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Integration of Control Methods and Digital Twins for Advanced Nuclear Reactors

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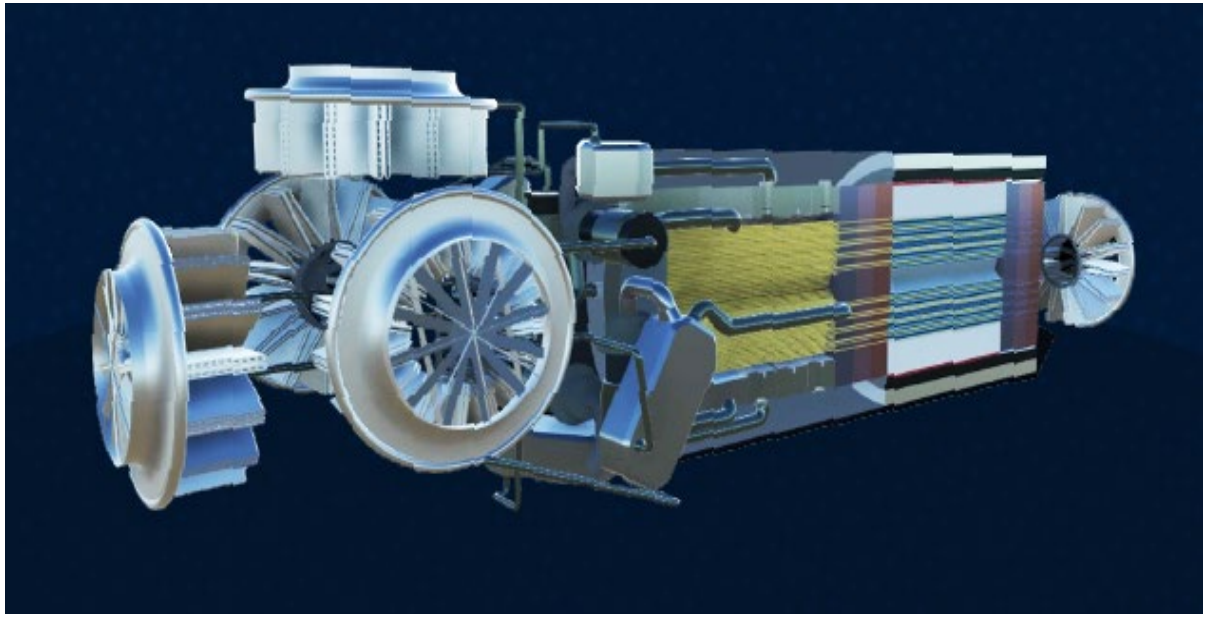
ASI | Advanced Sensors and Instrumentation

Advanced reactors will be highly autonomous, remotely controlled, and operated at variable power ratings and in rural locations



https://www.energy.gov/ne/articles/what-nuclear-microreactor

https://www.energy.gov/ne/articles/infographic-advanced-reactor-development

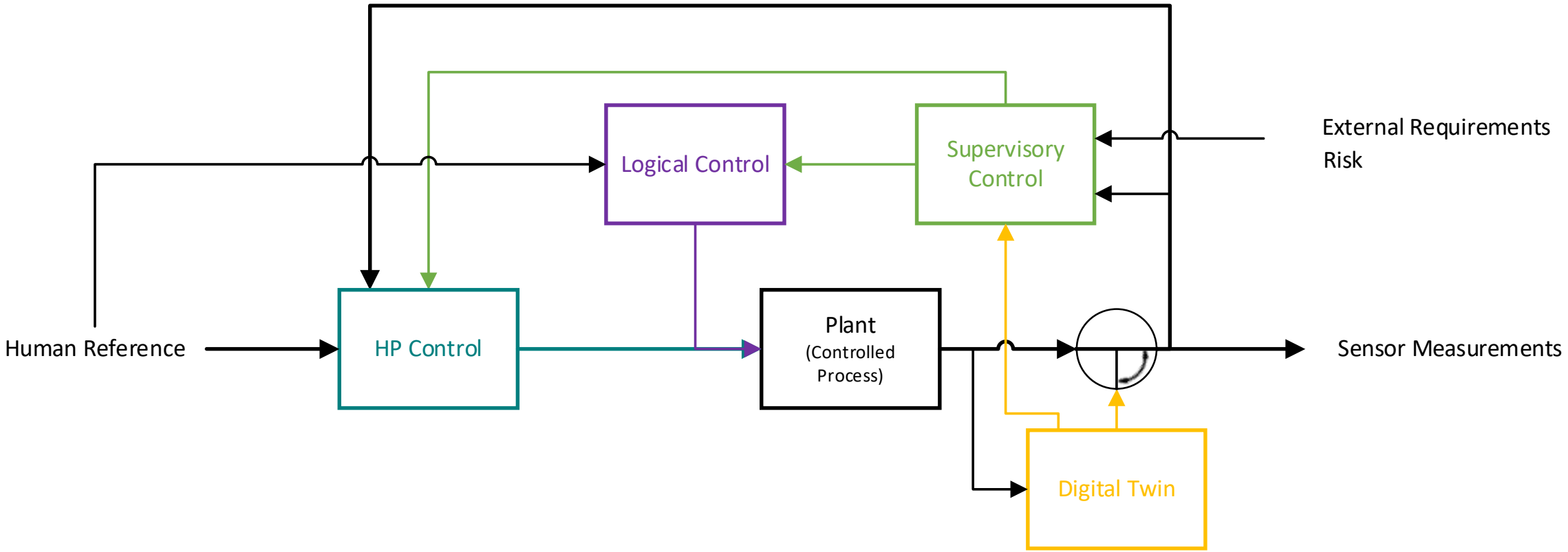
This research:

