The Field of PMUs

NASPI Fall 2017

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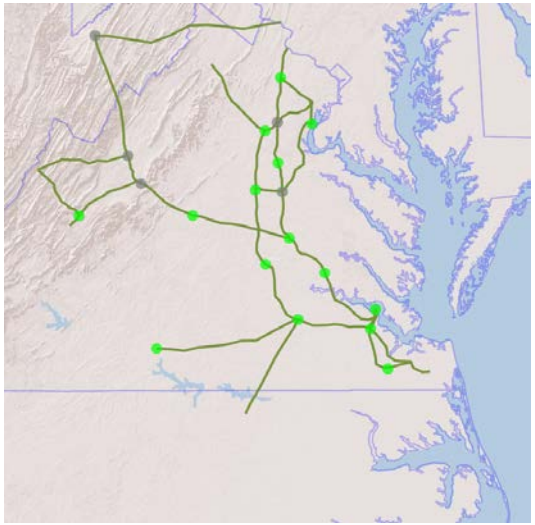
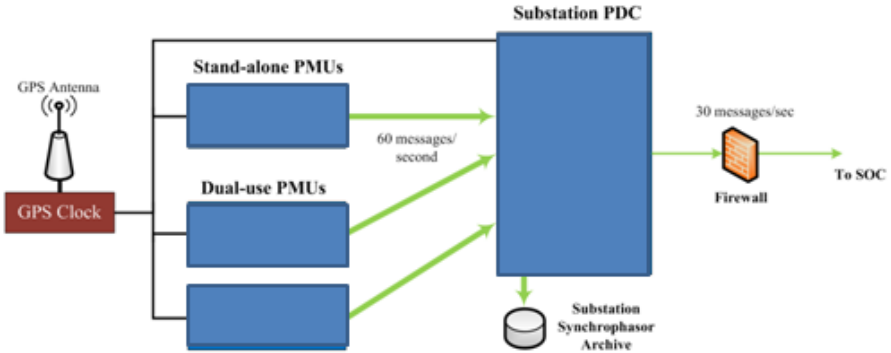
Dominion Energy

DOE SGIG Projects – Our start to synchrophasors

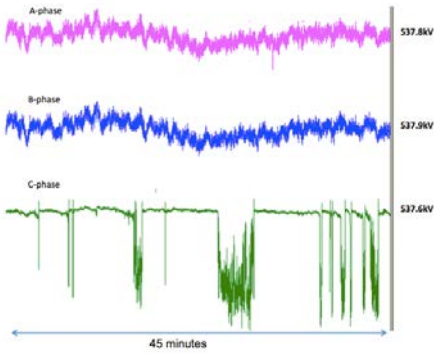
- Began with two SGIG projects where we partnered with Virginia Tech, PJM, GPA, Quanta, and many more
  - Deployed 80 Relay PMUs installed across our 500kV network, covering more than 20 substations
  - Developed open source applications, including the LSE, negative sequence unbalance, and more

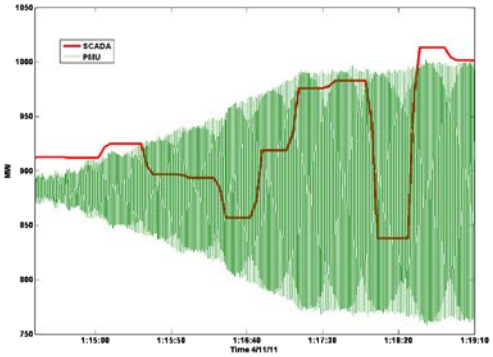


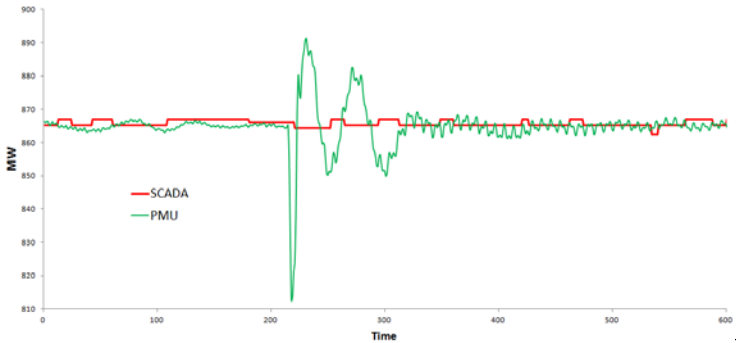


Finding applications and use cases

- Almost immediately we found additional use cases beyond the initial applications being developed
  - Equipment failures
  - Generator oscillations
  - Impact of arc furnaces on grid
  - GIC/GMD flows via monitoring transformer VAR consumption
  - Overall situational awareness of our grid and the EI







