PG&E
Smart Grid Investment Grant Update

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NASPI Work Group Meeting
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ARRA disclaimer

Pacific Gas and Electric Company®

WARNING: PG&E Proprietary Confidential Information

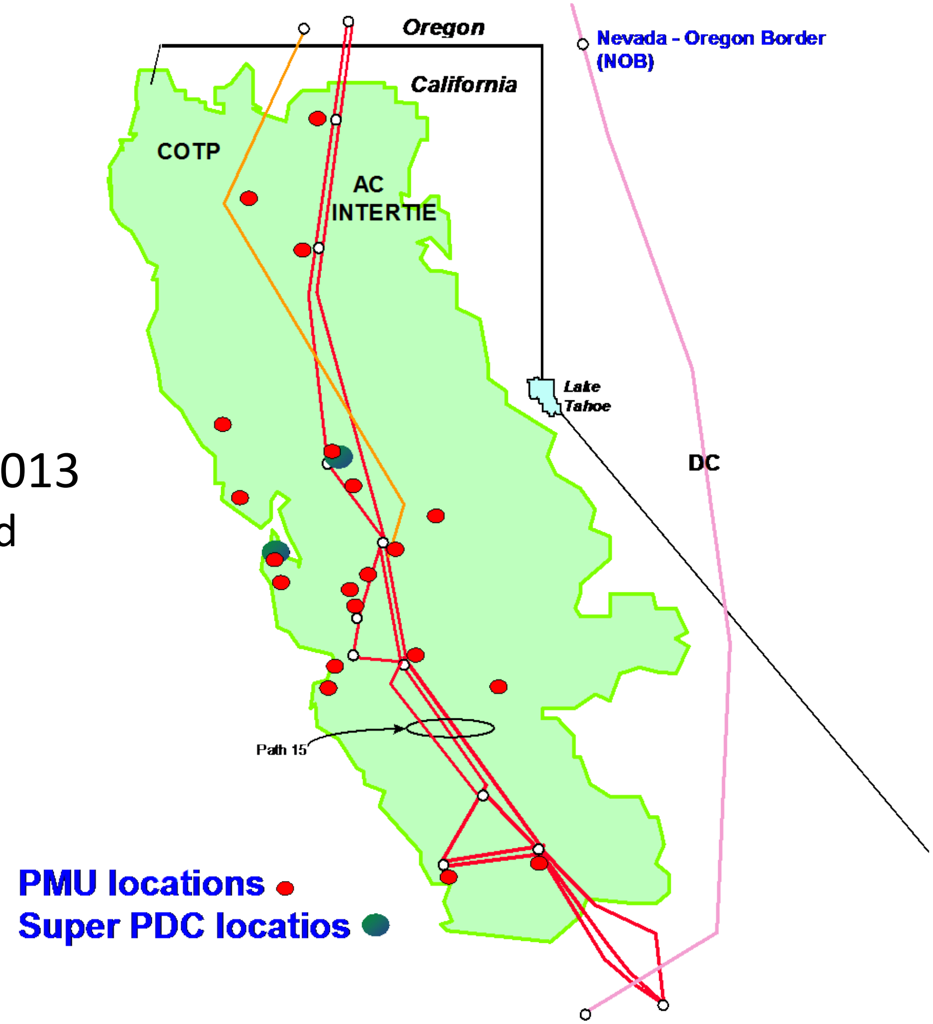
Project participants

- PG&E (a Sub-awardee of WECC)
- Strategic partners
  - Alstom Grid
  - General Electric
  - Mississippi State University
  - Quanta Technology

Project Timeline

SGIG End Date - March 31, 2012

1. ~ 25 substations
2. Hardware Installations – On Going
   – PMUs – 2/2013
   – Aggregate/Substation PDCs – 12/2012
   – Super PDCs – 12/2012
   – Communications Links – 2/2013
   – Servers, etc. for applications – 12/2012
3. Software Applications – On Going 3/2013
   – Situational Awareness, Visualization and Alarming
   – Enhanced EMS and State Estimation
   – Post-Disturbance Event Analysis
   – Enhanced Training Simulator
   – Distributed State Estimation
4. Training – On-Going 3/2013
   – NERC Certification
   – Started September 2012
   – Continued through March 2013



PMU and PDC

PMU

- ~ 25 substations with PMUs within PG&E territory
- Transmission elements monitored by PMUs
  - Broad regional footprint monitored by PMUs
  - Voltage monitored at 60-500kV
  - Many installations line voltage
  - PMU location criteria
    - Extensive studies
    - Infrastructure & Application based
    - Cyber security plan
- PMU installation rate
  - 15 substations installed (new or upgrade) by end of 2012
  - Remainder by April 2013

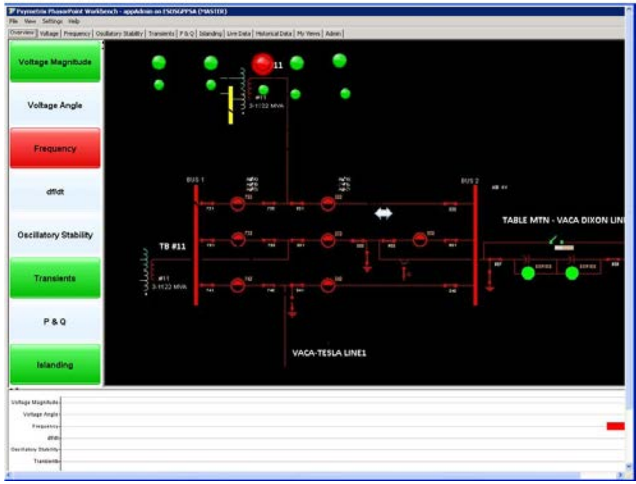
PDC and Communications

- PDCs
  - 13 field locations, fully redundant
  - PDC availability rate – Based on performance evaluation at the Proof of Concept facility
- Communications system
  - Communication links to RCs – WECC-arranged com link
  - System centralized ownership
  - System availability
    - Redundant architecture
    - Production system (designed for 99.95% - outage of 4.5 h/year)

