Merged Environment for Simulation and Analysis (MESA)

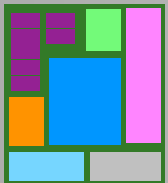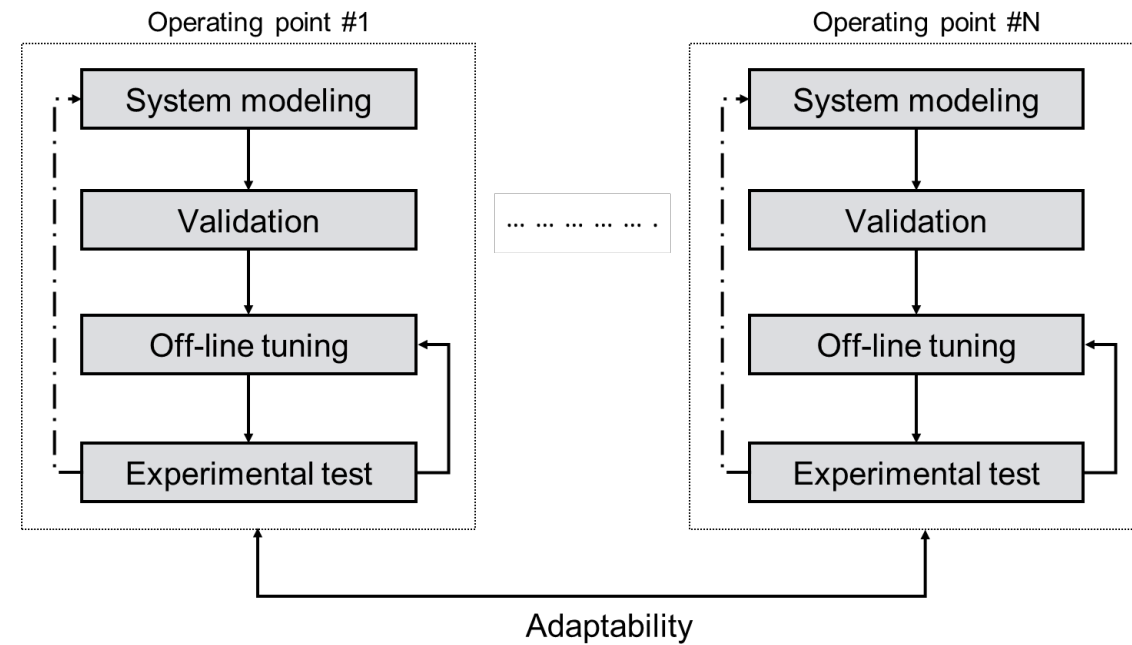|	
Project Investigator:	Dr. Mark Bryden
Post-doc Research Associate	Dr. Paolo Pezzini
Date:	04/12/2018
DOE Award Number	DE-AC02-07CH11358
Period of Performance	FY2017

1. Enabling high efficiency high turn down operation of hybrid power systems

2. Enabling rapid design and analysis of complex power systems

3. Creating on the fly updates for control systems for existing power plants
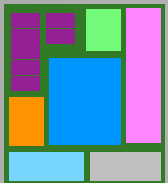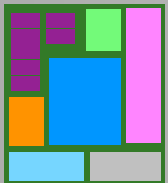
Objectives

- Model-based design

- Tuned for a specific operating point

Operating point #1

System modeling

Validation

Off-line tuning

Experimental test

... ...

Operating point #N

System modeling

Validation

Off-line tuning

Experimental test

Adaptability

Traditional Control Strategies

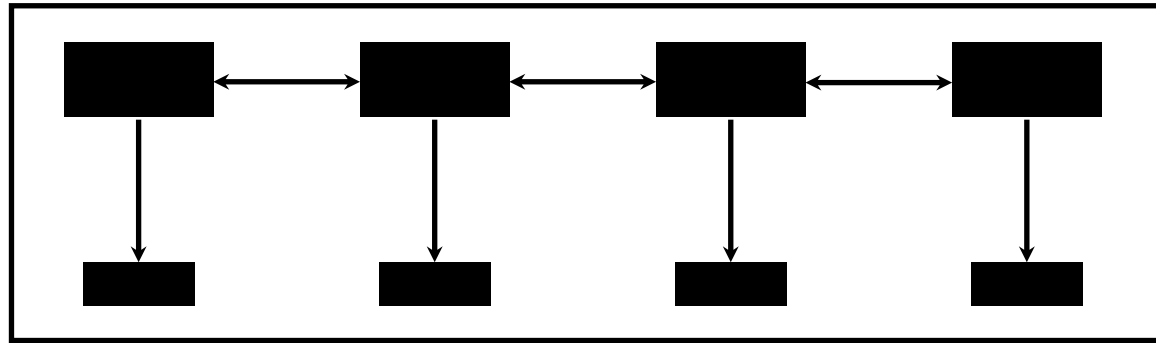**Characterization of each operating point**

- Process instability

- Adaptability cannot be reached without system identification
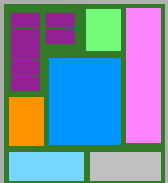
 Limitations

