Smart Energy Campus Program Overview

February 11, 2014

Facilities Management

Georgia Tech School of Electrical and Computer Engineering

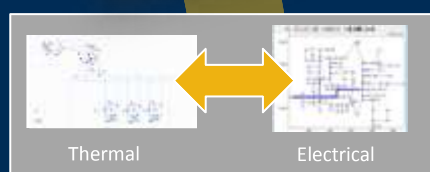
Georgia Tech Aerospace Systems Design Laboratory

Georgia Tech Smart Energy Campus

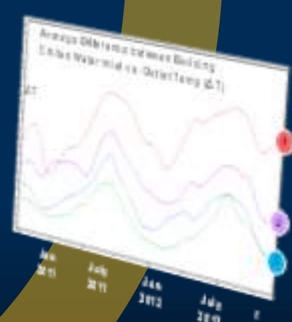
GT Campus Data

Visual Analytics
Situational Awareness

Virtual Campus:
real time data feeding into predictive models to provide situational awareness



Integrated
Simulation
Environments



Automated performance assessment via statistical analysis

Cost and ROI estimations on energy technologies and building retrofitting

- Integrates:
  - Disciplines
  - Data
  - Scales
  - Physical layers
- Enables automated assessment
- Provides: A facility for enabling campus planning for a 20-30 year horizon

Georgia Tech | Aerospace Systems Design Laboratory

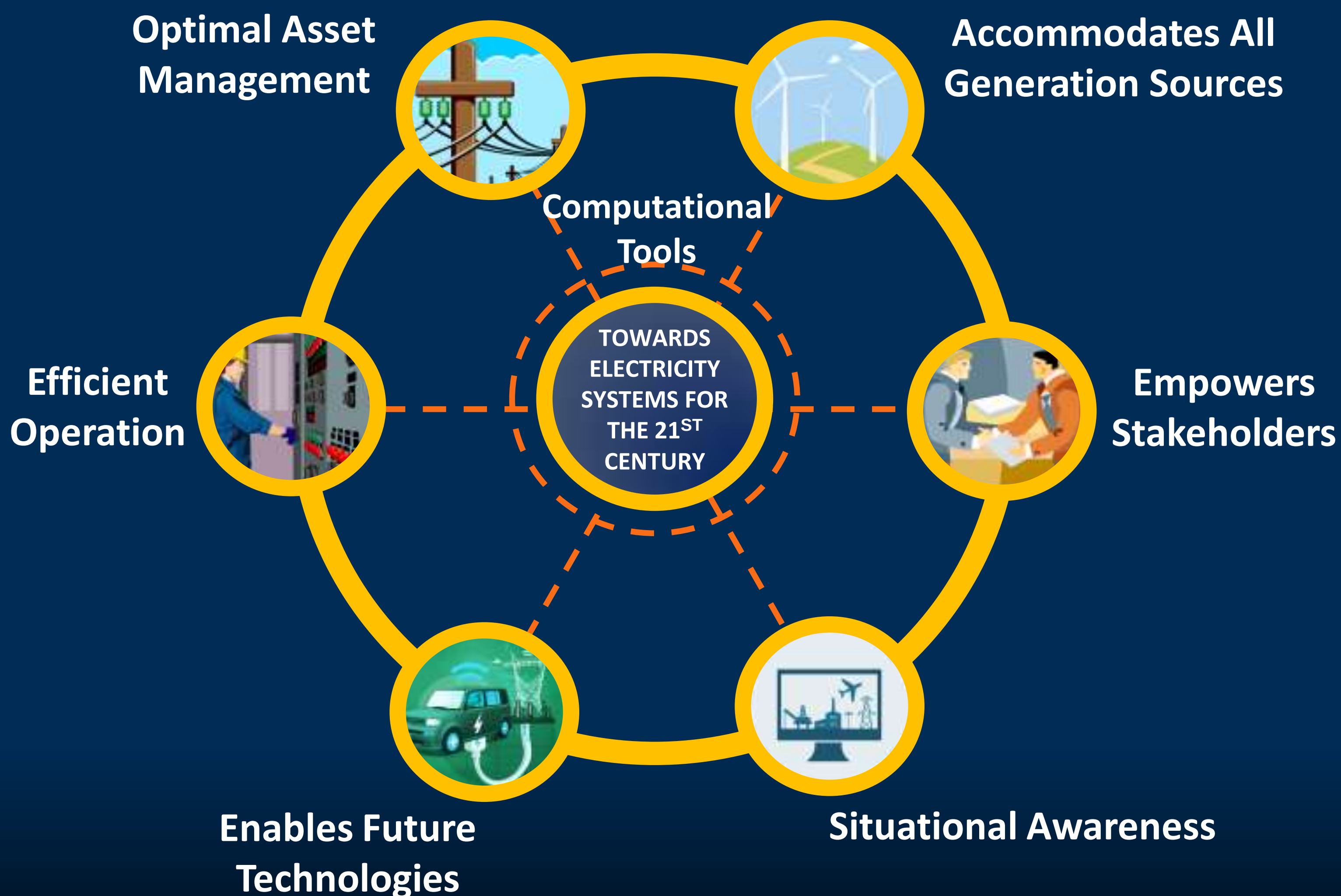
Smart Grid Newsflashes

Under Threat, Germany's Second-Biggest Utility Says It Will Create a New 'Prosumer Business Model'

