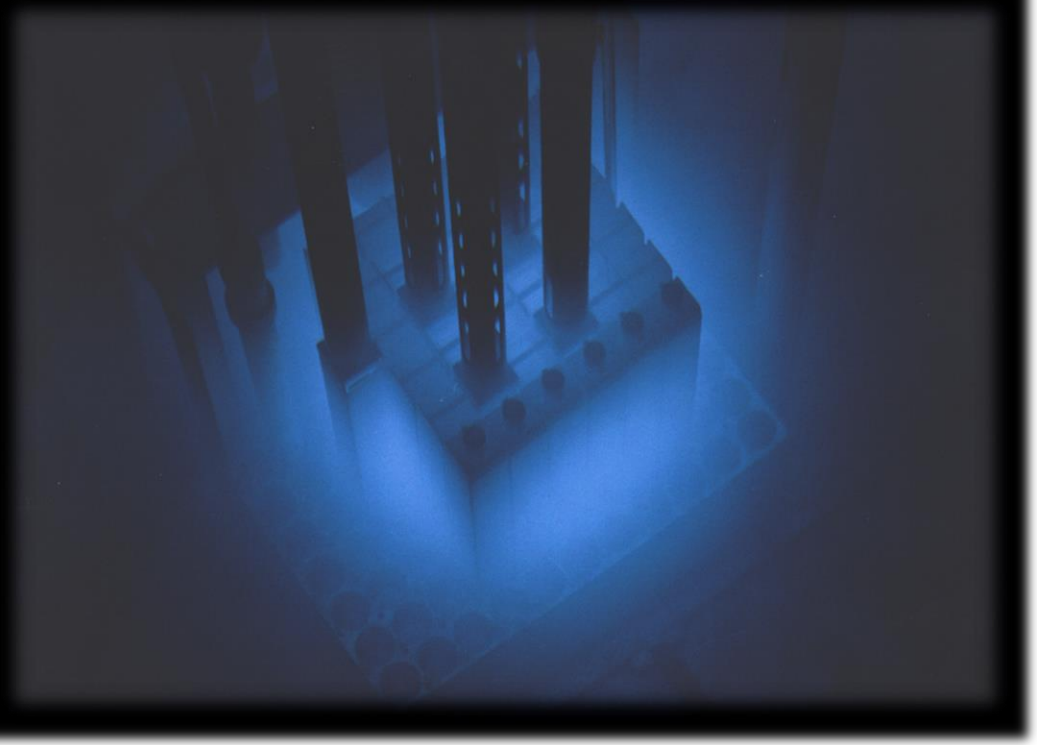
InfoSymbiotics / DDDAS2020
October 2-4, 2020

DATA-BASED DEFENSE-IN-DEPTH OF CRITICAL SYSTEMS



Styliani Pantopoulou, Pola Lydia Lagari, Clive H. Townsend, Lefteri H. Tsoukalas

School of Nuclear Engineering
Purdue University, West Lafayette, IN, US

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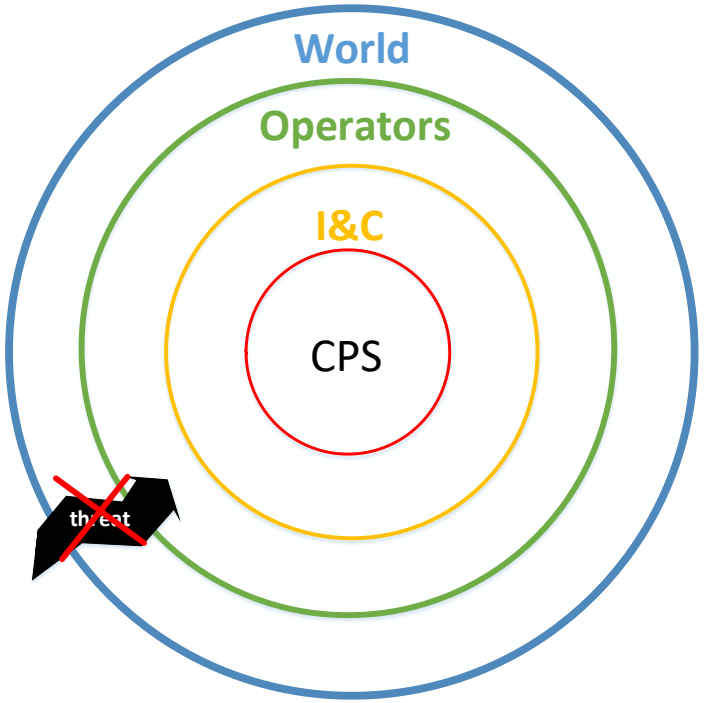
Outline

