

AI APPLICATION FOR ACCELERATING NRC LICENSING REVIEWS

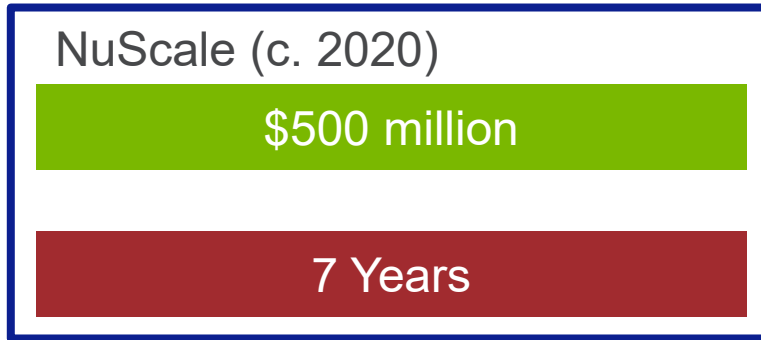
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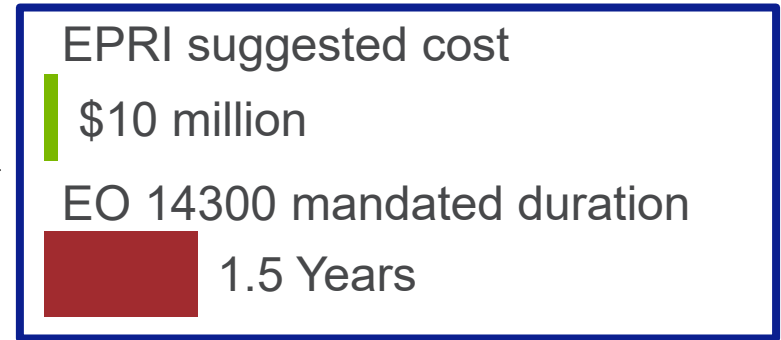
**THIS WORK WAS SUPPORTED BY THE DOE
REGULATORY FRAMEWORK MODERNIZATION
PROGRAM.**