Advanced Computational Electricity Systems Laboratory

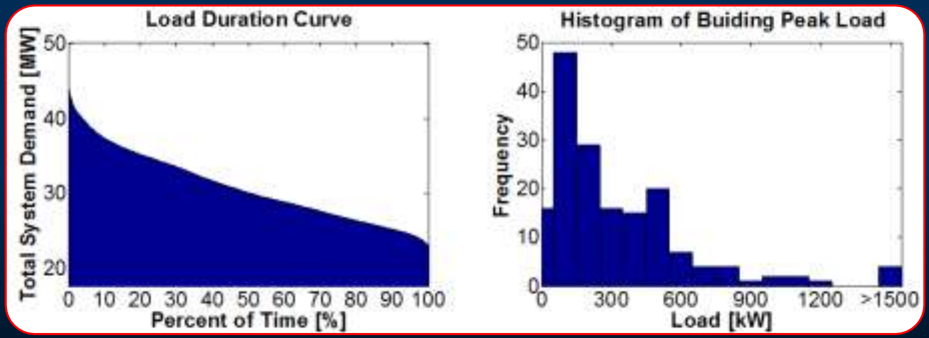
ELECTRICAL SYSTEM

Smart Energy Campus

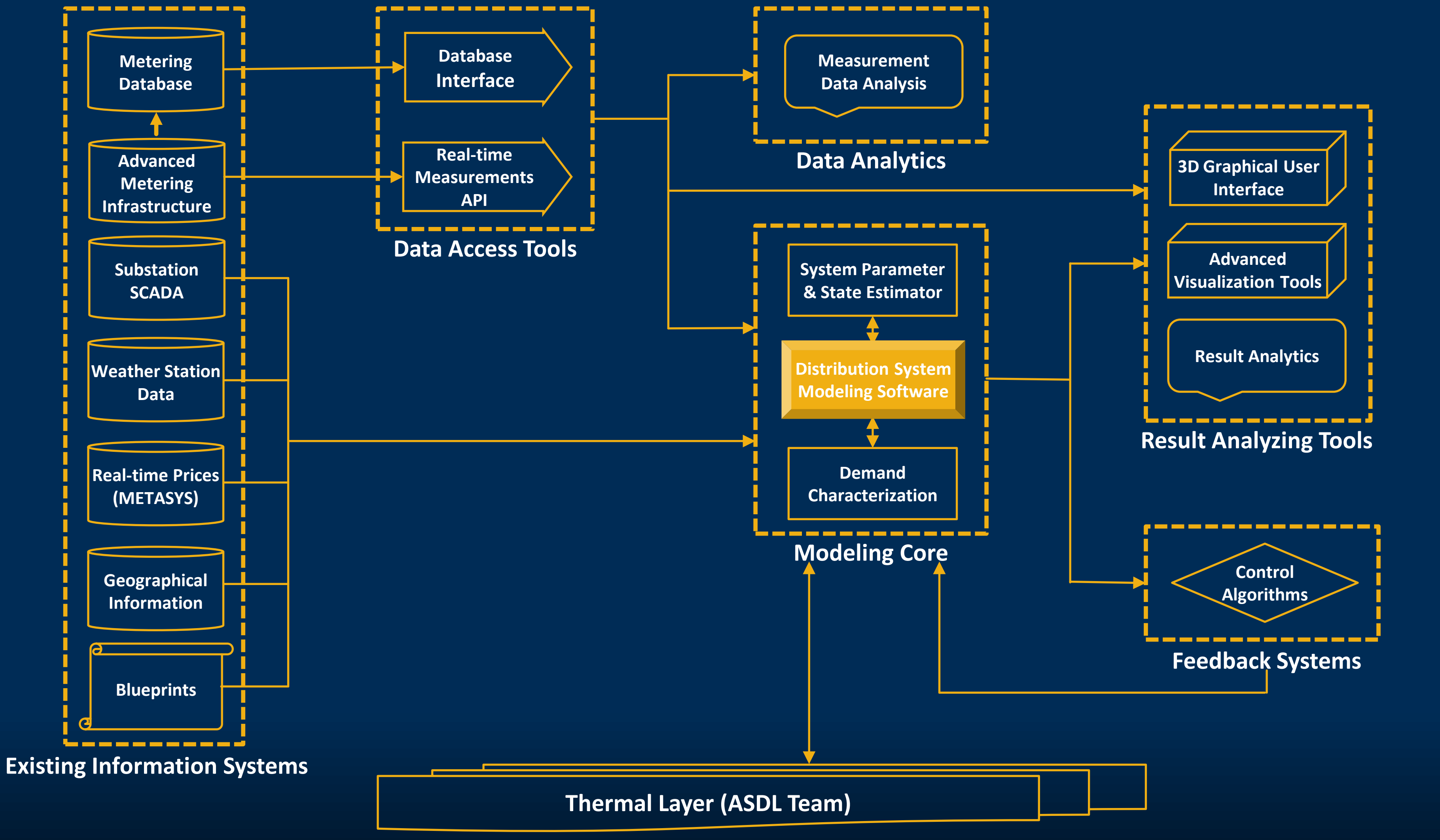


Campus Electricity Distribution System

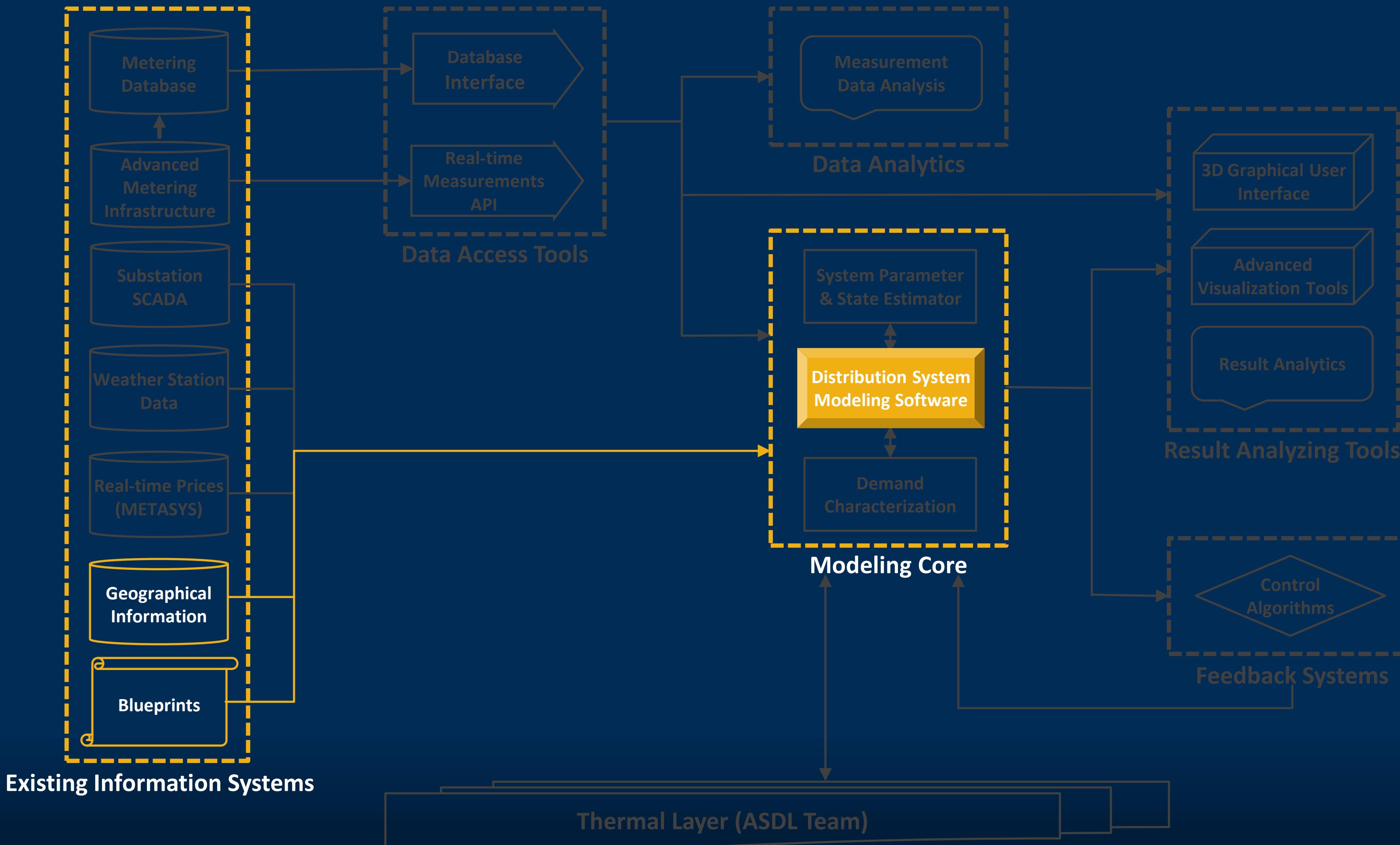
- Campus Electricity Distribution System
  - Connected to Georgia Power via GT owned and operated substation
  - Georgia Power real-time pricing
  - 15 feeders
  - 200+ buildings with 400+ meters
  - 80,000 kW capacity
  - 40,000 kW average demand



Electrical Energy Simulator

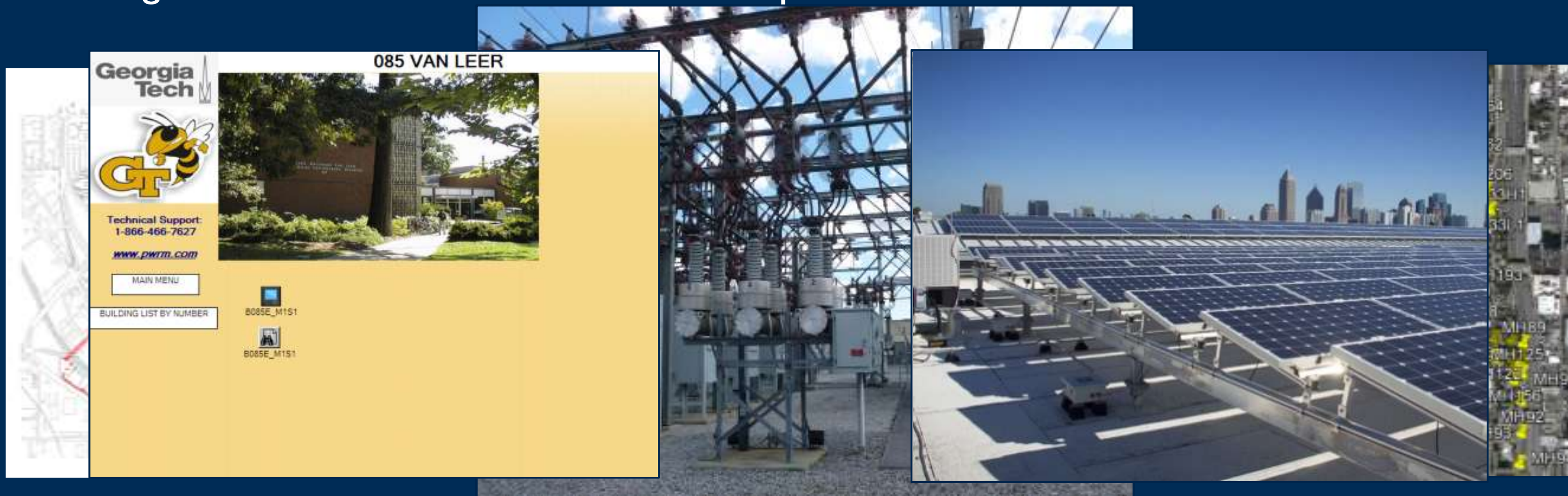


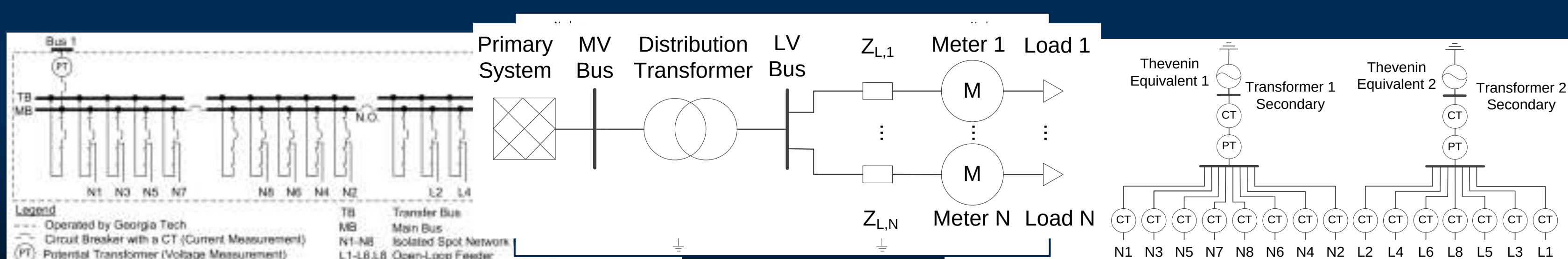
1. Detailed Integrated Simulation Environment



1. Detailed Integrated Simulation Environment

Mapping Data with Geographic Information Systems
Substation Representation
Lines and Transformers Representation
Buildings and Distributed Generation Representation