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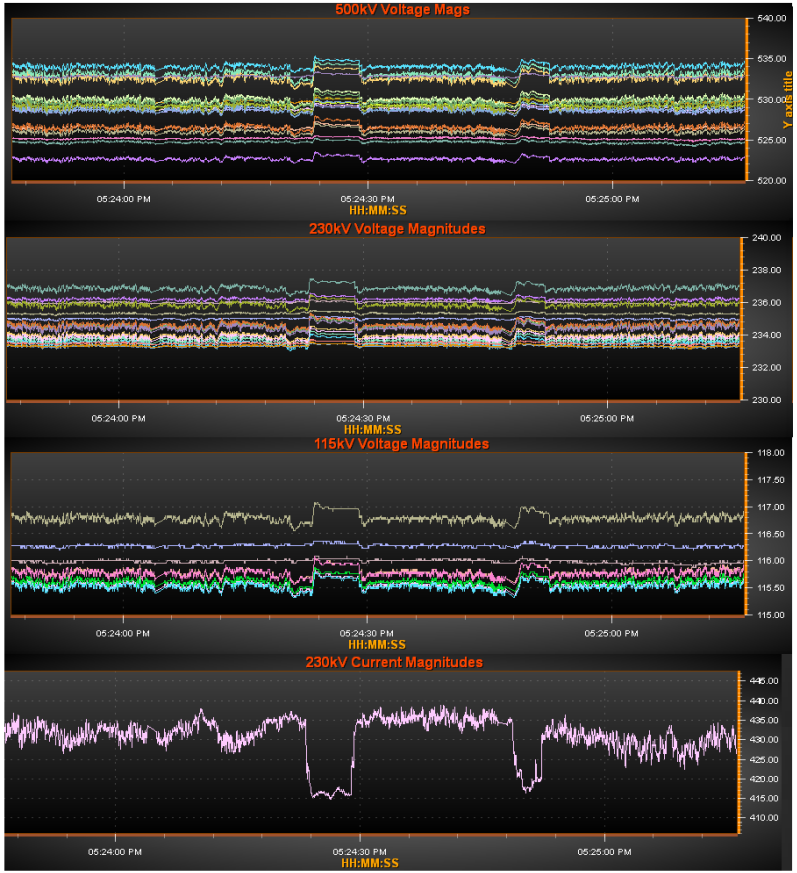