**COLLABORATORS: DAVID GRABASKAS (ANL),
JOSEPH RENEVITZ (INL), RICHARD B. VILIM (ANL)**

Where we are



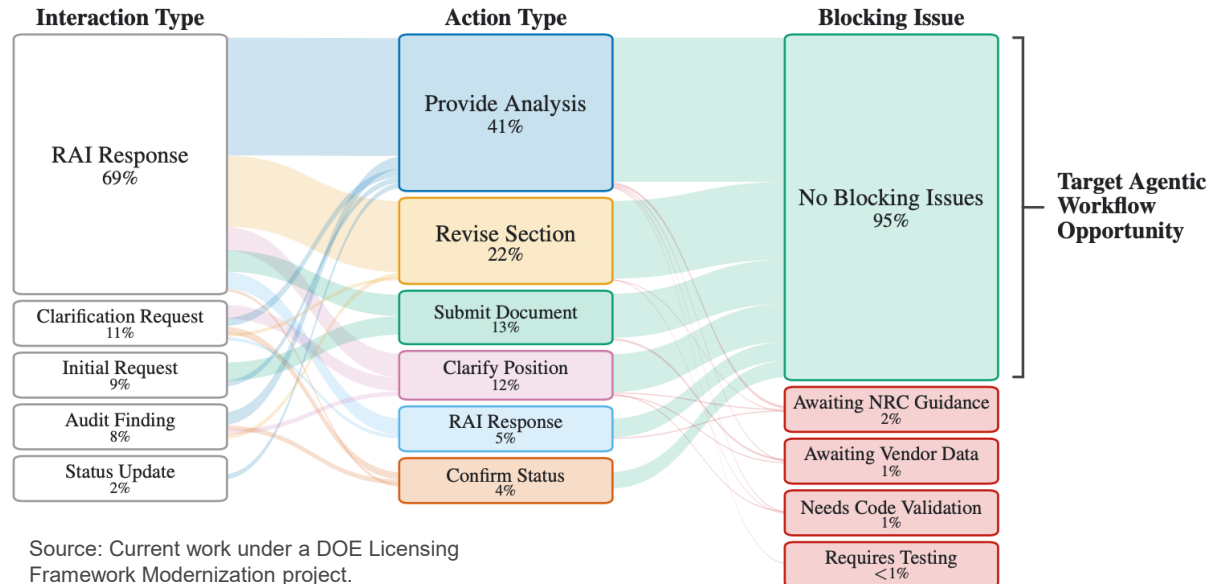
Where we want to be



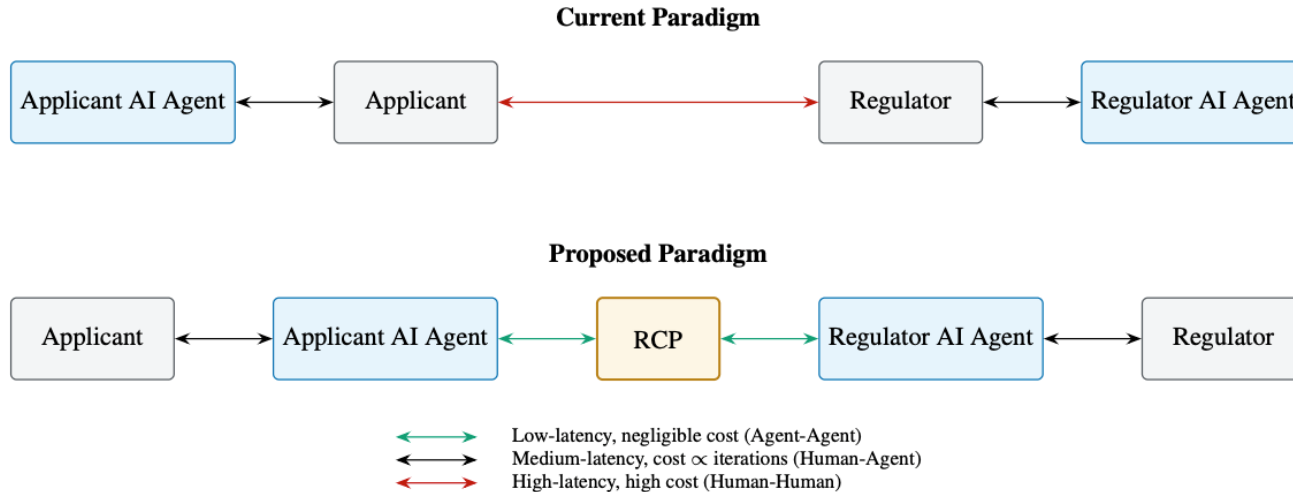
Source: <https://www.nrc.gov/docs/ML2208/ML22088A161.pdf>

WHY ARE APPLICATIONS SLOW & COSTLY?

- The NRC-Applicant interaction is dominated by information exchange patterns
 - RAI, Audits, RCI
- Sankey diagram analyzes 1200+ documents from advanced reactor docket
- The analysis shows that 95% of interactions did not have blocking issues



HOW CAN AI ASSIST?