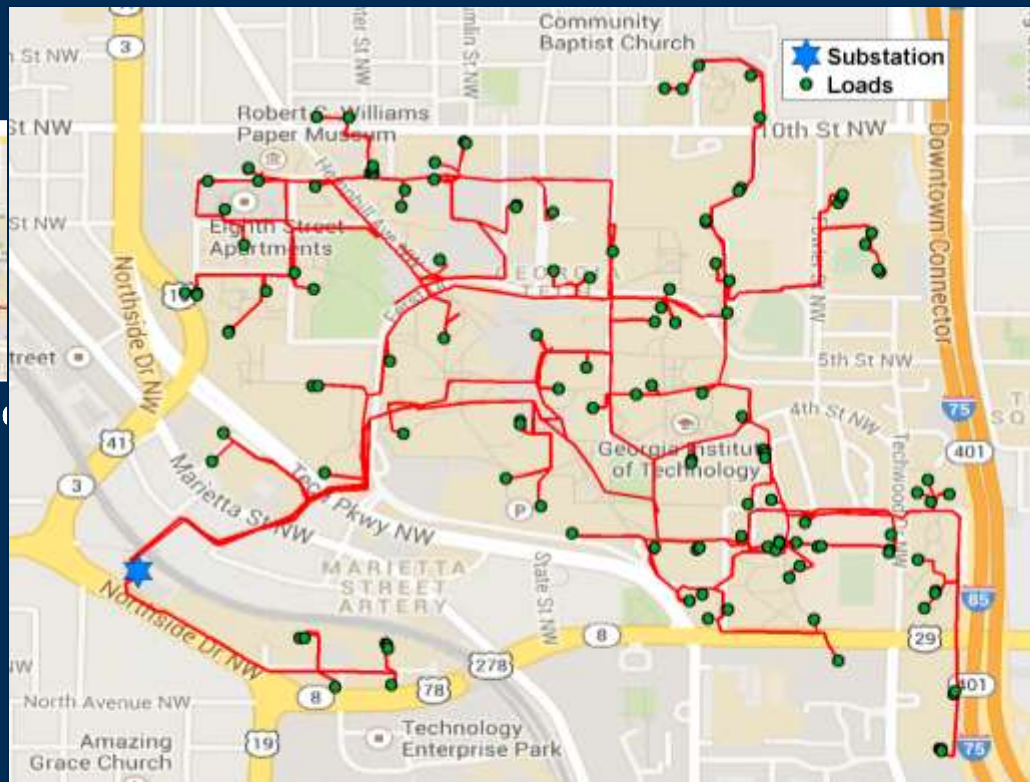




1. Detailed Integrated Simulation Environment

Feeder L1

Fe



GEORGIA TECH DISTRIBUTION SYSTEM

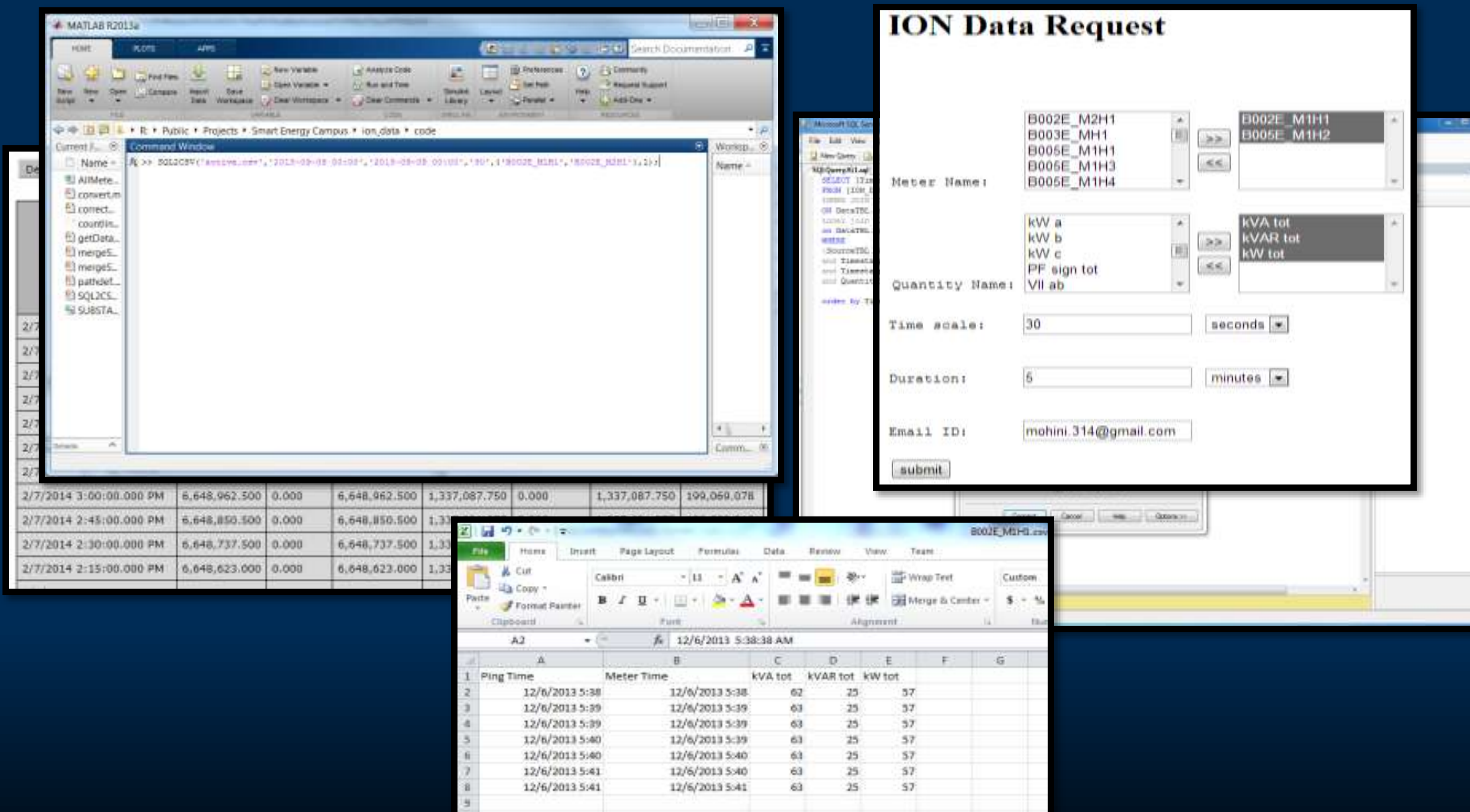
L5

Feeder L6

Feeder L8

Feeders N7 & N8

2. Empowering Stakeholders through Data

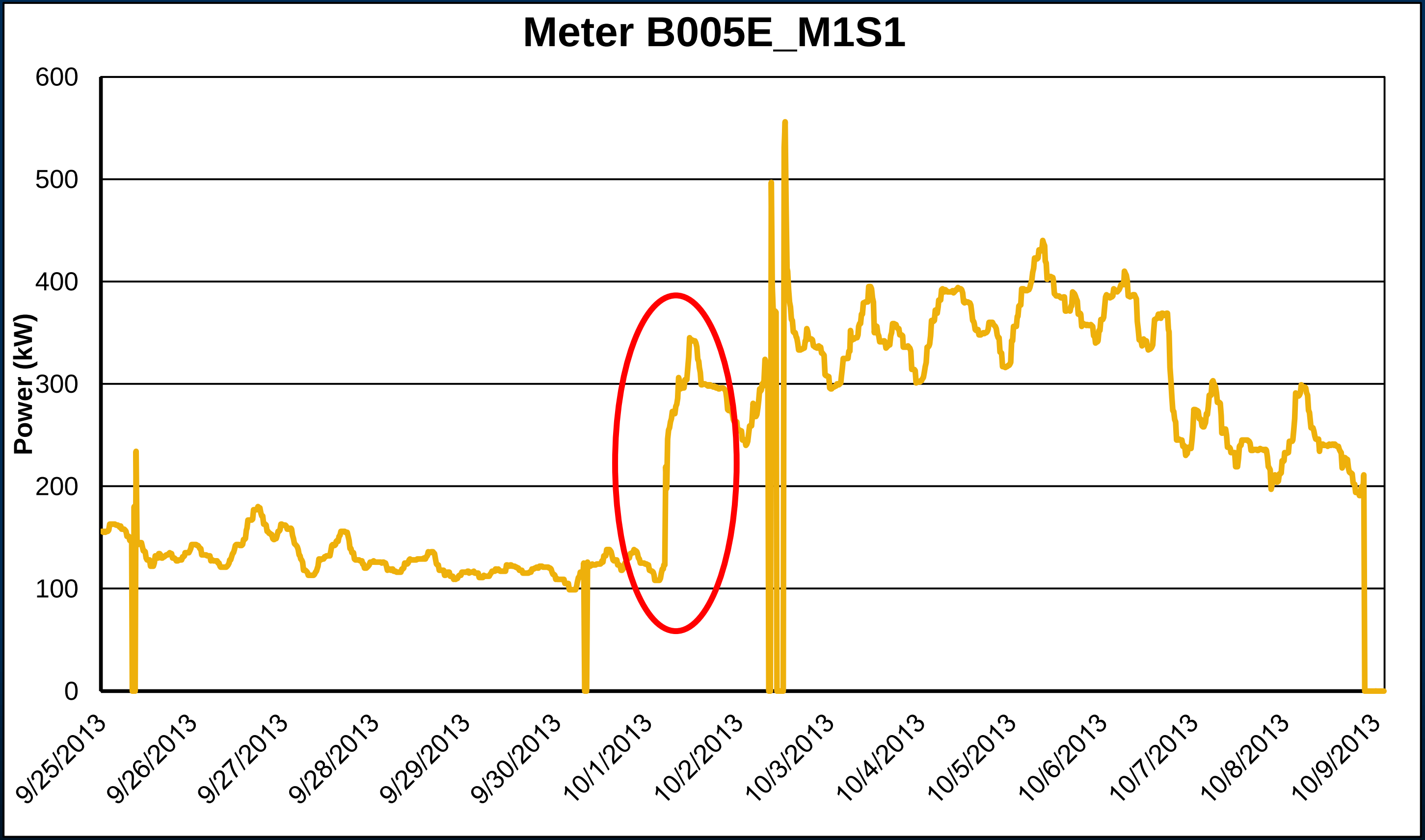


2. Empowering Stakeholders through Data

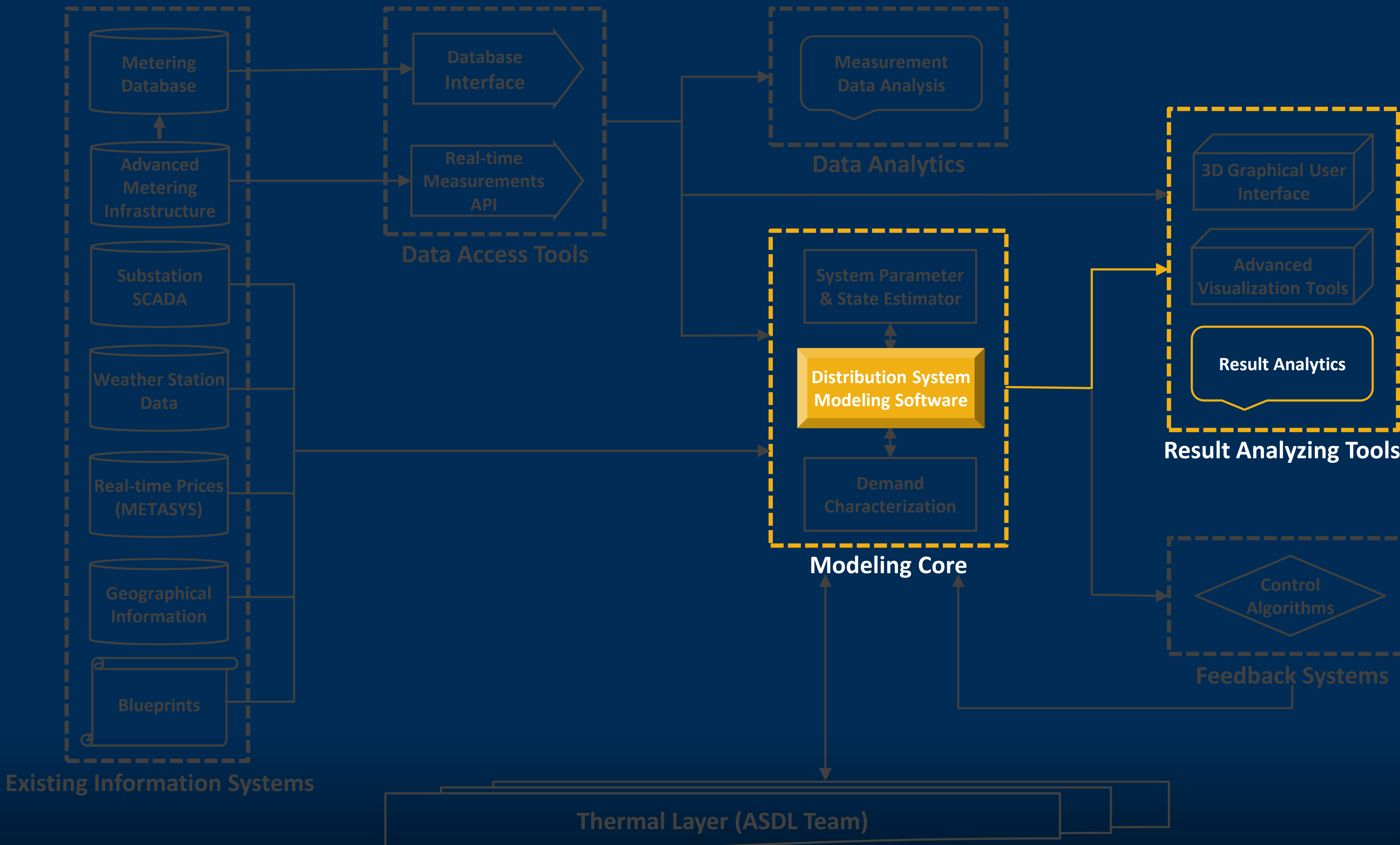
Time Synchronization

Power Mismatch

Corrected Current Transformer Ratio



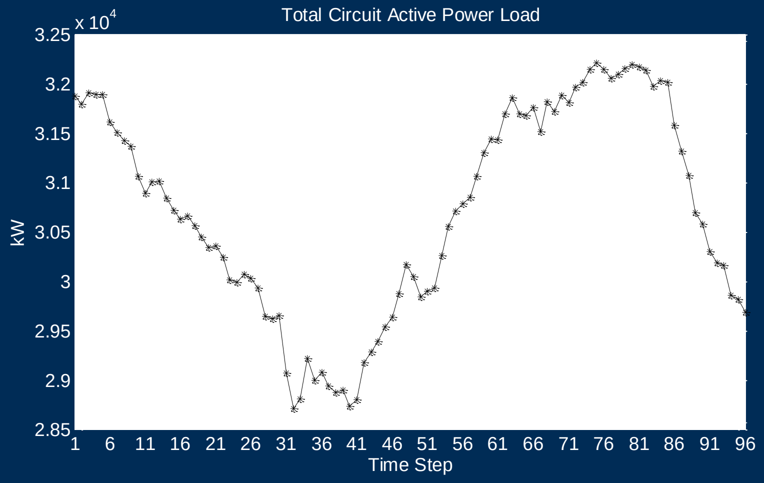
3. Result Analytics

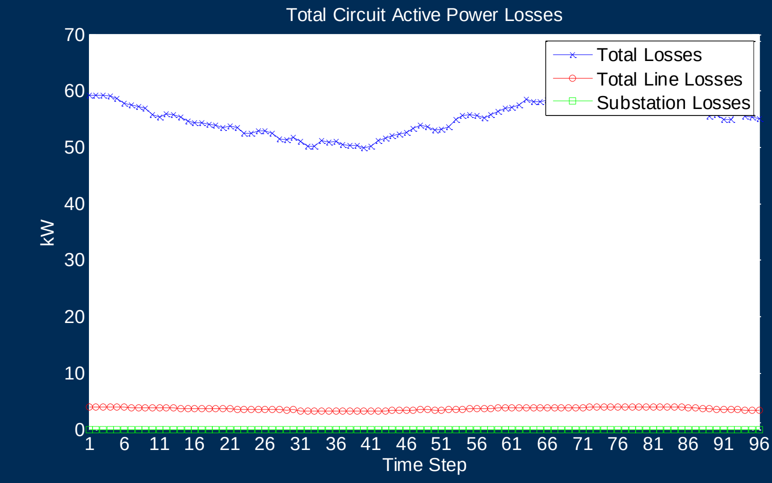


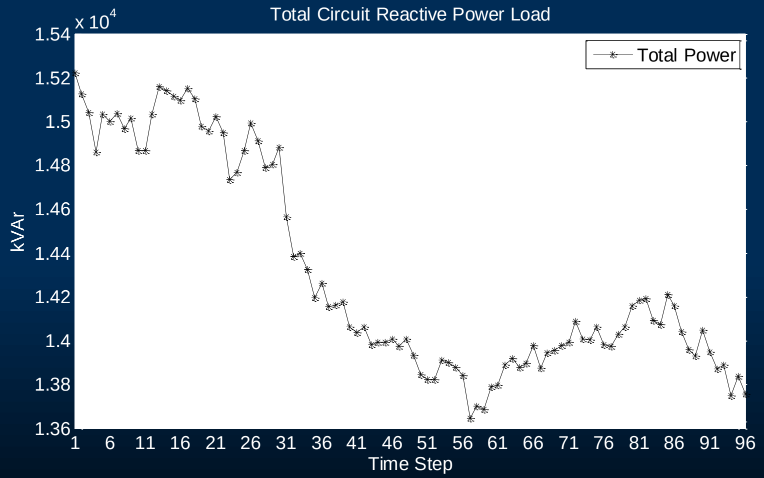
3. Results – Daily System Energy Consumption