Communications and Data

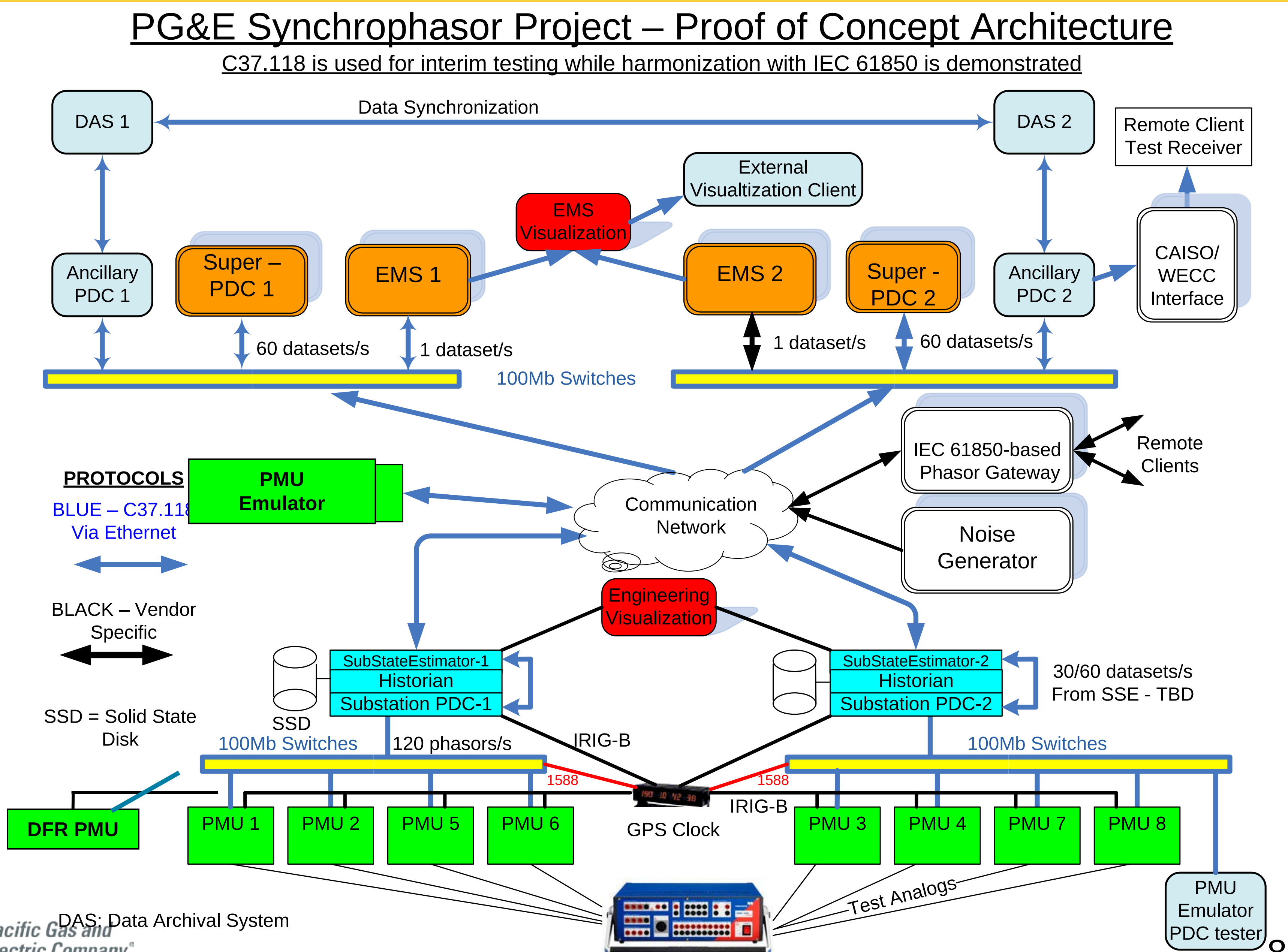
- Data flows and speeds
  - Phasor data to aggregate PDCs – *M class 60 f/s, P class 120 f/s*
  - PDCs to centrally processed applications – *various M class from 1 to 60 f/s, P class 120 f/s for event based triggers, or by user retrieval.*
  - Central applications to users/clients – *various*
  - Data speeds and volumes of data for each leg above for Class A data
  - Is all data flowing up to the archive in real time or is there data triage and storage or delayed batch deliveries along the way? *All M class data (real time) and P class event data stored in central data archrivals (with redundancy), there is also short term M and P class data storage at aggregate PDC (substation sites)*
- Data storage -- Archive/database status – what's stored in the field and what's archived in central facilities
  - Storage size – 230 GB per aggregate site, 135 TB each central Data Archival System (DAS), 60 TB each central EMS Historian (Disaster Recovery Infrastructure)
  - Continuous for about 18 months, event data indefinitely
  - Data access query process is mature and workable (production grade products)
  - 150 PMUs, 12 phasors per PMU, 3-phase voltages/currents and sequence values
    - Total volume data sent up by minute – 150 MB
    - Total volume data being generated and stored per year – approx. 100 TB/yr

