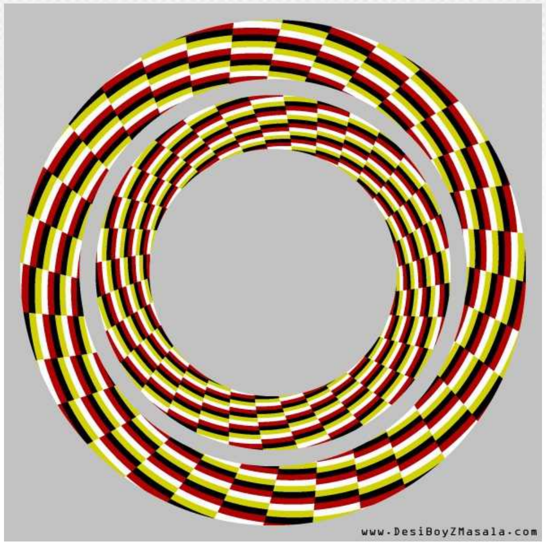
Smart Uses of Data in Smart Grids

Mladen Kezunovic
Texas A&M University, USA

Keynote Lecture
ISGCE 2013
Jeju Island, Korea
July 8, 2013

Outline



- Background
- Data Properties
- Translational Knowledge
- Implementation
- Q/A

Data "Explosion"

The Business value of data

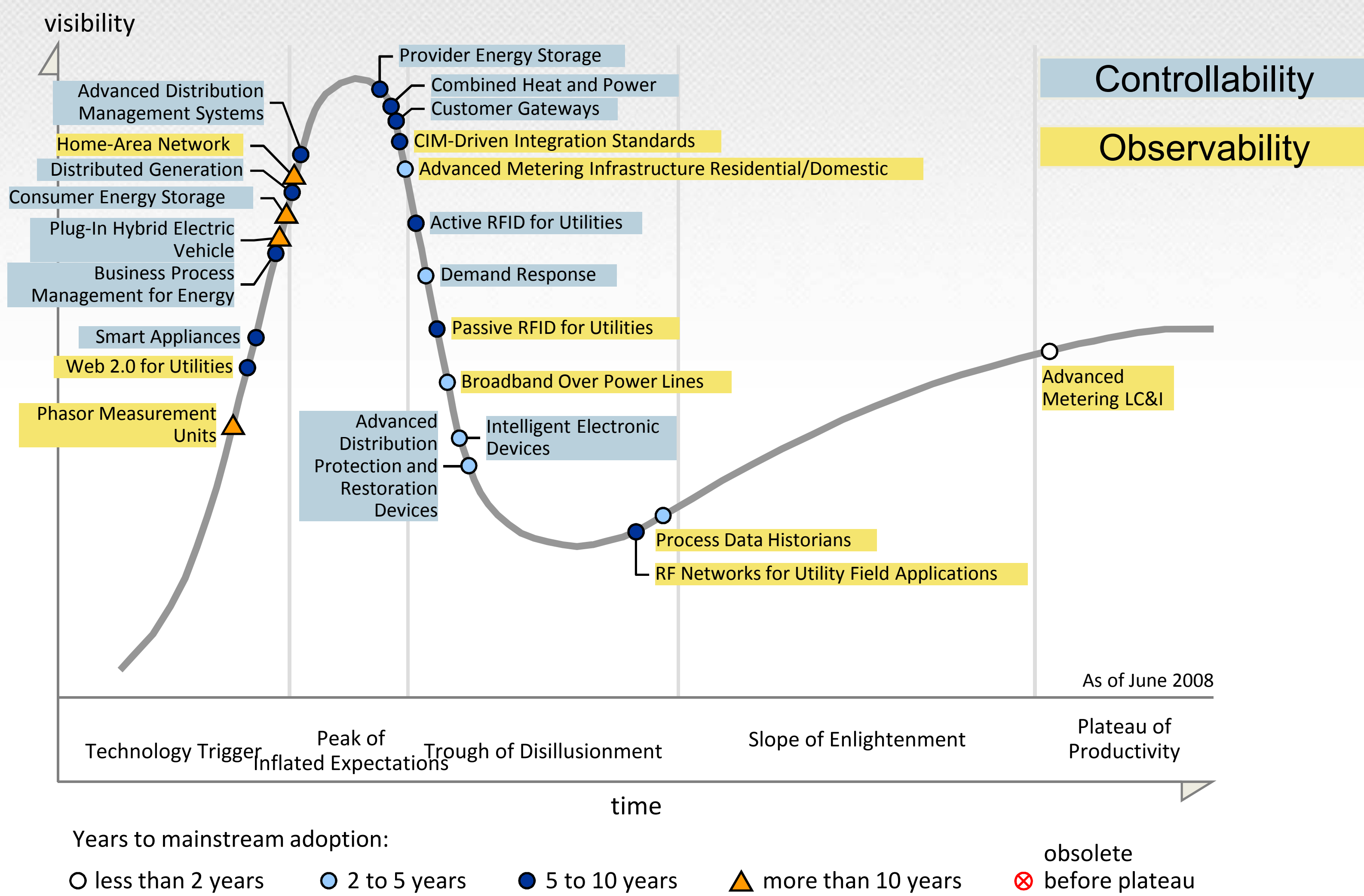
Integrative view

Technology landscape

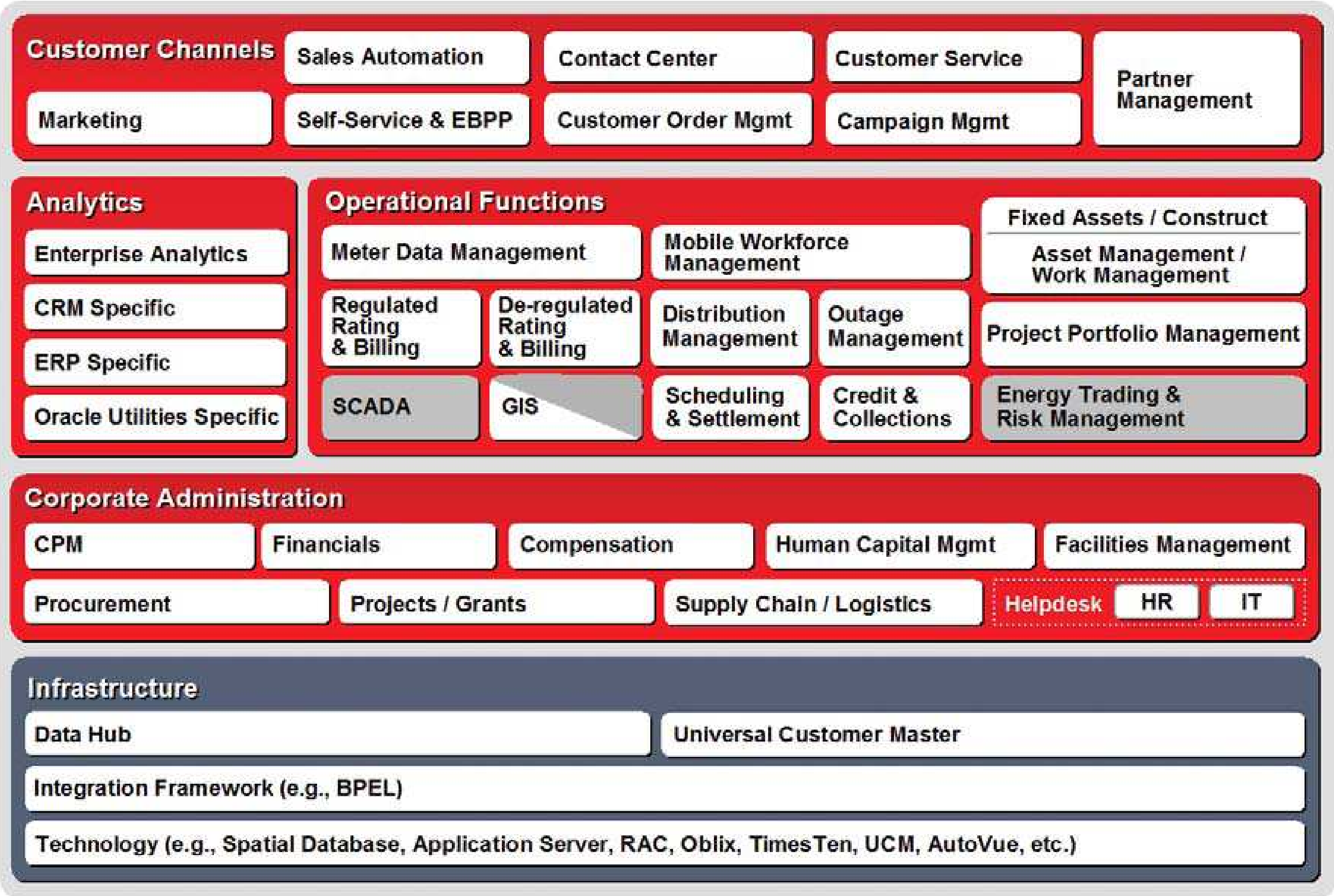
BACKGROUND

M. Kezunović, J. McCalley, T.J. Overbye, " Smart grids and beyond: Achieving the Potential of Electricity Systems," Invited Paper, *IEEE Proceedings, Vol.100, Special Centennial Issue, pp.1329-1341, May 13 2012.*

