IEEE PES GM2017
Panel: Big Data Access & Big Data Research Integration in Power Systems
Chair: Prof. Hamed Mohsenian-Rad, UC Riverside

Big Data Access, Analytics and Sense-Making

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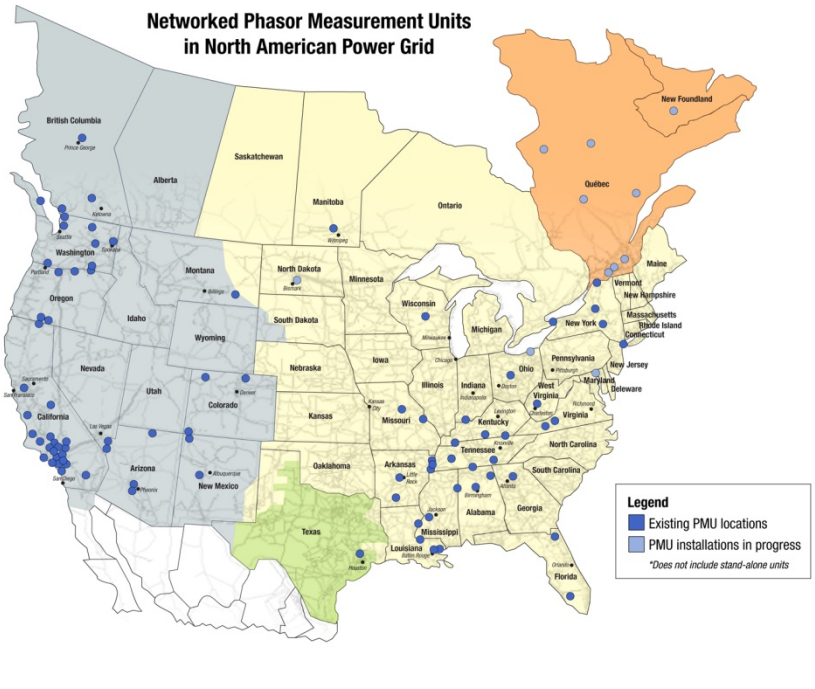
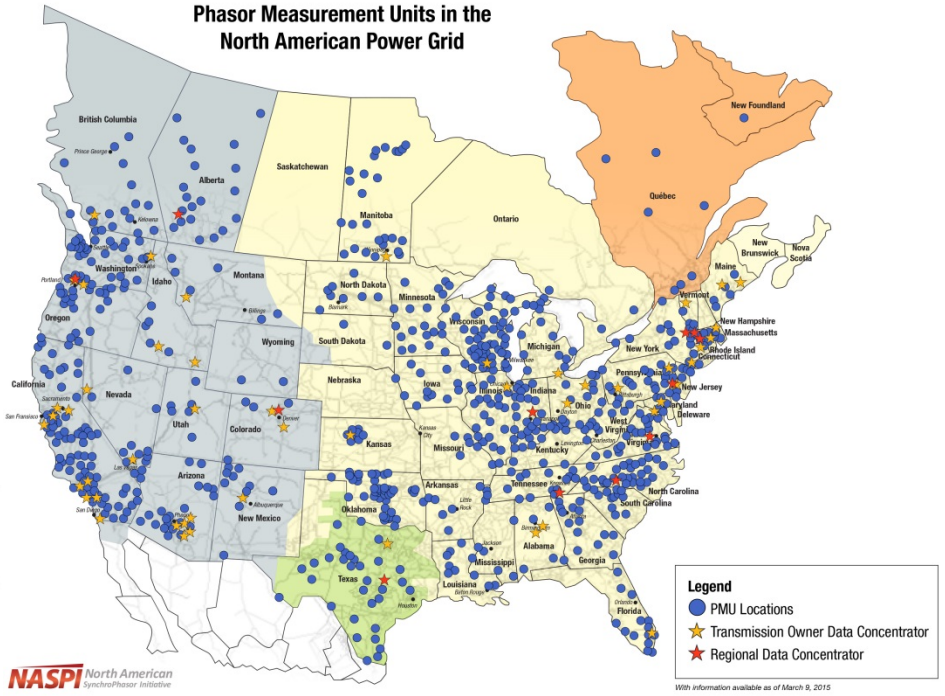
Deployment of a vast new phasor network is generating unprecedented real-time data