Operational Applications Using Phasor Data



1. Situational Awareness, Visualization and Alarming for Electric Transmission Operators
   – Unbalance power applications
   – Abnormal angles
   – Abnormal voltages
   – Line overloads, and
   – Oscillations (small signal oscillation) monitoring
   – System restoration
2. Enhanced Energy Management Systems and State Estimation for current EMS users
   – Adding synchrophasor measurements to existing SE measurements.
   – Track dynamic state changes of a system during disturbances
   – EMS measurement support Volt-VAR Optimization
3. Post-Disturbance Event Analysis for Planners and Engineers
   – Substation level data analysis
   – System level event analysis
4. Operator and Engineering Training, Enhanced Dispatch Training Simulator (DTS)
5. Cognitive Tasks and Human Performance Analysis
6. Provide interfaces with EMS and with third parties
7. Distributed State Estimation

Proof of Concept Testing - Architecture



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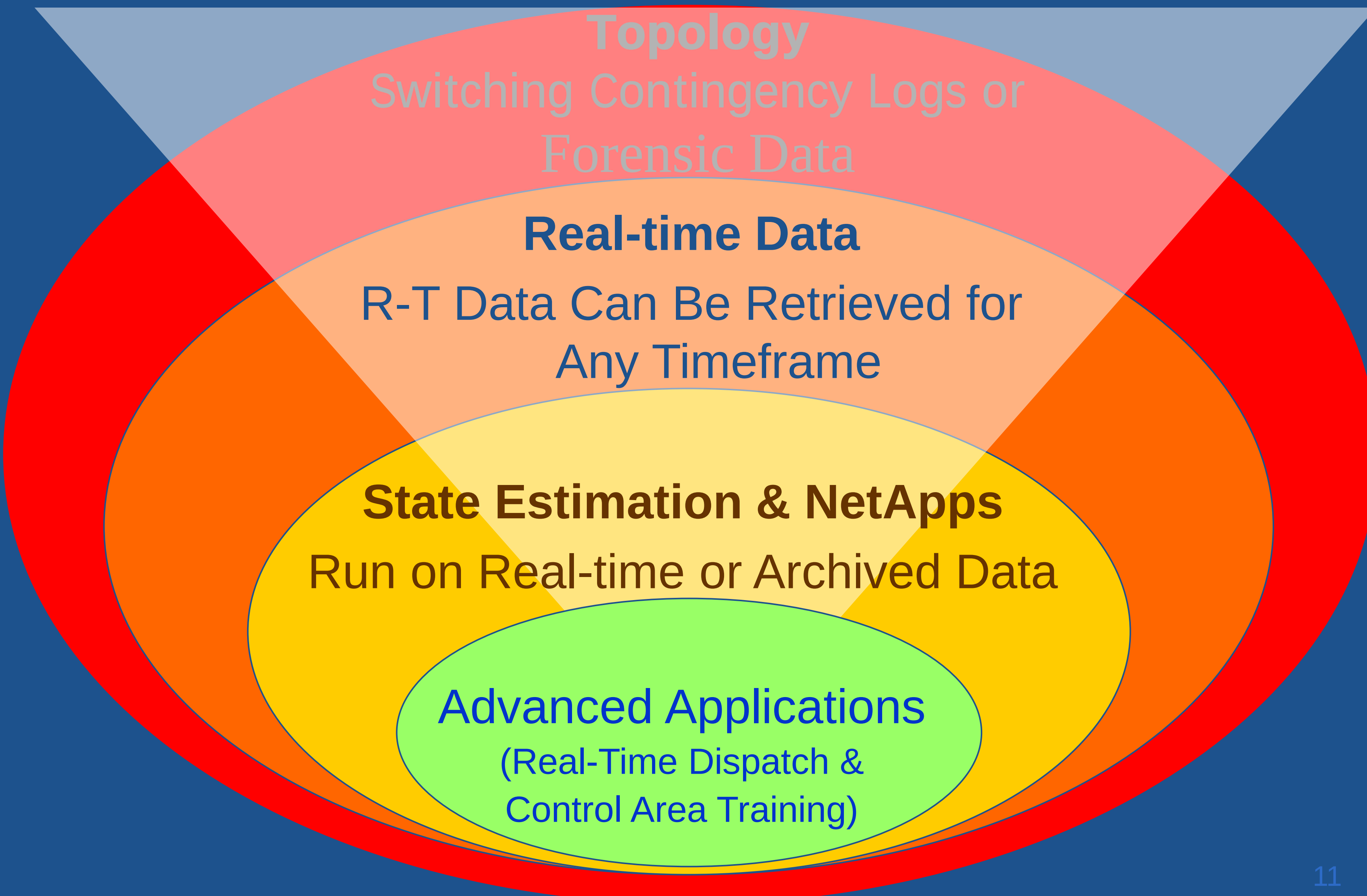
Phasor data-sharing

