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Advanced Sensors and Instrumentation – NRC Research Status Update

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Advanced Sensors and Instrumentation FY23 Annual Program Review Meeting

Key Messages

- Office of Nuclear Regulatory Research staff research and support current and future NRC activities related to Instrumentation and Controls (I&C).
- New sensor technologies are applicable for both modernizing the operating reactor fleet as well as advanced reactors.
- Staff are proactively looking at these technologies to be ready for the future.

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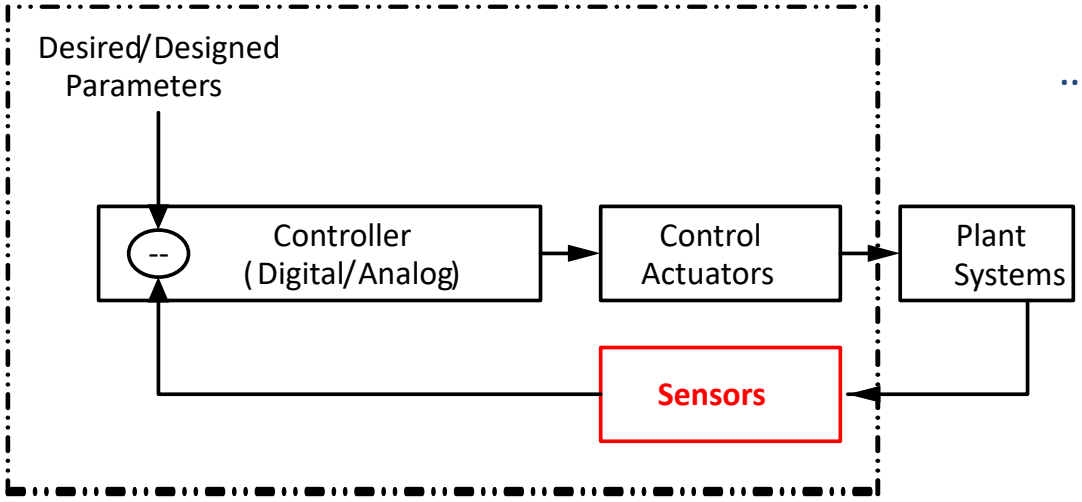
Regulatory Importance in Current NPPs

Sensors are the "center" of I&C System Designs…



…and Licensed Operation (Tech Specs)

3.4.6 RCS Loops-MODE 4

LCO 3.4.6 Two loops consisting of any combination of RCS loops and residual heat removal (RHR) loops shall be OPERABLE, and one loop shall be in operation.

----------NOTES----------

1. All reactor coolant pumps (RCPs) and RHR pumps may be removed from operation for ≤ 1 hour per 8 hour period provided:
   a. No operations are permitted that would cause introduction of coolant into the RCS with boron concentration less than required to meet the SDM of LCO 3.1.1; and
   b. Core outlet temperature is maintained at least 10°F below saturation temperature.
2. No RCP shall be started with any RCS cold leg temperature ≤ Low Temperature Overpressure Protection (LTOP) arming temperature specified in the PTLR unless the pressurizer water level is less than 50%, OR the secondary side water temperature of each steam generator (SG) is < 50°F above each of the RCS cold leg temperatures.

