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Unattended Operation of Fission Batteries

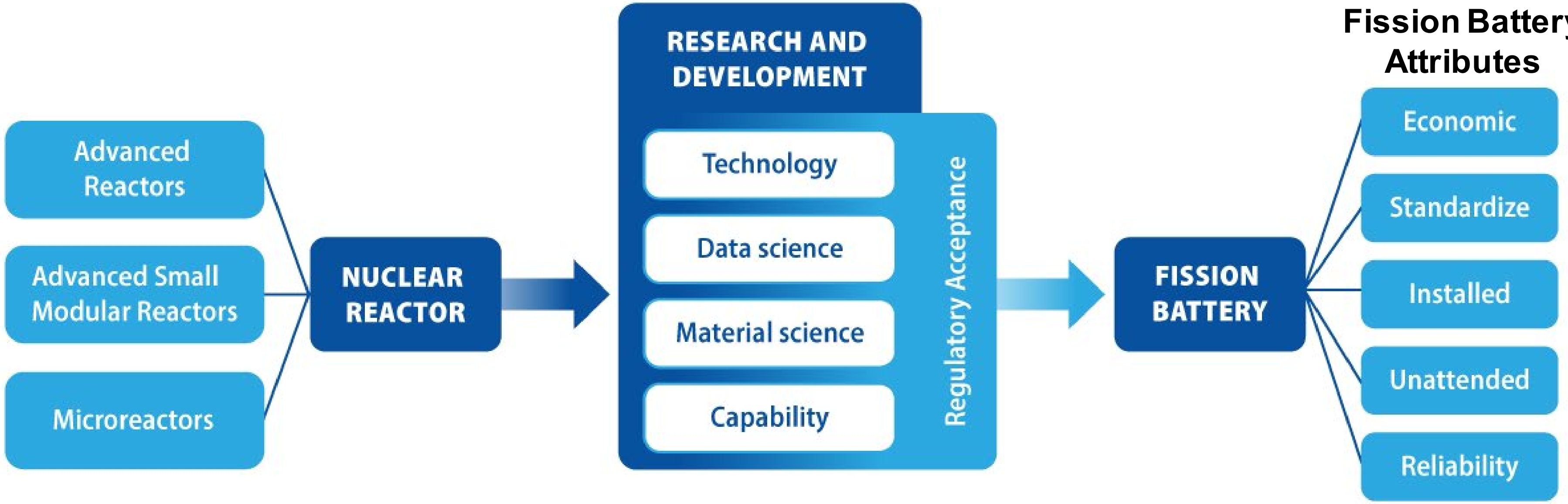
Artificial Intelligence and Machine Learning Symposium 11.0

Fission Battery Initiative

Nuclear Reactor Sustainment and Expanded Deployment

Vision: Developing technologies that enable nuclear reactor systems to function as batteries.

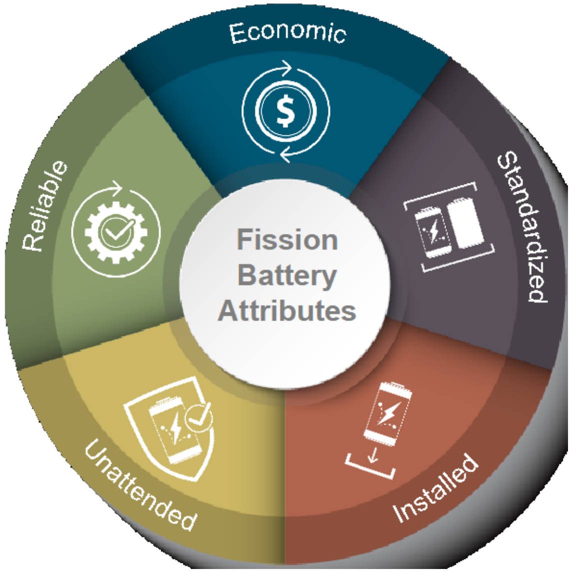
Outcome: Deliver on research and development needed to provide technologies that achieve key fission battery attributes and expand applications of nuclear reactors systems beyond concepts that are currently under development.