April 2007

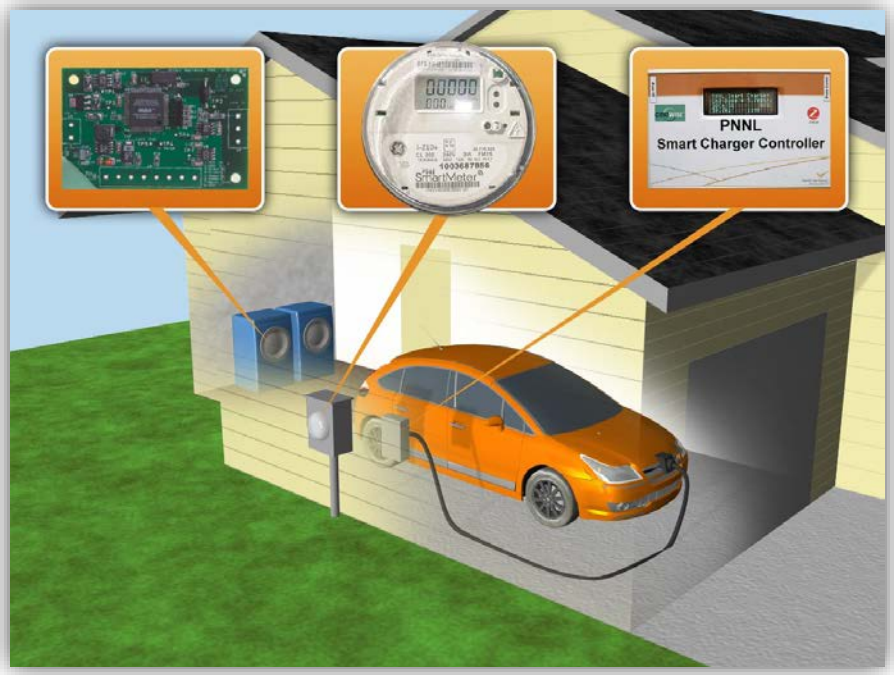


March 2015

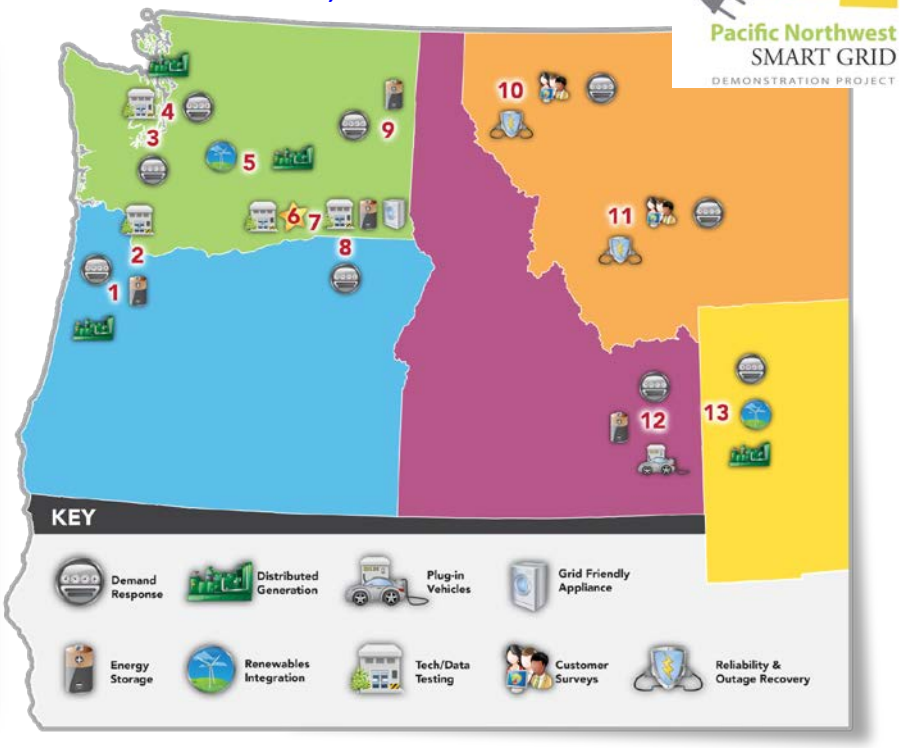


	Today – SCADA data	Emerging – phasor data	Improvement
Variety	voltage + current	+ phase angle, …	more information
Velocity	1 sample / 4 seconds	30-120 samples / second	~200x faster
Volume	8 terabytes / year	1.5 petabytes / year	~200x more data
Veracity	unseen ms-oscillations	oscillations seen at 10ms	greater accuracy

Smart devices and 2-way communication offer new opportunities, greater complexity



60,000 Smart Meters



Number of homes	100	1k+	10k+	100k+	500k+	1 Million
Compressed data size	2.5 GB	38.5 GB	366.3 GB	2.9 TB	13.6 TB	27.3 TB

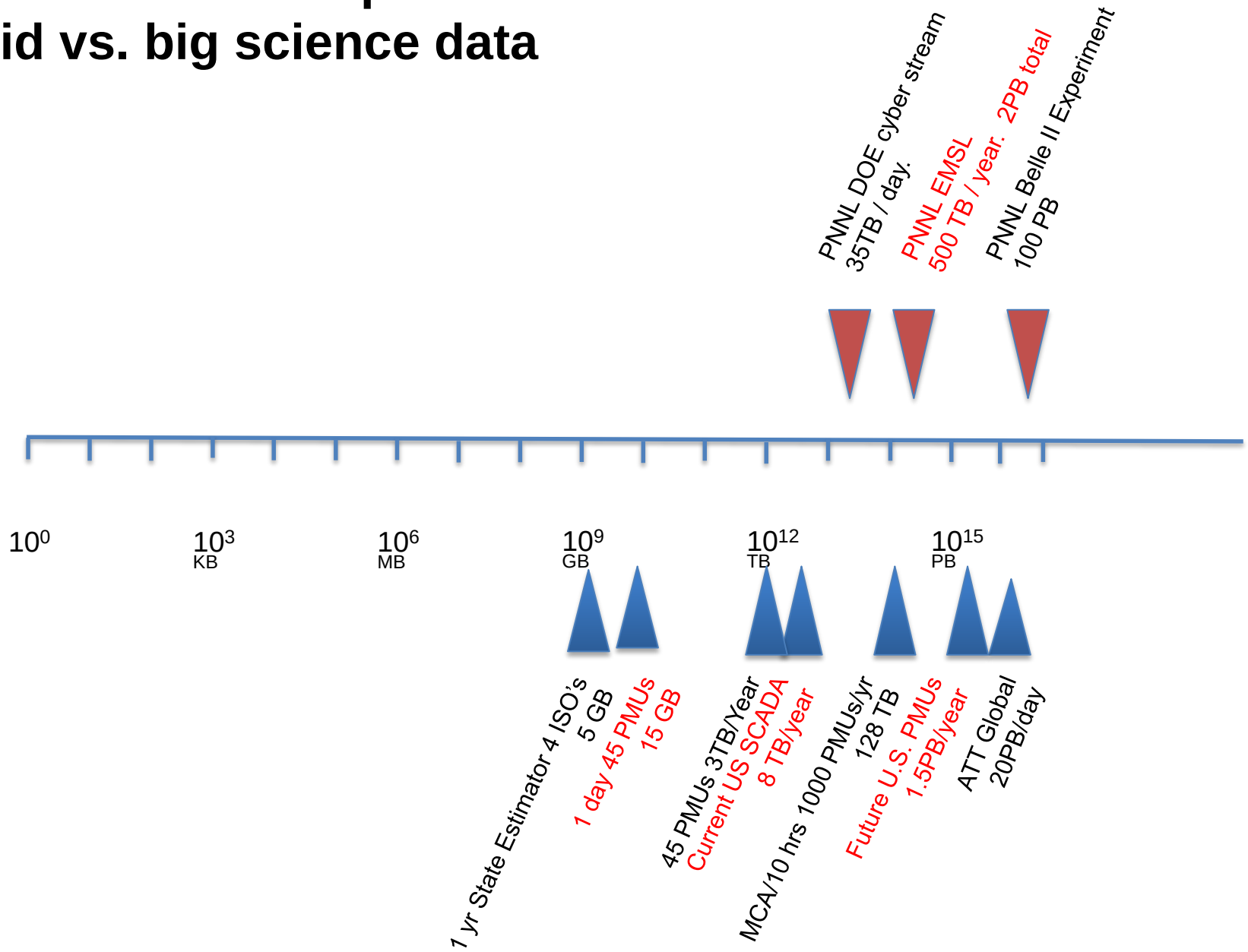
More diverse data add to the complexity

- Weather/climate data
  (e.g. PNNL ARM* Data)
  - 300 instruments, 2000 data streams 24/7
  - 500 GB/day rising to multiple TBs/day
  - Curating 20 years' data
- Market/business data
- Cyber/communication data
- Simulated data
  - Each contingency scenario generates 0.5M bytes data, adding up to TB scale

