

Cyber-Physical Systems Testbed: UCEF

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Federation of Experiments

- **Federated testing** or experiments allow components of experiments to be distributed locally, in clouds, and/or geographically dispersed.
- A **Federate** is a component of an experiment. It could be a piece of equipment, a simulation model, or a permutation of multiples of both....
- **Federates can be located anywhere** and are identified by their 'descriptor' and network address.
- A **federate descriptor** is JavaScript and exposes interface and timing requirements
- A **Federation** is a collection of Federates gathered together for at least one purpose.
- An **Experiment** defines a procedure that exercises the Federates in a Federation.
- The **Federation Manager** is a specialized Federate that orchestrates the Federation and operates on the Experiment definition and the Federation to perform the actual experiment.

Universal CPS Environment for Federation (UCEF)

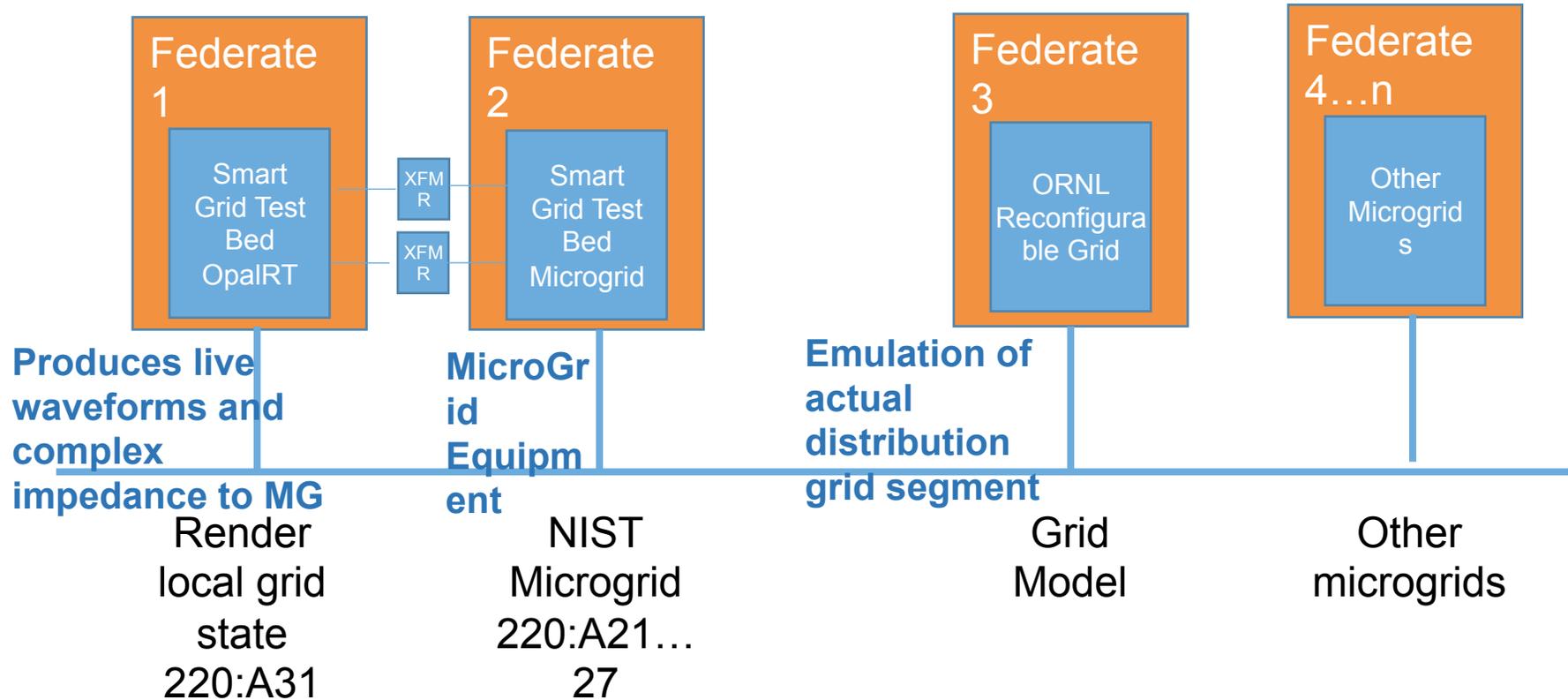
- UCEF as a **Testing Platform**
 - Federated Test Bed Architecture
 - Linux Virtual Machine Redistributable including federate and experiment design tools
 - Federates may be designed or pre-existing
- **Lightly Wrapped** (adapted) Simulators/Emulators
 - Light-wrapping of best of breed simulators/emulators such as Matlab/Simulink, Modelica, Optnet, Spice, Dymola, SUMO,....
- **Common experiment orchestration** using HLA bus –
 - IEEE 1516.1 Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) -- Federate Interface Specification
 - Open Source Run Time Implementation of HLA – Portico
 - Experiment Orchestration Languages – Colored Petri Nets (CPN) and Courses of Action (COA)