Intelligent Grid Technology Hype Cycle



The business value of data



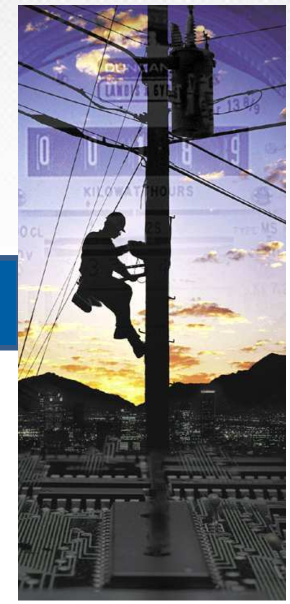
Integrative view

Data Technologies

Business Cases

Integrating smart, wise, intelligent, future, modern, perfect, empowered

Application Solutions



10 IT technologies in 2013

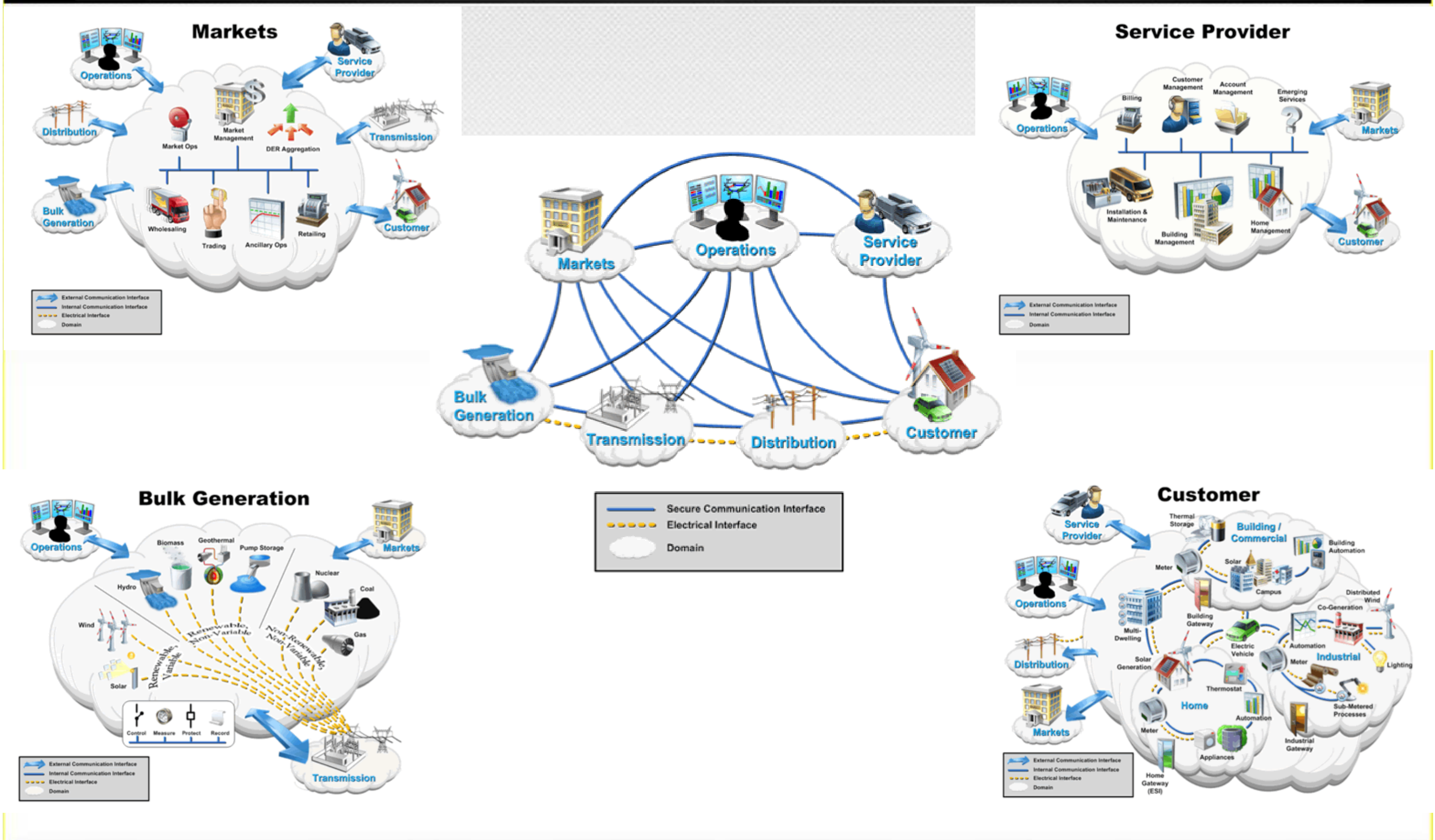
- Mobile devices
- Mobile Apps and HTML5
- Personal Cloud
- The Internet of Things
- Hybrid IT and Cloud Computing
- Strategic Big Data
- Actionable Analytics
- Mainstream In-Memory Computing (IMC)
- Integrated Ecosystems
- Enterprise App Stores

Future Electricity Grid
Grid Events
Operating States
Temporal and Spatial Aspects
Data Types

DATA PROPERTIES

M. Kezunović, A. Abur, "Merging the Temporal and Spatial Aspects of Data and Information for Improved Power System Monitoring Applications," *IEEE Proceedings,* Vol. 9, Issue 11, pp 1909-1919, 2005.

Future Electricity Grid

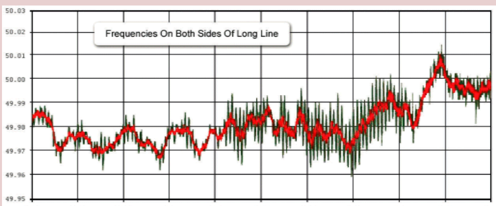


Smart Grid Center

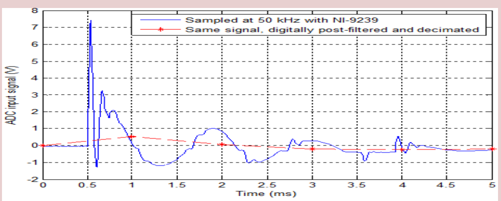
Grid Events

TEXAS A&M ENGINEERING TEES

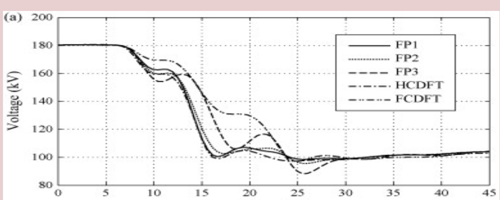
Power System States



Steady State



Transients



Dynamics

Contacts Switching Causing Changes

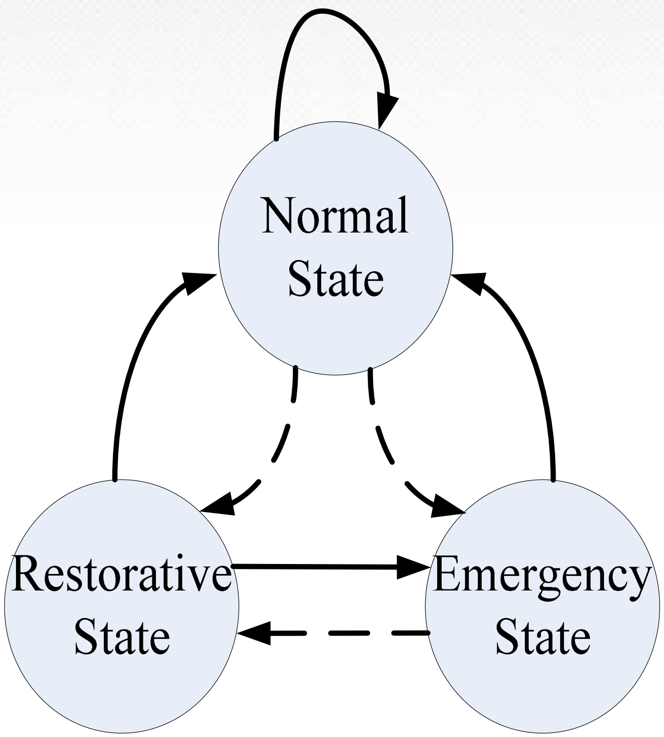
- Circuit Breaker Switching
- Auto-reclosing Sequence
- Switching by Various Controllers (FACT, etc.)

Models Reflecting Various States

- Power flow and State estimation
- Short circuit calculation
- Time domain EMTP
- Stability (transient, voltage, small signal, etc)

Operating States

System and Market Operating States



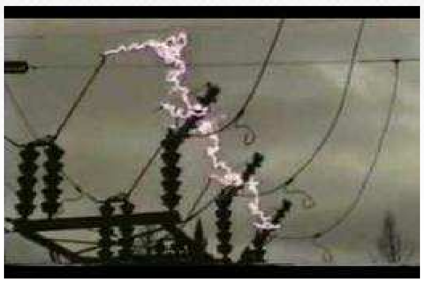
Type	Configuration	Market Parameters
Normal	All MPs active Complete config.	Within Limits
Emergency	All MPs active Complete config.	Parameter(s) violate the limits
Restorative	Structure incomplete	Within limits

***MPs (Market Participants) include generator companies, transmission owners, load serving entities and other non-asset owners such as energy traders.**

Time and space

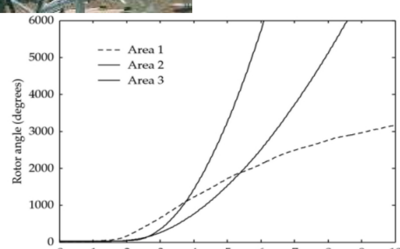
Local events sensed by substation equipment

Faults



Changes in switching state

Out of step (between equivalents)

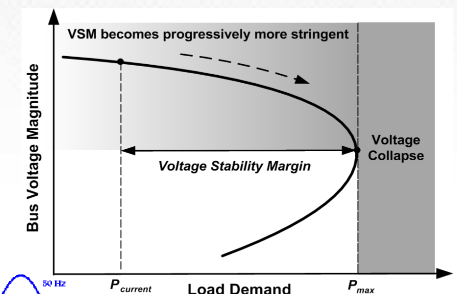


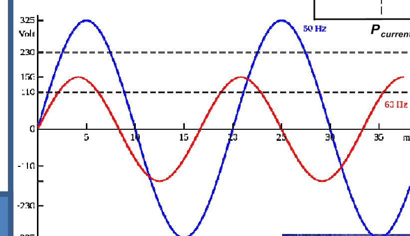
Correlating space and time matters

Models to data match

Global events sensed by wide-area measurement system

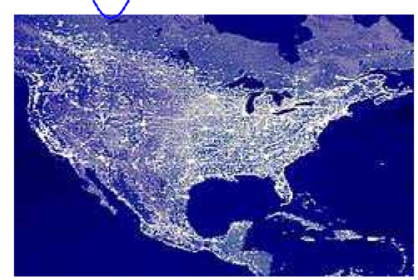
Stability (various types)