*ARM: Atmospheric Radiation Measurement

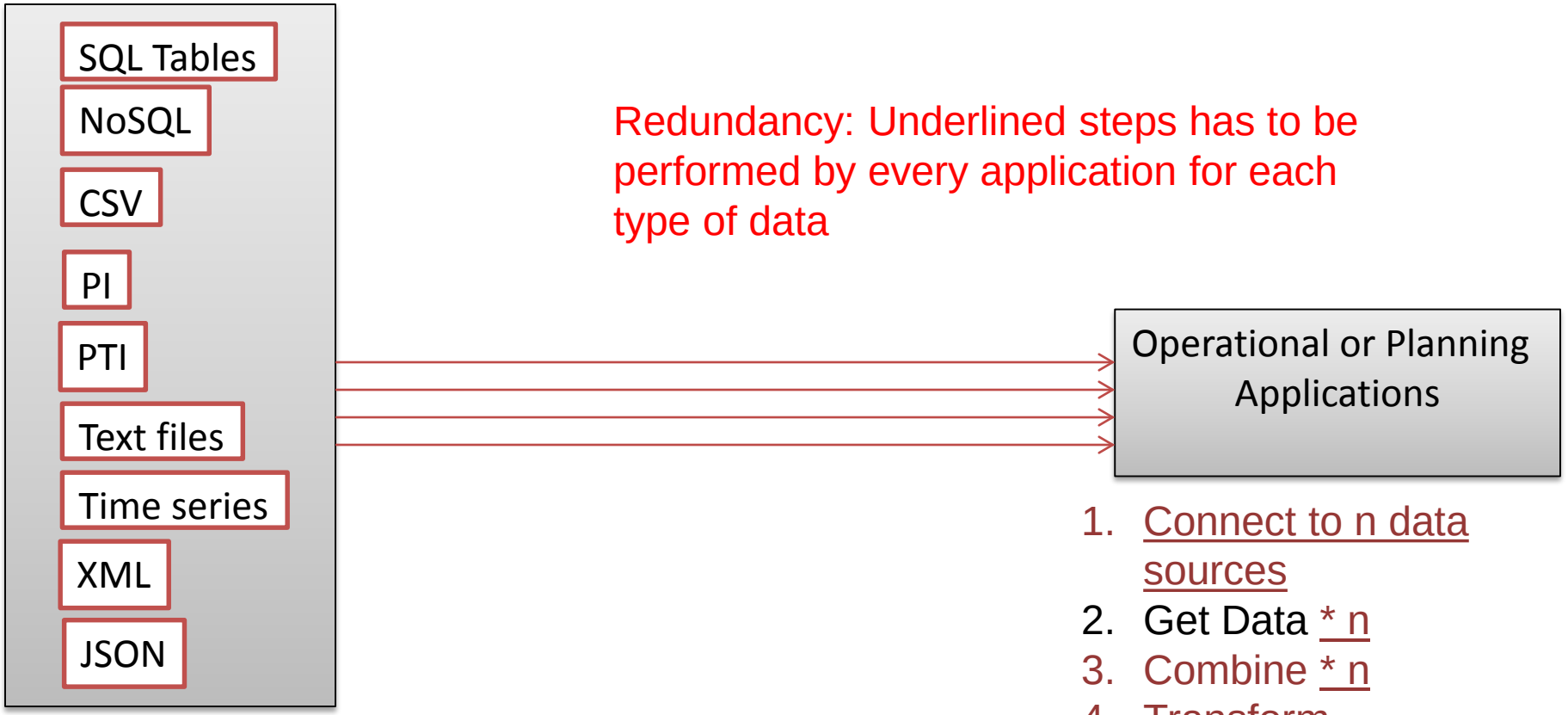
Contingency Analysis	Number of scenarios	Serial computing on 1 processor	Parallel computing on 512 processors	Parallel computing on 10,000 processors
WECC N-1 (full)	20,000	4 hours	~30 seconds 469x speed up	
WECC N-2 (partial)	153,600	26 hours	~3 minutes 492x speed up	~12 seconds 7877x speed up

Data volume comparison: Grid vs. big science data



Making data accessible is a big challenge

- Organizing and converting data to application specific formats



Redundancy: Underlined steps has to be performed by every application for each type of data

