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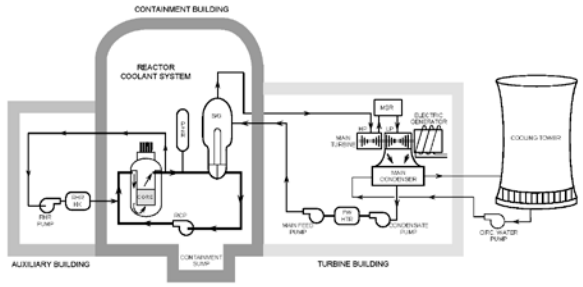

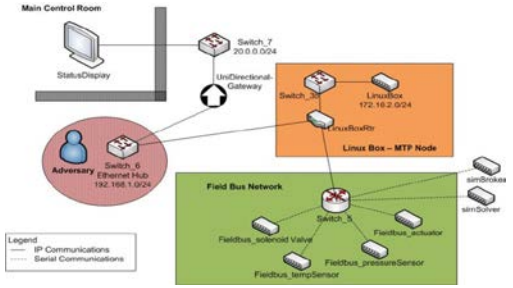

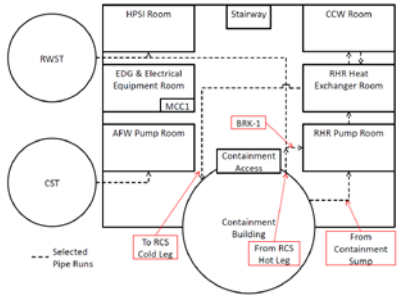

Preliminary Cyber-Informed Dynamic Branch Conditions for Analysis with the Dynamic Simplified Cyber MELCOR Model

