Advancing IST with Digital Twins and Condition Monitoring

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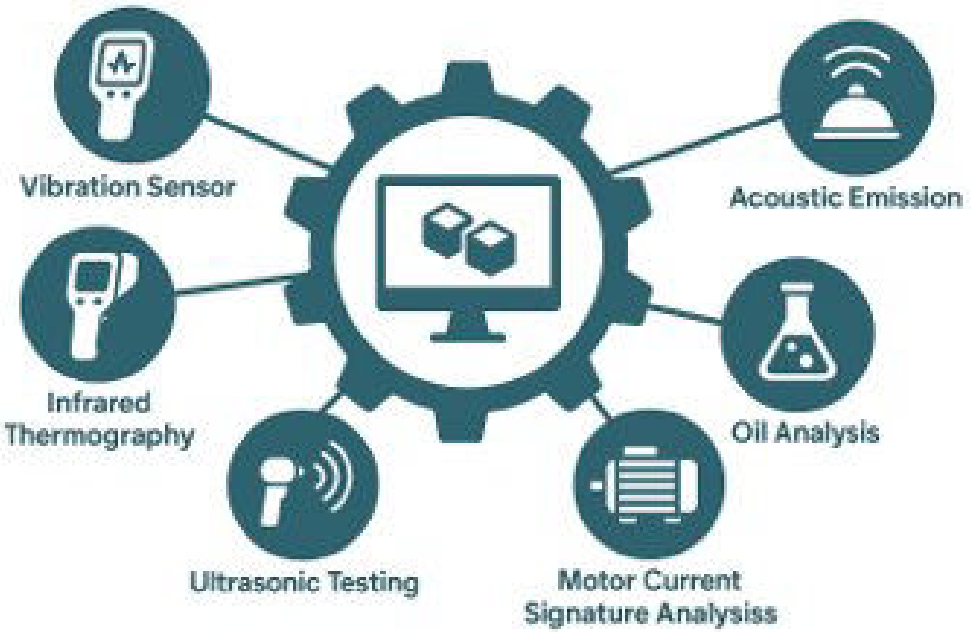
NRC on Digital Twins

- NRC staff are actively evaluating **Digital Twin (DT)** technologies as part of our broader assessment of advanced **condition-based monitoring (CBM)** for inservice testing (IST).
- Focus is on alignment with **10 CFR 50.55a**, **50.65**, and the proposed **10 CFR Part 53** framework for advanced reactors.
- Regulatory guides such as **RG 1.192 (OMN-29)** already support technology-inclusive, performance-based IST strategies.



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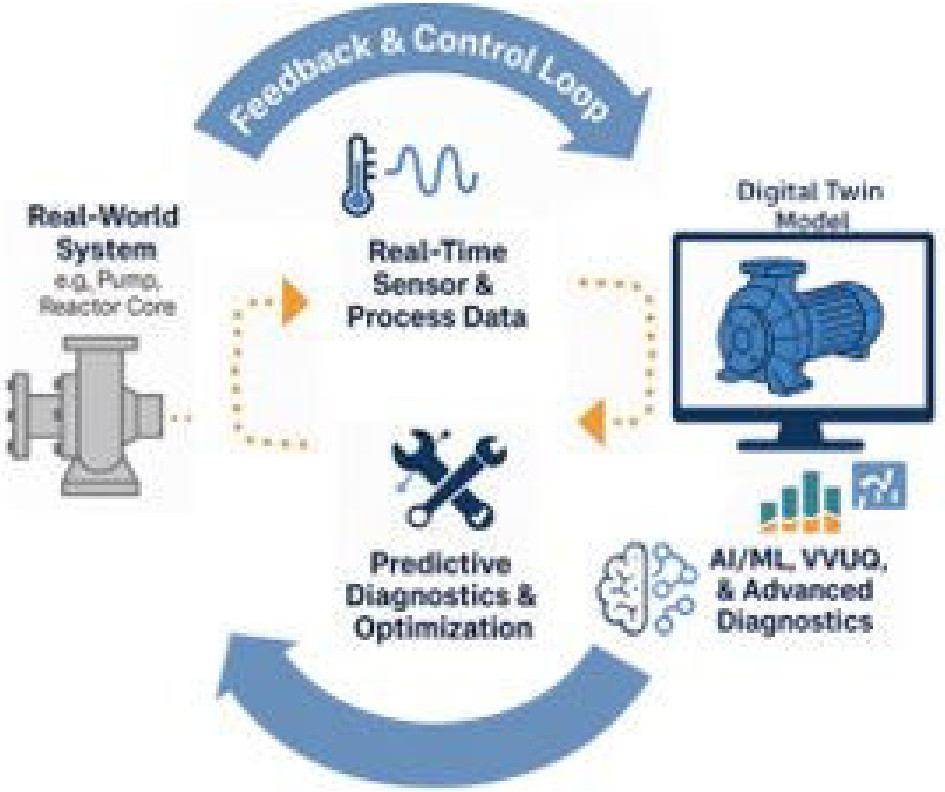
What We're Exploring

- NRC Office of Nuclear Regulatory Research has evaluated **hypothetical case studies** using synthetic data and simulation tools:
  - **Reactor Coolant Pump (RCP)**: Simulated thermal barrier leak detection with machine learning–enabled Digital Twins.
  - **Heat Pipe Monitoring**: Simulated passive component diagnostics in advanced reactor designs (e.g., microreactors).
- These are not field-deployed but help us understand potential benefits, limitations, and code implications.