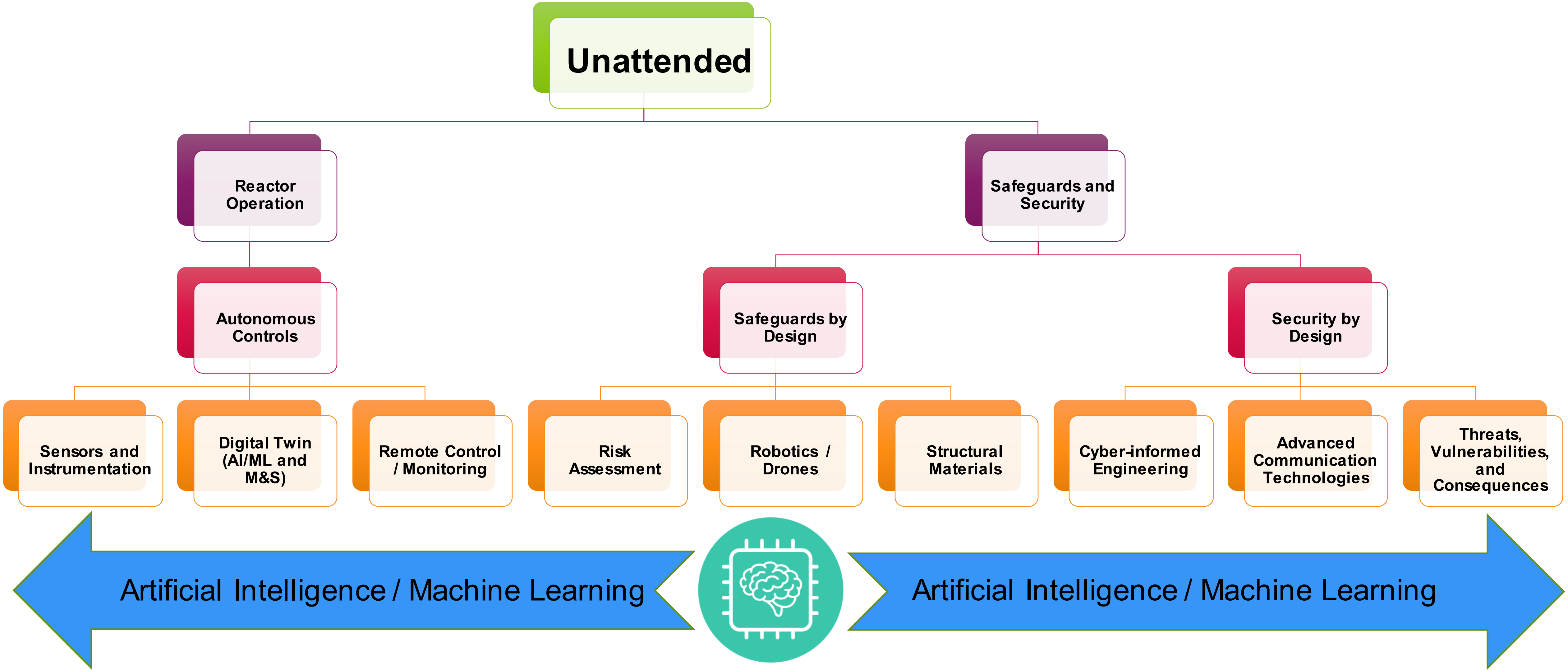
Research and development to enable nuclear reactor technologies to achieve fission battery attributes

Fission Battery Attributes

- **Economic** – Cost competitive with other distributed energy sources (electricity and heat) used for a particular application in a particular domain. This will enable flexible deployment across many applications, integration with other energy sources, and use as distributed energy resources.
- **Standardized** – Developed in standardized sizes, power outputs, and manufacturing processes that enable universal use and factory production, thereby enabling low-cost and reliable systems with faster qualification and lower uncertainty for deployment.
- **Installed** – Readily and easily installed for application-specific use and removal after use. After use, fission batteries can be recycled by recharging with fresh fuel or responsibly dispositioned.
- **Unattended** – Operated securely and safely in an unattended manner to provide demand-driven power.
- **Reliable** – Equipped with systems and technologies that have a high level of reliability to support the mission life and enable deployment for all required applications. They must be robust, resilient, fault tolerant, and durable to achieve fail-safe operation.