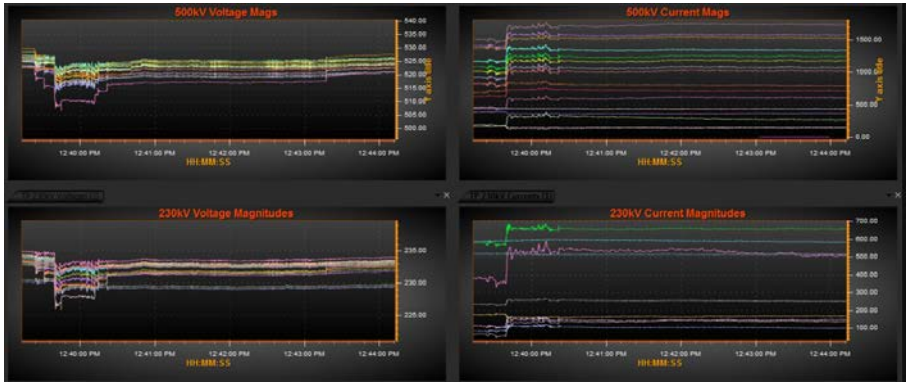

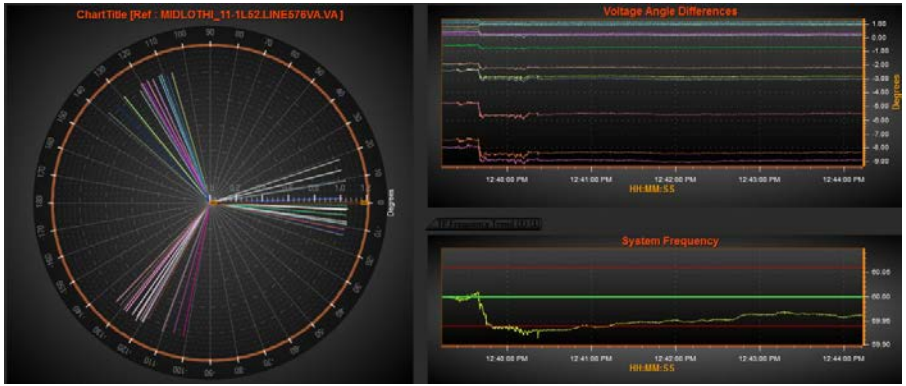

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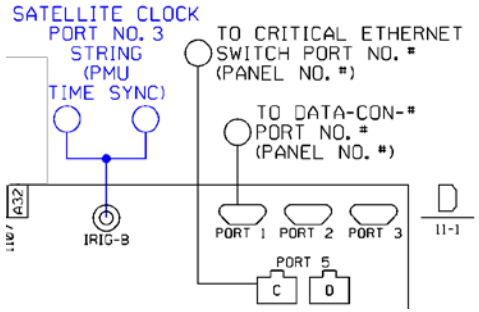
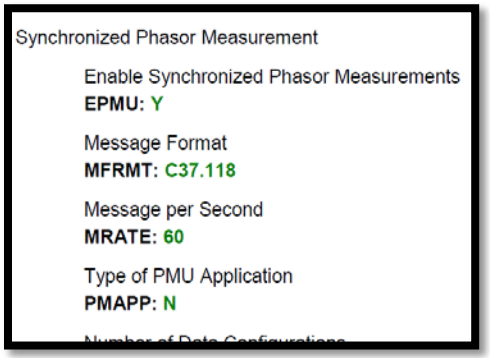
Providing use and value across the organization

- To date most of this is outside of our control center, in our engineering and support departments
  - This has been a success, as many departments are seeing value in the data, supporting many aspects of our business.
  - Synchrophasors are a critical complement to all our data sets, including SCADA data, power quality data, oscillography data, and any other data sets.
- Because of the core fundamentals of synchrophasors, we believed synchrophasors would be essential to the future of electric grids.
  - Observations and events continued to support this
  - We wanted to continue deployment to be ready whenever new users and use cases were realized
  - So we are building “the field of PMUs”

Standardization – Inside the substation

- Standardized synchrophasors inside Transmission Substations.
  - New digital relays installed for protection had PMU capability built in, just needed a few other components
  - Found the cost to do this are typically less than 1% of the overall project costs.
  - We didn't have all the servers and personnel in place to fully support all these, and we are continuing to build that.
    - But the most difficult part to this is the substation work (outages, planning, coordination)
    - Doing this PMU work during projects prevents a lot of additional work and saves on costs





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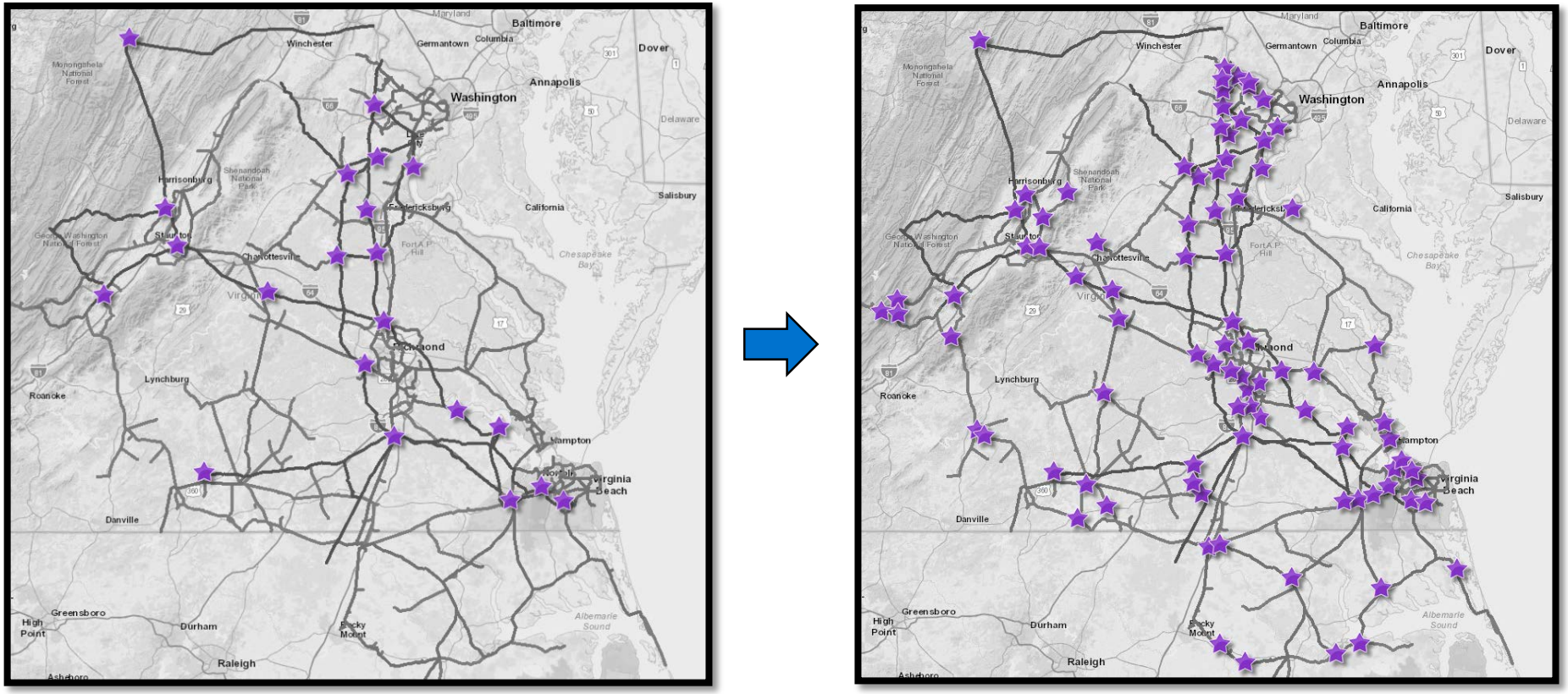