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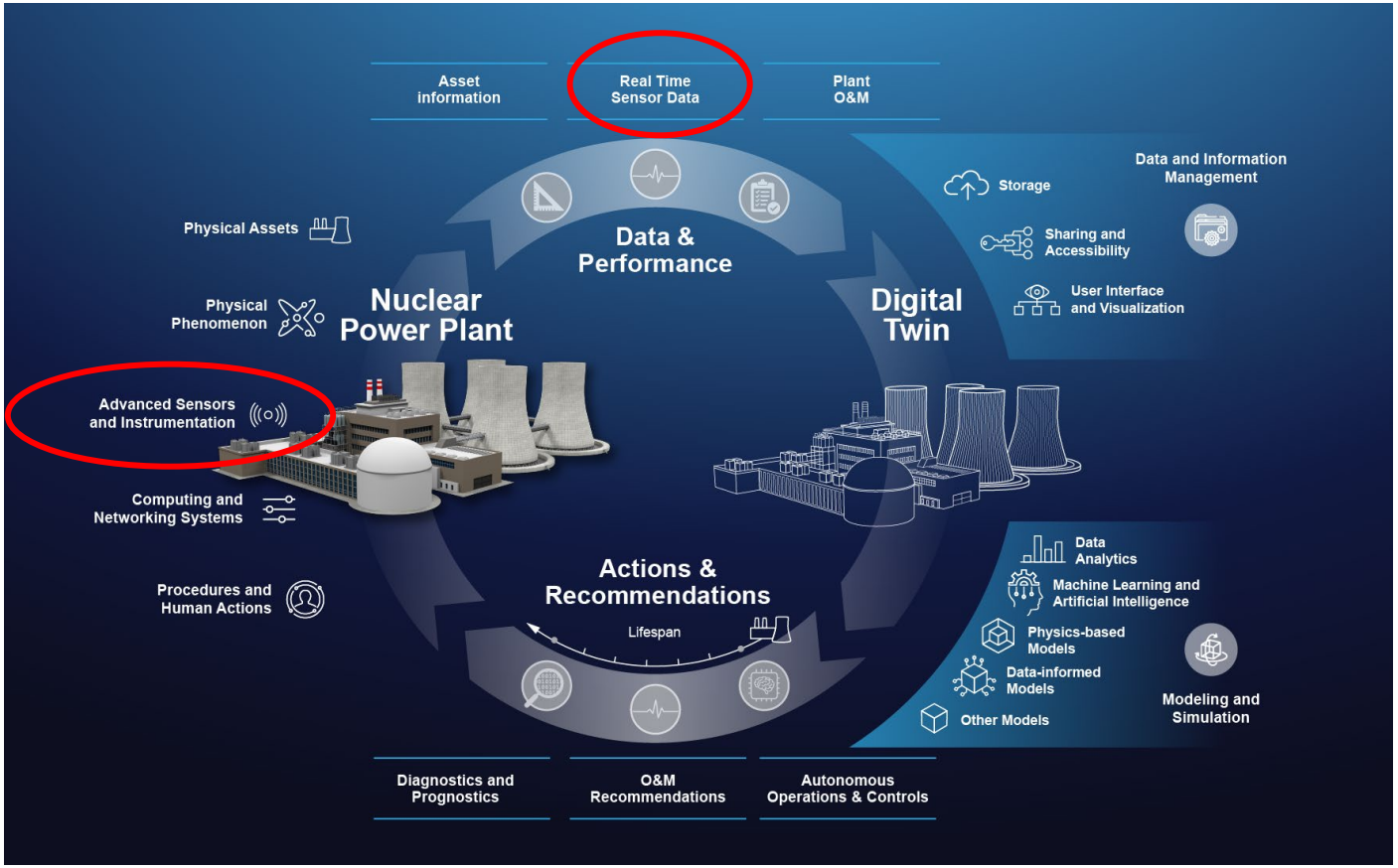
Example Future Use/Need?: Digital Twins



[**source:** TLR-RES/DE/REB-2023-02 at ML23058A085]

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Example Future Use/Need?: AI/ML…