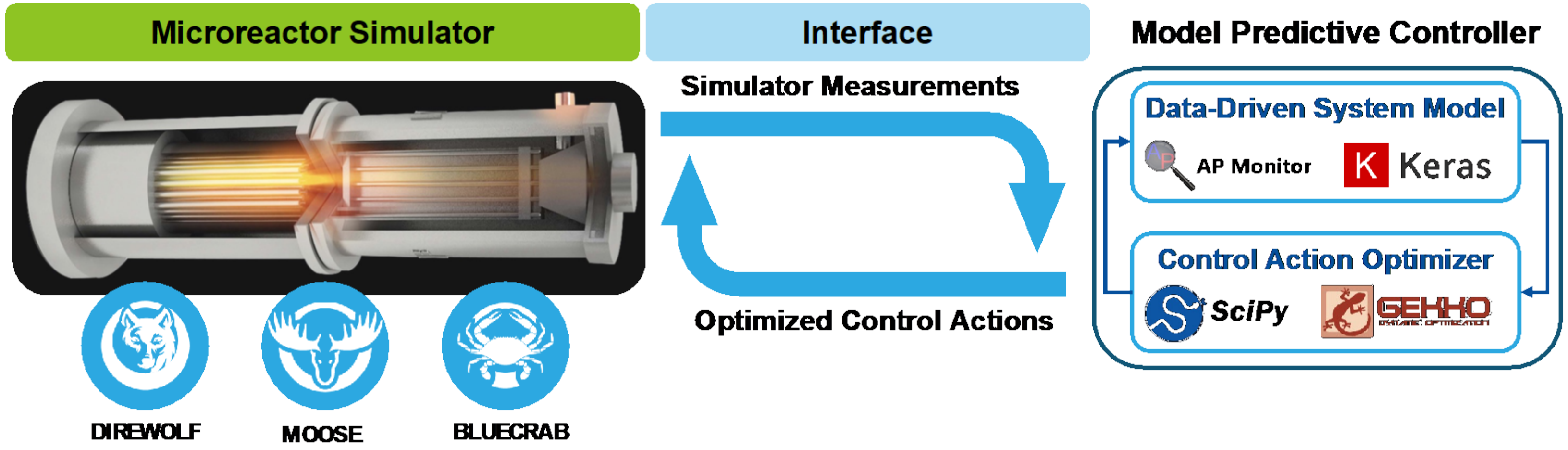


Unattended Operation of Fission Batteries



LDRD: Scalable Hybrid Modeling with Anticipatory Control Strategy for Autonomous Operation of Modular and Microreactor

- First-of-a-kind anticipatory controller **Autonomous Control fOr Reactor technology (ACORN)** to achieve autonomous control of microreactors
- Leverages and expands INL's modeling and simulation capabilities like DireWolf and BlueCRAB for capturing microreactor thermal and neutronic performance
- ACORN controller provides optimal control actions for microreactor under different scenarios and external uncertainties
  - Steady state and transient operations
  - Flexible operation (load following)
  - Failure or degraded operation

