Demonstration of Advanced Encryption for an Instrumentation and Control System using ARCADE

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Hardware-in-the-loop enables real-time testing of hardware by integrating it into a simulated environment. It is most useful for high-value low-volume systems.

Expensive

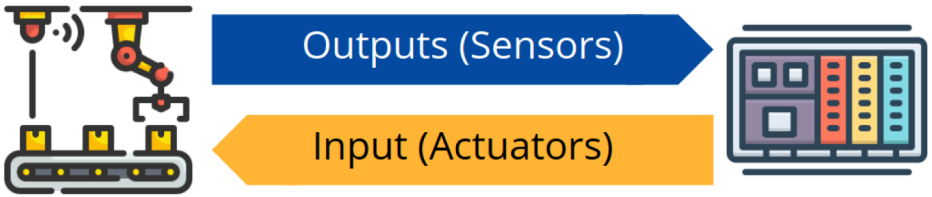
Inaccessible

Dangerous

https://www.nrc.gov/reactors/operating/licensing/renewal/applications/bvalley/bvalley_station.jpg

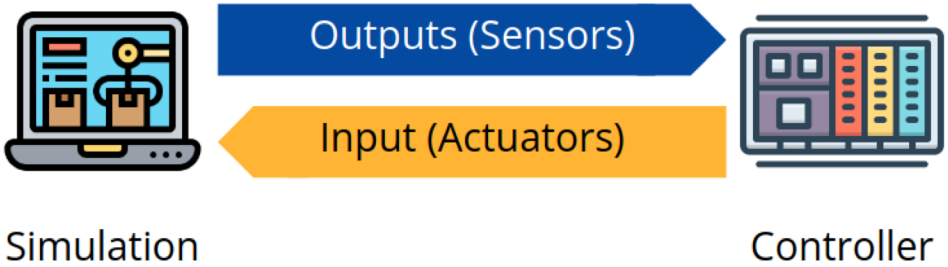
Hardware-in-the-loop simulation integrates real hardware with a virtual simulation environment to test and validate system performance in real-time

This is what a (simple) control system is:

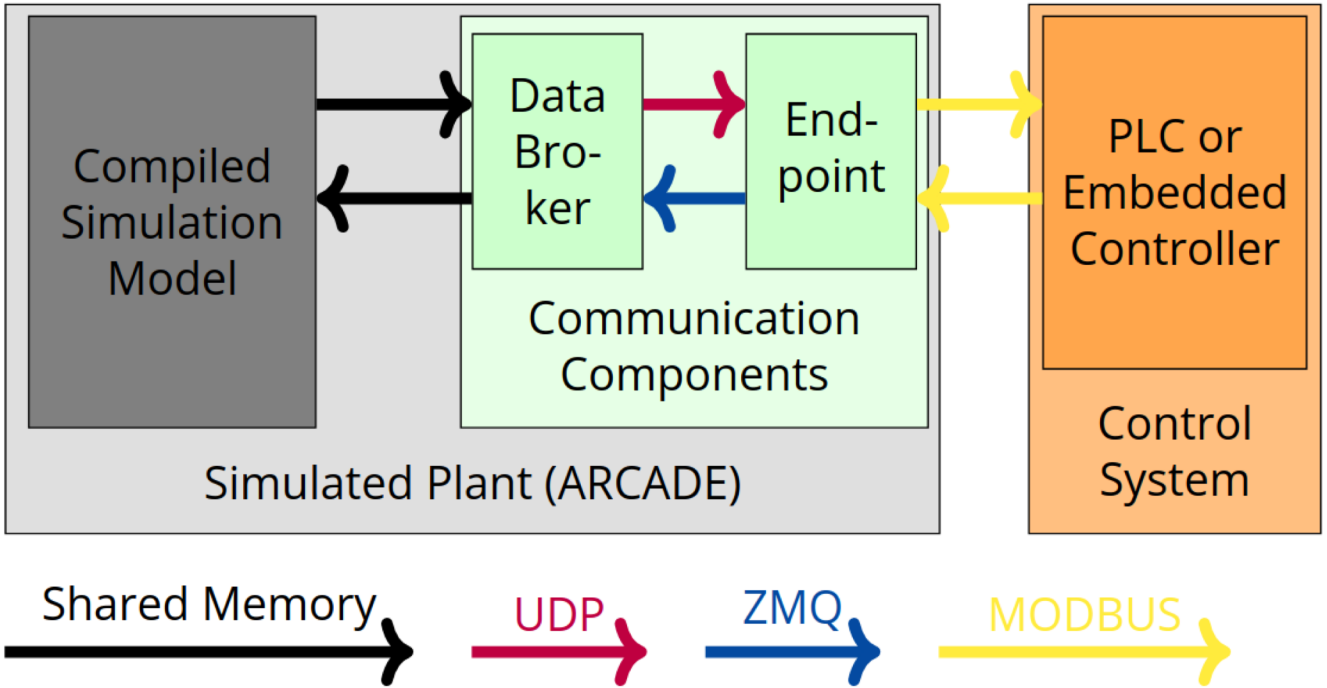


For Hardware-in-the-loop (HiL):

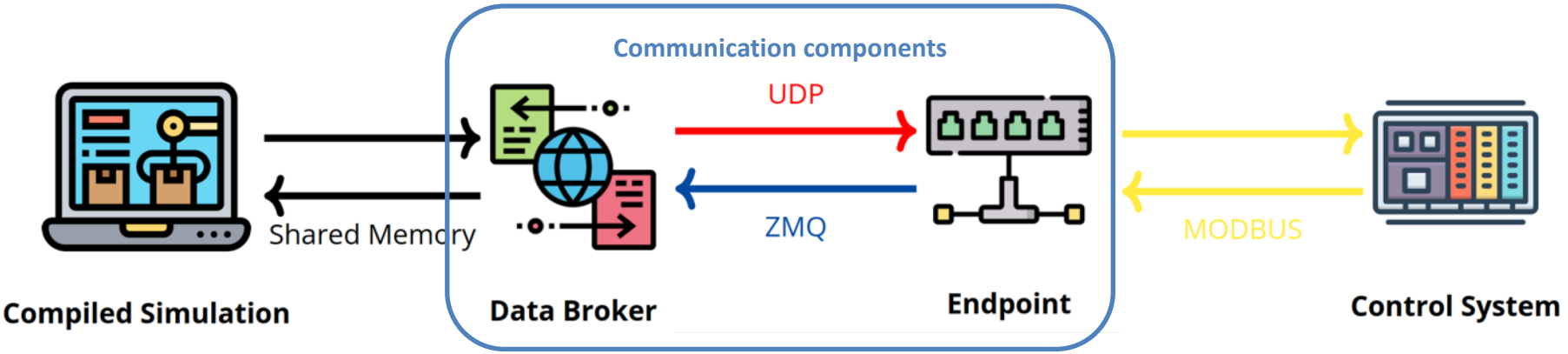
Replace the physical plant with a simulation:



ARCADE is an open-source solution between a pre-compiled simulation model and a control network



The data broker communicates between the simulation and other systems; the endpoint transmits data over Modbus, enabling control and monitoring