- Model-free design

- Adaptable on-the-fly

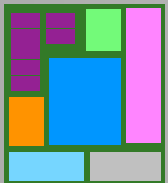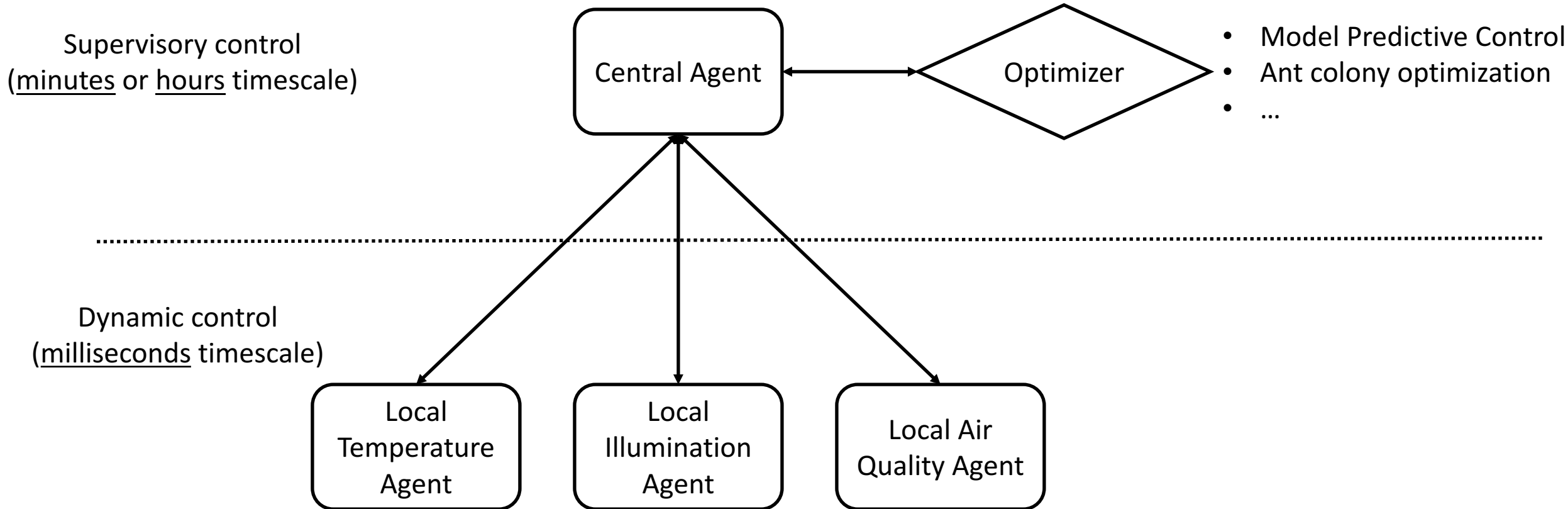- Reconfigurable on different power plants
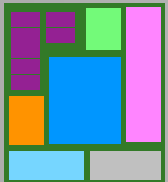
- Intelligent
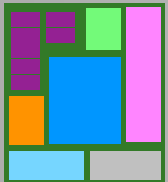
High efficiency high turn down operation

- Multi-agents emulates intelligent control

- Agents can coordinate their behavior

- Agents are not limited to a set of models

Agent-based Control

Multi-agents are mainly used for supervisory applications...

Supervisory control
(<u>minutes</u> or <u>hours</u> timescale)

Central Agent

Optimizer

- Model Predictive Control
- Ant colony optimization
- ...

Dynamic control
(<u>milliseconds</u> timescale)

Local Temperature Agent

Local Illumination Agent

Local Air Quality Agent

Multi-agents in building automation

Multi-agents for dynamic control of energy systems

Goal of Multi-agent Control Strategies
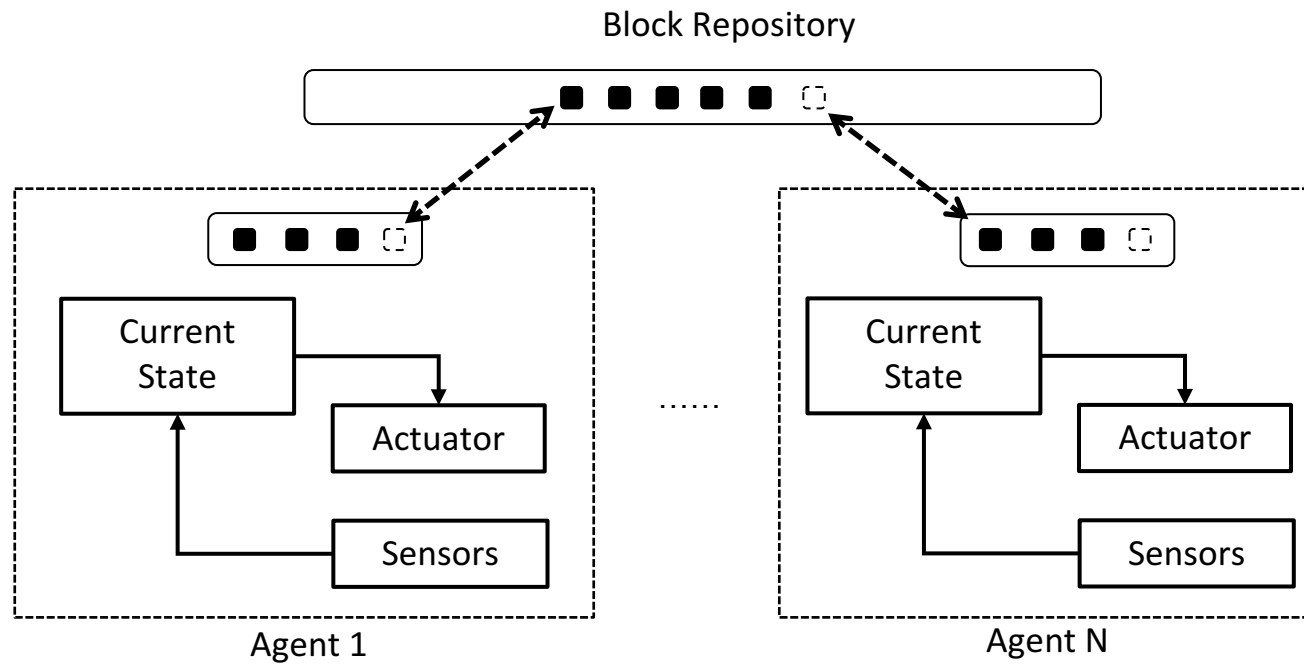
Agent Selection Criteria