- Motivation
- Methodology
- Results
- Conclusions & Future Work

Motivation

- Cybersecurity in focus because of the multifaceted nature of Cyber Physical Systems (CPS).
- Digitalization and cyber technologies offer advantages; but also pose challenges.
- The DDDAS paradigm can prove helpful towards data assortment and classification.



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Methodology
System Modeling

- System under review: a Nuclear Power Plant (NPP)

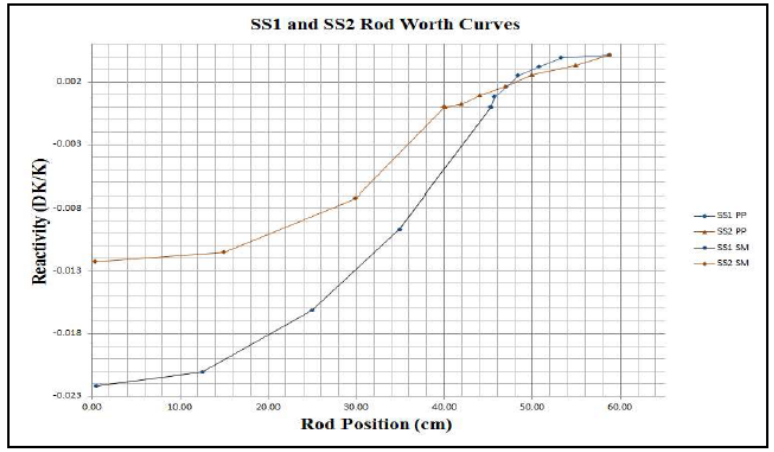
- State-space equations
  - n: neutron density
  - c: neutron precursor density
  - ρ: reactivity
  - z: control rod velocity

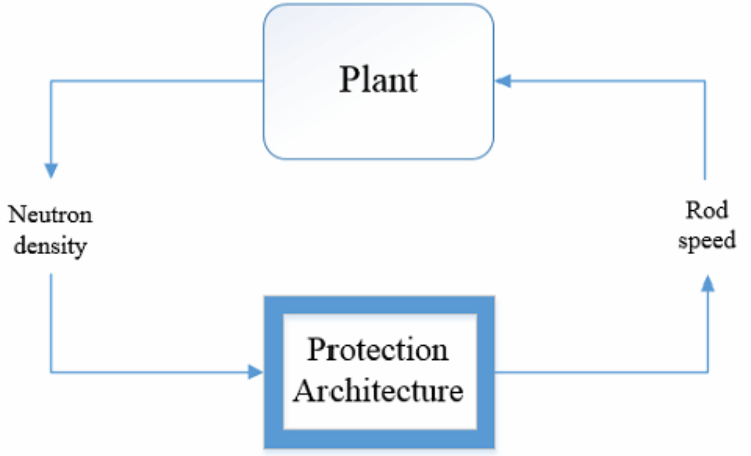
$$\begin{bmatrix}\dot{n}\\ \dot{c}\\ \dot{\rho}\end{bmatrix} = \begin{bmatrix}\frac{-\beta}{\Lambda} & \lambda & \frac{n_0}{\Lambda}\\ \frac{\beta}{\Lambda} & -\lambda & 0\\ 0 & 0 & 0\end{bmatrix}\cdot\begin{bmatrix}n\\ c\\ \rho\end{bmatrix} + \begin{bmatrix}0\\ 0\\ G\end{bmatrix}\cdot z$$

