially in cases involving unusual plant characteristics or factors that require different methods and assumptions. It is recognized that, when the embrittlement of a reactor vessel material is not significant and there is a large margin to the RT_{NDT} limits, more approximate methods for determining the fluence may be appropriate. **The guide recommends well developed approaches for fluence computations and to verify and quantify uncertainties based on experimental data. In principle, AI systems (e.g., neural networks) could be trained on tests and other fluence computations. This kind of application has not been considered in the set of examples examined, and this application of AI is considered unlikely at this time.**
2.8	Guidance for Implementation of 10 CFR 50.59, "Changes, Tests, And Experiments," At Non-Power Production or Utilization Facilities	Yes	Yes	This guide describes an acceptable approach to meet the regulatory requirements of 10 CFR 50.59, "Changes, tests and experiments," at a non-power production and utilization facility (NPUF). It endorses NEI 21-06, "Guidelines for 10 CFR 50.59 Implementation at Non-power Production and Utilization Facilities," Revision 1, issued December 2021. **If AI technologies are introduced, can this be done without proper scrutiny? No.** **Can computations based on AI technologies be used without proper scrutiny? This is unlikely.** **If AI technologies are used, for example in operations or special computations are updated using AI technologies, a screening and detailed analysis will be triggered in case the Change is directly or indirectly connected to UFSAR-described design functions. Screening is based on UFSAR-described design functions. If the change is deemed adverse, then a detailed analysis is required.** **Screening poses questions relevant to AI; for example, questions like the following would be posed related to computer codes:** **Has the facility-specific model been adequately qualified through benchmark**

RG	Title	Q1	Q2	Comment
				comparisons against test data, facility data or approved engineering analyses? Is the application consistent with the capabilities and limitations of the computer code? Has industry experience with the computer code been appropriately considered? **Those initial screening questions should identify limitations of codes or computations using AI technologies. Other relevant questions apply if AI techniques were considered to be used in facility operations. It is therefore concluded that the guide provides guidance to address changes involving AI technologies.**
3.72	Guidance for Implementation of 10 CFR 72.48, Changes, Tests, and Experiments	Yes	Yes	This guide describes an acceptable approach to meet the regulatory requirements of 10 CFR 72.48, “Changes, tests, and experiments.” Specifically, this guide provides guidance for addressing changes under 10 CFR 72.48 that affect an independent spent fuel storage installation (ISFSI), a spent fuel storage cask design, or a monitored retrievable storage (MRS) facility. The guide endorses NEI 12-04, Revision 2, “Guidelines for 10 CFR 72.48 Implementation,” issued September 2018, with exceptions and clarifications. The guide addresses the authority of licensees for nuclear reactors and ISFSIs, and of certificate holders for spent fuel storage casks, to make changes to the facility or procedures, or to conduct tests or experiments, with or without prior NRC approval. **Is it possible to introduce relevant AI technologies as “changes” without adequate oversight? No.** NEI 12-04 calls to execute a screening analysis for proposed modifications. For example, the guide identifies screening questions for proposed activities such as • Does the activity add or delete an automatic or manual design function or passive design characteristics of the SSC or cask? • Does the activity convert a feature that was automatic to manual or vice versa? • Does the activity introduce an unwanted or previously unreviewed system interaction? • Does the activity affect a method of evaluation used in establishing the design bases or in the safety analyses? Those example screening questions should trigger detailed assessments in case of introduction of AI technologies in relevant operations/analyses (related to UFSAR-described design functions). The screening process also calls to examine modifications to methods of evaluation (MOE). The MOE means the calculational framework for evaluating behavior or response of the ISFSI facility, cask or an SSC. In particular, computations adopting AI technologies would be considered a modification to MOE. Depending on the relationship of the modification to the MOE and the UFSAR, a relevant modification to the MOE will trigger analyses to establish if the modification should be approved by the NRC. Detailed analyses are needed if the MOE is used either in UFSAR safety analyses or in establishing the design bases, and if the methods are described, outlined or summarized in the UFSAR. The NEI 12-04 guide addresses software revisions associated with an MOE, which would encompass AI technologies.

RG	Title	Q1	Q2	Comment
				In summary, the guidance in NEI 12-04 would trigger detailed analyses if AI technologies are to be used in relevant operations or in support of relevant computations.
5.12	General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials, Classified Matter, and Safeguards Information	Yes	Yes	This guide describes methods and procedures acceptable for the selection, use, and control of locking devices. Locks can be used in the protection of areas, facilities, certain radioactive materials, and specific types of information (e.g., classified matter, National Security Information (NSI), Restricted Data (RD), Formerly Restricted Data (FRD), Safeguards Information (SGI)). **The guide concerns physical locks for physical protection, including electronic locks. In principle electronic locks could include AI technologies. Guidance is provided on redundancy such as two-factor authentication. AI technologies in locking devices are likely to be commercially developed, tested, and matured. It is considered at this time that the guide is appropriate for electronic locks, given that locks are accepted as delay devices only, rather than permanent impediments to unauthorized entry (any lock can be defeated by expert manipulation or force given enough time).**
5.74	Managing the Safety/Security Interface	Yes	Yes	This guide describes a method to assess and manage changes to safety and security activities to prevent or mitigate potential adverse effects that could negatively impact safety or security at power reactors. The guide is broad and addresses changes to safety and security (physical and cyber) activities and systems. The process for managing changes is technology neutral and independent of AI. The guide addresses changes to safety and security (physical and cyber) activities and systems, by relying on reviews by personnel knowledgeable of the site security programs. Any changes to a safety or security system where AI is introduced will be captured in the appropriate safety or security RG. **There is no impact to the process for managing the changes to assess a potential interface impact when using AI technologies. Therefore, it is considered that the guidance in RG 5.74 is sufficient to deal with AI**.

APPENDIX B: SCREENED-IN REGULATORY GUIDES WITH POTENTIAL GAPS

This appendix includes the set of screened-in regulatory guides (RGs) with potential gaps. The screened-in RGs are those with a yes response to the question

Q0: *Can AI technologies be used within the scope of the RG?*

For those RGs with a yes question to Q0, the questions Q1 and Q2 were posed in the analysis:

Q1: *Is the RG flexible to allow use of AI?*

Q2: *Does the RG provide adequate guidance to evaluate the use of AI?*

A negative answer to either of these questions would identify a potential gap. This appendix includes RGs with a no answer to Q1 or Q2. The RGs with no gaps are included in Appendix A. The Gap Type is described in Section 3.2 of the main report.

RG	Title	Q1	Q2	Comment	Gap Type
1.7	Control of Combustible Gas Concentrations in Containment	Yes	No	This guide is connected to CFR 50.44 providing requirements to mitigate combustible gas generated by a beyond-design-basis accident. The guidance provides recommendations for hydrogen and oxygen monitors, including survivability, power sources, display and recording, servicing, testing and calibration, and human factors. Monitors yield information to support execution of an emergency plan. **The guide explicitly refers to operators of equipment. AI offers alternatives to operate the equipment. Also, there may be opportunity to incorporate AI technologies in periodic testing. However, periodic testing should follow Regulatory Guide 1.118, "Periodic Testing of Electric Power and Protection Systems" (Ref. 12), pertaining to testing of instrument channels.** **The guide offers flexibility to incorporate AI technologies; however, the guide is not adequate in case of uses of AI to test, deploy, and operate equipment.**	1, 5
1.9	Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants	Yes	No	This draft guide (dated 2021) provides acceptable guidance to comply with the regulations for onsite emergency alternating current (AC) power sources, including emergency diesel generators (EDGs) and combustion turbine generators (CTGs), in nuclear power plants. This guide may also be used for other types of onsite emergency AC power sources. This guide may also be used for non-power reactors and nuclear facilities with suitable justification and demonstration, as applicable. This guidance helps ensure that the onsite emergency AC power sources: are qualified; have sufficient capacity, capability, independence, and testability; and have the necessary reliability and availability for design basis events (DBEs). The draft guide endorses IEEE Std 387-2017 and IEEE Std 2420-2019 as acceptable design qualifications and periodic testing in order to comply with the NRC regulations for EDGs, CTGs, and other emergency AC standby power sources with clarifications. **AI technologies could be used for control and periodic testing of equipment. The guide may need to point to general guidance on uses of AI.**	5

RG	Title	Q1	Q2	Comment	Gap Type
1.21	Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste	Yes	No	This guide describes acceptable methods for the following uses: (1) measuring, evaluating, and reporting licensed (plant-related) radioactivity in effluents and solid radioactive waste shipments from nuclear power plants and spent fuel storage facilities, and (2) assessing and reporting the public dose to demonstrate compliance with 10 CFR Part 20, “Standards for Protection Against Radiation,” 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations,” and nuclear power plant Technical Specifications. **The guide provides high-level guidance for monitoring and measuring effluents with radioactive material. It is possible AI technologies could be adopted in the future to perform measurements or for efficient monitoring. The guide is broad and not detailed enough to evaluate use of AI. This guide may not benefit from explicitly addressing AI technologies; instead, a general guide could address that need.** Dose computations are required to follow standard approaches, independently of AI technologies.	5
1.59	Design Basis Floods for Nuclear Power Plants	Yes	No	This guide discusses the design basis floods that nuclear power plants should be designed to withstand without loss of capability for cold shutdown and maintenance thereof. The design requirements for flood protection are the subject of Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants." The guide addresses floods to be considered to design equipment. Two appendices provide conservative estimates of probable maximum flood and probable maximum surge from hurricanes. **The guide allows for alternative methods to define "less conservative" and site-specific maximum floods. It may be possible considering AI methods to evaluate external hazards. The guidance provides high-level features of analyses, but not adequate to assess the validity of AI techniques. General guidance may be needed if AI methods are used for specialized computations.**	2

RG	Title	Q1	Q2	Comment	Gap Type
1.60	Design Response Spectra for Seismic Design of Nuclear Power Plants	Yes	No	This guide describes an acceptable approach for defining response spectra for the seismic design of nuclear power plants to satisfy the requirements of Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to Part 100, "Reactor Site Criteria," of 10 CFR Part 100. Regulatory Guide 1.60 forms part of the licensing basis for a number of nuclear power plants constructed during the 1970s and 1980s. Specifically, the safe shutdown earthquake ground motion (SSE) for these nuclear power plants is defined by a response spectrum. The guidance provides an approved method to define design response spectra. The guidance states that the provided method does not work for sites that (1) are relatively close to the epicenter of an expected earthquake or (2) have physical characteristics that could significantly affect the spectral pattern of input motion. In those cases, the Design Response Spectra should be defined considering site-specific characteristics. **AI methods could be used for special computations to address external hazards. The guidance does not impose constraints on the use of AI techniques. The guide is not adequate to evaluate uses of AI. General guidance on uses of AI for special computations may satisfy these needs.**	2
1.68	Initial Test Programs for Water-Cooled Nuclear Power Plants	Yes	No	The guide describes the general scope and depth of tests acceptable for demonstrating compliance with Initial Test Programs (ITPs) for light water-cooled nuclear power plants. ITPs include preoperational and startup. **The guide may require updates to explicitly recognize AI systems used for example to operate safety equipment. The inservice operation of AI systems may need to be tested; tests may need to also cover malfunction of AI systems for consistency with recommendations of risk management frameworks**.	3
1.68.2	Initial Startup Test Program to Demonstrate Remote Shutdown Capability for Water-Cooled Nuclear Power Plants	Yes	No	The guide describes an acceptable initial startup test program for demonstrating hot shutdown capability and the potential for cold shutdown from outside the control room. This guide is applicable to water-cooled nuclear power plants. The guidance assumes human operators would take the plant to a safe cold shutdown state from outside the control room. There is no consideration that AI systems could support safety functions. **Guidance may be needed to deploy and evaluate equipment with AI technologies, and to incorporate testing in initial test programs.**	3

