EE392n
Intelligent Energy Systems:
Big Data and Energy

March 31, 2015

Dan O'Neill
Dimitry Gorinevsky

Today's Program

- Class logistics
- Introductory lecture on Intelligent Energy Systems: Big Data and Energy

Instructors

- Dimitry Gorinevsky, Consulting Professor in EE
  - Big Data analytics for energy and aerospace
  - Information Decision and Control Applications in many industries
  - www.stanford.edu/~gorin
- Daniel O'Neill, Consulting Professor in EE
  - Streaming Analytics and Machine Learning
  - Executive and Startup experience
  - www.stanford.edu/~dconeill

Class Logistics

- 1 unit graded CR/NC
  - Attendance
  - No pre-requisites
- Weekly on Tuesdays
  - The room and time might change!
  - Watch the class website announcements
- Introductory lecture - today
- Nine lectures from industry leading companies

Planned Lectures

- March 31: Introductory Lecture, Dan ONeill, Stanford
- April 7: The Industrial Awakening: Analytics and the Internet of Things, David Mount, Kleiner Perkins
- April 14: Emerging Electricity Distribution Grid Technologies, James Bullock, Pacific Gas and Electric Company
- April 21: Keeping California Power System Stable with over 33% Renewables, Shucheng Liu, CAISO
- April 28: Big Data Analytics in Energy, Aaron Deyonker and Hemant Shukla, Siemens
- May 5: Navigating the changing needs of the CA electricity grid and regulatory policy Mona Tierney-Lloyd Senior Director, Western Regulatory Affairs EnerNOC, Inc.
- May 12: Energy and Analytics, Marco Annunziata, Chief Economist, GE
- May 19: The Future of Energy Industry, Arun Majumdar, Stanford (former VP for Energy at Google)
- May 26: Distributed Energy and Microgrids, Ed McCullough and Nick Haschka, NRG Energy
- June 2: Mike Dolbec, Managing Director, GE Venture Capital

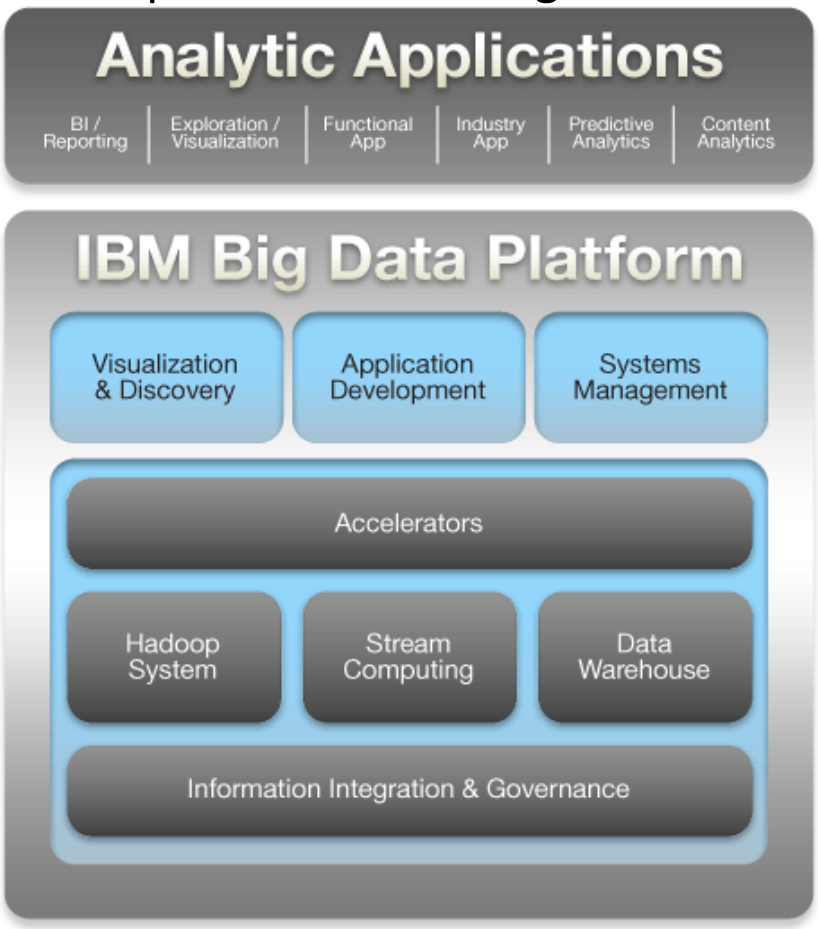
Big Data

~~Next~~ Current Big Thing

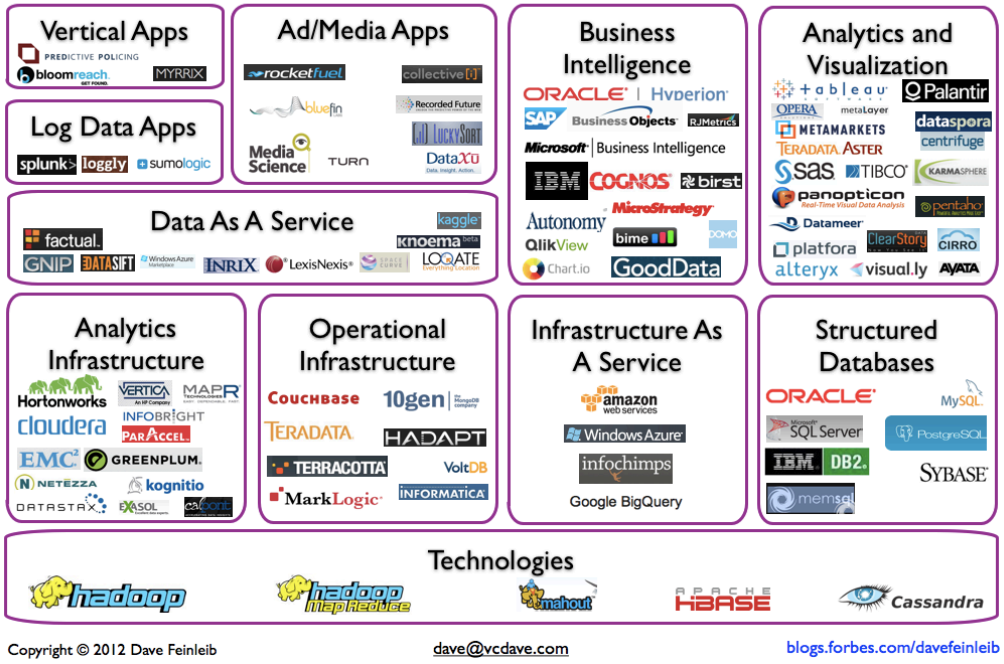
Data Science

Big Data Analytics

Example: IBM marketing



- Analytics provides value
- Need support infrastructure



Internet of Everything

- "The Next Big Thing for Tech: The Internet of Everything", *Time*, Jan 2014
  - IT/OT convergence