Presented by Matthew Denman

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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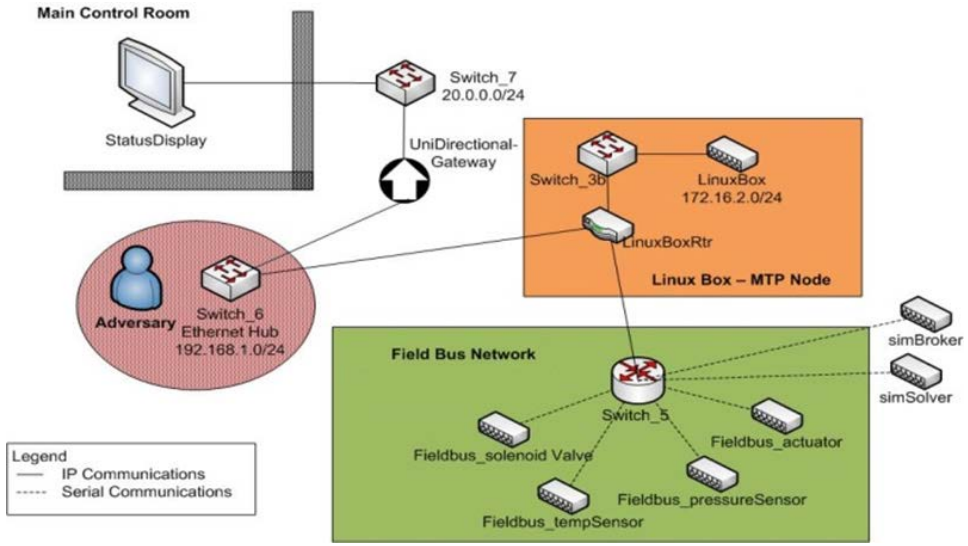
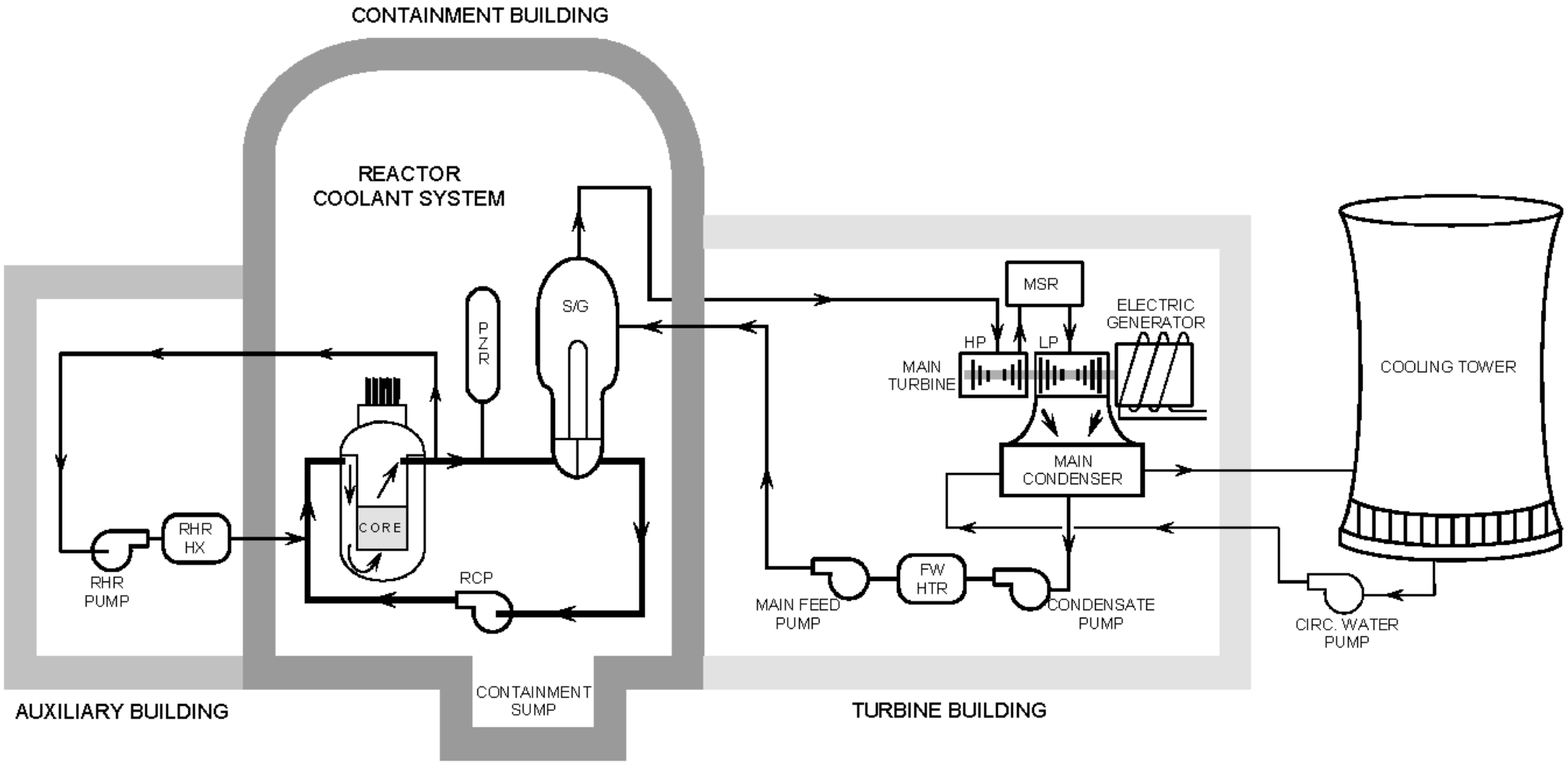
Overview of the Cyber Informed Dynamic Analysis

- Project Overview
  - Motivation – Safety Impact of Digital I&C
    - Defense in Depth –> Prevention may not be enough
    - Dynamic impacts may require simulations to assess impacts
  - Related papers in this conference
- Description of the case study
  - Plant layout
  - Accident sequence
  - Accident Mitigations
  - Path Forward



PWR Layout – Interfacing System LOCA



Project Motivation

- By identifying potential weaknesses in retrofitted DI&C systems before the retrofits occur, future designers can protect against cyber incidents easier, quicker, and cheaper than if the retrofits were found to require further modifications.
- A compromised DI&C system can have common attack vectors and impose common mode failures of active systems that may have been screened out of traditional safety analyses.
  - Mitigation of DI&C failures need to be analyzed at the systems level to ensure that the system is robust to new accident conditions.
  - Studying such potential time-sequenced cyber-attacks and their risks as they pertain to accident management can provide a risk-informed basis for developing effective cyber security controls for nuclear power.