$$n = [1 \quad 0 \quad 0]\cdot\begin{bmatrix}n\\ c\\ \rho\end{bmatrix}$$

- Controlling z gives output regarding n

- ρ is calculated through plant measurements





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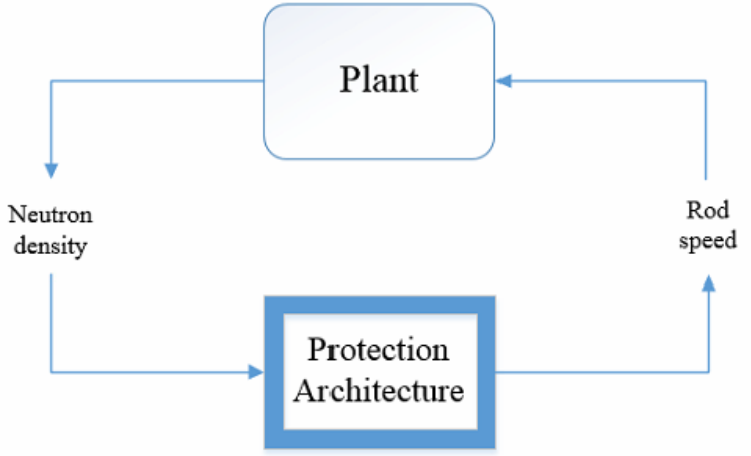
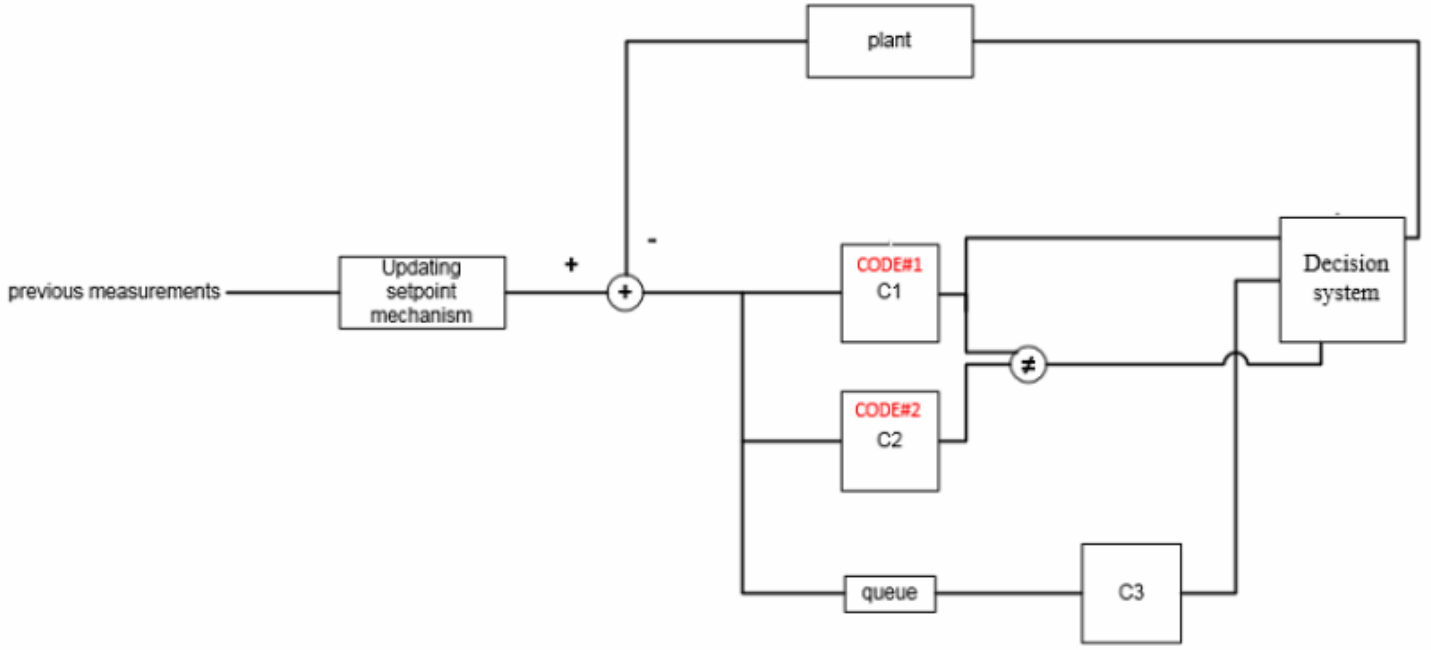
Methodology
Mitigation of a Cyber-attack

