Panel: "Potential Impact of High-Performance Computing on the Power Grid"
Sponsoring Committees:
Emerging Technology Coordinating Committee (ETCC) and
PSACE Computing and Analytical Methods Subcommittee (CAMS)
IEEE PES GM 2013
July 21-25, 2013

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From Data to Knowledge through an Open-Source Computing Architecture

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Power grid transition requires new computing capabilities

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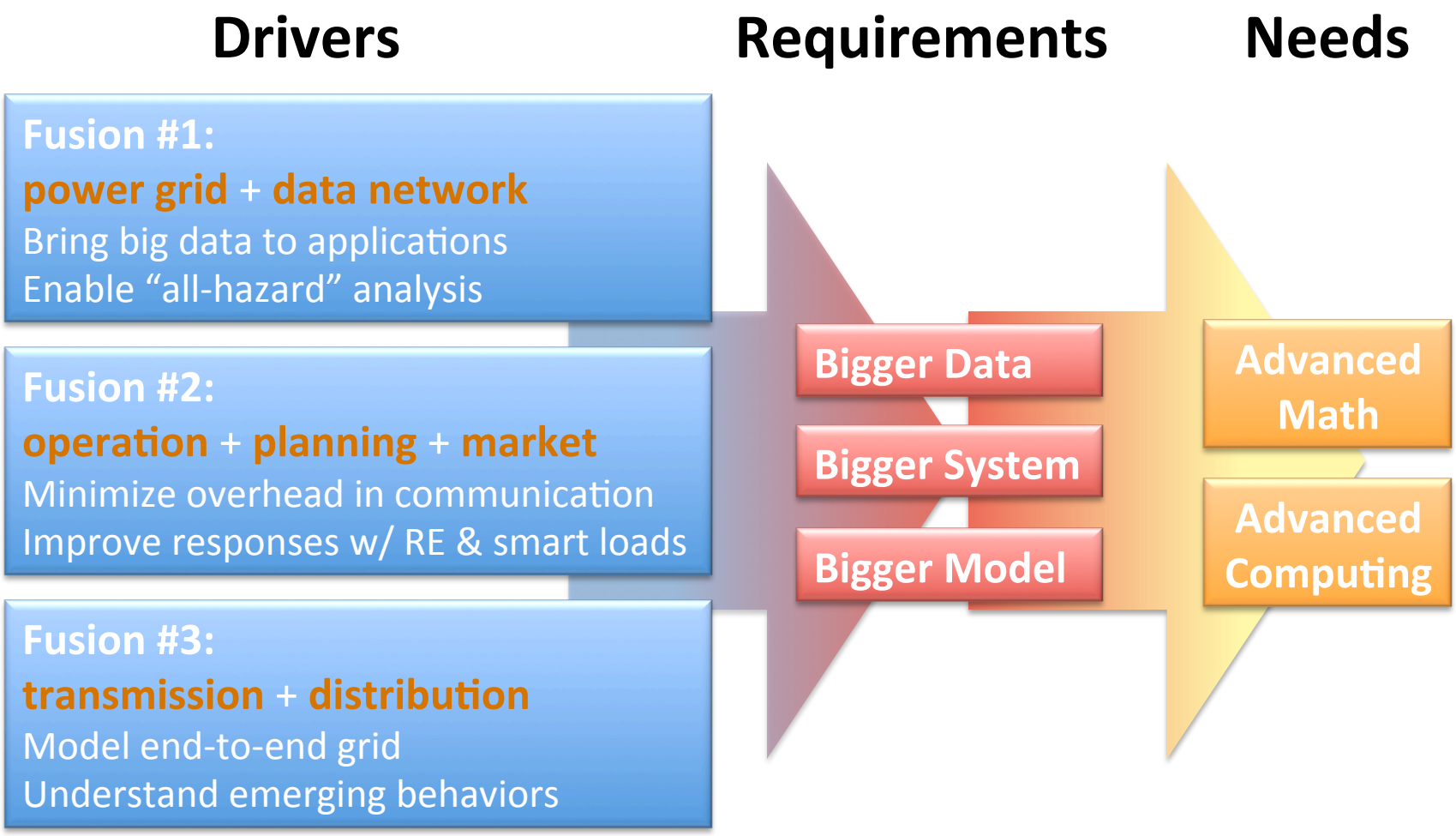