RG	Title	Q1	Q2	Comment	Gap Type
1.76	Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants	Yes	No	The guide provides acceptable guidance for use in selecting the design-basis tornado and design-basis tornado-generated missiles that a nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public. This guidance applies to the contiguous United States, which is divided into three regions; this document provides separate guidance for each region. The US is classified into 3 tornado regions, with a map delineating the 3 regions. A table is provided with missile features for the 3 regions. **The guide allows for a different design-basis tornado, possibly using AI methods, which would trigger a comprehensive analysis. There is no guidance on how to execute a comprehensive analysis which could be applied to AI methods**.	2
1.78	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release	Yes	No	The guide describes approaches and technical bases that are acceptable to meet regulatory requirements for evaluating the habitability of a nuclear power plant (NPP) control room (CR) during a postulated hazardous chemical release. Releases of hazardous chemicals, on site and off site, can result in the nearby CR becoming uninhabitable. General Design Criterion (GDC) 19 requires providing a CR from which actions can be taken to maintain the nuclear power unit in a safe condition under accident conditions, including loss-of-coolant accidents. This guide contains acceptable technical bases and guidelines for use in assessing the habitability of a CR during and after a postulated external release of hazardous chemicals (e.g., vapor and gaseous) from a stationary source on site and multiple mobile sources off site, based on the immediately dangerous to life or health (IDLH) values. **Regarding use of AI technologies, AI could be used in support of detection systems and isolation systems. For example, if chemicals are detected by a sensor above safe limits, the isolation system could be actuated (e.g., closing the CR air ducts with dampers) by an AI system. The RG 1.168 and RG 1.171 may guide deployment and testing of complex software for the control of isolation systems.** **The guide is consistent with requirements of human operation and humans present in the control room. There is no consideration of the possibility of control by an AI system, which, if allowed, may relax the need to keep the control room habitable.**	4

RG	Title	Q1	Q2	Comment	Gap Type
1.79	Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors	Yes	No	The guide describes the acceptable general scope and depth for preoperational testing of features in the emergency core cooling systems (ECCSs) of pressurized water reactors (PWRs). This guide also describes acceptable methods for preoperational testing of ECCS structures, systems, and components (SSCs). Appendix A of this guide contains a discussion of the ECCS for the current fleet of PWRs as well as diagrams and descriptions of the ECCS for advanced PWR designs including the U.S. Advanced Pressurized-Water Reactor, U.S. Evolutionary Power Reactor, and AP1000. **The guidance mostly concerns physical pre-operational testing of pumps and valves of the ECCS. The guidance calls attention to testing of software-based instrumentation and control (I&C) systems recommending checking of functional, performance, and interface requirements in specifications. AI systems could be used to control operation of the ECCS. Comprehensive verification and validation testing is addressed in RG 1.168. AI systems may require additional pre-operational testing to address robustness attributes (e.g., performance under challenges), to complement the criticality, risk, hazard, and security analyses recommended by RG 1.168.**	3
1.79.1	Initial Test Program of Emergency Core Cooling Systems for New Boiling-Water Reactors	Yes	No	This guide describes acceptable methods for preoperational, low power and power ascension testing features of the emergency core cooling systems (ECCS) for boiling-water reactors (BWRs). This guide also describes acceptable methods for initial plant testing of ECCS structures, systems, and components (SSCs). Additionally, this guide describes acceptable methods for testing of the Isolation Condenser System (ICS) and the Reactor Core Isolation Cooling (RCIC) System, which support functions for alternate water injection during station blackout. **The same comment made to RG 1.79 applies to RG 1.79.1: AI systems may require additional pre-operational testing to address robustness attributes (e.g., performance under challenges), to complement the criticality, risk, hazard, and security analyses recommended by RG 1.168.**	3

RG	Title	Q1	Q2	Comment	Gap Type
1.90	Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons	Yes	No	The guide describes acceptable methods for use in developing an appropriate inservice inspection (ISI) program for prestressed concrete containment structures with grouted tendons. The ISI of prestressed concrete containment structures is necessary to verify, at specific intervals, that operating and environmental conditions have not reduced the safety margins on prestress levels provided in the design of the containment structures, and that the leaktightness and structural integrity of the containment is maintained. A prediction of the time-dependent behavior of concrete, particularly creep and shrinkage, is very important because of its potential impact on the prestress level. **The guide calls for monitoring indicators of performance, based on instrumentation, sensors, and visual examination. It is implicitly assumed that humans interpret the information and diagnose degradation. In principle, AI systems could be used to interpret the information from sensors and cameras and identify degradation. The guide calls for periodic monitoring and reporting, which could be accomplished by AI systems (both monitoring and reporting). The guidance is not adequate to guide deployment of AI systems in support of ISI for concrete containment structures with grouted tendons.**	5
1.114	Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit	No	No	This guide describes an acceptable method for use in complying with regulations that require the presence of an operator at the controls of a nuclear power unit and the presence of a senior operator in the control room from which the nuclear power unit is being operated. In addition, this regulatory guide clarifies and provides guidance on the acceptable boundaries of the control room. The “vital area,” as defined in Title 10, Section 73.2, “Definitions,” of 10 CFR 73.2 and of 10 CFR 73.55(c), serves as the basis for the “control room vital area” as used in this regulatory guide. The guide calls for the presence of at least an operator and senior operator at all times while the unit is operating. It is assumed that operators supervise safety systems. **The guidance is consistent with the overarching assumption of human operation of facilities. The regulation assumes/requires human operation of facilities, without an option of autonomous operation supported by AI systems.**	1
1.118	Periodic Testing of Electric Power and Protection Systems	No	No	This regulatory guide describes an acceptable method for complying with regulations with respect to the periodic testing of the electric power and protection systems. **The goal of the testing is enhancing the reliability of protection systems. The guide endorsed IEEE Std 338-1987, which relies on periodic surveillance by humans following procedures. The guide and standard do not account for the possibility of AI systems performing the required surveillance. Also, if AI systems were used as part of the protection systems themselves, additional testing may be needed to ensure AI systems respond as expected.**	5
1.129	Maintenance, Testing, and Replacement of Vented Lead-Acid	Yes	No	This guide describes acceptable methods and procedures for use in complying with the agency’s regulations regarding the maintenance, testing, and replacement of vented lead-acid storage batteries in production and utilization facilities. This guide endorses (with certain clarifying regulatory positions described in Section C of the guide) IEEE Std 450-2020, “IEEE	5

RG	Title	Q1	Q2	Comment	Gap Type
	Storage Batteries for Production and Utilization Facilities			Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications." **For the periodic testing components, it may be feasible to deploy independent voltage and current sensors monitored by AI systems to measure the health of the lead-acid storage batteries. There is no guidance on the deployment of AI systems to actively monitor the health of components such as batteries, and whether such automatic monitoring could replace human monitoring.**	
1.141	Containment Isolation Provisions for Fluid Systems	Yes	No	This guide describes acceptable methods for use in complying with requirements for isolation of fluid systems that penetrate containment. The guide assumes a level of manual operation of valves, and certain motor operated valves operated by humans in the control room. The guide calls for the initiation of containment isolation depending on certain signals of leakage. **It may be possible incorporating AI system controls to monitor variables such as high containment pressure, high radiation level, and actuation state of a safety system or subsystem. The guide does not address evaluating the use of AI technologies to attain containment isolation**. **A general guide on uses of AI technologies may suffice.**	1, 5
1.147	Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1	Yes	No	This guide lists the approved ASME Boiler and Pressure Vessel (BPV) Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components", for use as voluntary alternatives to the mandatory ASME BPV Code provisions that are incorporated by reference into 10 CFR Part 50 "Domestic Licensing of Production and Utilization Facilities." **The codes include numerous codes to achieve examination, inspection, inservice inspection, visual examination, ultrasonic examination, surface examination. In general, it is implicitly assumed that humans accomplish those actions. Instead, AI systems could be used in support of those actions and existing codes and guidance may not be adequate to ensure safe use of those technologies. The main purpose of the guide is merely stating acceptable ASME codes and standards.**	1, 5

RG	Title	Q1	Q2	Comment	Gap Type
1.149	Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, and Applicant Experience Requirements	No	No	This guide describes acceptable methods for complying with those portions of the regulations associated with approval or acceptance of a nuclear power plant simulation facility for use in operator and senior operator training and license examination operating tests and for meeting applicant experience requirements. **The guide concerns simulators used for training operators and senior operators to satisfy requirements at 10 CFR 55.46. The simulators should be comprehensive and follow the procedures of the reference facility. However, if AI systems are allowed, the role of operators may change. Should operators remain fully knowledgeable of the way plants are operated as of 2023? Should operators be knowledgeable only of the parts they take action when assisted by AI systems? Which plant functions should be covered by the training and which functions should be accepted controlled by AI systems without human training required? Should AI systems allow for manual controls? In principle, training should only cover functions that allow for human intervention. If other functions can be reliably automatized and separated from human intervention, there may not be a need to train for those functions.**	1, 8

RG	Title	Q1	Q2	Comment	Gap Type
1.157	Best-Estimate Calculations of Emergency Core Cooling System Performance	No	No	This regulatory guide describes acceptable model correlations, data, model evaluation procedures, and methods for meeting the requirements for a realistic or best-estimate calculation of ECCS performance during a loss-of-coolant accident and for estimating the uncertainty in that calculation. Methods for including the uncertainty in the comparisons of the calculational results to the criteria of paragraph 50.46(b), in order to meet the requirement that there be a high probability that the criteria would not be exceeded, are also described in this regulatory guide. Paragraph 50.46(a) also permits licensees to use evaluation models developed in conformance with Appendix K. The guide states that other models, data, model evaluation procedures, and methods will be considered if they are supported by appropriate experimental data and technical justification. Any models, data, model evaluation procedures, and methods listed as acceptable in this regulatory guide are acceptable in a generic sense only but would still have to be justified as being appropriately applied and applicable for particular plant applications. **The guide emphasizes thermal-hydraulic models and physical differential equations. Although it states that alternative methods can be acceptable if justified, it is implied that a strong empirical basis will be sought. The guide is about "best-estimate" models to help quantifying uncertainties. It is not evident that alternative AI methods will be allowed within the context of the guide. The guide cites databases of experiments that, together with results of models, could be used to train machine learning functions. Thus, it is feasible AI methods could be proposed to be incorporated in total system evaluation models. The guide is not adequate to allow evaluation of AI methods. There is description in the guide regarding correlations and empirical models, and justification of extrapolation. For AI methods, systematic approaches may be implemented to explore the range of validity of AI solutions. A gap is identified because the guide does not appear to provide flexibility to use AI methods. Also, if AI methods are used, the guide is not adequate to support their evaluation.**	2