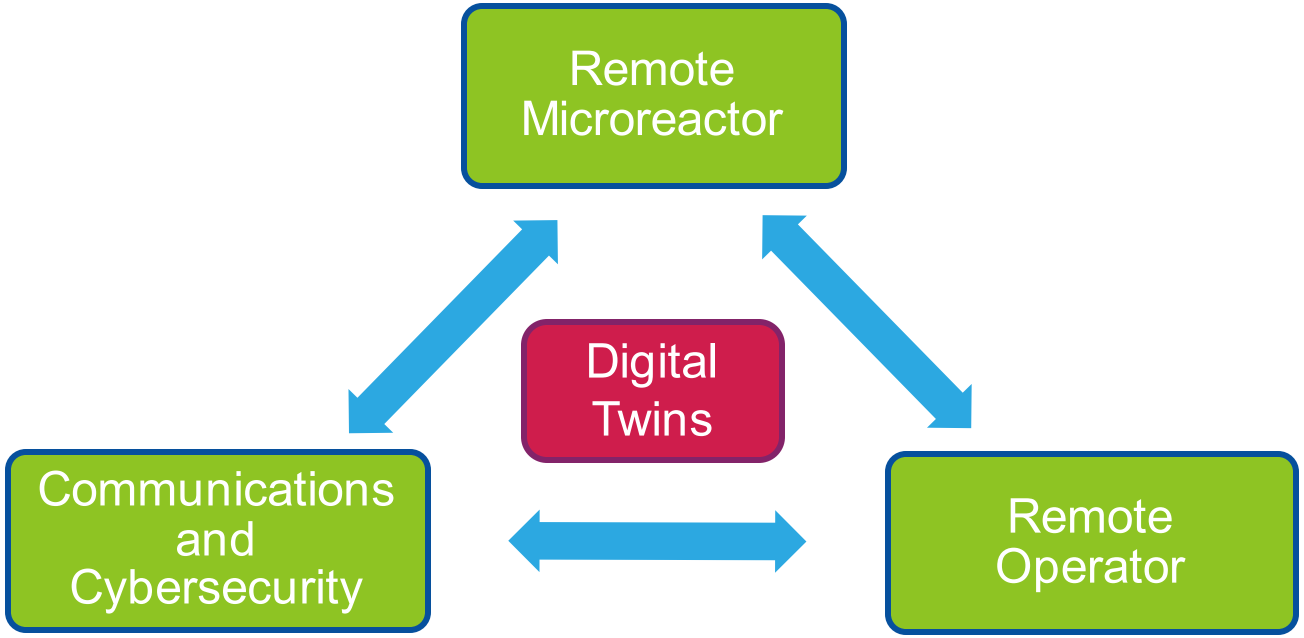


ACORN advances the level of automation to address the unattended attribute of the Fission Battery Initiative. This advancement also accounts for economics of operation of microreactors.

LDRD: Resilient Remote Operation of Microreactors and Fission Batteries

Project Hypothesis

A major unresolved technical challenge to the full deployment of microreactors and fission batteries is a reliable, resilient, and secure remote operations and monitoring capability.



Can we leverage AI/ML-informed digital twins to enhance the resiliency of remote monitoring and operations?