Data-Driven Computation and Visualization

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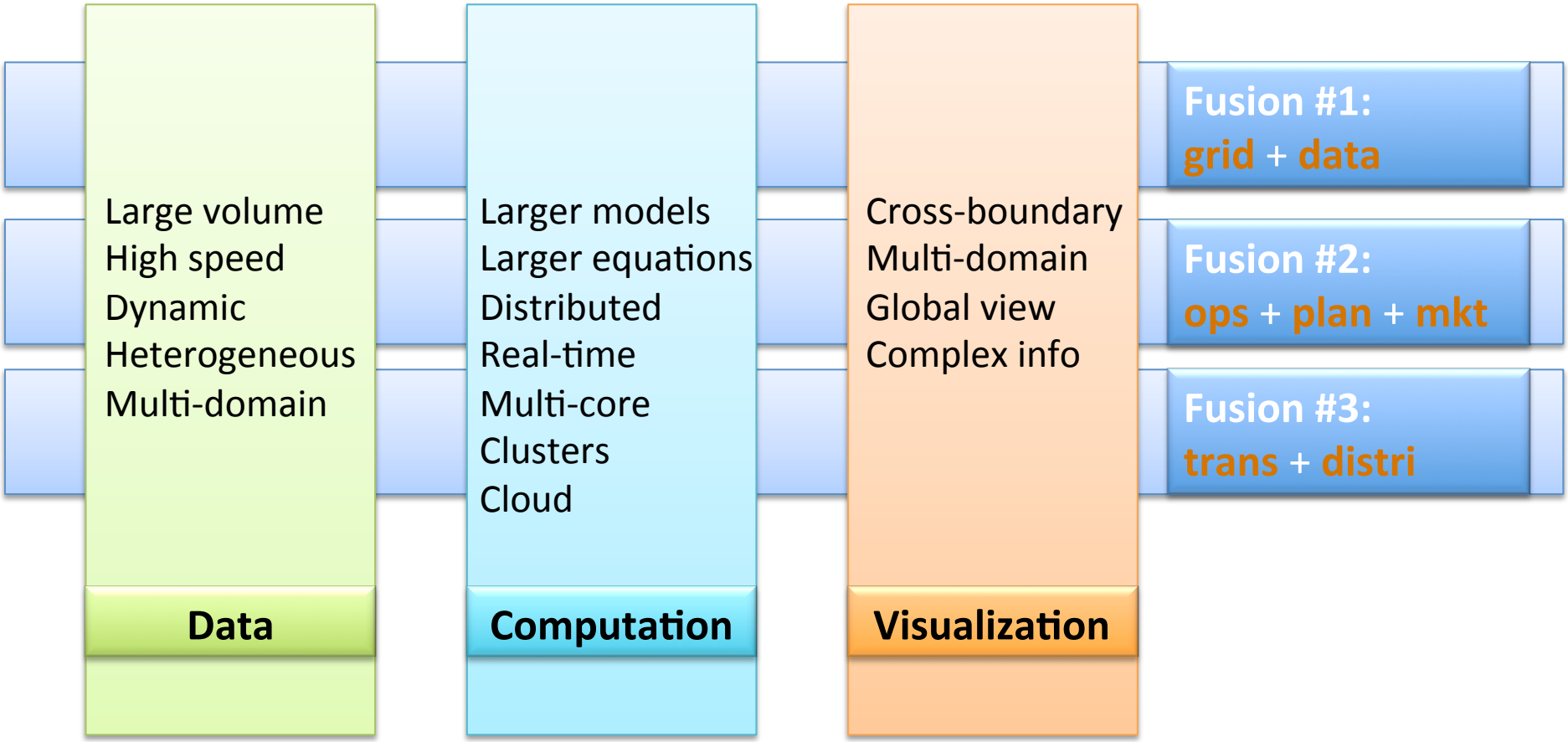

GridOPTICS™ Architecture: links data to computation to visualization

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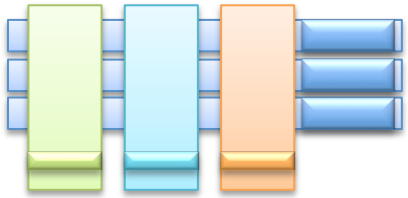
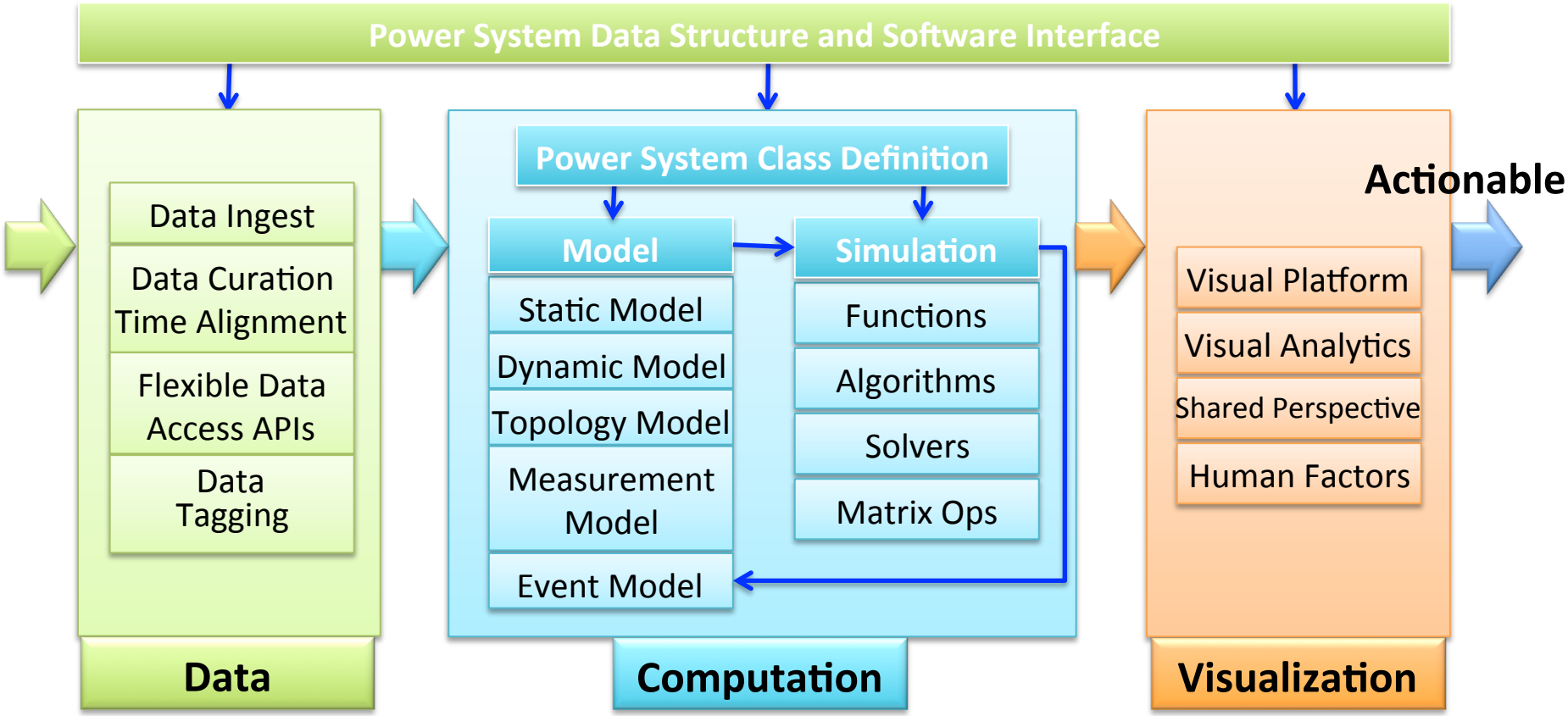
- Open Source; Open Format; Open Forum
  - Enable interoperability and accelerate development of advanced technologies and tools for the power grid.