Overlapping roles of safety and security

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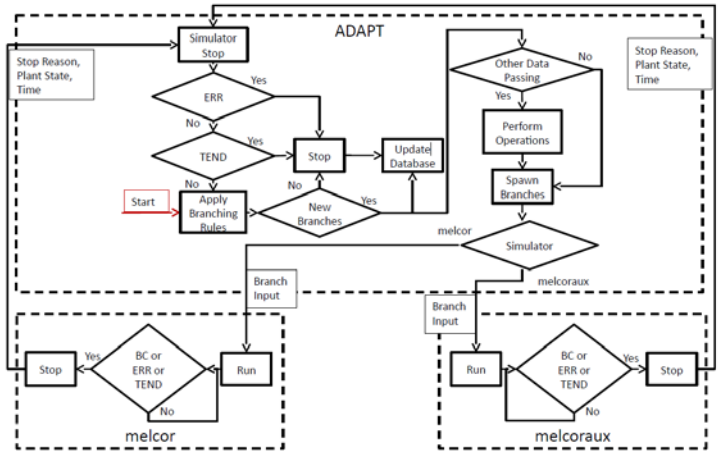
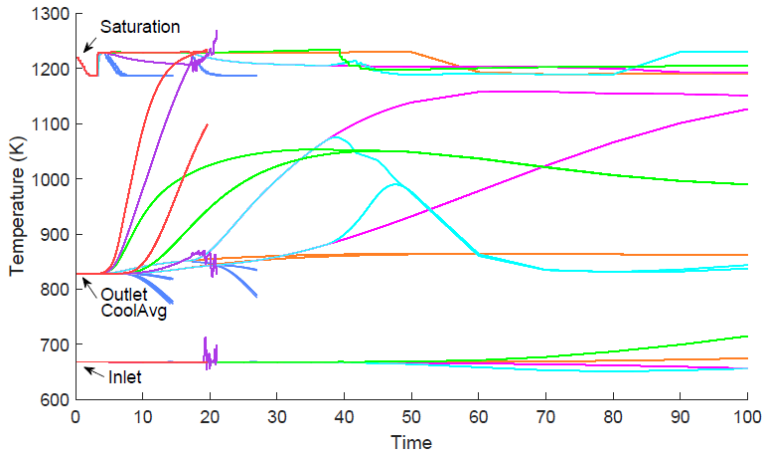
- Operator Response is key but DI&C systems can also delay diagnosis and remediation of a resulting transient by providing the operator with misleading data.
- This project is focused on accident sequences that would:
  - Lead relatively quickly to core damage.
  - Have redundancy of components which would cause the accident to be screened through traditional techniques, but
  - The redundancy is completely comprised of active digital components that could possibly be defeated by a cyber-faults.
- Codes and Models used to the support this work:
  - Physical Simulator – MELCOR
  - Cyber Environmental Simulators – OPNET and SCEPTRE (System for Circuit Evaluation and Prediction of Transient Radiation Effects)
  - Exploration of uncertainties – ADAPT (Analysis of Dynamic Accident Progression Trees)
  - Operator Habitability - RADTRAD

Related Publications at this Conference

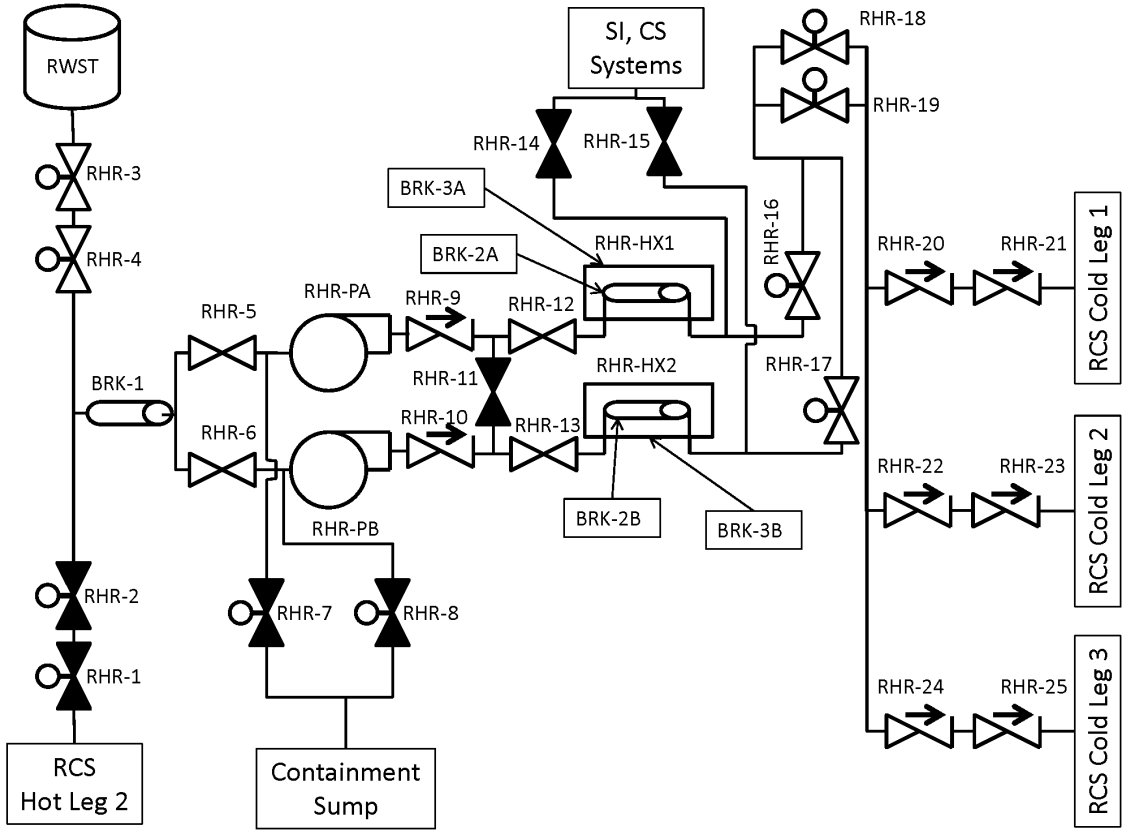
- N. Martin “Pruning of Discrete Dynamic Event Trees Using Density Peaks and Dynamic Time Warping”
  - Tuesday 1PM: Current Topics in Probabilistic Risk Analysis —I
- M. Denman “Preliminary Cyber-Informed Dynamic Branch Conditions for Analysis with the Dynamic Simplified Cyber MELCOR Model”
  - Tuesday 1:25PM: Current Topics in Probabilistic Risk Analysis —I
- Z. Jankovsky “Dynamic Importance Measures in the ADAPT Framework”
  - Tuesday 2:40PM: Current Topics in Probabilistic Risk Analysis —I
- Z. Jankovsky “Conditional Tree Reduction in the ADAPT Framework”
  - Wednesday 10:05AM: Computational Methods
- Z. Jankovsky “Extension of the ADAPT Framework for Multiple Simulators”
  - Wednesday 10:30AM: Computational Methods
- J. Cardoni “Severe Accident Modeling for Cyber Scenarios”
  - Wednesday 1:00PM: Nuclear Installations Safety: General —I