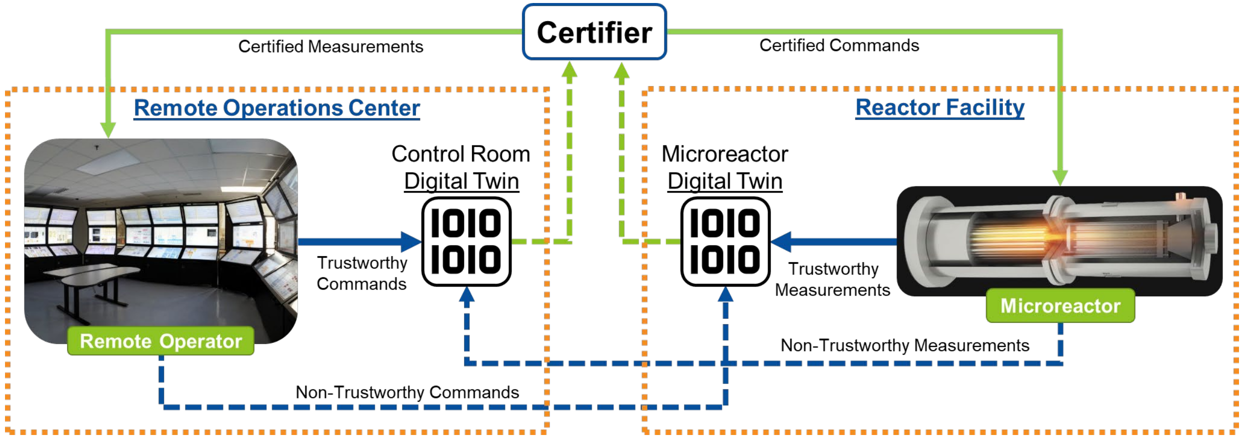
Proposed Work Tasks

1. Identify operator, control, and signal monitoring and verification needs *unique to remote operation* and monitoring.
2. Define a safe, secure, and resilient communications architecture that meets the needs of remote operation.
3. Develop a digital twin-based cybersecurity and operator augmentation system to enhance operational resilience.
4. Provide simulation and physical demonstrations of remote operation capabilities.

Resilient Remote Operation of Microreactors and Fission Batteries Major Deliverables

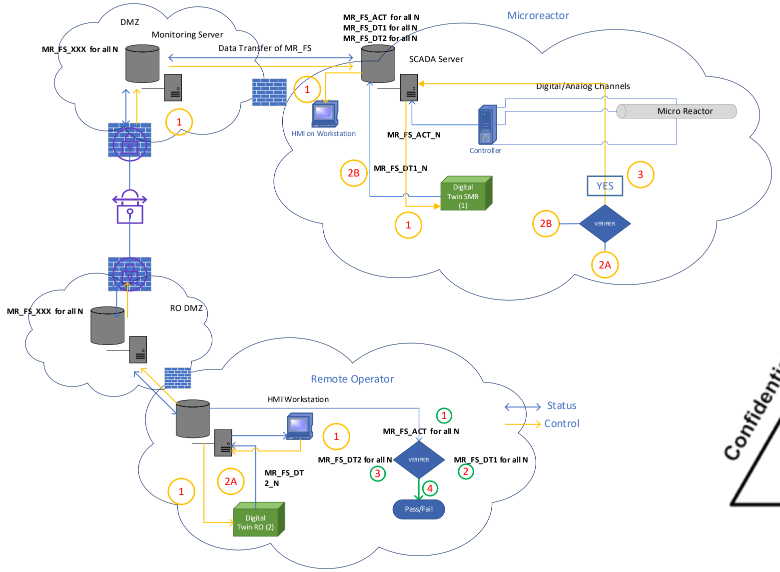
Digital Twin Command and Measurement Certification

- Leverage microreactor digital twins for use in a measurement and command certification system.
- Utilize digital twins to assess the authenticity, integrity, and accuracy of any commands or measurements transmitted between facilities.

