# 21st Century Energy Management

Big Data Analytics

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# Topics

- Problem
- Solution
- PBSE as a powerful enabler

# What Problem are we Addressing?

- Problem Statement: The need for advanced tools that correctly account for the multiple data inputs and parametrics needed for accurate simulation of smart grid operations

# Smart Grid 3.0

- Internet of Things (IoT) paradigm supersedes distribution SCADA
- Significant business drivers for this
  - Integrate high penetrations of DER
  - Optimize real-time distribution operations
  - Improved asset planning and maintenance
  - Improving customer service
  - Extend wholesale market to prosumer
- Enhanced data acquisition key to enabling

**Big data is bigger than you think**

# Platform Grid – Smart Grid 3.0

- Platform Grid – IoT Architecture
- Application of Industrial Internet of Things Technology Concept
- Extending sensing, data, computing, and automation to the edge of the distribution system – distributed intelligence.
- And beyond to the “Prosumer” who wants to actively participate in “our business”.

# D-SCADA and AMI = Bigger Data

| TEP Data Single Instant - Data Elements One Feeder | | | | | | Scaling Over Time - One Feeder | | | Company Scaling to 1 Million Meters | Company Scaling to 10 Million Meters |
|---|---|---|---|---|---|---|---|---|---|---|
| **Owner** | **Asset** | **Quantity Measured** | **No. Meas.** | **No. Assets** | **Total Meas.** | **Time Interval** | **Daily Meas.** | **Yearly Meas.** | **Yearly** | **Yearly** |
| **Utility** | SubTransf | 3 Ph Voltage Hi | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | 3 Ph Voltage Lo | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | 3 Ph Current Lo | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | MVA | 1 | 1 | 1 | 720 | 720 | 262800 | 151121334 | 1511213341 |
| | Fdr Head End | 3 Ph Voltage | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | 3 Ph Current | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | Power Factor | 1 | 1 | 1 | 720 | 720 | 262800 | 151121334 | 1511213341 |
| | | MVA | 1 | 1 | 1 | 720 | 720 | 262800 | 151121334 | 1511213341 |
| | Distr Transf | 3 Ph Voltage Hi | 3 | 291 | 873 | 720 | 628560 | 2.29E+08 | 131928924669 | 1.31929E+12 |
| | | 1 Ph-Grd Volt Lo | 1 | 291 | 291 | 720 | 209520 | 76474800 | 43976308223 | 4.39763E+11 |
| | | KW | 1 | 291 | 291 | 720 | 209520 | 76474800 | 43976308223 | 4.39763E+11 |
| | | KVAR | 1 | 291 | 291 | 720 | 209520 | 76474800 | 43976308223 | 4.39763E+11 |
| | | KVA | 1 | 291 | 291 | 720 | 209520 | 76474800 | 43976308223 | 4.39763E+11 |
| | Feeder Sect's | 3 Ph Current | 3 | 300 | 900 | 720 | 648000 | 2.37E+08 | 136009200690 | 1.36009E+12 |
| | | 3 Ph Voltage Hd | 3 | 300 | 900 | 720 | 648000 | 2.37E+08 | 136009200690 | 1.36009E+12 |
| | Reclosers | 3 Ph Voltage Hi | 3 | 0 | 0 | 720 | 0 | 0 | 0 | 0 |
| | | 3 Ph Voltage Lo | 3 | 0 | 0 | 720 | 0 | 0 | 0 | 0 |
| | | Boost/Buck | 1 | 0 | 0 | 720 | 0 | 0 | 0 | 0 |
| | Capacitor | 3 Ph Voltage | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | | Open/Closed | 3 | 1 | 3 | 720 | 2160 | 788400 | 453364002 | 4533640023 |
| | Fdr Switches | 3 Ph Voltage | 3 | 2 | 6 | 720 | 4320 | 1576800 | 906728005 | 9067280046 |
| | | 3 Ph Current | 3 | 2 | 6 | 720 | 4320 | 1576800 | 906728005 | 9067280046 |
| | | Open/Closed | 3 | 2 | 6 | 720 | 4320 | 1576800 | 906728005 | 9067280046 |
| **TOTAL DISTRIBUTION SYSTEM** | | | | | **3879** | | **2792880** | **1.02E+09** | **5.862E+11** | **5.862E+12** |
| **Customer** | Meter | 1 Ph Voltage | 1 | 1739 | 1739 | 96 | 166944 | 60934560 | 35040000000 | 3.504E+11 |
| | | 1 Ph Current | 1 | 1739 | 1739 | 96 | 166944 | 60934560 | 35040000000 | 3.504E+11 |
| | | KW | 1 | 1739 | 1739 | 96 | 166944 | 60934560 | 35040000000 | 3.504E+11 |
| | | KVAR | 1 | 1739 | 1739 | 96 | 166944 | 60934560 | 35040000000 | 3.504E+11 |
| | | KWH | 1 | 1739 | 1739 | 96 | 166944 | 60934560 | 35040000000 | 3.504E+11 |
| | | Other | 6 | 1739 | 10434 | 96 | 1001664 | 3.66E+08 | 210240000000 | 2.1024E+12 |
| **TOTAL CUSTOMER METERS** | | | | | **19129** | | **1836384** | **6.7E+08** | **3.8544E+11** | **3.8544E+12** |
| **TOTAL DISTR & CUSTOMER** | | | | | **23008** | | **4629264** | **1.69E+09** | **9.7164E+11** | **9.7164E+12** |
| | **SIZING Data Volumes** | | | | | | | | | |
| | | # Data Elements | | | | | **4629264** | **1.69E+09** | **9.7164E+11** | **9.7164E+12** |
| | | # Bytes - Low Side | | | | | **18517056** | **6.76E+09** | **3.88656E+12** | **3.88656E+13** |
| | | # Bytes - High Side | | | | | **46292640** | **1.69E+10** | **9.7164E+12** | **9.7164E+13** |
| | | TeraBytes - High Side | | | | | **4.6293E-05** | **0.016897** | **9.71639655** | **97.1639655** |

**For 1 million meter utility – 10TB per year**

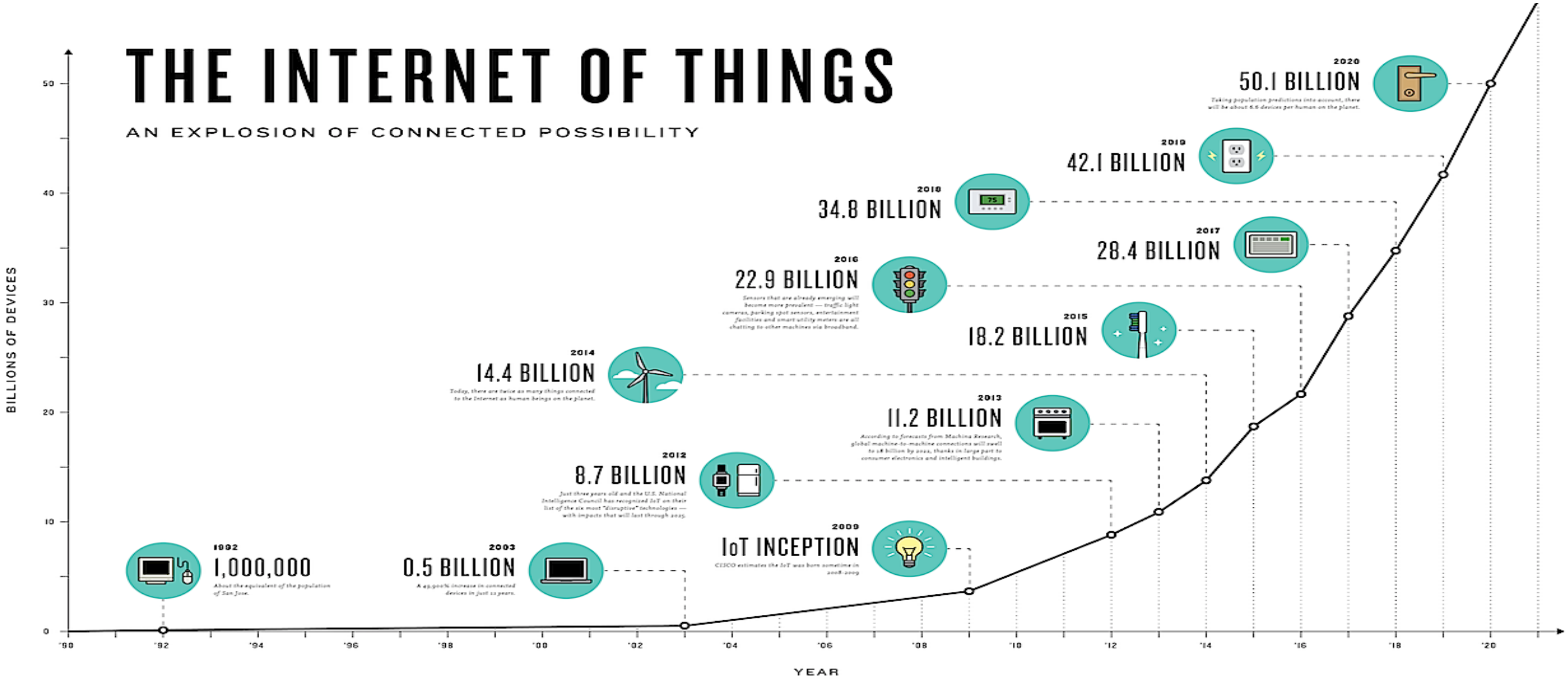
# Only The Start To Big Data

- Data Sources – Minimum In Future
  - D-SCADA
  - AMI Smart Meters (hrly)
  - Asset Monitoring – substation and feeder
  - Weather – temp, humidity, wind, solar, etc.
  - PMU
- IoT Will Bring More Data
  - Bldg. and Homes
    - DER – inverters and control
    - EV – inverters and control
    - Micro-Grids
    - In-premise services including DR