1. Connect to n data sources
2. Get Data * n
3. Combine * n
4. Transform
5. Analyze

Making data accessible is a big challenge

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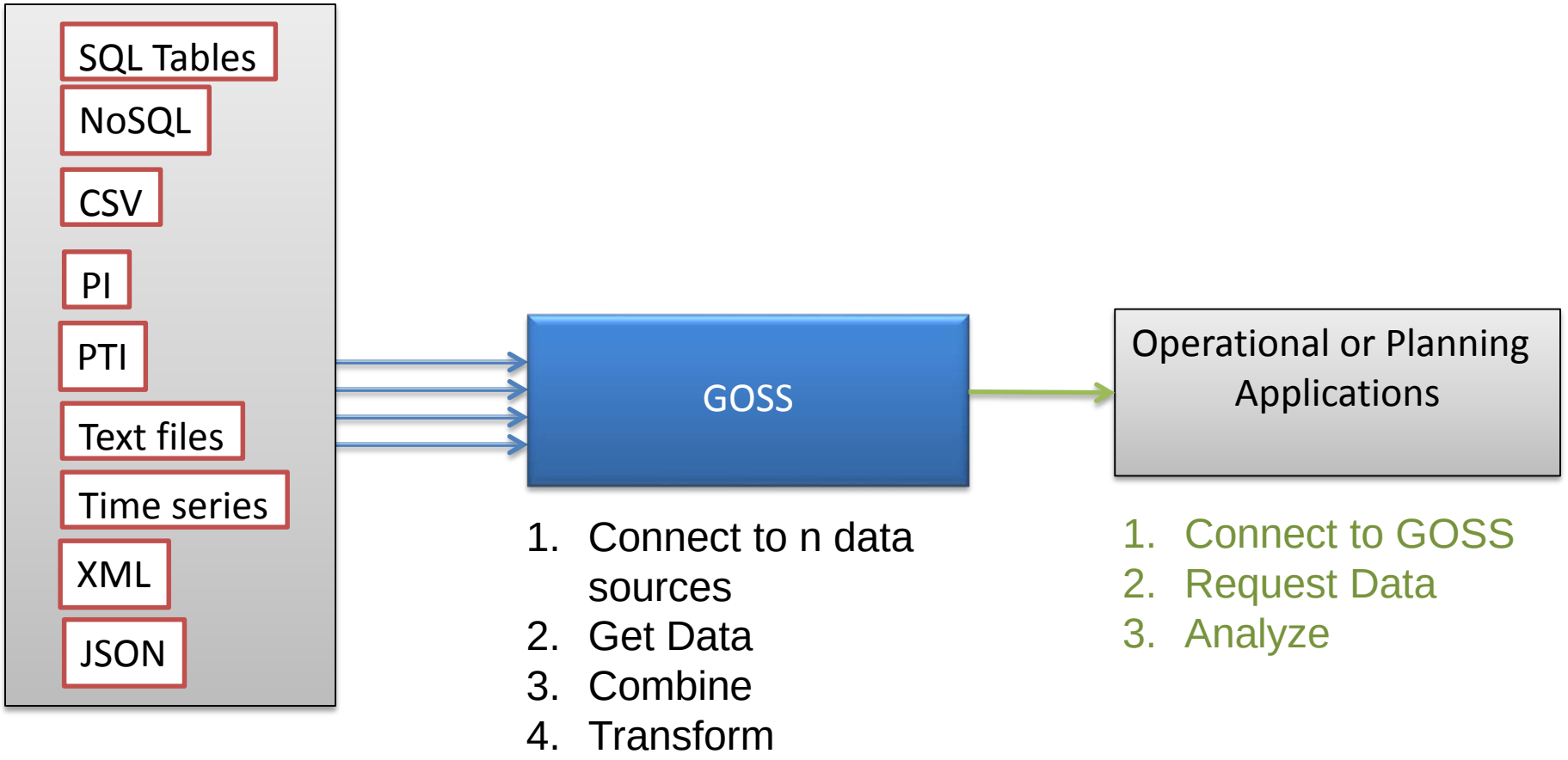
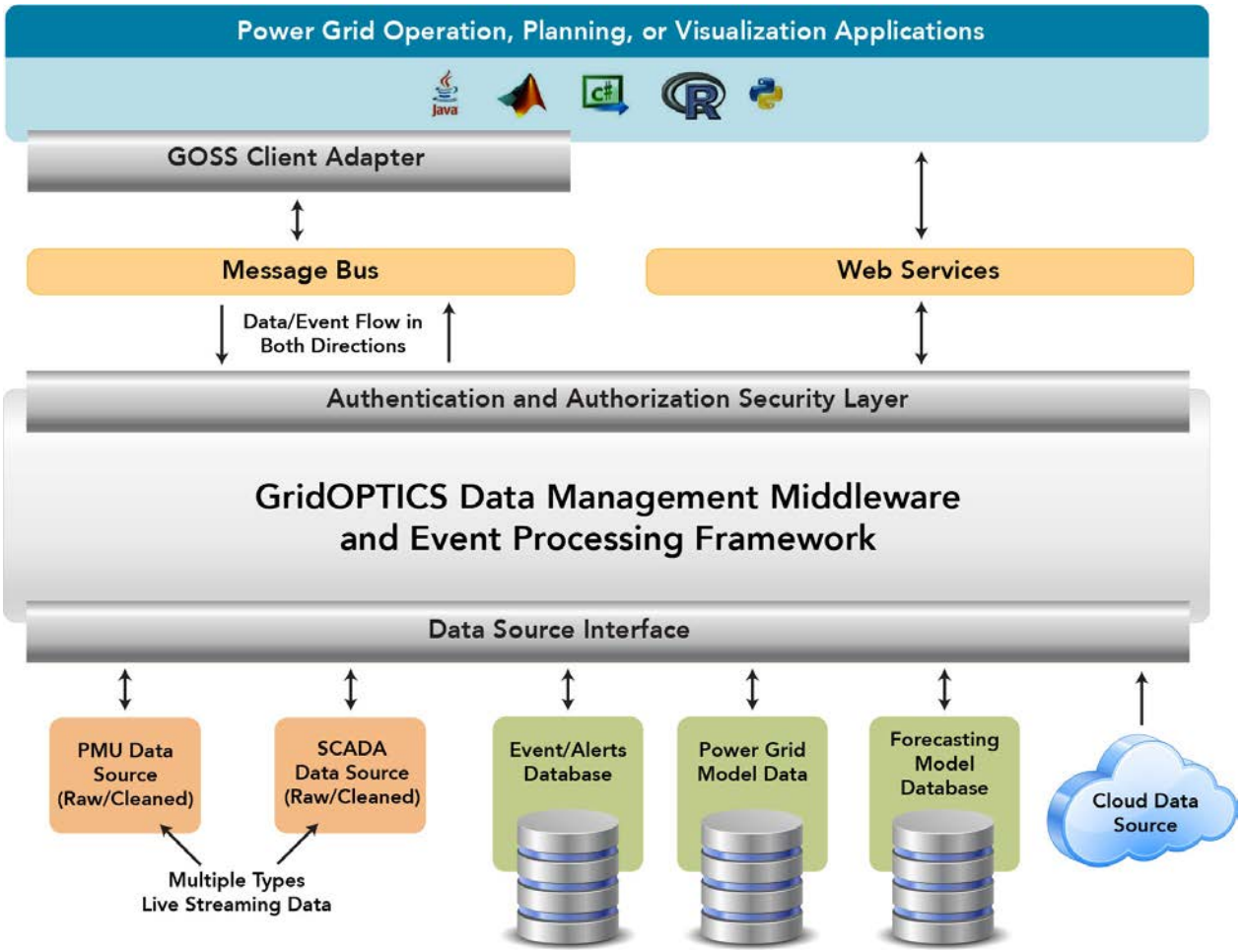
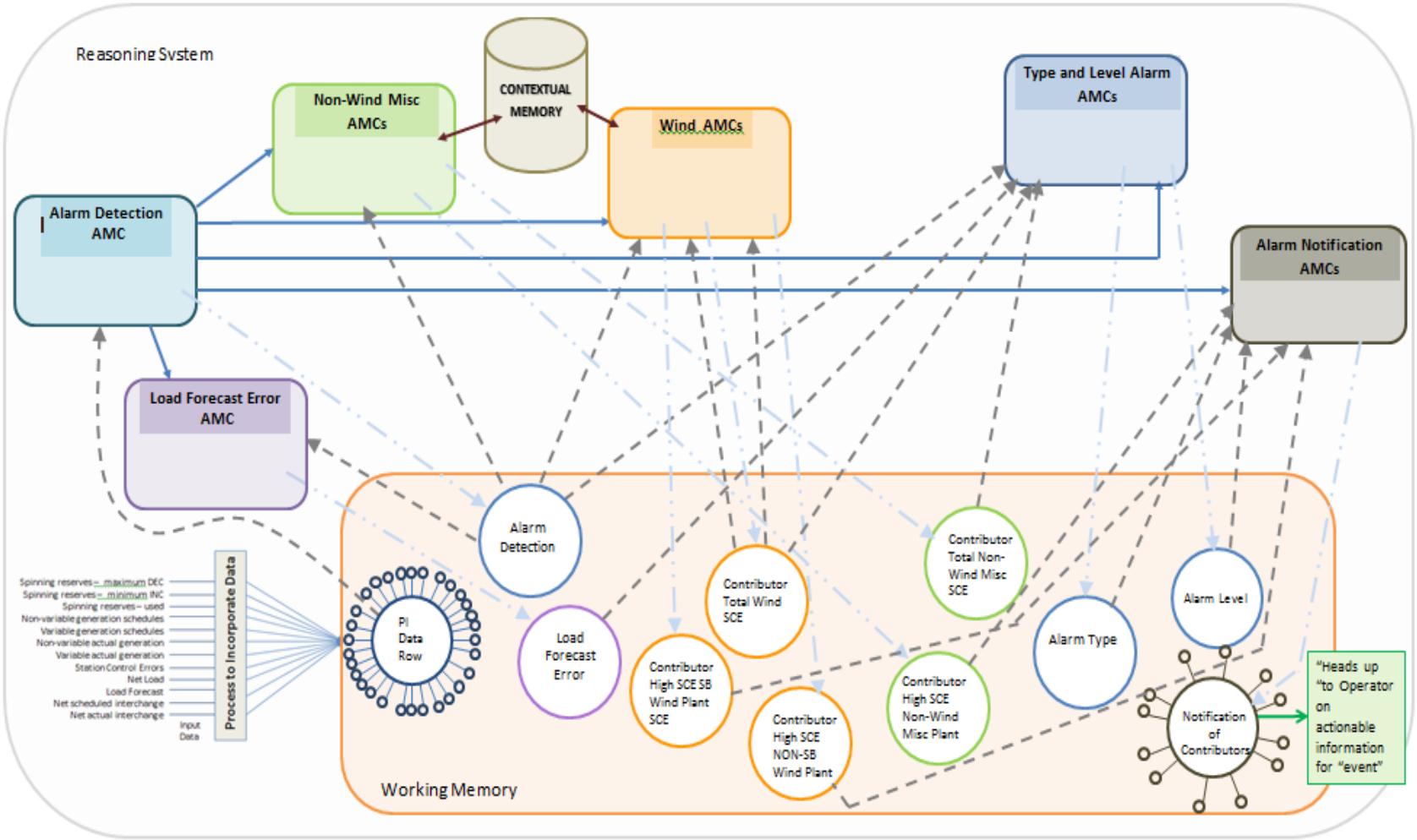