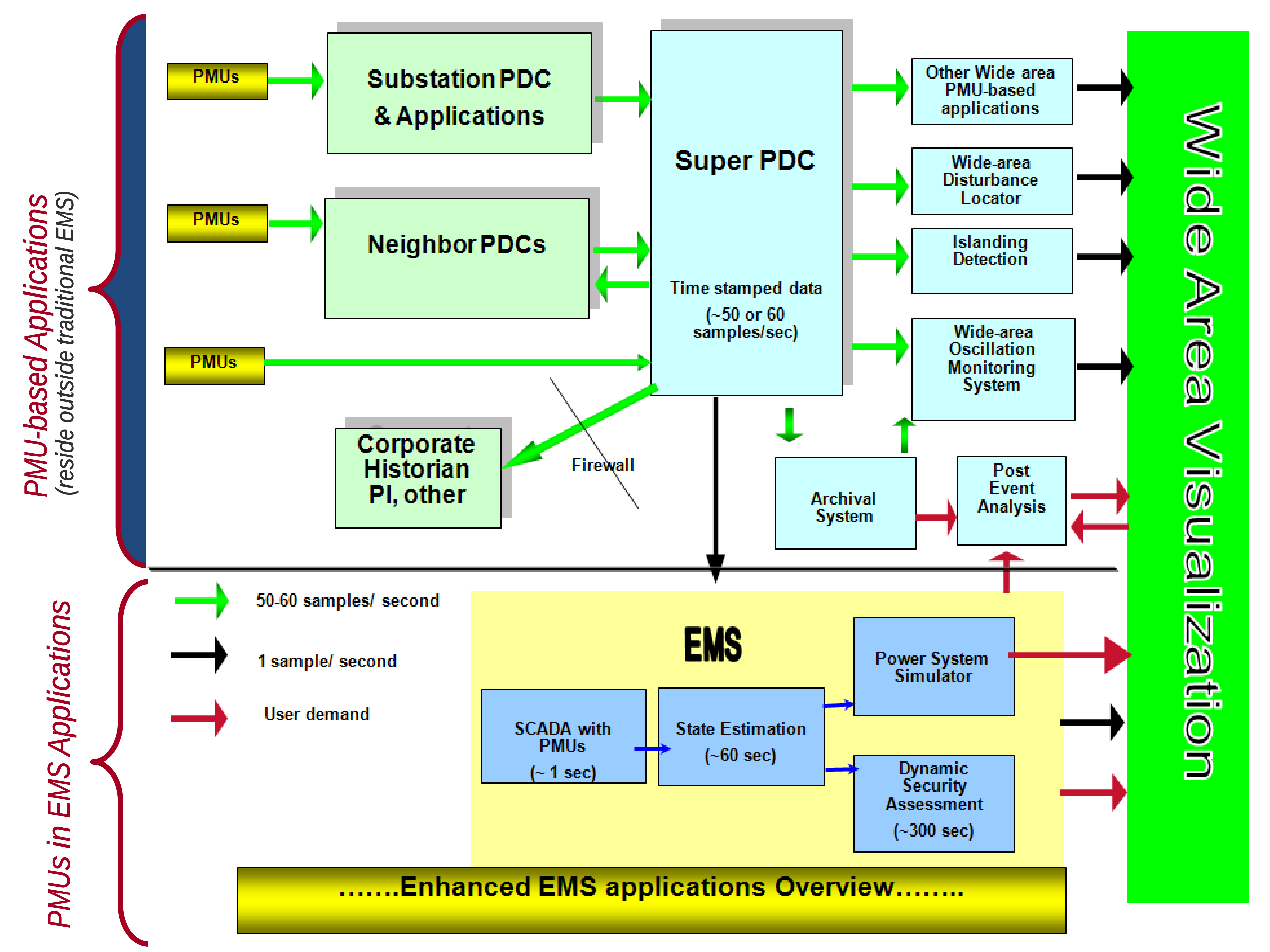
- **How many TOs and RCs** receive data from your PMUs/project?
  - Data available as needed subject to NERC NDA
- **How many receive applications** output that result from processing real-time phasor data?
  - Many - Through Solution Providers
- **Do you share phasor data for research purposes**?
  - UC Systems - CA Institute of Energy and Environment (CIEE)
  - Georgia Tech, Mississippi State U, Virginia Tech, Washington State U

Issues to Address

- Data exchange
  - Needs to be based on industry standard protocols
  - Need to be interoperable with other PGs using standard protocols
  - Customization / Aliasing should be responsibility of data receiver
- Configuration change management
  - How one make changes (e.g. upgrade etc.) in one the gateway and how that affects other gateways?
- Support of multicast
  - Point-to-point solutions result in inefficient bandwidth usage
- Need to be tested
  - Delays associated with testing, findings, corrections, and support during implementation (includes Cyber Security testing)
- Life time support
  - Provider's business sustainability?
  - Providing organization's size and resources
  - Track record