- Set of rules to avoid simultaneously actions

Random Probability of action

- Emergent behavior in social insects
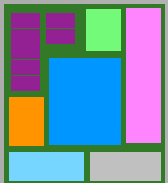
- Determines frequency of action taken
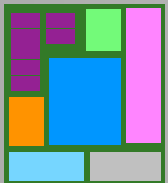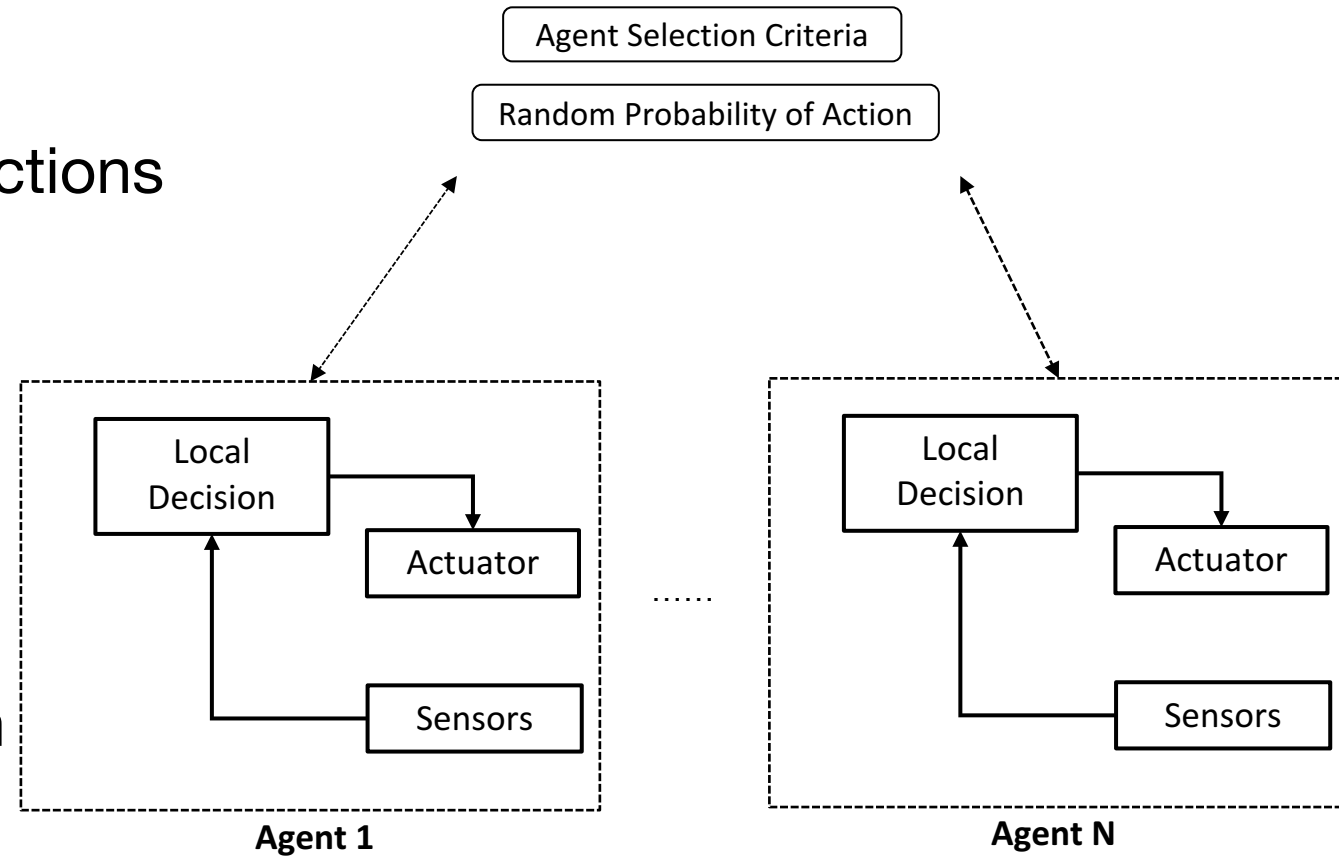
Shared Resource (Blocks) establishes cooperation and sharing
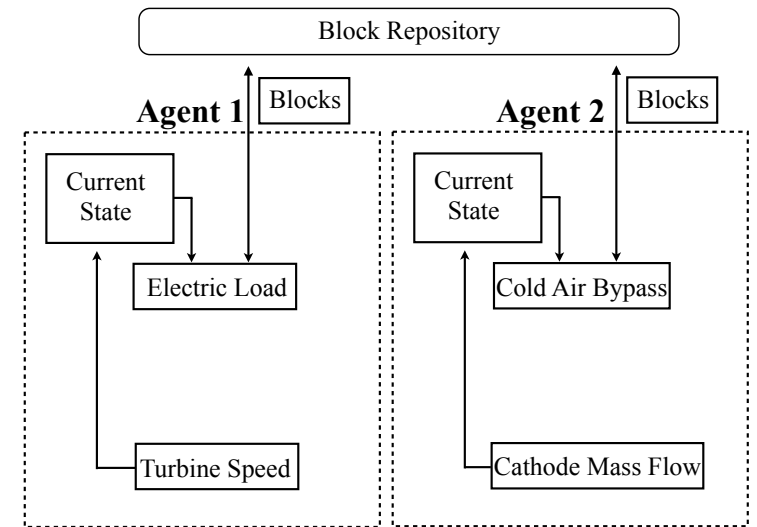
Blocks are a discrete unit of change to an actuator