***5-10 Times The SCADA - AMI Totals***

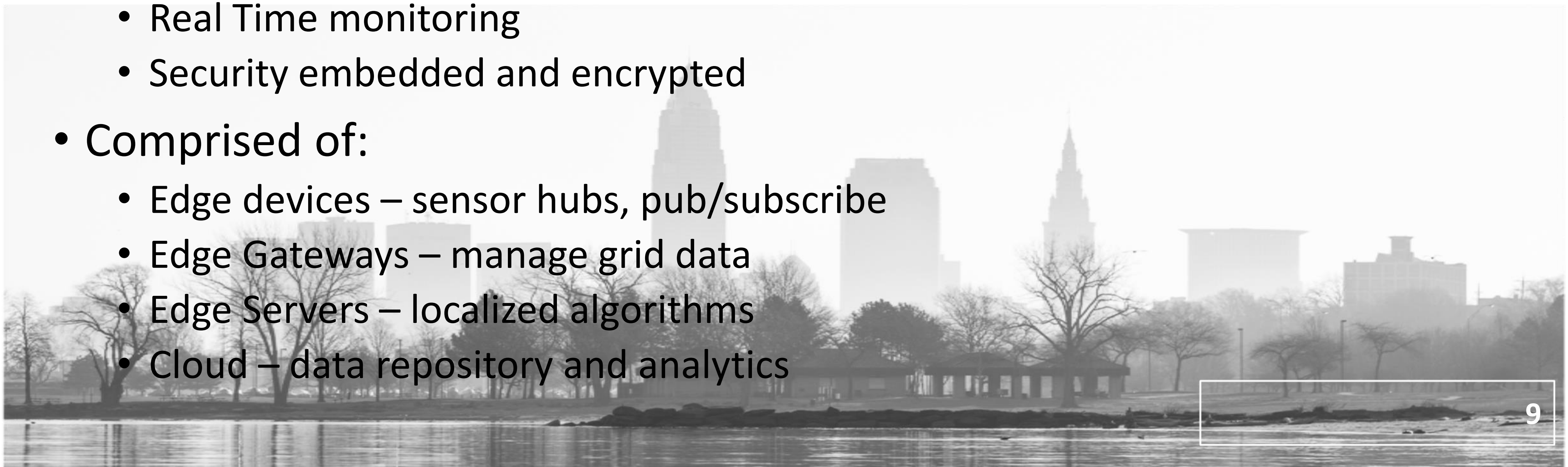
# Made Feasible by IIoT

*50 Billion Sensors by 2020*

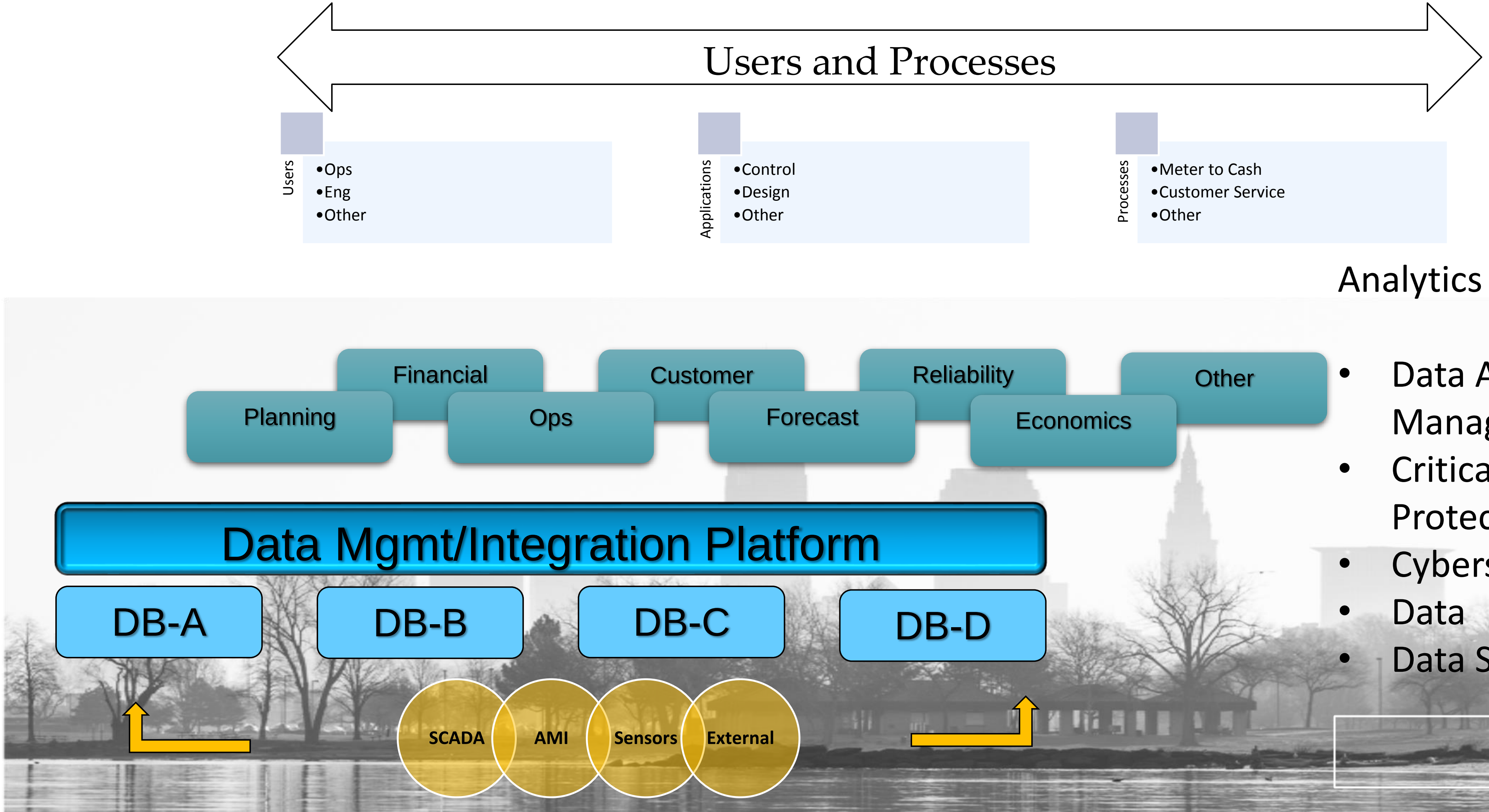


# The Platform Grid – Smart Grid 3.0

- Platform Grid is:
  - Open and interoperable
  - Scalable to millions of points
  - Distributed intelligence
  - Real Time monitoring
  - Security embedded and encrypted
- Comprised of:
  - Edge devices – sensor hubs, pub/subscribe
  - Edge Gateways – manage grid data
  - Edge Servers – localized algorithms
  - Cloud – data repository and analytics



# Your Challenge – Making Data An Enterprise Resource



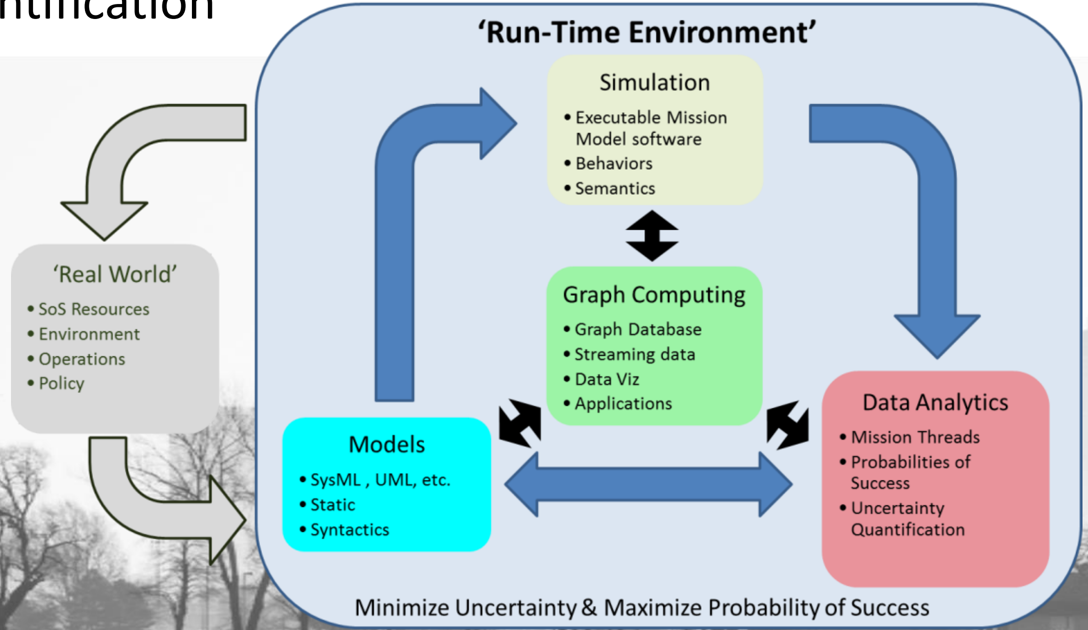

Analytics

- Data Access Management
- Critical Infrastructure Protection
- Cybersecurity
- Data
- Data Sources

# How are we going about Addressing the Problem?

# The Concept

- Iterative **Looping** between **Modeling, Simulation and Data Analytics**
- **Multiple iterations** used to reduce uncertainty and maximize probability of meeting mission goals
- Enabled and empowered by running on a common **graph computing Infrastructure** to address both structured and **semi/unstructured use cases**
- Used the PNNL GridLab-D sim engine, and the SNL Dakota tool to drive optimization and uncertainty quantification