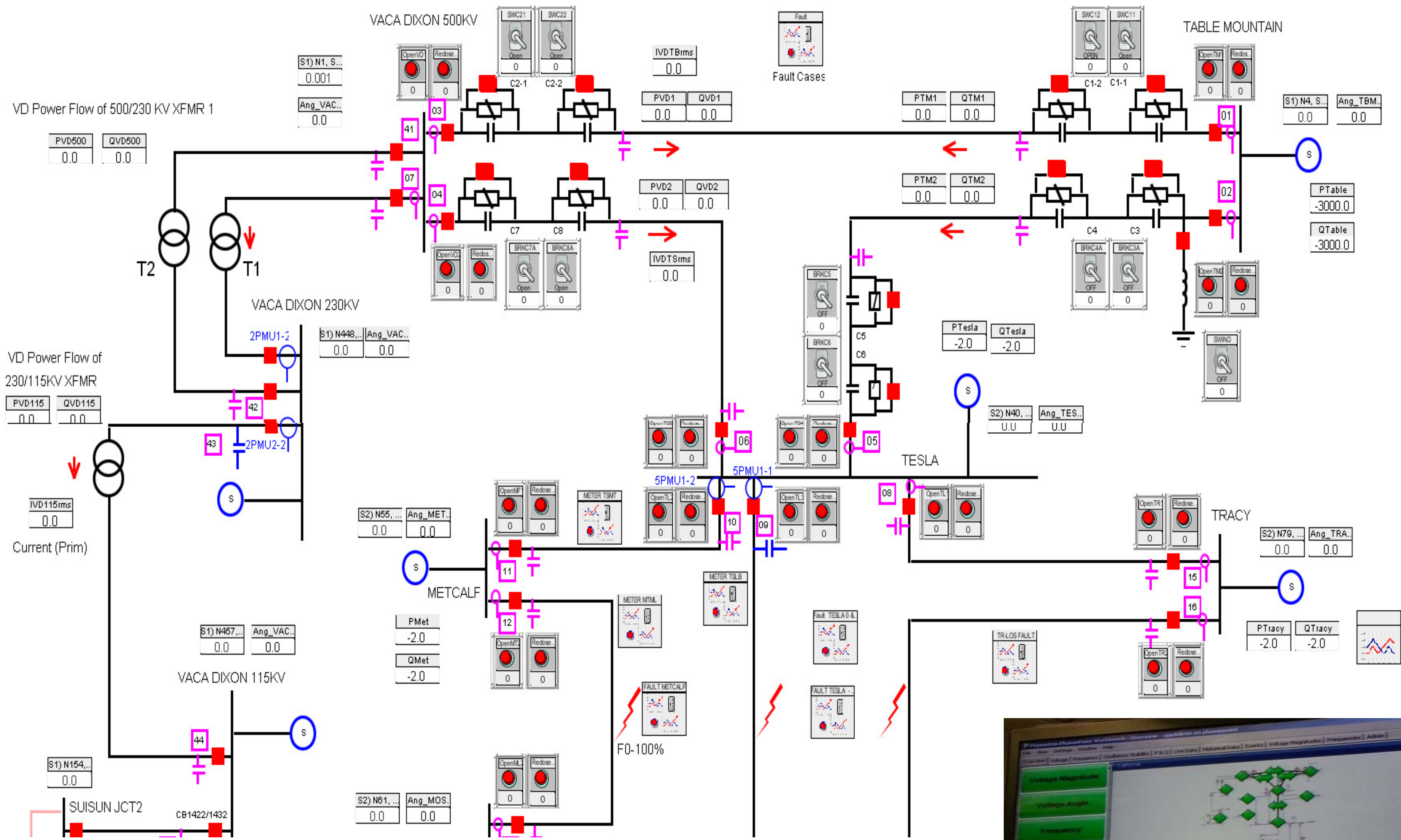
System Modeling Archiving / Trending

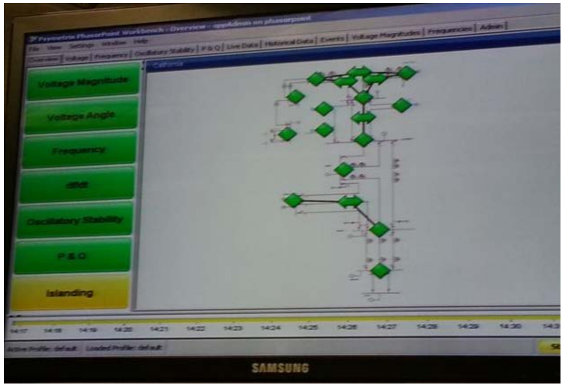




PMU-based Applications
(reside outside traditional EMS)
PMUs
Substation PDC & Applications
PMUs
Neighbor PDCs
PMUs
Super PDC
Time stamped data
(~50 or 60 samples/sec)
Other Wide area PMU-based applications
Wide-area Disturbance Locator
Islanding Detection
Wide-area Oscillation Monitoring System
Corporate Historian PI, other
Firewall
Archival System
Post Event Analysis
Wide Area Visualization
PMUs in EMS Applications
50-60 samples/ second
1 sample/ second
User demand
EMS
Power System Simulator
SCADA with PMUs
(~ 1 sec)
State Estimation
(~60 sec)
Dynamic Security Assessment
(~300 sec)
…….Enhanced EMS applications Overview……..

Modeling and Validation - Real-time Digital Simulator





Challenges and lessons learned

- **What have been your biggest technical challenges to date?**
  - Maturing technology and industry standards (IEEE and IEC) for production grade systems
  - Multiple standards are used for data exchanges (e.g. IEEE C37.118-2005, IEEE C37.118.2-2011, IEC 61850-90-5)
- **What have been your biggest programmatic or execution challenges to date?**
  - Issues outside sub- awardees' process
  - Data Exchange and Naming conventions
- **Research needs – what do we need to figure out next?**
  - Simplifying technology roll out
  - Enhancements in visibility tools
  - Broader training tools
  - Adaptive protection
- **Other lessons or insights**
  - Proof of Concept Facility Instrumental to managing risks and stranded assets
    - PMU performance
    - Communications system design and performance
    - Interoperability
    - Cyber-security
    - Data archiving and EMS Historian
    - Off line analysis tools
    - Operator or staff training
      - Have Established A comprehensive program at various corporate levels
    - Managing vendors, contractors or RC

Metrics and Valuation Measures

SE Differences

- Compare SE executions
  - Use better model based on model comparisons
    - Base case is with PMU data turned off
    - Change case is with PMU data turned on
  - Capture
    - Performance index differences
    - Largest voltage differences
    - Largest flow differences
    - Observability
    - Bad data detection