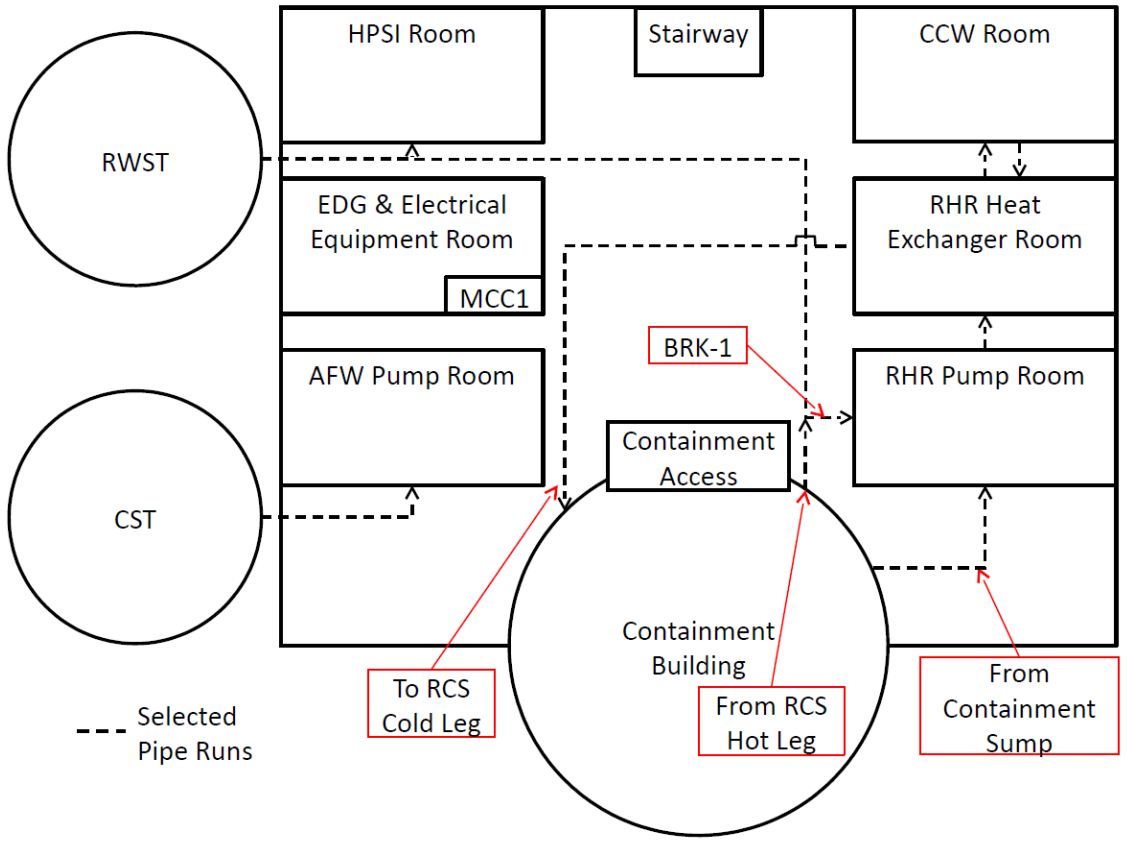
IS-LOCA in the Residual Heat Removal System