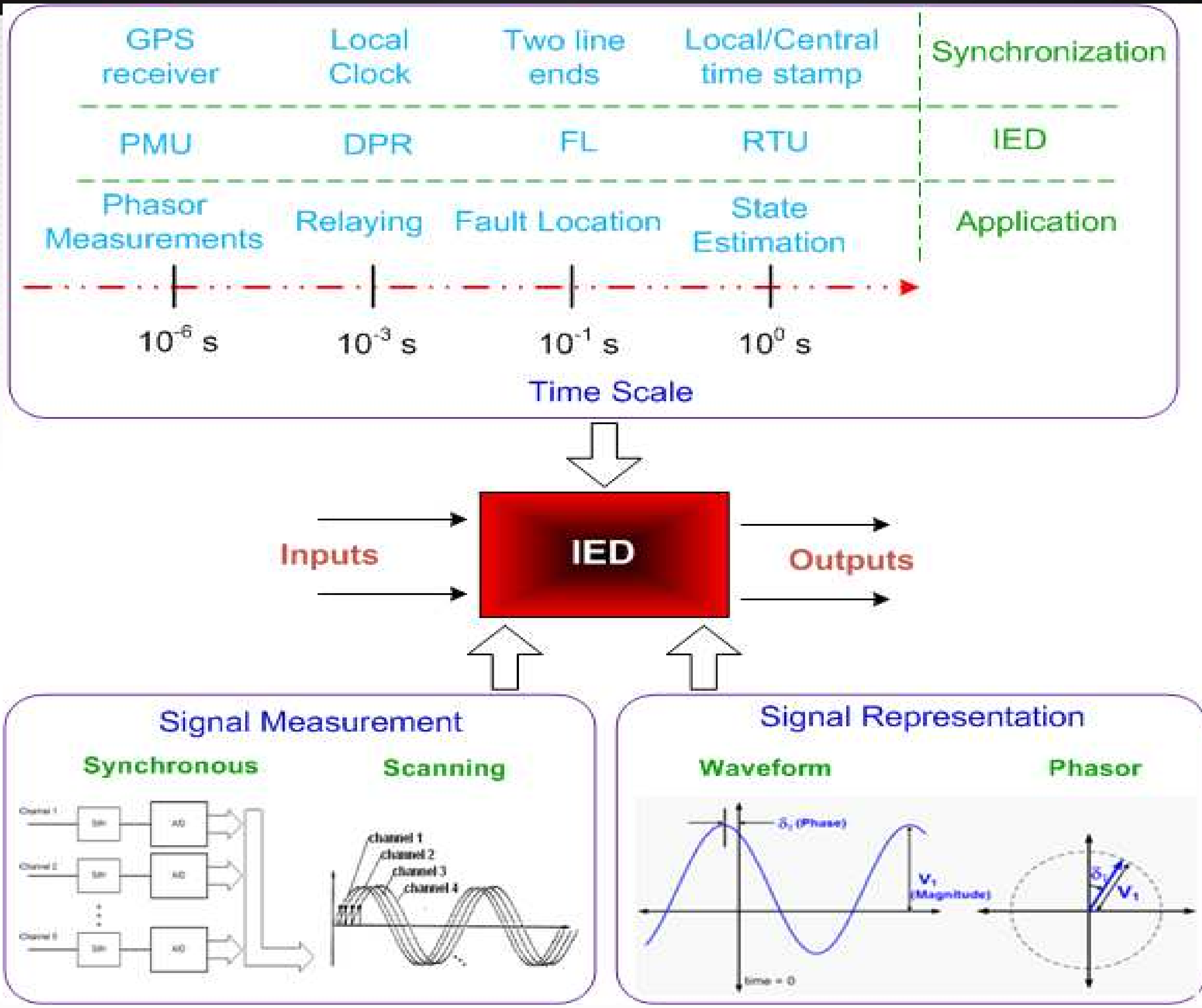


Frequency and voltage

Cascading events

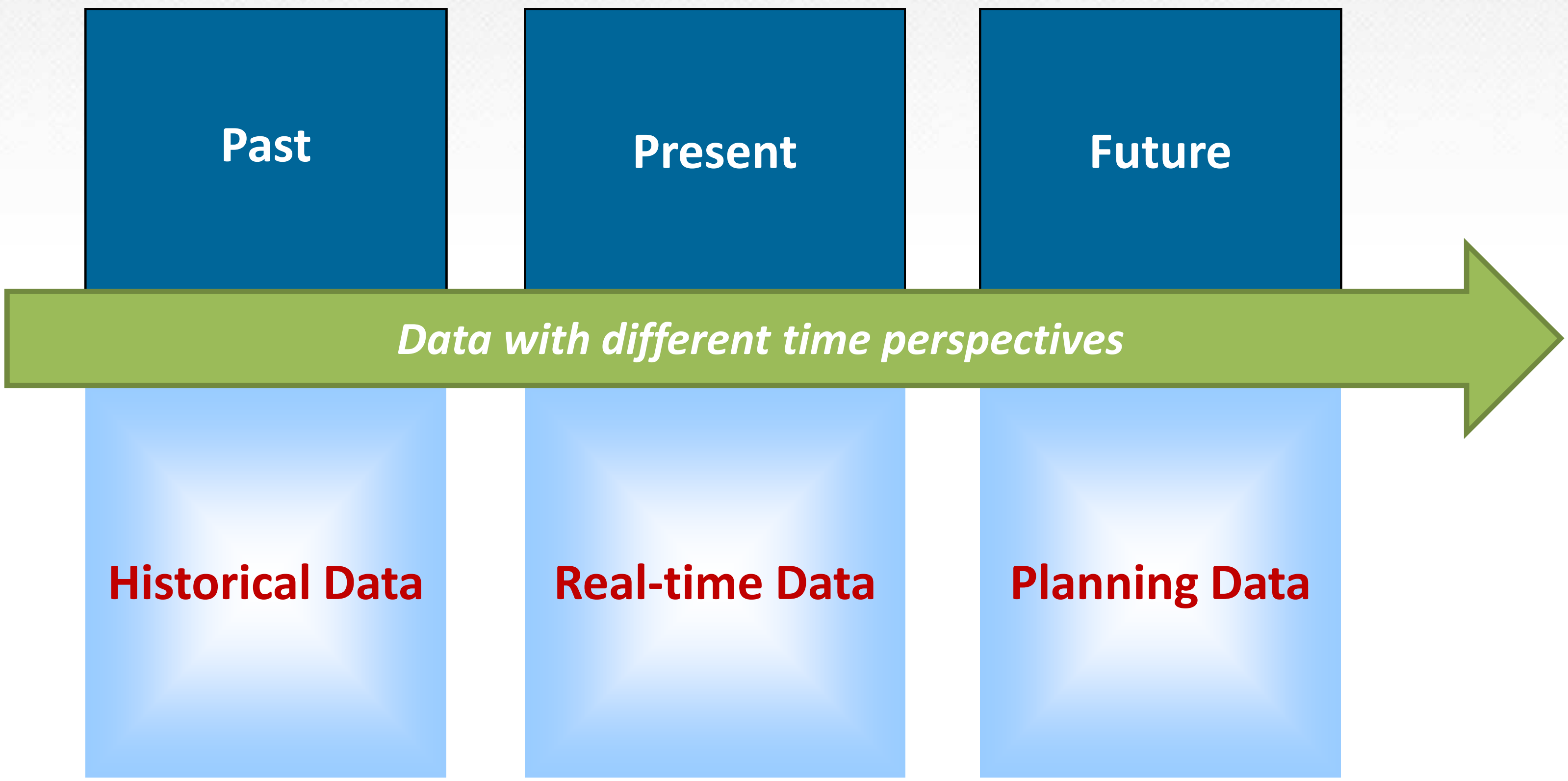


Temporal Issues



Temporal Issues

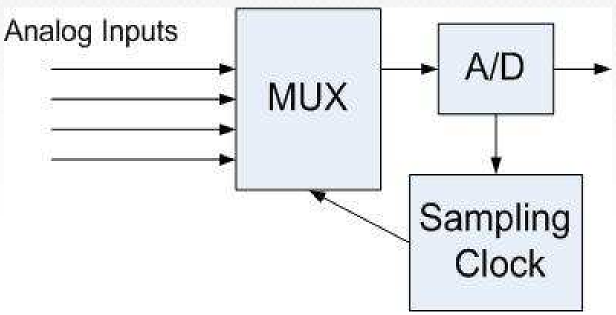
Data with different time perspectives



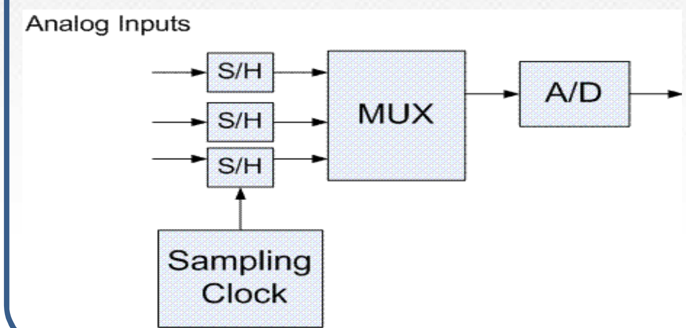
Temporal Issues

Difference between time correlation

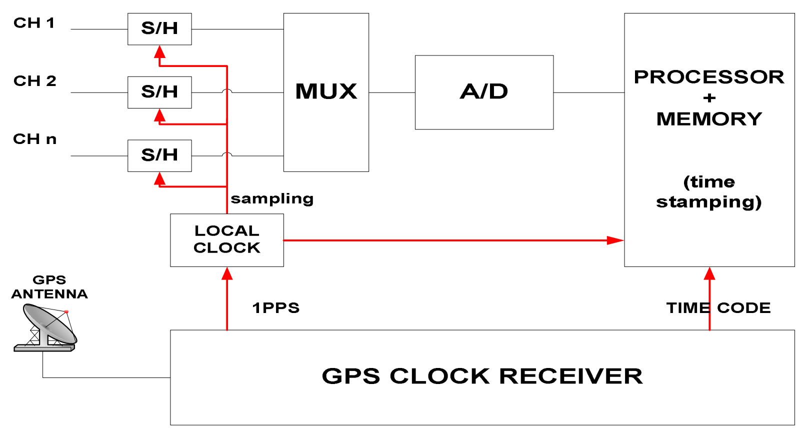
Scanning (relative)



Synchronous Sampling

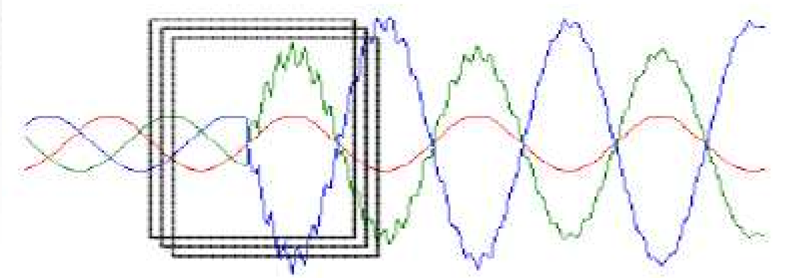


Time Stamping (absolute)

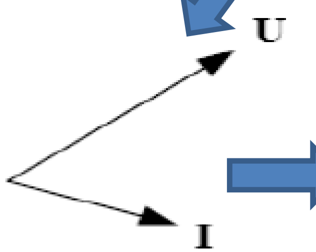


Temporal Issues

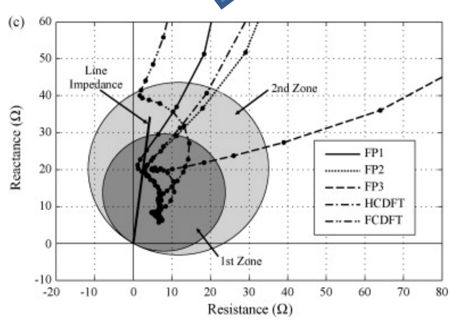
Phasors in Relaying (triggered sampling)