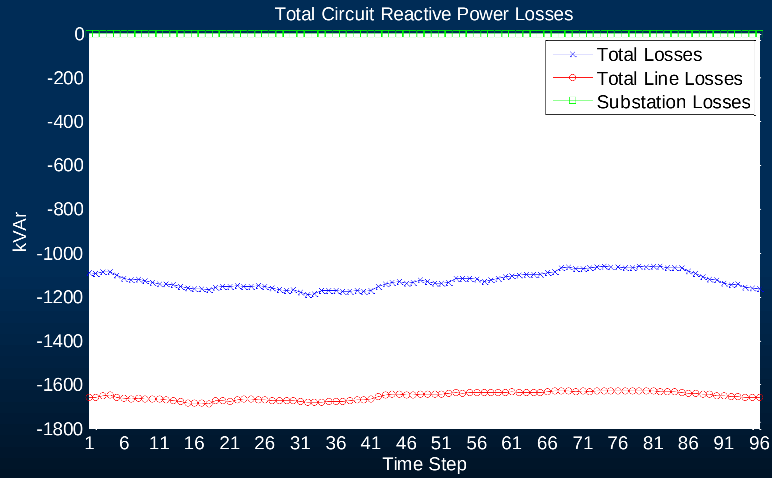
System Demand

System Losses



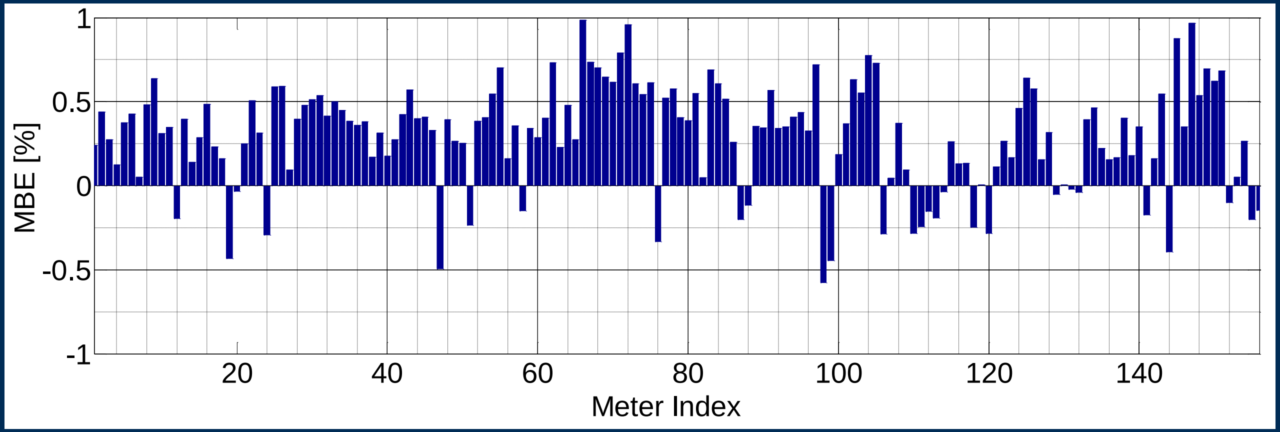




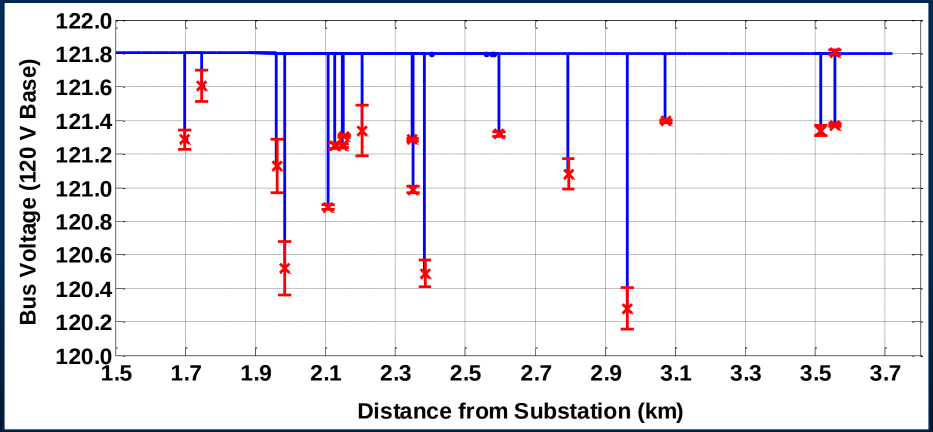


3. Results – Verification of Model Accuracy

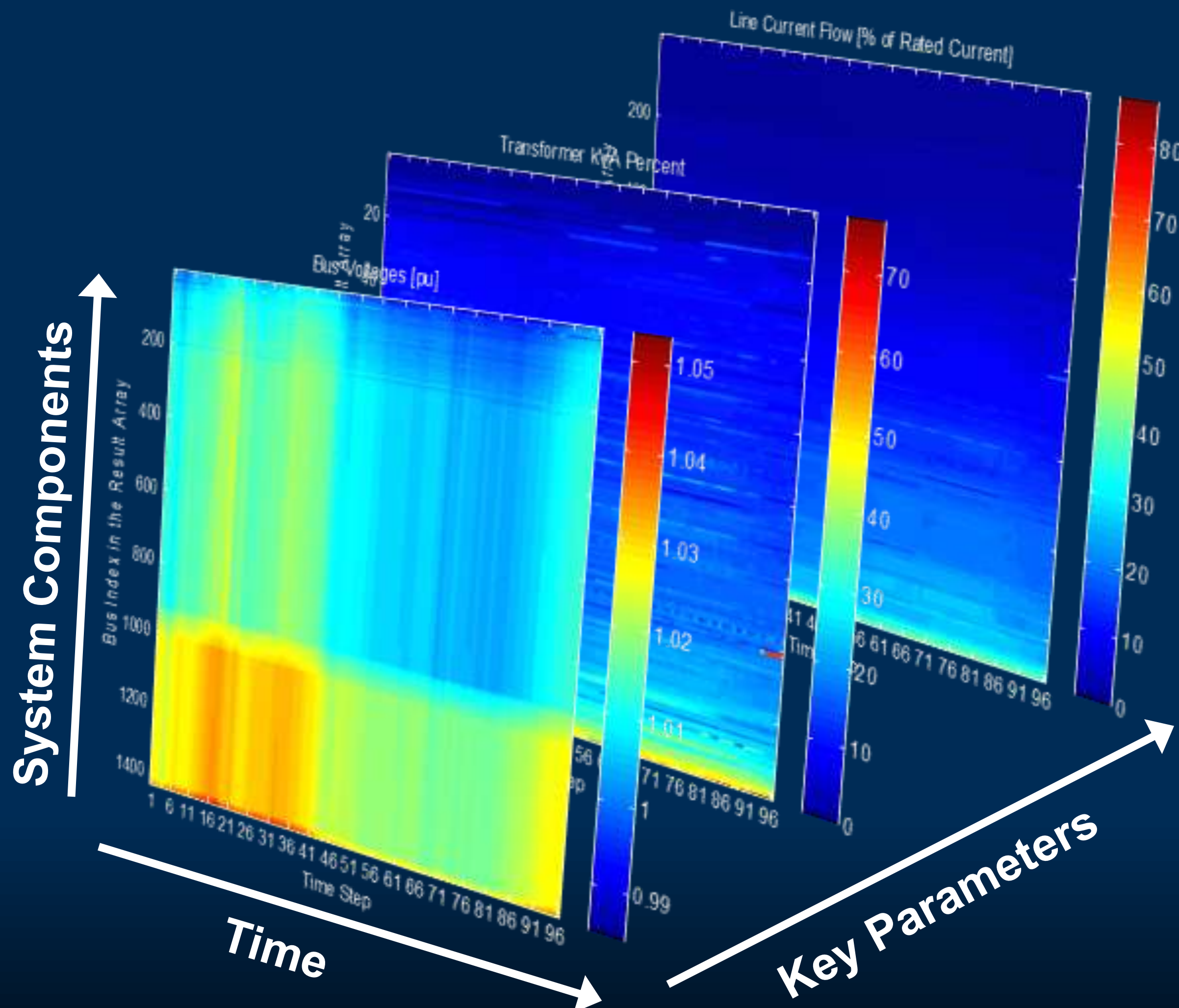
Model Validation Outcome



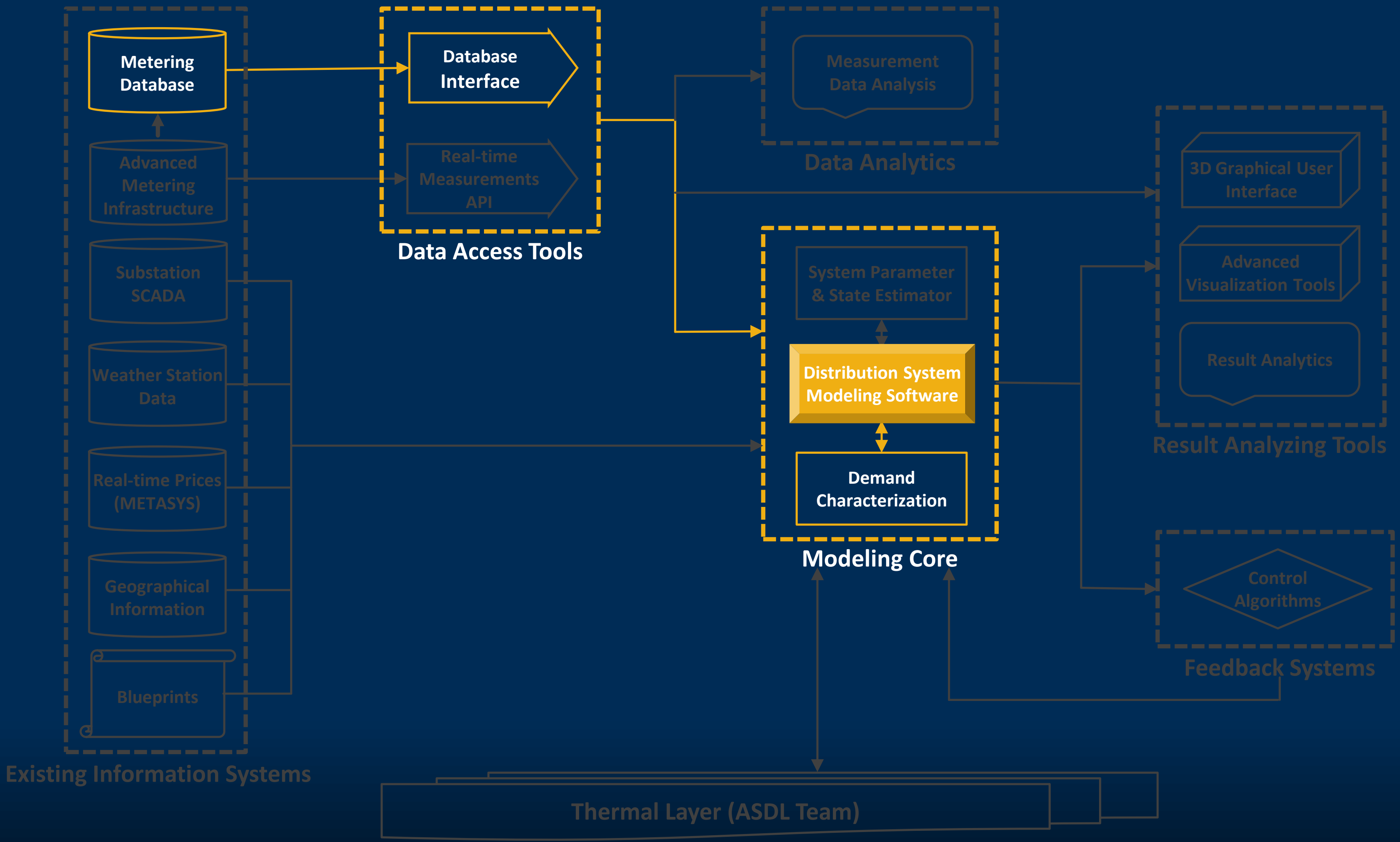
Significance of the Modeling Error