Information **T**echnology

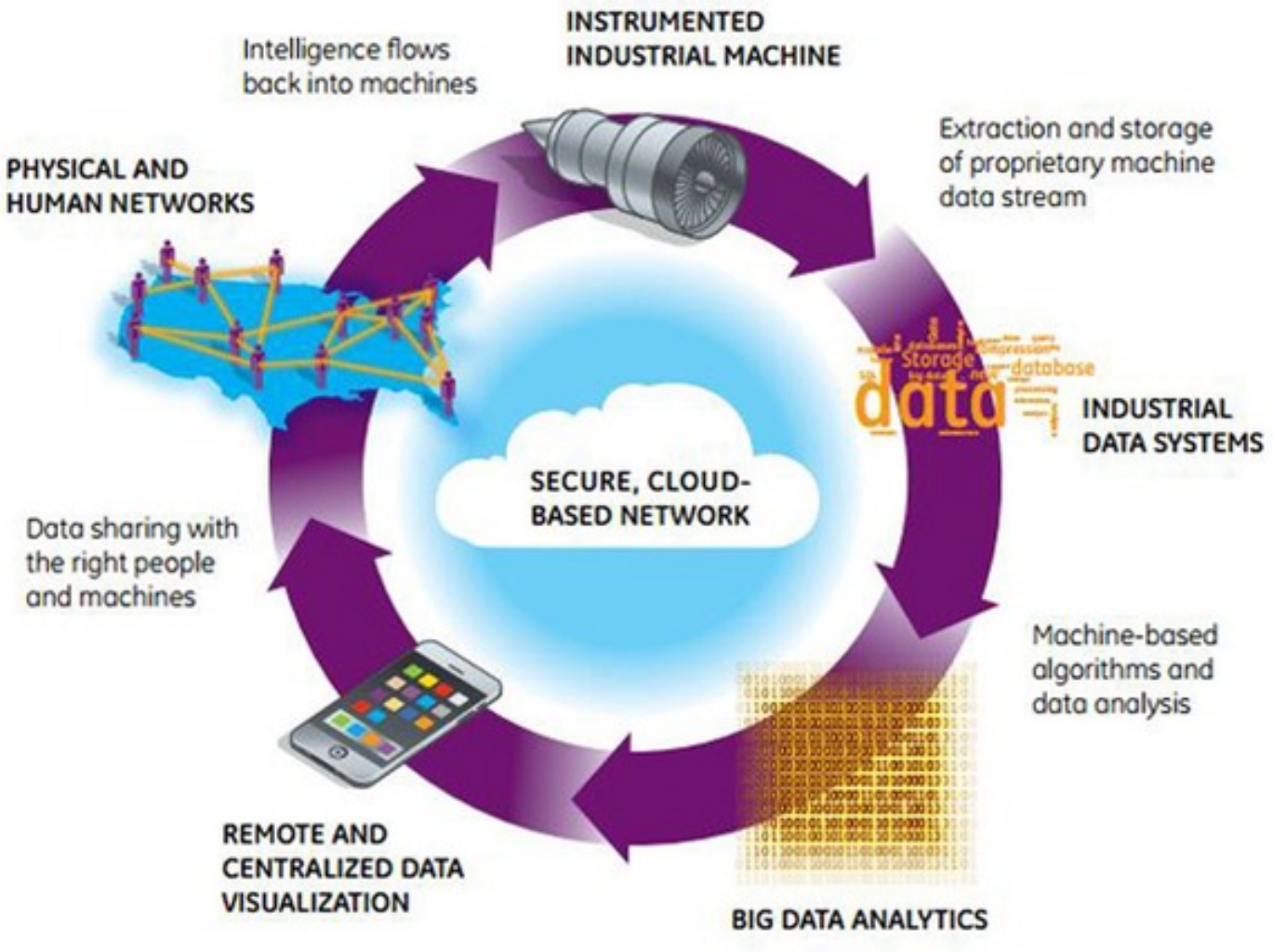
Operations **T**echnology

IT ↑↓ OT

- IT: Enterprise computing. Big Data
- OT: Embedded and industrial systems. Connected Everything.

