Data Science and AI Regulatory Applications Public Workshop

AI Regulatory Gap Analysis Update

September 17, 2024

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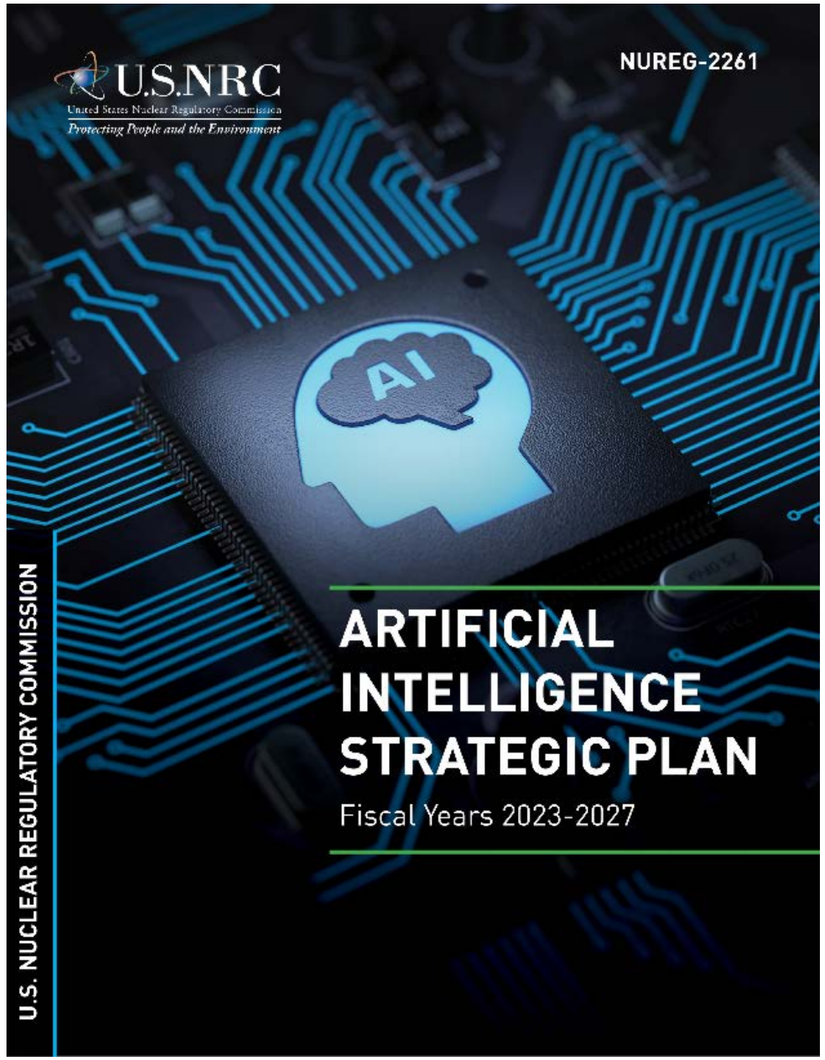
NRC AI Strategic Plan

- NUREG-2261 issued May 2023
- AI Project Plan (AIPP) issued September 2023
  - The AI Project Plan describes how the agency will execute the five strategic goals from the AI Strategic Plan
  - Provides estimated timelines for various task completions within each Strategic Goal
  - Communicates NRC priorities to internal and external stakeholders
- AI research activities
  - AI safety and security test, evaluation, verification and validation (AIPP, Task 1.3)
  - US-Canada-UK Trilateral Collaboration on AI (ML24241A252)
  - AI standards engagement (IEC, ANS, ASME)



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AI Regulatory Framework Applicability Assessment

- Project objectives
  - Assess the applicability of the existing regulatory framework in considering the unique aspects of AI applications
  - Determine where regulatory gaps may exist which could require updating existing or developing new regulations, guidance, or procedures to evaluate and review AI uses in NRC-regulated activities
- Project phases
  - AI-specific technology considerations
  - Literature review of regulatory requirements and guidance
  - Regulatory applicability assessment
  - AI-specific regulatory considerations
  - Review of AI standards
- Project supports AI Project Plan, Task 1.1

