HELICS

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U.S. Department of Energy

How Use Cases Drove the Design of the HELICS Co-simulation Framework

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NREL | Lawrence Livermore National Laboratory | Pacific Northwest National Laboratory | Argonne National Laboratory

HELICS Mini-Tutorial
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U.S. DEPARTMENT OF ENERGY

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The Vision for HELICS

- A Co-simulation platform that meets the current and future needs of the power system community
  - Transmission
  - Distribution
  - Communications
  - Markets
  - Controls
  - Others

Usability

- Scalability
  - We must scale to large number of different simulations
  - We must operate at multiple machine scales

Scalability

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  - We multiple machine scales

OK, Great. But what exactly do we need to build?

Scalability

HELICS™: Hierarchical Engine for Large-scale Infrastructure Simulation

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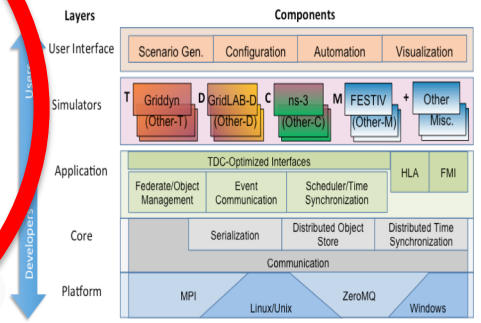
Use Case Requirements

	Domain			Simulation			Comm	
	Transmission	Distribution	Communication	Market	Steady State	Dynamic	Transient	Latency	Packets
DER's on Bulk Systems Reliability	X	X			X				
Load Modeling under high penetration of DERs	X	X				X			
Wide Area Voltage Stability Support Using DERs	X	X	X		X			X	
Voltage and Frequency Ride-Through Settings for Smart Inverters	X	X	X			X			
Real-time Co-simulation of Power Systems and Communication Networks for Transient Assessment	X	X	X				X	X	
Communications Architecture Evaluation for High-Pen Solar	X	X	X		X				X
New Control Paradigm – Centralized vs Distributed to Prevent Voltage Stability Collapse	X	X	X			X		X	
Wide Area Monitoring, Protection, and Control (WAMPAC)	X		X			X		X	X
Impacts of Distributed Energy Resources on Wholesale Prices	X	X		X	X				
Mitigating T/D Interface Congestion Through Demand Side Management	X	X		X	X			X	
Regional Coordinated Electric Vehicles Charging	X	X		X	X			X	
Real-time Coordination of Large Scale Solar PV and Energy Storage	X	X			X			X	

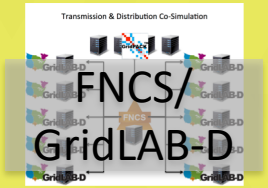
New Platform Design



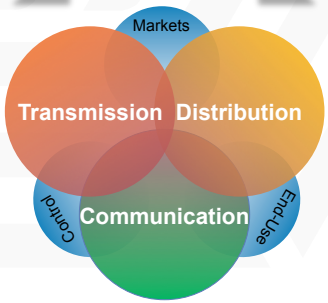
Best of Existing Tools

IGMS/FESTIV

FSKit/ GridDyn



FNCS/ GridLAB-D



"TDC Tool"

HELICS

Original 12 Use Cases

1. Impacts of DER's on Bulk Systems Reliability
2. Impacts of Distributed Energy Resources on Wholesale Prices
3. Regional Coordinated Electric Vehicles Charging
4. Real-time Coordination of Large-Scale Solar PV and Energy Storage
5. Evaluate modeling adequacy of composite load model under high penetration of DERs
6. Mitigating Transmission-Distribution Interface Congestion Through Demand Side Management
7. New Control Paradigm – Centralized vs Distributed to Prevent Voltage Stability Collapse
8. Wide Area Monitoring, Protection, and Control (WAMPAC)
9. Real-time Co-simulation of Power Systems and Communication Networks for Transient Assessment
10. Communications Architecture Evaluation for High-Pen Solar
11. Adaptive Voltage and Frequency Ride-Through Settings for Smart Inverters
12. Wide Area Voltage Stability Support Using DERs

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Original 12 Use Cases – Many Time Scales