Exchange of blocks when the current state is not at nominal condition
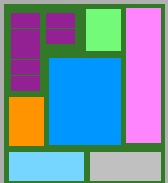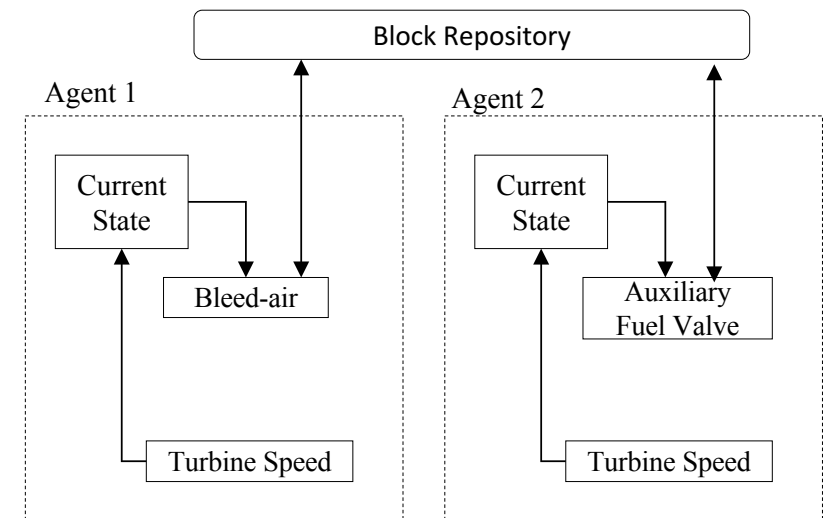
Resource sharing algorithm