- Protection architecture
  - PLC controllers
  - Updating setpoint component
  - Delay queue
  - Decision system





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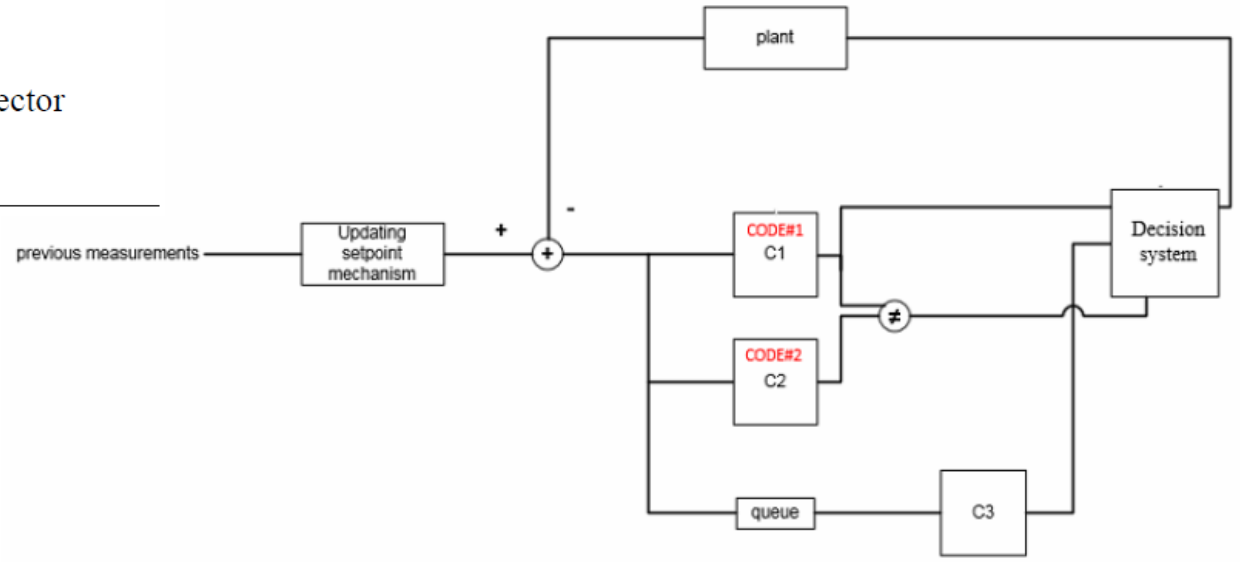
Methodology
Mitigation of a Cyber-attack