GridOPTICS™ powerNET Functional Testbed

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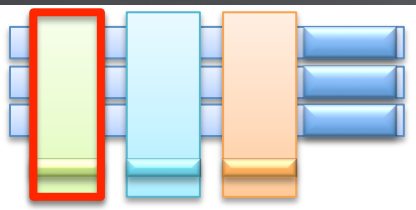
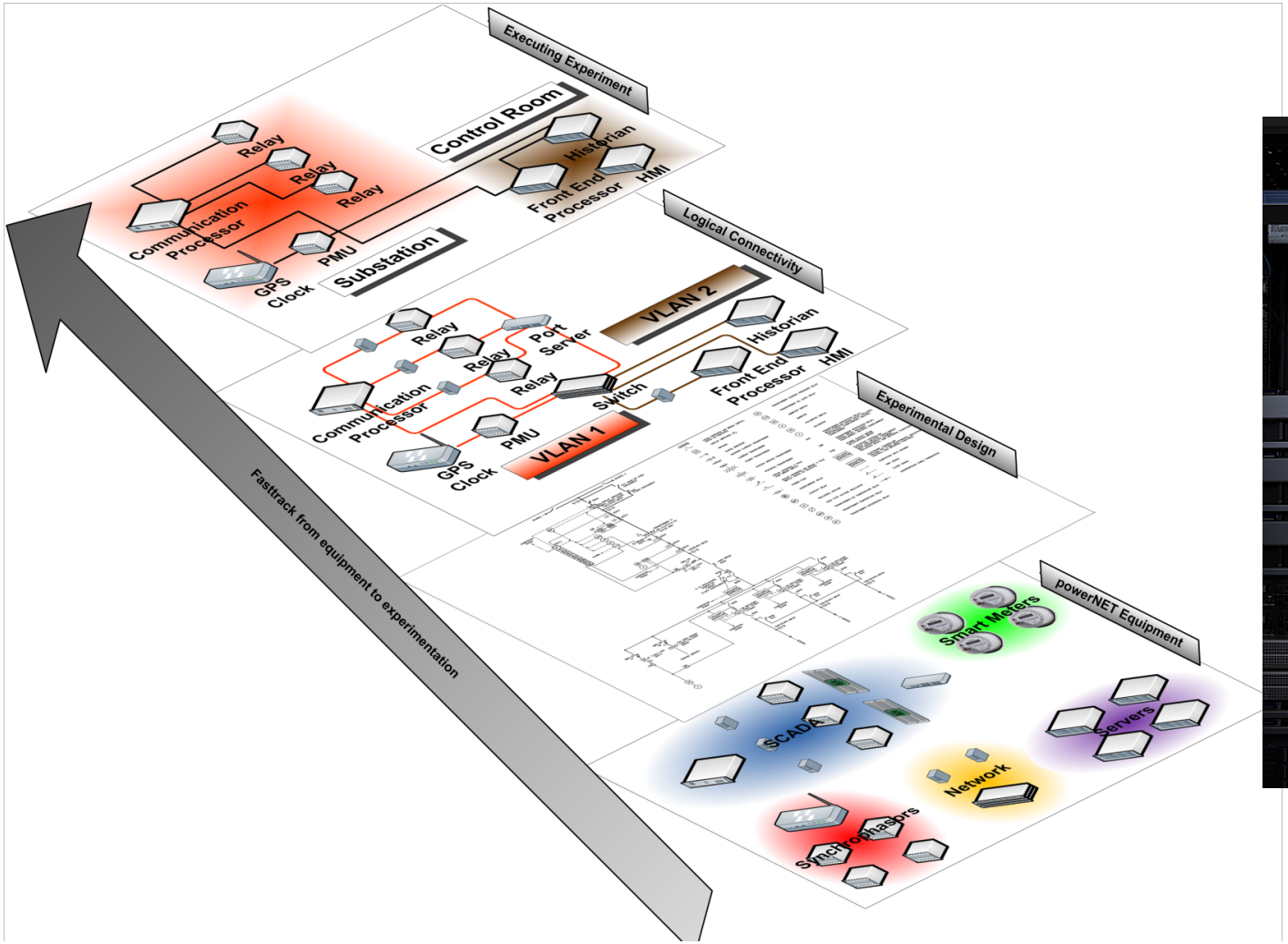