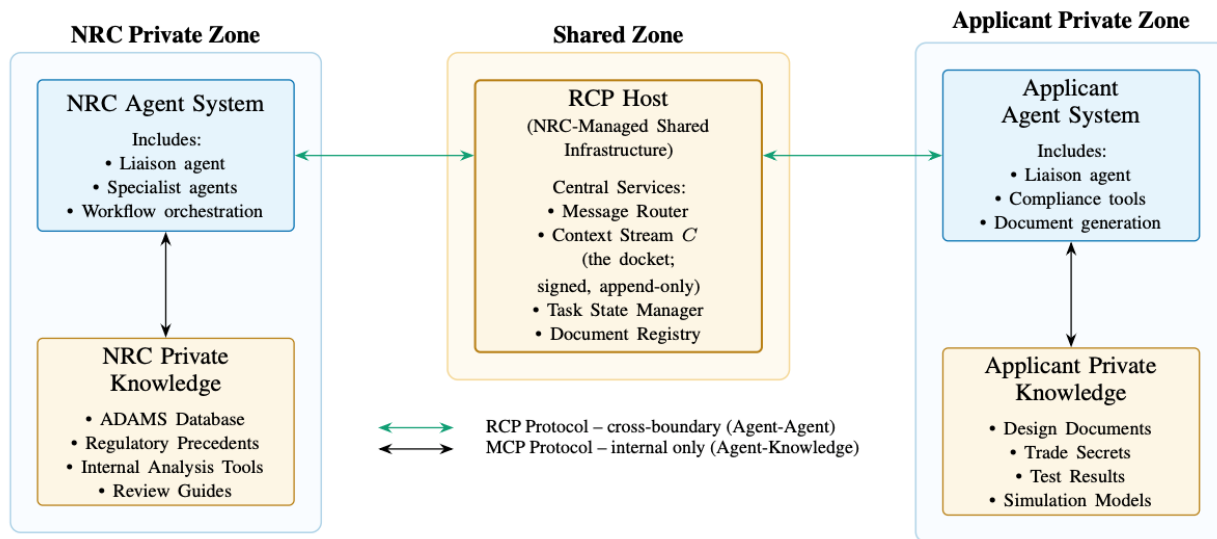


- Remove high-latency, high cost per iteration, limiting reaction
- Resolve non-blocking issues for information exchanges using AI agents as intermediaries
- Current result: \$28M cost, 15-month timeline (vs. \$500M, 7 years)

Source: Current work under a DOE Licensing Framework Modernization project.

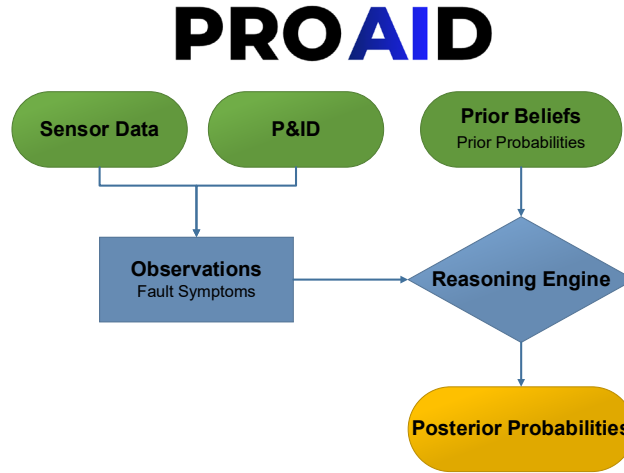
SYSTEM ARCHITECTURE

- ADAMS corpus can inform agents & MCP servers required
- RCP used for formalizing communications between external systems
- MCP used for communication within systems: agents to tools



Model-based diagnostics

- Physics-based diagnosis:
 - Enables detection and diagnosis of component and sensor faults
 - Provides robust treatment of uncertainty in the reasoning process



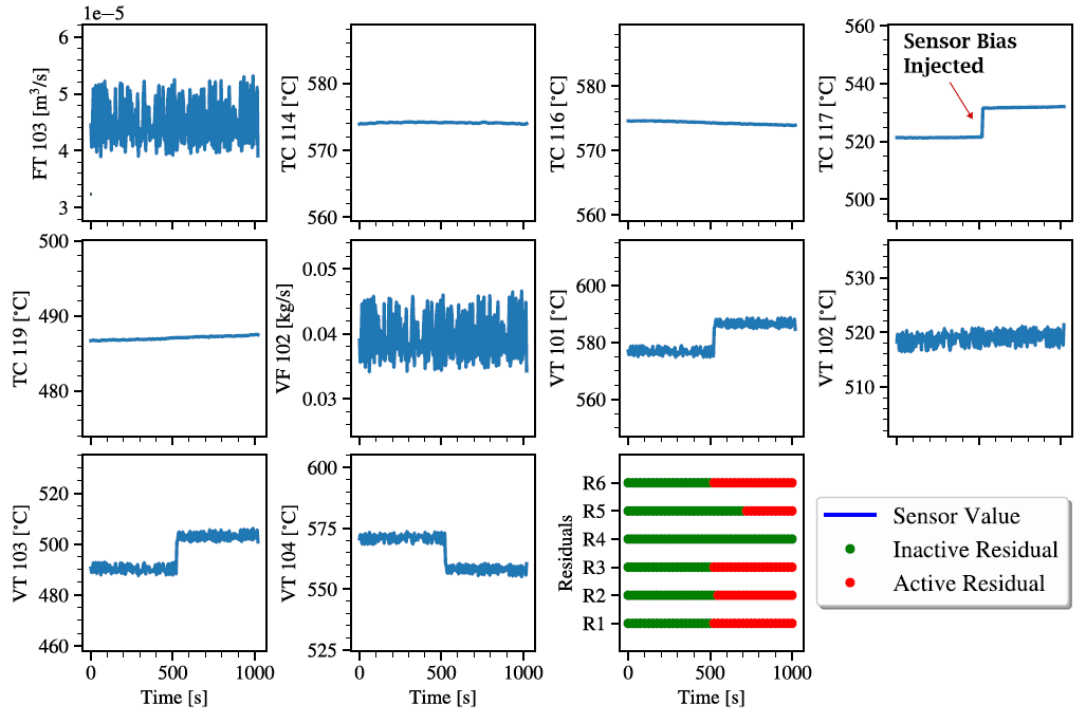
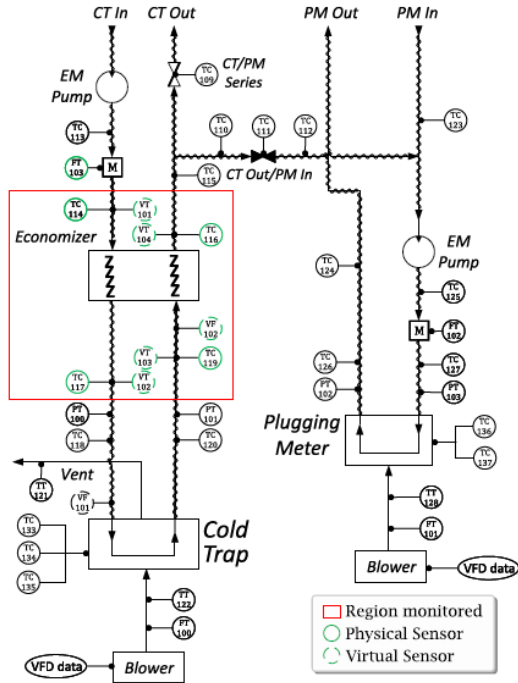
Probabilistic Reasoning Framework in PRO-AID