3. Results – Understanding Large Data Sets

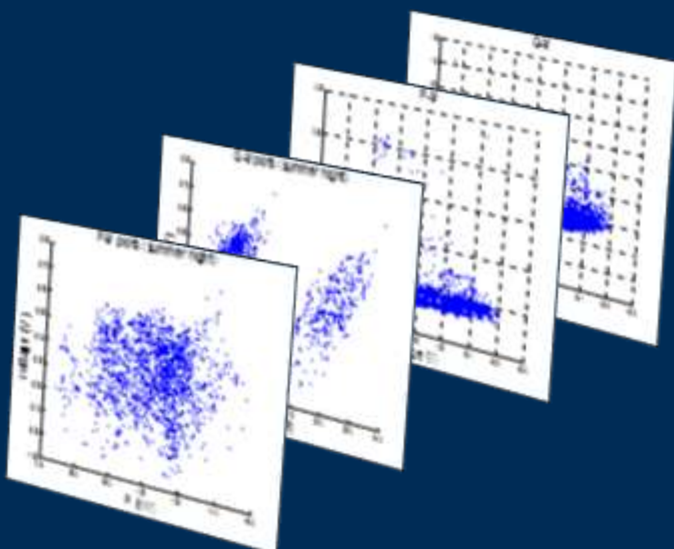


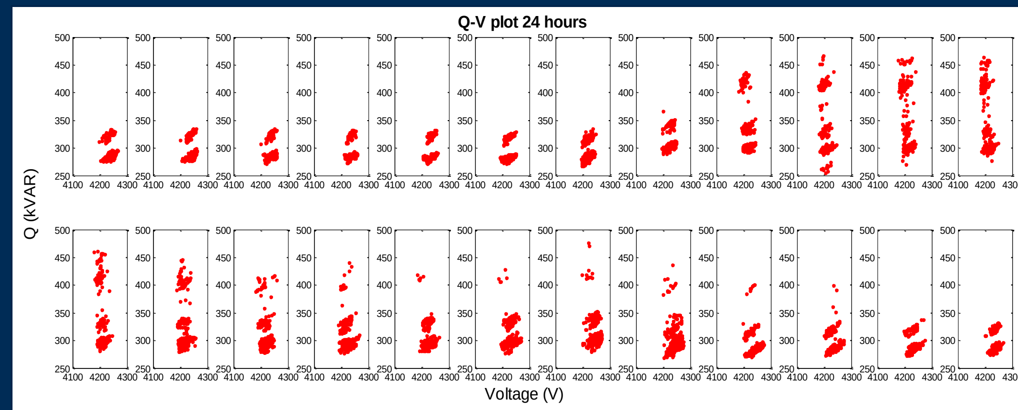
4. Demand Characterization

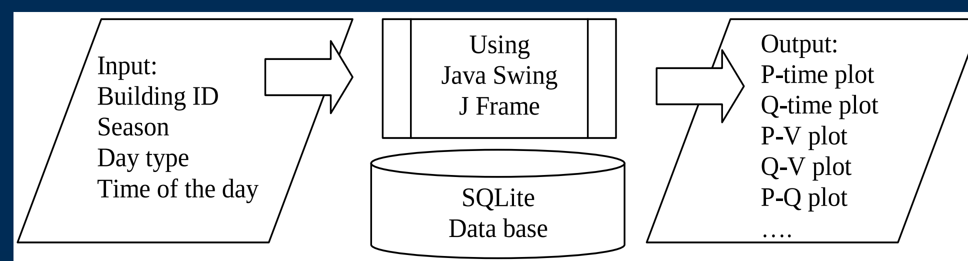


4. Demand Characterization

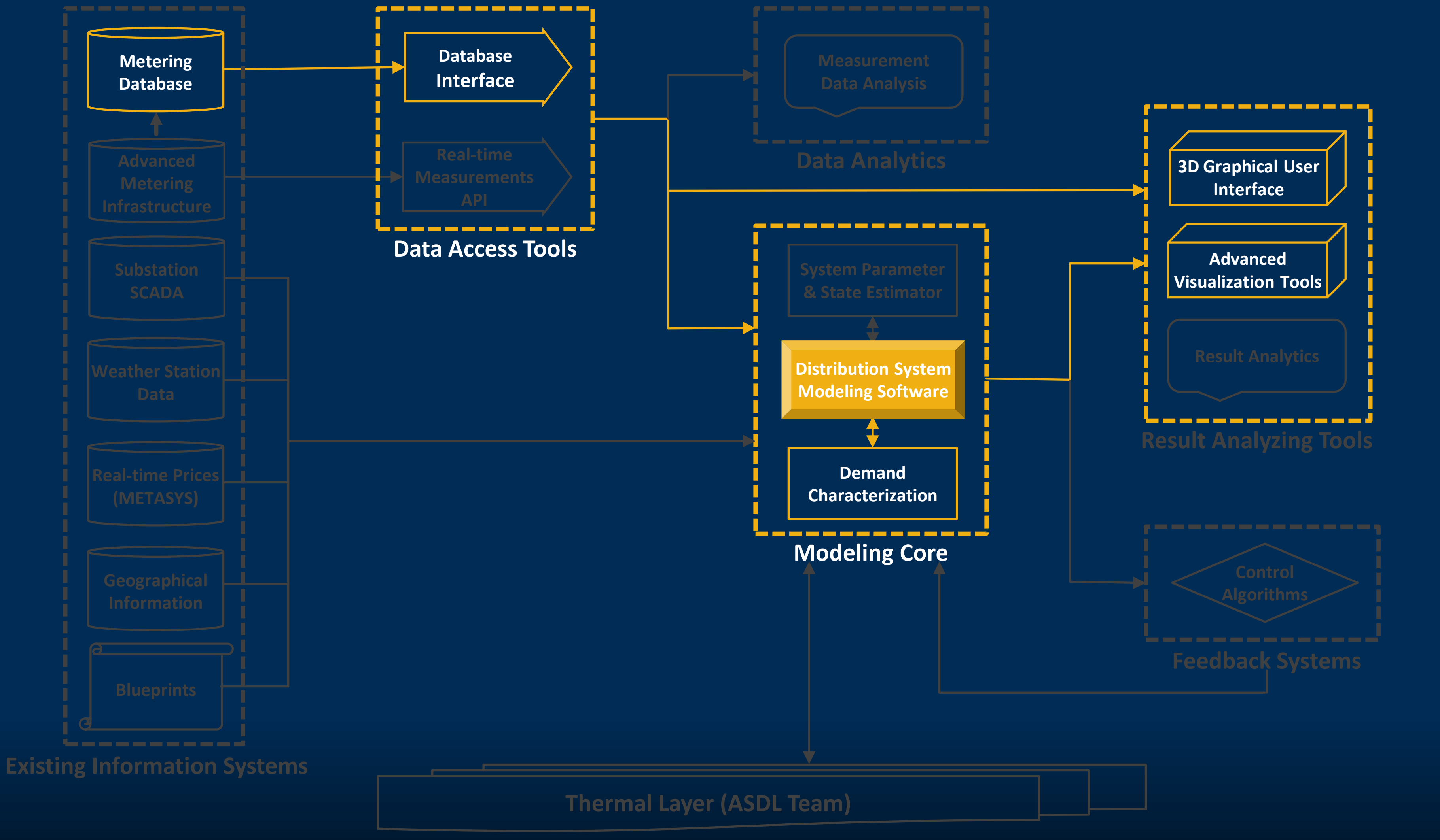
Representing Intra-Building Electricity Usage Dynamics