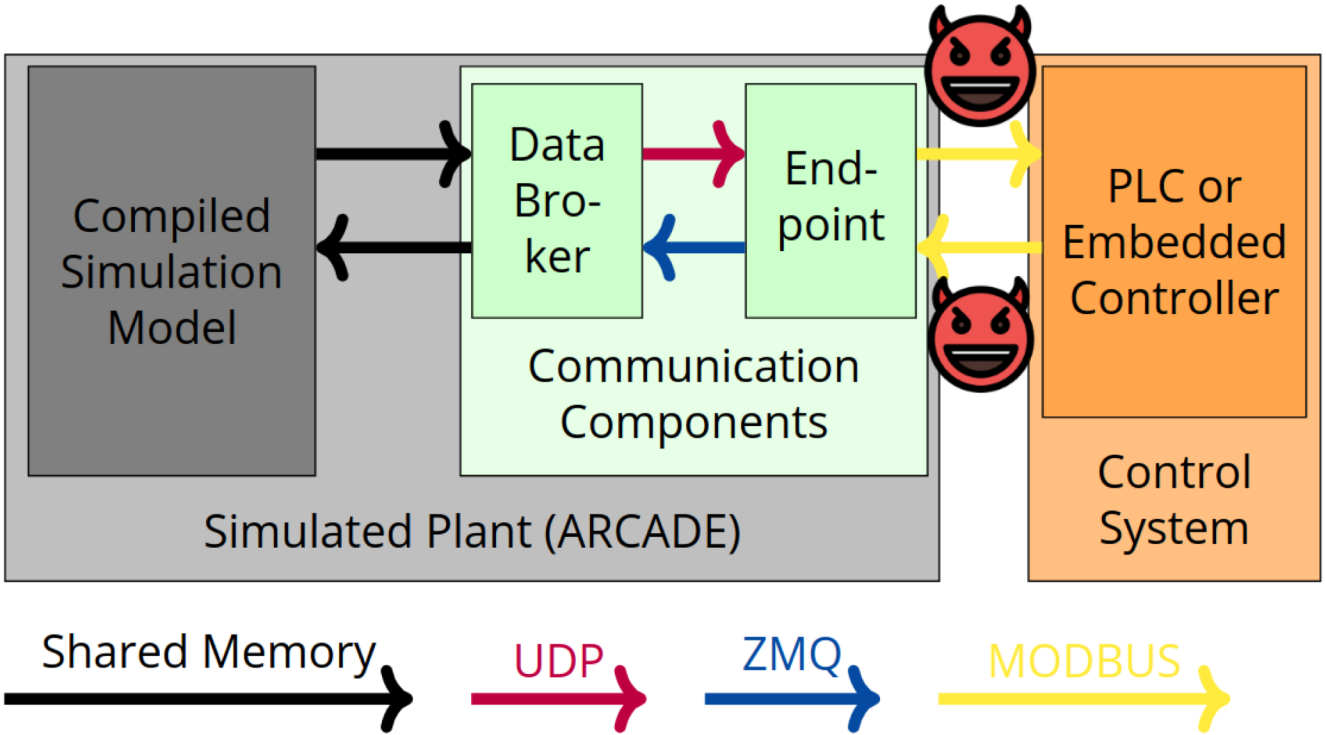
- C/C++ code from SimulinkCoder
- Share memory with the Data Broker

- Reads and writes data to shared memory with the simulation
- Manages the “real-time” pace of the simulation
- Configures the endpoint
- Broadcasts sensor values

- Monitors PLC memory
- Sends PLC control signals to the data broker
- Writes sensor values to the control system
- Listens for updated control signals

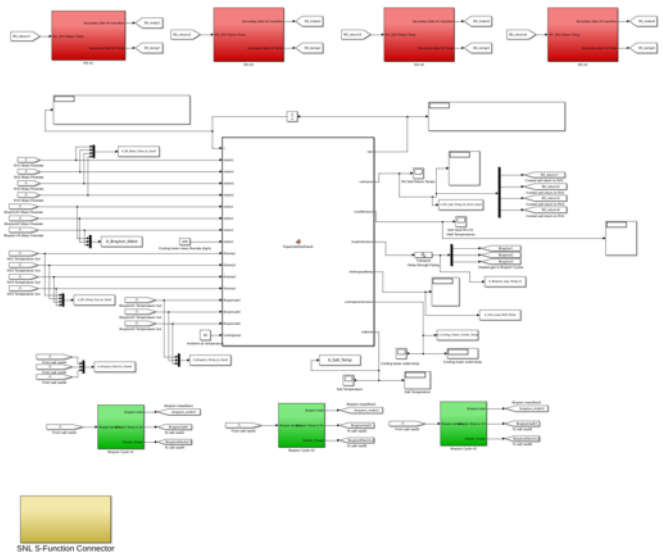
- OpenPLC, real PLC (HiL), or embedded control system
- Has no clue it’s in a simulation

ARCADE allows full control and manipulation of signals, facilitating research into system robustness, cyberattack scenarios, and the measurement of harm