1. Impacts of DER's on Bulk Systems **Reliability**
2. Impacts of Distributed Energy Resources on Wholesale **Prices**
3. Regional Coordinated Electric Vehicles Charging
4. Real-time Coordination of Large-Scale Solar PV and Energy Storage
5. Evaluate modeling adequacy of **composite load model** under high penetration of DERs
6. Mitigating Transmission-Distribution Interface Congestion Through Demand Side Management
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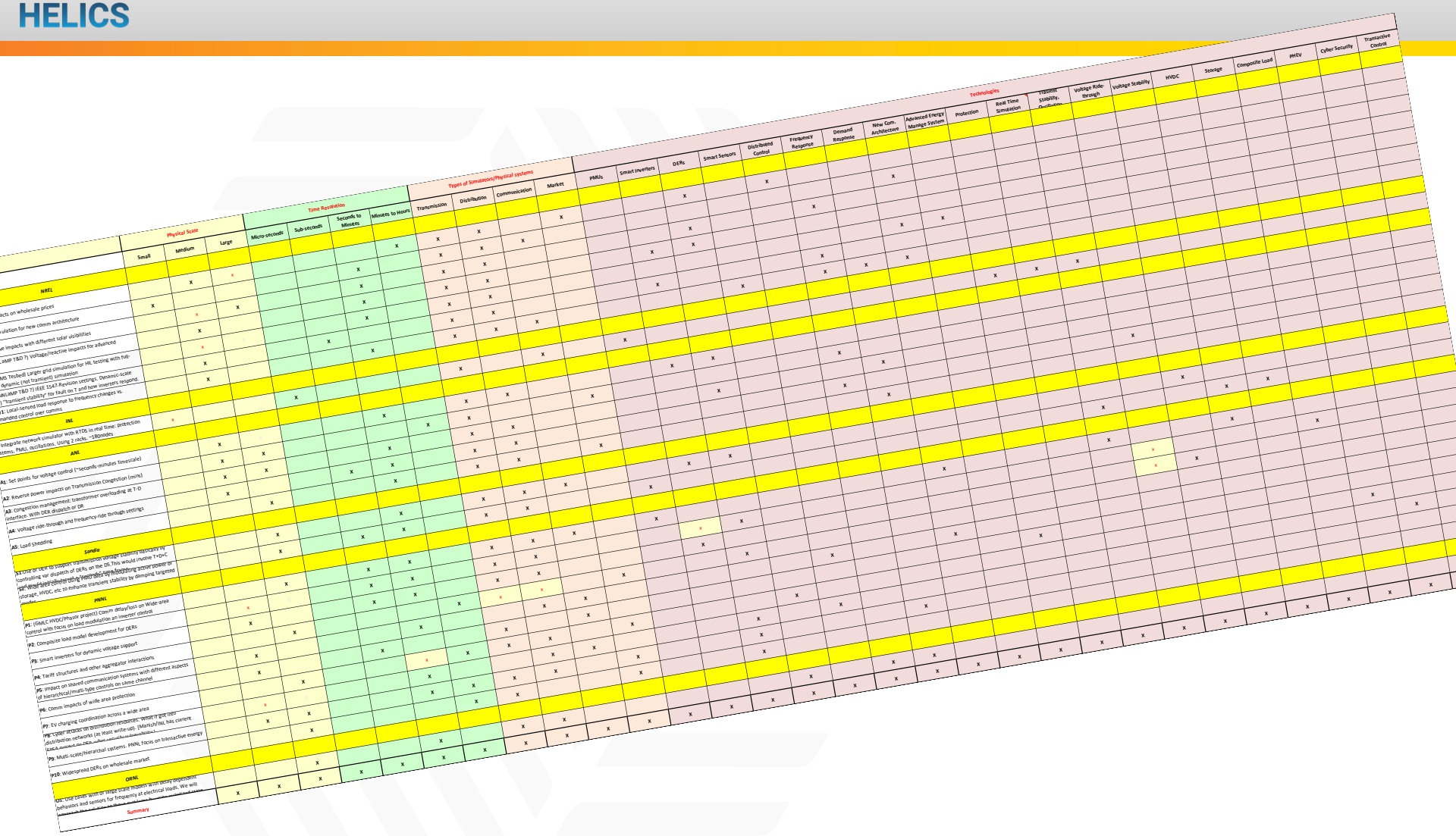
Detailed use case analysis