Current state-of-art is to integrate only two blocks at a time using relational data architectures (structured data) that are not extensible with increasing complexity (think McCabe's Cyclomatic number)

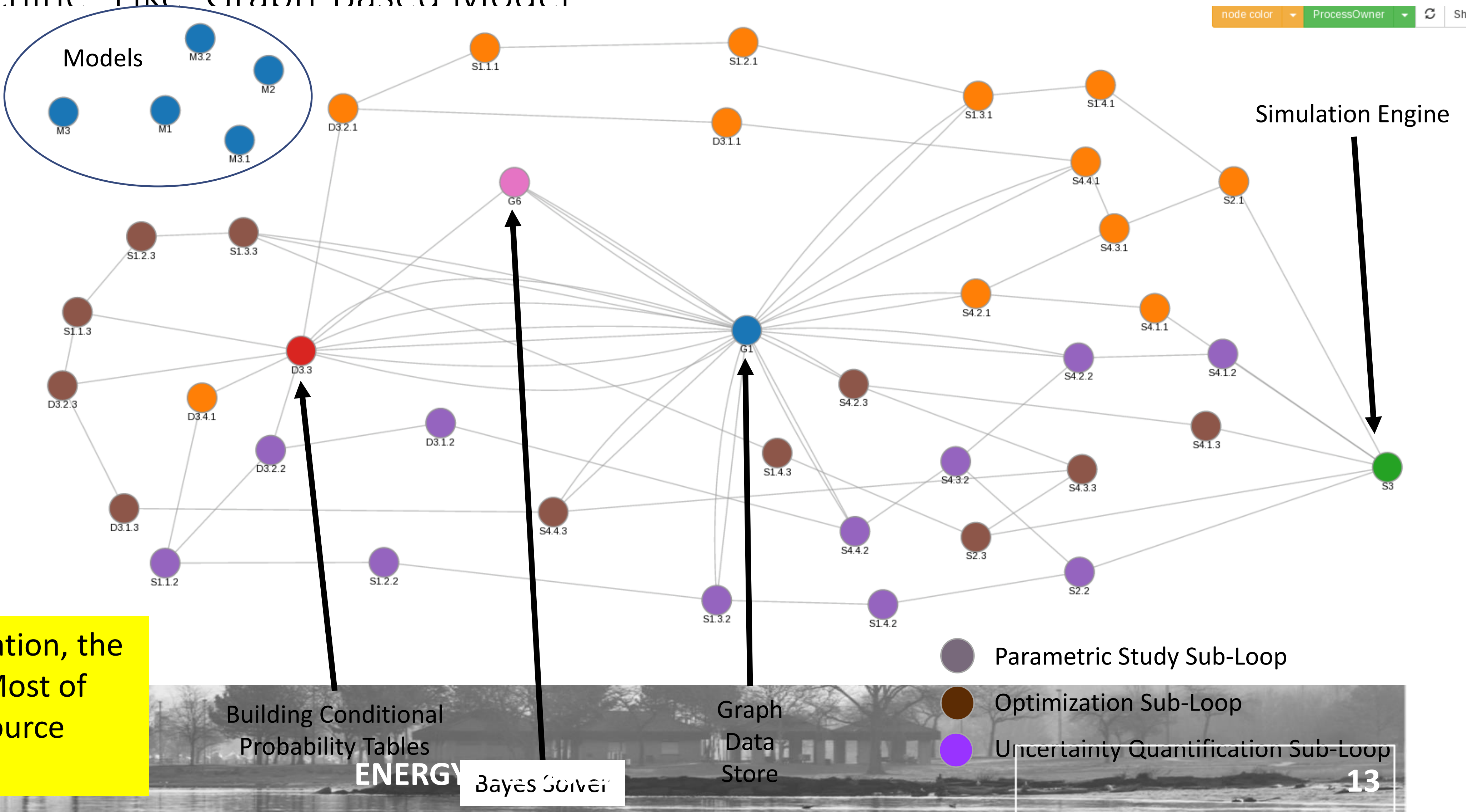
# The Implemented Architecture

## A State Machine-'Like' Graph-Based Model

**Assume a single, given:**

- Mission Environment (M1)
- Model Under Test (M2)
- Mission Model (M3)
- Mission Goals (M3.1)
- Mission Threads (M3.2)

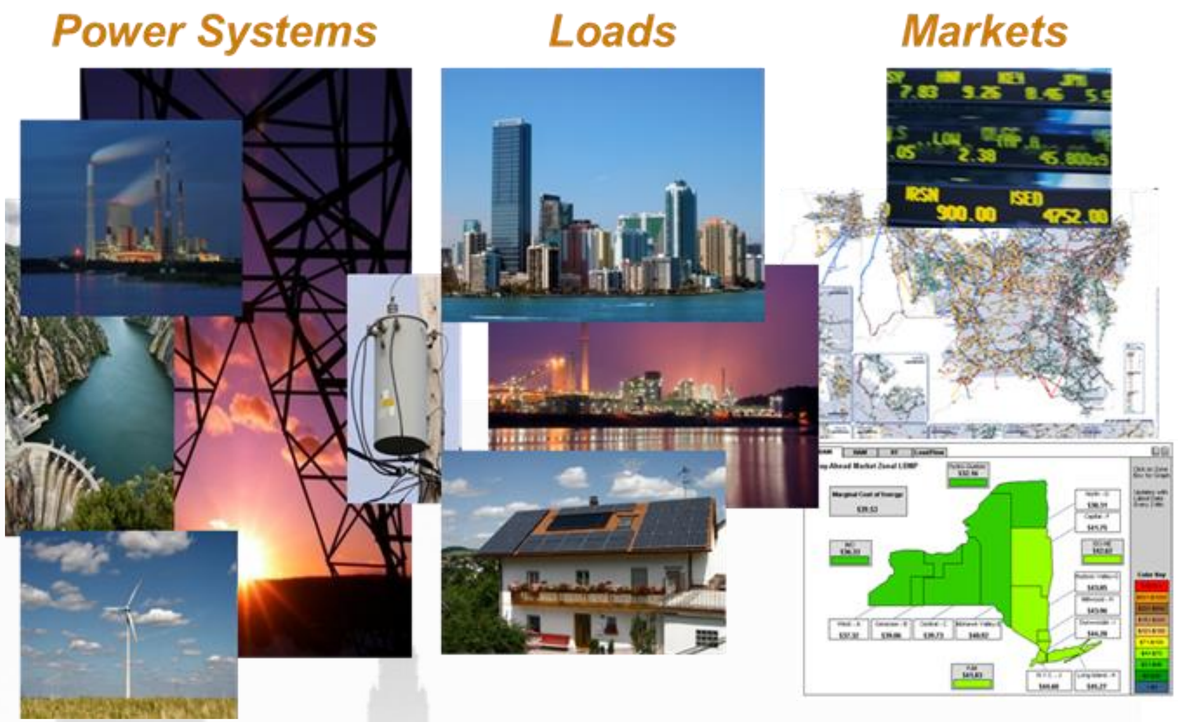
The simulation engine, graph data store, CPT tables and the Bayes Solver are common to all three sub-loops




The focus is on integration, the edges, of the graph. Most of the nodes are open source software.

# U.S. Department of Energy Small Business Technology Transfer (STTR) Program – 2016

- **PSG awarded 2016 STTR Grant ($150K)**
  - **Topic: Big Data Technologies**
- **Proposed Objective(s) Leveraging our Power & Energy Distribution Simulation**
  - **Decision optimization in electric utility distribution systems**
  - **Scale to Big Data Volumes**
  - **Study effects of high PV penetrations using a real distribution system model**
  - **Experiment with Big Data Analytics (Uncertainty Quantification)**
  - **Prototype distribution system control method**

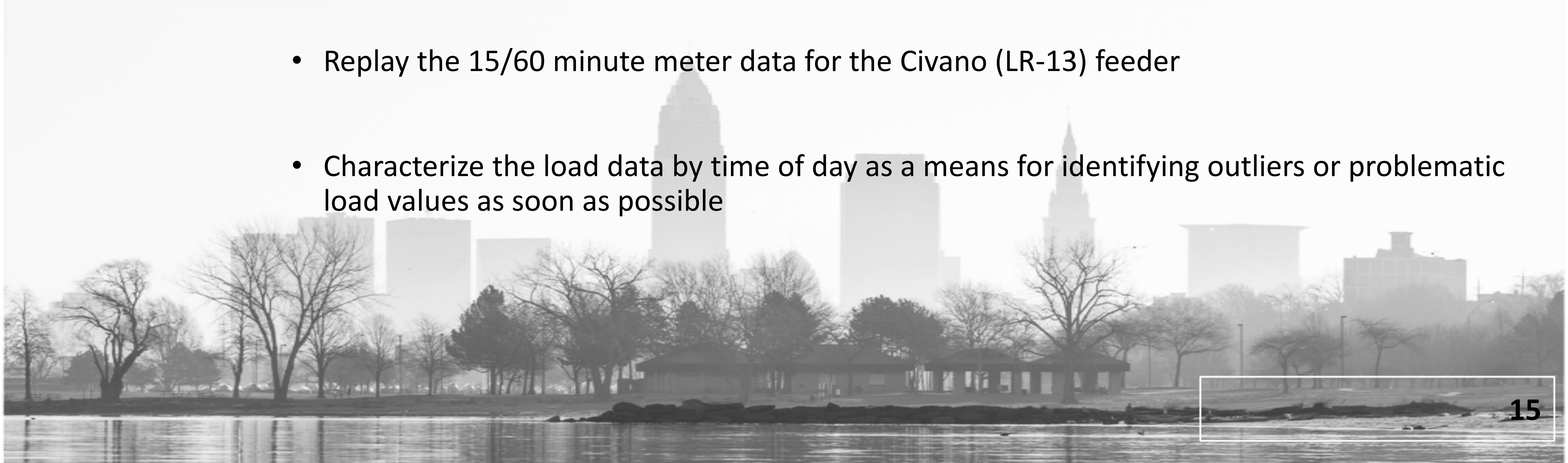



Power & Energy Simulator shows effect of Renewable Power on the Grid

# TEP Project Goals

## Using DOE grant PSG will develop a prototype application using a graph database to provide TEP the capability to:

- Perform load analysis and forecasting (simulation)
- Visualize the 15/60 minute meter data for the Civano (LR-13) feeder
- Replay the 15/60 minute meter data for the Civano (LR-13) feeder
- Characterize the load data by time of day as a means for identifying outliers or problematic load values as soon as possible