- Federated testing environment leveraging multiple organization's hardware and testing equipment



Real-time data ingestion from a distributed sensor network with myriad devices

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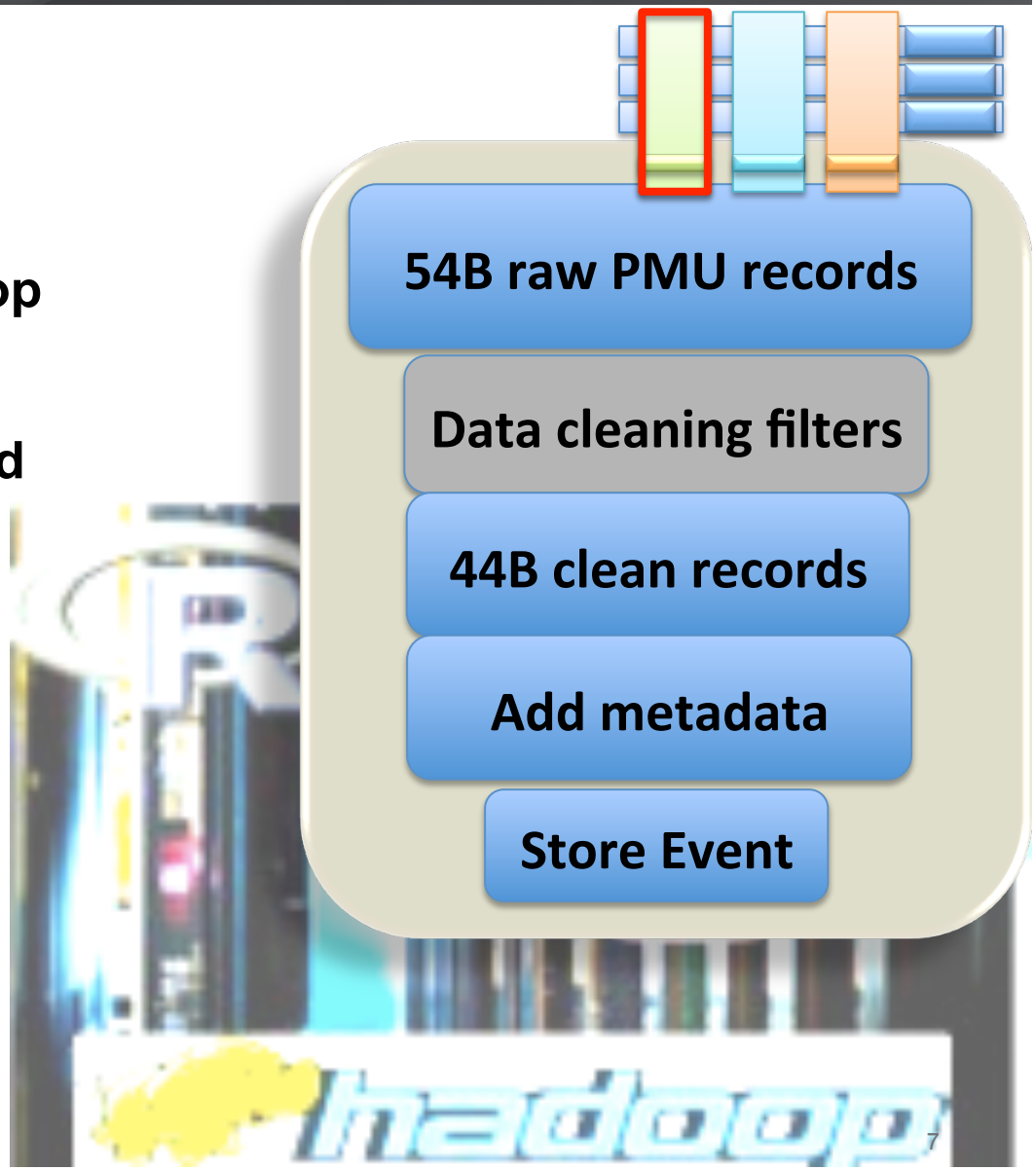
- **Requirements**
  - **Cyber-secure sensor network**
  - **Data provenance and privacy**
  - **Real-time ingestion & curation**
- **Solution: scalable, flexible middleware**
  - **Mediate huge amounts of data**
  - **Overlap data processing with disk and network operation for near-optimal performance**
  - ***Linearly scales to multiple nodes***
  - ***10^3 times faster than MySQL***

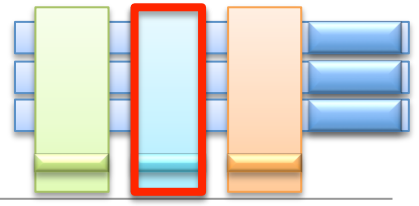
Data curation identified and eliminated 20% erroneous PMU records in sensor data set