Industrial Internet

@GE



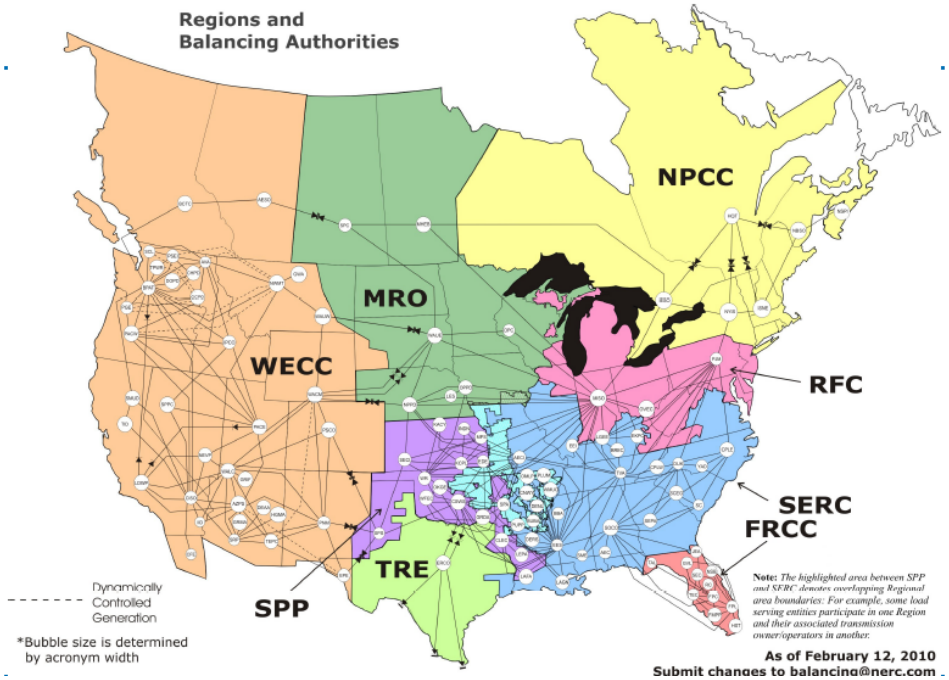
Energy Systems

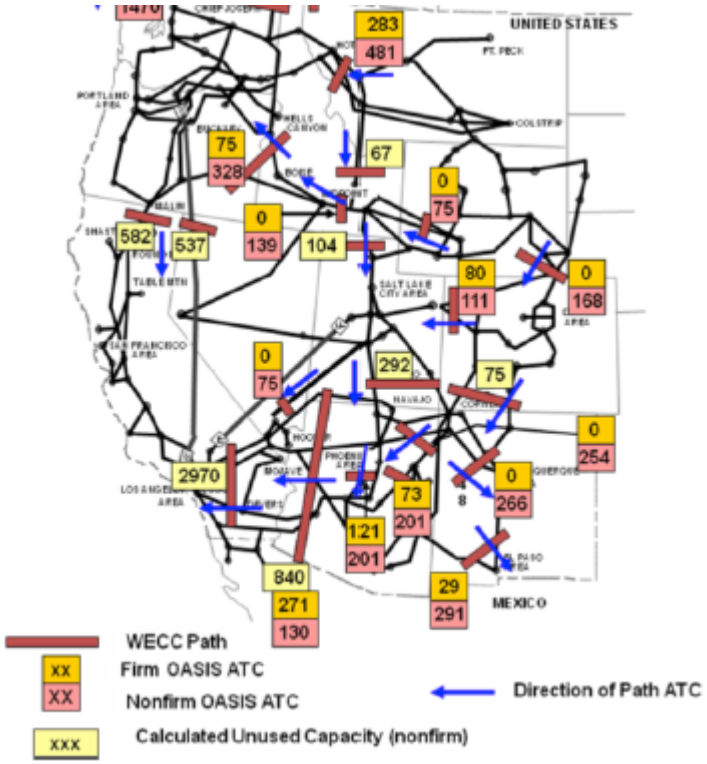
- The focus of the class
- Power systems
  - Power generation
  - Power consumption
  - Smart Grid

The Traditional Grid

- Worlds Largest Machine!
  - 3300 utilities
  - 15,000 generators, 14,000 TX substations
  - 211,000 mi of HV lines (>230kV)
  - SCADA control
  - Mostly unidirectional
- Capacity constrained graph

Interconnect



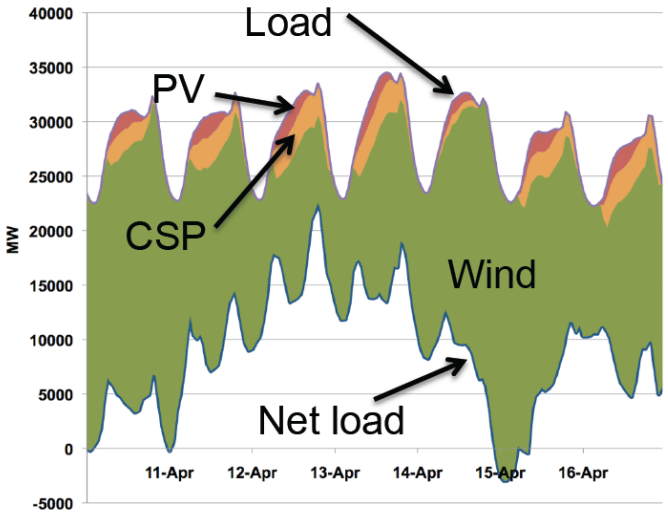


Nearer Term Initiatives

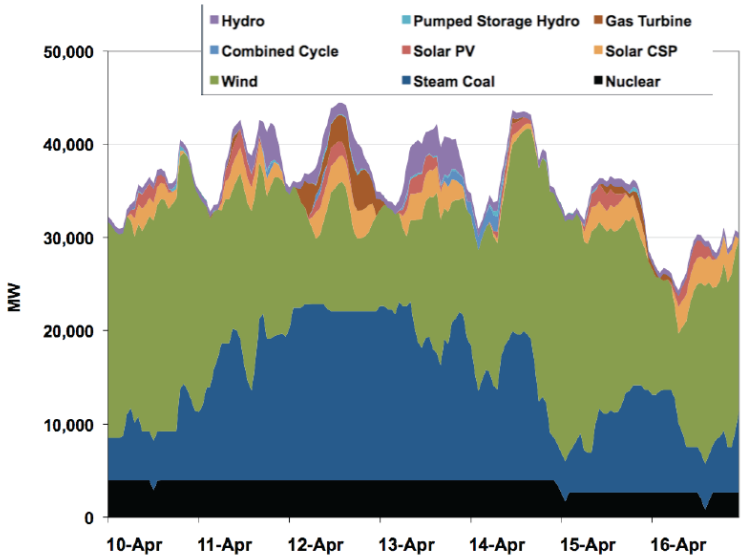
- Energy Usage
- Power Flow Management
- Asset Management

Renewables: The System Problem

Net Load



Dispatch



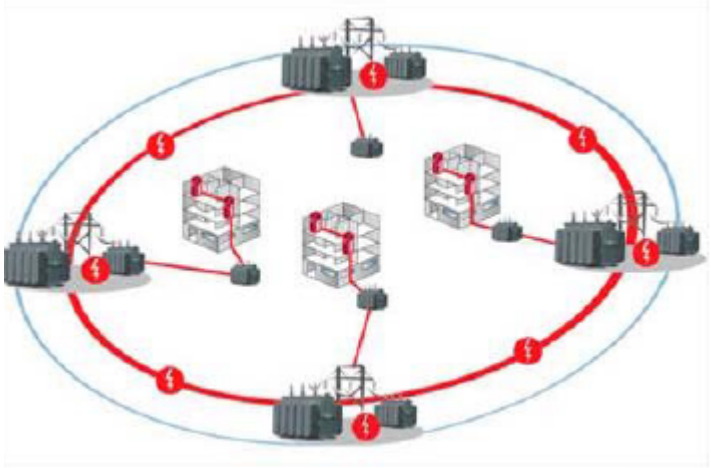
Need for conventional plants to cycle and ramp