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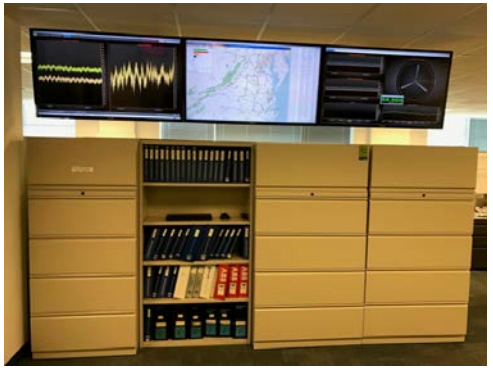
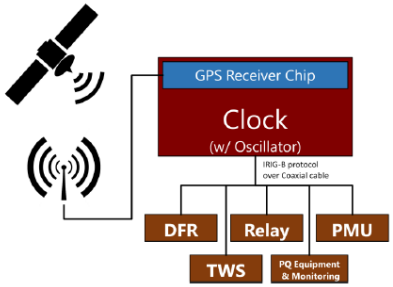
Standardization – Outside the substation

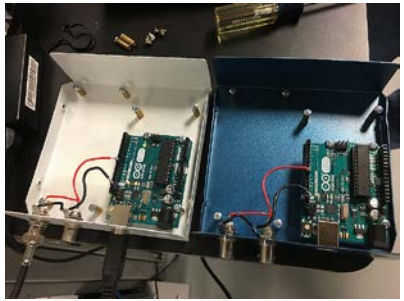
- We continued “standardization” outside the substation
  - New synchrophasor course in our relay technician training program
  - Installed real-time synchrophasor displays in common areas of a few of our engineering offices
    - Allows us to easily explore, learn, and improve visualizations for grid situational awareness
    - Found certain visualizations can provide fundamental support to the operators
      - System wide voltage trends show step changes in voltage when equipment switch in/out (ex: cap bank)
      - Operator gets immediate verification of a control decision made



Standardization – Outside the substation

- Precise Timing
  - Working to improve our substation and overall timing architecture to be more reliable and highly available
  - Continuing to become more and more important for all the digital systems being installed
- Communications networks from substation to control center
  - Synchrophasors increased our bandwidth usage
  - Working closely with Telecom personnel to improve overall performance across the entire network
- Expansion into other departments & business units
  - Fault Analysis, System Operations Center
  - Distribution
  - Generation (traditional and distributed)
- Analytics & Real-time Control Applications (openECA)





Year	Day	Time	LSP	LS	DSP	DST	TZS	TZ Offset	TZ30M	TFOM	Parity	CTQ	SBS
16	366	18:59:56	1	0	0	0	1	5	0	0	1	0	68396
16	366	18:59:57	1	0	0	0	1	5	0	0	0	0	68397
16	366	18:59:58	1	0	0	0	1	5	0	0	0	0	68398
16	366	18:59:59	1	0	0	0	1	5	0	0	1	0	68399
16	366	18:59:60	1	0	0	0	1	5	0	0	1	0	68400
16	366	19:00:00	0	0	0	0	1	5	0	0	1	0	68400
16	366	19:00:01	0	0	0	0	1	5	0	0	0	0	68401
16	366	19:00:02	0	0	0	0	1	5	0	0	0	0	68402