Volt / VAR Optimization Measurement

- For differences between SE with and without PMU data
  - Capture
    - Differences in Voltage margins due to optimization
    - Differences in Var requirements due to optimization

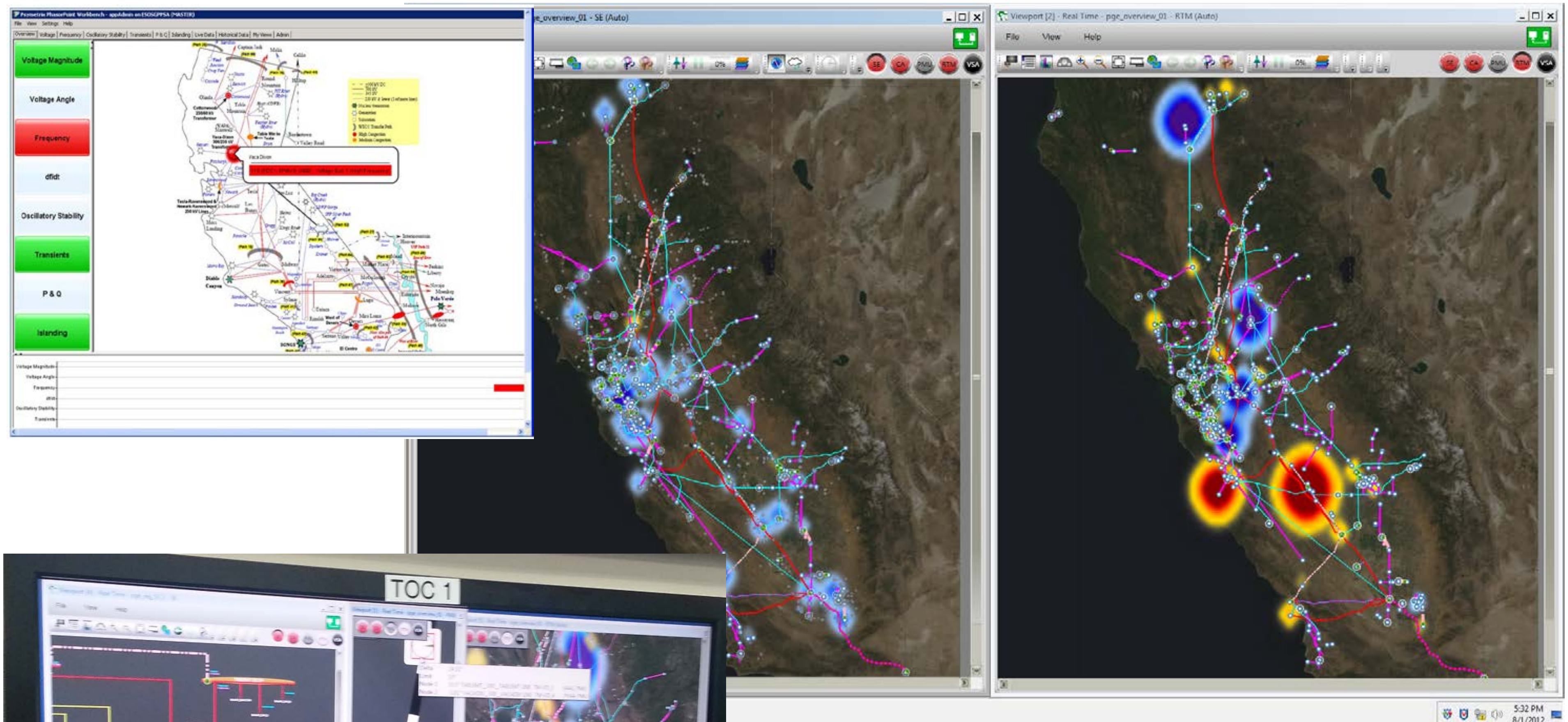
Congestion Management

- Based on SE results
- Compare on critical stability limited and voltage limited critical paths
  - Nominal Transfer Capability (NTC)
  - Real-time Transfer Capability (RTC)
  - Changes to LMPs and/or flowgates
  - Changes to Congestion
- Capture change in cost based on LMP or Flowgate