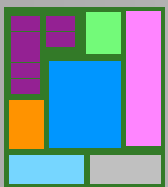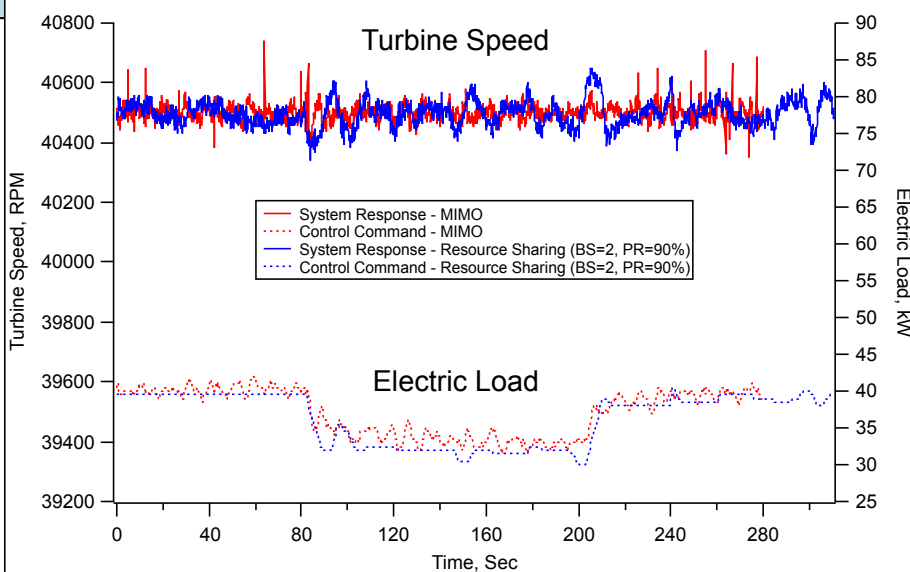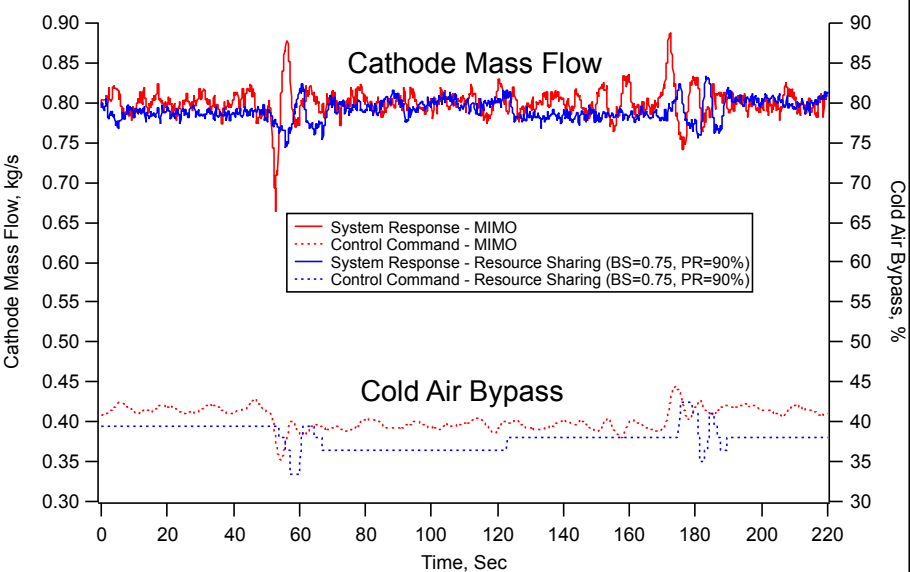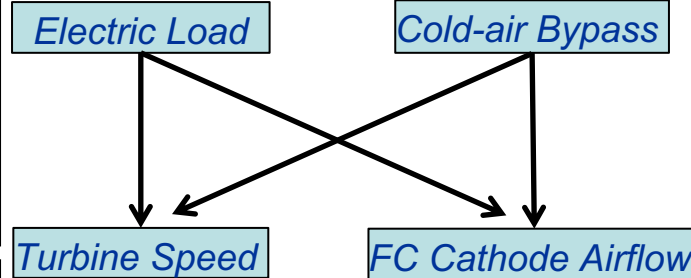# 1. Multi-input multi-output (MIMO)
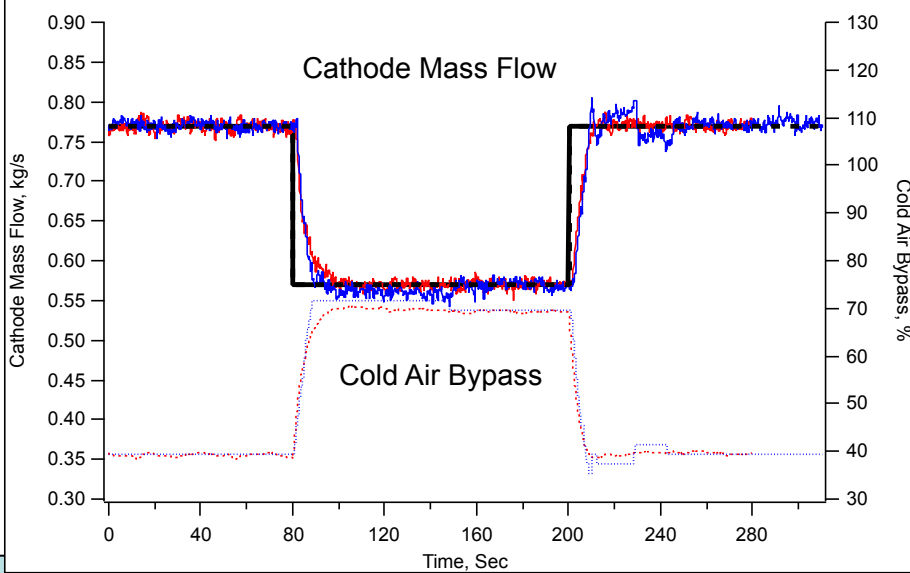
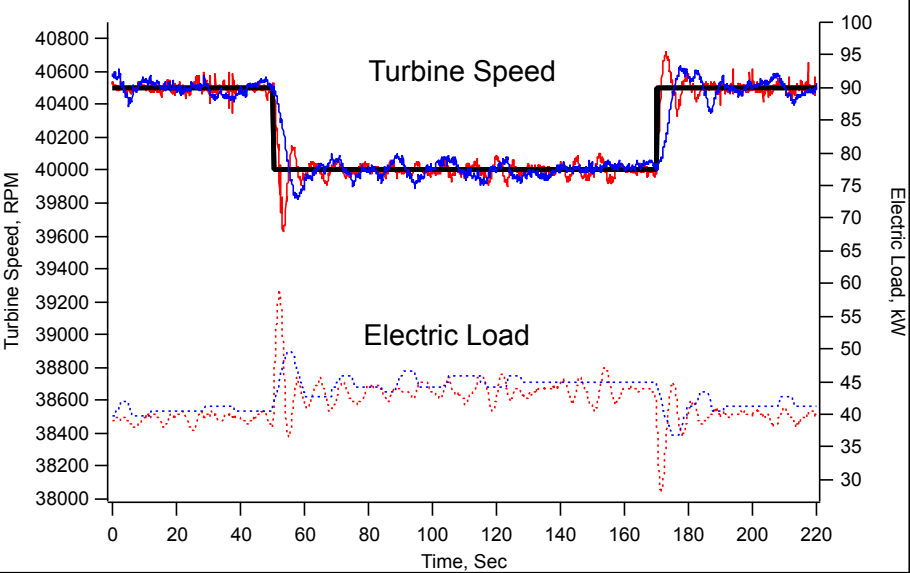- 2 sensors and 2 actuators
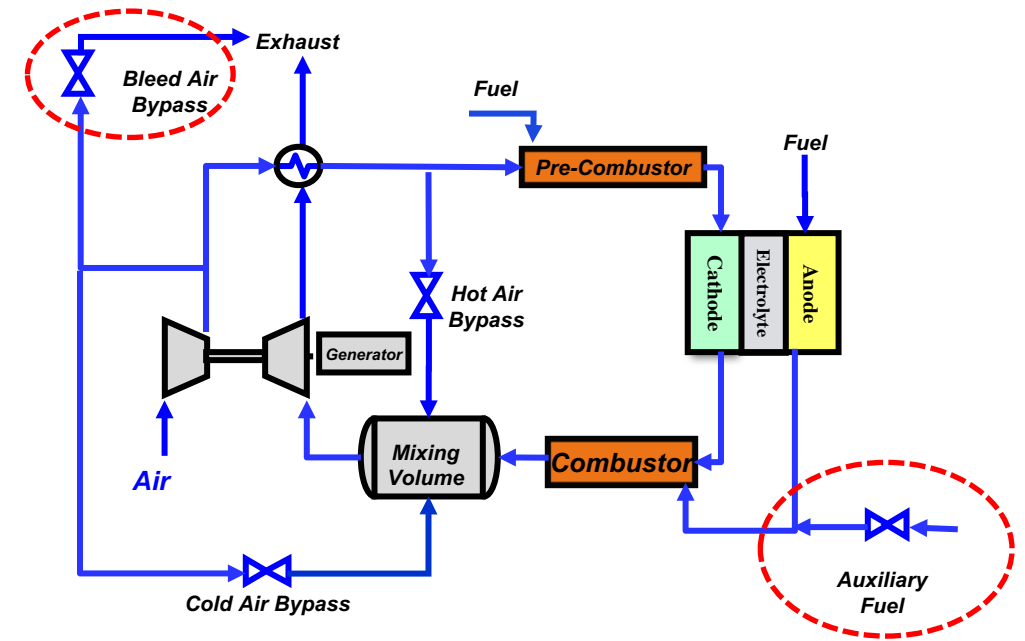
- 2 agents
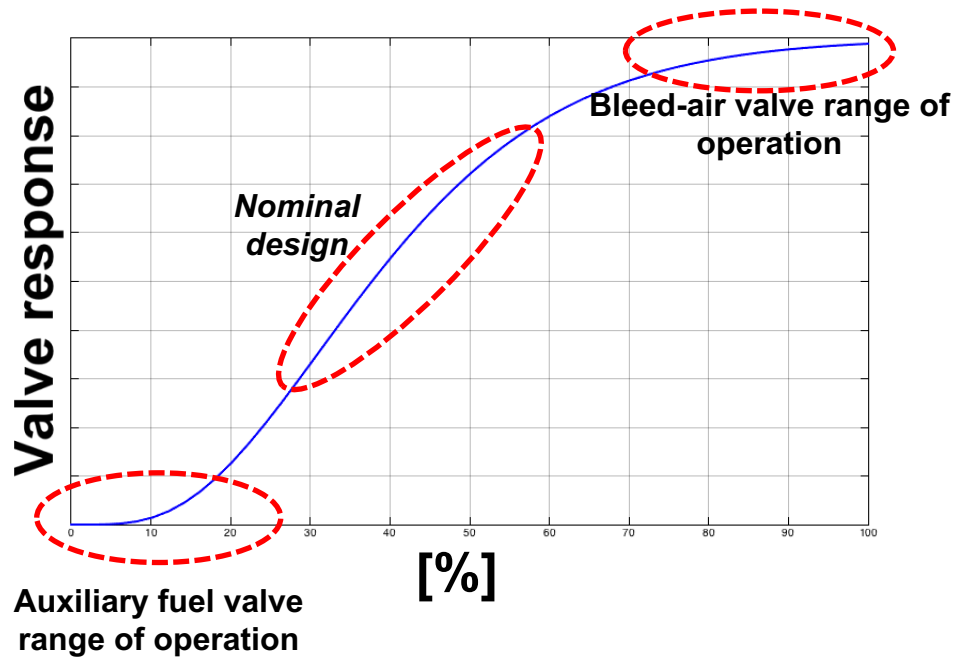
2. Multi-input single-output (MISO)