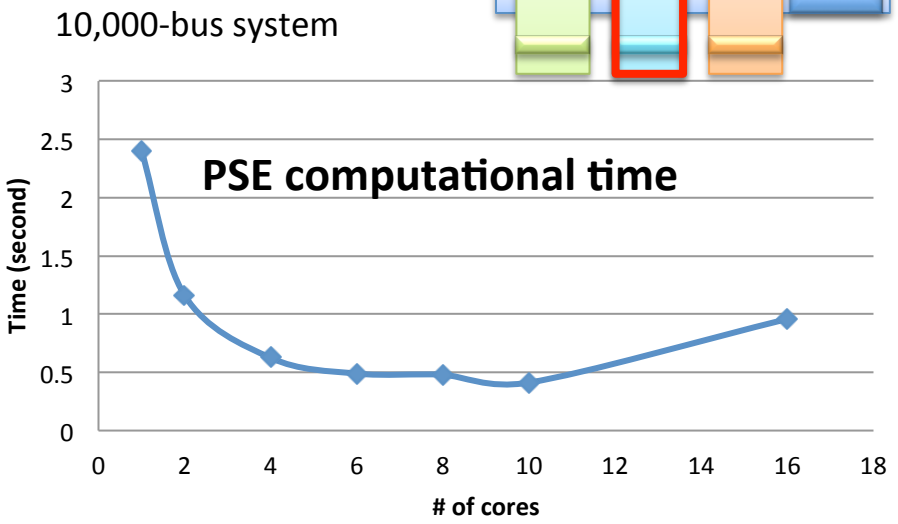
- 2TB of historical PMU data in 54B records
- Transformed into R / hadoop friendly data format
- Developed heuristics-based data cleaning filters
- Found 10B bad records out of 54B records
- Cleaned data eliminated 10,000 false positives from two event detection algorithms

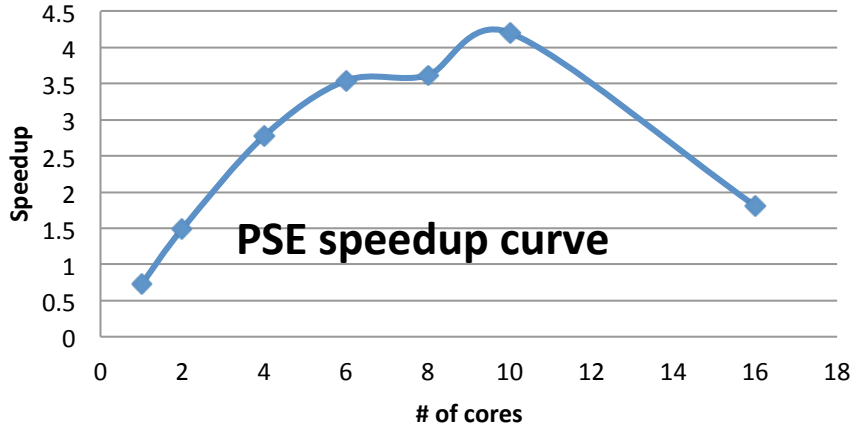


Fast state estimation improves real-time responses

- Parallel State Estimation (PSE): 3-5 sec for large-scale models
  - 4-20x faster
  - In synch with SCADA cycles
  - Linear solver: Conjugate Gradient vs. LU Decomposition
  - Further improvement possible ➔ 0.1 second
- Value of fast state estimation (SE):
  - Improve convergence and accuracy of SE
  - Improve response to emergency
  - Arm Remedial Action Schemes
  - Wide area control fed by SE, instead of raw measurements







Real-time path rating through fast computation to manage transmission congestion

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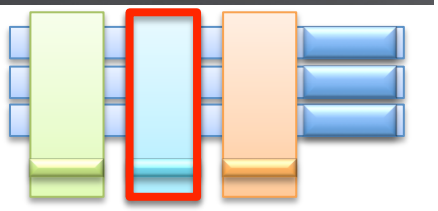
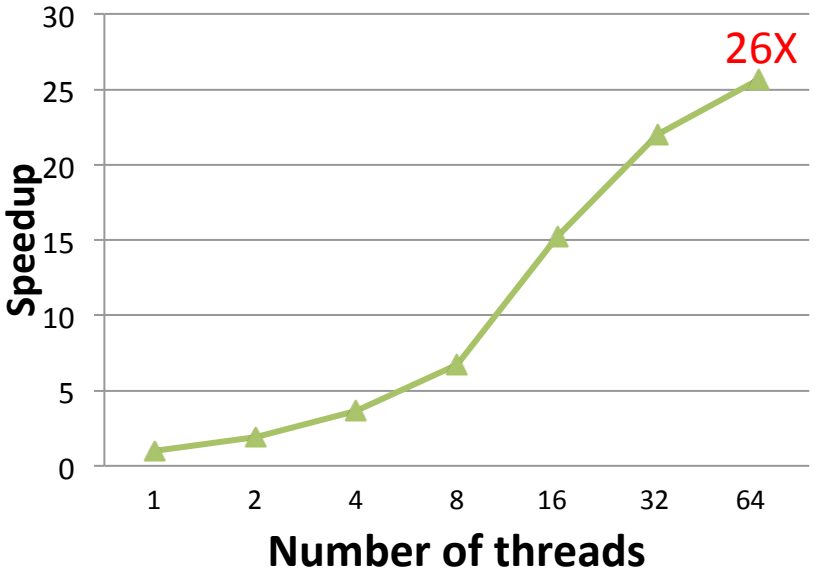
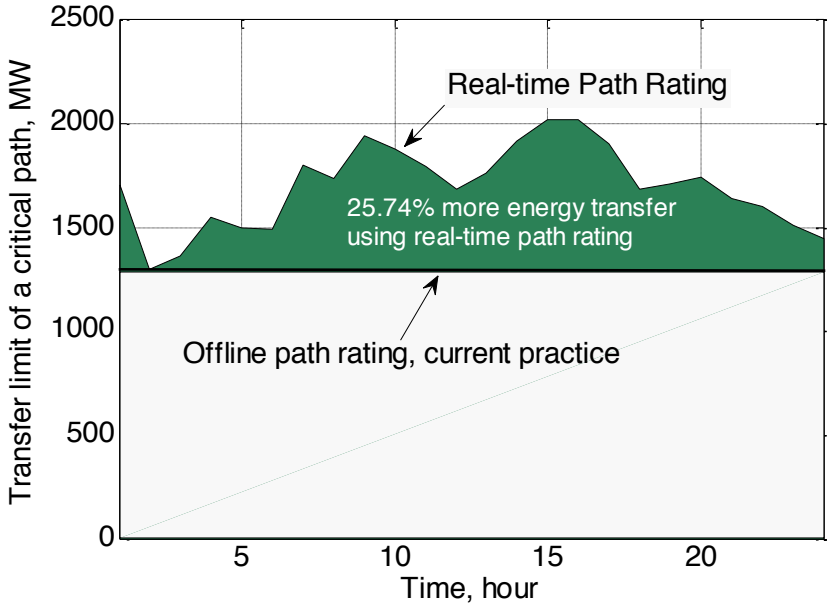
- Look-Ahead Dynamic Simulation
  - 16,000-bus w/ simplification
  - 9 sec for 30-sec simulation
  - 13X faster than today's commercial tools
  - Selective matrix operation