RG	Title	Q1	Q2	Comment	Gap Type
1.168	Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants	Yes	Yes	This guide describes an acceptable method for use in complying with regulations with respect to verification, validation, reviews, and audits for digital computer software used in safety systems of nuclear power plants. The guide endorses IEEE Std 1012-2004. The standard recommends standard software life-cycle practices, such as software requirements description, software development plan, software testing, validation and verification, and required quality assurance documentation. The standard recommends classifying software in 4 levels, with higher requirements for levels 3 and 4. The standard calls for a criticality, hazard, security, and risk analysis. The risk analysis appears downplayed. The hazard analysis addresses "what can go wrong?" The hazard/risk analysis is applied at various levels, including interface with hardware and system interface. The standard calls to examine "performance at boundaries (e.g., data, interfaces) and under stress conditions." This can be interpreted to mean that the software should be tested under extreme conditions as well as in interfaces with hardware and other software. The standard also includes identification of mitigation alternatives. The standard can be considered complete to evaluate AI. Possibly the standard may need supplemented with best practices to document V&V of AI technologies and define fail-safe approaches. According to RG 1.168, IEEE Std 7-4.3.2-2016 standard includes provisions on preexisting (pre-developed or commercial off-the-shelf) software. Also, EPRI Topical Report (TR)-106439, “Guideline on Evaluation and Acceptance of Commercial Grade Digital Equipment for Nuclear Safety Applications,” issued October 1996, which was endorsed by an NRC safety evaluation report (SER) dated July 17, 1997, define requirements on commercial software. Commercial software should have a level of testing and documentation equivalent to developed software, including software with AI technology.	6

RG	Title	Q1	Q2	Comment	Gap Type
1.169	Configuration Management Plans for Digital Computer Software Used in Safety Systems of Nuclear Power Plants	Yes	No	This guide describes an acceptable method for use in complying with regulations on configuration management plans for digital computer software used in the safety systems of nuclear power plants. **The guide endorses IEEE Std 828-2005, which defines an enhanced approach to configuration management, including interfaces between software and hardware. Most AI methods can be made to fit configuration management systems of traditional software. Adaptive AI does not fit into a strict configuration frame. Adaptive AI uses reinforcement to learn from experience, and the response from adaptive AI systems change with time as learning proceeds. Adaptive AI could learn from manual actions by an operator. Large language models (LLM) could be used in the control room, for example to retrieve information from manuals, operating procedures, operation and maintenance records and so forth to recommend actions to an operator or to generate commands for another AI system. A LLM could be paired with an adaptive system to learn from an operator. The "learning trajectory" may be important to the final state of the AI system, which may create complexities in the configuration management system. Adaptive AI systems could be non-functional during a testing stage. After reaching maturity, the adaptive AI systems could be transformed to "fixed" or "locked" AI systems and deployed under a strict configuration management system. Therefore, with some adjustments it is envisioned that any AI system can be made to fit into a strict configuration control system.**	6
1.171	Software Unit Testing for Digital Computer Software Used in Safety Systems of Nuclear Power Plants	Yes	No	This guide describes an acceptable method for use in complying with regulations with respect to the software unit testing of digital computer software used in the safety systems of nuclear power plants. This guide endorses ANSI/IEEE Std. 1008-1987, “IEEE Standard for Software Unit Testing," with the clarifications and exceptions. ANSI/IEEE Std. 1008-1987, which was reaffirmed in 2002, describes an acceptable method for complying with regulations for promoting high functional reliability and design quality in the software used in safety systems. The guide concerns testing of software incorporated into the instrumentation and control systems. Software should be subject to validation and verification as described in RG 1.168. Some potential gaps related to adaptive AI have been noted under RG 1.168. **Under the Test Program, the licensee is required to identify and justify the Coverage of Model Structure to be applied. The licensee should define the range of inputs/outputs of AI systems to be tested, including stress/challenge tests. It is implicitly assumed that the software is mature, and fits into a strict configuration management structure. The guide may need to be complemented to test AI systems incorporated in safety systems**.	6

RG	Title	Q1	Q2	Comment	Gap Type
1.172	Software Requirement Specifications for Digital Computer Software and Complex Electronics Used in Safety Systems of Nuclear Power Plants	Yes	No	This guide describes an acceptable method for use in complying with regulations on software requirement specifications (SRSs) for digital computer software used in the safety systems of nuclear power plants. This guide endorses IEEE Std. 830-1998, "IEEE Recommended Practice for Software Requirements Specifications," issued in 1998 and reaffirmed in 2009, with the exceptions. **The guide concerns specification of requirements. It is possible to make AI systems abide by the format of requirements established for traditional software. The guide may need to be supplemented to recognize special features of AI.**	6
1.173	Developing Software Life Cycle Processes for Digital Computer Software Used in Safety Systems of Nuclear Power Plants	Yes	No	This guide describes an acceptable method for use in complying with regulations on the development of software life cycle processes for digital computer software used in the safety systems of nuclear power plants. The guide endorses IEEE Std 1074-2006. **The guide identifies life-cycle tasks and documents. The guide appears adequate for locked AI systems. A focused supplement may be needed to recognize special features of AI systems, and fail-safe states.**	6

RG	Title	Q1	Q2	Comment	Gap Type
1.189	Fire Protection for Nuclear Power Plants	Yes	No	This guide describes an acceptable approach to meet the regulatory requirements of 10 CFR 50.48(a) and (b), and 10 CFR Part 50, Appendix R, “Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979." These regulations state the requirements governing a civilian nuclear power generating plant’s fire protection program (FPP). The fire protection program (FPP) includes components such as automatic and manual trigger, testing of equipment, training of personnel, audits. The guide is consistent with the assumption that plants are operated by humans, and that those humans should be warned and kept safe. There are recommendations to protect essential equipment and keep the control room protected and with habitable conditions to protect humans therein. **If full autonomous operation supported by AI was proven successful, habitability requirements could be relaxed.** The guide includes recommendations on fire modeling, including reference to fire dynamics models that have been verified and validated. Other models may be used, but licensees must provide validation and verification evidence and documents. If AI was used in fire modeling, the analyst must demonstrate the validity of AI-based models, and it is considered that the guide is complete in this regard. However, the guide is high level and does not go into details on how to demonstrate model validity. **The guide refers to automatic fire detection systems. Fires are mitigated with automatic systems actuated with traditional methods and manual mitigation by humans, which actions are difficult to envision replaced by AI systems soon. However, the possibility remains for AI to be used in fire alarms, fire detection, fire mitigation, and fire suppression systems. The industry and the national laboratories have considered use of AI with computer vision as fire watches as part of fire detection systems.** **A general guide on uses of AI technologies may satisfy identified needs.**	1, 4
1.196	Control Room Habitability at Light-Water Nuclear Power Reactors	No	No	This guide provides acceptable guidance and criteria for implementing regulations in Appendix A, “General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” as they relate to control room habitability (CRH). Specifically, this guide outlines a process that licensees may apply to control rooms that are modified, are newly designed, or must have their conformance to the regulations reconfirmed. The guide concerns actions to ensure the habitability of the control room, in case of accidents. The control room should remain habitable to allow operators control the reactor and take the plant to a safe shutdown when required. It is implicitly required for plants to be operated by humans, instead of allowing for levels of autonomous operation. **The guidance is consistent with the overarching assumption of human operation of facilities. The regulation requires human operation of facilities; there is no consideration of autonomous operation supported by AI systems. Under autonomous operation, habitability requirements could be relaxed**.	4

RG	Title	Q1	Q2	Comment	Gap Type
1.198	Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites	Yes	No	This regulatory guide has been developed to provide guidance to license applicants on acceptable methods for evaluating the potential for earthquake-induced instability of soils resulting from liquefaction and strength degradation. It discusses conditions under which the potential for such response should be addressed in safety analysis reports. The guidance includes procedures and criteria currently applied to assess the liquefaction potential of soils ranging from gravel to clays. The scope of this guide is limited to evaluation of the behavior of soils subjected to earthquake shaking. It specifically excludes nonseismic failure of sensitive clays, failure under static loads (such as flow slides in loose point bar deposits), and soil response to machine vibrations and blasting. The selection or synthesis of appropriate ground motion records to use for a response analysis is not included. **The guide is high level, and it implies a level of uncertainty in the understanding of the potential for liquefaction. Empirical methods are mentioned in the guide, which could encompass AI methods. It may be feasible to assemble a database of earthquakes, soil characteristics, and soil response to explore AI methods such as deep neural networks to characterize liquefaction. The guide is not adequate to evaluate the use of AI methods**.	2

RG	Title	Q1	Q2	Comment	Gap Type
1.200	Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities	Yes	No	This guide describes one acceptable approach for determining whether the technical adequacy of a base PRA is adequate to provide confidence in the results, such that the PRA can be used in regulatory decision-making for light-water reactors. The guide is intended to reflect and endorse guidance provided by standards-setting and nuclear industry organizations. **AI methods could be used to provide inputs to the PRA or to support PRAs, for example input parameter estimation (e.g., frequency of initiating events and reliability of components), human reliability analyses (e.g., inferring human performance from records such as incident reports), hazard and fragility analyses (seismic, high wind, external flood, and other hazards) could use AI methods. The guide calls for complete documentation of analyses and peer reviews of those analyses. Peer reviewers may be capable of detecting shortcomings in analyses supported by AI methods; however, there is a need for guidance to ensure the AI supported analyses address AI technology issues. RG 1.168 is perceived adequate for the development of "fixed" AI systems. However, RG 1.168 applies to software development, and isolated analyses could rely on AI technologies without being part of a "software." For example, neural networks could be developed to support a single or few analyses of narrow scope, and not to be used repeatedly as software. Special checks may be needed to ensure those neural networks are properly used and that predictions are reasonable and can be justified and explained based for example on test data. Guidance for sufficient verification and validation of AI systems may be needed for AI systems in special computations.** **Note**: modern software allows efficient development and training of neural networks, performing computations and output of predictions for special analyses. Those computations are similar to curve fitting empirical data. Those AI-supported computations would be recorded in scientific notebooks together with supporting files, and they would be outside of a software development cycle.	2