Example: Topology of a Proposed Smart Grid Federated Experiment

Use Case: Use a physical emulation of a grid segment at one lab, along with Microgrid simulations at other labs in a combined experiment analyzing behavior of a grid of microgrids

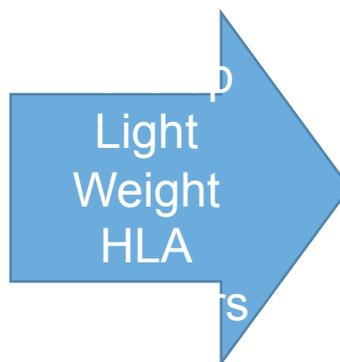
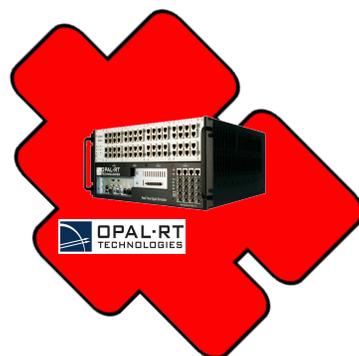
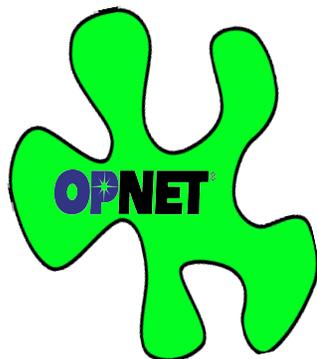
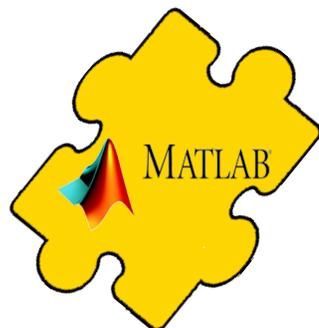
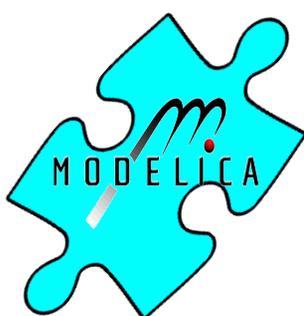
NIST Federates

