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AI model performance metrics for application in nuclear power plants

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1. Introduction

As the trends and convergence of cutting-edge technology into nuclear energy sector, it is agreeable that regulatory standards and guidelines will also need to respond flexibly. What should we consider in order to develop the performance metrics especially for artificial intelligence (AI) model by classifying performance evaluation?

As in Table 1, most of the national R&Ds related for nuclear energy are composed of AI-based technologies and software products including bigdata for safety enhancement.

Table 1 R&D topics related to IoT[1]

	Total RFP	Standard Interface	IoT, AI, bigdata
MOTIE	16(81.3%)	4(25%)	9(56.3%)
MSIT	61(78.6%)	24(39.3%)	24(39.3%)

This article describes examples and practice to categorize the reliability metrics and provide the additional performance metric elements that should be considered in special theme that is closely relevant to AI models.

2. Conventional Integrity Levels

2.1 IEC 61508 series[1]

IEC 61508 series is a basic functional safety standard applicable to all industries, and provides SIL of safety-related systems.

Table 2 IEC 61508-1 SIL

Safety Integrity Level (SIL)	Probability of Failure Demand (PFD_{avg})	Risk Reduction Factor (RRF)
SIL 4	$\geq 10^{-5}$ to $<10^{-4}$	100,000 to 10,000
SIL 3	$\geq 10^{-4}$ to $<10^{-3}$	10,000 to 1,000
SIL 2	$\geq 10^{-3}$ to $<10^{-2}$	1,000 to 100
SIL 1	$\geq 10^{-2}$ to $<10^{-1}$	100 to 10

2.2 IEEE 1012[2]

IEEE 1012 provides a range of values that represents complexity, criticality, risk that represent software complexity, safety level, security level, desired performance, reliability, or other project-unique characteristics that define the importance of the software to the user and acquirer as in Table 3 and 4.

Table 3 Consequence

Consequence	Definitions
Catastrophic	Loss of human life, complete mission failure, loss of system security and safety, or extensive financial or social loss
Critical	Major and permanent injury, partial loss of mission, major system damage, or major financial or social loss.
Marginal	Severe injury or illness, degradation of secondary mission, or some financial or social loss.
Negligible	Minor injury or illness, minor impact on system performance, or operator inconvenience.

Table 4 Consequence and SIL

Error consequence	Likelihood of occurrence of an operating state that contributes to error			
	Reasonable	Probable	Occasional	Infrequent
Catastrophic	4	4	4 or 3	3
Critical	4	4 or 3	3	2 or 1
Marginal	3	3 or 2	2 or 1	1
Negligible	2	2 or 1	1	1

3. Performance metrics

3.1 Microsoft AI builder performance metrics [3]

Microsoft announce the grade for AI model (Table 5) used in general industry that could be considerable in nuclear power plants.

Table 5 MS AI builder performance metrics

Grade	Guidance
A	It might still be possible to improve the model, but this is the best grade you can get.
B	The model is correct in a lot of the cases. Can it be improved? That depends on your unique circumstances, data, and requirements.
C	The model is doing slightly better than a random guess. It might be acceptable for some applications, but in most cases, this is a model that you'd continue to tweak and improve.
D	Something's wrong. Your model is either

[1] Operational plant safety enhancement R&D topic-based

Grade	Guidance
	performing worse than we'd expect a random guess to perform (underfit model). Or, it's performing so well (at or near 100%) that you've probably got a data column that is directly correlated to the result (overfit model) .

3.2 NRC's AI autonomy level [4]

Recently NRC issues the report of "AI Strategic plan" to ensure continued staff readiness to review and evaluate AI applications effectively and efficiently for ultimately application in nuclear power plants. NRC announces the AI autonomy level and its description (Table 6) that may require greater regulatory scrutiny of the AI system.

Table 6 NRC AI autonomy level

National AI and autonomy level	Potential Uses of AI and Autonomy in Commercial Nuclear Activities
Level 0: AI not used	No AI or autonomy integration in systems or processes
Level 1: Insight (Human decision-making by a machine)	AI integration in systems is used for optimization, operational guidance, or business process automation that would not affect plant safety/security and control
Level 2: Collaboration (Human decision-making augmented by a machine)	AI integration in systems where algorithms make recommendations that could affect plant safety/security and control are vetted and carried out by a human decisionmaker
Level 3: Operation (Machine decision-making supervised by human)	AI and autonomy integration in systems where algorithms make decisions and conduct operations with human oversight that could affect plant safety/security and control
Level 4: Fully autonomous (Machine decision-making with no human intervention)	Fully autonomous AI in systems where the algorithm is responsible for operation, control, and intelligent adaptation without reliance on human intervention or oversight that could affect plant safety/security and control

Through §2 and §3, this material summarizes the conventional reliability and AI model performance metrics in general and nuclear industry. Just as the NRC studies regulatory strategies for applying AI model nuclear power plants, regulations, strategies, and guidelines should be studied domestically as well.

In other words, in order to guarantee performance through learning and optimization of the AI model, direct factors (data quality, data quantity and use of meta data, etc.) in addition to existing AI performance indicators must be used as grading criteria input.

4. Conclusion

For application of AI model in nuclear power plants, reasonable performance metrics and relevant AI standards should be prepared for readiness of regulation and application. *Accuracy*, *precision*, *recall*, *F1 score*, *ROC*[2] and *AUC*[3] are one of performance metrics based on confusion matrix.

Based on the contents here, stakeholder and regulator need to keep up with preparing the performance metrics and integrity level to evaluate the AI model for ultimate goal of application in nuclear power plants according to the safety class and function.

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REFERENCES

[1] IEC 61508 series, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
[2] IEEE 1012-2016, Standard for System, Software, and Hardware Verification and Validation
[3] https://learn.microsoft.com/en-us/ai-builder/prediction-performance
[4] NUREG-2261, Artificial Intelligence Strategic Plan, Fiscal year 2023-2027

[2] Receiver Operating Characteristics
[3] Area Under Curve