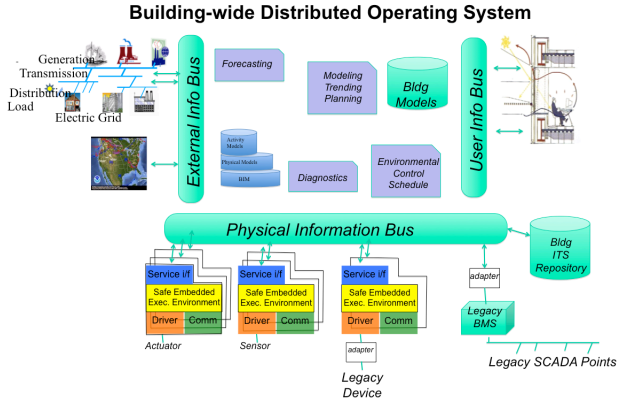
National Renewable Energy Laboratory

Can be addressed by managing usage – Demand Response

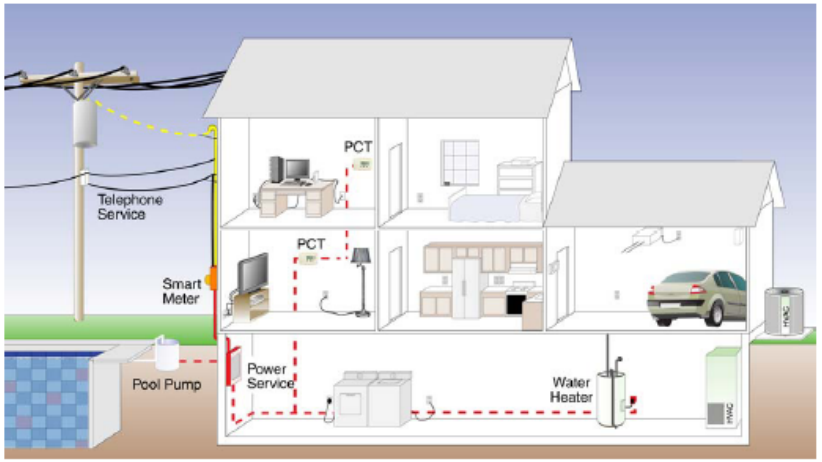
Energy Usage

Campus and Buildings





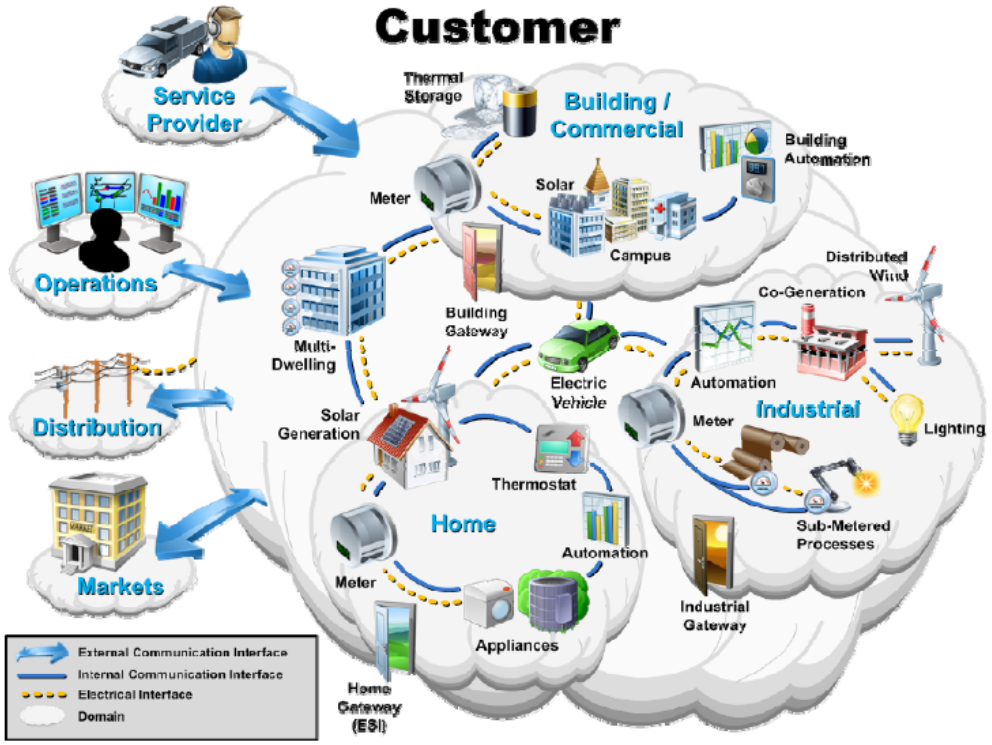
Home



- DR – Demand Response
- AMI – Advanced Metering Infrastructure
- EMS – Energy Management System
- Smart devices

Power Flow Management

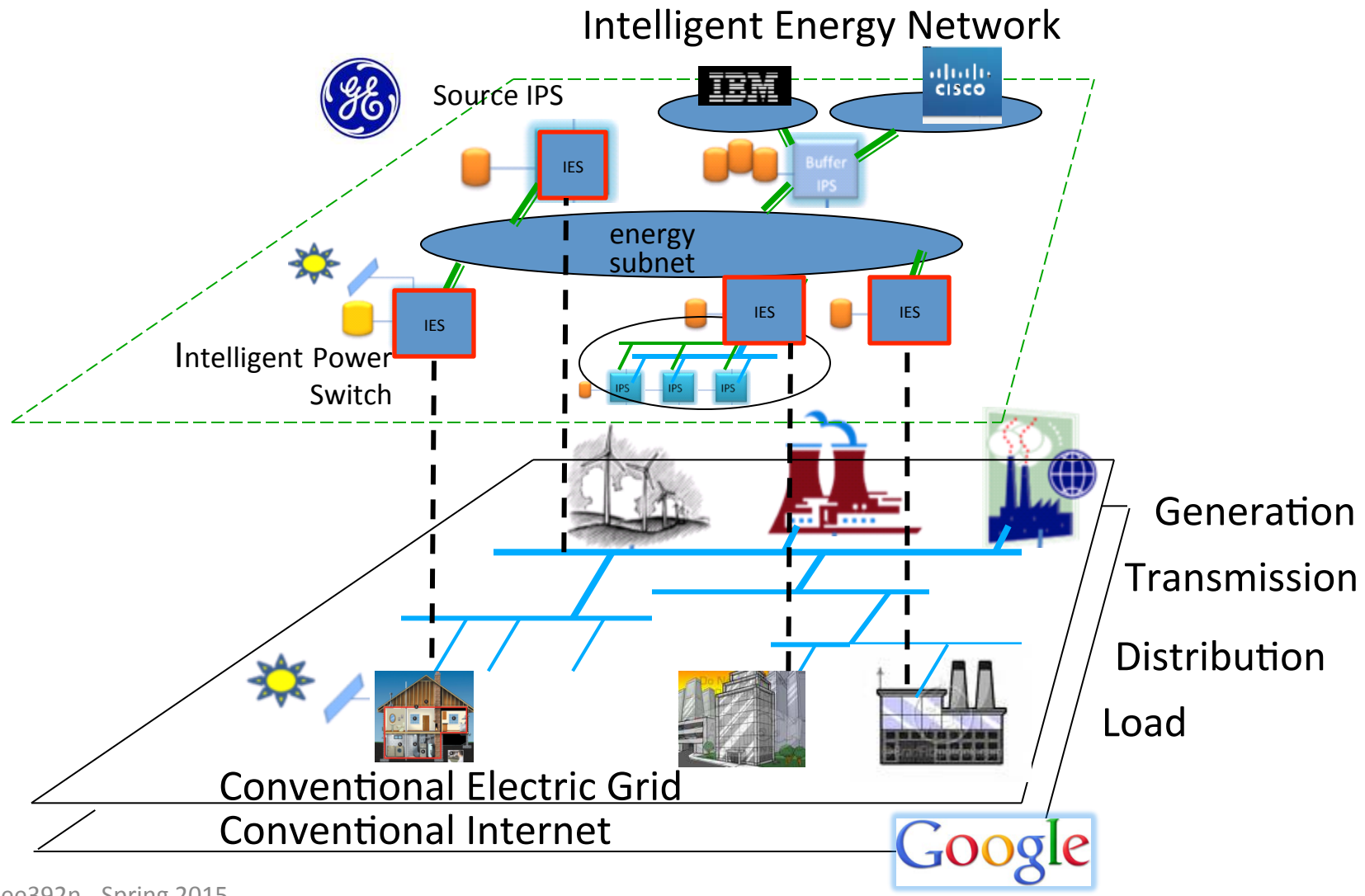
- Adjusting supply
- Routing power flow
- Managing demand
  - for aggregated users
  - for commercial buildings
- Revenue protection



