Analyzing Large and Complex Systems with Co-Simulation

- Co-simulation is a method for unifying multiple models in a coordinated fashion.
  - Models may or may not cover similar domains
  - Models may or may not have a similar concept of time
  - Models may or may not be written in the same language
  - Simulators using models may or may not run on the same computer or operating system, or be in the same network

- Co-simulation allows models that have interactions with each other to express those interactions and influence each other’s behavior.

- Co-simulation essential functionality:
  - Time synchronization
  - Data exchange
Co-Simulation Examples

Precipitation, ambient temperature

Humidity, sunlight reflectivity

Service voltage, Market information

Power consumption, Market participation signals
Co-Simulation with Buildings

• Software-only co-simulation

• Hardware-in-the-loop (HIL) co-simulation
PNNL HIL Co-Simulation Demonstration

• Market-based control technique (transactive energy)
  ▪ Loads in the system bid for energy
  ▪ A central market clears all bids from generators and loads
  ▪ Prices are distributed to all loads in system
  ▪ Loads adjust energy consumption based on price (HVAC setpoints)

• Modeling choices
  ▪ Power system: software only
  ▪ Markets: software only
  ▪ Loads: mostly software with one PNNL building HIL-connected with VOLTTRON
PNNL HIL Co-Simulation Demonstration

[Diagram showing the relationship between FNCS, LSE, FNCS-Volttron Bridge, and various components such as Building Internal Market, Electricity, AHU+Chiller, Air, VAV-1, VAV-2, VAV-3, VAV-4, and the flow of Demand Curves and LMP price.]
HELICS: Multi-Lab DOE-Sponsored Co-Simulation Platform

HELICS co-simulation platform is composed of:

• Libraries and language bindings to use for integrating a simulator
  ▪ C
  ▪ C++
  ▪ Python
  ▪ MATLAB
  ▪ Java
  ▪ …

• Executables for running co-simulations and assisting in co-simulation development and testing
  ▪ Data exchange and synchronization services
Other HELICS applications

• PNNL’s Transactive Energy Simulation Platform (TESP) (in-development)
  ▪ Transactive energy simulation in a box
  ▪ Goal is to enable easy testing of transactive energy controllers and mechanisms
  ▪ Models transmission and distribution power system, generators, and residential and commercial loads

• DOE’s North American Energy Resilience Model (NAERM)
  ▪ Increased interdependency between electricity and natural gas systems introduces new vulnerabilities
  ▪ NAERM is developing nationwide electrical system and natural gas system models to evaluate the vulnerabilities
  ▪ Future work will add in other system interactions such as communications and transportation