What do we need to figure out next

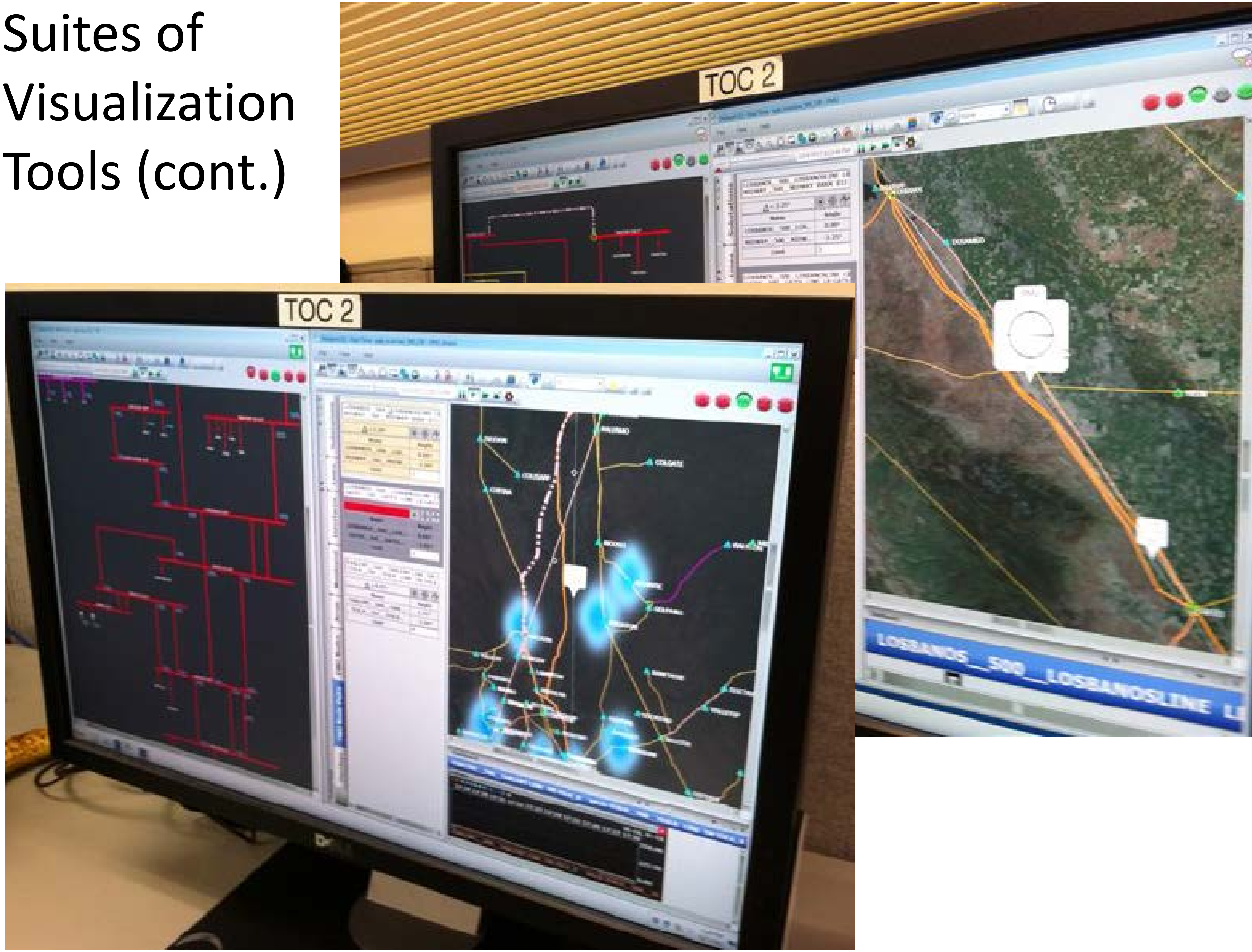
- Results from the Metrics
- Sustainable vision
- Effective data exchange using NASPI-net or similar tools
- Effective policy for data exchange, and supporting external data management
  - Not limited to any one specific function/perspective.

Situational Awareness Tools



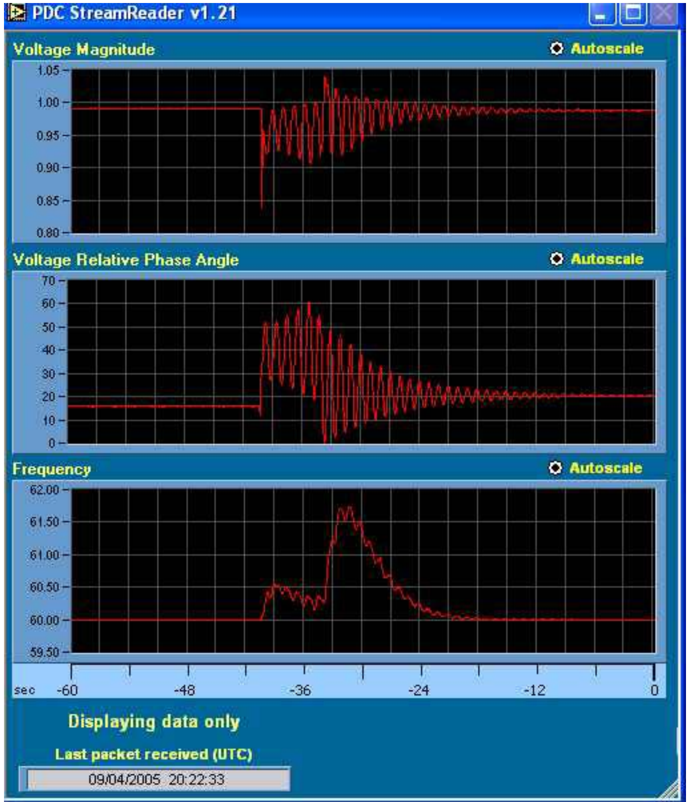
"...by marrying synchrophasor "measurement-based" analytics with "model-based" stability analytics, we're building the next generation Energy Management System capable of assessing power system dynamics and grid stability in real time for improved reliability and better asset utilization".

Suites of Visualization Tools (cont.)