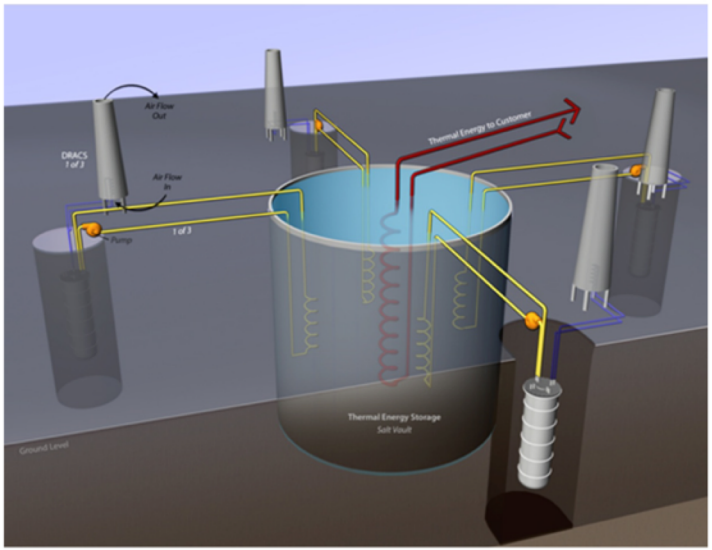


In ARCADE, we have modelled a SmAHTR:
Small Modular Advanced High Temperature Reactor