GOSS™: link data to applications

https://github.com/GridOPTICS/GOSS

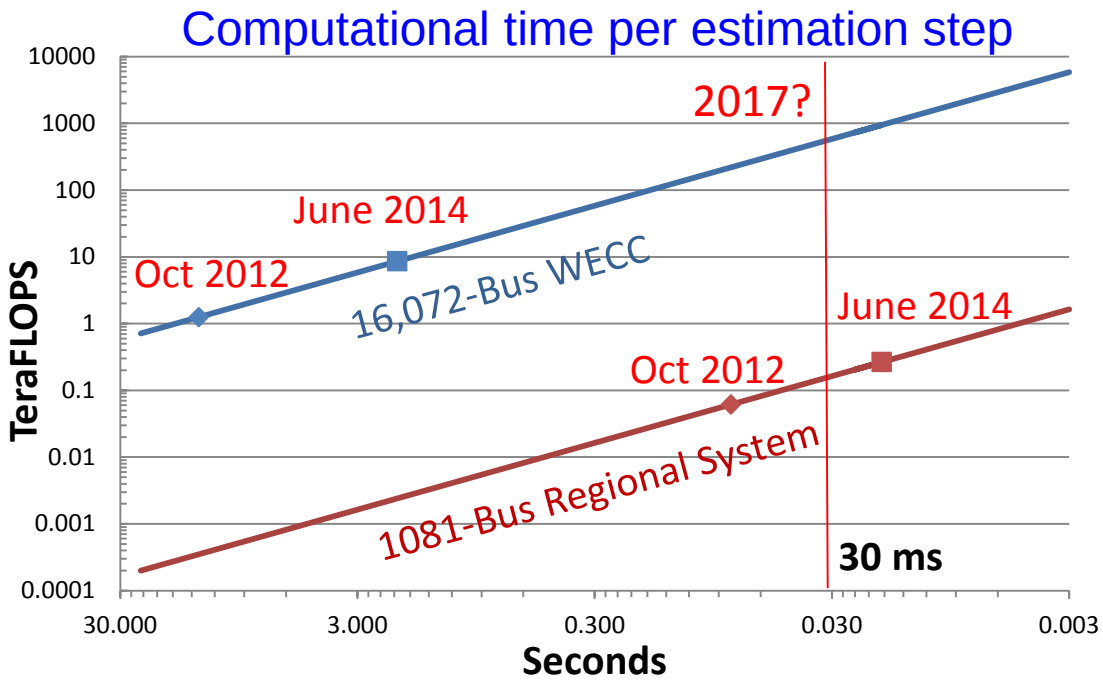


Multi-layer data-driven reasoning

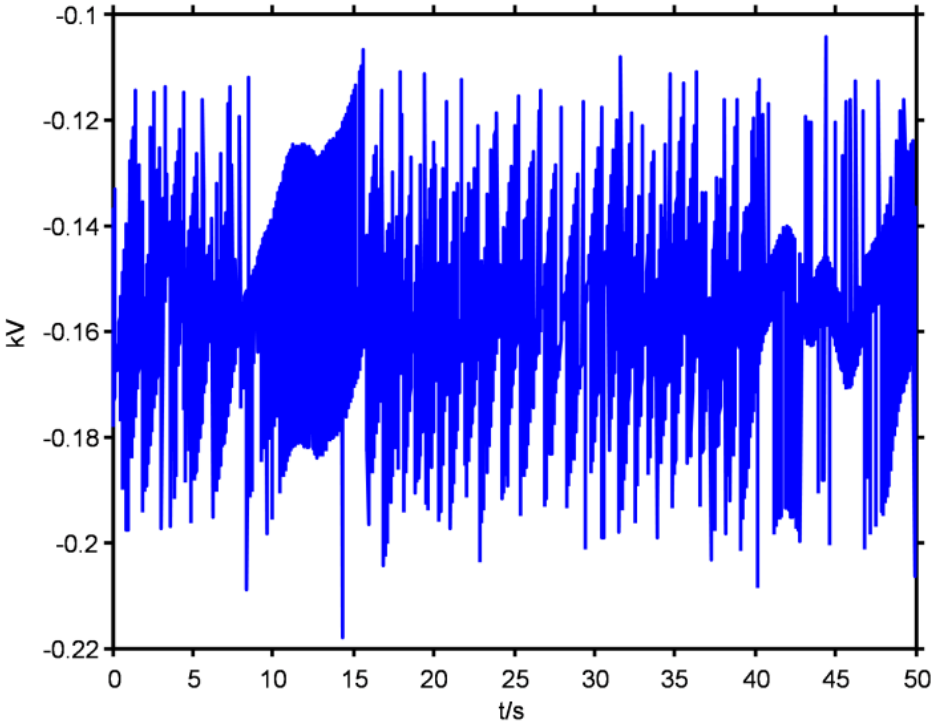


Computational challenges in keeping up with data cycles

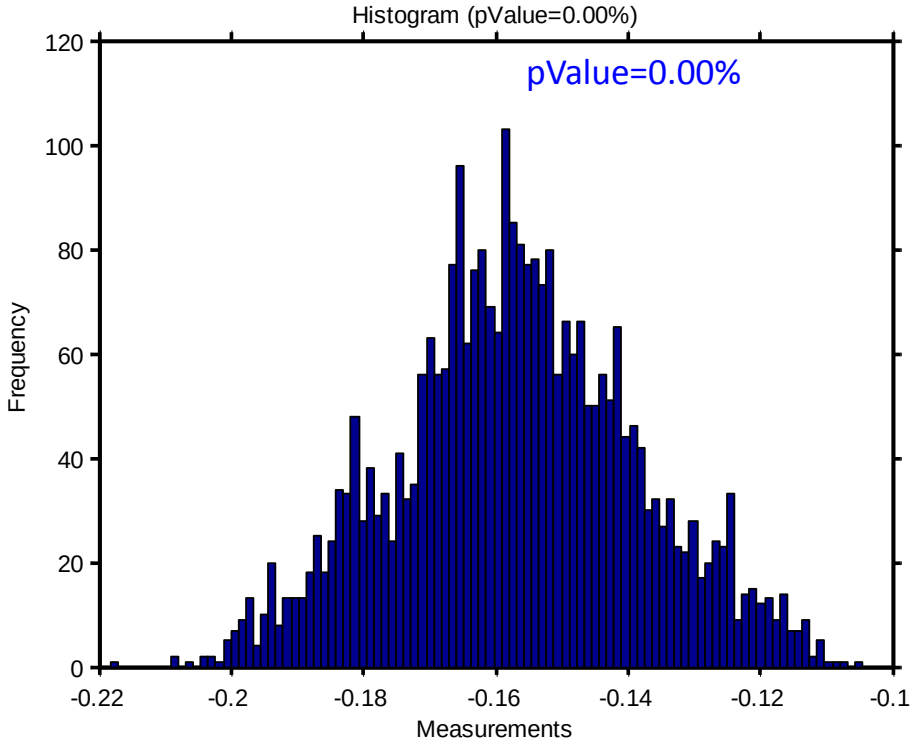
- Current dynamic state estimation codes scale to ~1,000 cores
- Current computational performance meets the real-time requirement for regional systems
- Challenge: real-time performance (30 milliseconds) for interconnection-scale systems.