RG	Title	Q1	Q2	Comment	Gap Type
1.203	Transient and Accident Analysis Methods	Yes	Yes	This guide describes an acceptable process for use in developing and assessing evaluation models that may be used to analyze transient and accident behavior that is within the design basis of a nuclear power plant. The guidance is for evaluation models (EM) of reactor response under accident conditions. The guide emphasizes "mechanistic" models in the EM; but allows use of phenomenological models and correlations as "calculational devices" (components of the EM). **Guidance to review calculational devices can be applied to examine AI systems. Acceptable AI system may be constrained to perform limited computations consistent with separated effect tests (SET). AI systems could be used to simulate more complex processes, consistent with integrated effect tests (IEF). There is guidance to test the overall performance of the EM, including uncertainty and sensitivity analyses, that are consistent with the "explainability" attribute. Applying AI to achieve complex computations will trigger a high level of scrutiny, for a good reason. The guidance is perceived adequate to examine AI systems.** **The corresponding section of the SER in NUREG 0800 to this guide is Chapter 15, Section 15.0.2. The SER emphasis is on mechanistic models, and physics-based models that highlight conservation of mass, momentum, and energy. There is limited attention to examining empirical and phenomenological equations (which approach could also be applied to examining computations with AI techniques). The SRP refers to "frozen" models, to point to model versions that have reached a level of maturity and are no longer modified. The "frozen" model concept can also be applied to AI models (i.e., AI models with constant parameters, that are no longer adjusted as part of a training process). The SRP would benefit of general guidance for examining AI systems that are used in support of computations or analyses. This type of guidance would also work for computations in support of PRA models under RG 1.200.**	2

RG	Title	Q1	Q2	Comment	Gap Type
1.205	Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants	Yes	No	This guide describes an acceptable approach to meet the regulatory requirements of Title 10, “Energy,” of 10 CFR 50.48(c) and National Fire Protection Association (NFPA) Standard 805, “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” 2001 Edition, which is incorporated by reference in 10 CFR 50.48(c). **The guide concerns adopting a risk-informed performance-based program for fire protection. The guide assumes humans take control of operations under accident conditions. For example, there is a "dedicated shutdown" option in Section III.G.3 of Appendix R to 10 CFR Part 50. A system or component that has been specifically installed under the dedicated shutdown concept is a system or component that is operated by humans from a location outside the control room and is fully separated from the fire area where its use is credited. There is another option for "alternative shutdown" that is electrically separated from the control room and the fire area. The control room team evacuates to the alternative location and use alternative shutdown controls to safely shut down the plant. Control actions assumed executed by humans could be executed by AI systems.** **The guide refers to fire models to examine success paths. It is the responsibility of the licensees to provide evidence of validation and verification. There are similar features to RG 1.189. As in RG 1.189, it is considered unlikely the use of AI methods as computational devices for fire simulations, but if used, the analyst must justify their validity. There is no issue in the guide regarding AI in special computations (Gap 2).** **As stated in RG 1.189, the national laboratories have considered the use of AI in fire detection systems (monitoring systems like computer vision). NFPA 805 requires licensees to establish a monitoring program to ensure the availability and reliability of the fire protection systems and features, assess the performance of the FPP in meeting the performance criteria, and ensure the assumptions in the engineering analyses remain valid. Monitoring programs could include AI technologies.** **Guidance may be needed on uses of AI technologies in fire alarms, fire detection, fire suppression, and fire mitigation systems, and monitoring technologies.**	1, 5

RG	Title	Q1	Q2	Comment	Gap Type
1.206	Applications for Nuclear Power Plants	Yes	No	This guide provides guidance on the format and content of applications for nuclear power plants submitted under 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” which specifies the information to be included in an application. The guide is a detailed description of the content of applications, which is independent of AI technologies. However, the guide addresses details on human factors engineering (HFE), and this is the only guide related to reactors that we are aware with those details. HFE is addressed in SRP Section 14.3.9, “Human Factors Engineering—Inspections, Tests, Analyses, and Acceptance Criteria.” Special consideration should be given to HFE in case of remote operation of nuclear facilities, which may or may not include AI systems. **It is not clear the guidance and the SRP are adequate to evaluate the use of HFE for safe deployment of AI technologies. The potential gap is related to whether traditional HFE is adequate to address AI technologies. We do not have a full perspective of HFE to answer this question, and thus, this is labeled as a potential gap for further consideration.**	8
1.231	Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Safety-Related Applications for Nuclear Power Plants	Yes	No	This guide describes acceptable methods to meet regulatory requirements for acceptance and dedication of commercial-grade design and analysis computer programs used in safety-related applications for nuclear power plants. This guide endorses Revision 1 of EPRI Technical Report 1025243, “Plant Engineering: Guideline for the Acceptance of Commercial-Grade Design and Analysis Computer Programs Used in Nuclear Safety-Related Applications,” with respect to acceptance of commercial-grade design and analysis computer programs associated with basic components for nuclear power plants. The EPRI TR 1025243 is an important document for the gap analysis. The guide applies to software affecting a safety-related SSC, if procured by a commercial vendor (without an Appendix B program). The guide defines additional verification activities to be applied on the software. Computer program functions that typically impact SSCs include: • The computer program is used to facilitate design of the safety-related SSC. • The computer program is used to analyze how the safety-related SSC will function or withstand design conditions. • The computer program is used to monitor operation or control functions of a safety-related SSC. The guide considers standard software errors such as conceptual, numerical, and interface errors. The guide calls to perform a failure modes and effects analysis (FMEA) to identify failure mechanisms of the item in the specific applications. This FMEA is analogous to the risk analysis called for the NIST risk management framework, and the risk analysis of the IEEE standard for software development in RG 1.168. Section 6 of the EPRI document defines four software acceptance methods: (1) special tests and inspections, (2) survey of commercial vendor, (3) source verification, (4) item and vendor performance. The objective of the guide is to ensure adequate performance of the software in support of safety-related SSCs. The EPRI guide was developed in 2013, and there is no consideration that software could include AI methods. For AI, tests must be highlighted exploring a broad range of inputs, especially on the edges of the input space and reasonable performance must be documented. Also, it should be recognized that AI	6

RG	Title	Q1	Q2	Comment	Gap Type
				methods, such as deep neural networks can yield unexpected outputs to inputs very different to those in the training of the network. Solutions to address unexpected outputs are needed, especially if the software is used to monitor operation or control functions of a safety-related SSC. **The guide assumes that if the software is procured as a basic component (i.e., developed and supplied under a QA program meeting 10 CFR Part 50 Appendix B), the QA program of the vendor is sufficient. However, additional guidance may also be needed to supplement software development standards regarding software with AI technologies. In general, for software with AI technologies, the software must be checked in a broad range of inputs including boundaries of the input parameter space, and the software should incorporate strategies to handle inputs very outside the training space as well as anomalous outputs.**	
1.245	Preparing Probabilistic Fracture Mechanics (PFM) Submittals	Yes	No	This guide describes an acceptable framework performing probabilistic fracture mechanics (PFM) analyses in support of regulatory applications. **The guide concerns PFM models. The guide is high level and, in principle, allows for the incorporation of AI algorithms within a PFM, similar to empirical or semi-empirical models. It is unlikely AI models will be used to replace a full PFM, because a clear connection is expected to physics. However, parts of a PFM could use AI algorithms. There is no special guidance for developers and reviewers to evaluate AI models. This potential gap could be addressed with general guidance on the use of AI systems.**	2
1.246	Acceptability of ASME Code, Section XI, Division 2, Requirements for RIM Programs for NPPs, for Non-LWRs	No	No	This guide describes an approach for the development and implementation of a preservice inspection (PSI) and in-service inspection (ISI) program for non-light water reactors (non-LWRs). The guide endorses, with conditions, ASME Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” Division 2, “Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants” for non-LWR applications. **The guide concerns development of a RIM program that relies on maintenance, surveillance, and periodic testing. Inspection campaigns may occur at multi-year periods, possibly during refueling, and be conducted by humans. AI technologies may be used to execute some surveillance, monitoring, and testing, with a level of autonomy, at more frequent intervals. The guide does not account for the possibility of automatic inspection supported by AI systems, including automatic reporting. This gap is similar to the gap under RG 1.147.**	5

RG	Title	Q1	Q2	Comment	Gap Type
1.247	TRIAL - Acceptability of Probabilistic Risk Assessment Results for Non-Light Water Reactor Risk-Informed Activities	Yes	No	This guide describes one acceptable approach the NRC staff has developed for determining whether a design-specific or plant-specific PRA used to support an application is sufficient to provide confidence in the results, such that the PRA can be used in regulatory decision-making for NLWRs. The guide concerns development of PRA models. A gap similar to the gap for RG 1.200 was identified, related to the use of AI systems to generate inputs to the PRA such as component reliability or human reliability. The adequacy of the PRA relies heavily on peer reviews, and it is unclear that peer reviewers will be able to detect shortcomings of analyses based on AI techniques. The guide refers to new developed methods (NDM), which could include AI technologies, and the acceptability criteria for using NDM in a PRA including 1) that the purpose and scope of the NDM are clearly stated, 2) that the NDM is based on sound engineering and science relevant to its purpose and scope, 3) that the data are relevant to the NDM, 4) that uncertainties in the NDM are characterized, 5) that the results of the NDM are reproducible, reasonable, and consistent with the assumptions and data, 6) that the documentation of the NDM provides traceability and facilitates incorporation of the method in a PRA model. Peer reviews are also used to examine the adequacy of an NDM. **These principles are also adequate to examine AI technologies. However, in general peer reviewers would benefit of general guidance on the use of AI technologies.**	2
3.27	Nondestructive Examination of Welds in the Liners of Concrete Barriers in Fuel Reprocessing Plants	Yes	No	The methods described in this guide are acceptable general approaches to achieve leak tight integrity of metal liners of concrete confinement barriers, which is an important consideration in safety evaluations. The guide identifies non-destructive evaluation (NDE) methods and techniques for liner seam welds and for penetration, airlock, and access opening welds. Reference is made to sections of the ASME code for specific techniques such as radiographic examination, magnetic-particle examination, ultrasonic examination, and leak testing. The guide calls for the use of qualified personnel for NDE testing. **It may be possible to supplement NDE with AI techniques. It may be necessary to supplement the guide with general guidance on AI techniques and validation and verification to ensure the reliability of information output by AI techniques.**	2, 5

RG	Title	Q1	Q2	Comment	Gap Type
3.76	Implementation of Aging Management Requirements for Spent Fuel Storage Renewals	Yes	No	This guide describes an acceptable approach for the format and content of applications for renewals of specific licenses for independent spent fuel storage installations (ISFSIs) and certificates of compliance (CoCs) for spent fuel storage cask designs, and for implementation of aging management programs (AMPs) for holders of CoCs and specific and general ISFSI licensees subject to renewal requirements. It endorses, with clarifications, the NEI guidance in NEI 14-03, Revision 2, “Format, Content and Implementation Guidance for Dry Cask Storage Operations-Based Aging Management,” issued December 2016. **The guide defines the format and content of applications, which is independent of AI technologies. However, the guide also provides implementation guidance where AI technologies could be used. For example, the guide calls for time-limited aging analyses, which could include AI methods for effects and magnitudes of aging processes. The guide calls for inspections, which for example could incorporate computer vision methods. The industry, through the Institute of Nuclear Power Operations (INPO) maintains an Aging Management INPO Database recording to records issues and instances relevant to aging management programs. AI methods and large language models could be used to efficiently process information in the INPO Database. The guide is broad, and it allows for the use of AI technologies, but it does not provide help to evaluate the use of those technologies. General guidance on the use of AI technologies could address this potential need**.	2, 5
4.1	Radiological Environmental Monitoring for Nuclear Power Plants	Yes	No	This guide describes a method acceptable for use in establishing and conducting an environmental monitoring program at nuclear power plants. The guide describes programs for preoperational and operational environmental monitoring. **The guide is broad and high-level. It is feasible that monitoring programs could include AI technologies for physical monitoring and inspection, or to deploy routine monitoring and reporting more efficiently. However, the guide is high level, and it would not benefit to explicitly address AI. A general guide on AI could fulfill the need.**	5
4.14	Radiological Effluent and Environmental Monitoring at Uranium Mills	Yes	No	This guide describes acceptable programs for measuring and reporting releases of radioactive materials to the environment from typical uranium mills. **AI technologies could be used for periodic monitoring and reporting. However, the guide is high level it would not benefit from explicitly addressing AI. A general guide for AI could fulfill guidance needs.**	5