- Real-Time Path Rating
  - Realistic ratings
  - +1000 MW = +$240M/year
  - Avoid renewable curtailment





Advanced optimization for better market efficiency

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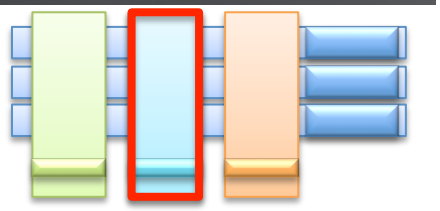
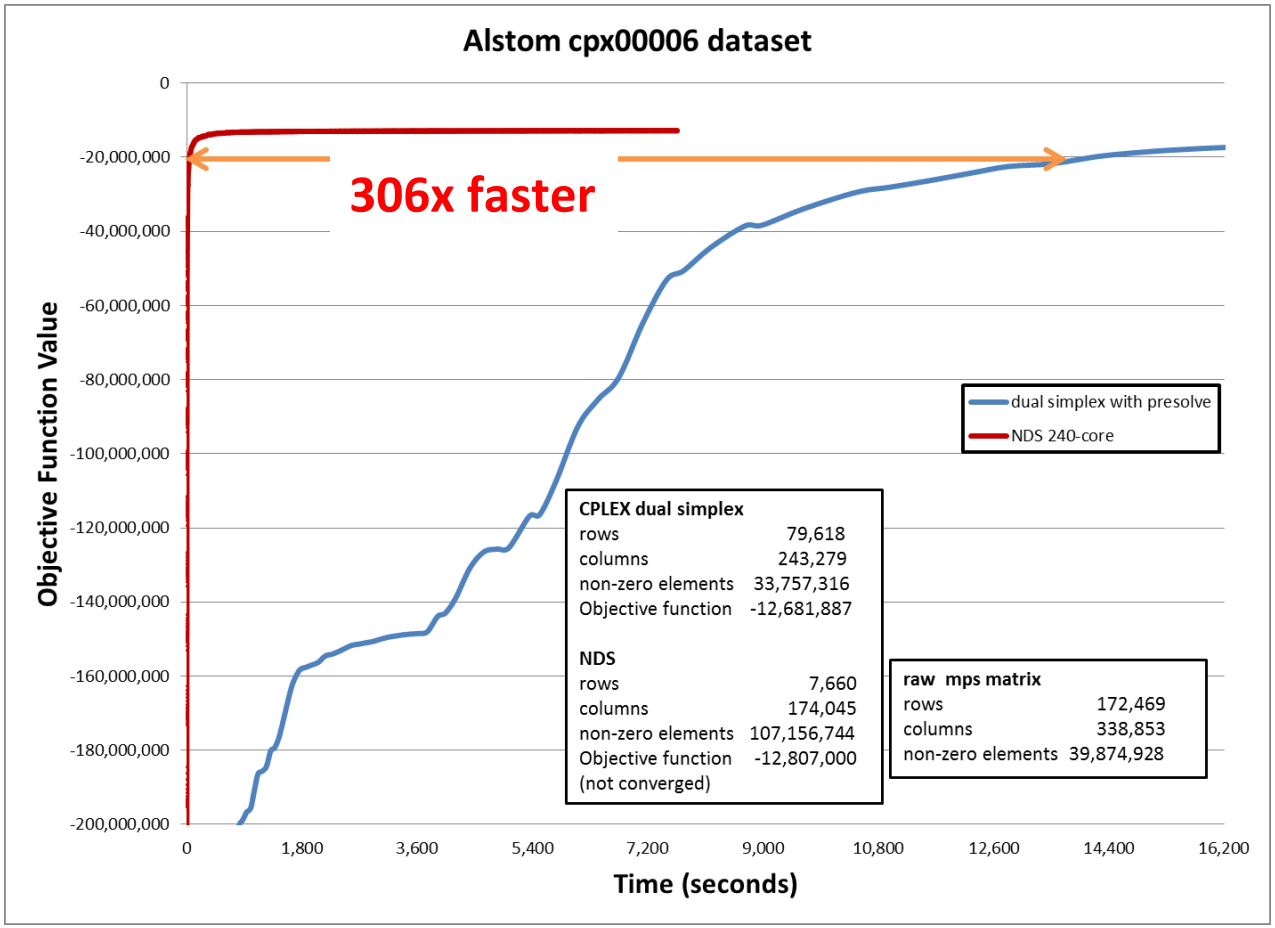