# Integration Work Performed

- Independent data sources
  - GIS
    - Access Synergi DB
    - Synergi line dump
    - Transformer and Meter position data
  - MDM
    - Service point load and generation data for May 2016
- Utilized sequence of database operations:
  - Created set repeatable SQL operations to take TEP inputs and create tables needed for rapid model generation
  - TEP will need to perform these tasks to create a rapid prototyping modeling environment

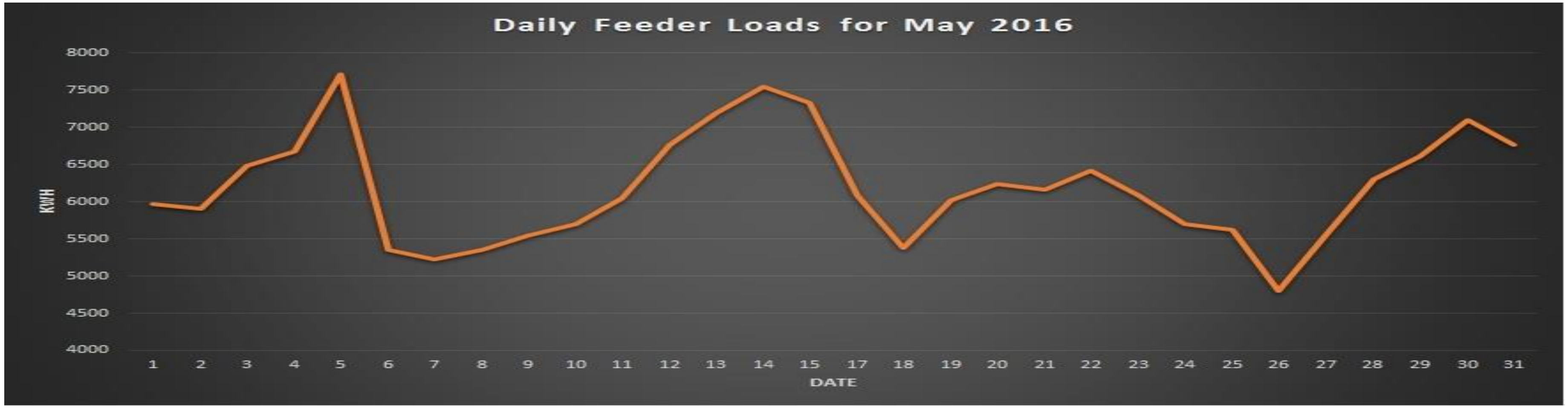
# Modeling Work To Date

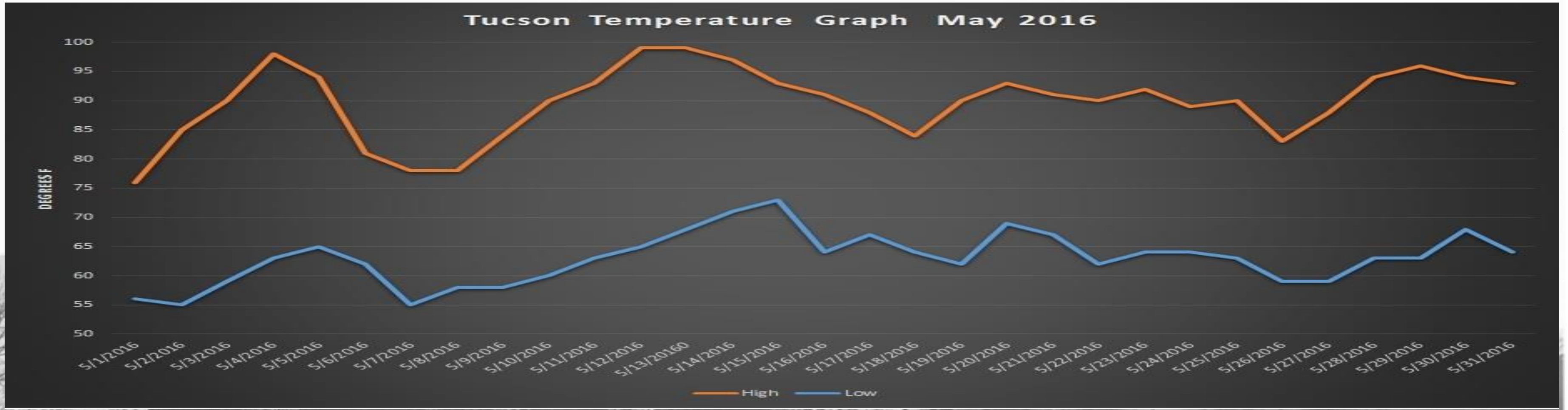
- Portion of Los Realos 13 Subsection
  - 4522 Line Sections
  - 161 Transformers
  - 836 Residential Loads
  - 96 Solar Generators

- Modeling activities to date:
  - Processed May daily data to populate transformer loads
  - Processed average monthly load data for each service point
  - Solar penetration studies:
    - Using average daily loads and solar generation
    - Incremented solar penetration by 10% from current (15%) to 100%