RG	Title	Q1	Q2	Comment	Gap Type
4.16	Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants	Yes	No	This guide describes an acceptable method for the development and implementation of effluent monitoring programs described in license applications and for monitoring and reporting effluent data by licensees. The guidance is applicable to nuclear fuel cycle facilities, with the exception of uranium milling facilities and nuclear power reactors. The NRC has developed other regulatory guides applicable to those facilities. **AI technologies could be used for periodic monitoring and reporting. However, the guide is high level it would not benefit from explicitly addressing AI. A general guide for AI could fulfill guidance needs.**	5
5.7	Entry/Exit Control for Protected Areas, Vital Areas, and Material Access Areas	No	No	This guide describes measures the NRC staff considers acceptable for implementing entry/exit control requirements at facilities. **It is envisioned AI systems could be used to enhance physical protection and physical security systems. AI system could be used to monitor and activate access to facilities, to monitor individuals, and material accounting. Individuals could be inspected remotely, and not necessarily through "hands-on," "strip search," and hand-held detectors. Words referring to manual actions should be reconsidered to ensure generality and recognize possibilities and alternatives offered by AI systems acting at distance.** **The guide is high-level; however, in this case it may be necessary to examine the content of the guide in detail and consider alternative wording to acknowledge actions that could be accomplished with existing and future AI technologies.**	1, 5
5.11	Nondestructive Assay of Special Nuclear Material Contained in Scrap and Waste	Yes	No	This guide details acceptable procedures to provide a framework for the use of nondestructive assay (NDA) in the measurement of scrap and waste components generated in conjunction with the processing of special nuclear material (SNM). Other guides detail procedures specific to the application of a selected technique to a particular problem. **The guide identifies accepted NDA techniques. Given the abundance of empirical data, it appears feasible that AI techniques could be proposed to complement NDA. The guide is high-level, and it is not evident how the guide would benefit from explicit discussion of AI. If AI was used to complement NDA, possibly a general guide may be used to address questions on accuracy and reliability of AI supported predictions and analyses**.	2, 5

RG	Title	Q1	Q2	Comment	Gap Type
5.21	Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry	Yes	No	This guide describes acceptable conditions for U-235 enrichment measurements using gamma ray spectrometry and provides procedures for operation, calibration, error analysis, and measurement control. Examples of U-235 enrichment assays using portable and in-line instruments based on the techniques outlined in this guide are available in cited references. **As observed in Regulatory Guide 5.11, it appears feasible AI technologies be proposed to complement non-destructive assay (NDA) methods, including the specific method addressed in this guide. A general guide may be used to address questions on accuracy and reliability of AI supported predictions and analyses.**	2, 5
5.23	In Situ Assay of Plutonium Residual Holdup	Yes	No	Plutonium residual holdup is defined as the plutonium inventory component remaining in and about process equipment and handling areas after these collection areas have been prepared for inventory. Whenever possible, process equipment should be designed and operated so as to minimize the amount of holdup. In this guide, acceptable procedures for the in-situ assay of the plutonium residual holdup are described. **As observed in Regulatory Guide 5.11, it appears feasible AI technologies could be proposed to complement non-destructive assay (NDA) methods, including the specific method addressed in this guide. A general guide may be used to address questions on accuracy and reliability of AI supported predictions and analyses.**	2, 5
5.27	Special Nuclear Material Doorway Monitors	Yes	No	This regulatory guide describes an acceptable method to implement the search requirement for concealed special nuclear material (SNM) applied to personnel, vehicles, packages and all other materials exiting a material access area (MAA). Special nuclear material doorway monitors provide an efficient, sensitive, and reasonably unobtrusive way of searching individuals for concealed SNM upon exit from an MAA. With proper installation and operation, gram quantities or less of SNM can be detected with a high level of reliability while maintaining a low false alarm rate. Portal type walk-through metal detectors are often used in conjunction with radiation detection to assure that personnel entering or leaving MAAs are screened for metallic nuclear shielding materials.**AI technologies could be potentially used to complement mature technologies for SNM detection. The guide is high level, and it does not provide adequate guidance in case of the use of AI technologies. A general guidance could satisfy a need for demonstrating reliability and accuracy of AI supported measurements.**	5

RG	Title	Q1	Q2	Comment	Gap Type
5.37	In Situ Assay of Enriched Uranium Residual Holdup	Yes	No	Residual holdup is defined as the inventory component remaining in and about process equipment and handling areas after those collection areas have been prepared for inventory. In situ assay is used to ensure that a measured value of residual holdup is included in each material balance. This guide describes procedures acceptable for the in-situ assay of the residual enriched uranium holdup. Because of the difficulty in measuring in-process holdup, the procedures described in this guide for calibration and error evaluation differ from general guidance on measuring residual holdup in more accessible controlled situations. **As observed in Regulatory Guide 5.11, it appears feasible AI technologies be proposed to complement non-destructive assay (NDA) methods, including the specific method addressed in this guide. A general guide may be used to address questions on accuracy and reliability of AI supported predictions and analyses.**	2, 5
5.38	Nondestructive Assay of High-Enrichment Uranium Fuel Plates by Gamma Ray Spectrometry	Yes	No	This guide describes features of a gamma ray spectrometry system acceptable for nondestructive assay of high-enrichment uranium fuel plates or fuel plate core compacts. This guide includes a brief section on computer control in support of data acquisition and data analytics. **As observed in Regulatory Guide 5.11, it appears feasible AI technologies be proposed to complement non-destructive assay (NDA) methods, including the specific method addressed in this guide. A general guide may be used to address questions on accuracy and reliability of AI supported predictions and analyses.**	2, 5
5.41	Shipping, Receiving, and Internal Transfer of Special Nuclear Material at Fuel Cycle Facilities	Yes	No	This regulatory guide describes approaches and methods acceptable when developing material control and accounting (MC&A) system capabilities required by 10 CFR Part 74 “Material Control and Accounting of Special Nuclear Material,” for monitoring facility shipments and receipts, as well as internal transfers of licensed materials, at fuel cycle facilities. **AI technologies appear feasible to complement MC&A systems, to complement non-destructive assay technologies, and to support production of periodic reports. The guide is flexible to allow use of AI technologies. A general guide on software development and deployment may be needed to address reliability of AI software used in MC&A systems.**	5

RG	Title	Q1	Q2	Comment	Gap Type
5.44	Perimeter Intrusion Alarm Systems	Yes	No	This draft guide describes an approach that is acceptable to meet regulatory requirements for perimeter intrusion alarm systems used to identify unauthorized or attempted unauthorized access to: Category I, II, or III quantities of special nuclear material possessed by NRC licensees at fixed sites, and Source or byproduct material that NRC licensees receive, possess, use, transfer, and/or deliver. **The guide provides recommendations on intrusion alarm systems, their installation, and testing. This part of the guide is deemed independent of AI technologies. The guide also addresses surveillance within a protected area in case the intrusion detection system is bypassed. The main approach for surveillance is direct visual observation by patrols or video assessment equipment. NUREG-1959 addresses video playback. Video playback is assumed inspected by humans. AI provides surveillance alternatives including continuous monitoring of signals and video. The draft guide is modern, it was revised February 2023; however, it does not recognize AI alternatives for surveillance. Guidance is needed to address the reliability of video surveillance by AI systems.**	1, 5
5.71	Cyber Security Programs for Nuclear Power Reactors	Yes	No	This modern guide (2023) describes an approach that is acceptable to meet the regulatory requirements of 10 CFR 73.54, “Protection of digital computer and communication systems and networks.” This guide describes methods acceptable for establishing a cybersecurity program at a commercial nuclear power plant (NPP) to comply with regulations for adequately protecting digital computer and communication systems and networks against cyberattacks, up to and including the design-basis threat (DBT) as described in 10 CFR 73.1. This guide also provides guidance on the development of a cybersecurity plan (CSP) and examples of its security controls. The guide concerns cybersecurity plans and their broad components. The guide is modern, sound, and it is expected that software using AI technologies would comply with cybersecurity strategies described in the guide. The guide provides recommendations valid in general, including for software incorporating AI technologies. Use of AI technologies is within the scope of 10 CFR 73.54 and RG 5.71, and RG 5.71 Revision 1 are flexible to allow use of AI technologies. However, RG 5.71 does not provide adequate guidance for the use of AI technologies for cybersecurity applications. Future revisions of RG 5.71 may include guidance on use of AI for cybersecurity functions within nuclear facilities and may provide guidance regarding the security of AI applications used for safety, important to safety, security, and emergency preparedness functions at nuclear facilities. This includes security guidance for procuring, vendor and licensee testing, and operation and maintenance of the AI software.	5, 6
8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power	Yes	No	This regulatory guide provides information relevant to attaining goals and objectives for planning, designing, constructing, operating, and decommissioning a light-water reactor (LWR) nuclear power station to meet the criterion that exposures of station personnel to radiation during routine operations will be "as low as is reasonably achievable" (ALARA). **AI and large language models (LLMs) could possibly support some administrative practices such as analysis and reporting historical monitoring data to support radiation**	5, 7

RG	Title	Q1	Q2	Comment	Gap Type
	Stations Will Be as Low as Is Reasonably Achievable			**safety staff activities. The guidance has clearly defined roles for radiation safety staff (e.g., radiation protection manager, trained personnel) that limits the extent to which AI technology could be applied.**	
8.10	Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable	Yes	No	This regulatory guide describes acceptable methods and procedures for maintaining radiation exposures to workers and the public as low as is reasonably achievable (ALARA). **AI and large language models (LLMs) could support some of the administrative practices such as analysis and reporting historical monitoring data to support radiation safety staff activities. The guidance has clearly defined roles for radiation safety staff (e.g., RSO, technicians) that limits the extent to which AI technology could be applied.**	5, 7
8.11	Applications of Bioassay for Uranium	Yes	No	This regulatory guide describes acceptable methods for the development and implementation of a bioassay program for monitoring the intake of mixtures of uranium isotopes (U-234, U-235, and U-238) by occupationally exposed workers. This RG applies to special nuclear material licensees under 10 CFR Part 70, “Domestic Licensing of Special Nuclear Material.” **While many aspects of implementing a bioassay program would be conducted by cognizant radiation protection staff, air monitoring data analysis and related decision-making aspects could be supported by AI technology such as large language models.**	5, 7
8.15	Acceptable Programs for Respiratory Protection	Yes	No	This regulatory guide describes an acceptable respiratory protection program. This guide also provides guidance on performing evaluations to determine whether the use of respirators optimizes the sum of internal and external dose and other risks. Much of the guide addresses respiratory equipment and best practices for its use. The guide, in addressing evaluations (e.g., ALARA analyses), indicates supporting information could include the results of surveys, measurements and calculations, previous history with a job or similar jobs, or other pertinent data. **AI technology and LLMs could support evaluations of surveys and other historical data.**	5, 7
8.18	Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be as Low as Reasonably Achievable	Yes	No	This regulatory guide describes acceptable methods for maintaining exposures in medical institutions as low as is reasonably achievable (ALARA). **Some of the administrative practices such as analysis and reporting historical monitoring data to support radiation safety staff activities could plausibly be supported by AI technology and LLMs. The guidance has clearly defined roles for radiation safety staff (e.g., RSO, technicians) that limits the extent to which AI technology could be applied.**	5, 7
8.19	Occupational Radiation Dose Assessment in	Yes	No	This regulatory guide describes an acceptable method for performing an assessment of collective occupational radiation dose as part of the ongoing design review process involved in designing a light water-cooled power reactor (LWR) so that occupational radiation exposures will be ALARA.	5