Measurements through moving data window

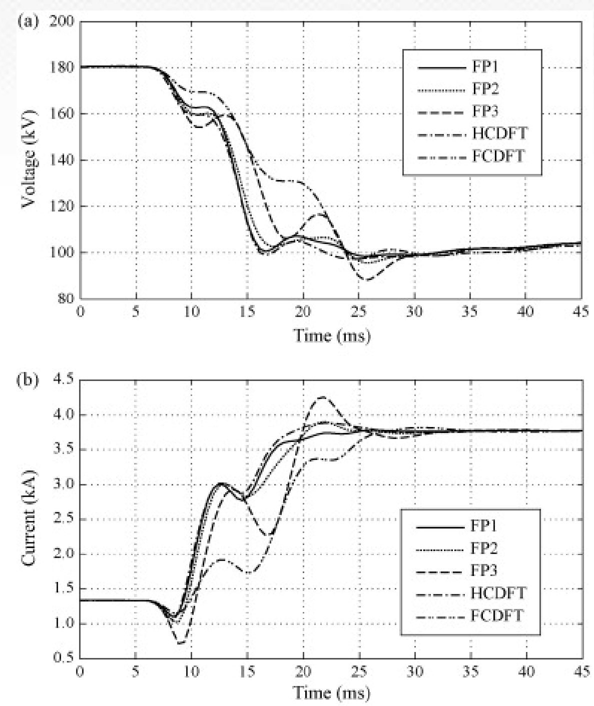


Relay calculated phasors



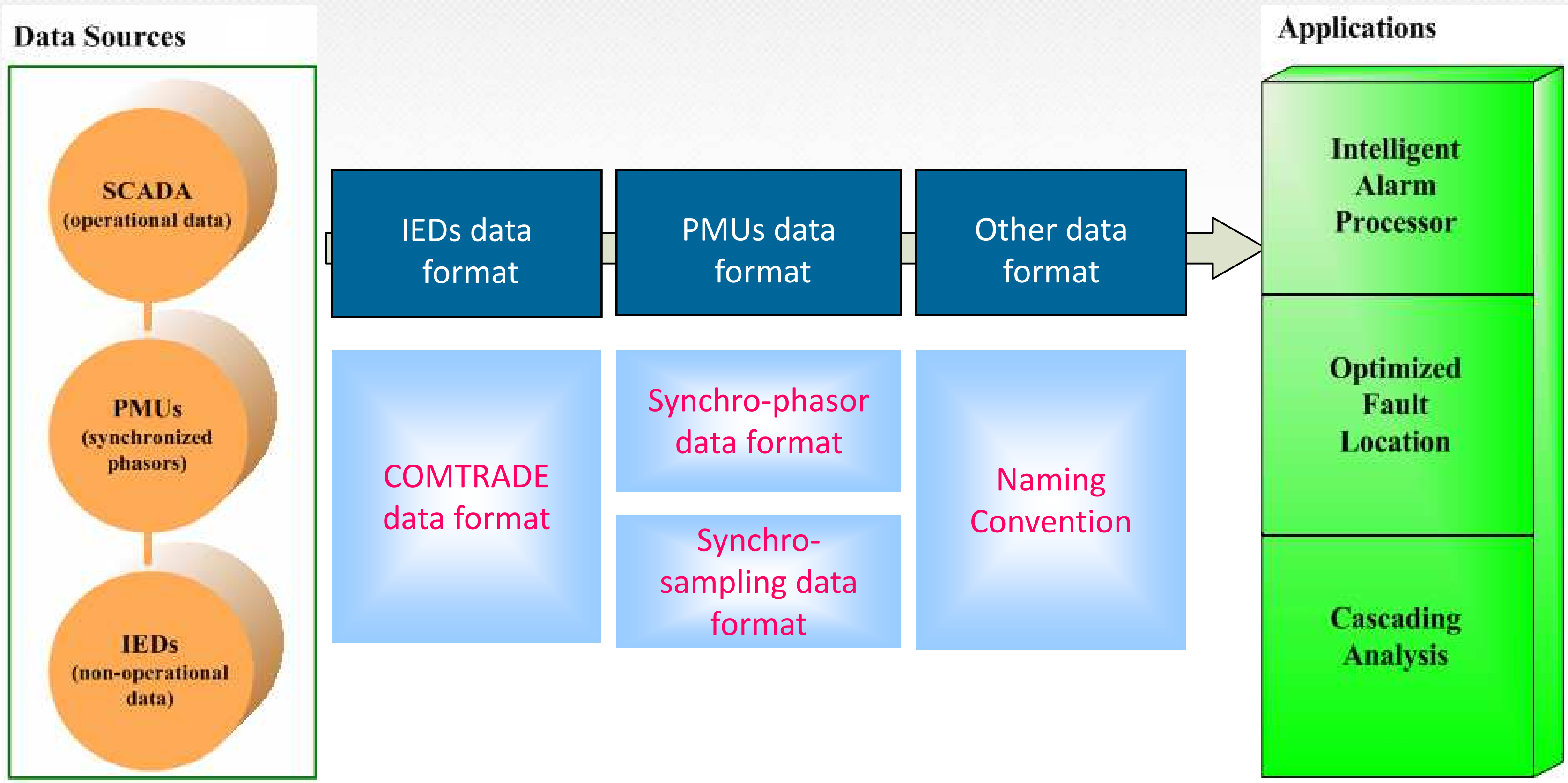
Compare with settings

Phasors in Monitoring (continuous sampling)



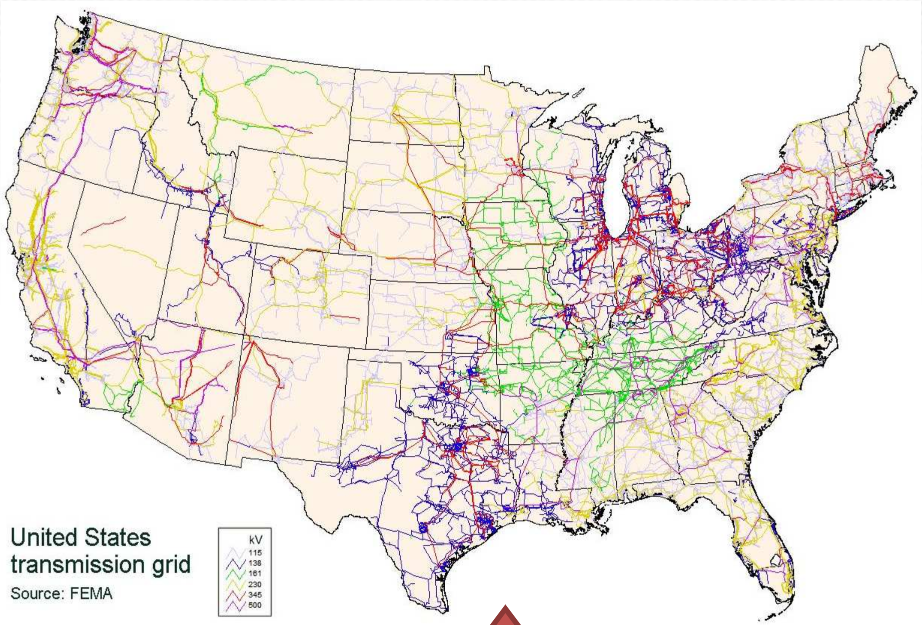
Spatial Issues

Uses of data: driven by applications

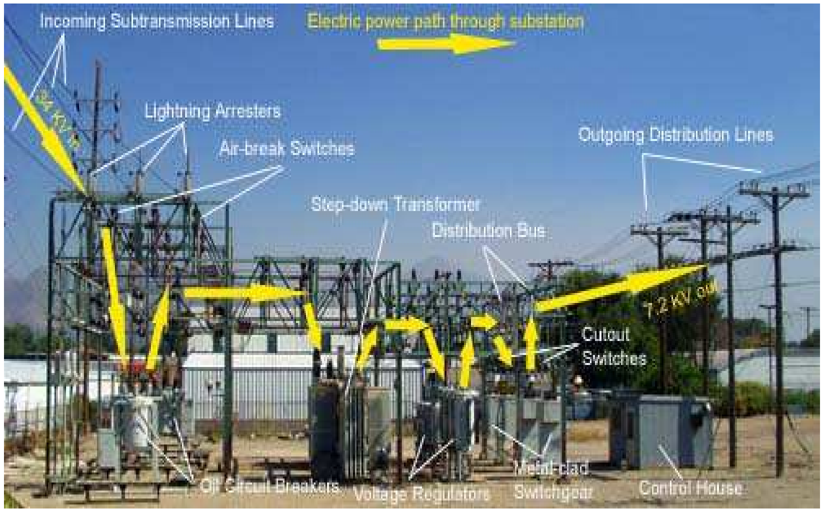


Spatial Issues

Broad (system-wide)



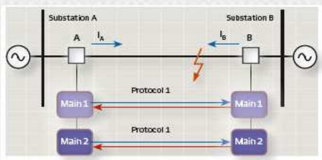
Local (substation-wide)

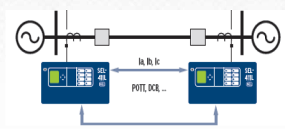


Spatial issues (System wide)

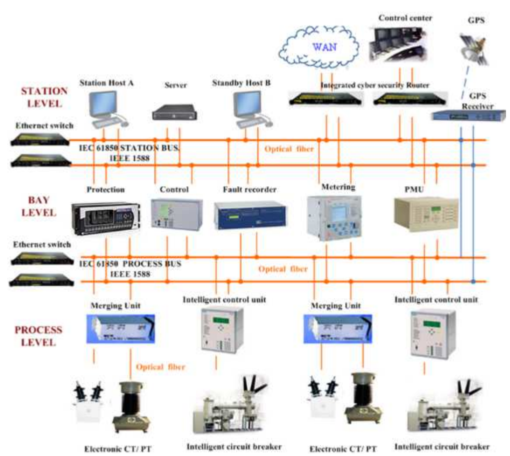
(

Inter-station

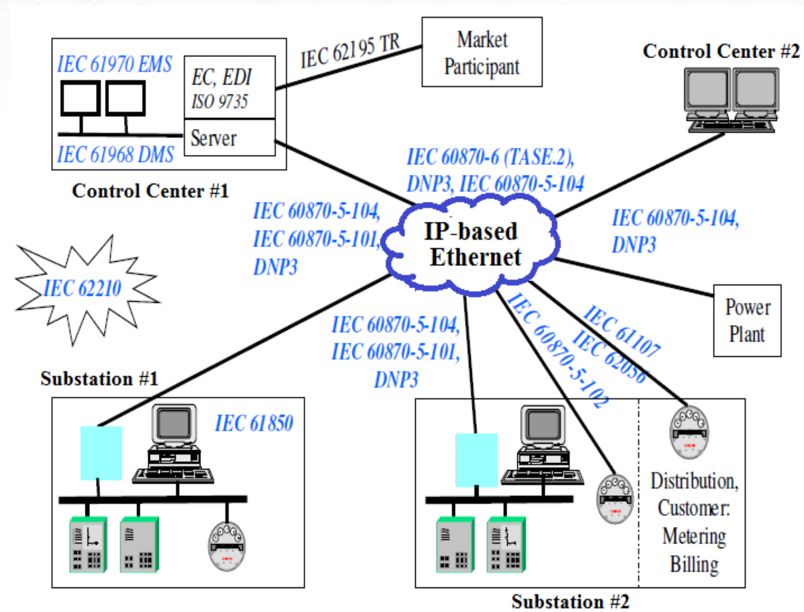




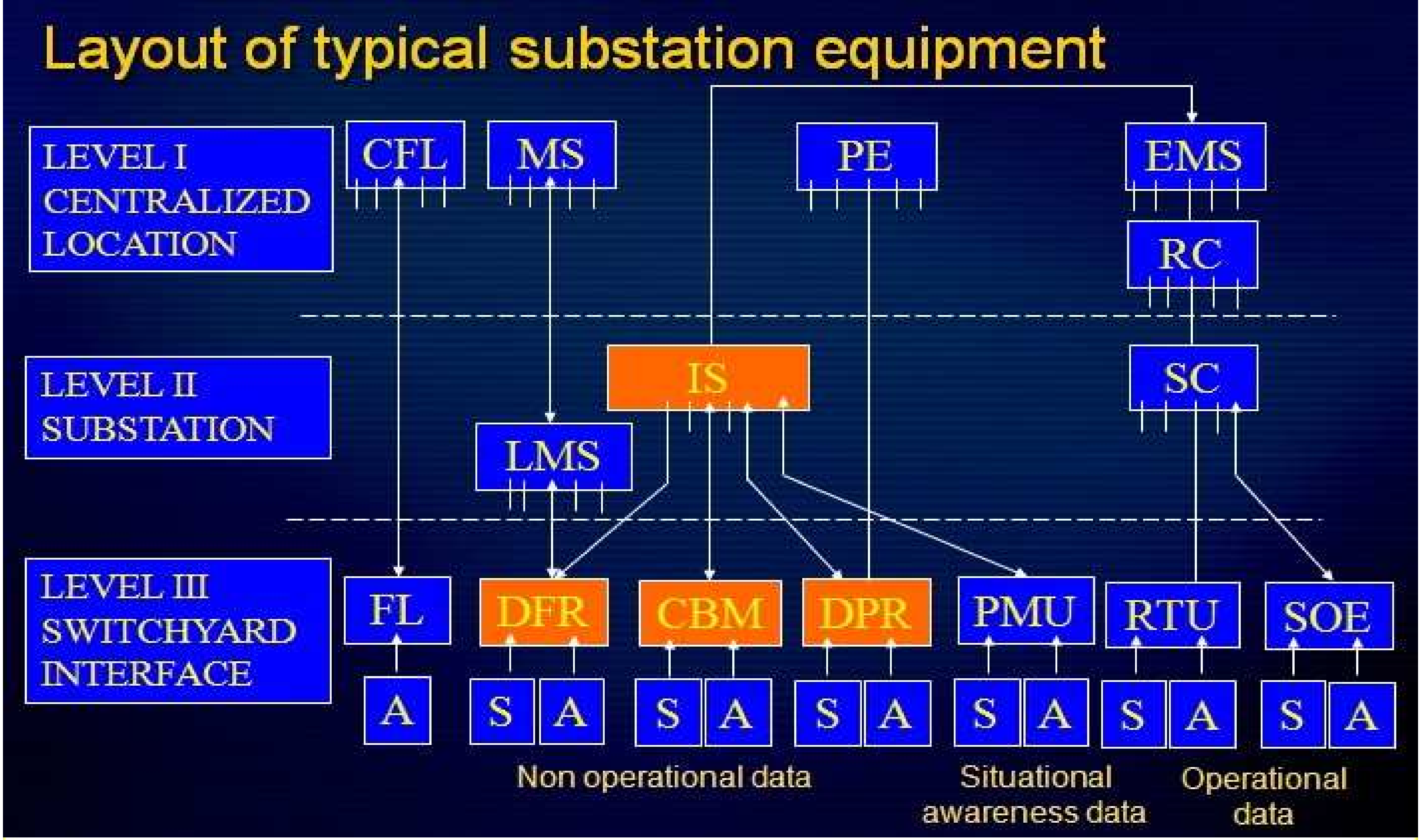
Intra-station



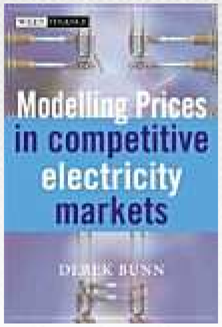
General Communications (IP-based schemes)