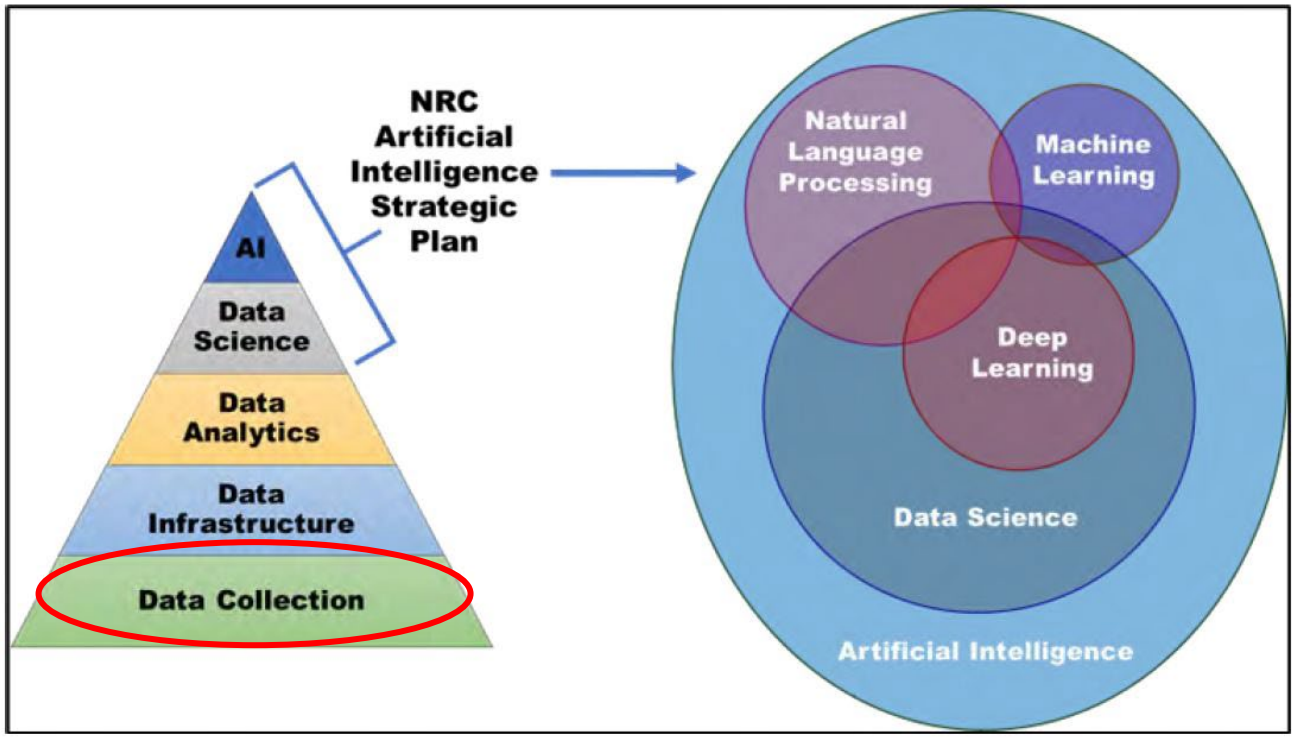

Figure 1 Artificial Intelligence Hierarchy and Relationship with the NRC AI Strategic Plan (adapted from [5] and [6])

[source: NUREG-2261 at ML23132A305]

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Instrumentation & Controls Regulatory Framework

- **Part 50/52:** Staff are implementing the vision to develop an integrated strategy to modernize the NRC's I&C regulatory infrastructure.

  https://www.nrc.gov/reactors/digital/modernize.html

- **Part 53:** The staff developed rule package was sent to the Commission on March 1, 2023, with a request to approve and publish the draft proposed rule in the Federal Register for comment. It remains with the Commission.

https://www.nrc.gov/reactors/new-reactors/advanced/rulemaking-and-guidance/part-53.html

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Current Regulatory Touchpoints:

- **10 CFR 52.47(a)(13):** FSAR must include "The list of electric equipment important to safety that is required by 10 CFR 50.49(d)". This subsection pertains to Environmental Qualification of electric equipment **important to safety** for nuclear power plants. See also RG 1.89.

- **RG 1.97**: Starting with Rev 4 of RG 1.97, new instrumentation systems in advanced nuclear power plant designs for severe accident conditions were specified **using performance-based criteria** to select instrument variables that are needed. This increases flexibility and avoids prescribing the specific variables to be monitored.

- **Regulatory Touchpoints (BTP 7-10)**: sensor types and range, redundancy, allowable deviations, instrument power, and pointers to other guides (e.g., BTP 7-12 on set points), etc...

Standard Review Plan, Chapter 7:
https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/ch7/index.html

Current Branch Research: Sensor-Intensive Activities

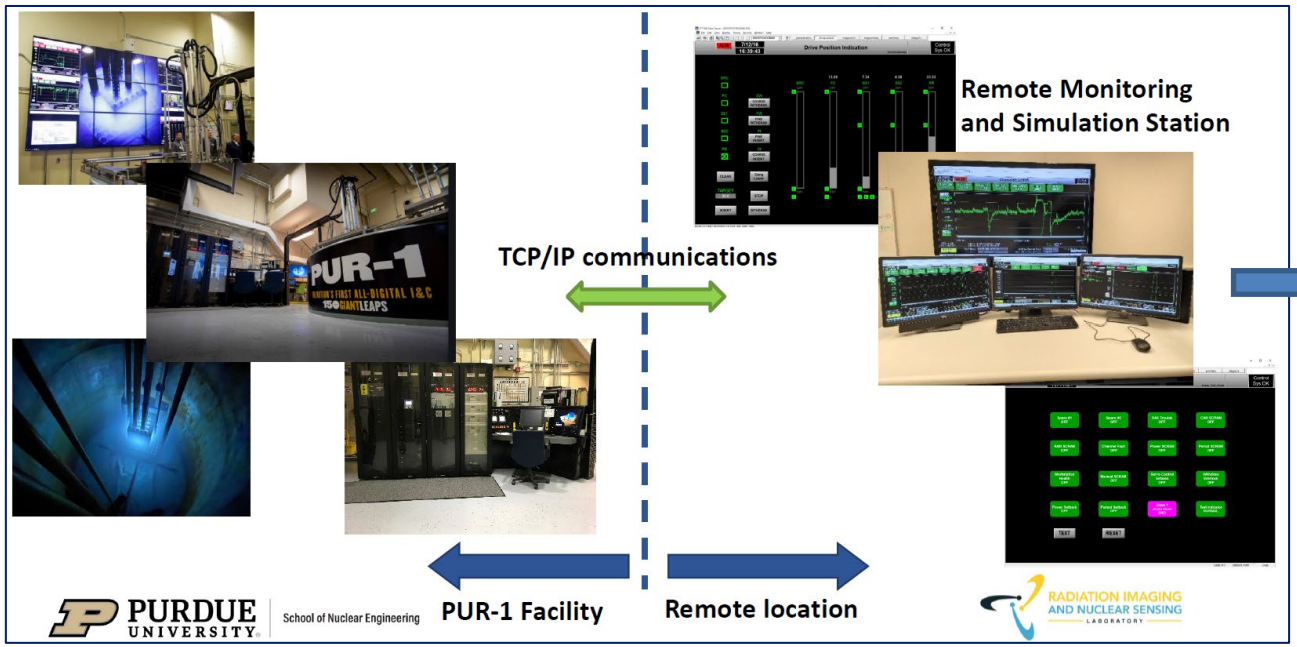
- Artificial Intelligence & Machine Learning (AI/ML) research for cybersecurity