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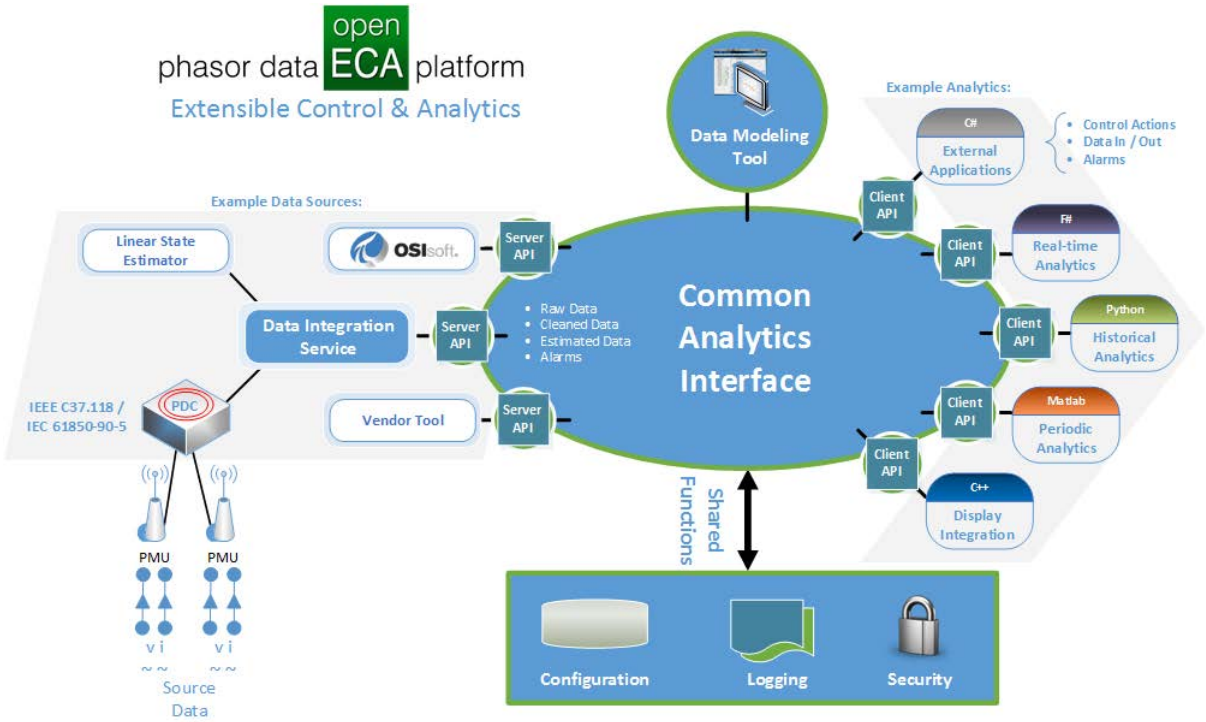
Dear Mr. Jones,

Welcome to The Sheraton Springfield Monarch Place! We are delighted to be hosting you and all other attendees visiting us for NASPI 2017! We got word that you are a COOKIE MONSTER, so we thought you'd appreciate this gift to hold you over while you are away from home!! Don't tell anyone, but there may be a few more cookies in your future over the next few days at the conference, just remember to share! Enjoy!