Potential AI Technical Considerations for Regulatory Decision-Making

Explainability	Trustworthiness	Bias
Robustness	Ethics	Security
Risk Analysis	Test, Evaluation, Verification and Validation	Assurance Processes
Model Maintenance	Domain Adaptation	Data Drift
Fielded Performance Degradation	Life Cycle Management	Data Quality, Quantity, Applicability, and Uncertainty

Regulatory Framework Applicability Assessment of Artificial Intelligence in Nuclear Applications (AIRGA: AI Regulatory Gap Analysis)

SOUTHWEST RESEARCH INSTITUTE®

O. Pensado, P. LaPlante, M. Hartnett, K. Holladay

Data Science and AI Regulatory Applications Workshop:
AI Regulatory Framework Applicability Considerations

September 17, 2024

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- The work is an independent product of SwRI and it does not necessarily reflect the views of the NRC

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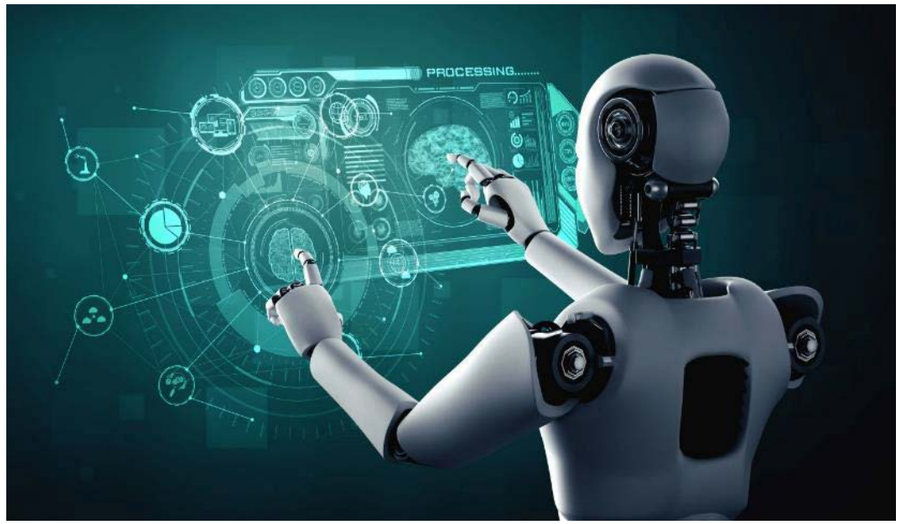
Project Objective

- Support NRC's readiness to evaluate uses of AI technologies in NRC-regulated activities
- Main task: conduct an AI regulatory gap analysis (AIRGA)
  - Identify types of AI technologies to be potentially used in the nuclear industry
  - Identify potential AI uses in NRC-regulated activities
  - Examine whether the existing regulatory framework is appropriate for AI technologies



Project Scope

- Regulatory framework considered
  - NRC's regulations, Title 10, Chapter I, of the Code of Federal Regulations, Parts 1 – 171
  - 517 regulatory guides (RGs)
- Out of scope guidance documents:
  - NUREGs, Interim Staff Guidance (ISG), Standard Review Plan (SRP), Inspection Procedures, and standards cited in regulations
  - Technical areas without specific RGs, such as human factors engineering (ISG 2023-03, NUREG-0711, NUREG-0700), may need to be examined in the future