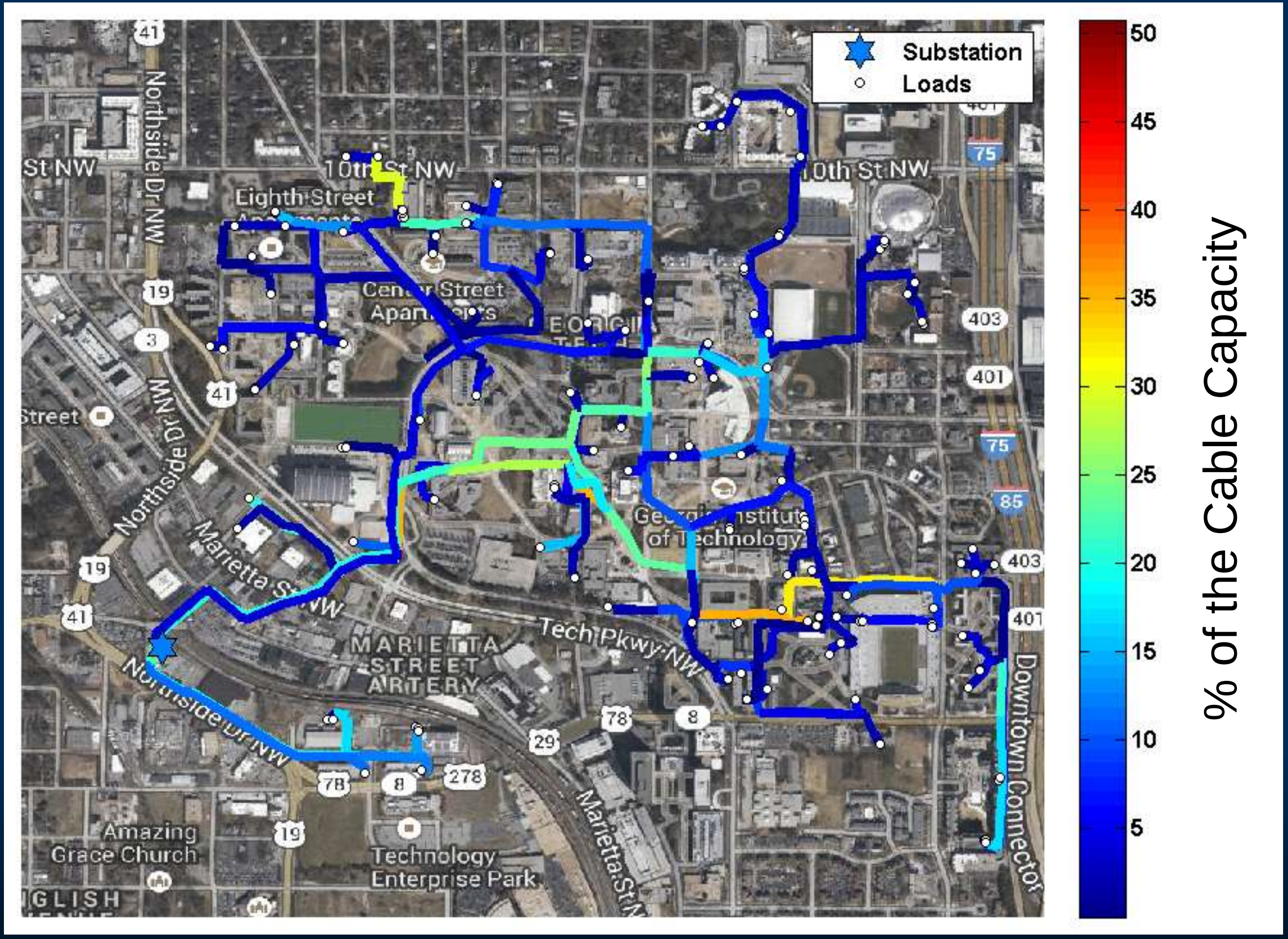


5. Situational Awareness



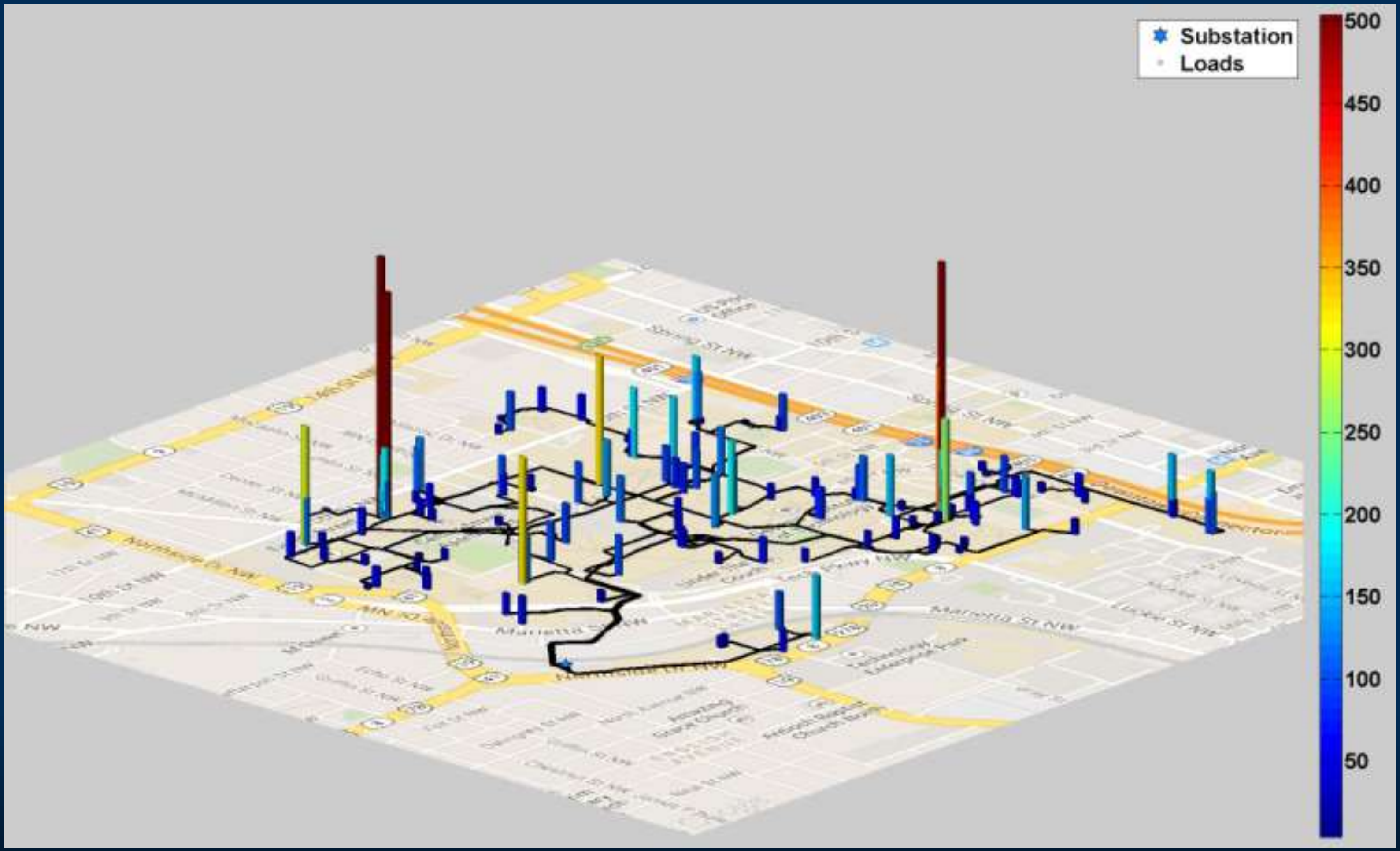
5. Situational Awareness

Instantaneous Cable Utilization



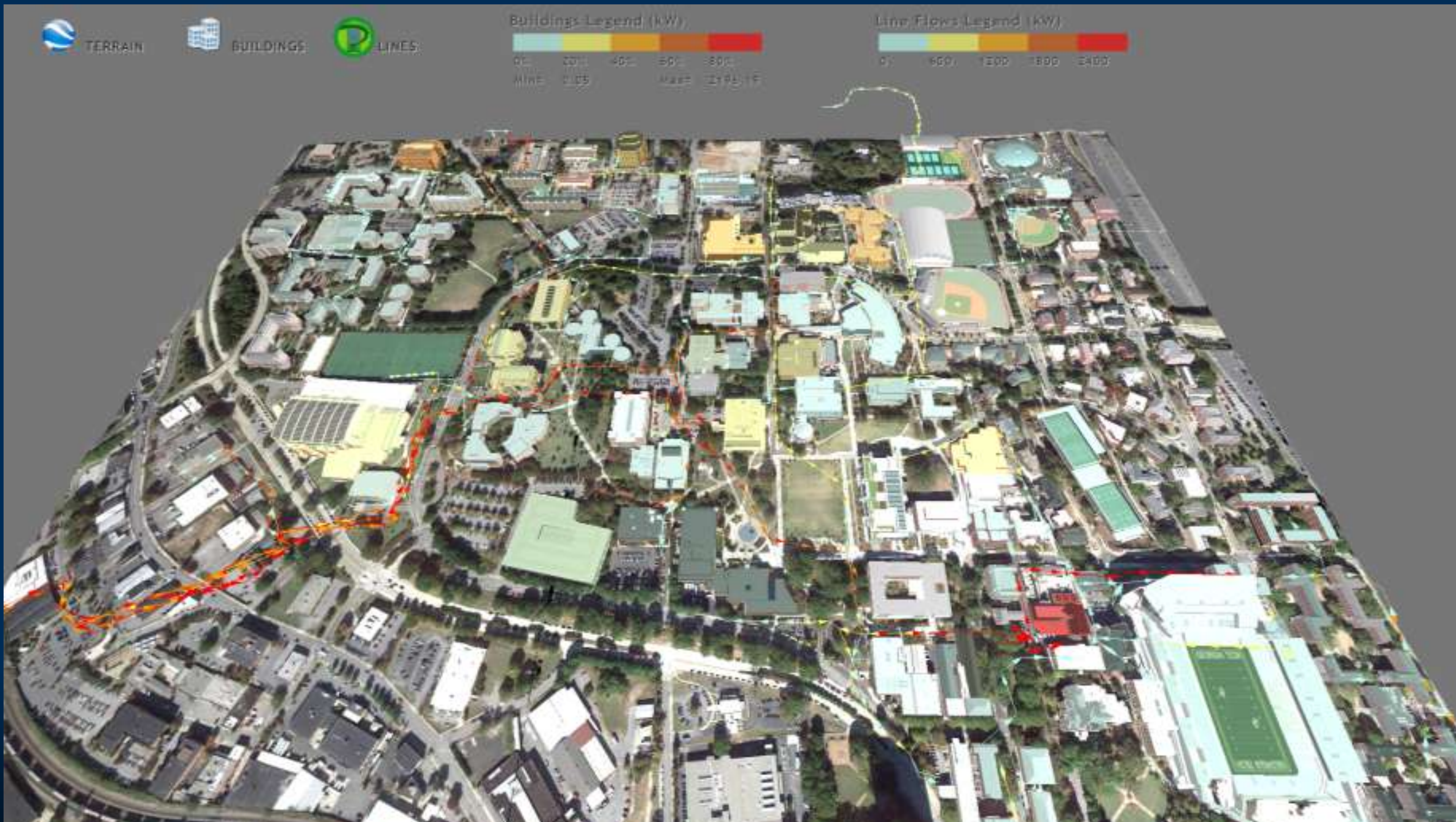
5. Situational Awareness

Bird's-eye View of the Campus Energy Consumption

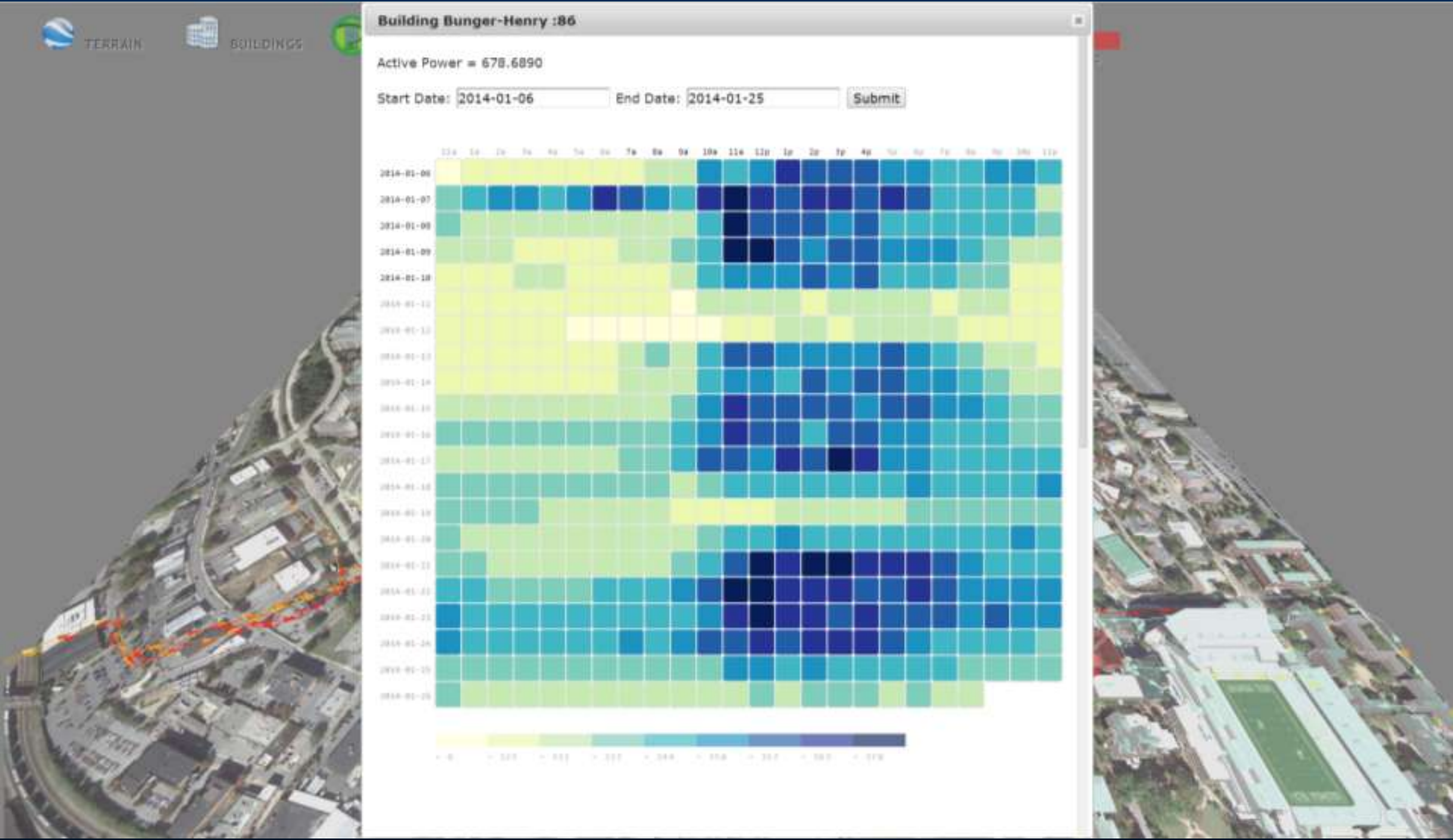


5. Situational Awareness

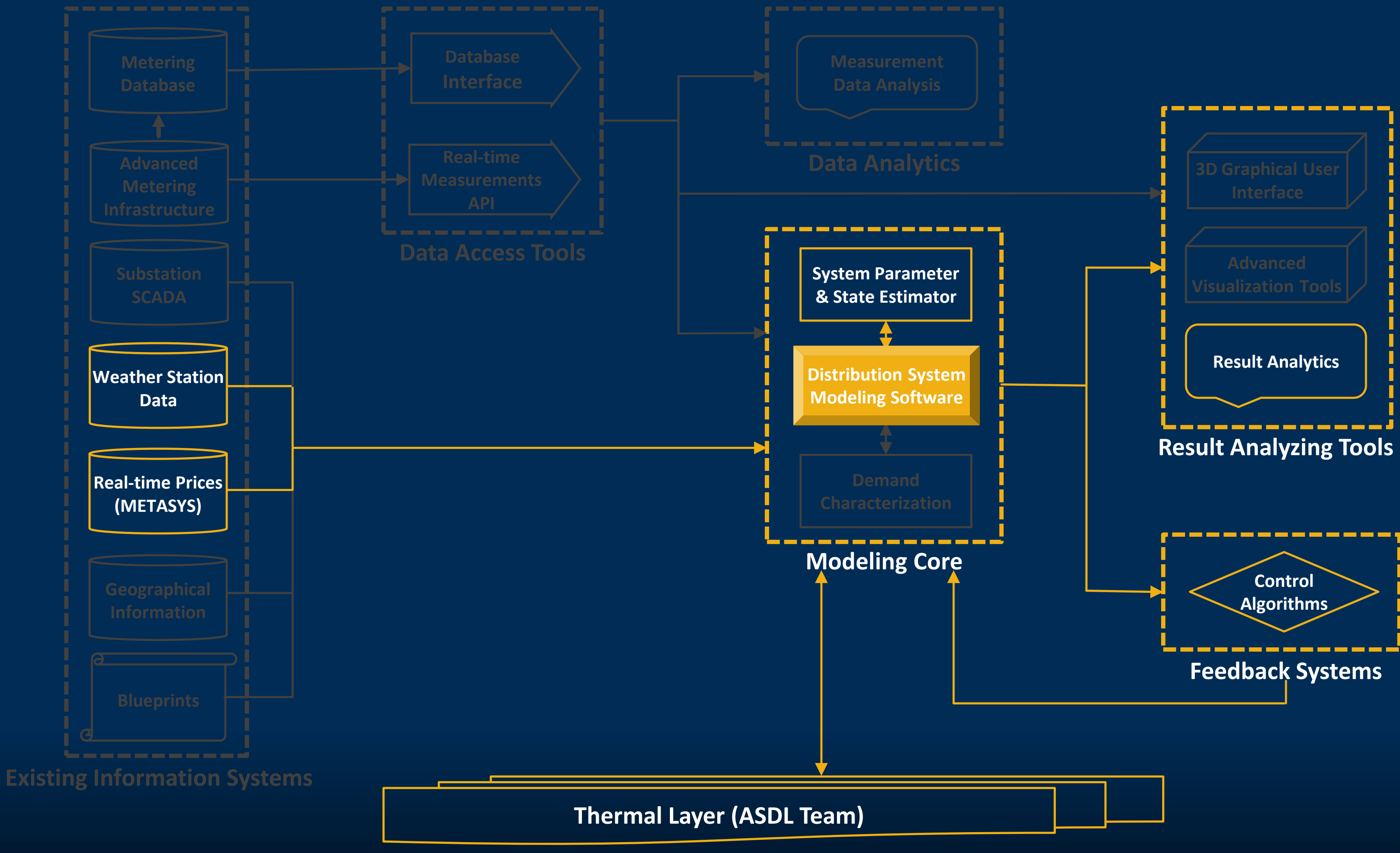
Overview



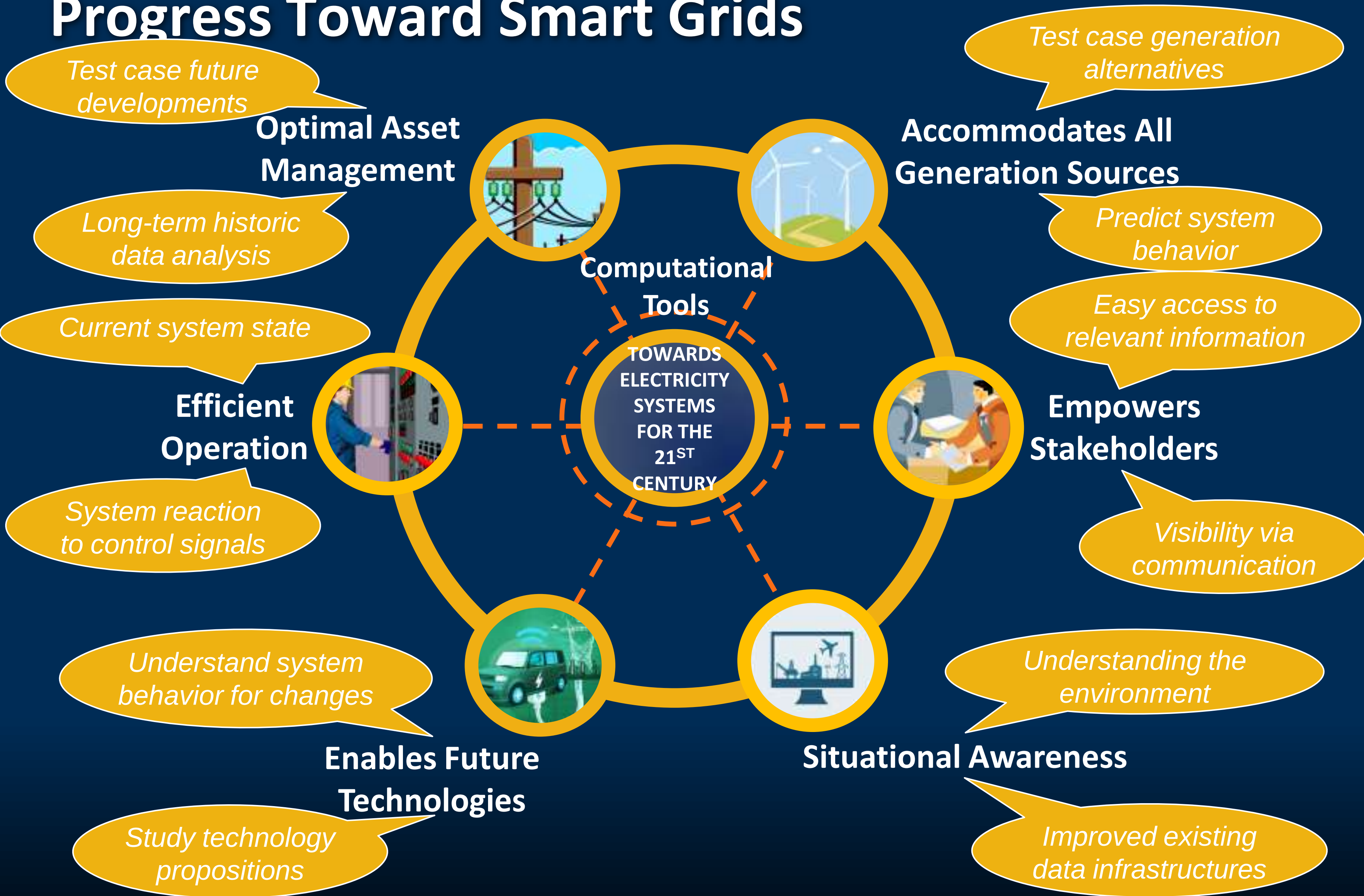
5. Situational Awareness



Ongoing Work



Progress Toward Smart Grids



Georgia Tech School of Electrical and Computer Engineering

Georgia Tech Aerospace Systems Design Laboratory

Aerospace Systems Design Laboratory

THERMAL & MECHANICAL SYSTEMS

Overview: Thermal & Mechanical

GT Physical plants generate and distribute energy for:

- Heating (gas or electric)
- Cooling (electric)

Motivation for analytics & simulations:

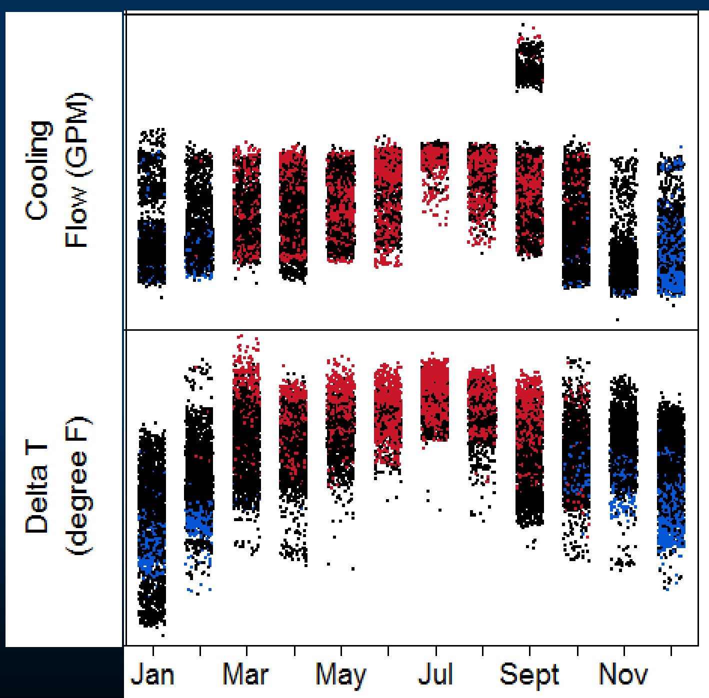
- What drives consumption?
- What affects efficiencies?
- How can we improve both?
  - System tuning
  - New technologies & schemes
- How to detect anomalous behavior?
- How to achieve resilient systems?

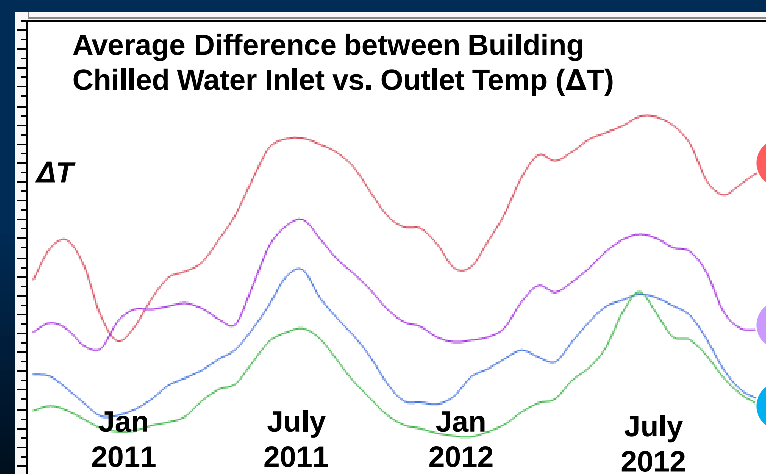
Visual Data Analytics to Support Operations

Data Storage, Aggregation, & Integration Framework

"Quad"-level

Building-level

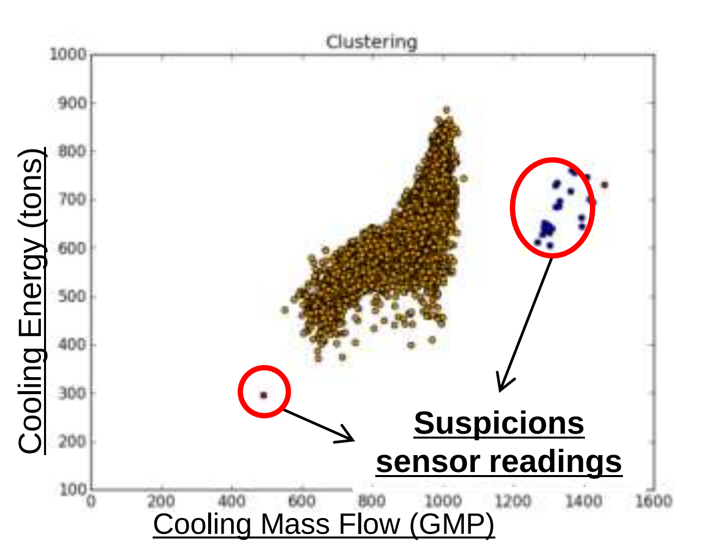




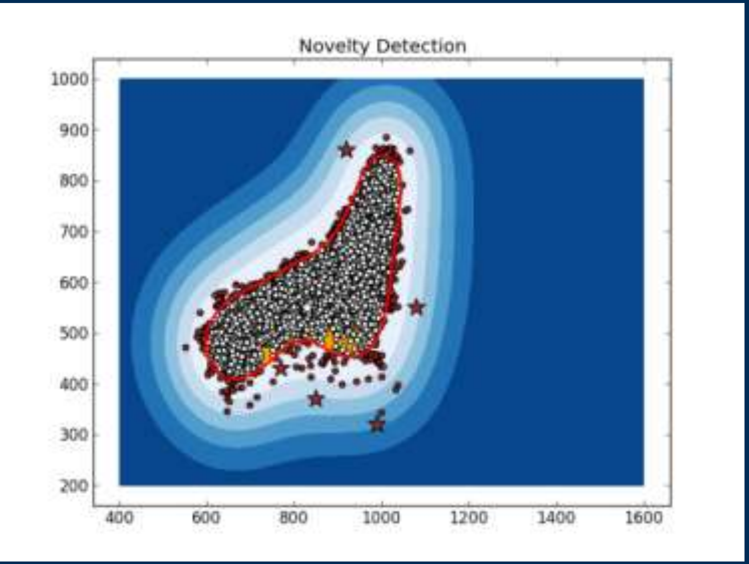
Automated Abnormality Detection

Evaluate data sets "blindly" with machine learning algorithms; anomalies for human inspection

Use statistical reference: Are data out of the norm from comparable days, season, schedules, etc.?