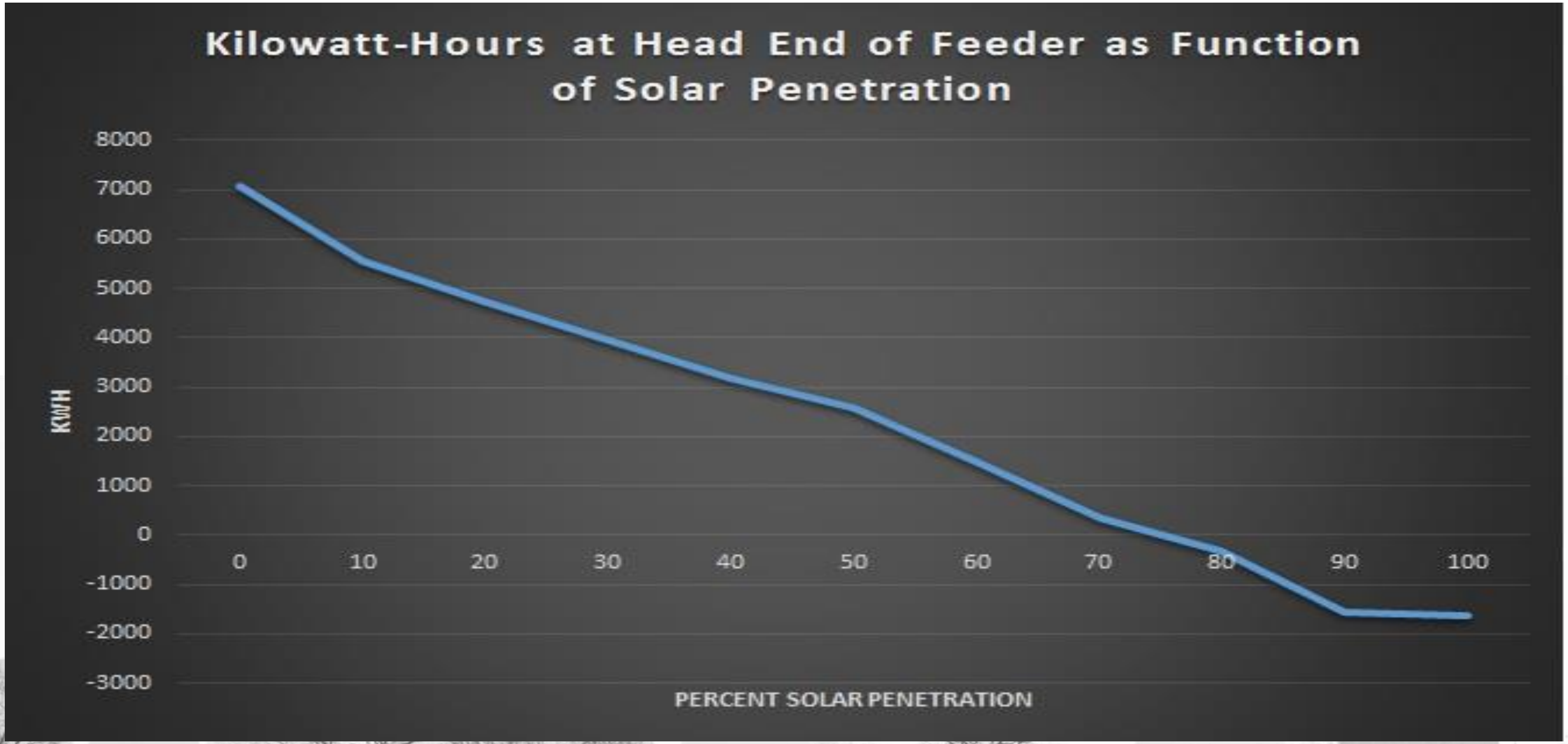
- Model Validation

- Modeled Feeder Loads vs May Temperatures



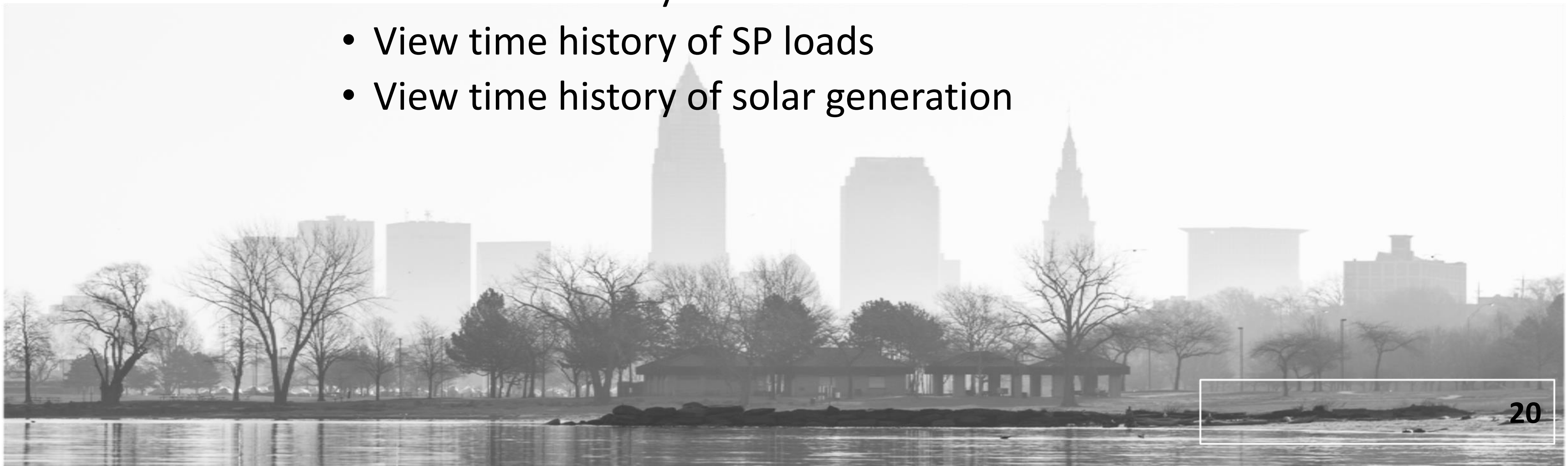



- Modeled Feeder Loads vs Solar Penetration

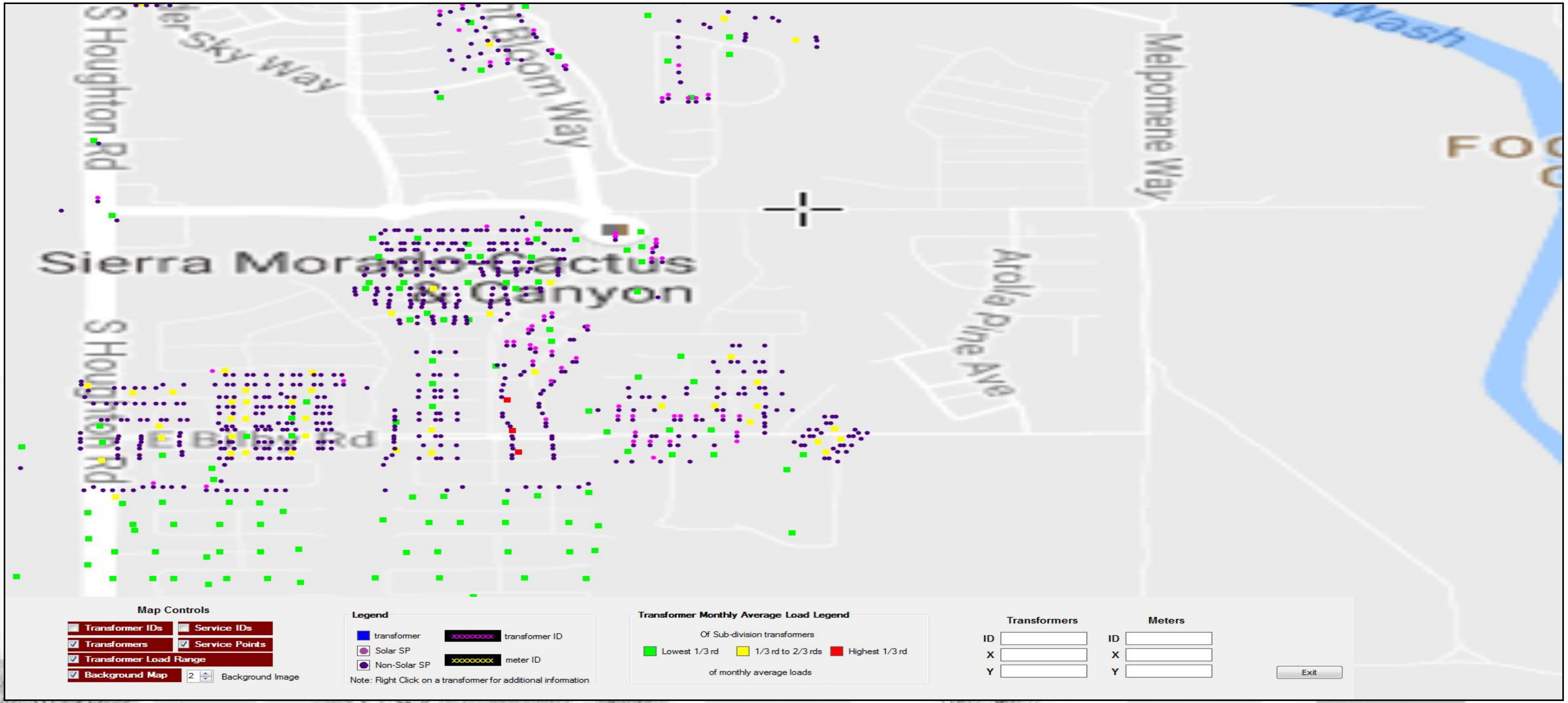


# Visualizer…..

- GIS Display of Transformers and Service Points (SPs)
- SPs color-coded for solar and non-solar
- Drill-down capability for each transformer
    - GIS view of all transformer connections
    - View time history of transformer total load
    - View time history of SP loads
    - View time history of solar generation



# Visualizer…..


S Houghton Rd
Melpomene Way
Sierra Morado Cactus & Canyon
Arolla Pine Ave
Map Controls
Transformer IDs
Service IDs
Transformers
Service Points
Transformer Load Range
Background Map
2
Background Image
Legend
transformer
Solar SP
Non-Solar SP
transformer ID
meter ID
Note: Right Click on a transformer for additional information
Transformer Monthly Average Load Legend
Of Sub-division transformers
Lowest 1/3 rd
1/3 rd to 2/3 rds
Highest 1/3 rd
of monthly average loads
Transformers
Meters
ID
X
Y
Exit