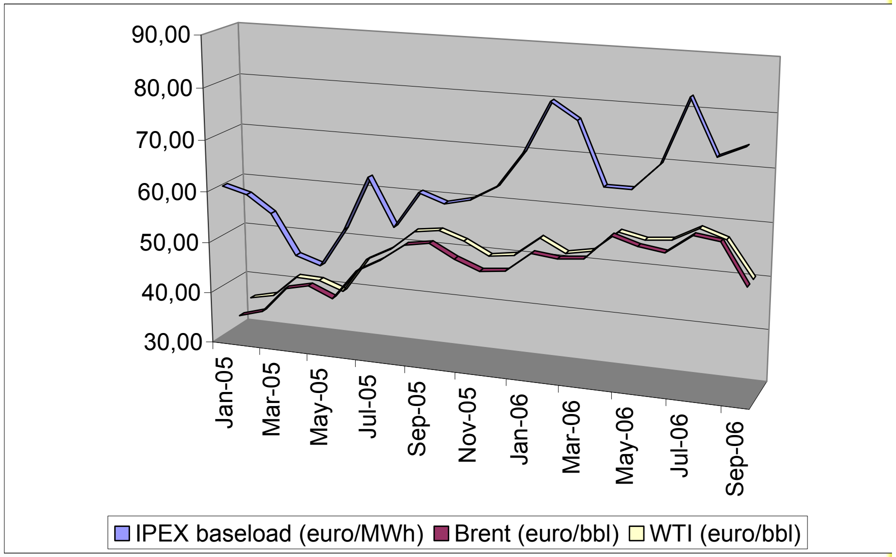
Spatial issues (local)



Markets



Oil and Electricity Monthly Average Price

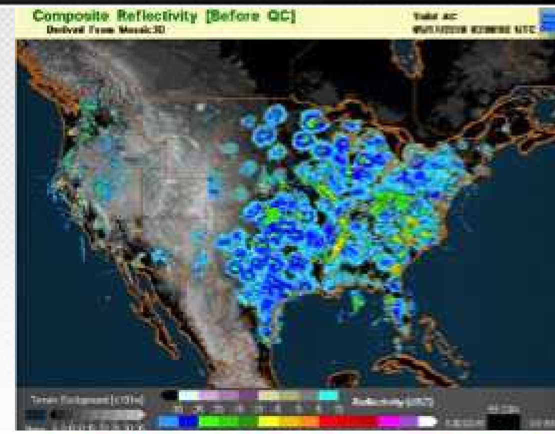
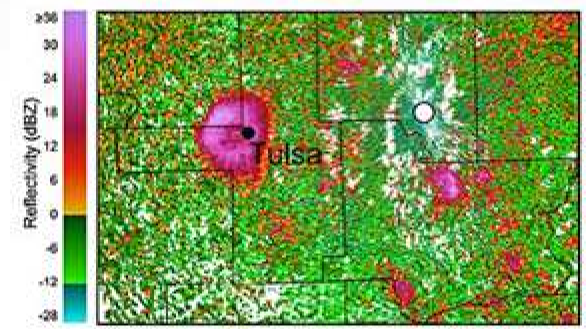
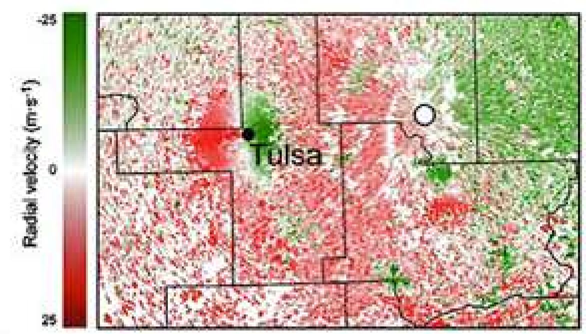


Animals

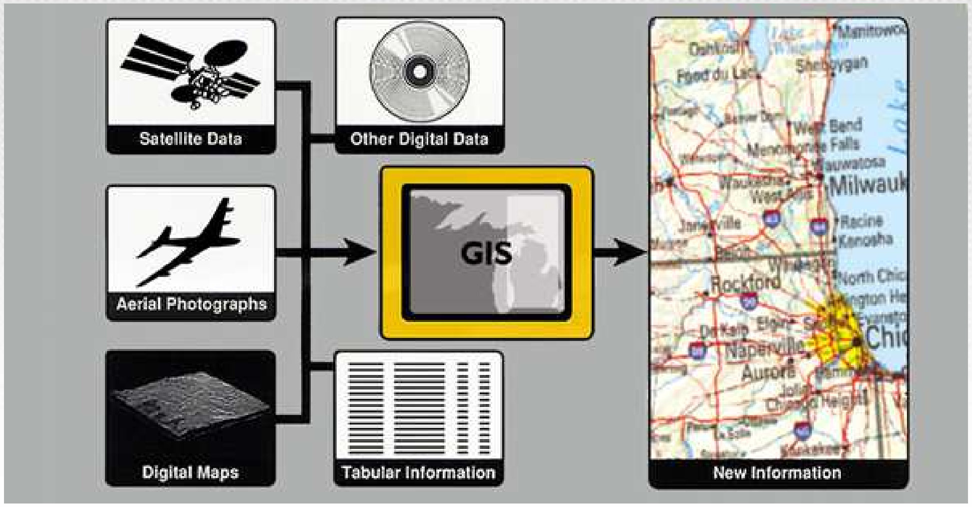




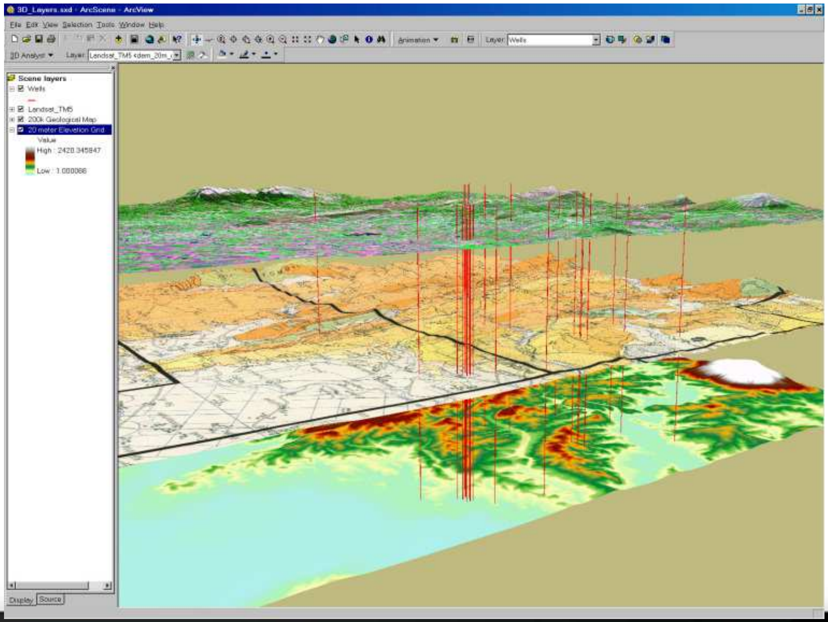



Composite Reflectivity [Before QC]

Reflectivity (dBZ)
≥36
30
24
18
12
6
0
-6
-12
-28
Tulsa

Radial velocity (m·s^{-1})
-25
0
25
Tulsa

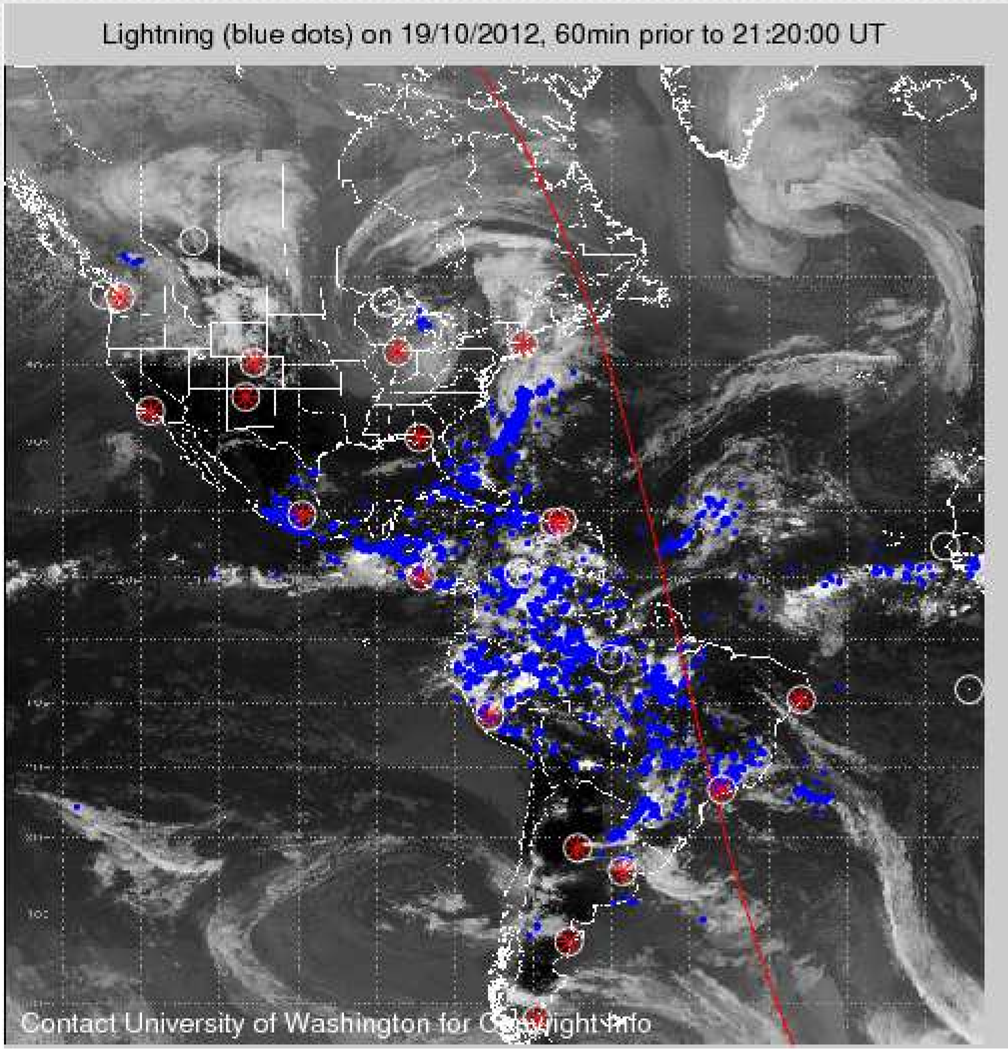
GIS and GPS

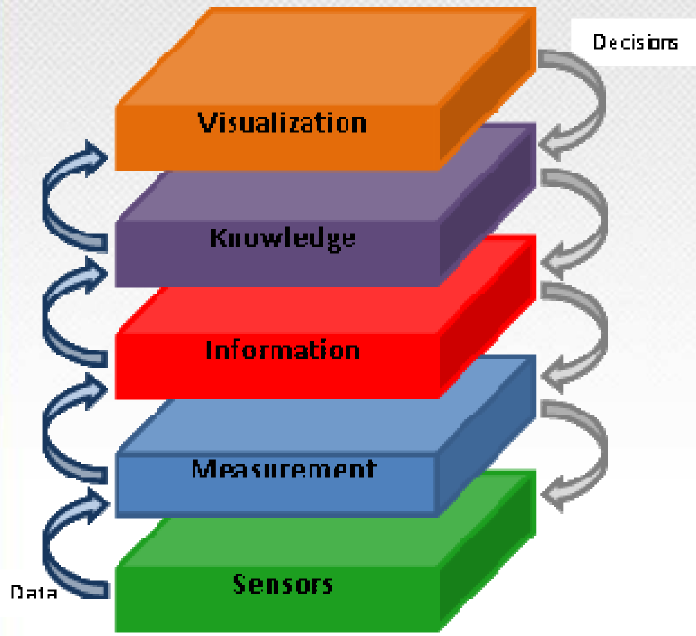

Satellite Data
Other Digital Data
Aerial Photographs
GIS
Digital Maps
Tabular Information
New Information


QuickBird Satellite Image - GIS Tax Mapping
Little Rock - Arkansas
© 2007 - DigitalGlobe - All rights reserved
www.satimagingcorp.com



Weather


Lightning (blue dots) on 19/10/2012, 60min prior to 21:20:00 UT
Contact University of Washington for Copyright Info



Sampled data

Synchrophasor Data

Operational/nonoperational data

Big Data

TRANSLATIONAL KNOWLEDGE

M. Kezunović, "Translational Knowledge: From Collecting Data to Making Decisions in a Smart Grid," *IEEE Proceedings, 2011*, Vol. 99, No.6, pp. 977-997, June 2011.