SmAHTR Simulink model

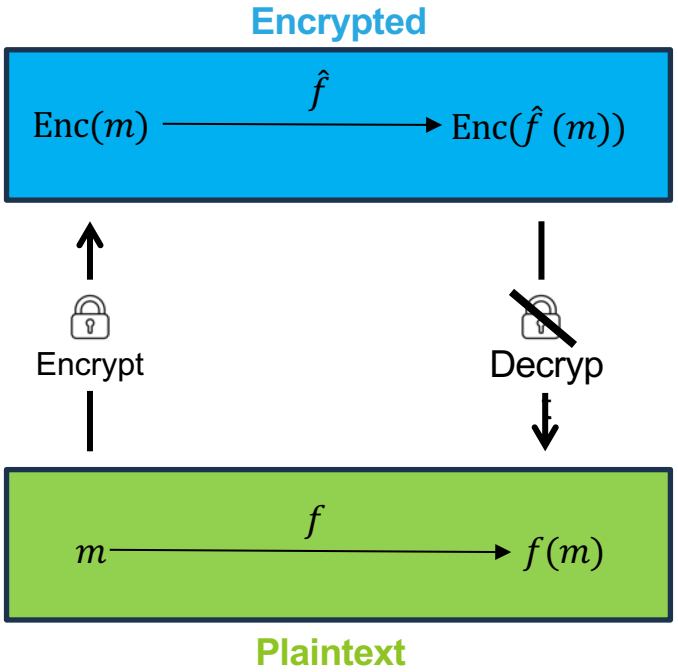


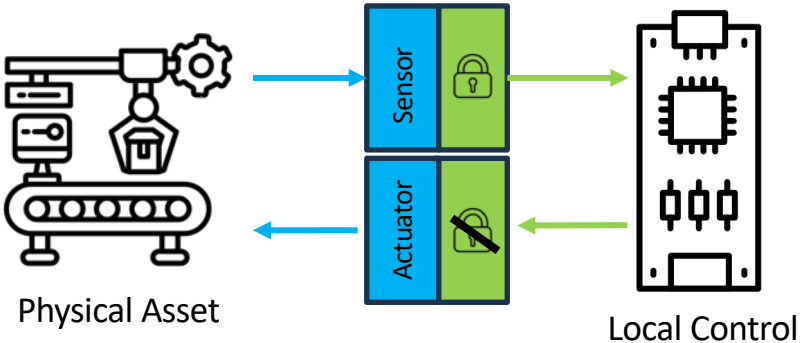
SmAHTR reactors with a salt vault

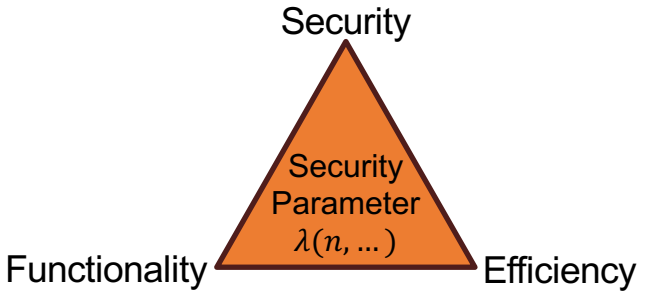


https://info.ornl.gov/sites/publications/files/Pub26178.pdf

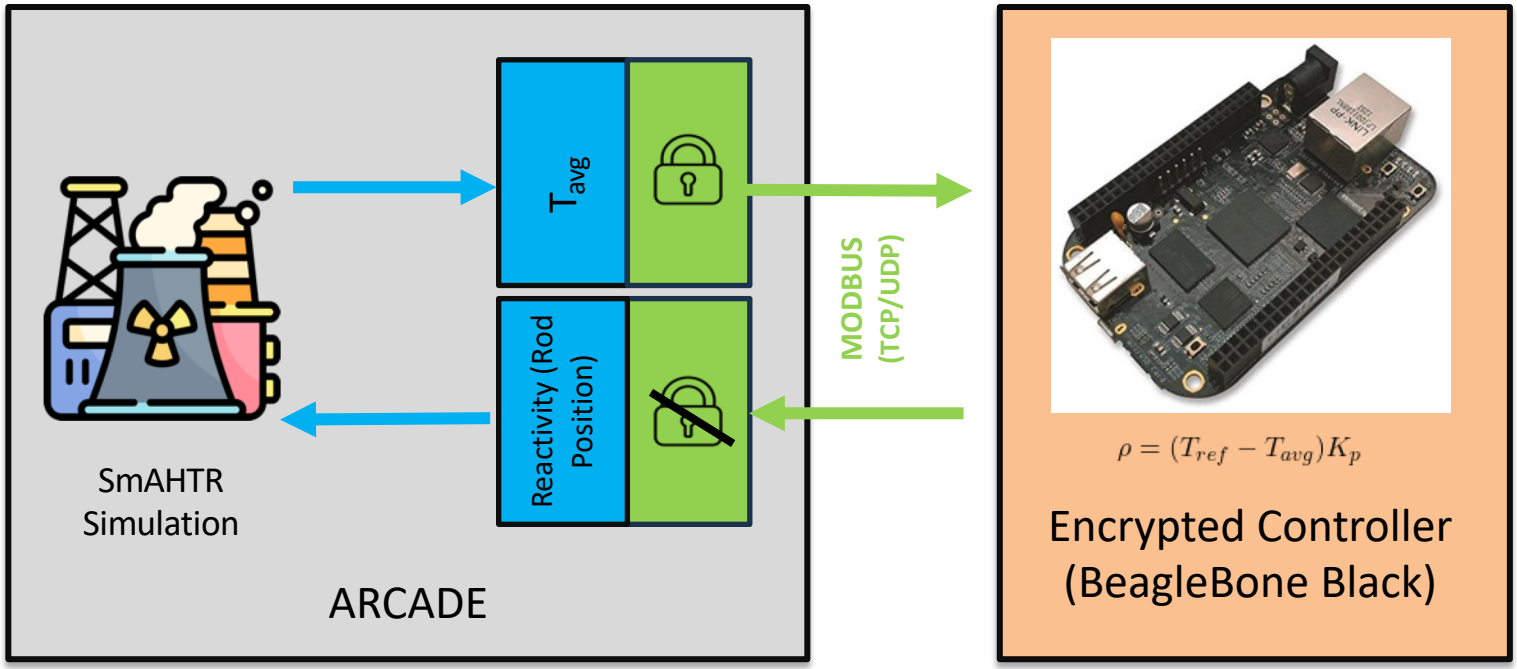
Homomorphic encryption allows computations to be performed on encrypted data without decrypting it