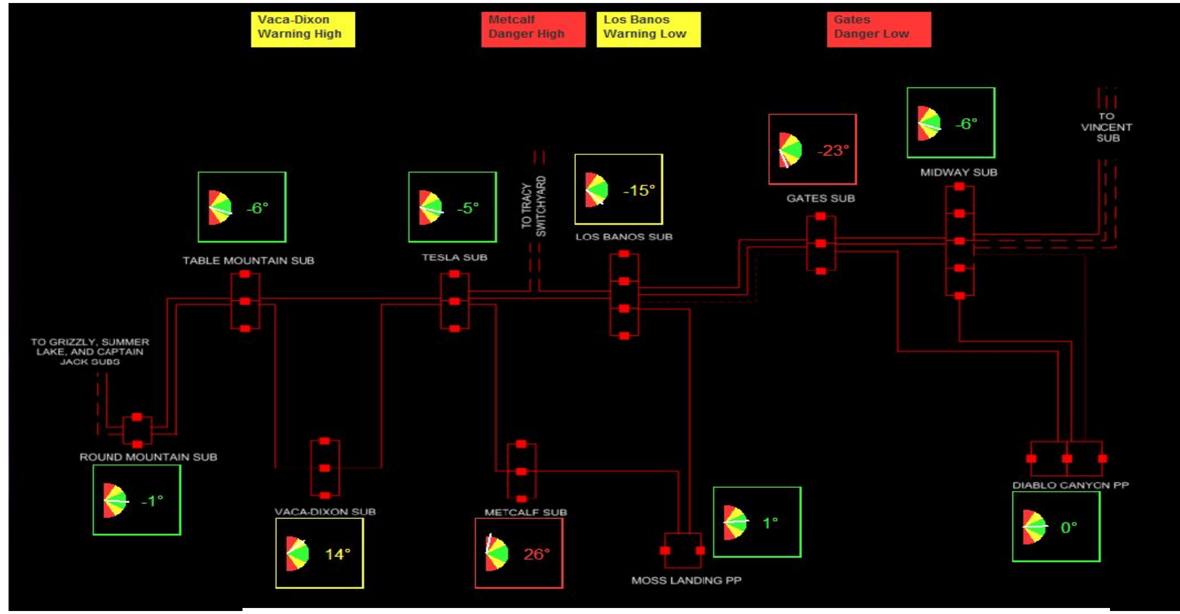
Suites of Visualization Tools (3)

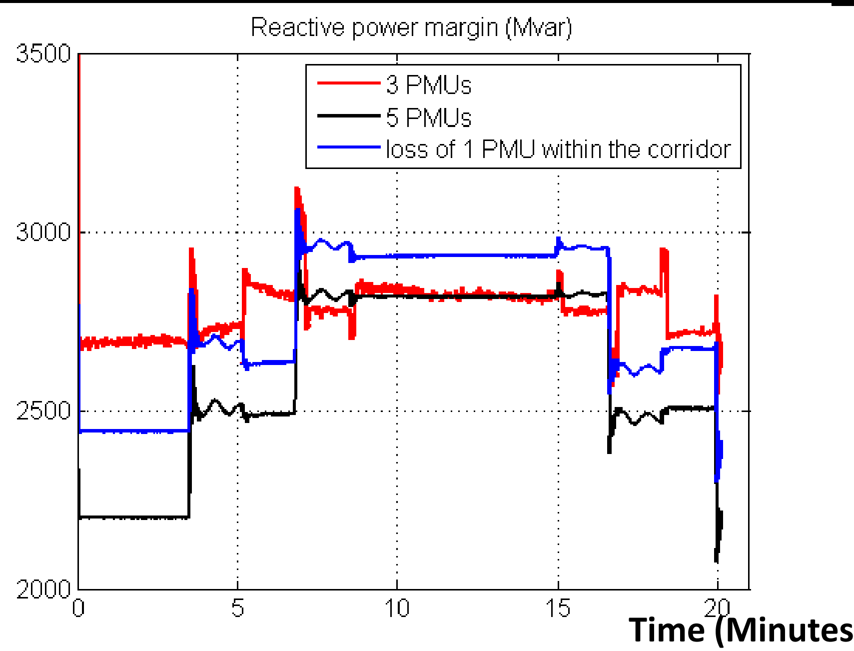
Situational Awareness Analysis Tools (cont.)



Measurements

Speedometer





Observability

- ❖ **Real-time Voltage Instability Indicator / Index (RVII)**
  - ➢ Model-free, fast real-time detection, independent of state estimation (using PMU and SCADA data)

- ❖ **Real-time and Contingency Analysis based on PMU availability**

Next Steps for Successful Deployment

- Continue with Collaboration
- Life cycle support strategy
- Engineering developments and new tools
- Impact of Observability
- Comprehensive Training
- Assessment of Training
- Metrics and Valuation
- Documentation

NASPI Tour – October 2011

Tools and Further Reading

❖ **PMU Connection Tester available**

http://pmuconnectiontester.codeplex.com/releases/view/87611

- Allows selection of a specific network interface when using a TCP or UDP socket
- Allows for specifying a multicast source IP for multicast subscriptions for devices or systems that require this

❖ **NASPI / PSTT – 2010-2012,** www.naspi.org/site/Module/Team/pstt/psttresources.aspx

❖ **IEEE P&E – September / October 2012** - Control Center Analytics for Enhanced Situational Awareness

❖ **IEEE P&E - July / August 2012** - See It Fast to Keep Calm: Real-Time Voltage Control Under Stressed Conditions

❖ **IEEE GM – July 2012** - Enhanced Power Grid Operations with a Wide-area Synchrophasor & Communication Network

❖ **IEEE ISGT** (Innovative Smart Grid Technology) - Washington DC-January 2012

❖ **IEEE PES PSCE – March 2011** - A Roadmap for Optimal PMU Placement

❖ **IPCGRID March Annual Workshop 2008-2012** – Innovation in Protection & Control Workshop for Greater Reliability Infrastructure Development, San Francisco

❖ **PAC World Magazine**

❖ **IEEE GM – July 2007** - Strategies and Applications to Meet Grid Challenges and Enhance Power System Performance