RG	Title	Q1	Q2	Comment	Gap Type
	Light-Water Reactor Power Plants - Design Stage Man-Rem Estimates			The approach is a prescriptive accounting of accumulated population dose for various activities based on average dose rate, number of involved workers, duration, and frequency for each activity evaluated. **However, the guide does not specify how to obtain dose rates for the computation of collective doses. It may be possible to obtain dose rates from other facilities and reactors using AI methods such as large language models (LLMs), and/or using machine learning models to predict interpolated dose rates specific to the facility characteristics.**	
8.20	Applications of Bioassay for Radioiodine	Yes	No	This regulatory guide describes acceptable methods for the development and implementation of bioassay programs for adult workers and for licensees handling or processing unsealed materials containing iodine-123, iodine-124, iodine-125, iodine-129, and iodine-131, or a combination of these radionuclides. This guide does not address measurement techniques, radiochemistry analytical procedures, or dose assessment. It applies to both reactor and materials licensees. **Air monitoring data analysis and related decision-making aspects could be supported by AI technology and LLMs.**	5, 7
8.22	Bioassay at Uranium Mills	Yes	No	This regulatory guide describes an acceptable method for bioassay programs at uranium mills during uranium recovery operations and applicable portions of uranium conversion facilities where there is potential for exposure to uranium dust. This guide does not address measurement techniques and procedures. **Air monitoring data analysis and related decision-making aspects by radiation safety personnel could be supported by AI technology and LLMs. The regulatory guide states that trained personnel should review bioassay data, therefore, such activities are limited to staff (humans) rather than AI technology.**	5, 7
8.25	Air Sampling in the Workplace	Yes	No	This regulatory guide addresses air sampling in restricted areas (as defined in 10 CFR Part 20) of the workplace. The guide does not apply to activities conducted under 10 CFR Part 50 at reactor facilities. In this guide, the term "air sampling" includes the collection of samples for later analysis as well as real-time monitoring in which samples are analyzed as they are collected. The guide does not cover environmental or effluent sampling or the analysis of samples. **While much of the guidance is focused on methods, the guide also describes various evaluations of monitoring data that are used to assess representativeness of monitoring and to evaluate the effectiveness of the monitoring. These analyses and continuous monitoring could be supported by AI technology.**	5, 7
8.26	Applications of Bioassay for Fission and Activation Products	Yes	No	This regulatory guide identifies the bases used in evaluating the need for license provisions to require bioassay programs in installations where employees may be subject to internal radiation exposure from the inhalation or ingestion of fission or neutron activation products. The guide also describes methods for determining the persons to be included in a bioassay program, the sampling and measurement techniques to be used, the frequency of bioassay measurements, actions to be taken based on designated levels of internal radioactivity, estimations of internal dose to be calculated from bioassay measurements, and record systems to be maintained	5, 7

RG	Title	Q1	Q2	Comment	Gap Type
				appropriate to such bioassay programs. **It is envisioned radiation safety functions, including data analysis and decision-making aspects, could be supported by AI technologies including LLMs.**	
8.31	Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable	Yes	No	This guide addresses design criteria and administrative practices for maintaining occupational exposures ALARA in uranium recovery (UR) facilities (e.g., uranium milling, in situ leach facilities, ion exchange facilities, heap leach facilities). **Some of the administrative practices such as analysis and reporting historical monitoring data to support radiation safety staff activities could plausibly be supported by AI technology and LLMs. The guidance has clearly defined roles for radiation safety staff (e.g., RSO, technicians) that limits the extent to which AI technology could be applied.**	5, 7
8.32	Criteria for Establishing a Tritium Bioassay Program	Yes	No, but unlikely use of AI	This regulatory guide addresses conditions under which the NRC will consider the need for license conditions related to tritium bioassays under Part 20.108 of 10 CFR Part 20 and the scope, types, and frequency of tritium bioassay programs conducted by licensees for the purpose of demonstrating compliance with these requirements. **The guidance defines tritium activity and concentration levels that trigger tritium bioassay. While it is possible such criteria could be included in AI technology in support of general radiation safety functions, the approach described in the guidance is straightforward to implement and unlikely to benefit from application of AI technology.**	5, 7
8.34	Monitoring Criteria and Methods to Calculate Occupational Radiation Doses	Yes	No	This regulatory guide describes an acceptable approach to meeting the 10 CFR Part 20 requirements for monitoring and determining the radiation dose to occupationally exposed individuals. **Most of the guide addresses very specific calculation methods that are independent of AI technology. AI technology could be applied to querying monitoring data records for various purposes including determining if monitoring is required or reporting. Another specific portion of the guidance addresses the use of dosimeters that require processing to obtain results. The guidance states such dosimeters must be processed and evaluated by a dosimetry processor (technician) holding accreditation from the NVLAP pursuant to 10 CFR 20.1501(d). This presumably implies a certified human technician is required and that would limit the potential application of AI technology for this very specific and narrow activity (processing and evaluating dosimeters).**	5, 7
8.35	Planned Special Exposures	Yes	No	The regulatory guide addresses the conditions and prerequisites for permitting planned special exposure(s), as allowed by 10 CFR Part 20, the associated specific monitoring and reporting requirements, and examples of acceptable means of satisfying these requirements.	7

RG	Title	Q1	Q2	Comment	Gap Type
				Planned special exposures authorize exposures exceeding the routine occupational dose limits (e.g., to address an off-normal condition that could lead to even higher worker exposures) if several very specific conditions outlined in the guidance are met. Most of these conditions involve evaluating unique and emergent circumstances that are unlikely to be addressed by AI technology. One condition that involves determining the worker's doses from all previous planned special exposures and all doses in excess of the limits (including doses from accidents and emergencies) received during the lifetime of the individual involves extraction and processing of data from historical records which could be accomplished by AI technologies, including LLMs. It appears unlikely an AI system would be developed exclusively for this purpose, but it could be part of a broader occupational health software tool in support of radiation safety functions.	
8.36	Radiation Dose to the Embryo/Fetus	Yes	No	This regulatory guide addresses calculating radiation dose to the embryo/fetus based on monitored occupational exposure of a declared pregnant woman to radioactive materials. **The methodology for the calculation described in the regulatory guide is flagged for revision but is specific and independent of AI technology. The guide includes dose threshold criteria that is applied to monitoring of the declared pregnant woman. When the threshold is exceeded then an embryo/fetus dose calculation is triggered. Therefore, the evaluation of occupational exposure data to determine if a calculation should be conducted could be triggered by AI technologies, including LLMs. It appears unlikely an AI system would be developed only for this purpose but could be part of a broader occupational health software in support of radiation safety functions.**	5, 7
8.37	ALARA Levels for Effluents from Materials Facilities	Yes	No	This regulatory guide describes how to design an acceptable program for establishing and maintaining ALARA levels for gaseous and liquid effluents at materials facilities. **An ALARA program for these effluents includes procedures, engineering controls, and process controls, surveys and effluent monitoring, ALARA training, and reviews that can include analysis of trends in release concentrations and radionuclide usage as well as other available monitoring data. Aspects of such an ALARA program that involve data science applications to evaluate effluent monitoring data, human reliability/performance, component reliability, site conditions, historical trends or generate reports or engineering analysis focused on structures, systems, component reliability or longevity, preventive maintenance strategies could potentially utilize AI technology including LLMs. Development and implementation of AI methods may be limited due to development cost and typically low levels of operational effluent doses at materials facilities.**	5
8.38	Control of Access to High and Very High Radiation Areas of Nuclear Plants	Yes	No	This regulatory guide recommends a framework of graded radiation protection procedures to ensure that the controls for access to high and very high radiation areas at nuclear power plants are appropriate to the radiation hazards during both normal operations and abnormal operational occurrences. It addresses job planning, radiation protection coverage, survey techniques and frequencies, training of workers, prework briefing, frequency for updating radiation work permits (RWPs) or their equivalent, placement of measuring and alarming dosimeters.	5, 7

RG	Title	Q1	Q2	Comment	Gap Type
				Aspects that involve information gathering to make recommendations examining for example work orders, maintenance reports, condition reports could use AI technology including LLMs, including automatic production of reports and documents. AI technology could be used to support functions of radiation safety personnel.	
10.2[7]	Guidance to Academic Institutions Applying for Specific Byproduct Material Licenses of Limited Scope	Yes	No	This regulatory guide is limited to endorsing the methods contained in NUREG-1556, “Consolidated Guidance about Material Licenses,” Volume 7 "Program-Specific Guidance About Academic, Research and Development, and Other Licenses of Limited Scope, Including Electron Capture Devices and X-Ray Fluorescence Analyzers " which is focused on applicants providing descriptions, commitments, and procedures that appear unlikely to involve AI technologies with some exceptions (**e.g., approach to facility radiation surveys could potentially involve robotics and AI technology for compilation, storage, data analytics, and reporting**). **The guide is general, and it may not benefit from explicit discussion of AI technologies. Instead, reference to a general guide on AI uses may address potential needs.**	5
10.3[7]	Guide for the Preparation of Applications for Special Nuclear Material Licenses of Less than Critical Mass Quantities	Yes	No	This regulatory guide is limited to endorsing the methods contained in NUREG-1556, “Consolidated Guidance about Material Licenses,” Volume 17 "Program-Specific Guidance About Special Nuclear Material of Less Than Critical Mass Licenses" which is focused on applicants providing descriptions, commitments, and procedures that appear unlikely to involve AI with some exceptions **(e.g., approach to facility radiation surveys could potentially involve robotics and AI technology for compilation, storage, data analytics and reporting)**. **The NUREG does not include AI-specific guidance. Reference to a general guide on AI uses may address potential needs.**	5

[7] RG 10.2, 10.3 and 10.4 listed here in Appendix B were withdrawn on January 25, 2024. However, because they directly reference and have been replaced with guidance in NUREG-1556, they were included in this report.