Remote Grid Federates



Federation Concept

**Best of Breed
heterogeneous Simulators/
Emulators/HIL Test Beds**

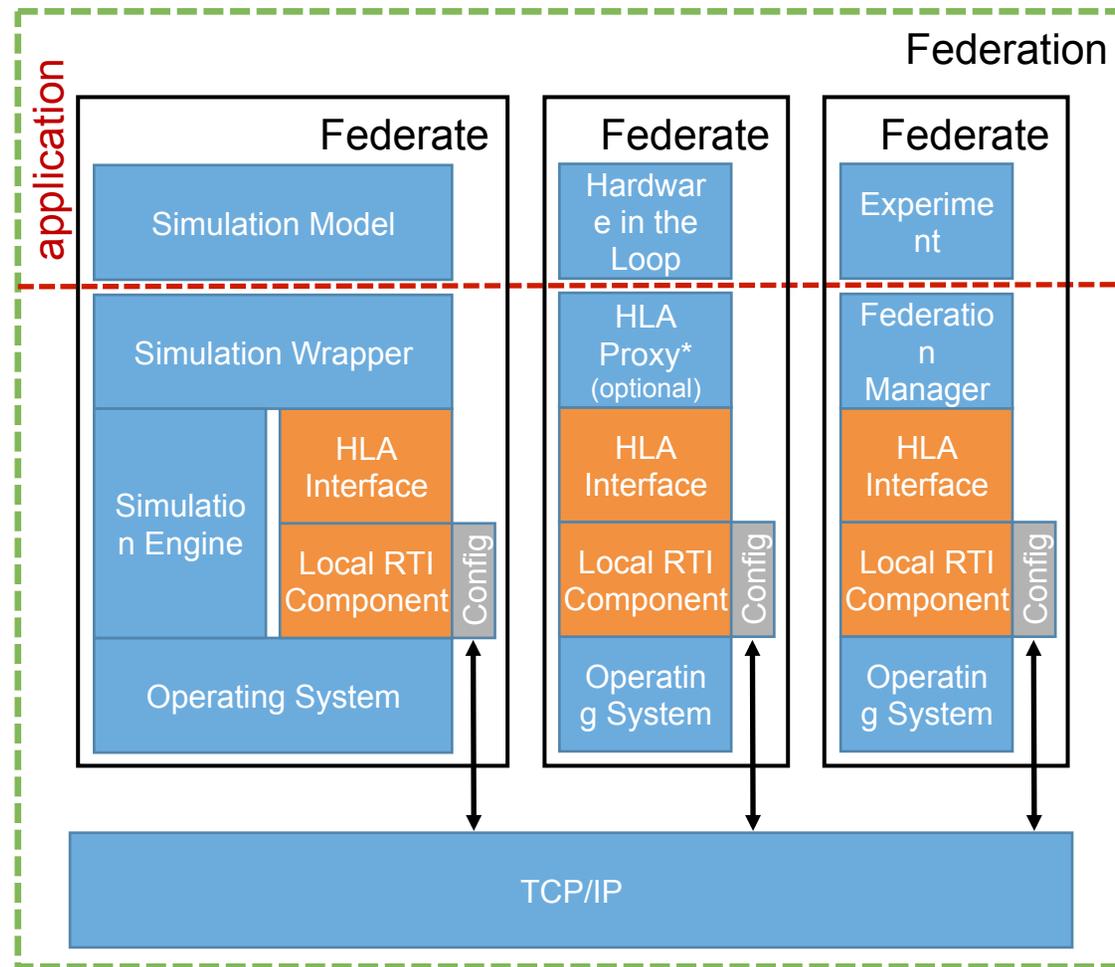


**Light-Integration Wrappers
+ Common Experiment
Orchestration Bus**



*<https://standards.ieee.org/findstds/standard/1516-20>

UCEF Federation Architecture (Stack)