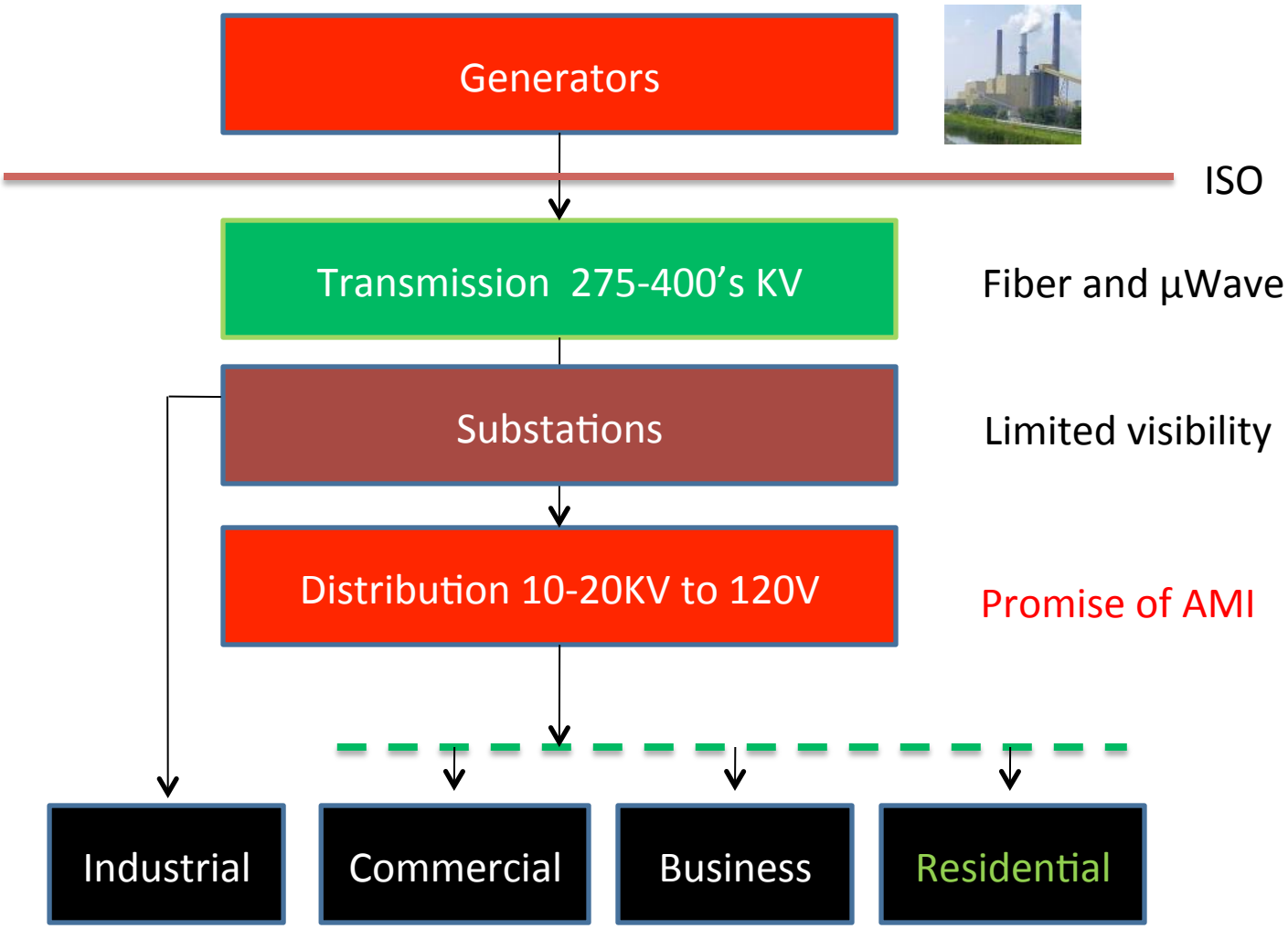
Asset Management

- $10T in assets
  - 1% of failures per year = $100B

Computing and Communications

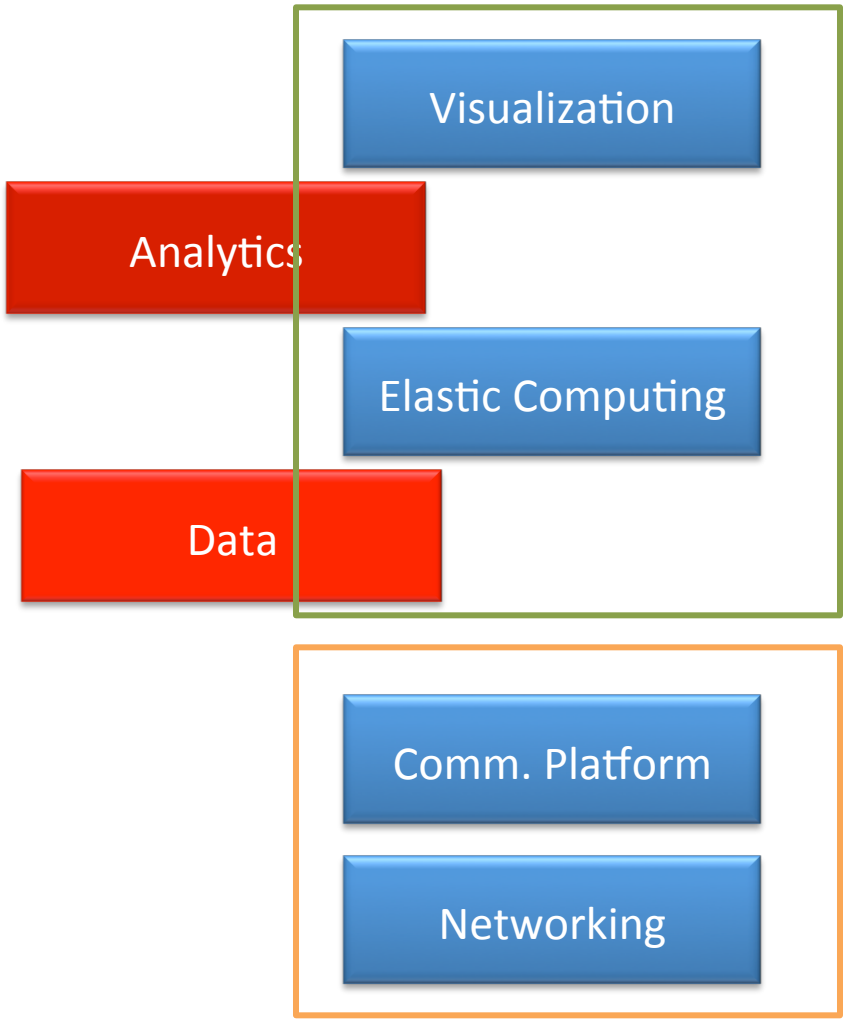


T&D and Data Flow



Today…

- Integrated platforms
  - IBM, Oracle, …
  - GE, Siemens, ABB,…
  - Cisco, …
- But
  - Analytic tools
  - Vertical analytic products
  - Data integration



Intelligent Energy Systems