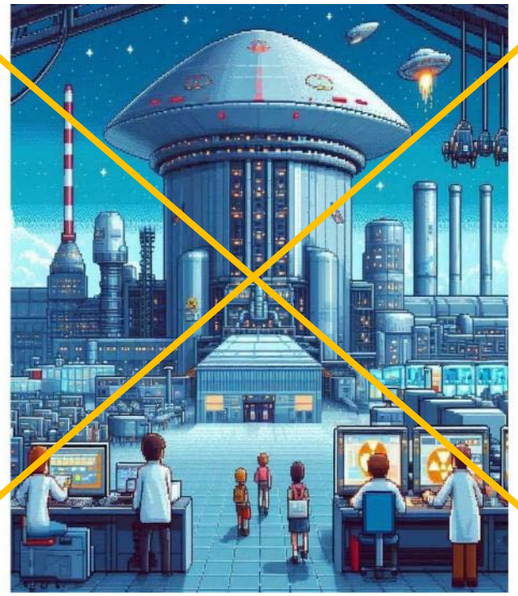
Main Project Tasks

Task 1: Identify examples of AI uses

Task 2: Analyze RGs to identify potential gaps

Task 3: Analyze regulations applicable to the subset of RGs with potential gaps

Task 4: Examine AI standards by professional communities



- Considered examples of AI uses based on known applications and R&D activities
- Examples discussed in past Data Science and AI Regulatory Applications Workshops
- Examples in NUREG/CR-7294

Analysis Approach for Regulatory Guides

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

NO → RG is excluded from further analysis. No gap in the RG

YES

Q1: Is the regulatory guide flexible to allow use of AI?
Q2: Does the regulatory guide provide adequate guidance to evaluate the use of AI?

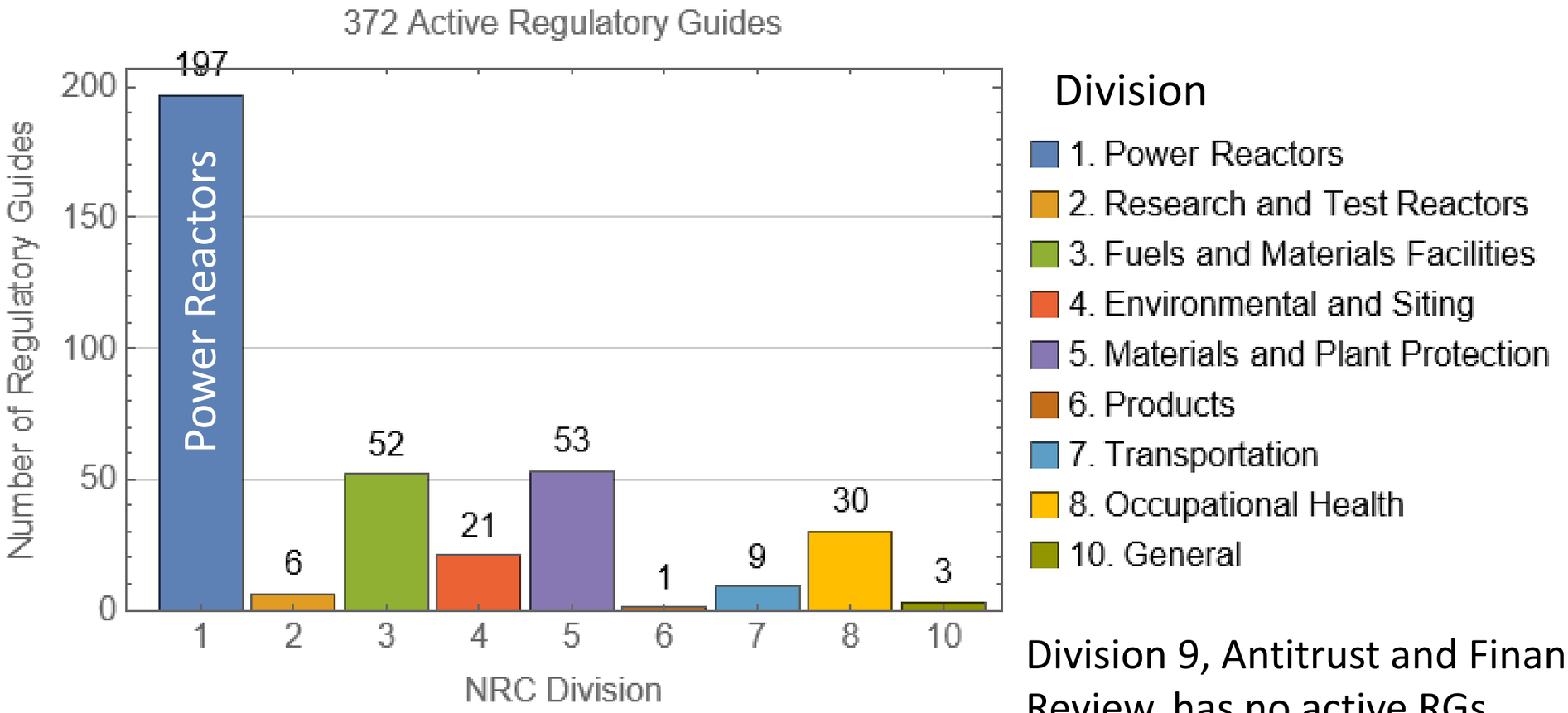
Answer to Q1 or Q2 is NO → The RG has a potential gap: detailed notes are recorded in report appendices