- 1 sensor and 2 actuators

- 2 co-worker (homogenous) agents

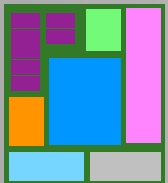**Multi-agents control tested on Hyper**

Multi-agents vs Centralized MIMO control
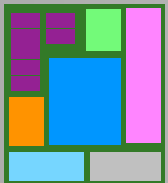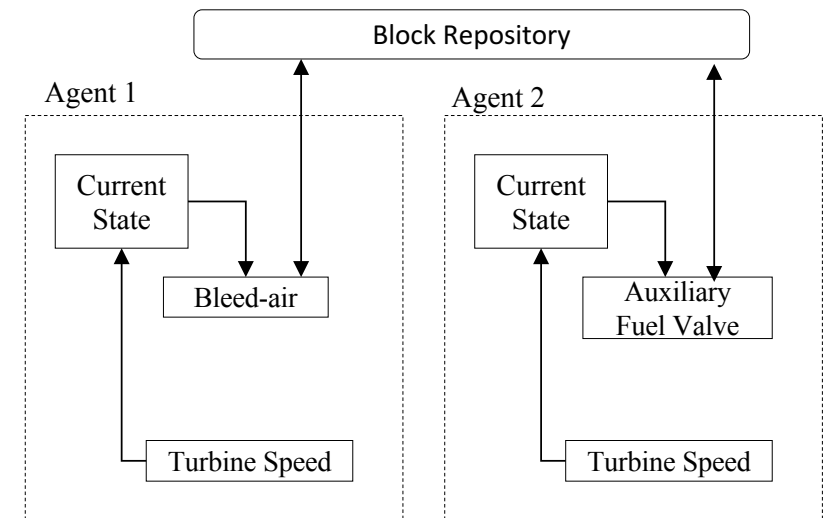
Nominal condition:

- Fuel cell thermal heat drives the gas turbine

- Closed valves position to maximize system efficiency

- Valve opening during transient operation
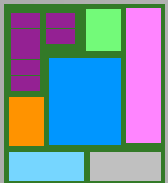
Multi-input single-output (MISO)
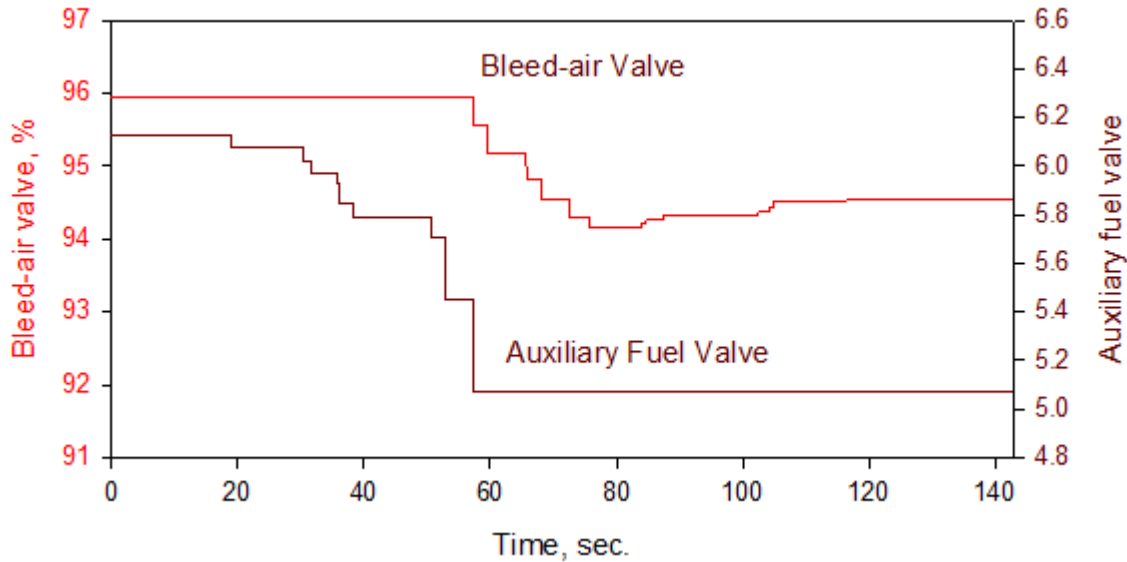
Asynchronous agent selection criteria
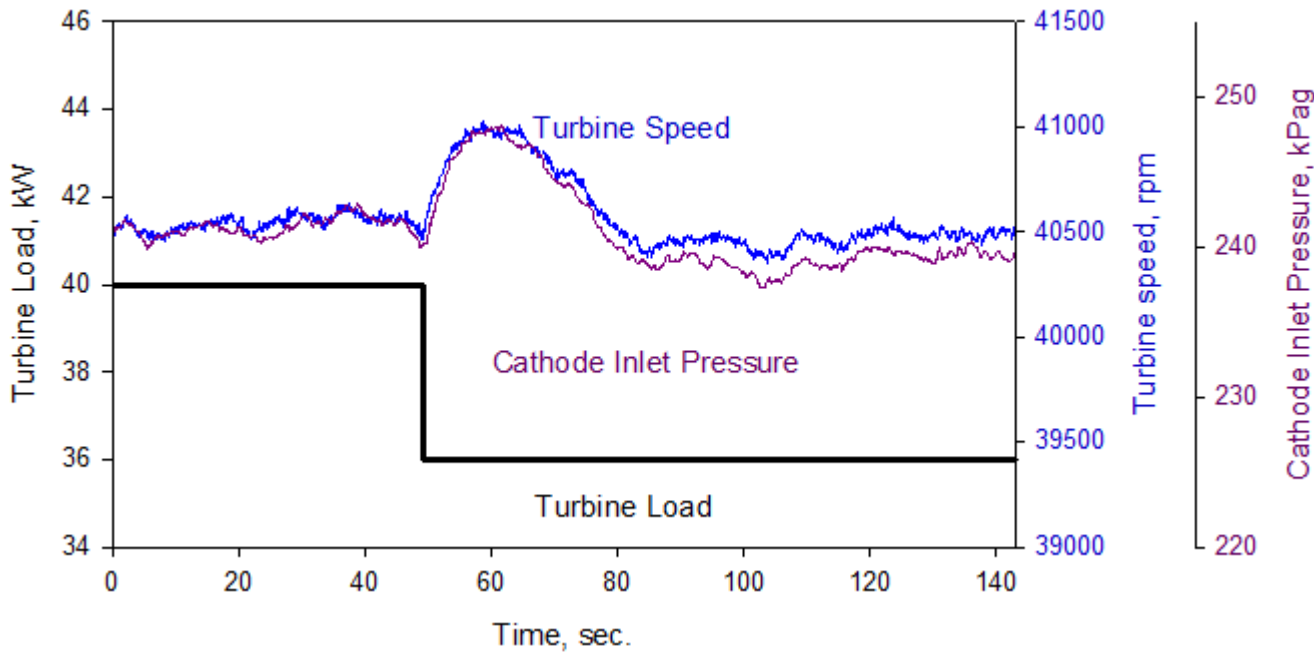
- Saturation limit as agent selection criteria