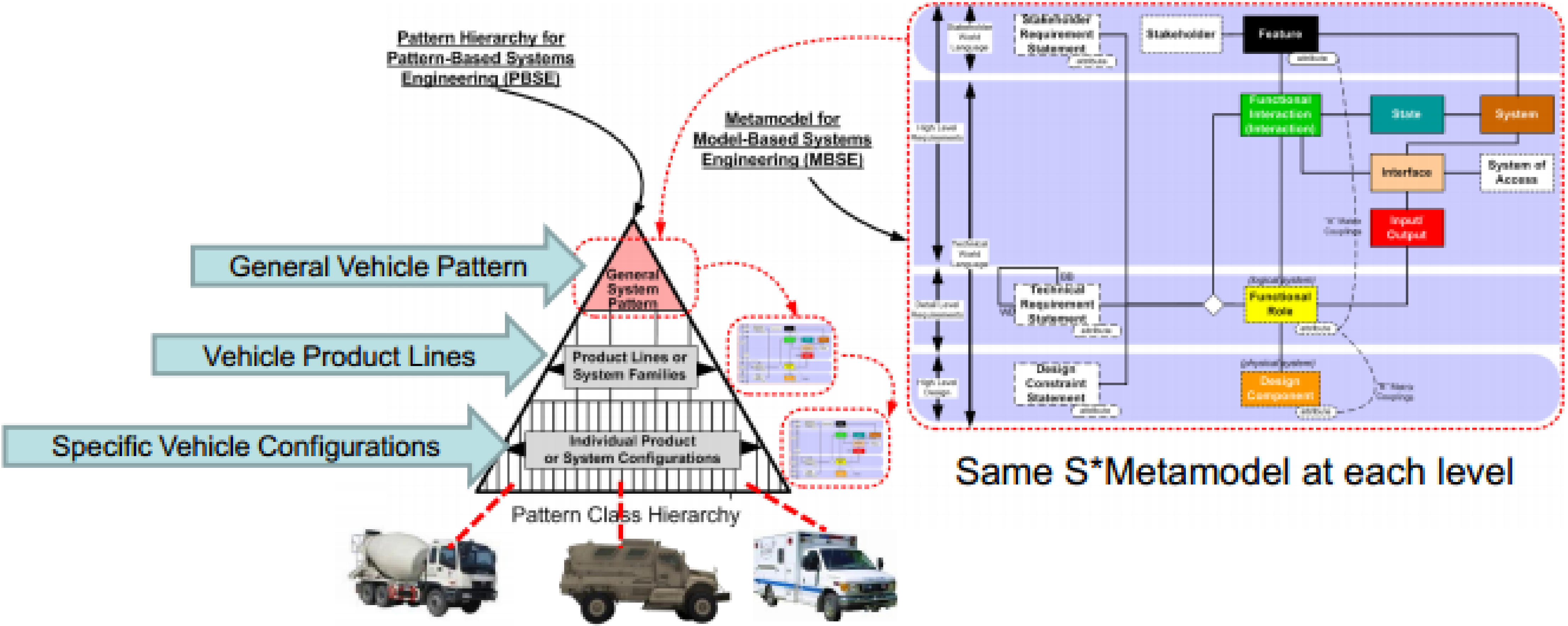
# Getting Serious about Big Data

- Add a Big Data Dimension to an already complex problem

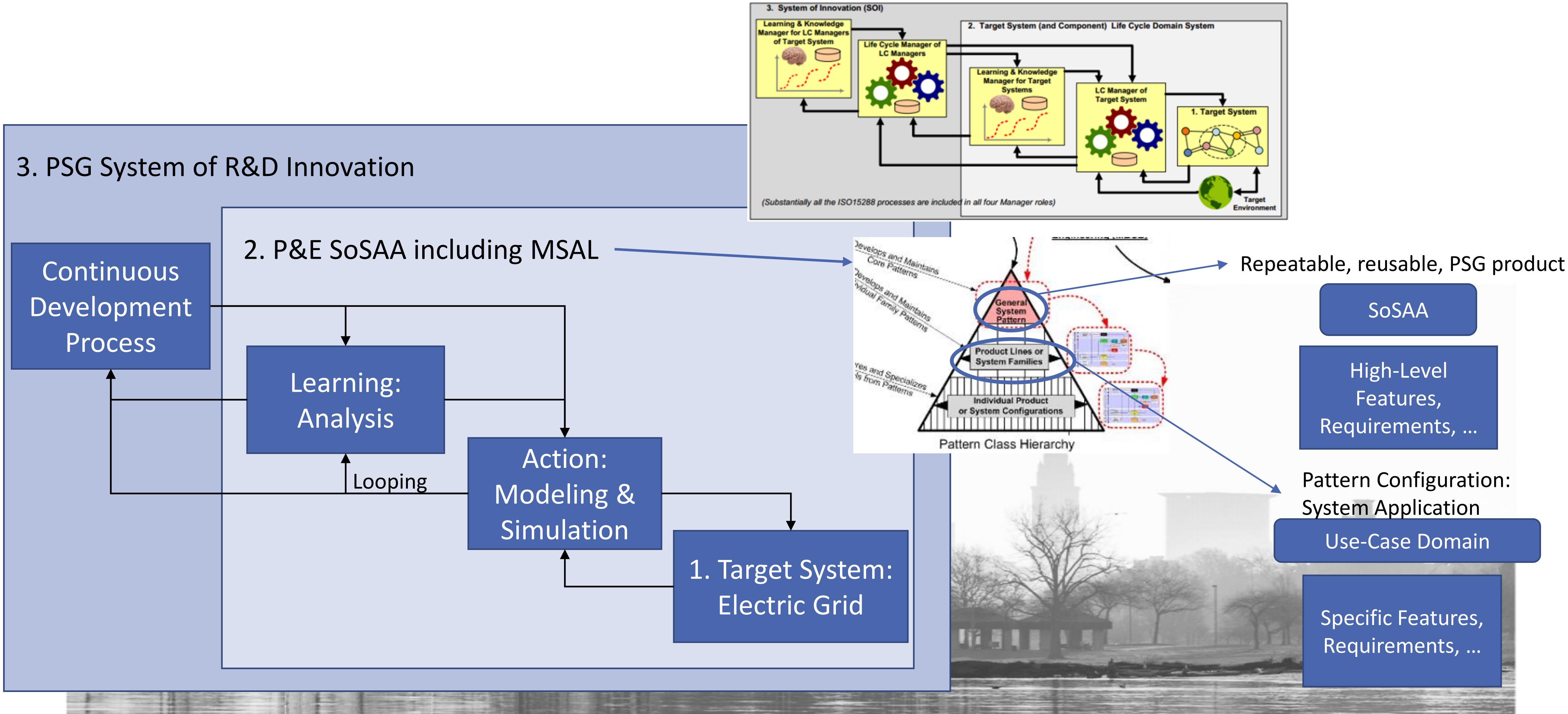
# Pattern Based Systems Engineering

- An approach that fits the complexity and need for reconfigurable, repeatable solutions based on patterns

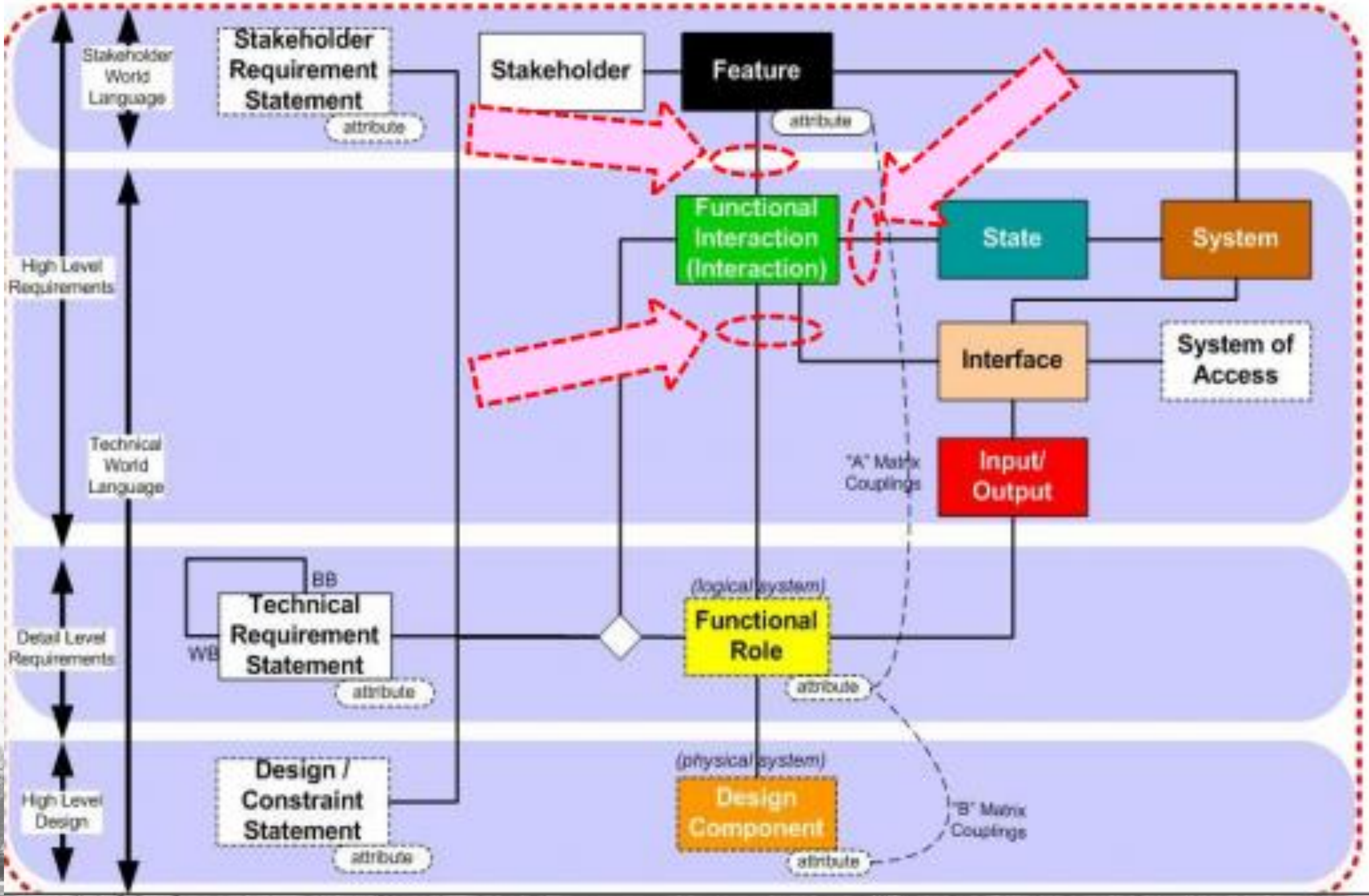
- An **S* Pattern** is a configurable, re-usable S* Model. It is an extension of the idea of a Platform (which is a configurable, re-usable design) or Enterprise / Industry Framework.
- The Pattern includes not only the physical Platform information, but all the extended system information (e.g., pattern configuration rules, requirements, risk analysis, design trade-offs & alternatives, decision processes, etc.):