Analytics: Software Function

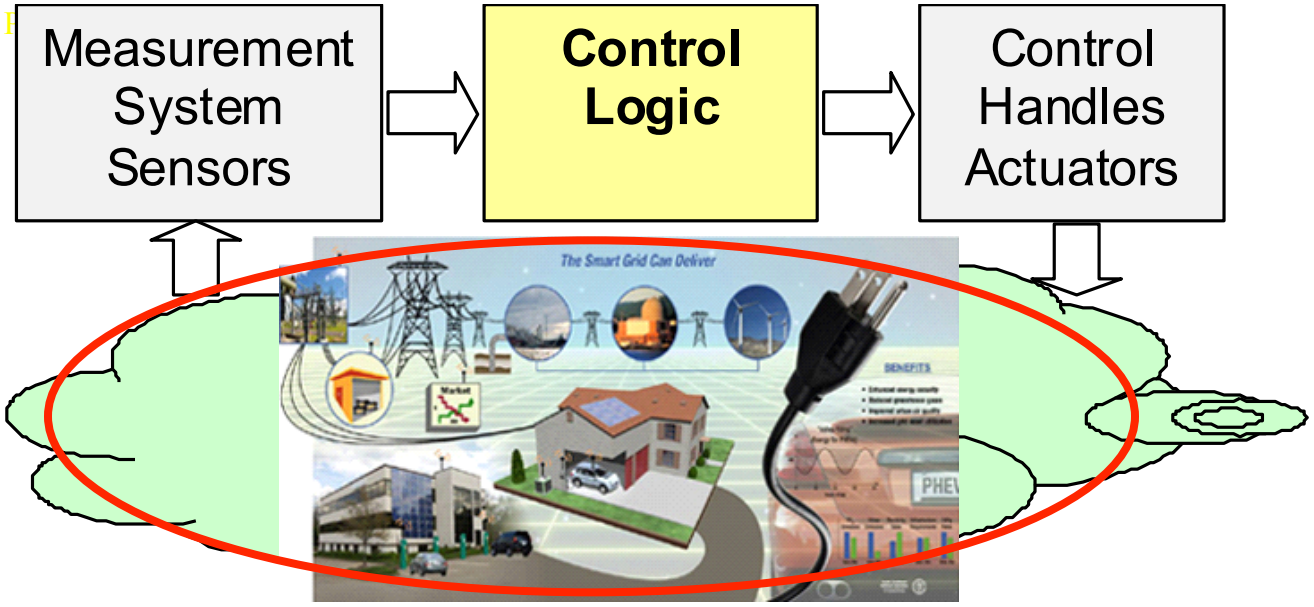
Computing and Communication

Data

Energy System

Feedback Control Functions

- Closed loop update



Closed Loop Control Energy Applications

Supply

- Real time energy and reserve optimization at ISO
- Power Flow Optimization
- Volt Var Optimization

Demand

- Demand Response
- Thermostat

OT Applications

Substation Example (OT)