YES

Answer to both Q1 and Q2 is YES

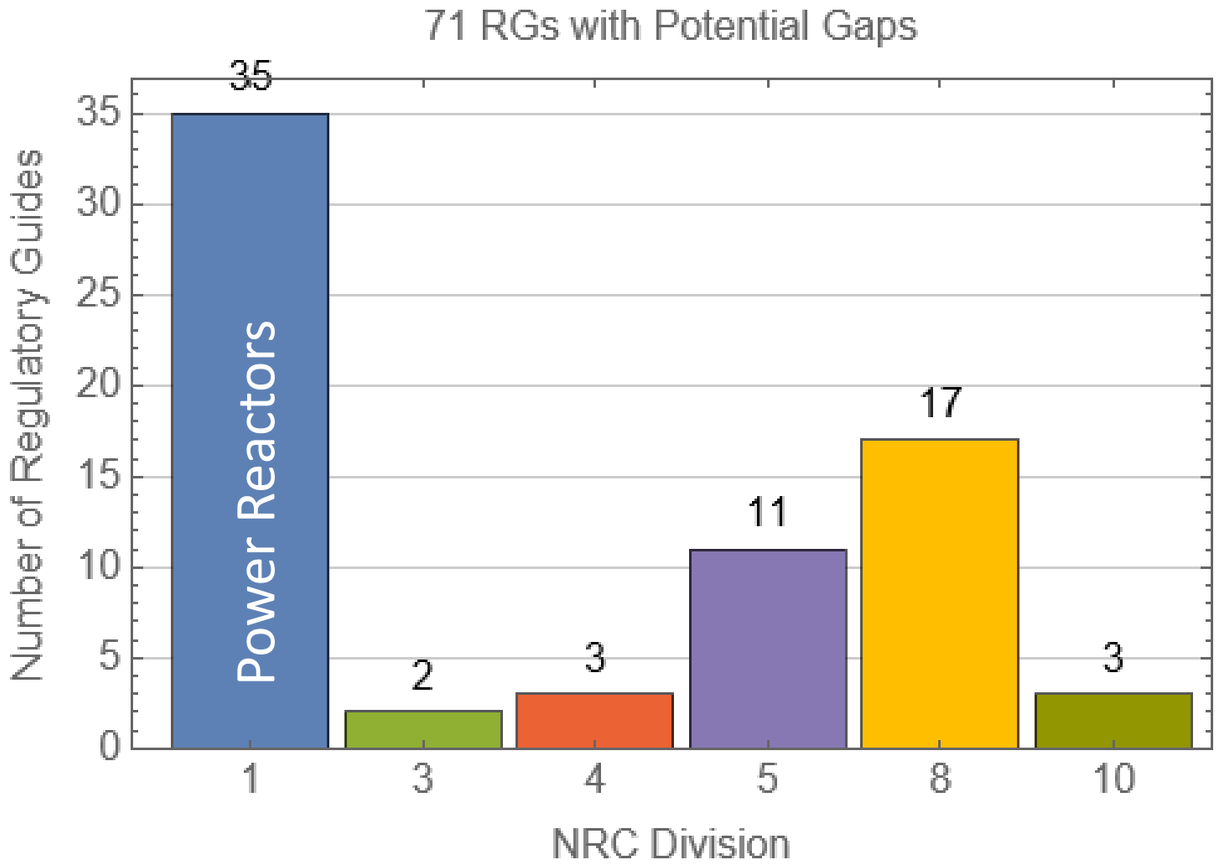
No gap in the RG

Regulatory Guides: 372 active RGs



Division 9, Antitrust and Financial Review, has no active RGs

Regulatory Guides with Potential Gaps



Division
- 1. Power Reactors
- 3. Fuels and Materials Facilities
- 4. Environmental and Siting
- 5. Materials and Plant Protection
- 8. Occupational Health
- 10. General

The RGs of divisions missing in the chart do not have potential gaps

- 71 RGs with potential gaps after applying the process from slide 7
  - Questions Q0, Q1, and Q2

Categories of Potential Gaps

- 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 Critical Applications
- Gap 7: Radiation Safety Support
- Gap 8: Miscellaneous: Training, Human Factors Engineering, and AI Introduced as Changes

Gap 1: Guides call for human manual actions; AI systems may offer different alternatives to execute those actions

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

Gap 2: AI techniques may be used in special computations; guidance may be needed on documentation and verification

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

Gap 3: Critical AI systems may need to be explicitly included in preoperational and initial testing programs

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

Gap 4: Habitability conditions under autonomous operations; variable role of operators

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

Gap 5: Periodic testing, monitoring, surveillance, and reporting; AI systems may offer different strategies for those activities

- RGs related to testing and monitoring deemed with potential gaps:

1.7	1.205	5.11	**5.71**	8.22	8.38
1.9	1.246	5.21	8.8	8.25	10.2
1.21	3.27	5.23	8.1	8.26	10.3
1.9	3.76	5.27	8.11	8.31	10.4
1.118	4.1	5.37	8.15	8.32	
1.129	4.14	5.38	8.18	8.34	
1.141	4.16	5.41	8.19	8.36	
1.147	5.7	5.44	8.2	8.37	