- Developed a novel parallel adaptive dynamical system (PADS) approach
- Parallelized to solve large linear programming (LP) problems for FTR application within few hours (cloud compatible)



Next Generation Network Simulator

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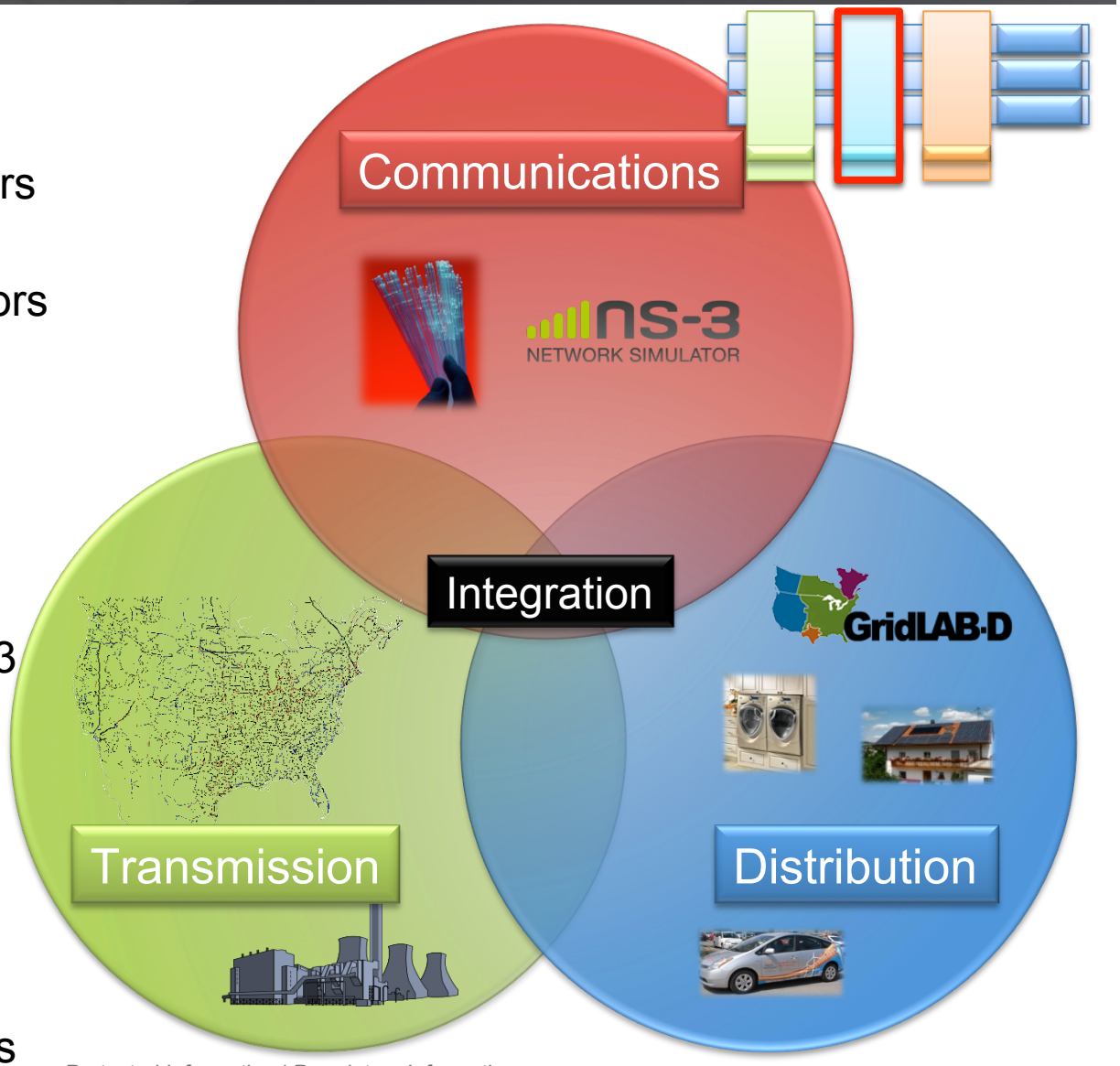
Objective

- Interface existing power grid and communication simulators
- Investigate bottlenecks and limitations of current simulators
- Develop optimized HPC simulation platform

Approach

- Coordinate interaction of ns-3 with GridLAB-D and transmission simulators
- Modular framework links simulators at run-time via ZeroMQ
- Platform dynamically adjusts synchronization requirements among simulations



Visual analytics of massive contingency analyses for real-time decision support

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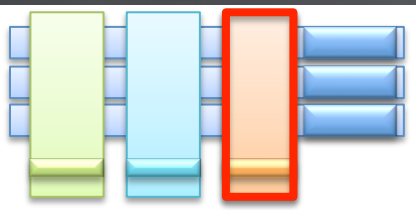
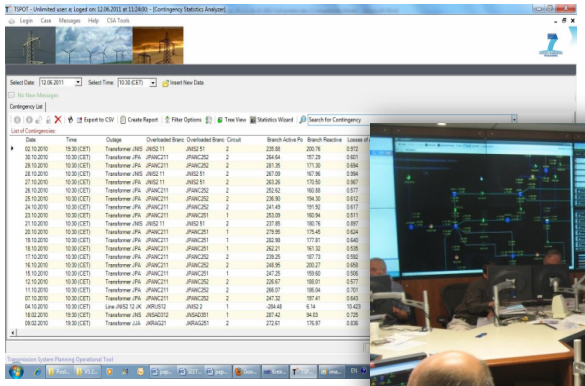