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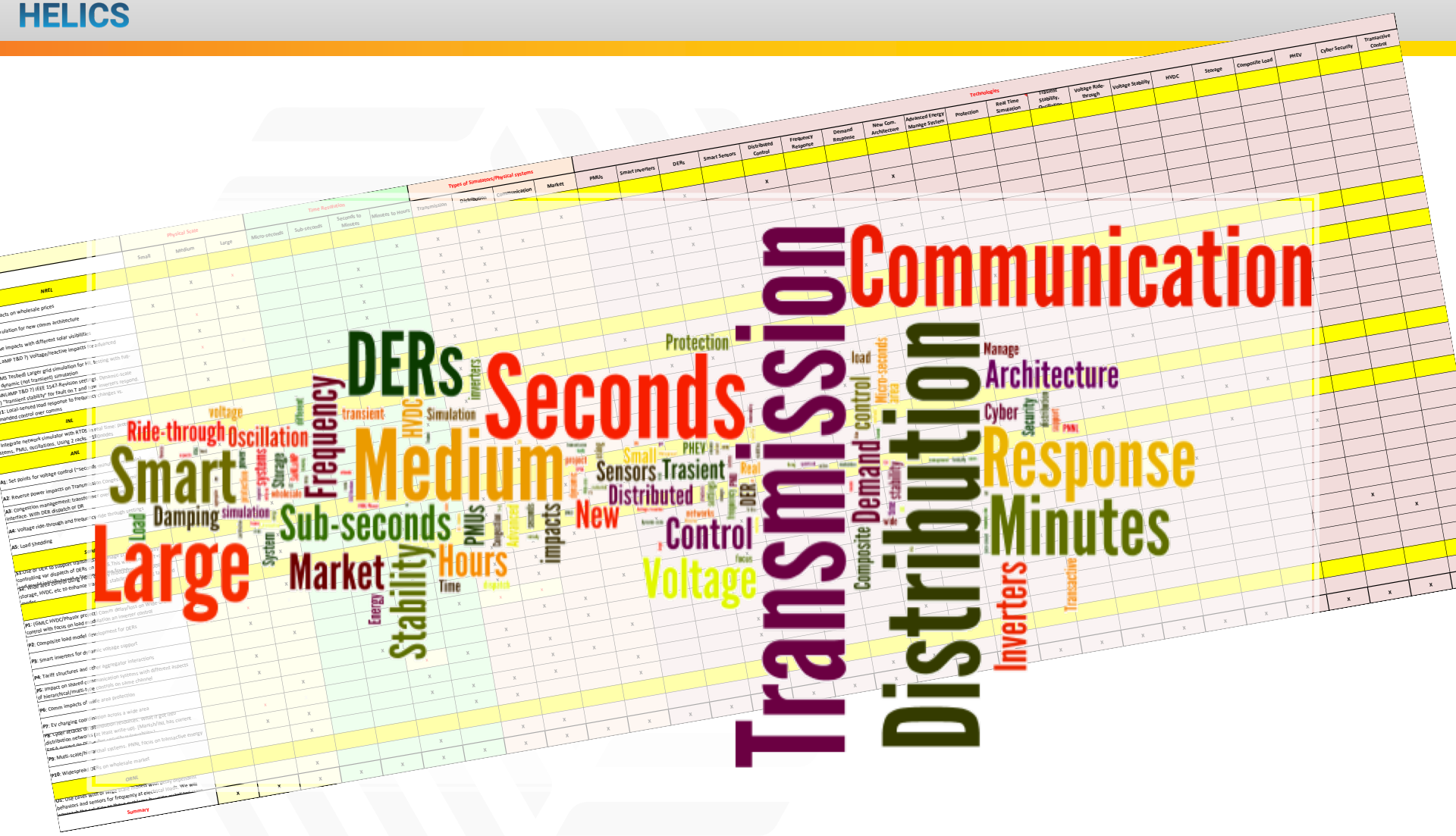
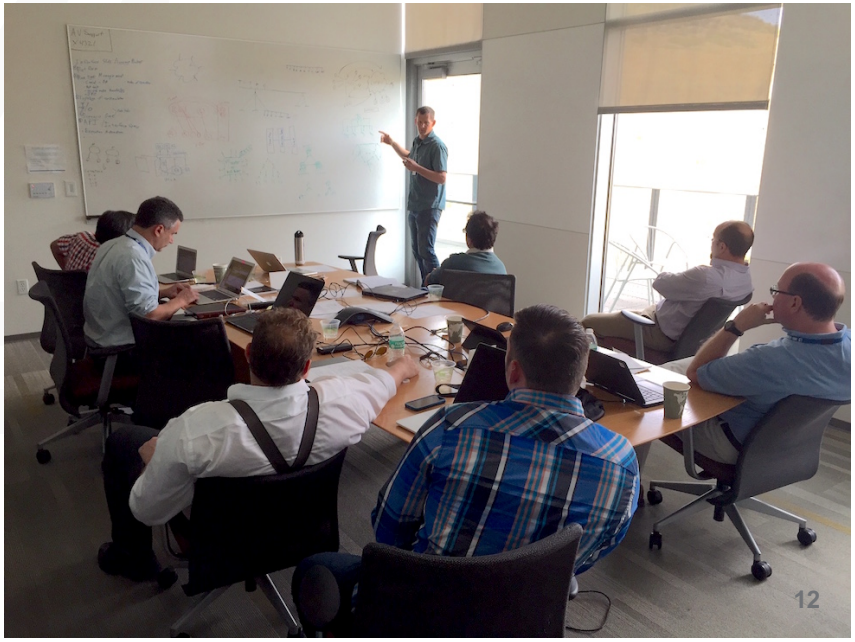