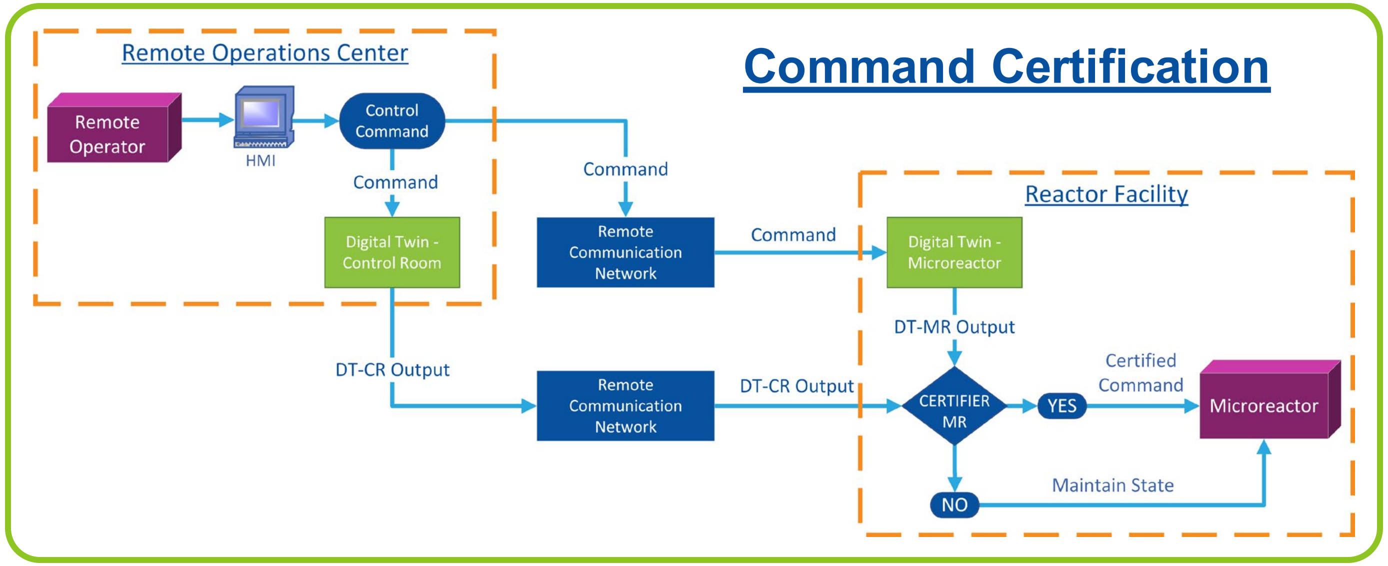


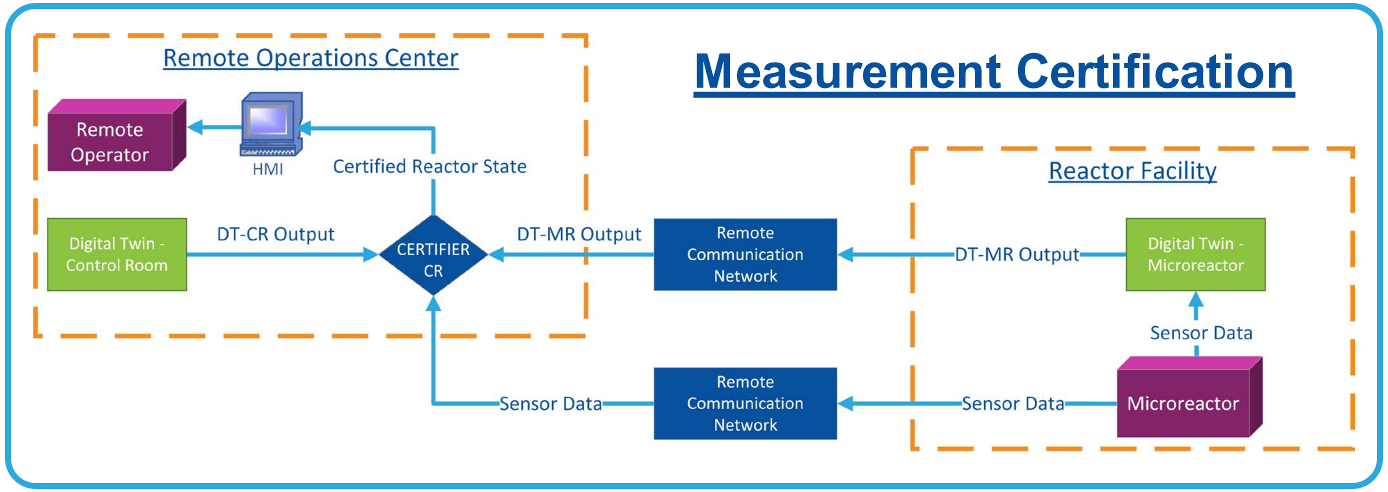
Communication and Cybersecurity Architecture

- Resilient, secure communications architecture designed using consequence-driven cyber-informed engineering principles.



Digital Twin – Based Data Certification System





This project proposes a novel framework for a digital twin-based data certification system as an additional layer of security and assurance of the status of the microreactor as viewed by a remote operator.

- This framework significantly raises the bar to mitigate unauthorized, unsafe, and unallowable commands.
- Increases the trustworthiness of the system state information, such as sensor data or component status, sent from the microreactor to the remote operations center.

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For any questions or discussion, I can be reached at Vivek.Agarwal@inl.gov