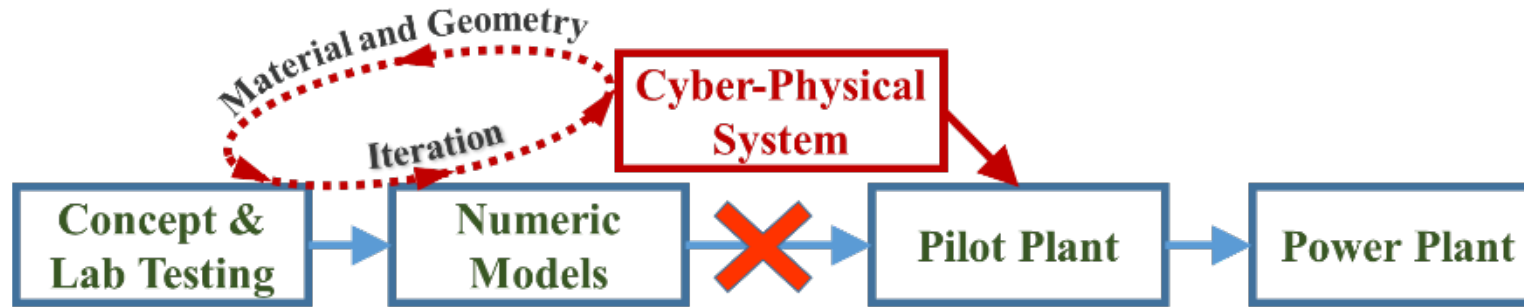- 10% Probability of action

Turbine Speed Deviation

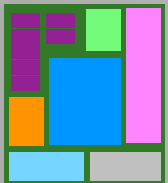- In open-loop: 1000 rpm

- Multi-agent: 500 rpm

Turbine load following – turn down

Engineered **systems** that are built from, and depend upon, the seamless integration of computational algorithms and physical components

Rapid design and analysis of complex power systems

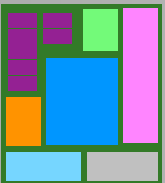# Hybrid Performance Project (HYPER)

Design and Validation of Advanced Sensors
- Advanced Sensing
- High Temperature & Harsh Environment Applications
- Smart Sensors
- Sensor Placement

Design and Validation of Novel Control Strategies

- Distributed Intelligent Control
- Smart Actuation
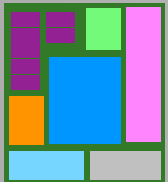- Efficient Decision Making
- Digital twin
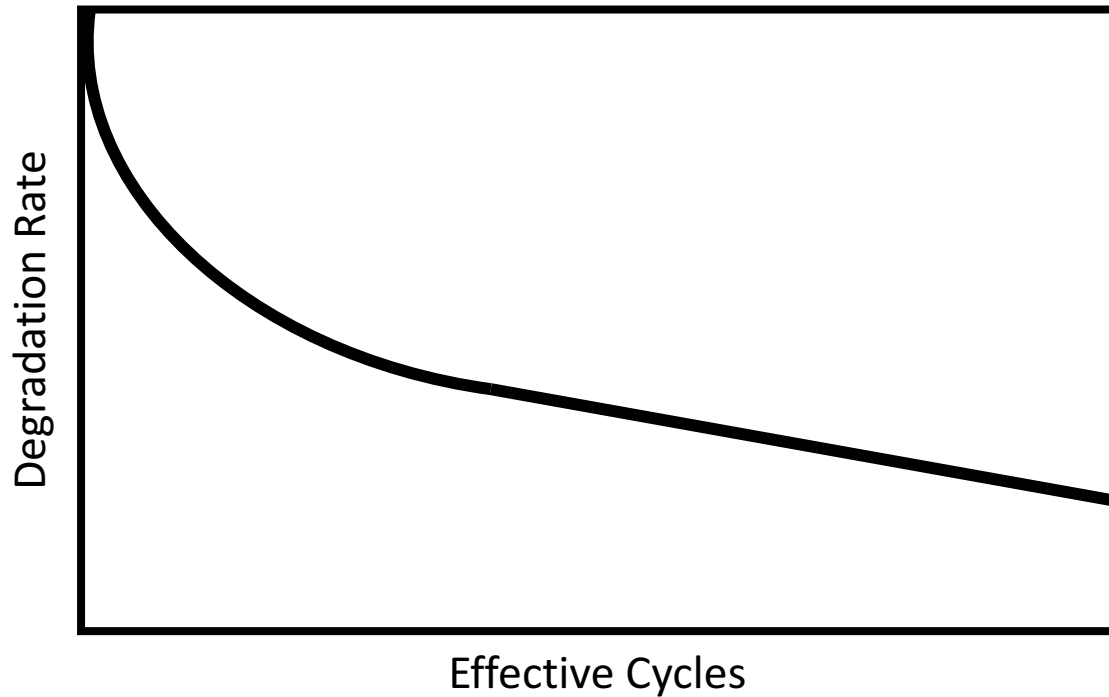
NETL's Cyber-physical System