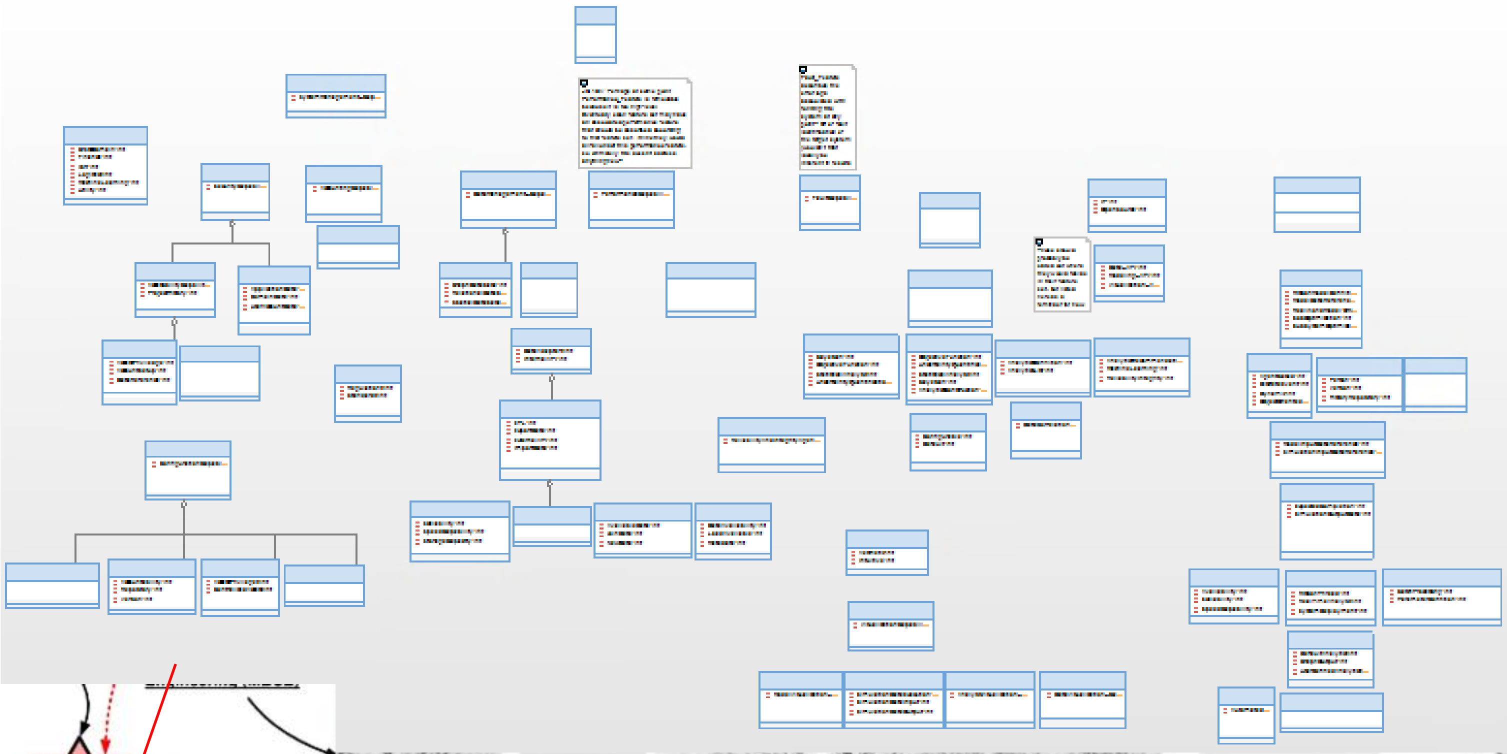
# v.beta Internal PSG Use of PBSE

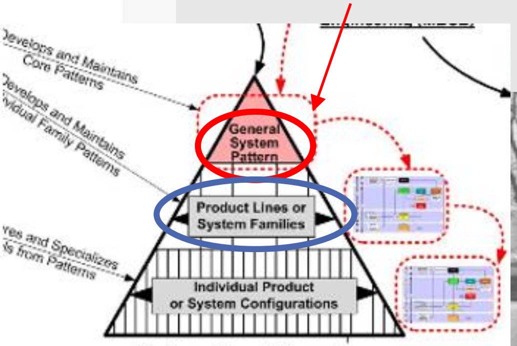


- The three traces to Interactions, seen in the S*Metamodel:



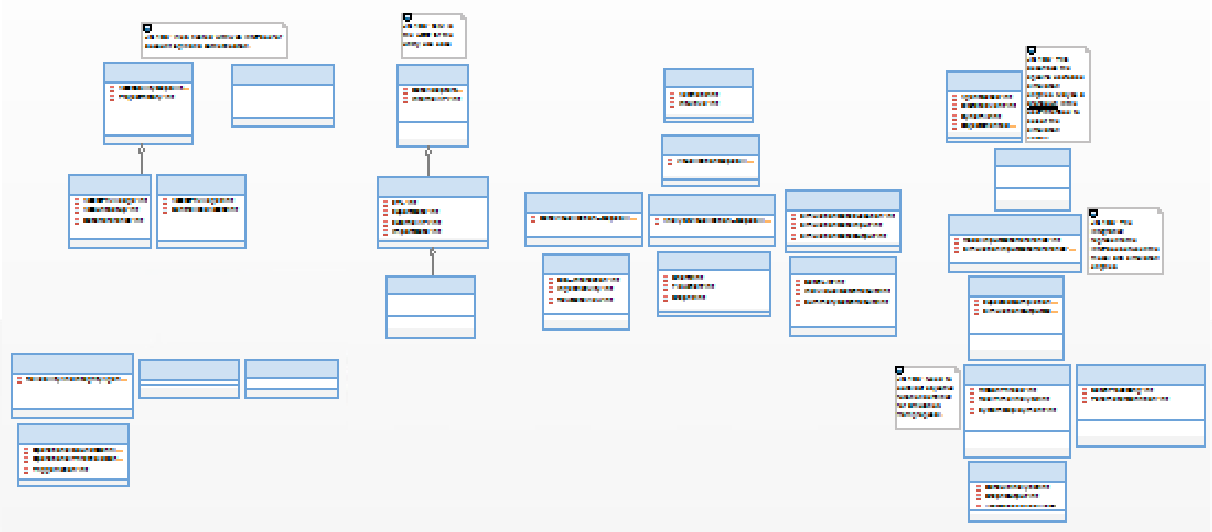
# General System Pattern Features (Pattern Management)

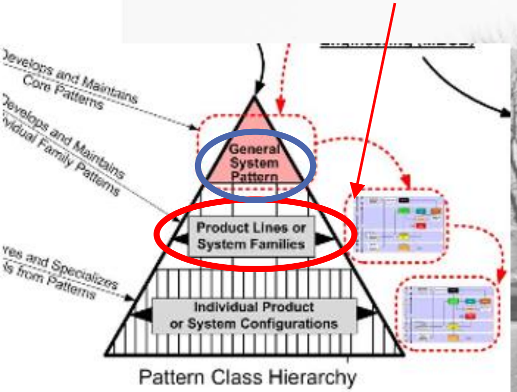





- Feature Groups
  - Data Management
  - Big Data Performance
  - Modeling and Simulation
  - Advanced Analytics
  - *Multi-Domain Use-Case*
  - Security
  - Configurability
  - Compliance
  - Accounting
  - Fault Mitigation

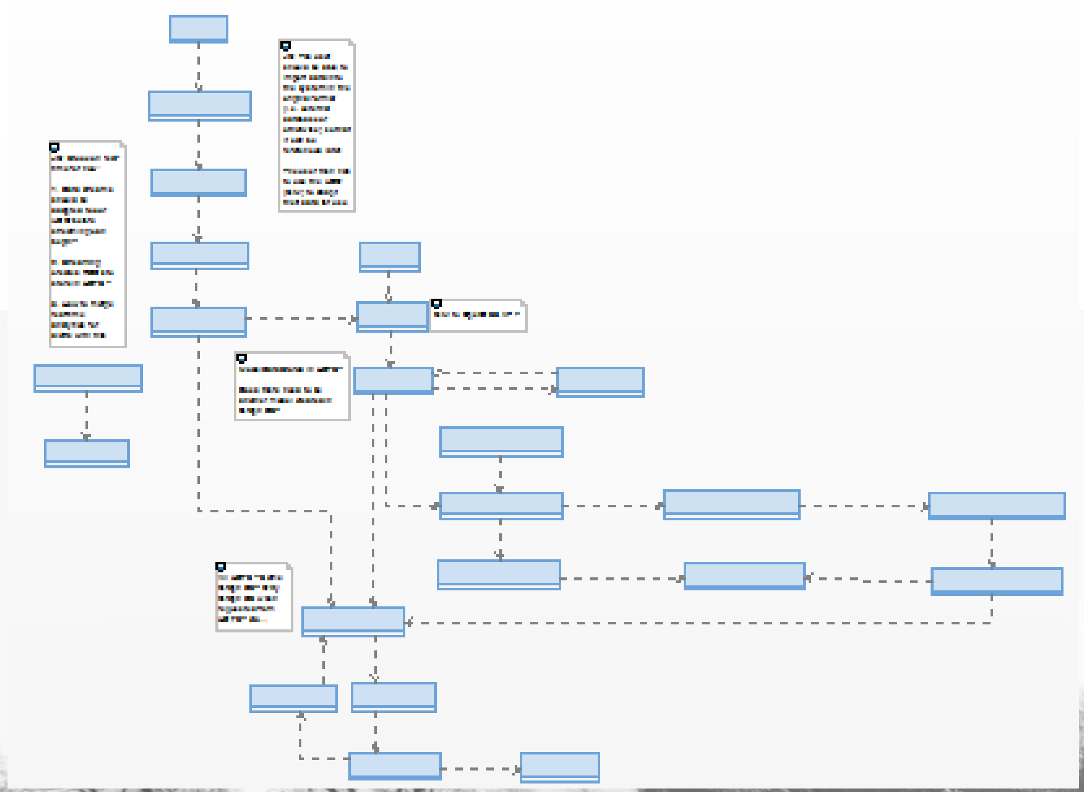
# Product Line - Domain System Pattern Features (Pattern Configuration)






- Feature Groups Focus
  - Data Management
  - Big Data Performance
  - Advanced Analytics
  - Modeling and Simulation
  - Configurability