Tool Development Workshop

- Held a small workshop at NREL to determine software development needs.
- Used the use case descriptions to derive key features necessary for a TD&C co-simulation tool.
  - Distilled into “must have” features, and “would be nice” features.
- Evaluated existing toolsets against these requirements.



Summary Table

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Regional Coordinated Electric Vehicles Charging	X	X		X	X			X	
Real-time Coordination of Large Scale Solar PV and Energy Storage	X	X			X			X	

"Must Haves" for Stakeholders

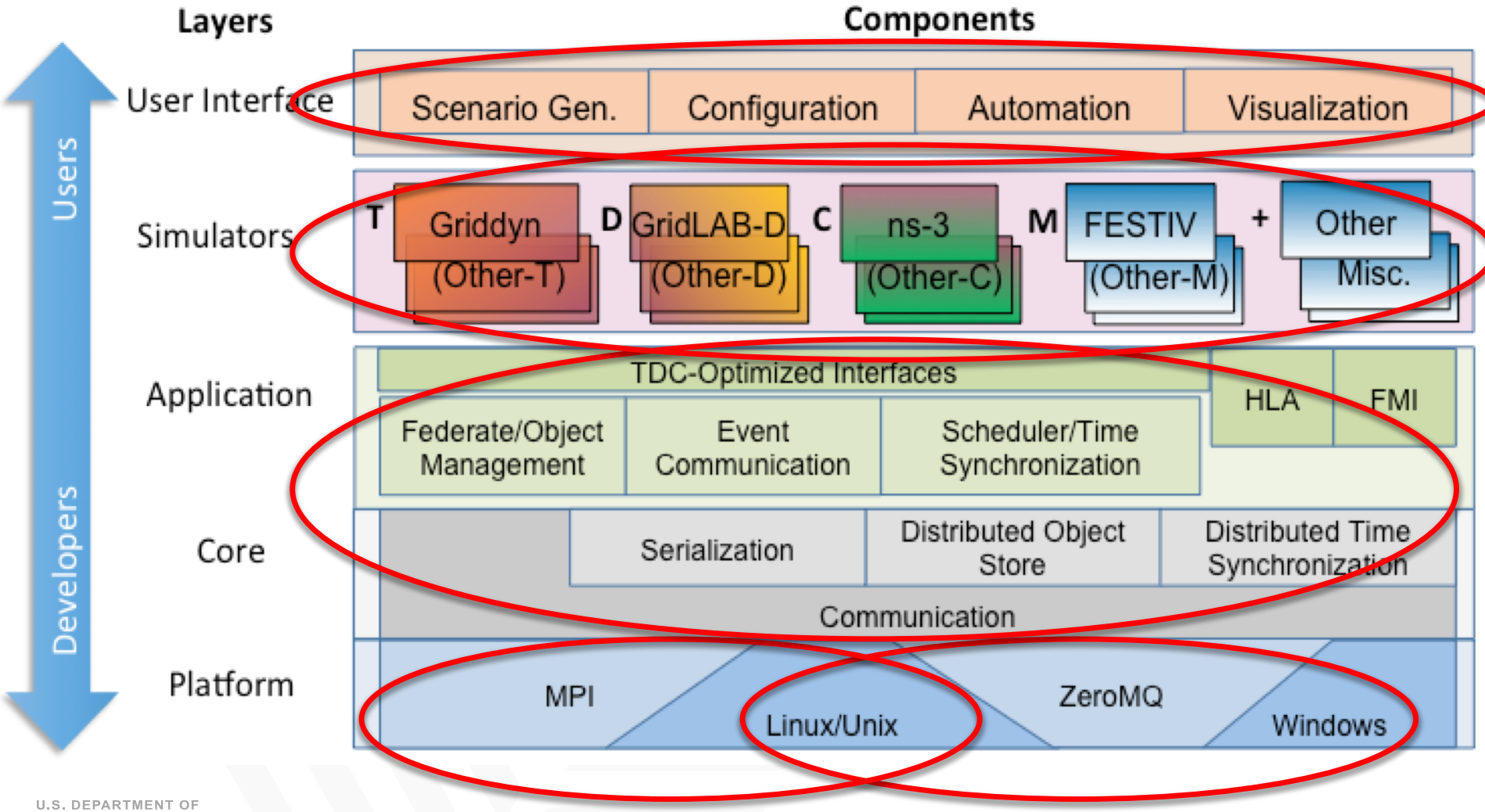
- Tool/platform released open source with (nearly) all use cases accessible with the open-source tool
- Support variety of simulation types
  - Discrete Event
  - Time Series
  - Quasi-Static Time Series
  - Phasor (Dynamics)
- "Easily" incorporate existing tools/elements
  - From other labs
  - From vendors and other developers
  - Make provisions for open-source & commercial software

Intended stakeholders:
- National Labs
- Academics/Students
- Utility Planners
- Vendors
- Consultants

“Must Haves” for Stakeholders

- Support massive problem scales
  - 2 - ~100,000 federates
  - For example, simultaneously simulate all T, D, and C for the State of California
- Support a wide variety of compute systems
  - Laptop/Workstation (Windows and Mac)
  - High-performance computing, including cloud/servers
- Focus on usability (research-grade usability)
  - Standard file structures and I/O
  - Execution tools/scripts
- Documentation and Examples

HELICS Layered Design



3 Types of Federates

1. **Value:** Nominally physical value
   - E.g. Voltage, Current, Power, etc.
   - Support for co-iteration
2. **Message:** Nominally data (only) sent over communication system
   - E.g. Control signals, sensors, market signals
   - Connectivity only (see below)
   - Point to point or broadcast

3. **Filters:** Manipulate data in transit, e.g. ICT simulation
   - E.g. Delay, ossy channel, Full packet simulation (ns-3)
   - Rerouting for complex ICT in federates
   - Allows swappable fidelity for communication simulation

- **For all:** Consistent API across platform:
  - Single executable, Zero-MQ, MPI
  - Expose both discrete event and time series (DE under hood)