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Case studies

TEXAS A&M ENGINEERING TEES

Application	Temporal	Spatial	Model
Optimal Fault Location	Synchronized or unsynchronized phasor or sample vector	Local and system-wide	Power System Network for short circuit study
Intelligent Alarm Processing	Synchronized or unsynchronized phasors	Substation and system-wide	Petri-Net Logic for cause-effect representation
Inherently Adaptive Fault Detection and Classification	Synchronized sample vector	Local	Power system model for training pattern clustering

Fault Location

- Phasor based Methods

  Use fundamental frequency component of the signal and lumped parameter model

- Time-domain based Methods

  Use transient components of the signal and lumped or distributed parameter model

- Traveling wave based Methods

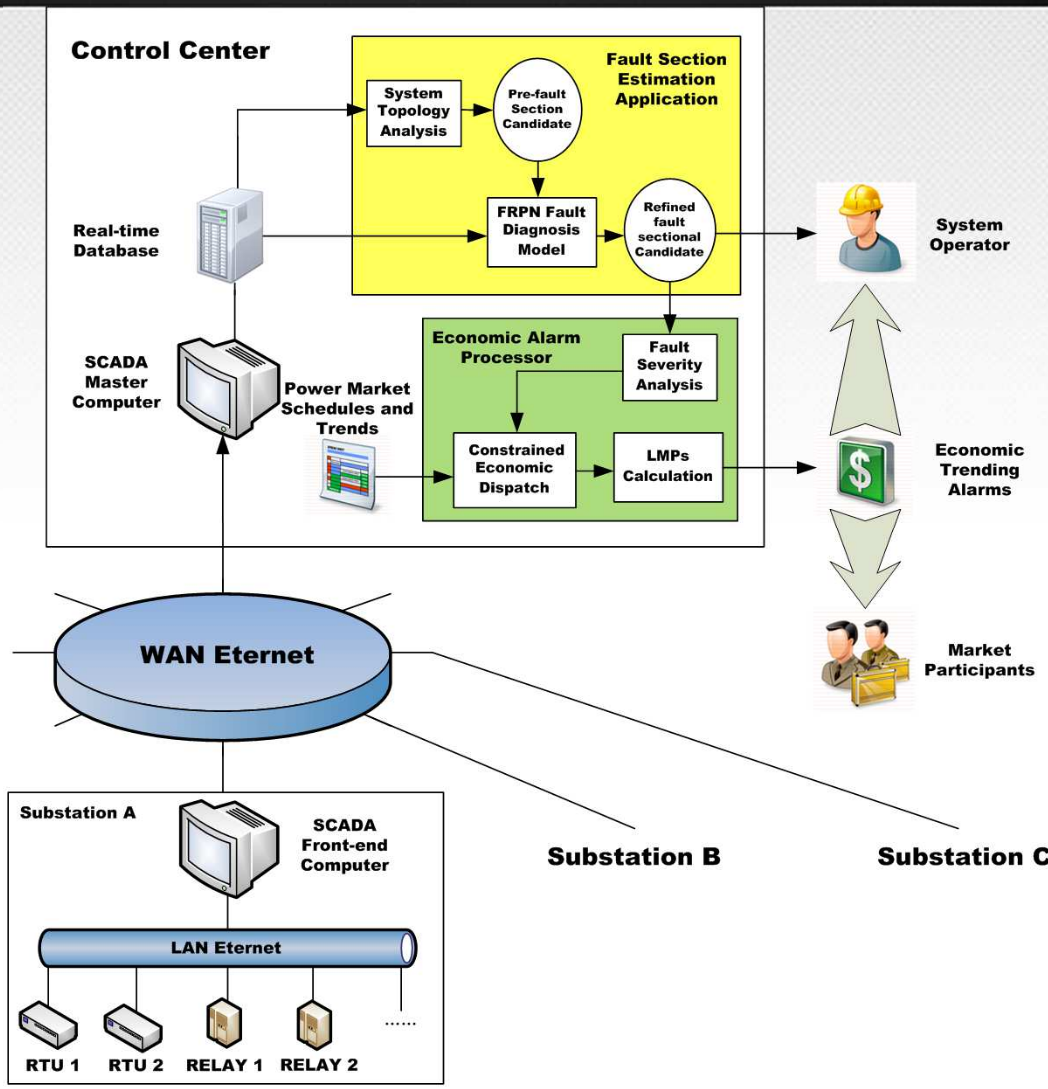
  Use correlation between the forward and backward travelling waves along a line or direct detection of the arrival time