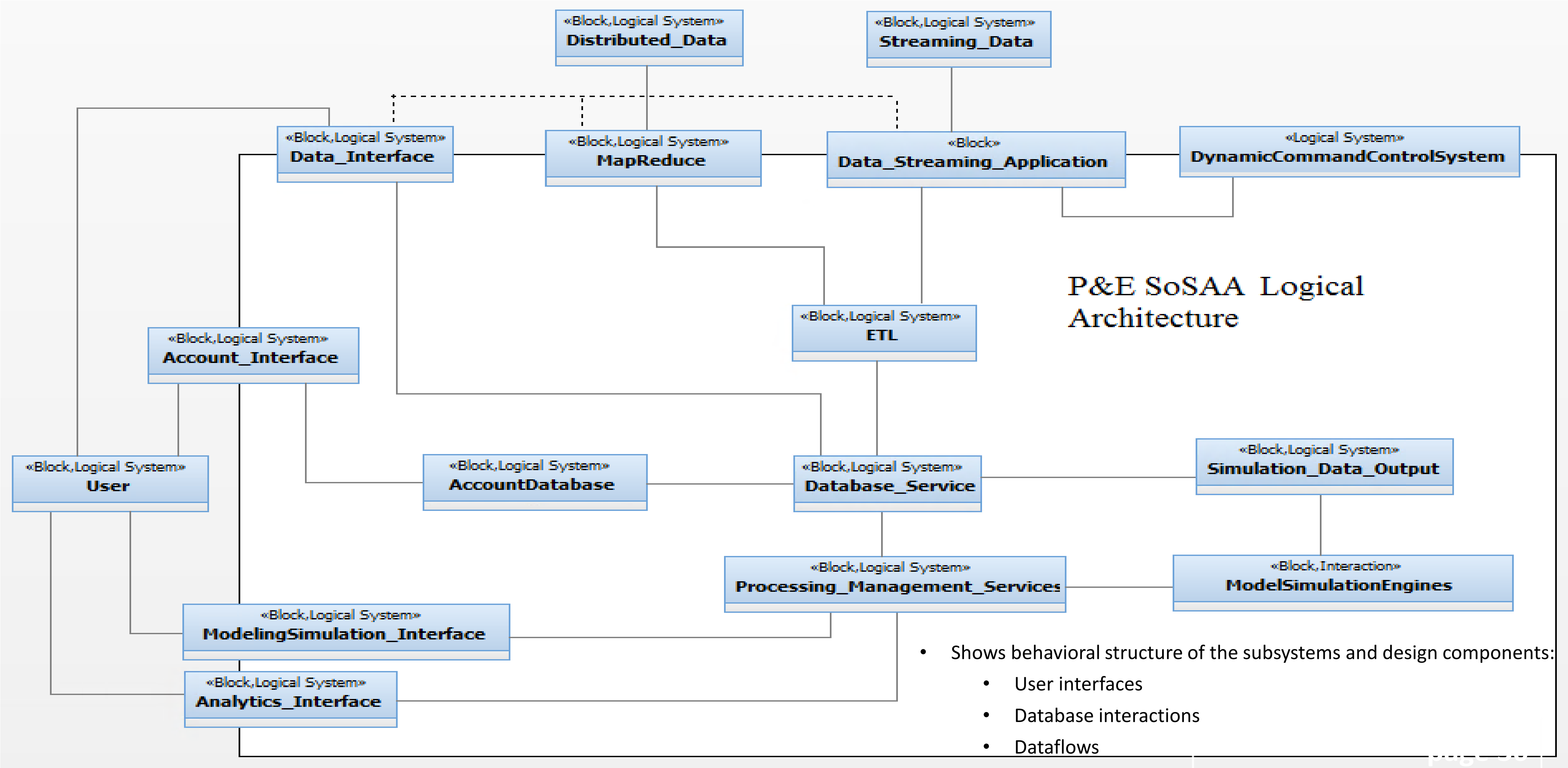
# Product Line State Model



- State model provides a view of scenarios for the product – where the product line is configured, and scenarios are validated

# Product Line Logical Architecture

energytech 2017



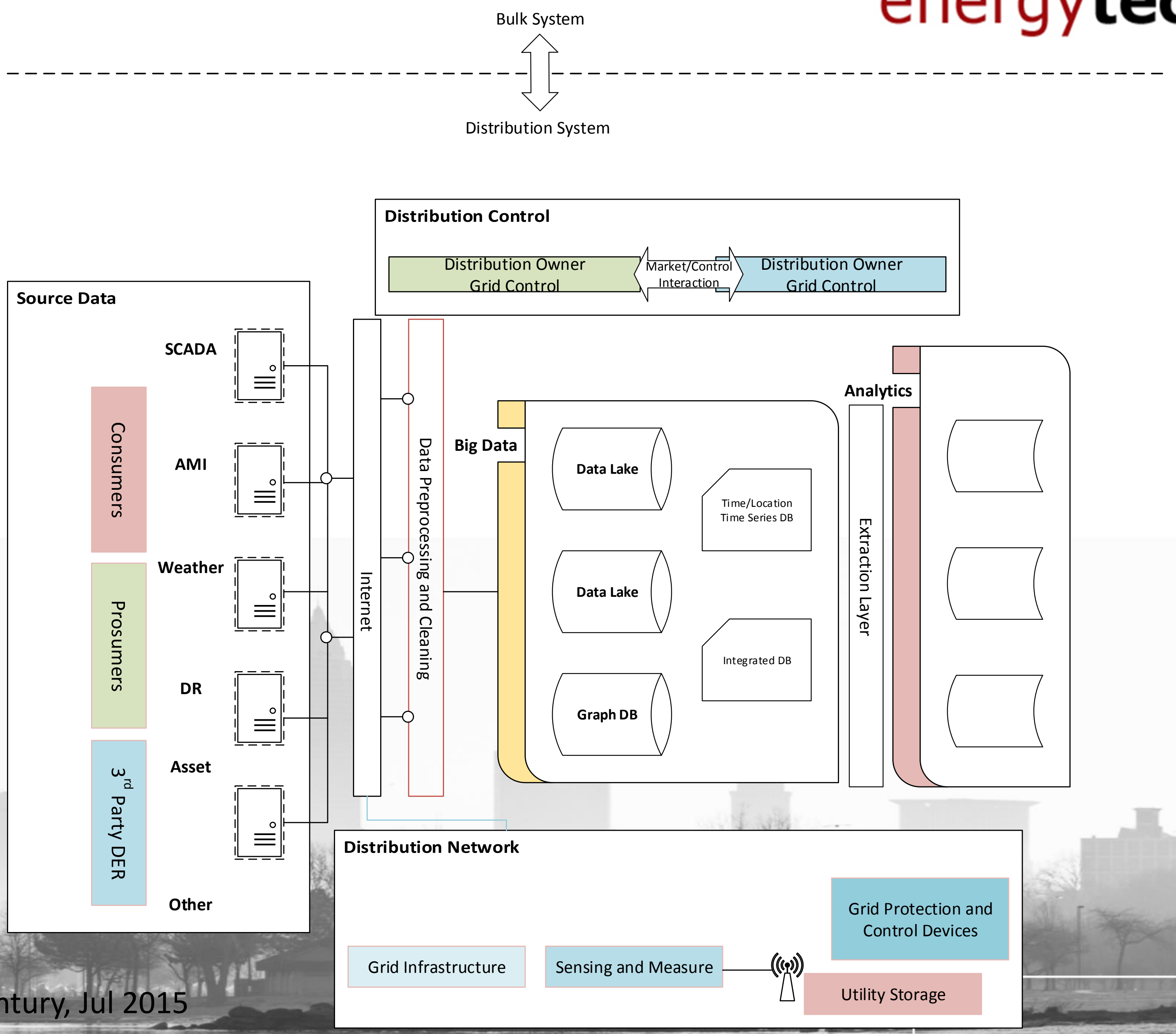

- Shows behavioral structure of the subsystems and design components:
  - User interfaces
  - Database interactions
  - Dataflows

# Interactions – Requirements!


- Iterating through these models helps accelerate interactions and requirements discovery

| | | | Actors | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| REQID | Interaction Name | Interaction Definition | User | External Database | Streaming Data | Account Database | External UDO API | Internal UDO API | OpenDSS | Database System |
| 23-29, 31-33, 41, 42 | Convert External Data | External data shall be converted from external HDFS sources to the UDO (including CIM definitions) for use in the internal application. | x | x | | | x | | | x |
| 35, 59, 68-69, 73-74 | Convert Internal Data | Internal data shall be converted from the internal UDO to OpenDSS model constructs. | x | | | | | x | | x |
| 49, 51 | Execute Simulation | Simulation shall be executable through OpenDSS. | x | | | | | | x | |
| 60-63 | Reference Data | Data shall be traceable to the earliest source of creation or ingestion into the system. This includes inputs and outputs. | | x | x | | x | x | | x |
| 51, 57 | Loop Execution | The application shall be able to run batch simulations. | | | | | | x | x | |
| | Verify User | The user must be given permission to access the authorized parts of the system. | x | | | x | | | | |
| 10, 21 | Store Data | Data shall be stored in the application for availability. | x | | | | | | | x |
| | Export Data | Available data can be exported from the application. | x | | | | x | | | x |
| 43 | Ingest Data | External data can be ingested into the system. | x | | | | x | | | x |

# Reference Architecture*




*PNNL, A Reference Model for Distribution Grid Control in the 21st Century, Jul 2015

# Summary

- Use of PBSE allows us to leverage fundamental research into a configurable and repeatable solution
- Get at the things that matter (features and interactions) ahead of formalized requirements definition (constant change)
- Communicate what we are building
- Apply agile systems and software development methods

# References


1. W. Schindel and T Peterson, "Introduction to Pattern-Based Systems Engineering (PBSE): Leveraging MBSE Techniques", Tutorial at INCOSE Great Lakes Regional Conference, September, 2016.
2. Schindel, W., "System Interactions: Making The Heart of Systems More Visible", Proc. of INCOSE Great Lakes Regional Conference, 2013.