Mathematical challenges in handling non-Gaussian noise in power grid measurement

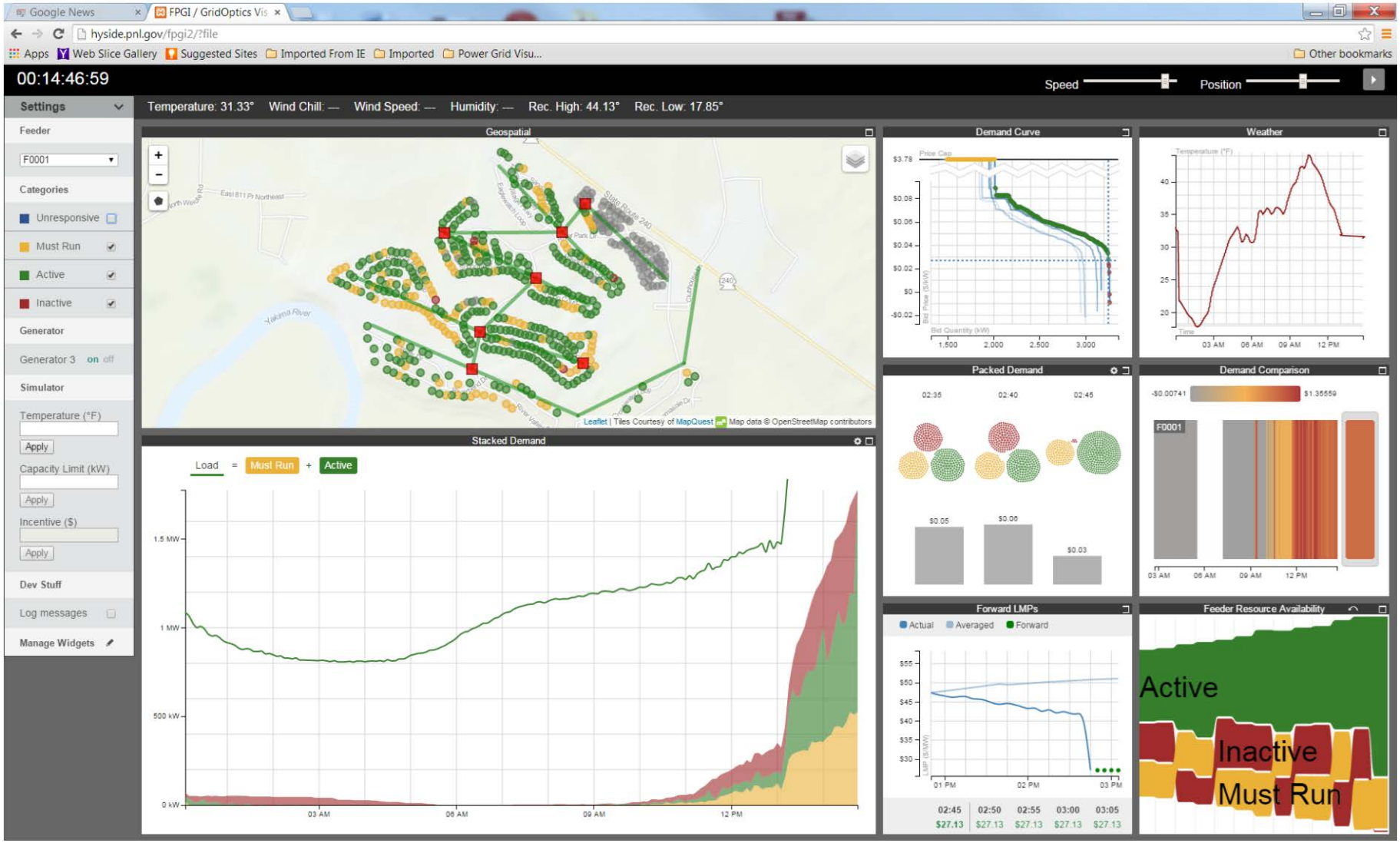


Noise extracted from PMU



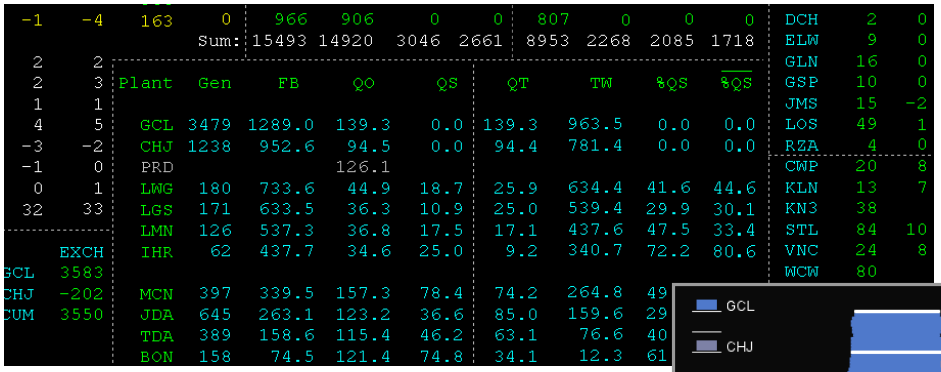
Noise property analysis

Advanced modular visualization for easy exploration of large-scale data



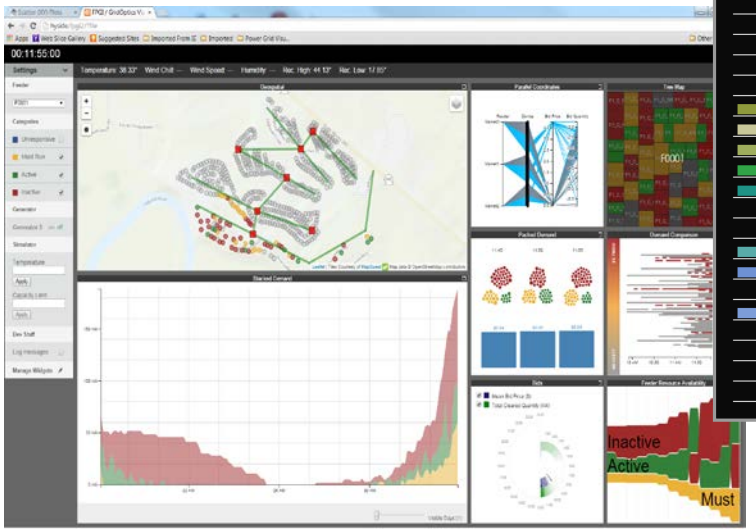
Advanced visualization for improving hydro state awareness (Hydromap)

- Modernize displays for hydro planning and operations
- Develop new, novel visualization techniques and paradigms for analyzing dynamic data
- Develop modular framework for deploying and integrating new data visualizations