  - Single end
  - Double end

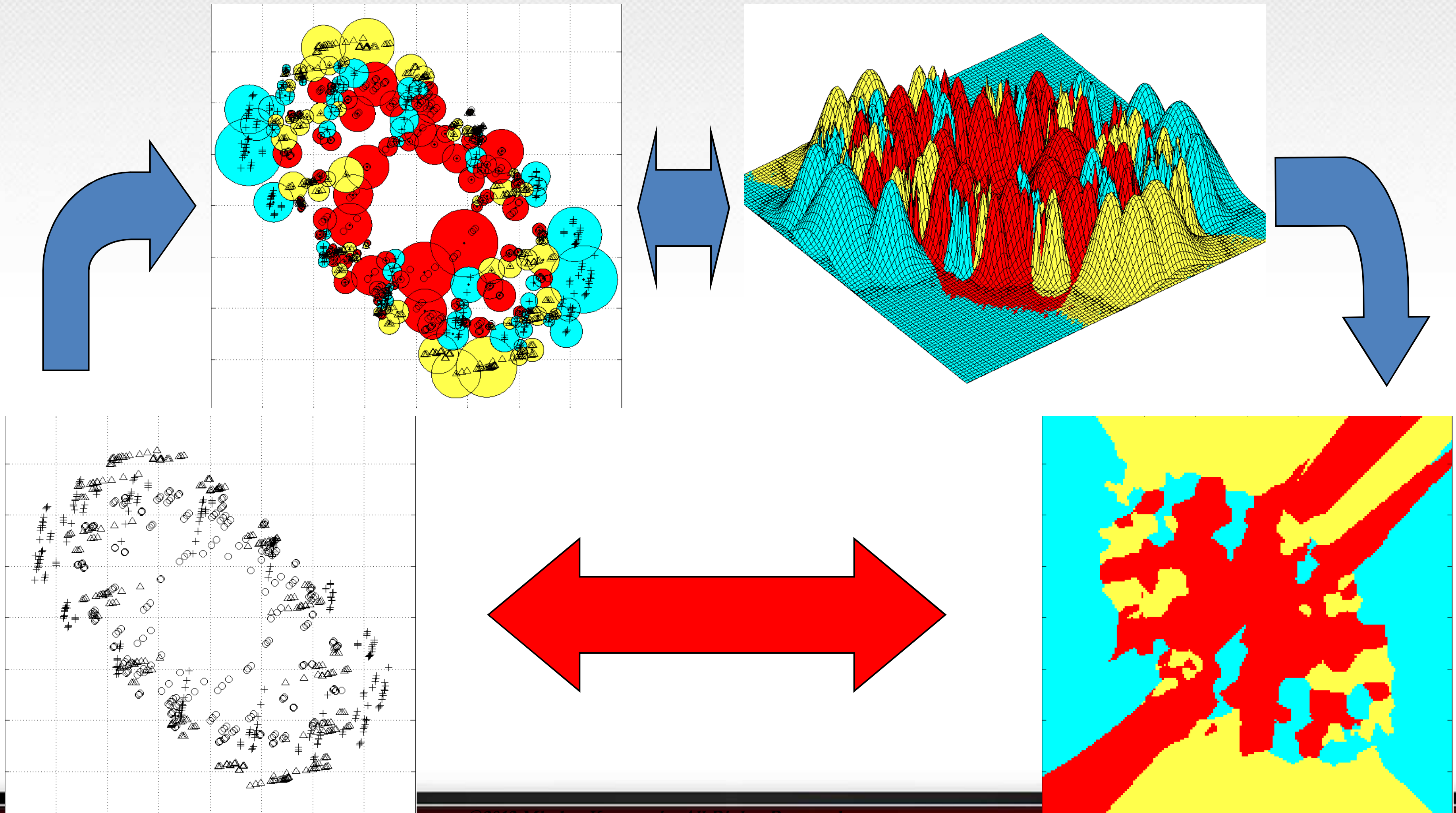
  - Synchronized
  - Unsynchronized

  - Phasors
  - Samples

Alarm Processor



Inherently adaptive event detection



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Big Data and Analytics

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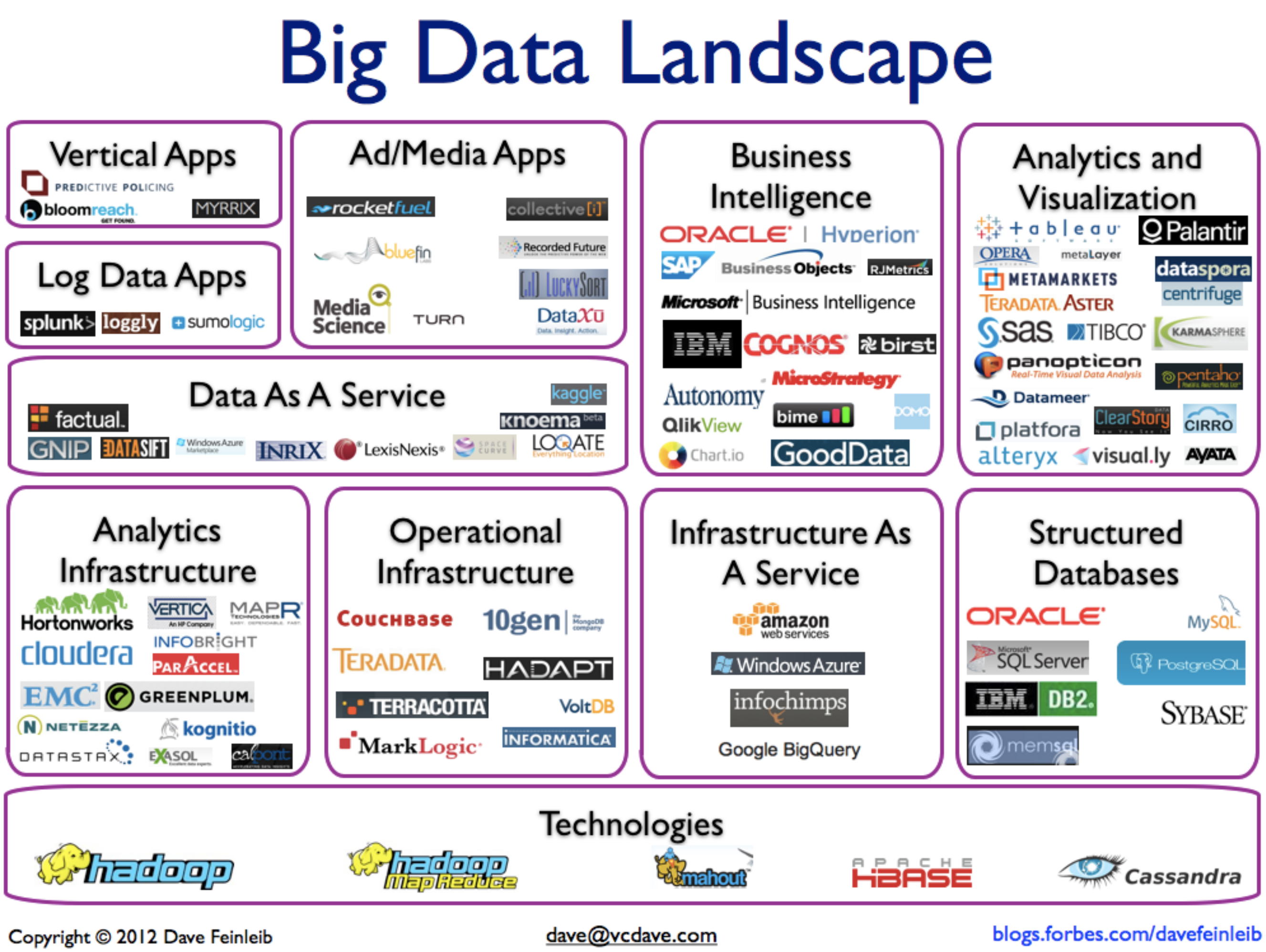
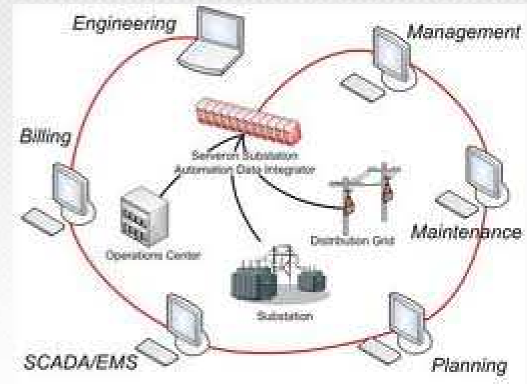




Cyber-Physical security

Privacy

Standardization

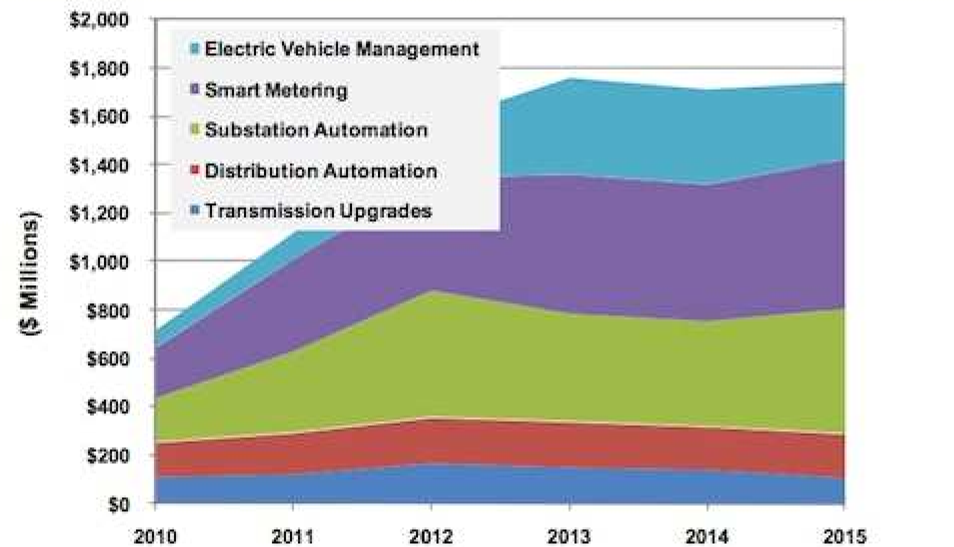
Testing and certification

IMPLEMENTATION

M. Kezunovic, et al., "Smart Grid Barriers and Critical Success Factors," Chapter on Smart Grids: Infrastructure, Technology, and Solutions, Stuart Borlase, Editor, CRC Press, 2012

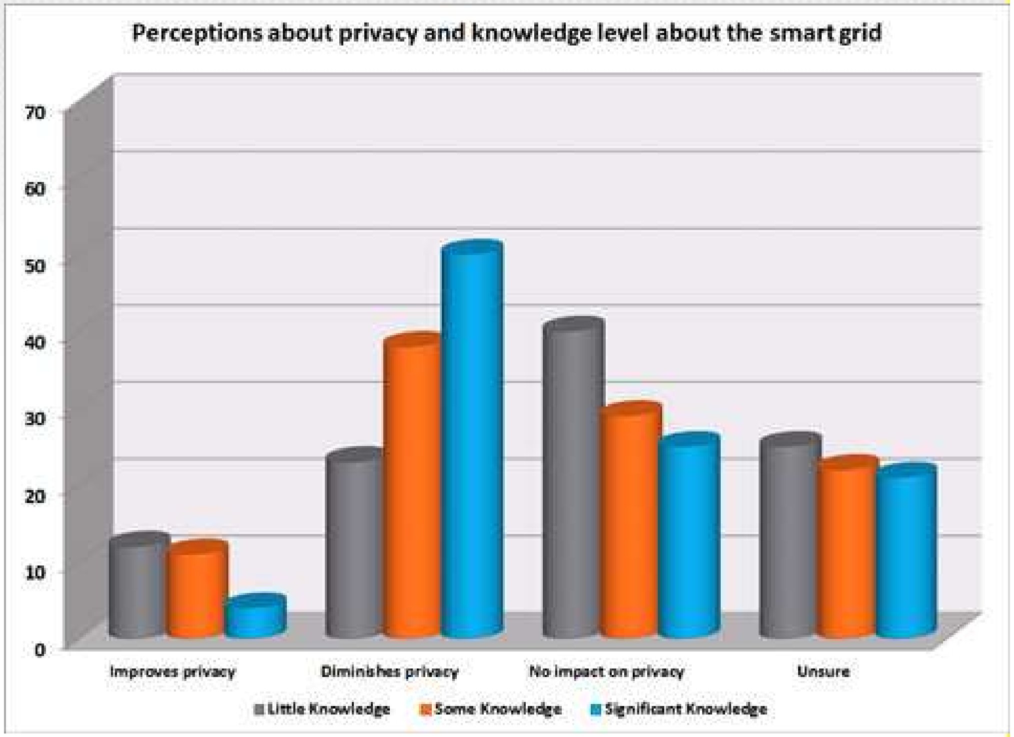
Cyber security

Chart 2.1 Smart Grid Cyber Security Revenue by Application, World Markets: 2010-2015

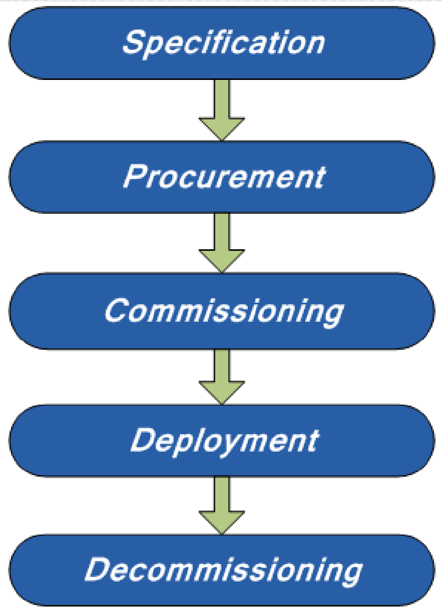


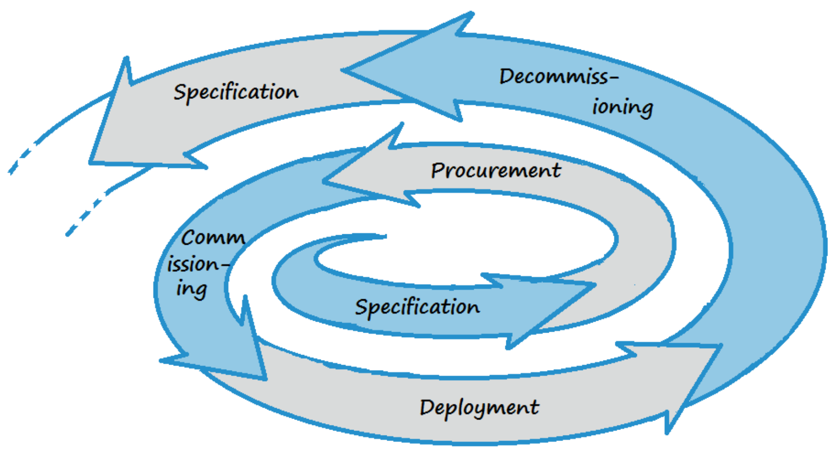
(Source: Pike Research)