T. N. Nguyen, et al. "A digital twin approach to system-level fault detection and diagnosis for improved equipment health monitoring." *Annals of nuclear energy* 170 (2022): 109002.

T. N. Nguyen, et al. "A physics-based parametric regression approach for feedwater pump system diagnosis." *Annals of Nuclear Energy* 166 (2022): 108692.

CAPABILITY	DD	PB
Immune to operating point change?	N	Y
Diagnosis resolved to specific fault?	N	Y
Rank ordering of likelihood of faults?	N	Y
Applicable to engineering systems?	—	Y
Free of need for library of fault signatures?	N	Y
Generates virtual sensors?	N	Y
Adapts upon dropped sensor?	—	Y
Yields component performance index?	N	Y
Supports design of optimal sensor set?	N	Y

EXAMPLE RESULTS SENSOR BIAS INJECTION



Path A Lightweight Exchange

Regulator Agent

information-request PUBLIC

As part of the review of PRO-AID condition monitoring application APP-2025-METL-001, provide the SPRT change detection parameters: false alarm probability (α), missed detection probability (β), detection threshold, and baseline window size. Reference: 10 CFR 50 Appendix B, Criterion III (Design Control).

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Applicant Agent

information-response PUBLIC

PRO-AID SPRT parameters: $\alpha = 0.01$ (1% false alarm), $\beta = 0.01$ (1% missed detection), 3σ detection threshold (99.7% confidence), 100-sample moving window (≈ 1.7 min at 1 Hz). Per RG 1.174, these maintain defense-in-depth with 99% detection reliability while limiting false alarms to < 1 /day under normal operation. Ref: Wald (1945), IEEE 603-2018.

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Regulator Agent

information-request PUBLIC

Follow-up: What are the expected detection times for credible SPS degradation mechanisms (e.g., cold trap fouling, EM pump efficiency loss)? Confirm whether the α/β values have been validated against fault injection scenarios.

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Applicant Agent

information-response PUBLIC

Expected detection: cold trap fouling ≈ 5 min (gradual drift), EM pump degradation ≈ 2 min (step change in efficiency). Parameters validated via Monte Carlo simulation (10,000 runs with synthetic fault injection): measured false alarm rate = 0.8% ($< 1\%$ target), missed detection rate = 0.6% ($< 1\%$ target). Validation report PRO-AID-VAL-003 Rev. 0 available.

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Path B Formal RAI

Regulator Agent

information-request

PUBLIC

Describe the software verification and validation program for PRO-AID virtual sensor models, including validation methodology, test data sources, and compliance with 10 CFR 50 Appendix B. Reference: RG 1.152, Criteria III and XI.

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Applicant Agent

information-response

PROPRIETARY

PRO-AID models were validated against EBR-II operational data and ANL sodium chemistry loop measurements per IEEE Std 7-4.3.2. Formal SRS and SDD documents are under revision (Rev. 2 in preparation). Validation reports and uncertainty quantification analyses are available for NRC review upon request.