- RG 5.71 Cyber Security Programs for Nuclear Power Plants: AI may be used as monitoring tool to detect anomalies as indicators of cyber attacks

Gap 6: Software guides may need to be updated to address special features and risks of AI systems

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

Gap 7: Radiation safety support; AI may be used for tasks and functions of radiation safety professionals

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

Gap 8: Miscellaneous: Training, Human Factors Engineering, and AI Introduced as Changes

Table 3-8. Regulatory guides related to Gap 8: Miscellaneous: Training, Human Factors Engineering, and AI Introduced as Changes	
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
5.74	Managing the Safety/Security Interface

The analysis identified only few gaps in applicable regulations

- Regulations applicable to the RGs deemed with potential gaps were examined
  - Not all the regulations were examined in detail
- In general, the applicable regulations (10 CFR 1 to 171) were high level and adequate for AI technologies, with a few exceptions
- The exceptions are related to regulatory statements calling for actions by humans when those actions could also be executed by AI systems
  - Surveillance using computer vision
  - Searches of people and vehicles
  - Escorting people in facilities
- Some regulations should be examined in light of questions related to autonomous operation and control room habitability
  - Role of operators, protection of equipment in the control room, constraints on autonomous operation

Recommendations

- Develop few general guides addressing cross-cutting issues associated with potential gaps, such as software development with AI systems and use of AI in special computations
  - More efficient to develop few guides than inserting explicit AI considerations in many RGs
- Existing AI standards by professional societies do not readily address the identified potential gaps