Best,

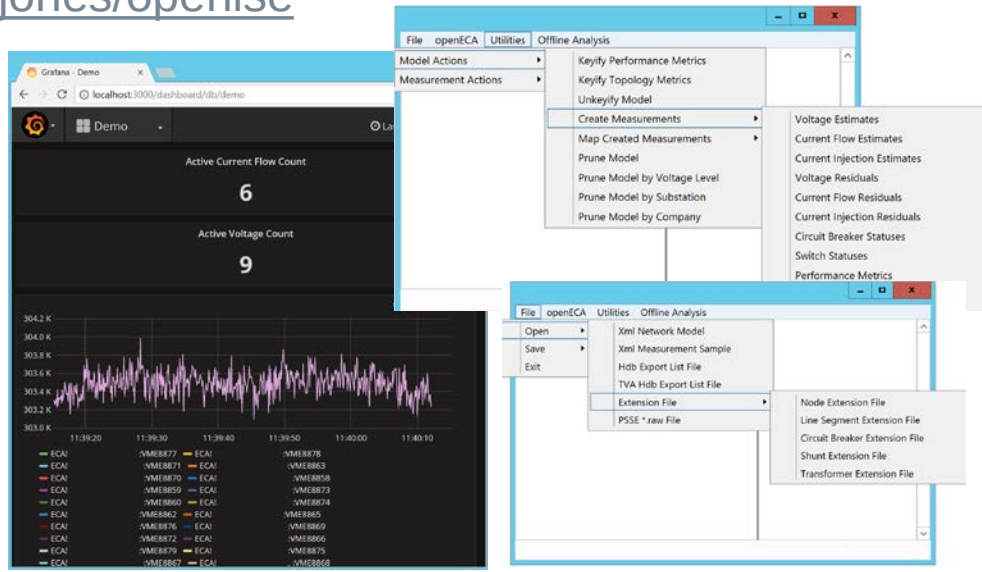
Sheraton

The Management & Staff of The Sheraton Springfield


phasor data open ECA platform
Extensible Control & Analytics
Example Data Sources:
Linear State Estimator
OSIsoft.
Server API
Data Integration Service
Server API
Raw Data
Cleaned Data
Estimated Data
Alarms
IEEE C37.118 / IEC 61850-90-5
PDC
Vendor Tool
Server API
PMU
PMU
Source Data
Common Analytics Interface
Data Modeling Tool
Example Analytics:
C#
External Applications
Control Actions
Data In / Out
Alarms
Client API
F#
Real-time Analytics
Python
Historical Analytics
Matlab
Periodic Analytics
C++
Display Integration
Shared Functions
Configuration
Logging
Security

openLSE

- **Core libraries:** https://www.github.com/kdjones/linear-state-estimator
- **openLSE:** https://www.github.com/kdjones/openlse
- **Features and Improvements:**
  - Installation Package
  - Self-hosted
  - Integrated directly with openECA
  - Improved modeling and troubleshooting tools
  - Modeling workflow automation



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openECA Demonstration Day

- Dominion is hosting an **openECA Demonstration Day on November 8, 2017**
  - Presentations and Poster-Demo Session
  - See me today or email me at kevin.d.jones@dominionenergy.com if you are interested in attending.

- ***Project Provided Analytics***
  - Linear State Estimation
  - Oscillation Detection Monitor (ODM)
  - Oscillation Mode Meter (OMM)
  - Topology Estimation
  - Regional VAR Control
  - Local VAR Control
  - PMU Synchroscope
  - PMU Transducer Calibration
  - Line Parameter Estimation
  - Impedance Calculator
  - Synchronous Machine Parameter Estimation Acceleration Trend Relay (ATR) Improvement

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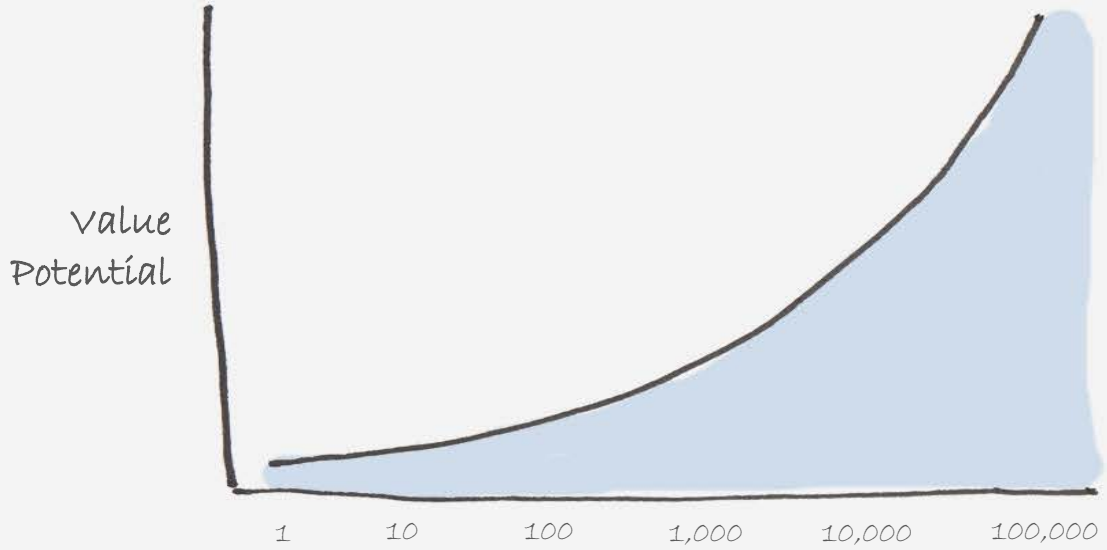
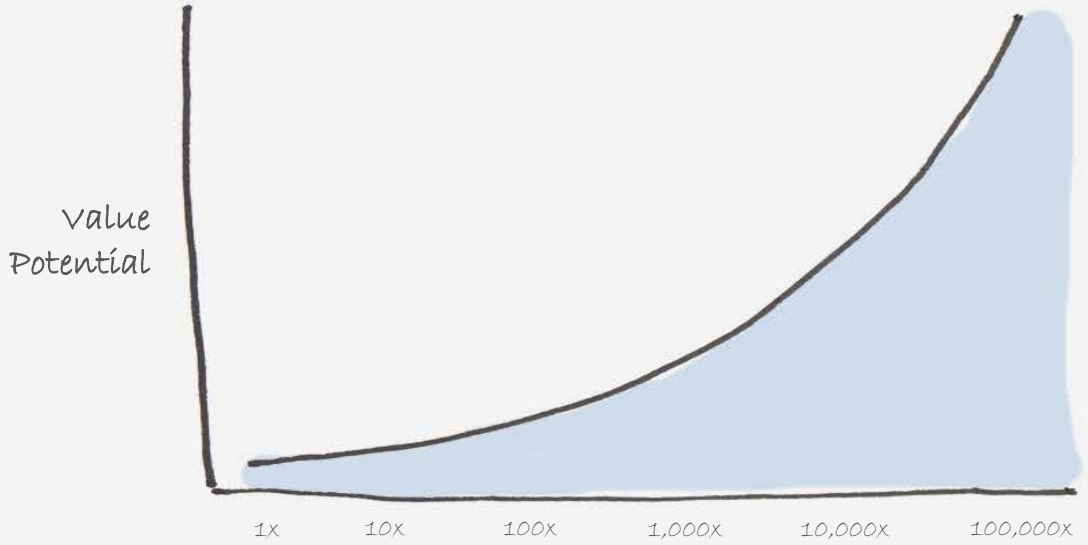
IF YOU BUILD IT,
THEY WILL COME.