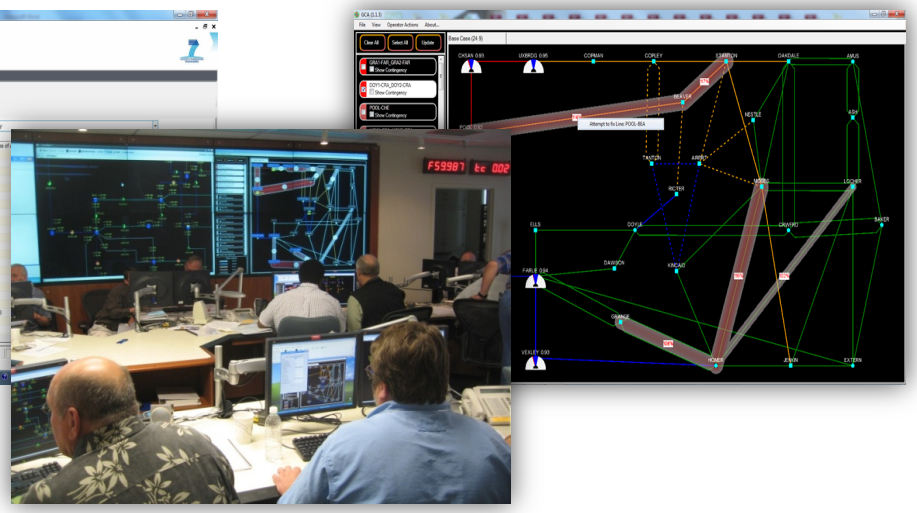
Contingency Analysis	Number of scenarios	Serial computing on 1 processor	Parallel computing on 512 processors	Parallel computing on 10,000 processors
WECC N-1 (full)	20,000	4 hours	~30 seconds 469x speed up	
WECC N-2 (partial)	153,600	26 hours	~3 minutes 492x speed up	~12 seconds 7877x speed up

- Computation and visualization in tandem for actionable info
- Operators reported 30% improvement in emergency response

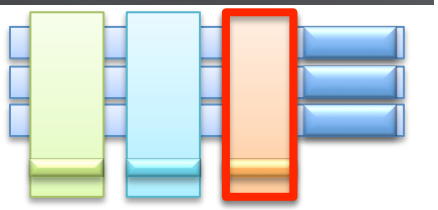
Current tabular format presents data, not information



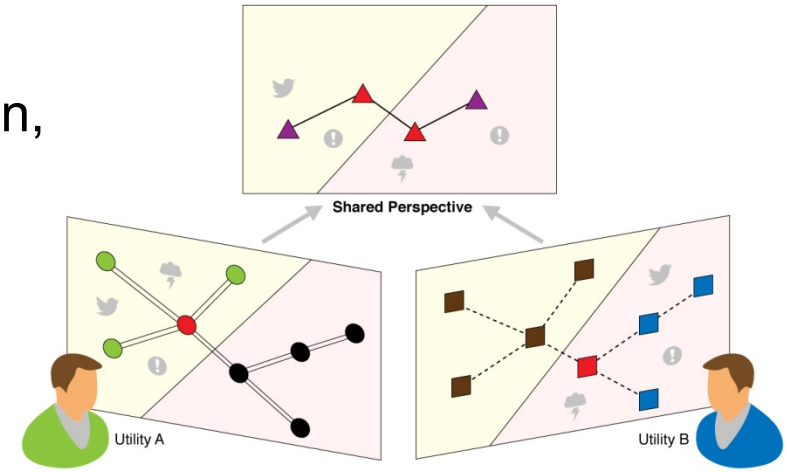
New visualization tool displays prioritized risks



Shared Perspectives for progressive information/knowledge sharing



- Augment voice communication with light-weight, secure, customizable visual analytics
- Support collaborative problem solving
- Push selected information into a common, shared view of the event
- Organizations to control shared content
  - Control of information type and form remains in organizational hands
- Secured, customized, shared views of critical information
  - Information is shared progressively, as dictated by protocol and need
- Interface with existing PNNL visualization tools for customized shared perspective needs
  - Shared Perspectives does not replace internal tools, but allows select information from these tools to be shared with neighboring organizations



Community Building: FPGI Workshop

http://gridoptics.pnnl.gov/FPGWS/

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- Time and Location: Nov 29-30, 2012; Seattle, WA.
- Theme: Workshop on Challenges in Next-Generation Analytics for the Future Power Grid
- Participants: National Labs, Universities, Power Companies, Vendors
- Major Findings:
  - A power-grid-specific open computing architecture is needed and requires a community.
  - Numerical libraries can help overcome the barriers to parallel computing.
  - The community needs to advocate for the importance of visualization.
  - Survey today's grid software tools in terms of the use of advanced computing and identify common and essential elements for a numerical libraries.
  - Building datasets for research is a priority.
  - Bring a core group together again to focus on developing an action plan. (workshop in planning)

GridOPTICS™ Open Computing Architecture

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- High performance computing holds promise for significant impact on power grid applications.
- However, computing alone would not achieve what's expected.
  - Data → Computation → Visualization
- An open architecture would facilitate interoperability
  - HPC compatible: reduces barrier to the use of HPC
  - Modularized application development: enables focus on applications than being overwhelmed by surrounding issues
- Open Source; Open Format; Open Forum
  - Needs a community effort

Questions?

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