RG	Title	Q1	Q2	Comment	Gap Type
10.4[7]	Guide for the Preparation of Applications for Licenses to Process Source Material	Yes	No	This regulatory guide is limited to endorsing the methods contained in NUREG-1556, “Consolidated Guidance about Material Licenses,” which has 21 volumes, each volume provides guidance applicable to different program areas that license applicants could use to assemble material license applications. Differences in the programs or types of licenses that are addressed (across volumes) leads to varying possibilities for the application of AI technologies. Some program-specific guidance is narrowly focused with no potential for AI use (i.e., volumes. 8,16,19), other programs involve potential security/access control considerations where AI technology could be applied (i.e., volumes 1-6), and several (i.e., volumes 7, 9-14, 17, 18, 21) involve more detailed radiation protection considerations (many citing applicable radiation protection regulatory guides that have been reviewed in preceding rows of this sheet) with many volumes also addressing security/access control considerations where AI technology could be applied. One (volume 20) is administrative in focus (e.g., the NRC license review process) and therefore is mostly independent of AI technology; however, it does describe specific roles for radiation safety staff that may need to be updated if AI technology is applied to radiation protection programs in a way that conflicts with existing descriptions of staff roles and responsibilities (e.g., an AI system could be developed to take functions of radiation safety officers). Overall, these material license guidance documents summarize or incorporate existing guidance addressed in the regulatory guides already reviewed and therefore, in general, do not introduce new issues regarding potential AI technology uses, rather, issues already identified in the review of regulatory guides would apply to the same topics that are addressed in these guidance documents. **The cited NUREGs do not include guidance useful to evaluate uses of AI technologies. A general guide on AI uses may address potential needs.**	2, 5, 7

APPENDIX C: COMMENTS ON REGULATIONS ASSOCIATED WITH THE SUBSET OF REGULATORY GUIDES WITH POTENTIAL GAPS

The following table includes comments on regulations associated with RGs with potential gaps with wording potentially conflicting with the use of AI technologies. The section symbol § in the table is used to avoid repetition because all cited sections are within Title 10 of the CFR. The Gap Type is described in Section 3.2 of the main report.

The referenced regulations listed in the fourth column of the following table are typically those cited in the most recent version of the regulatory guide. In certain instances, regulations have been revised without updating the corresponding regulatory guide. For example, RG 8.8 was published in 1978, and the regulations in 10 CFR Part 20 were subsequently revised. Therefore, some of the regulatory citations in RG 8.8 are no longer valid. In some of these instances, additional citations from available periodic NRC staff review documentation for the regulatory guide are listed. This was done to facilitate review of some regulations known to be related to the topic of the regulatory guide but is not intended to be an exhaustive or complete listing of all applicable regulations for these older guides.

RG	RG Title	Gap Type	Referenced Regulations	Comment
1.78	Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release	4	Part 50 Appendix A GDC 4, 19, §50.34(3)(i) §52.47(a)(3)(i), §52.79(a)(4)(i) Part 20 Subpart H, Part 20 Appendix A	Part 50 Appendix A General Design Criterion (GDC) 19 requires a control room with adequate radiation protection for human occupancy under normal and accident conditions. If autonomous operation supported by AI systems was successful so that human presence in the control room was not required all the time, the habitability criteria could be replaced, for example, by criteria to protect critical equipment. The radiation protection criterion in GDC 19 is expressed as a human dose (5 rem whole body dose or its equivalent to any part of the body) during the duration of the accident. Different radiation protection criteria may apply to equipment in the control room.
1.114	Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit	1	§73.2, §73.55(c) §50.54(k), Part 50 Appendix A GDC 19, 50.54(m)(2)(iii) §55.4	§50.54(k) calls for a licensed operator or licensed senior operator to be present at all times during the operation of a facility. It is implicit that the role of the operator is to “operate” the facility. This regulation could be interpreted to mean that actions by human operators are not to be replaced by actions by AI systems. Clarification would be useful on permissible actions by AI systems replacing human operators. Is it permissible for a human operator to take a passive role and to merely overview actions by AI systems? Should operators be present when they are not actively participating in operation? Part 50 Appendix A GDC 19 requires, in part, that a control room be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions, and to maintain the nuclear power plant in a safe condition under accident conditions. The term “actions can be taken” stated in the regulation is broad and could be interpreted to mean actions by anyone, human or computer. However, since human operators are required in the control room, it can also be interpreted that the only executors of “actions” in the control room are operators. Clarification would be useful on permissible actions by AI systems. §50.2 states that the term “controls,” when used with respect to nuclear reactors, means apparatus and mechanisms, the manipulation of which directly affects the reactivity or power level of the reactor. This definition appears general; it does not specify who executes the manipulation, which could be an AI system. §50.54(m)(2)(iii) states that when a nuclear power unit is in an operational mode other than cold shutdown or refueling, as defined by the unit’s technical specifications, each licensee must have a person possessing an active senior operator license for the nuclear power unit present in the control room at all times. In addition to this senior operator, a licensed operator or senior operator must be present at the controls at all times for each fueled nuclear power unit. It is implicit that operators are present to take actions and control, and not just to provide oversight for example of actions by AI systems. Clarification would be useful on whether control actions can be directly executed by AI systems, and if so, whether humans should be present in the control room when not actively engaged in the operation of the facility.

RG	RG Title	Gap Type	Referenced Regulations	Comment
1.157	Best-Estimate Calculations of Emergency Core Cooling System Performance	2	§50.46, §50.46(a)(1), §50.46(b)(1) through (b)(5), Part 50 Appendix K	Requirements in §50.46 emphasize physical models for emergency core cooling systems to demonstrate the system operates within specifications. Part 50 Appendix K regulations emphasize physical models, and the regulations are explicit and detailed on acceptable models. Machine learning (ML) models trained on empirical data and data from other high-resolution models would likely differ from acceptable models stated in the regulations. ML models synthesize information from databases and could be used for predictions; however, these ML models may not satisfy Part 50 Appendix K. In this case, the use of AI models in the scope of RG 1.157 is practically not allowed by the underlying regulations, mainly Part 50 Appendix K.
1.189	Fire Protection for Nuclear Power Plants	4	Part 50 Appendix A GDC **3**, 5, **19**, 23, §50.48(a) through (c), Part 50 Appendix R §52.47, §52.79, §52.137 and §52.157	The applicable regulations cited in RG 1.189 are robust to address AI systems. The only issue identified concerns habitability requirements under Part 50 Appendix A GDC 19. Fires can damage computer equipment and existing requirements to keep computer equipment safe also apply for computer systems hosting AI systems. The only potential issue is related to Part 50 Appendix A GDC 19, which requires habitability of the control room (including under fires). As identified in other entries in this table, habitability requirements (e.g., breathable and clean air, free of smoke and with sufficient oxygen) could be replaced by requirements to keep equipment safe, if power plants could be autonomously operated supported by AI systems.
1.196	Control Room Habitability at Light-Water Nuclear Power Reactors	4	Part 50 Appendix A GDC 1, 3, 4, 5, 19	The main regulation concerning control room habitability is Part 50 Appendix A GDC 19. GDC 19 calls for a control room with radiation protection to allow human operation. The regulation does not define in detail the meaning of habitability; habitability requirements are only implicit. As stated in RG 1.79 and RG 1.189, habitability requirements could be replaced by requirements to keep equipment safe if a power plant could be autonomously operated supported by AI systems. It would be useful to address whether habitability under accident conditions in the control room is required independently of the level of autonomy achievable with AI systems.
1.203	Transient and Accident Analysis Methods	2	§50.34, §50.46, Part 50 Appendix K	As stated under RG 1.157, requirements in §50.46 emphasize physical models for emergency core cooling systems to demonstrate the system operates within requirements. Part 50 Appendix K regulations emphasize physical models, and the regulations are explicit and detailed on acceptable models. Machine learning (ML) models trained on empirical data and data from other high-fidelity models may differ from acceptable models stated in the cited regulations. ML models synthesize information from databases and could be used for predictions; however, these ML models may not satisfy requirements in Part 50 Appendix K. The use of AI models in the scope of RG 1.203 is practically not allowed by the underlying regulations, mainly Part 50 Appendix K.

RG	RG Title	Gap Type	Referenced Regulations	Comment
1.245	Preparing Probabilistic Fracture Mechanics (PFM) Submittals	2	§50.55a, §50.60, §50.61, §50.61a, §50.66, §50.69, Part 50 Appendix G, Part 50 Appendix H §52 Appendix A, §52 Appendix B, §52 Appendix C, §52 Appendix D, §52 Appendix E, §52 Appendix F, §52 Appendix G §71.43, §71.45, §71.51, §71.55, §71.64, §71.71, §71.73, §71.74, §71.75 §72.122	The main concern expressed in the regulatory guide is the use of AI technologies in special computations in support of probabilistic fracture mechanics analyses. §50.61 “Fracture toughness requirements for protection against pressurized thermal shock events” and §50.61a “Alternate fracture toughness requirements for protection against pressurized thermal shock events” describe specific approaches to compute fracture toughness. Those specific approaches may constrain the use of AI technologies for specific calculations. The applicable regulations cited in the regulatory guide are extensive and are potentially related to other issues than AI in special computations. The applicable regulations also refer to operation of nuclear power plants (which may have statements on the implicit role of operators). For example, §50.55a(a)(1)(iv) lists ASME codes of Operation and Maintenance of Nuclear Power Plants. The operation and maintenance ASME codes may refer to the role of human operators, which could implicitly limit the scope of AI systems. **The list of ASME codes in §50.55a(a)(1)(iv) is extensive and those codes were not examined in this project in detail**. The following standards are referenced in Part 50 Appendix H “Reactor Vessel Material Surveillance Program Requirements: • ASTM E 185–73, "Standard Recommended Practice for Surveillance Tests for Nuclear Reactor Vessels" • ASTM E 185–79, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels", and • ASTM E 185–82, "Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels" Special techniques are commonly used to examine radiation effects on mechanical properties of materials, which require human actions envisioned difficult to replace with AI systems. It is unlikely AI techniques would be used for surveillance of reactor vessels. Nonetheless, the ASTM codes referred in the prior bullets may need to be examined to identify if actions implicitly or explicitly stated as executed by humans could be replaced by actions controlled by AI systems. **That detailed examination was not accomplished in the current project**.