Substation Automation & Control

Advanced automation and data management with integrated cyber security functions

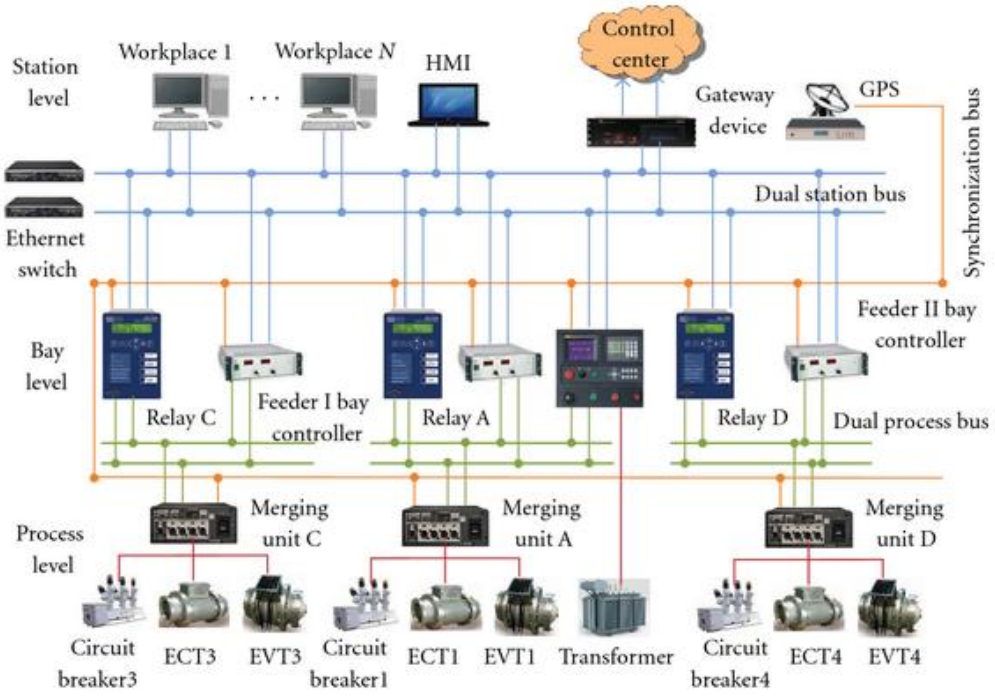
Asset Optimization

Advanced solutions providing real-time monitoring and control to improve dependability

Recloser Control

Reliable breaker protection and control with local HMI and battery backup

GE Digital Energy



Lu, Wang, & Ma, 2012

Cascaded Control (Nested Loops)

EMS

Asset Optimization (minutes)

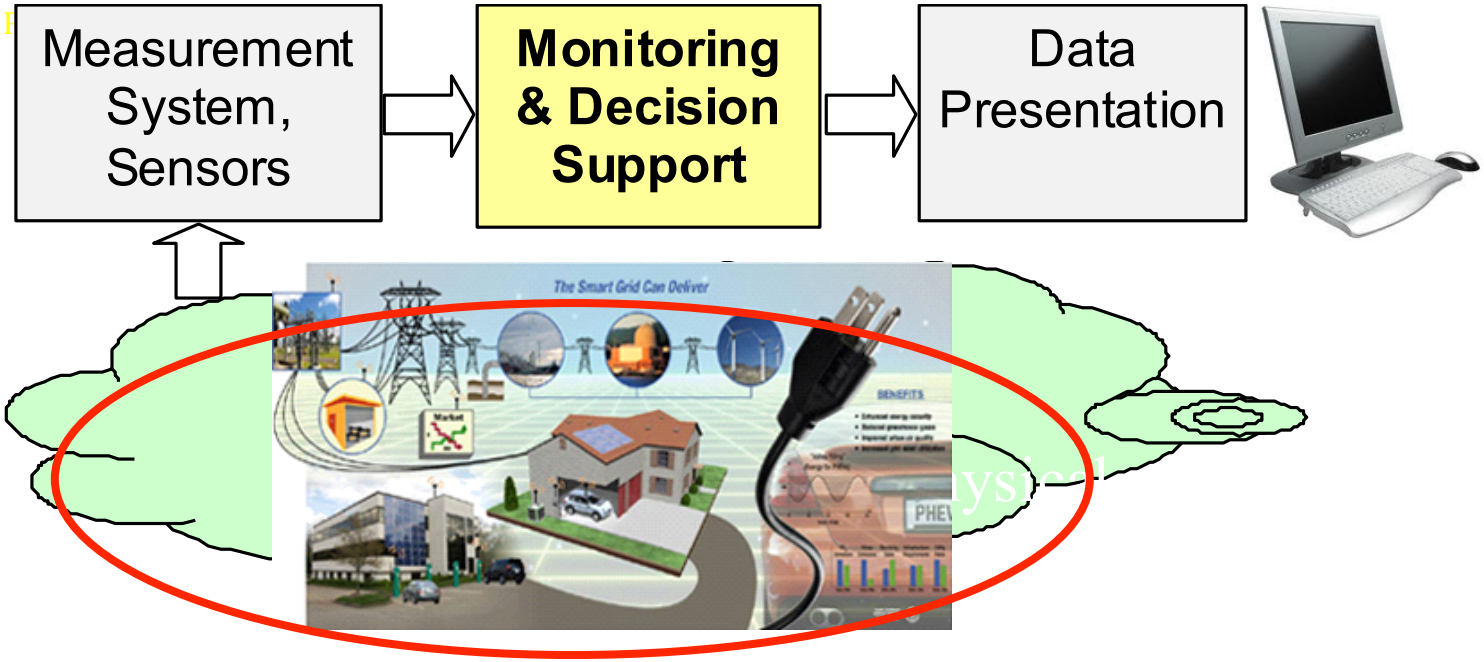
Monitoring & control (seconds)

Protection (millisecs)

Circuit

Monitoring and Decision Support Functions

- Open-loop functions
  - Results are presented to an operator



Decision Support Applications

Supply

- Asset Management
- Load Forecasting
  - Renewables generation
- Power Quality Monitoring