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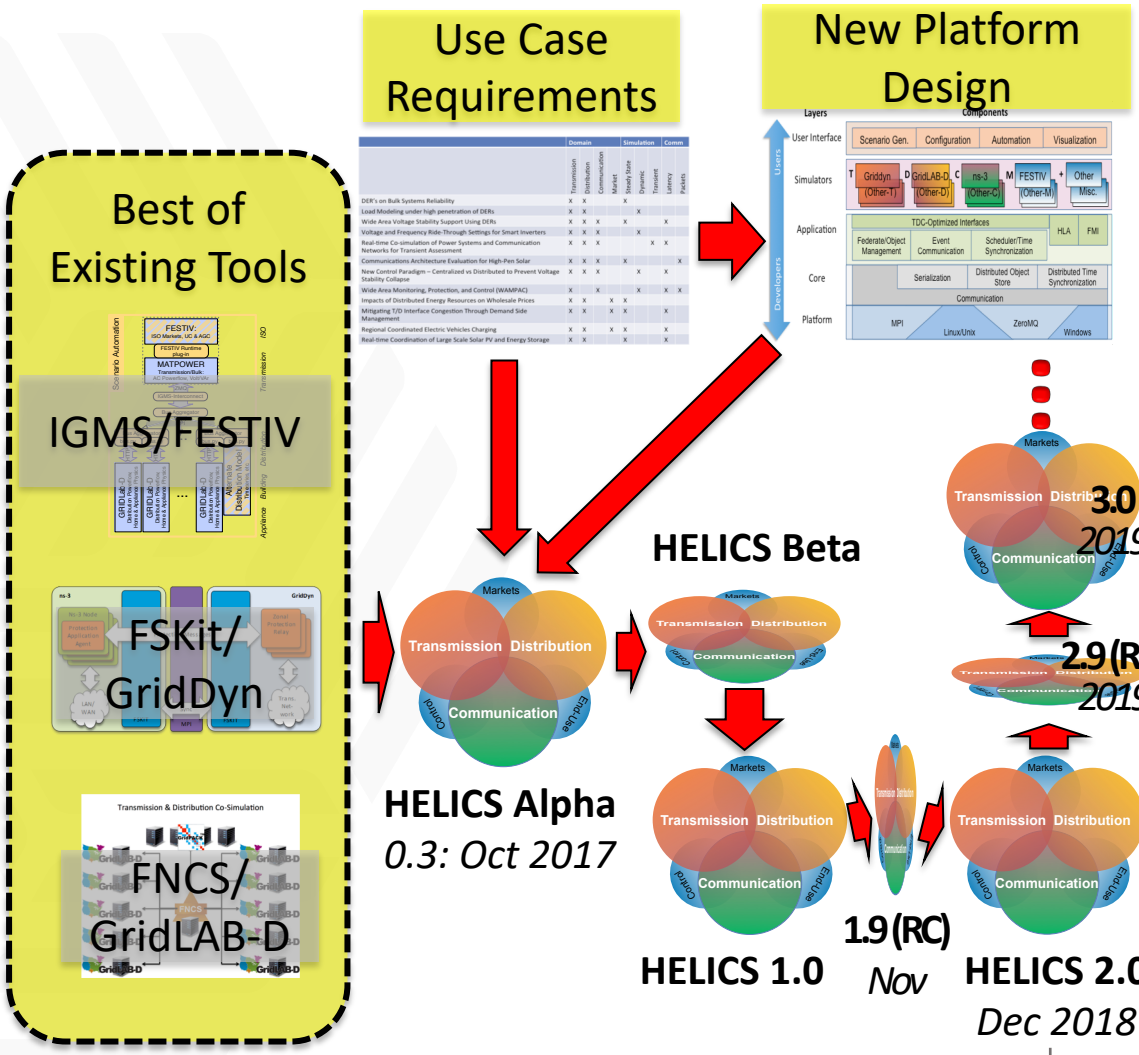
Requirements:

- **Scalable:** 2-100,000+ Federates
- **Cross-platform:** HPC (Linux), Cloud, Workstations, Laptops (Windows/OSX)
- **Modular:** mix and match tools
- **Minimally invasive:** easy to use lab/commercial/open tools
- **Open Source:** BSD-style
- **Many Simulation Types:**
  - Discrete Event
  - QSTS
  - Dynamics
- **Co-iteration enabled:** "tight coupling"



Thank you!

Further Reading: B. Palmintier, D. Krishnamurthy, P. Top, S. Smith, J. Daily, and J. Fuller, "Design of the HELICS High-Performance Transmission-Distribution-Communication-Market Co-Simulation Framework," in *Proc. of the 2017 Workshop on Modeling and Simulation of Cyber-Physical Energy Systems*, Pittsburgh, PA, 2017.

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