RG	RG Title	Gap Type	Referenced Regulations	Comment
5.27	Special Nuclear Material Doorway Monitors	1, 5	§73.46(d)(9), §73.60(b), §73.20(b)(4), §73.46(g), §73.60(d)(1)	§73.46(d)(9) calls for "searches" for firearms, explosives, and incendiary devices, but it does not say how those searches should be executed. However, §73.46(d)(9) states that "All vehicles, materials and packages, including trash, wastes, tools, and equipment exiting from a material access area must be searched for concealed strategic special nuclear material by a team of at least two individuals who are not authorized access to that material access area. Each individual exiting a material access area shall undergo at least two separate searches for concealed strategic special nuclear material. For individuals exiting an area that contains only alloyed or encapsulated strategic special nuclear material, the second search may be conducted in a random manner." In this case, the regulation defines actions by humans that could not be substituted by AI systems. Likewise, §73.46(d)(10) and §73.46(d)(11) refer to actions by at least two individuals, implicitly stating that those actions cannot be executed by AI systems. §73.46(d)(13) refers to escorted access by a "watchman." §73.46(e)(3) states "Vaults and process areas that contain strategic special nuclear material that has not been alloyed or encapsulated shall also be under the surveillance of closed-circuit television that is monitored in both alarm stations." This type of surveillance could be executed by AI systems, but the regulation implicitly states humans do the surveillance of video. §73.46(e)(9) states "Methods to observe individuals within material access areas to assure that strategic special nuclear material is not moved to unauthorized locations or in an unauthorized manner shall be provided and used on a continuing basis." It is implicit that human personnel "observe" instead of systems with computer vision. §73.60(b) Exit Requirement states "Each individual, package, and vehicle shall be searched for concealed special nuclear material before exiting from a material access area unless exit is into a contiguous material access area. The search may be carried out by a physical search or by use of equipment capable of detecting the presence of concealed special nuclear material." In this case, the regulation explicitly allows for alternatives than search by humans.

RG	RG Title	Gap Type	Referenced Regulations	Comment
5.44	Perimeter Intrusion Alarm Systems	1, 5	§20.1801, §20.1802 §50.34(c)(1), §50.34(c)(2), §52.79(a)(35)(i) §70.22(h)(1) §72.180 §73.20, §73.40, §73.45(c), §73.45(f), §73.46(c), §73.46(e)(1), §73.46(e)(3), §73.46(e)(4), §73.46(e)(5), §73.46(e)(7), §73.46(e)(8), §73.46(g), §73.46(h)(4), §73.46(h)(6)	73.46(e)(3) states "Vaults and process areas that contain strategic special nuclear material that has not been alloyed or encapsulated shall also be under the surveillance of closed-circuit television that is monitored in both alarm stations." It is implicit that monitoring is executed by humans.
8.8	Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable	5, 7	§20.1(c), §20.103, §20.203, §20, Appendix B, Table 1, Col 1	Access control requirements in §20.1601(a)(2) refer to "a supervisor" being present and informed of an access to a high-radiation area; §20.1601(f) refers to "personnel" being present to take action to control exposures in high radiation area in a hospital. Note: Referenced regulations cited in RG 8.8 are out of date. Relevant regulations with perceived potential gaps are discussed here and listed in Section 3.3, Table 3-9.

RG	RG Title	Gap Type	Referenced Regulations	Comment
8.10	Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable	5, 7	§20.1003 (definition ALARA), §20.1101(b), §20.1101(c), §20.1101(d), §20.1206(c)(3), §20.1402, §20.1601(f), §20.1702(a), §20.1702(b), §20.2002(d), §20.2105(a)(5), §20.2203(a)(2)(vi), §20.2203(b)(1)(iv)	20.1601(f) refers to "personnel" being present to take action to control exposures in high radiation area in hospital.
8.18	Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be as Low as Reasonably Achievable	5, 7	§20.1101(b), §20.1301, §20.1601, §20.1902 §35.24(e), §35.24(f), §35.50, §35.59, §35.67(g), §35.69, §35.70(a), §35.75, §35.92, §35.2067(b)	Access control requirement in §20.1601(a)(2) refers to "a supervisor" being present and informed of an access to a high-radiation area; §20.1601(f) refers to "personnel" being present to take action to control exposures in high radiation area in hospital. §35.24(e) and §35.24(f) pertains to the establishment of a Radiation Safety Officer and Radiation Safety Committee, respectively, under specified conditions to implement the radiation protection program and oversee all uses of byproduct material permitted by the license. Committee is comprised of "members" who can be reasonably assumed to be people, which is limiting regarding membership and functions; however, it does not appear to restrict use of AI technology in a supporting role. §35.50 in addressing training for Radiation Safety Officers and Associate Radiation Safety Officers describes detailed qualifications for an RSO and associate RSO, which establishes the RSO as an "individual". The requirements do not appear to limit use of AI technology in a supporting role. §35.59 addresses recentness of training for all "individuals" trained under Part 35 Subparts B, D, E, F, G, and H (inclusive of qualifications for various individuals performing a variety of medical treatments including medical physicists, imaging and localized studies, administration of byproduct material, ophthalmic use of Sr-90, teletherapy, and others). The requirements do not appear to limit the use of AI technology in a supporting role. §35.2067(b) addresses inventory records requirements for leak tests, sealed source and brachytherapy source inventory. §35.2067(b) indicates that the inventory record should include “name of the individual who performed the inventory.” The requirements do not appear to limit the use of AI technology in a supporting role.

RG	RG Title	Gap Type	Referenced Regulations	Comment
8.25	Air Sampling in the Workplace	5, 7	§20.1204, §20.1501, §20.1703, §20.1902, §20.2103, §20.2202, §20.2203	§20.1501(d) requires dosimeters that require processing in order to determine the radiation dose and that are used by licensees to comply with NRC requirements or license conditions must be processed and evaluated by a dosimetry processor holding current personnel dosimetry accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of Standards and Technology. This requirement suggests a person would be needed process these dosimeters and that would limit application of AI technology for this purpose, although it does not appear to limit the use of AI technology in supporting the human processor. §20.2103(b) requires the licensee to retain records until the Commission terminates the license (that requires the record) including records of the results of surveys to determine the dose from external sources; records of the results of measurements and calculations used to determine individual intakes of radioactive material and used in the assessment of internal dose; records showing the results of air sampling, surveys, and bioassays required pursuant to §20.1703(c)(1) and (2); and records of the results of measurements and calculations used to evaluate the release of radioactive effluents to the environment. These requirements do not fully restrict the use of AI technology, however, they may limit how the technology can be used (i.e., if AI technology, for example, processes monitoring data, conducts calculations, or provides reports that are used in demonstrating compliance with Part 20 requirements or license conditions then those inputs to compliance/safety determinations may need to be captured as physical or individual records at the time they are used/generated rather than be reproducible from system queries of raw data or recalculations at a later time).
8.26	Applications of Bioassay for Fission and Activation Products	5, 7	§20.108	As noted (in more detail) for RG 8.25, requirements at §20.2103(b) do not fully restrict the use of AI technology, however, they may limit how the technology can be used (i.e., if AI technology, for example, processes monitoring data, conducts calculations, or provides reports that are used in demonstrating compliance with Part 20 requirements or license conditions, then those inputs to compliance/safety determinations may need to be captured as physical records at the time they are used/generated rather than be reproducible from system queries of raw data or recalculations at a later time). Note: Referenced regulations cited in RG 8.26 are out of date. Relevant regulations with perceived potential gaps are discussed here and listed in Section 3.3, Table 3-9.
8.32	Criteria for Establishing a Tritium Bioassay Program	5, 7	§20.101, §20.103, §20.108, §20.405. §20.408, §20.409	As noted (in more detail) for RG 8.25, requirements at §20.2103(b) do not fully restrict the use of AI technology, however, they may limit how the technology can be used (i.e., if AI technology, for example, processes monitoring data, conducts calculations, or provides reports that are used in demonstrating compliance with Part 20 requirements or license conditions then those inputs to compliance/safety determinations may need to be captured as physical or individual records at the time they are used/generated rather than be reproducible from system queries of raw data or recalculations at a later time). Note: Referenced regulations cited in RG 8.32 are out of date. Relevant regulations with perceived potential gaps are discussed here and listed in Section 3.3, Table 3-9.

RG	RG Title	Gap Type	Referenced Regulations	Comment
8.34	Monitoring Criteria and Methods to Calculate Occupational Radiation Doses	5, 7	Part 19, §19.12, §19.13 Part 20, §20.1003, §20.1007, §20.1101, §20.1201, §20.1202, §20.1203, §20.1204, §20.1206, §20.1207, §20.1208, §20.1501, §20.1502, §20.1701, §20.1702, §20.1703, §20.1704, §20.1705, §20.2103, §20.2104, §20.2106, §20.2206, §20.2301	§20.1501(d) requires dosimeters that require processing to determine the radiation dose and that are used by licensees to comply with NRC requirements, or license conditions must be processed and evaluated by a dosimetry processor holding current personnel dosimetry accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of Standards and Technology. This requirement suggests a person would be needed process these dosimeters and that would limit application of AI technology for this purpose, although it does not appear to limit the use of AI technology in supporting the human processor. §20.2103(b) requires the licensee to retain records until the Commission terminates the license (that requires the record) including records of the results of surveys to determine the dose from external sources; records of the results of measurements and calculations used to determine individual intakes of radioactive material and used in the assessment of internal dose; records showing the results of air sampling, surveys, and bioassays required pursuant to §20.1703(c)(1) and (2); and records of the results of measurements and calculations used to evaluate the release of radioactive effluents to the environment. These requirements do not fully restrict the use of AI technology, however, they may limit how the technology can be used (i.e., if AI technology, for example, processes monitoring data, conducts calculations, or provides reports that are used in demonstrating compliance with Part 20 requirements or license conditions, then those inputs to compliance/safety determinations may need to be captured as physical or individual records at the time they are used/generated rather than be reproducible from system queries of raw data or recalculations at a later time).
8.38	Control of Access to High and Very High Radiation Areas of Nuclear Plants	5, 7	§20.1101, §20.2102, §20.1601, §20.1602, §20.1902	Access control requirement in §20.1601(a)(2) refers to "a supervisor" being present and informed of an access to a high-radiation area; §20.1601(f) refers to "personnel" being present to take action to control exposures in high radiation area in hospital. Other access control requirements use flexible language (e.g., shall take measures to control) or otherwise do not include text that would restrict or conflict with the use of AI technology.

RG	RG Title	Gap Type	Referenced Regulations	Comment
10.3	Guide for the Preparation of Applications for Special Nuclear Material Licenses of Less than Critical Mass Quantities	5	Part 70 §150.11	§70.62(c)(2) addresses integrated safety analysis team qualifications including that the analysis must be performed by a team with expertise in engineering and process operations and include a minimum number of persons that have experience in specified topics (e.g., criticality safety, radiation safety, fire safety, chemical process safety, and the specific integrated safety analysis methodology being used). This may limit the degree that AI technology could be used in an integrated safety analysis but may not limit its use in a supporting role. §70.74 addresses reporting to the NRC Operations Center the events described in Part 70 Appendix A and that reports must be made by a knowledgeable licensee representative. This appears to limit the act of reporting to individuals but may not limit the use of AI technology in a supporting role (e.g., event detection, compiling information, analysis of data, triggering actions support).
10.4	Guide for the Preparation of Applications for Licenses to Process Source Material	2, 5, 7	Part 20 Part 40 Part 71 Part 75 Part 76	Reviews of the cited requirements in the radiation protection regulatory guides are expected to sufficiently address the key Part 20 requirements (see preceding notes for RGs in the 8.X series where some requirements in Part 20 were found to contain text that could potentially restrict the use of AI under specific circumstances). Parts 40, 71, 75, and 76 were reviewed in their entirety and found to not contain text that conflict with the use of AI technology in the context of where it might be applied. Note that Part 76 applies only to specific facilities that have ceased operations and were returned to DOE for decommissioning.