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Regulator Agent

information-request

PUBLIC

Follow-up: Provide the validation test results for each virtual sensor model, including statistical acceptance metrics (RMSE, R^2 , bias) and uncertainty bounds. Reference: 10 CFR 50 Appendix B, Criterion XI (Test Control).

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Applicant Agent

information-response

PROPRIETARY

Validation was performed against available operational datasets; however, formal test reports per IEEE 7-4.3.2 format requirements are not yet complete. Preliminary results show acceptable agreement but have not undergone independent QA review per Criterion XI. Formal documentation is in progress.

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Regulator Agent

rai-content

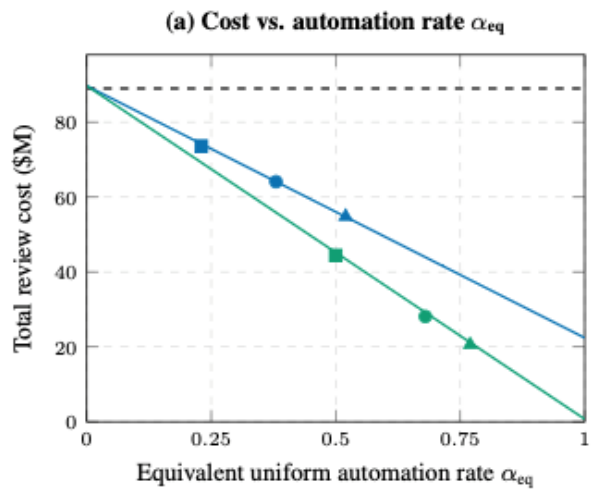
PUBLIC

RAI-SPS-2025-001-Q1: Two information requests have not yielded adequate V&V documentation per 10 CFR 50 Appendix B, Criterion III. Submit: (a) Software Requirements Specification and Design Description per IEEE 7-4.3.2; (b) model validation reports with metrics (RMSE, R^2 , bias) for each virtual sensor; (c) uncertainty quantification with propagation analysis per Criterion XI.

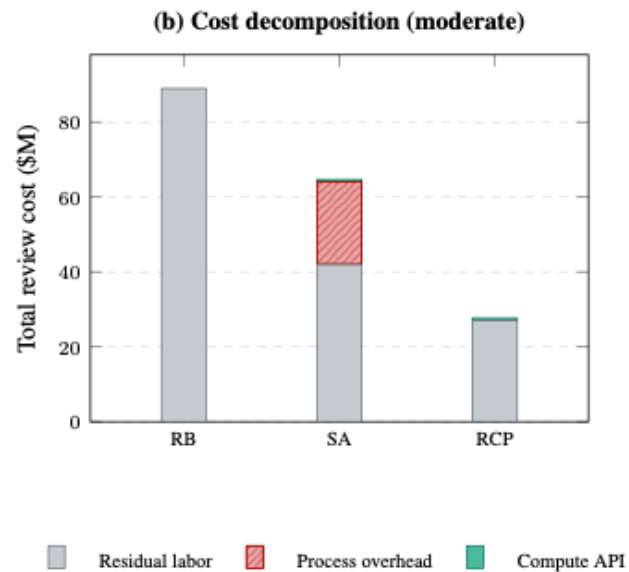
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Human On The Loop Checkpoint

NRC reviewer confirms RAI technical adequacy and regulatory basis before issuance. RAI enters formal docket for applicant response.



- - - RB
 ■ Conservative — SA — RCP
 ● Moderate ▲ Optimistic



■ Residual labor ■ Process overhead ■ Compute API

CONCLUSIONS

- RCP addresses structural bottlenecks in modern administrative review
- For Nuclear Reg. Review, this presents a 65% compression in time, and up to 77% savings in labor
- Adoption requires commitment from industry and government – political will
- Applied to US regulatory paperwork burden estimated at \$426.5B per year, RCP offers savings approaching 1% of US GDP

Paradigm	Scenario	Cost	Savings	Timeline	Reduction
RB	Baseline	~\$89M	—	42 mo	—
SA	Cons.	~\$73M	17%	~21 mo	50%
	Mod.	~\$64M	28%		
	Opt.	~\$54M	38%		
RCP	Cons.	~\$44M	50%	~15 mo	65%
	Mod.	~\$28M	68%		
	Opt.	~\$21M	77%		