Return on Synchrophasor Technology is Exponential



* Channel count is not solely an effective metric for determining value potential

Return on Synchrophasor Technology is Exponential



Normalized Accessibility
How easy is it for your all of your experts to access high fidelity synchrophasor data?
(Inverse access-cost per channel)

Historical Volume
How much data have you collected?

Experiment Count
How many hypotheses are you testing with your data?

PMU Channel Count x Normalized Accessibility x Historical Volume x Experiment Count

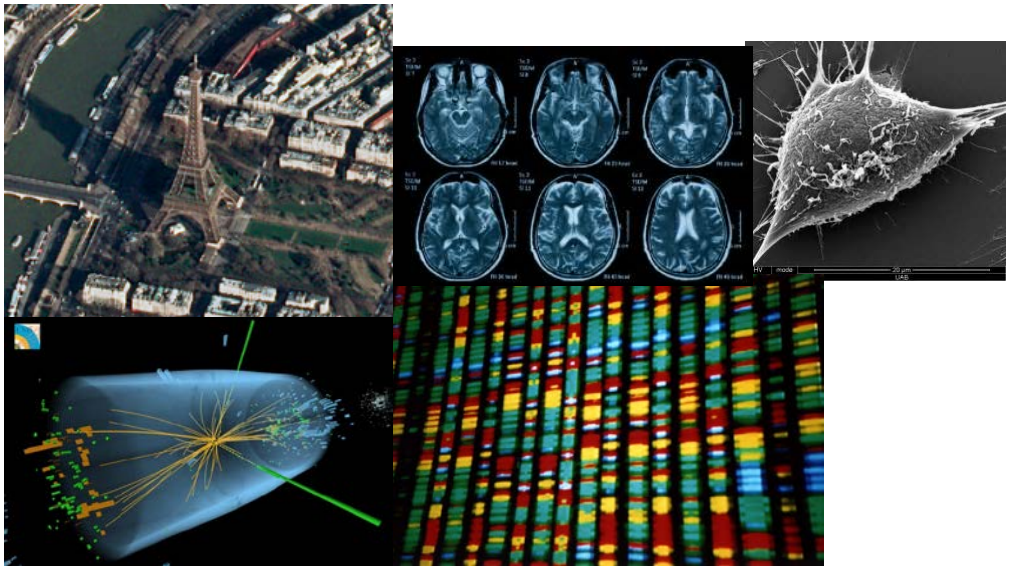
The 10X Rule of Innovation

- Succinctly stated, a technology is only worth investing in if it provides an order of magnitude improvement over existing technologies.
- Is synchrophasor technology 10 times better – in key dimensions – that anything other streaming grid telemetry?