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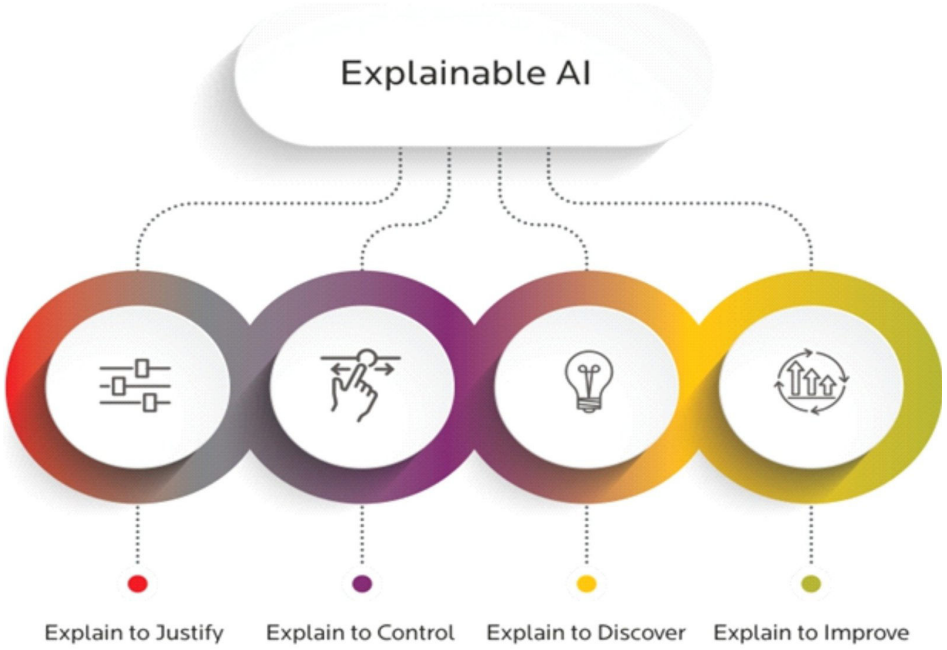
Key Challenges Under Review

- **VVUQ** (Verification, Validation, and Uncertainty Quantification) for AI/ML models.
- **Sensor integrity and long-term reliability** in nuclear environments.
- **Model explainability** to support transparency and regulatory confidence.



Source: Adadi, A., & Berrada, M. (2018). *Peeking inside the black-box: A survey on explainable artificial intelligence (XAI)*. IEEE Access, **6**, 52138–52160.

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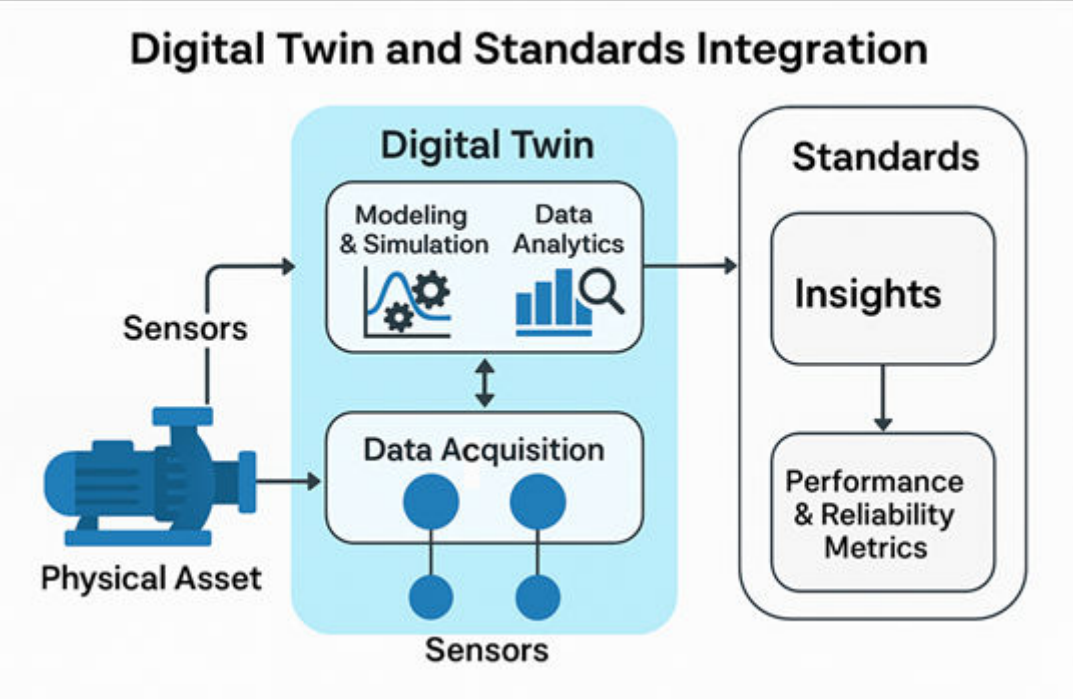
ASME Code Implications

- Code Case OMN-29 supports pump monitoring – expand to DTs
- OM-2 Code supports performance-based IST – ready for DT/CBM
- Define: sensor criteria, model metrics, VVUQ expectations



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Recommendations

- **Develop guidance** on integrating DTs into IST programs.
- **Support pilot projects** to benchmark performance and understand implementation gaps.
- **Form a working group** to coordinate DT applications across OMN-29, OM-2, and future OM Code initiatives.

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QUESTIONS?