IT

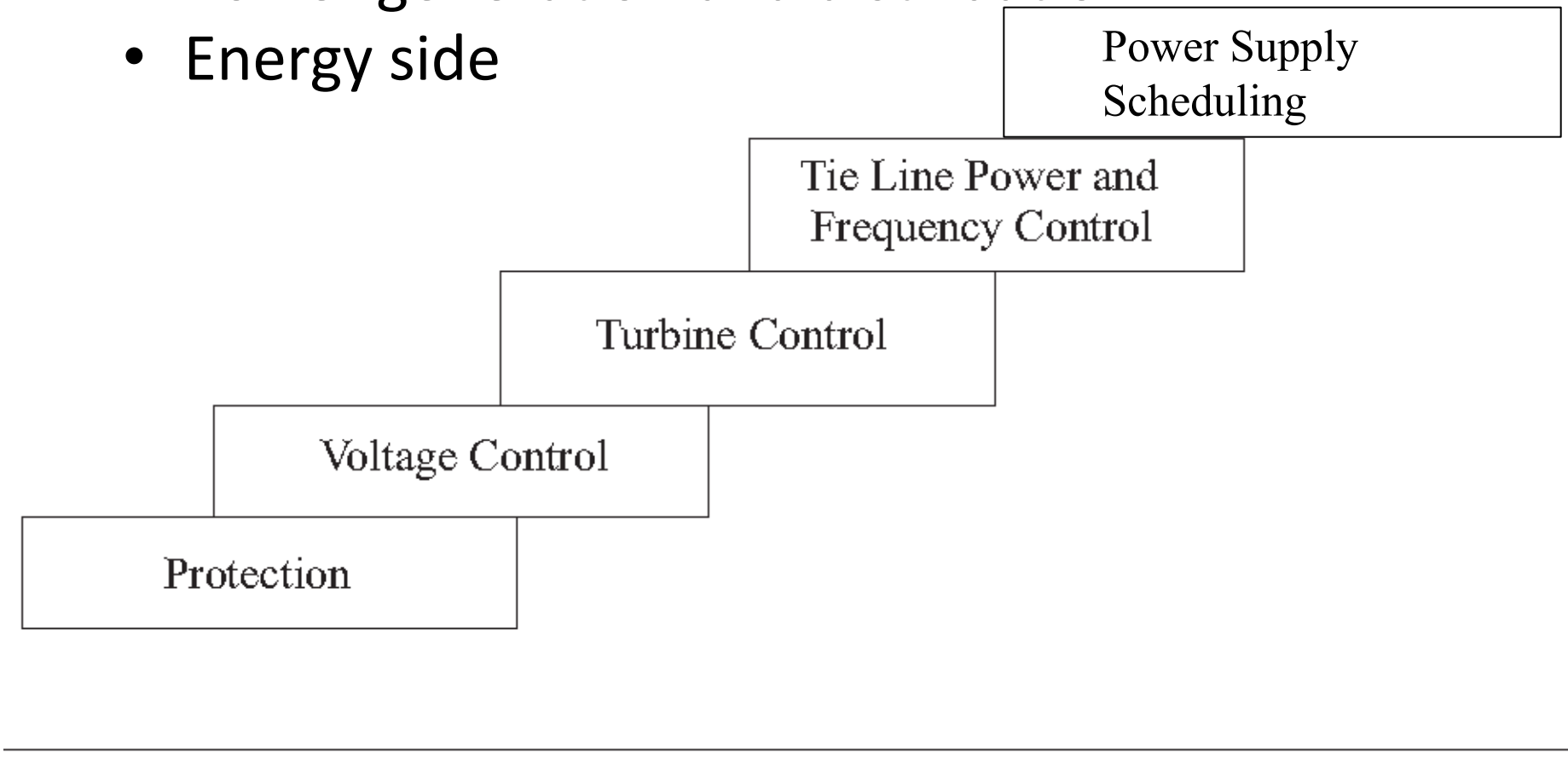
OT

Demand

- Energy Efficiency Monitoring
- Revenue Protection

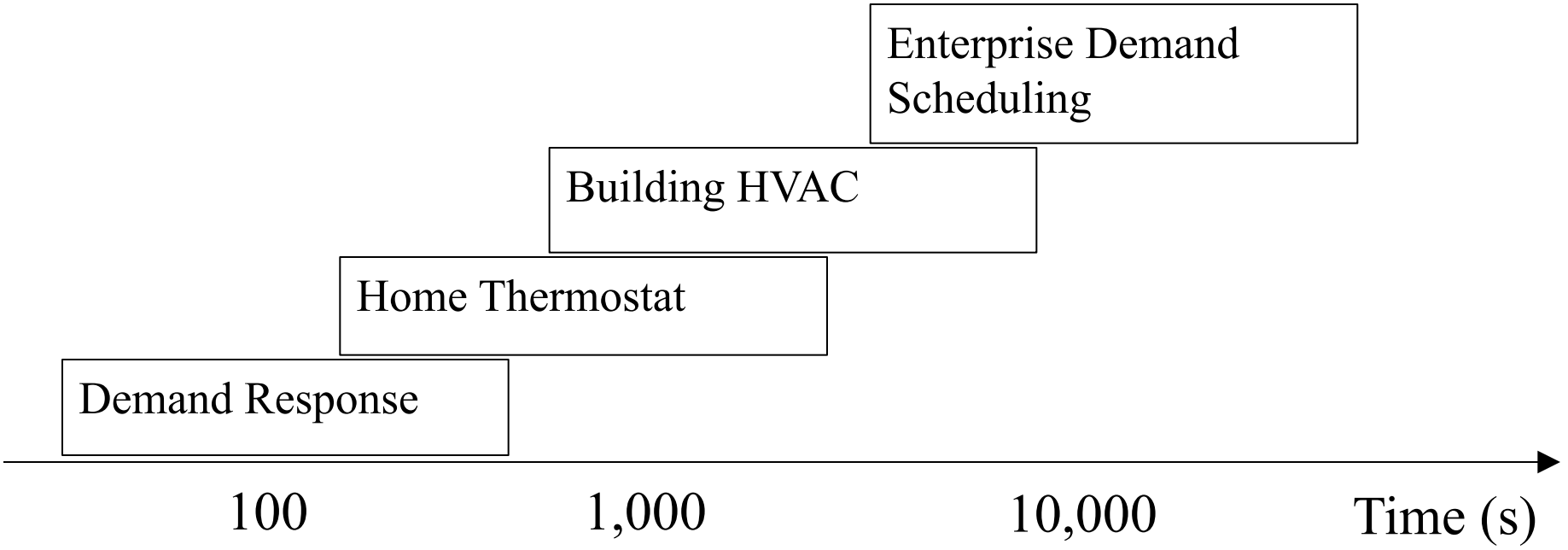
Power Generation Time Scales

- Power generation and distribution
- Energy side



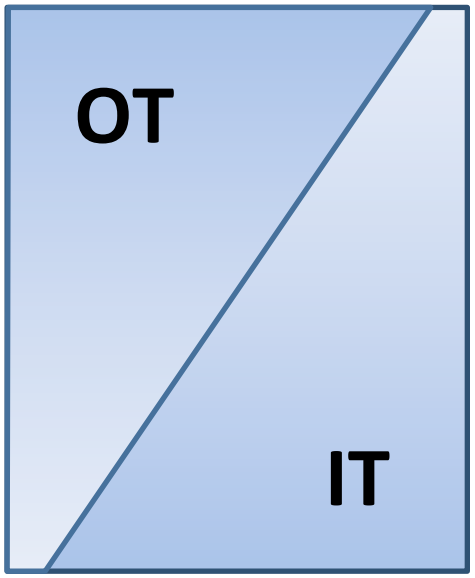
Power Demand Time Scales

- Power consumption
  - DR, Homes, Buildings, Plants
- Demand side



Big Data Analytics

- Feedback Control Functions
- Monitoring and Decision Support Functions
- Data Mining Functions



Data Mining Functions

- Data Exploration
  - Performed interactively
- Model Training
  - Known as system identification in control
- Model Exploitation
  - Estimation, eg, forecasting
  - Decision support, eg, monitoring
  - Control, eg, embedded optimization

Next

- Watch for class website announcements
- Next lecture:
  Dave Mount, General Partner, KPCB! Startup opportunities in IoT