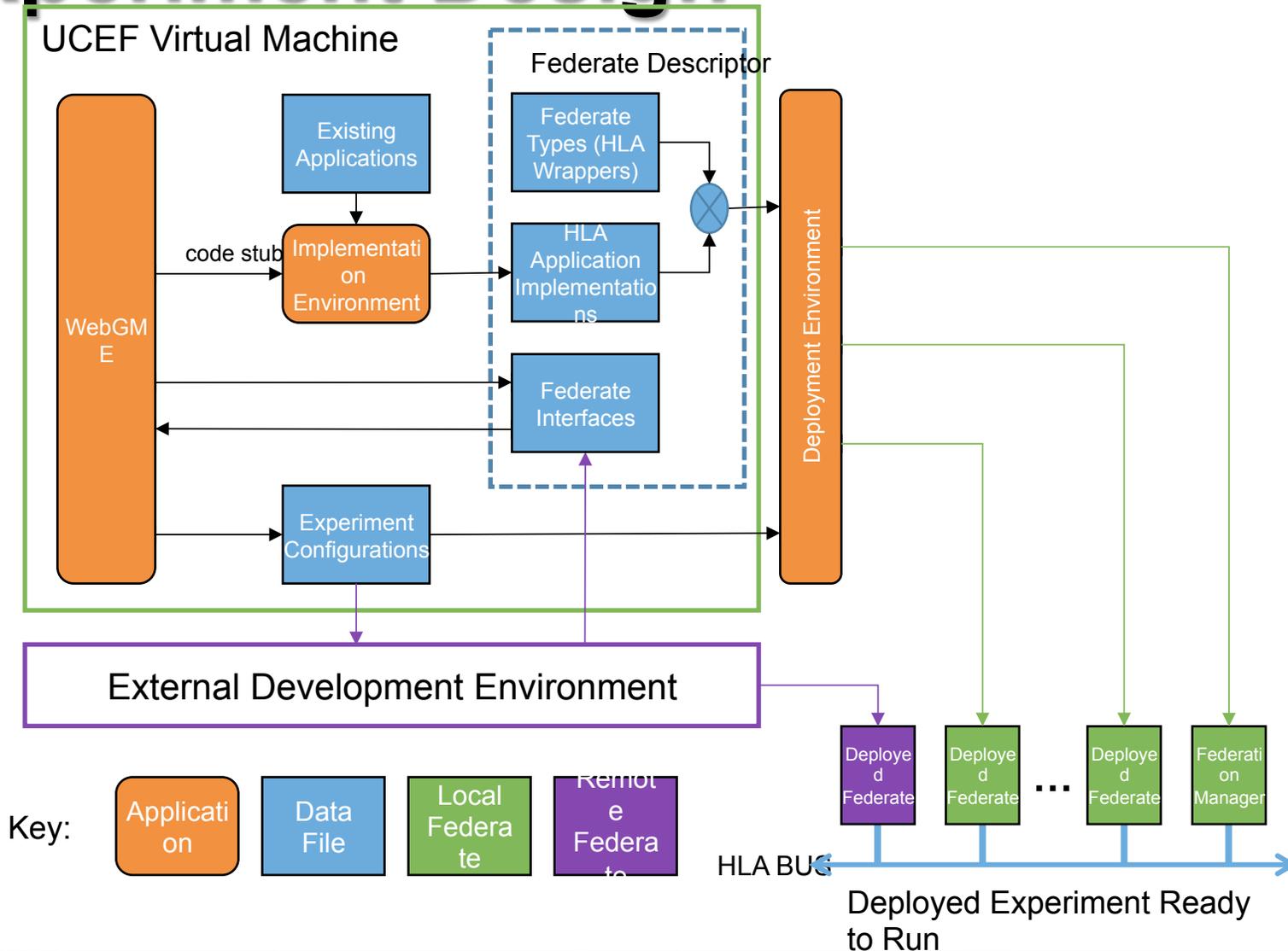
* proxy needed if target CPS function cannot support

Experimental Use Cases Enabled by UCEF Test Bed

- Local Experiment
- Cloud Hosted Simulations and Experiments
- Hardware In The Loop
- Collaboration w/Remote Federates at other Labs
- Large Scale Experiments (10s, 100s, 1000s of federates)

- +++ Combinations of above

Anatomy of Federated Experiment Design



'Control Room' Model

- Situational awareness for multiple CPS (Including Autonomous Vehicle, Traffic System (Intel), Power Grid (Energy Independence Act of 2007)
 - Monitoring rooms, experiments
- Emulation of control rooms for
 - Autonomous Vehicle Function (SAE Vehicle Trustworthiness)
 - Energy Management
 - Grid Control Centers
 - Smart Cities (NIST, White House, DoT joint effort)
 - Emergency Response (Critical Infrastructure Initiative_

UCEF Construction: Federation Pkg.

Ubuntu Linux System and Experiment Design Environment
Virtual Machine (VM) (NIST-Vanderbilt)

WEBGme (Web-based System and Experiment Design)

Deployment Tool

Open Source Tools

Maven	Java SDK
MySQL	Mongo db
Archiva	Portico
Ansible	NodeJS
Docker	Chrome
Eclipse	
Wireshark	
Kafka	

Simulation Wrappers Simulation Runtimes

Simulink	Simulink
GridLabD	GridLabD
Omnet	Omnet
NS3	NS3
Java	
C++	

System Trustworthiness Testbed

Takeaways:

- NIST federated testbed technology UCEF's use in industry, including:
 - Autonomy (AEB/'automatic emergency braking' cyber/physical decomposition)
 - Federation/Reuse (most systems currently modelled as a single Simulink Model (without vehicle dynamics))
 - Importance of Curation - 'system federate library'
- NIST Federated CPS Testbed technology UCEF:
 - low-effort and remote reuse of CPS models across multiple domains
 - multiple 'best in class' modeling tools
 - current collaborations (Ground Vehicle [autonomy, connectivity], Traffic System [Intel Project], Power Grid [NIST Smart Grid Lab, PNNL, MIT Lincoln])
- Benefits and challenges to industrial application:
 - Overcomes intellectual property issues in collaborative systems development