Biotech Building: Summer Months



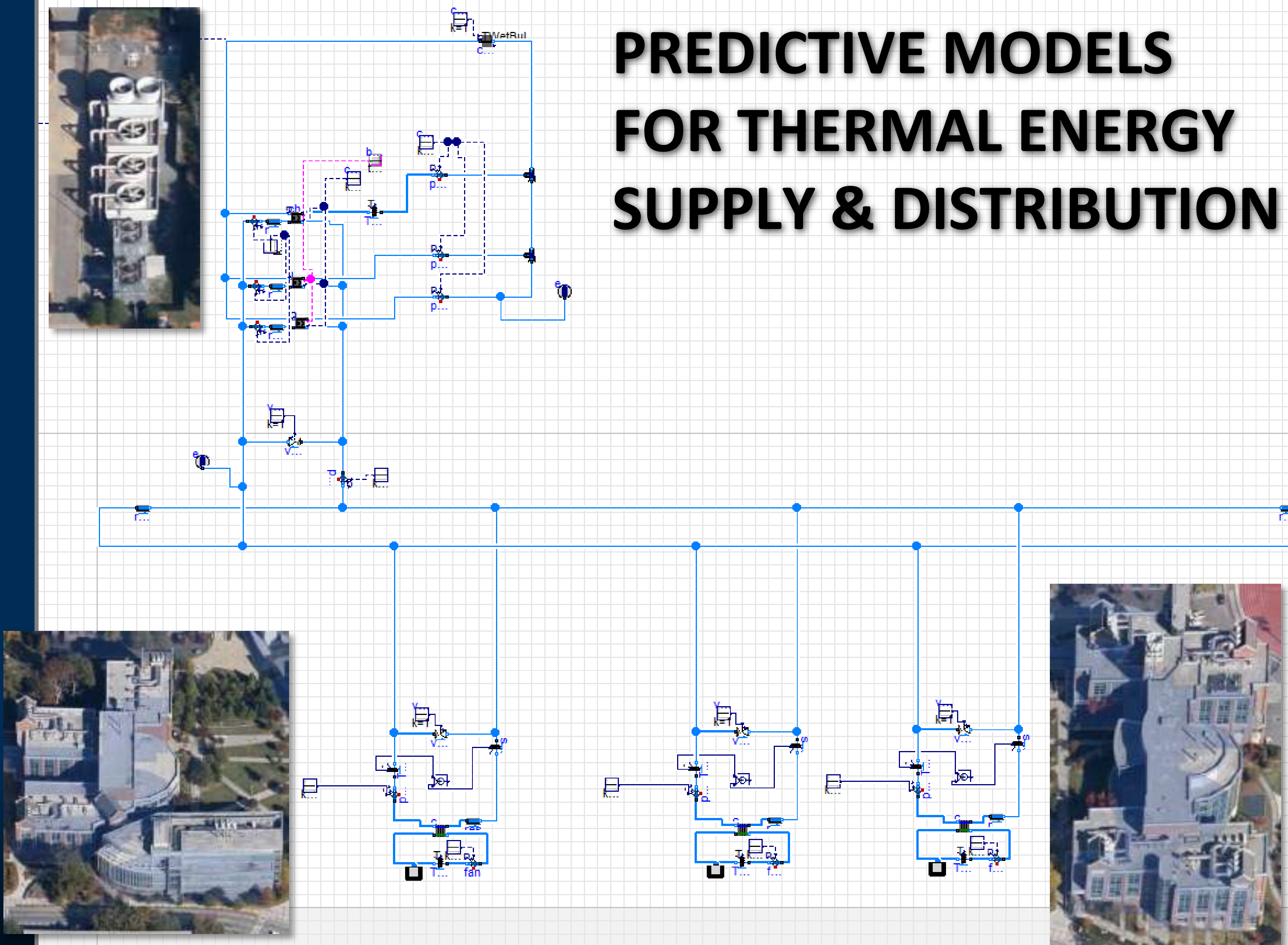
Test Point	Abnormal	Distance/Rank	Below/Above ΔT
(920,860)	Yes	-16.2853	High
(770,430)	Yes	-4.1452	Low
(830,550)	No	1.9355	-
(850,320)	Yes	-20.1344	Low
(990,320)	Yes	-37.6190	Low
(1080,550)	Yes	-16.8119	Low

- Apply outlier detection algorithms to each sensor
- Obtain a ranked list of abnormal sensors

Real-time Maintenance Ranking:

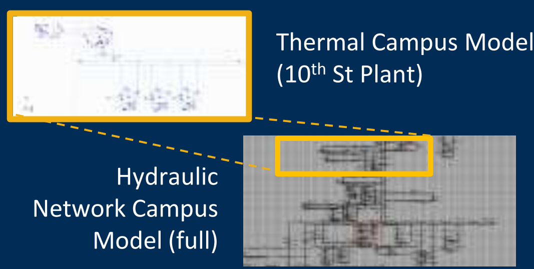
Highest priority: Below ΔT with minimum distance

PREDICTIVE MODELS FOR THERMAL ENERGY SUPPLY & DISTRIBUTION

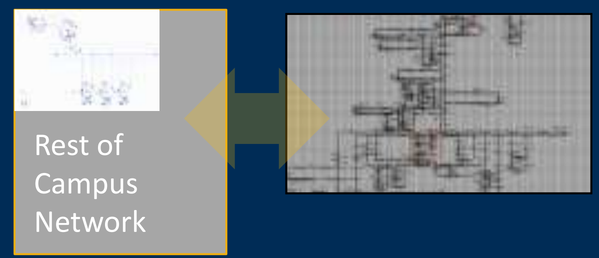


Performance Prediction: Campus Level *Model Development Roadmap*

Initial Scope: Chilled Water



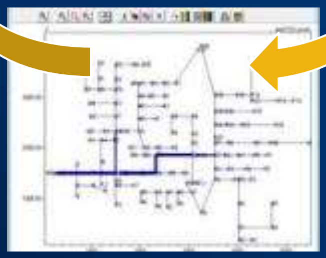
Scaling to Full Campus, More Layers



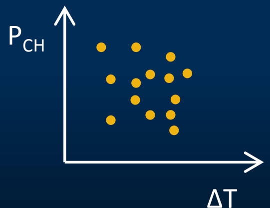
- Topology as in PIPE-FLO Hydraulic model by GT Facilities
- Building parametric setup according to actual specifications

Full Campus M&S Facility with

Thermal



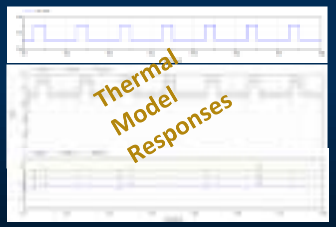
Electrical



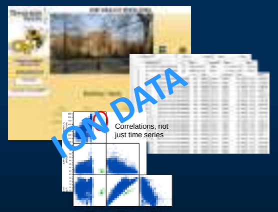
Scenario Types:

- Change of ambient T
- Building occupancy schedules
- Fault events

Run Experiments for Preliminary Trade Studies



VS.



Full Campus Thermal Model Verification

FUTURE WORK

Joint Case Simulation

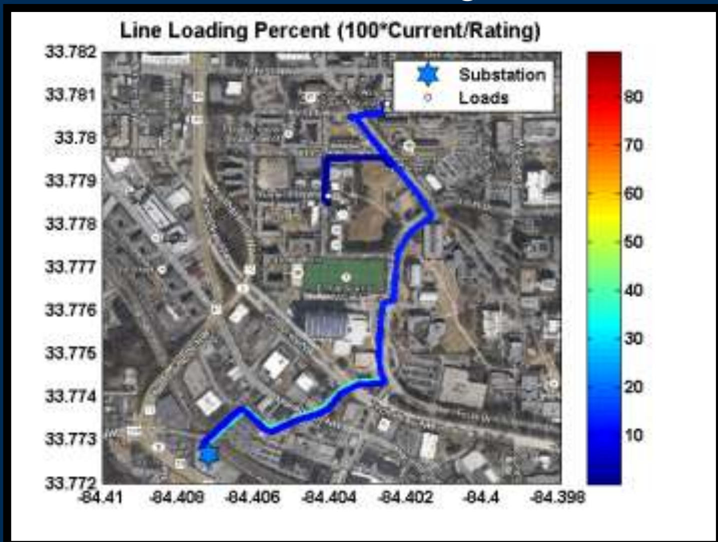
Analyzing the impact of future cooling load on the electrical system

Case #	B133_S1 [kW]	B133_S2 [kW]	Total Chiller Load [kW]
1	5243.1	1256.9	6500
2	5243.1	2756.9	8000
3	5243.1	4256.9	9500
4	5243.1	5756.9	11000
5	5933.1	6566.9	12500
6	6677.1	7322.9	14000
7	6677.1	8822.9	15500

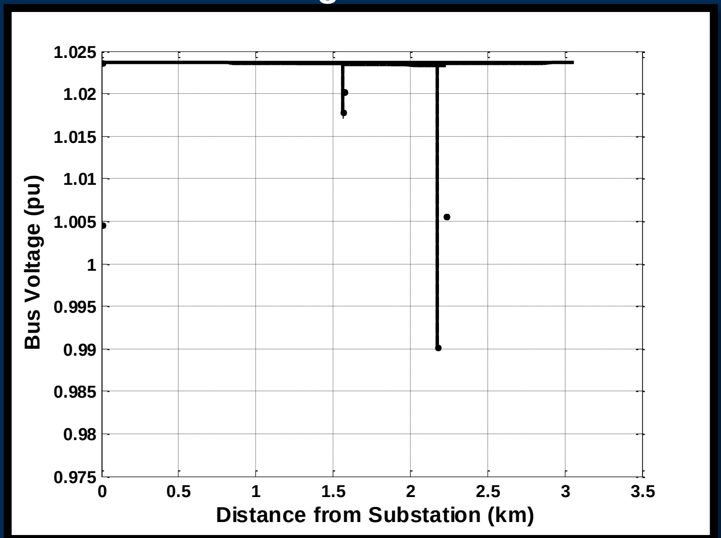
Joint Case Simulation

Base Peak Load Case (June 28, 2013 18:15)

Line Loading



Voltage Profile

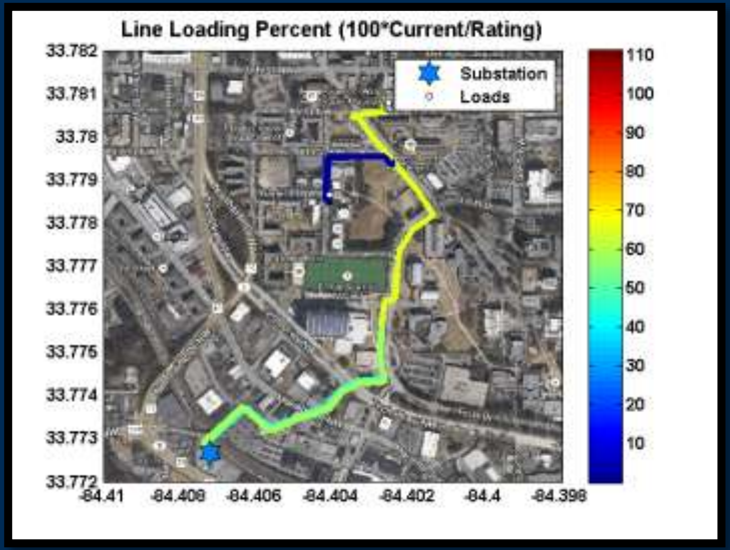


Transformer	Real Power [kW]	Reactive Power [kVAr]	Apparent Power [kVA]	Rating
B133_S1	5243.1	2652.3	5875.8	5000/5600/6250
B133_S2	1902.7	991.17	2145.4	6000/7500/8400

Joint Case Simulation

Worst Case Scenario

Line Loading



Voltage Profile

Transformer	Real Power [kW]
B133_S1	6677.1
B133_S2	8822.9

Next Step: Case Studies (“What-If” Scenarios)

Potential “Stimulus” Events

New building addition

Cost of fuel

Chiller Shutdown

Extreme Weather

Increase of Campus population and energy demand

Actions and Responses

Planning for new campus energy technologies

Thermal Storage

Cogeneration

Biofuel

PV

Planning for new campus infrastructures

Transportation Electrification

High Performance Computing

Grid-building Interface

Optimizing campus energy system operations

System Reliability

Energy Efficient Operation

System Maintenance