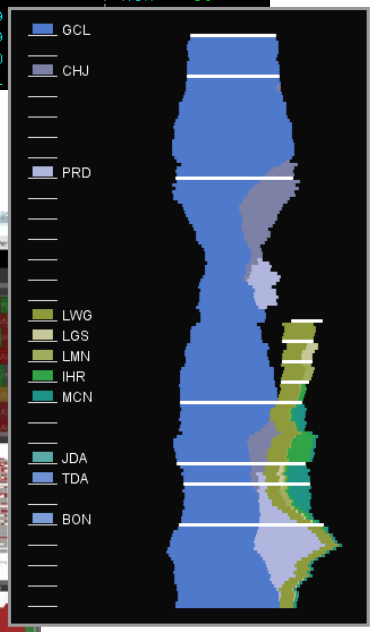


-1	-4	163	0		966	906	0	0		807	0	0	0		DCH	2	0
			Sum:		15493	14920	3046	2661		8953	2268	2085	1718		ELW	9	0
2	2														GLN	16	0
2	3	Plant	Gen		FB	QO	QS		QT	TW	%QS	%QS			GSP	10	0
1	1														JMS	15	-2
4	5	GCL	3479		1289.0	139.3	0.0		139.3	963.5	0.0	0.0			LOS	49	1
-3	-2	CHJ	1238		952.6	94.5	0.0		94.4	781.4	0.0	0.0			RZA	4	0
-1	0	PRD				126.1									CWP	20	8
0	1	LWG	180		733.6	44.9	18.7		25.9	634.4	41.6	44.6			KLN	13	7
32	33	LGS	171		633.5	36.3	10.9		25.0	539.4	29.9	30.1			KN3	38	
		LMN	126		537.3	36.8	17.5		17.1	437.6	47.5	33.4			STL	84	10
	EXCH	IHR	62		437.7	34.6	25.0		9.2	340.7	72.2	80.6			VNC	24	8
GCL	3583														WCW	80	
CHJ	-202	MCN	397		339.5	157.3	78.4		74.2	264.8	49						
CUM	3550	JDA	645		263.1	123.2	36.6		85.0	159.6	29						
		TDA	389		158.6	115.4	46.2		63.1	76.6	40						
		BON	158		74.5	121.4	74.8		34.1	12.3	61						

Current data display in need of modernization

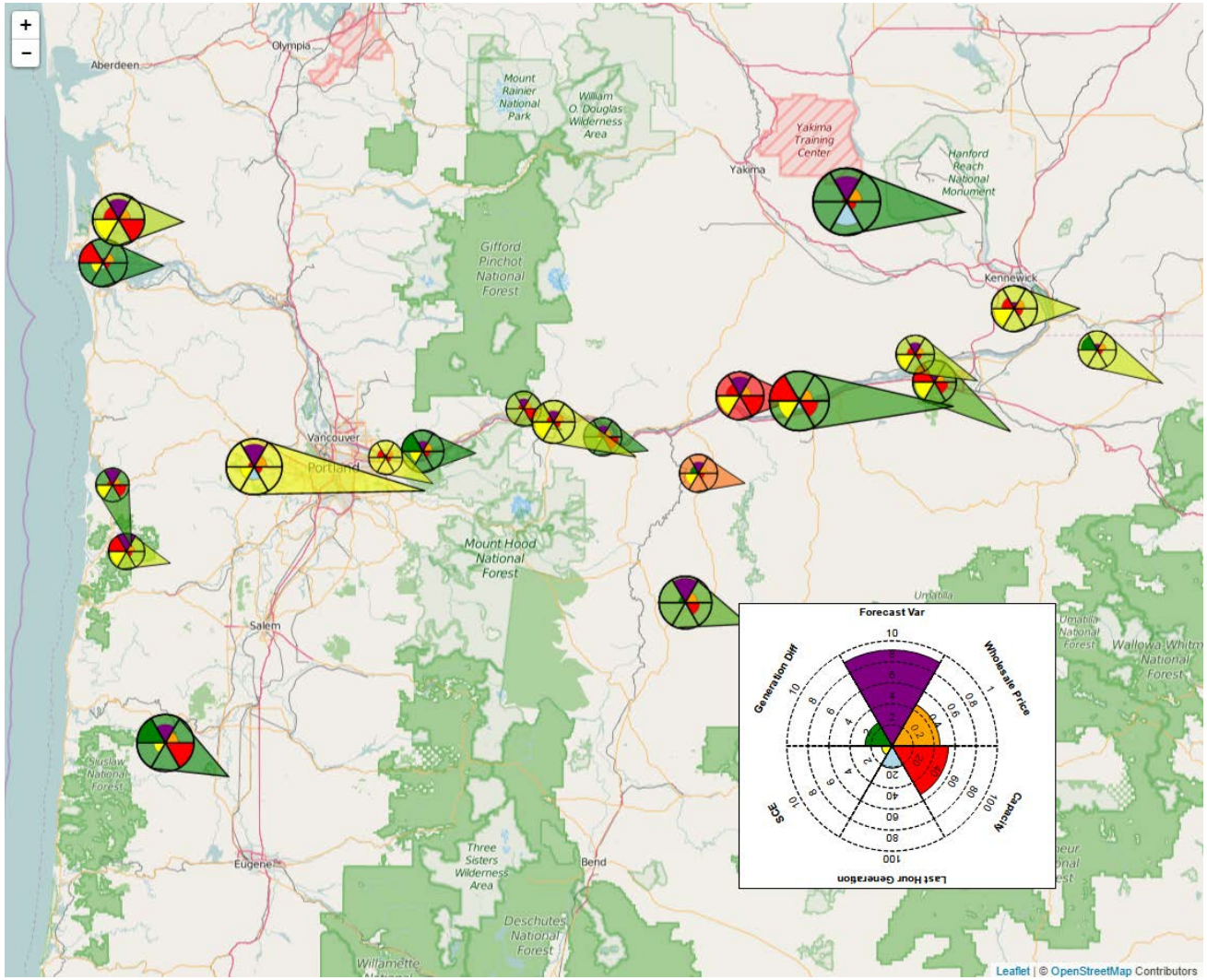


Example modular visualization framework



Interactive hydro map as a new visualization paradigm

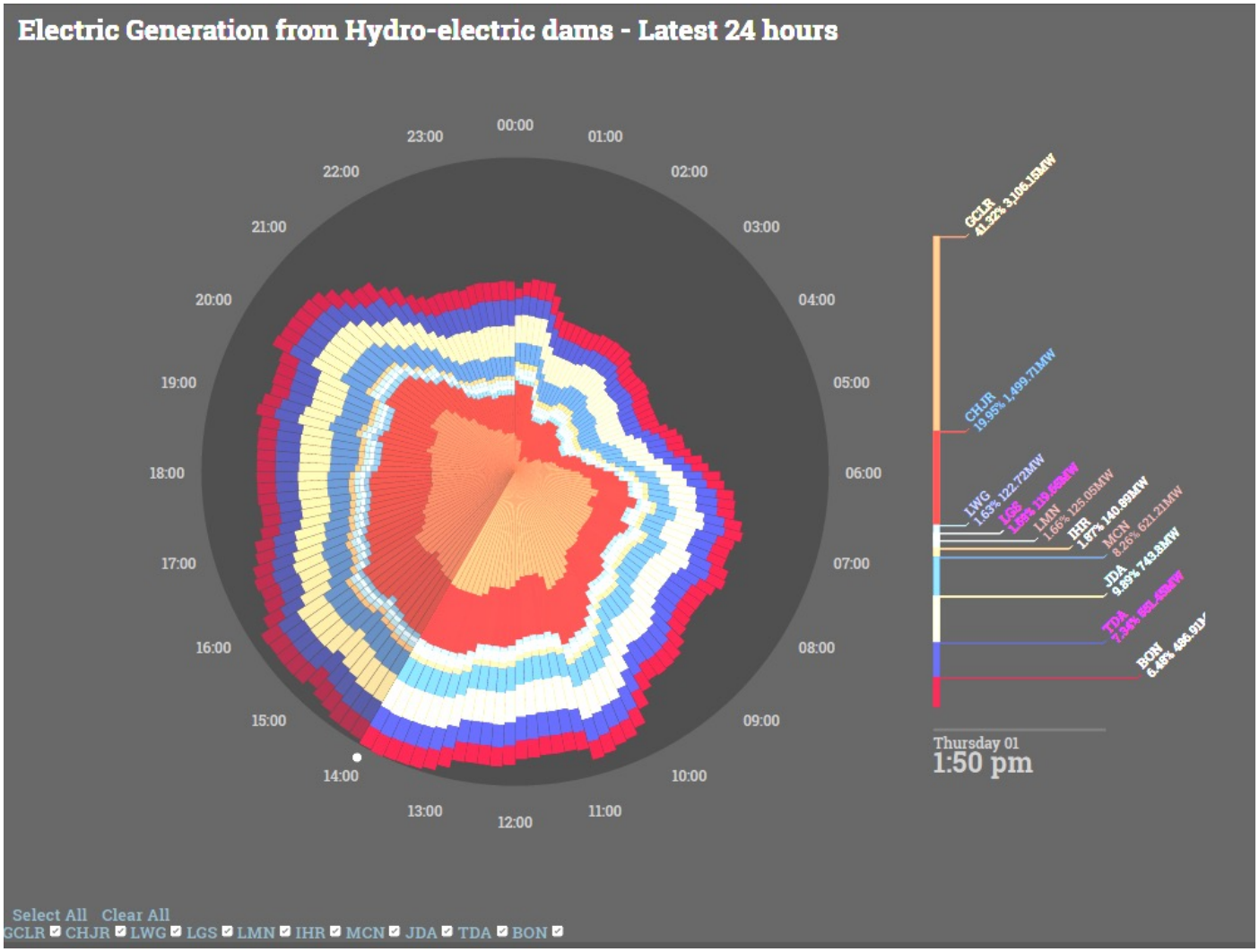
Multi-dimensional wind visualization (Glyphs)