- Identifies control system requirements to enable more autonomous operations
- Identifies remaining research gaps that need to be resolved

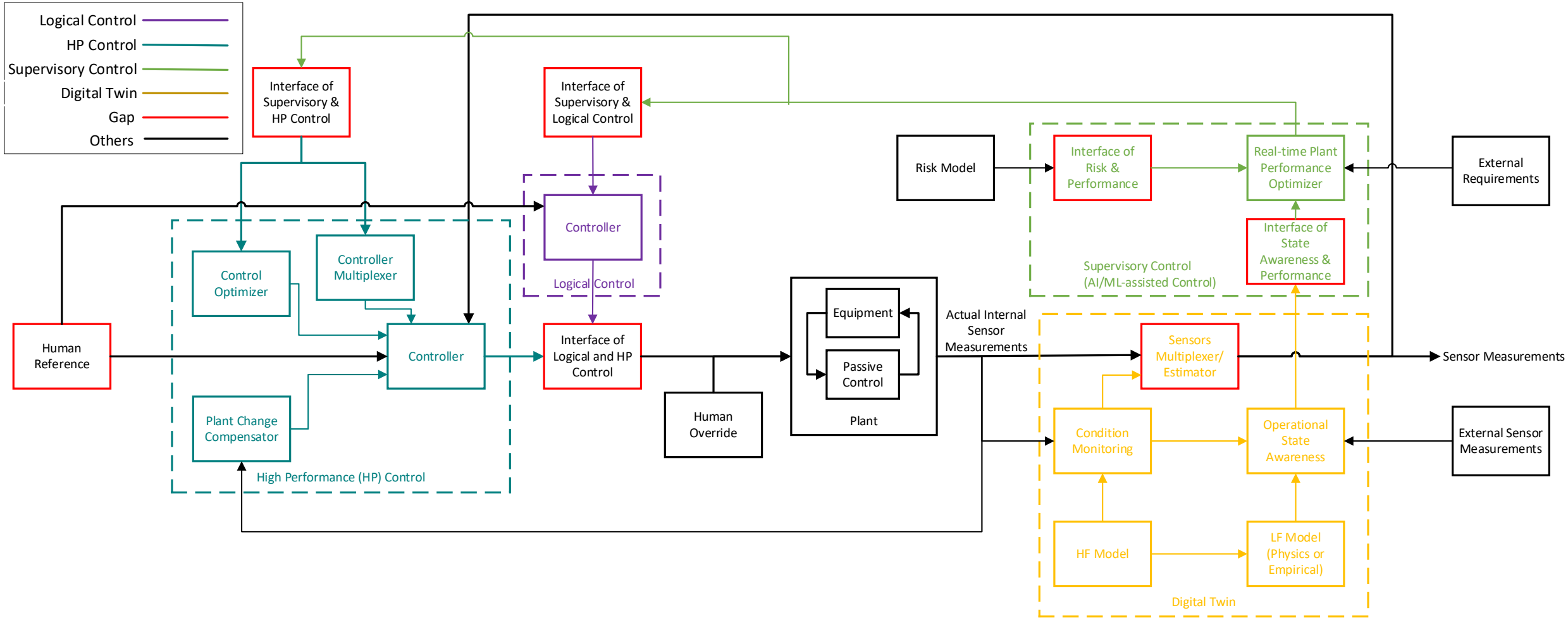
Advanced reactors have unique aspects and challenges that resulted in the proposed set of control system requirements

Unique Aspect	Challenge	Control Requirement
Regulatory Requirements	AI/ML control may not meet regulatory requirements, such as deterministic and explainable behavior	Include an interface control layer between the plant and any AI/ML decision making
Operating Environment	I&C equipment will endure harsh environments for extended periods, increasing probabilities of failures	Identify and compensate for sensor, communication, and electronics failures
High Consequence	Manual investigation to reduce uncertainty and avoid shutdown may not be feasible	Incorporate risk elements to prevent unnecessary loss of power generation
Highly Coupled	Compact and simpler designs will produce strongly coupled systems, making “isolated” control less feasible	Integrate highly coupled control loops and state-awareness methods
Evolving Knowledge	Novel concepts of physics and operation will be used that may not be fully understood or validated	Incorporate robustness into the control loop design
Operating History	There will be limited operating history with which to make operational decisions	Use software models to identify and react to or track unanticipated physical phenomena Define the human role and allowable human interventions

To meet these control requirements, we propose a hierarchical solution that makes use of supervisory control and digital twins



This solution can be expanded to show research gaps that need to be closed before implementing this hierarchical approach



Conclusions

- The unique aspects and challenges of highly autonomous operations were assessed, which resulted in a set of control system requirements.
- To meet the requirements, a layered approach was proposed that interfaced a supervisory control system with a digital twin.
- This led to gaps that can serve as a roadmap for future research on controls in advanced reactors.

Questions?

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