Privacy

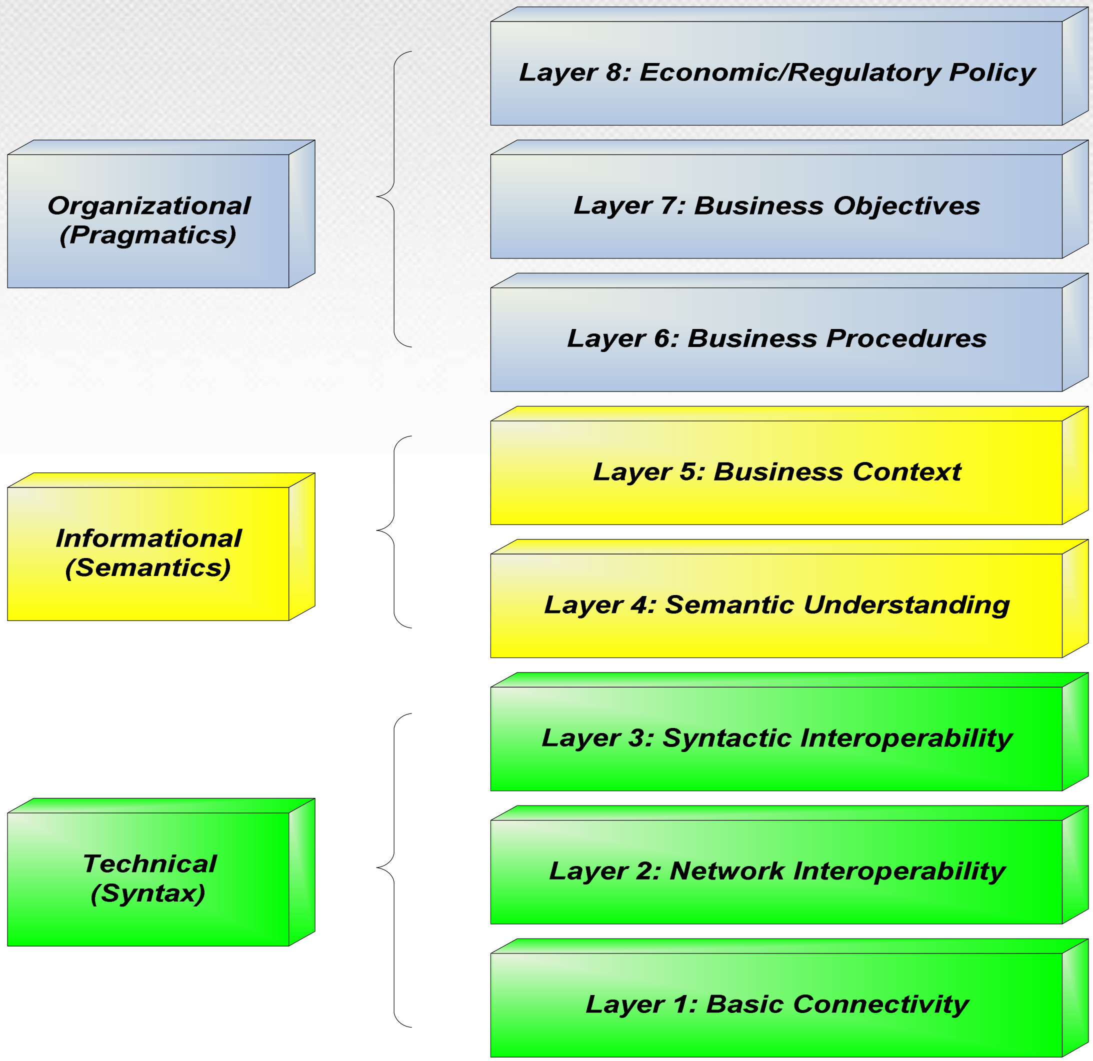

Perceptions about privacy and knowledge level about the smart grid
70
60
50
40
30
20
10
0
Improves privacy
Diminishes privacy
No impact on privacy
Unsure
Little Knowledge
Some Knowledge
Significant Knowledge

The role of standards

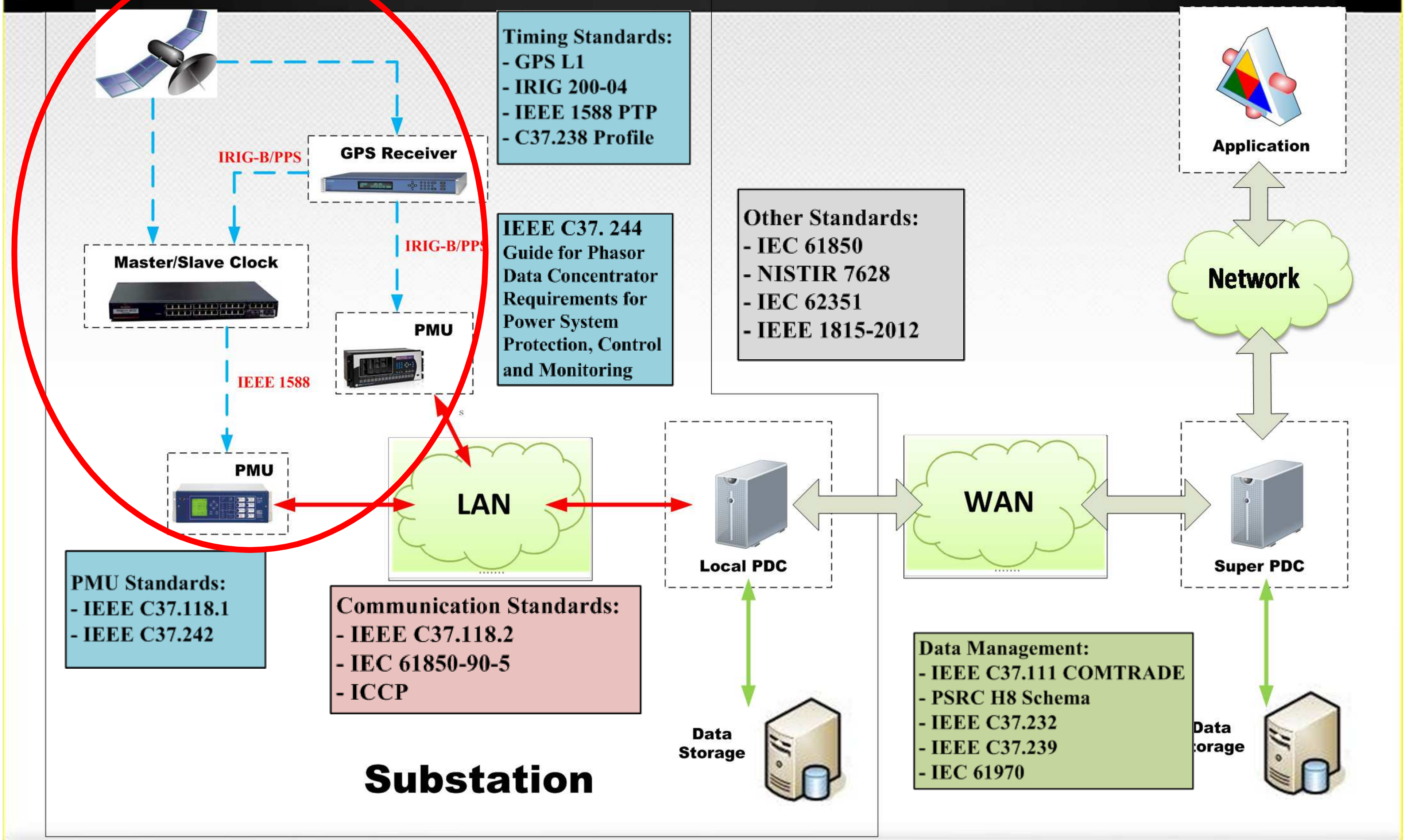




Interoperability



Standards Landscape for synchrophasors



Why Testing and Certification Matters

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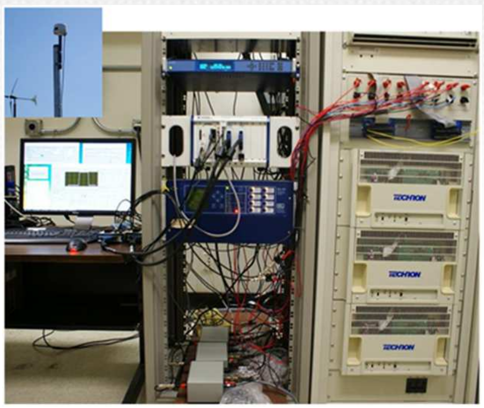
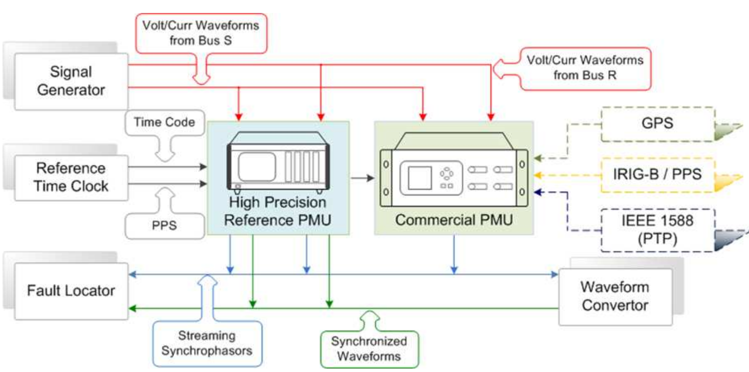
Procedure: how to test?





PMU	Class	Dynamic State Test								
		Measurement Bandwidth			Frequency Ramp			Step Change		
		TVE	FE	RFE	TVE	FE	RFE	RT	DT	MO
A	P	S	F	S	S	F	F	F	F	F
	M	S	F	S	F	F	F	S	F	F
A-1*	P	S	F	S	S	F	F	F	S	F
	M	S	F	S	S	F	F	S	S	F
B	P	S	F	S	S	F	F	S	F	S
	M	F	F	S	F	F	F	S	F	S
C	P	S	F	S	S	F	F	S	S	S
	M	S	S	S	F	F	F	S	S	S
D	P	S	F	S	S	F	F	F	F	F
	M	F	F	S	F	F	F	S	F	F
E	P	S	F	S	S	F	F	F	S	F
	M	F	F	S	S	F	F	S	S	F
F	P	S	F	S	F	F	F	S	S	S
	M	F	F	S	F	F	F	S	S	S
G	P	S	F	S	S	F	F	F	S	F
	M	S	F	S	S	F	F	S	S	F
H	P	S	S	S	S	F	F	S	S	S
	M	S	S	S	S	F	F	S	S	S

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Why T&C Matters

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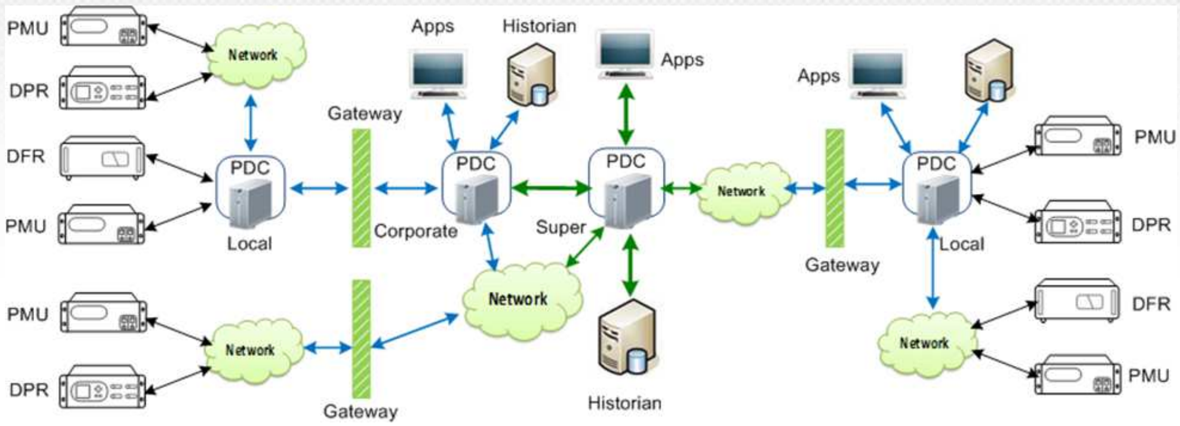
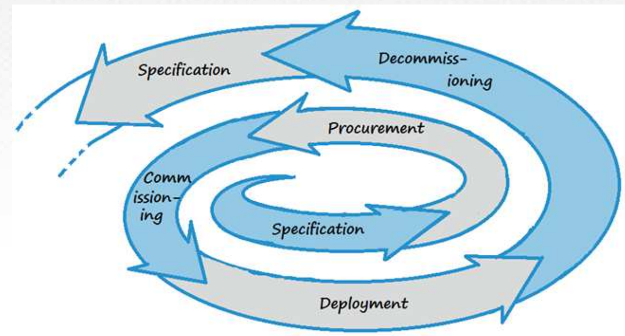
Process: how to certify?





	PMU A	PMU A*	PMU B	PMU C	PMU D	PMU E	PMU F	PMU G	PMU H
PDC A	S	S	S	S	S	S	S	S	S
PDC B**	F	F	F	S	S	S	N	S	S
PDC C***	S	S	S	F	F	F	F	F	F

FYI

Smart grid center:

http://smartgridcenter.tamu.edu/sgc/

EV-TEC:

http://ev-tec.org

PSerc:

http://www.pserc.org

ARPA-E:

http://smartgridcenter.tamu.edu/ratc/

Smart Energy Campus Initiative:

http://smartgridcenter.tamu.edu/seci/

Smart Grid Center

Q/A

TEXAS A&M ENGINEERING

Thank you!

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Texas A&M University
College Station, U.S.A.
kezunov@ece.tamu.edu
http://smartgridcenter.tamu.edu/pscp_kezunovic/