Potential cross-cutting guides

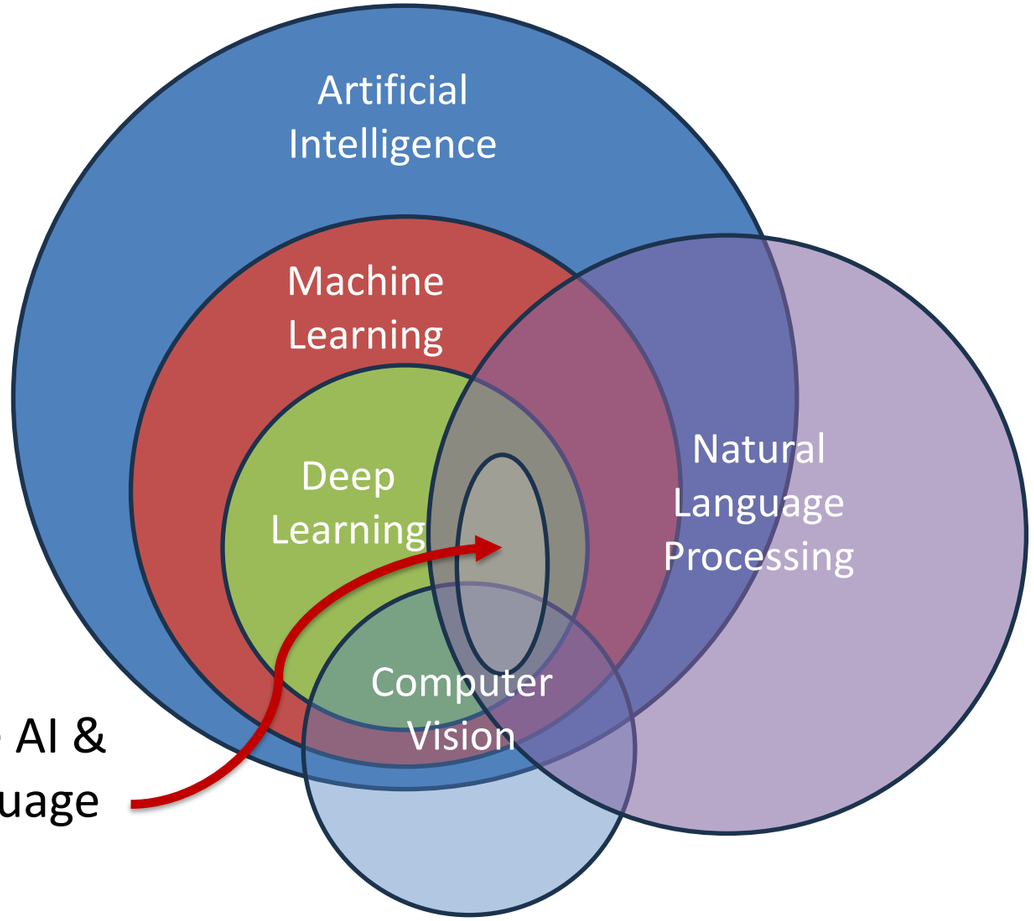
1. Data quality for machine learning (ML) purposes, including aspects of accuracy, context, data management, data variety, and data quantity.
2. Type of systematic testing and documentation needed to enhance confidence in responses by AI systems, with emphasis on rare and extreme inputs.
3. Systematic 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. Types of testing and documentation needed to enhance confidence in computations and predictions that use AI techniques.

Backup Slides

Abbreviations and acronyms

AI	Artificial intelligence
AIRGA	AI regulatory gap analysis
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
FAA	U.S. Federal Aviation Administration
FDA	U.S. Food and Drug Administration
HFE	Human factors engineering
IEEE	Institute of Electical and Electronics Engineers
ISG	Interim Staff Guidance
LLM	Large language model
ML	machine learning
NRC	U.S. Nuclear Regulatory Commission
PFM	Probabilistic fracture mechanics
R&D	Research and development
RG	Regulatory Guide
SRP	Standard Review Plan
SwRI	Southwest Research Institute

Terminology



- AI includes a range of technologies
- Deep neural networks and machine learning methods are notable because of their broad range of applicability

Potential future work

- Examine work by the FDA and FAA to regulate AI, to yield insights useful in developing the guidance described in recommendations 1 through 4.
- Deploy a pilot program aimed at evaluating computations by an existing licensee using AI technologies, to yield insights relevant to recommendation 4 (use of AI for special computations).