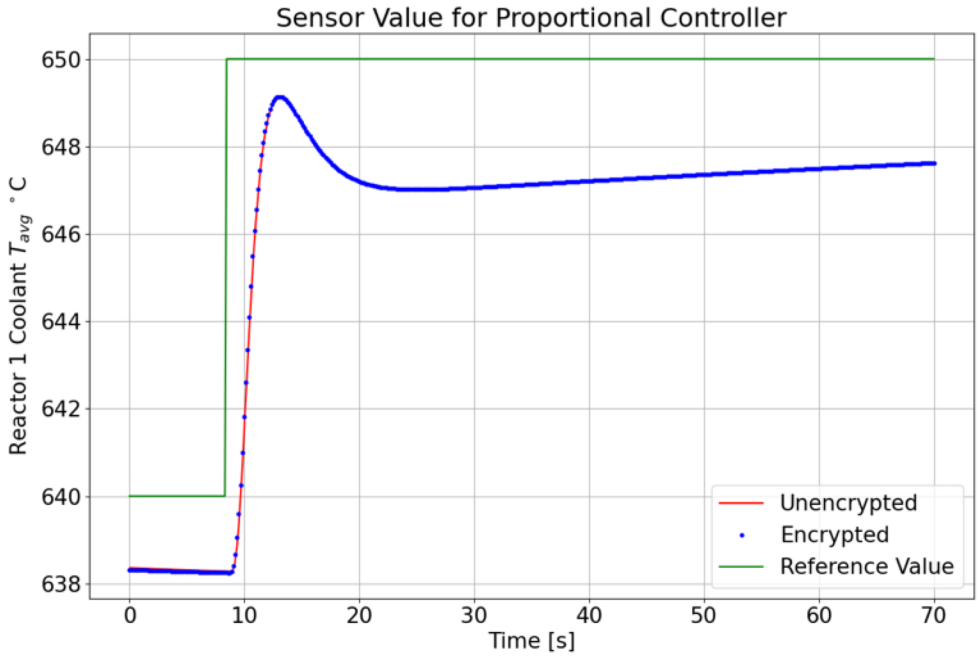




We have used this encryption scheme on a BeagleBone Black connected to the SmAHTR simulation using ARCADE



The encrypted controller is the same as the unencrypted controller



Memory	Unencrypted Controller	Encrypted Controller
Scalar signal (LWE)	4 B	48 B
Scalar gain (GSW)	4 B	3456 B

This demonstrates encrypted control systems for secure control systems in advanced reactor instrumentation and control

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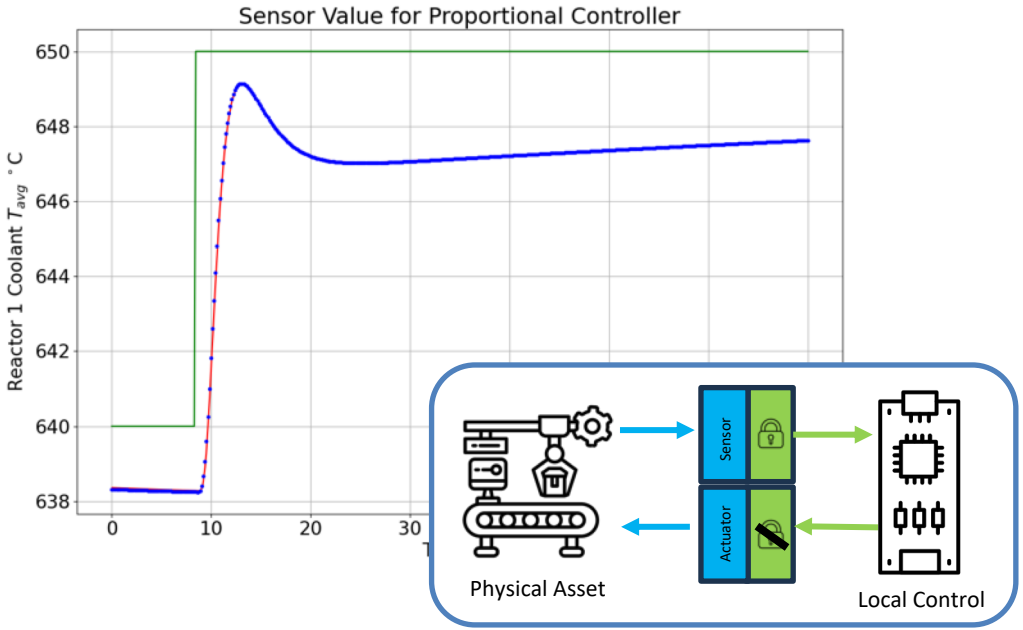
Questions?



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