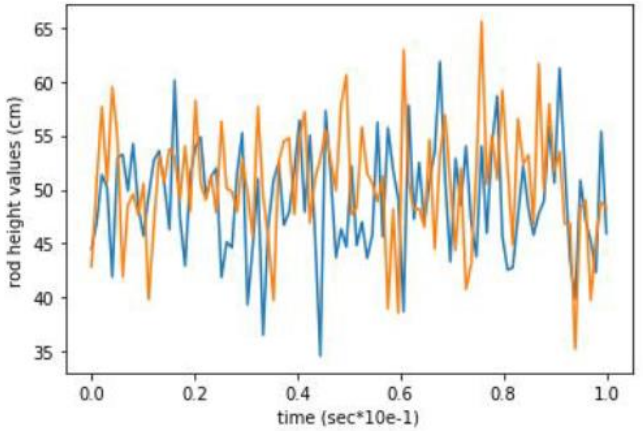
Algorithm

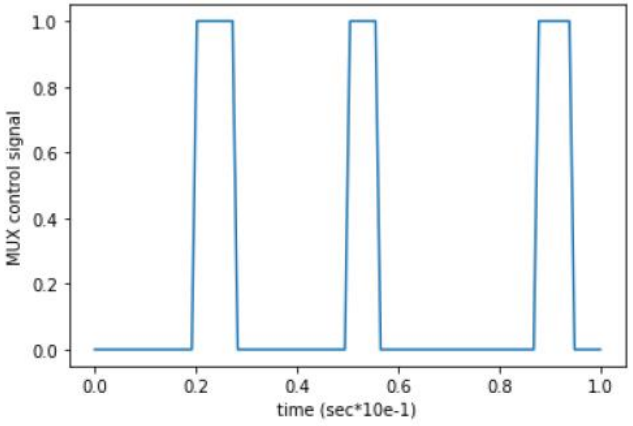
1. Get measurement $x(n)$ from plant
2. $x(n-k)\cdot h(n-k)+x(n-k+1)\cdot h(n-k+1)+\ldots+x(n-1)\cdot h(n-1)=x(n-k+1)$
   ...
   $x(n-1)\cdot h(n-k)+x(n-2)\cdot h(n-k+1)+\ldots+x(n-k)\cdot h(n-1)=x(n)$
3. $\hat{x}(n)=h(1)\cdot x(n-1)+\ldots+h(k)\cdot x(n-k)$
4. Controllers C1 and C2 get error signal $\hat{x}(n)-x(n)$
5. C1 runs PLC_code1, C2 runs PLC_code2
6. Comparator checks $|out1-out2|$
7. If $|out1-out2| \leq$ noise threshold $\rightarrow$ $Mux\_control\_signal = 0$
   Else $Mux\_control\_signal=1$
8. Contents of queue erased and not added to previous_measurements vector
9. C1, C2 get restarted
10. $x(n+1)$ calculated from state space equations



Results

- Response of decision system.
- Plant measurements considered as following the normal distribution, with specific μ and σ.
- When the two controller outputs differ more than a threshold related to noise; C3 forwards its output to the plant.





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Conclusions & Future Work

- Importance and connection of the DDDAS paradigm with critical systems.
- A NPP can be transformed into a trustworthy digital system.
- A second layer of protection or suitable operators' training would aid towards avoiding dangerous situations.
- More complex attack schemes have to be tested in order to ensure the system's integrity and security under a greater variety of circumstances.

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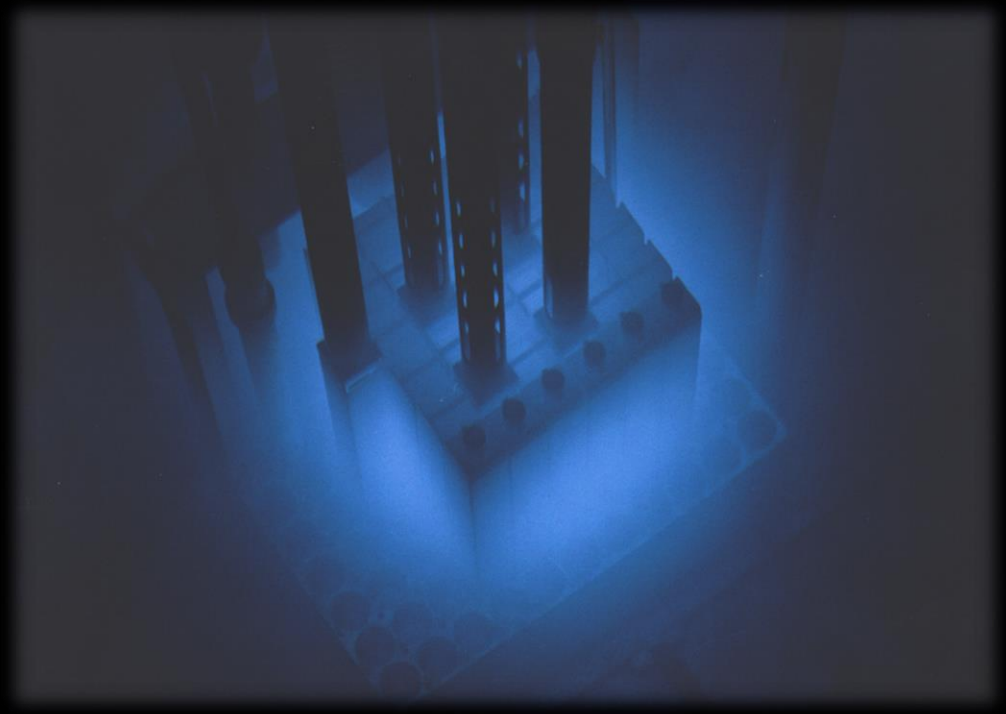
THANK YOU!
QUESTIONS?



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