Wind Visualization/Wind Forecast Visualization

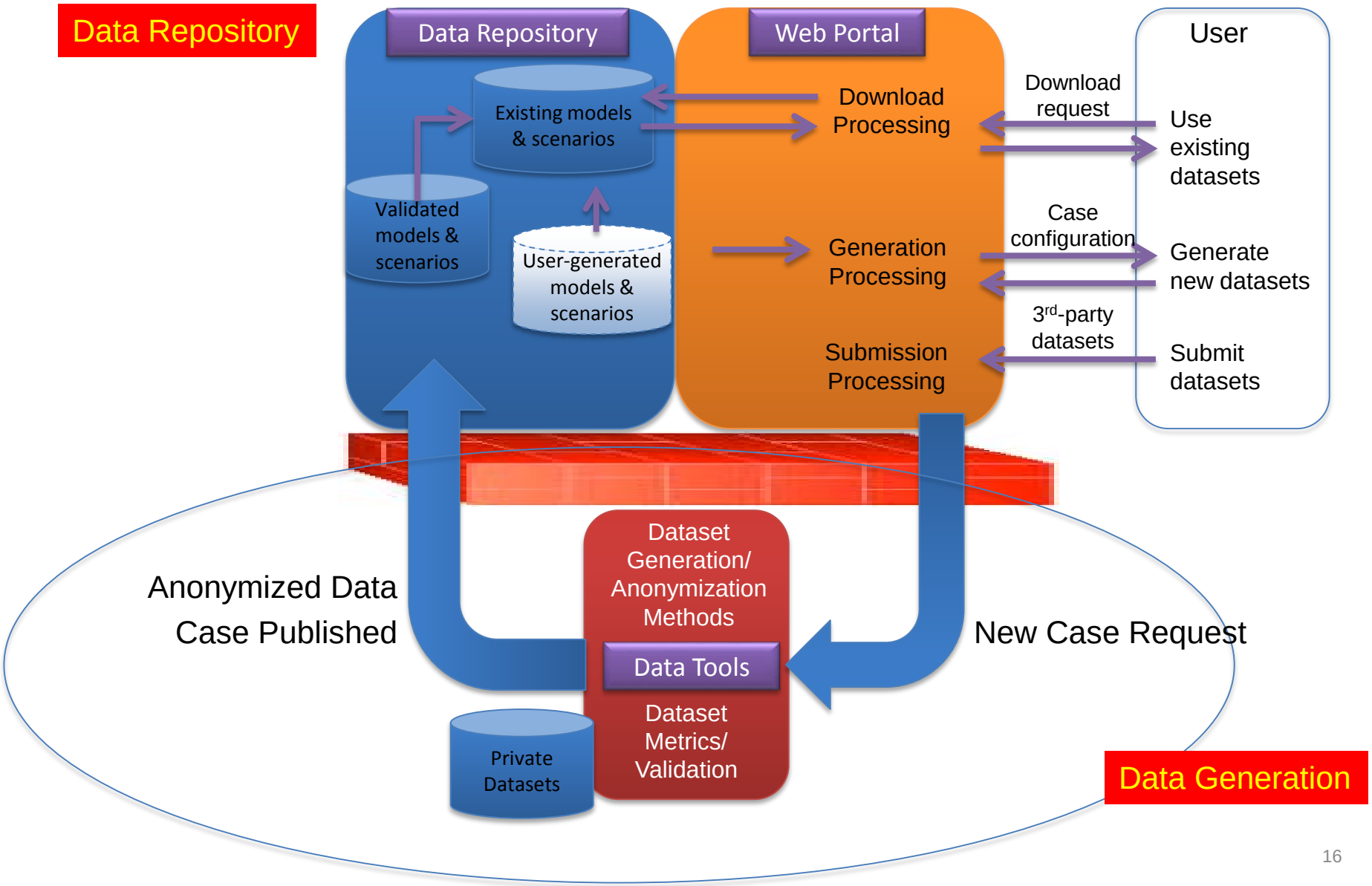
- Wind visualization showing multi-dimensional data in glyphs
  - Wind speed (length of tail)
  - Wind direction (angle of tail)
  - Generation (size of head)
  - Uncertainty (color of tail)
  - Forecast variability
  - Wholesale price
  - Capacity
  - Last hour generation
  - SCE error code
  - Generation difference from forecast

Historical hydro view using radial visualization



- Compares hydropower generation across different projects along Columbia and Snake rivers
- Alternative view shows generation across different sources such as hydropower, nuclear, renewables, and miscellaneous sources

Data repository for data hosting (ARPA-E funded)



Summary

- Grid data complexity is increasing with big volumes, diverse types, and various attributes.
- Such complexity poses significant challenges in data access, transformation, analytics, sense making.
- Math, computing and visualization technologies need to be developed to meet these challenges.
  - GOSS as a big data platform.
  - Multi-layer data reasoning and high performance computing.
  - Modular visualization as interface for information presentation.

Acknowledgement

- PNNL Researchers: *(Data and Computing)* Bora Akyol, Poorva Sharma, Yin Jian, Steve Elbert, Shuangshuang Jin, Bruce Palmer, George Chin; *(Power Engineering)* Ruisheng Diao, Yousu Chen, Mark Rice, Shaobu Wang, Karen Studarus
- Former PNNL Researchers: Terrence Critchlow, Ning Zhou, Ning Lu, Pengwei Du

Questions?

Further Information:
GridOPTICS: http://gridoptics.pnnl.gov/
GridOPTICS™ Software System (GOSS): https://github.com/GridOPTICS/GOSS
Interactive Visualization and Demo Center: http://vis.pnnl.gov/

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