Dimension	Existing	Synchrophasors
Frame resolution	1 frame/sec	30/60/120/240 frames/sec
Timestamp variance	10^{0} seconds	10^{-6} seconds
Value	Scalar	Vector

Macro Trends: Demand For Information Density

- Using higher precision data to understand and control complex systems.
  - Microscopy
  - DNA sequencing
  - Medical Imaging
  - Satellite Imaging
  - Quantum [anything]



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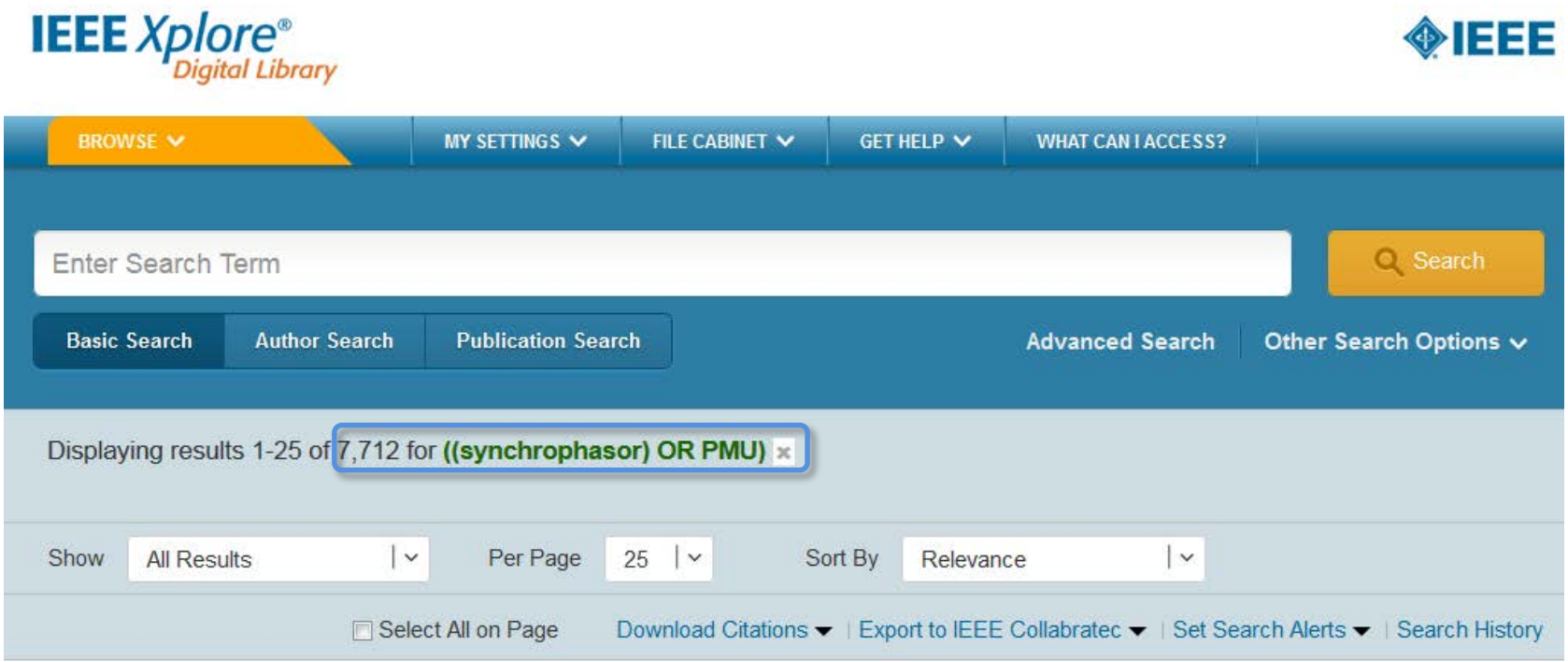
The Application Space is Large and Documented



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Supporting Organizations in the U.S.

- Department of Energy (DOE)
  - https://www.smartgrid.gov/recovery_act/program_impacts/applications_synchrophasor_technology.html
- The North American Synchrophasor Initiative (NASPI)
  - https://www.naspi.org/home
- The Joint Synchronized Information Subcommittee (JSIS)
  - https://www.wecc.biz/OC/Pages/JSIS.aspx
- NERC Synchronized Measurement Subcommittee (SMS)
  - http://www.nerc.com/comm/PC/Pages/Synchronized-Measurement-Subcommittee-%28SMS%29-Scope.aspx

Reliable Sources

"Two Virginia Tech electrical engineers named among the greatest in science, engineering, and technology in the world" - *Virginia Tech Engineering News*

https://www.fi.edu/laureates/arun-phadke

https://www.fi.edu/laureates/james-thorp

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IF YOU BUILD IT,
THEY WILL COME.

Data is an “Asset”

100011100
010110111
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