- Autonomous Control + Remote (Operation and Monitoring) Techniques

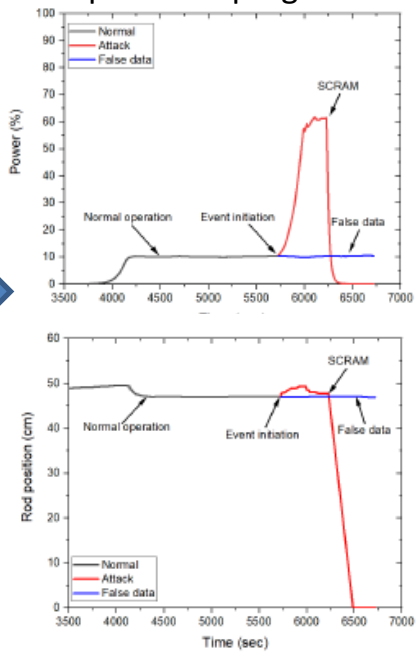
- Wireless safety and security

AI/ML Research: FFR for Cybersecurity

Perform “future focused research” (FFR) to assess feasibility of AI/ML to identify, characterize, and differentiate nuclear states.



Example event progression



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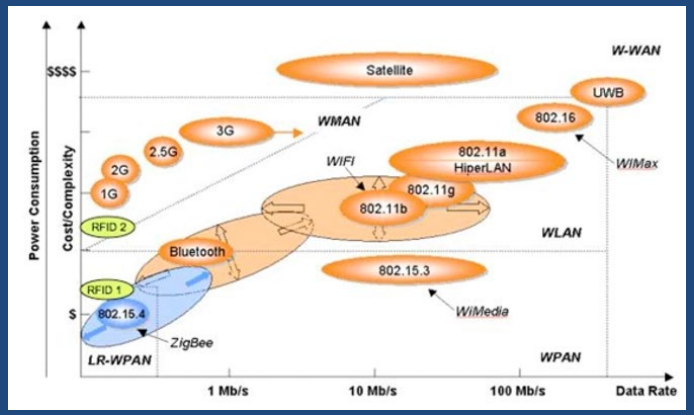
Autonomous Control + Remote (Operation and Monitoring) Techniques

- Motivation/purpose includes:
  - Document existing standards and best-practice guidelines on standardized use of autonomous + remote techniques for ICS
    - Example: National Institute of Standards and Technology (NIST) special publications (SPs).
  - Document insights from technical subject matter experts on additional/changing attack vectors and how to mitigate their risk.
  - Develop the technical basis to characterize autonomous + remote techniques using a multidimensional framework

Wireless: Safety and Security

- **Security:**
  - Research on cybersecurity insights from other safety-critical industries.
- **Safety:**
  - Review of EMI and RFI from modern wireless technologies. Supports conclusions in RG 1.180, Rev 2.
  - ***Report in final internal review.***



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Technical Letter Report
TLR-RES-DE-2022-007

[**source:** ML22180A008]

STUDY OF WIRELESS TECHNOLOGY IMPLEMENTATION IN ISOLATED, HIGH CONSEQUENCE NETWORKS

July 2022

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Conclusions

- Research staff activities are worked in coordination with program office staff to produce **timely and useful products.**
- Technology readiness level and licensees' plans for proposed use of new sensor technologies **factor into research topics.**
- Activities are **aligned to complement** DOE-funded research for differences in mission, purpose, and scope.
- Research staff use MOUs, standards organizations, public meetings and international forums to **calibrate internal priorities** and enable NRC readiness for timely review of future submittals.

Questions?

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