- Residual Heat Removal System (RHR) Interfacing System Loss of Coolant Accident (ISLOCA)
  - Both isolation motor-operated valves (MOVs) held open in cyber-induced controller failure
    - Administrative controls may lock the circuit breakers for these MOVs out in some plants
  - May lead to large pipe break outside containment
    - Uncertain timing of initiation and resolution
  - May lead to RHR heat exchanger tube rupture, introducing reactor coolant system (RCS) water into component cooling water (CCW)
    - Possibility of failing CCW, upon which many engineered safety features depend
    - May lose safety injection (SI) pumps



Operator Response and Remediation

- Cyber incidents may require operators to respond to the IS-LOCA from outside the Auxiliary Building
  - Manual signal to isolating the RHR isolation MOV
  - Closing the manual valves in the RHR Pump Room
    - Isolates RWST and prevents further drainage
- Some actions from the control room may help if available:
  - Opening of the Pilot Operated Relief Valves of the Pressurizer



Operators may be hindered in their responce

- Operator Hazards
  - Flooding
  - Steam
  - High Temperatures
  - High Radiation Levels
  - Hydrogen and other combustible materials
- These hazards impact the operators ability to navigate the plant and respond to the accident
  - RADTRAD

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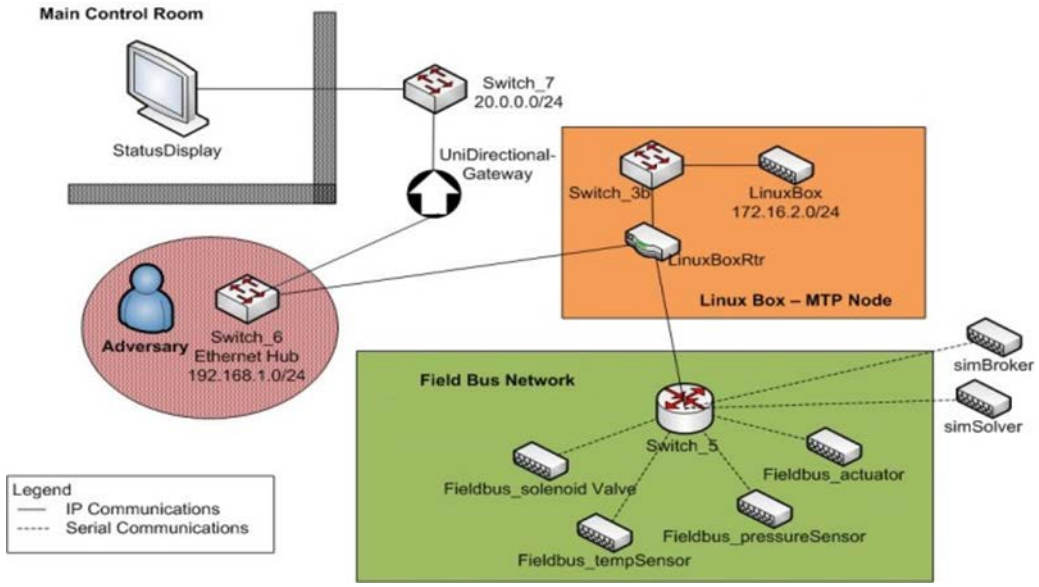
Kenji Tetawa

Path Forward

- Conduct integrated cyber-physical-operator assessment of the cyber incident
  - ADAPT controlled and schedule on the SNL Tree Cluster
    - MELCOR - Plant
    - SEPTRE/OPNET – Network
    - RADTRAD – Habitability
  - Evaluate the effectiveness of various mitigation strategies in optimizing the end state of the reactor.
- Study to be finished by September of 2017



Thank you for your time

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- The Ohio State University (Prof. Tunc Aldimer) was contracted with to made interacting improvements to ADAPT in support of this effort.