Technical Issues

- Part-load operation

- Increase degradation of components

- Controls are designed for based–load operation

Controls update for existing power plants

Degradation rate is function of

- Effective cycles

- Physical age

J. S. Litt, K. I. Parker, S. Chatterjee, "Adaptive Gas Turbine Engine Control for Deterioration Compensation Due to Aging," Proceedings of the 16th International Symposium on Airbreathing Engines (ISABE–2003–1056), NASA/TM—2003-212607
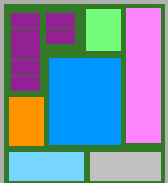
Health Parameter Degradation Profile
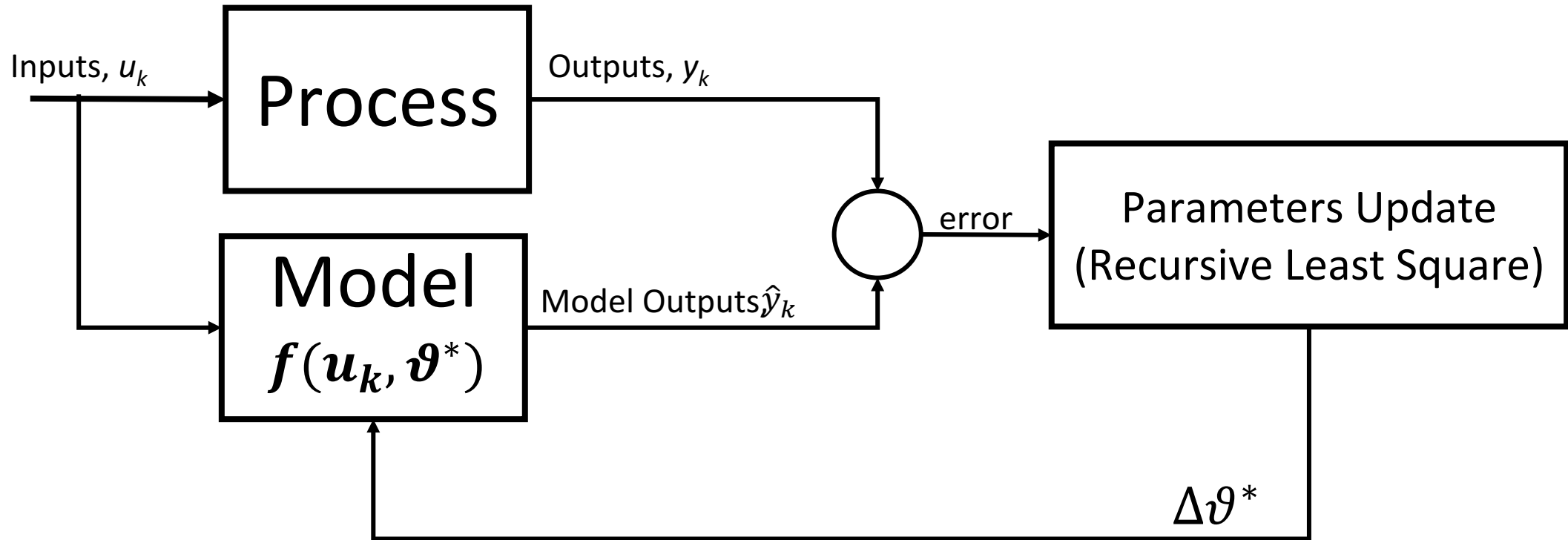
- Deviation in the model parameter due to aging of equipment

- Unsupervised real-time learning algorithm to support dynamic control

Online System Identification

1. Enabling high efficiency high turn down operation of hybrid power systems

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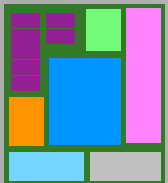
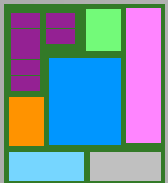**Summary**

Co-worker/Homogenous agents

- Fuel cell model in the loop – test reproducibility

- Supercritical CO_2 power cycle

Virtual plant and cyber-physical track

- ASME Power and Energy Conference

Existing power plants

- Online system identification

Future work

MESA Team in Ames

Dr. Peter Finzell

Dan Bell (PhD grad, Iowa State U)

Zach Reinhard (PhD grad, Iowa State U)

Tina Akinyi (PhD grad, Iowa State U)

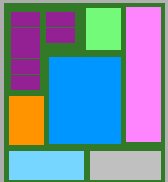Wadood Daoud (PhD grad, Iowa State U)

Hyper Team in NETL

Dr. David Tucker

Dr. Larry Shadle

Dr. Farida Nor Harun

Dr. Nana Zhou

Mr. Harry Bonilla

Acknowledgements