Analytics and Optimization for Smart Grid Resiliency

February 5, 2014

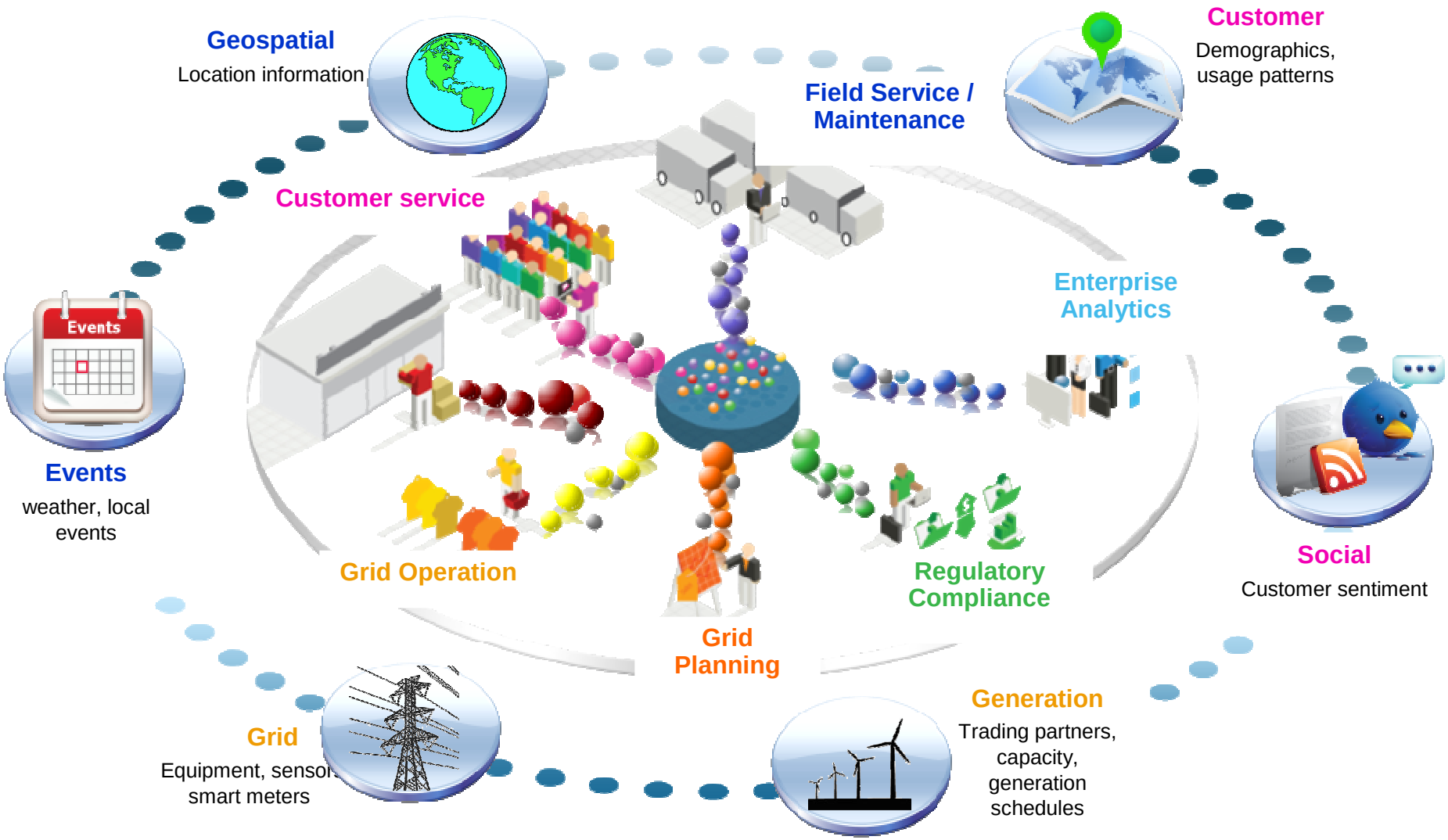
Resiliency in Electric Power Grid Operations

- Correct design
  - Engineer
  - Build
- Proper operation
  - Equipment limits
  - Standards
  - Recommendations
- Maintenance
  - Predictive
  - Repair/Replace/Restore policies
- Natural Effects
  - Weather damage
  - Weather induced demand
  - Renewable generation variability

Resiliency in Electric Power Grid Operations

- Security
  - Physical
  - Cyber
  - Human
- Failure
  - Prevent
  - Recognize fast
  - Recover fast
- Automation induced
  - Sensor value
  - Communications
  - Data validity
    - Value
    - Time
  - Time skew
  - Algorithmic
  - Configuration
  - Integration

Utility data is very distributed, and of many types and sources



Enable unconstrained analytics with collaborative and new access to data

To be competitive companies must be able to deliver new and compelling insights from the distributed data being collected

Benefits of a Data & Analytics Platform

Access to Data

- Enable access to any data by any group within the enterprise
- Availability of a common data management system with storage, in memory processing, archiving

Analytics

- Enable traditional & new analysis of data
- Best-practices & analytics modules

Integration

- Out-of-the-box connectors and integration modules to enterprise applications
- Extensible framework to allow analytics application plug-in

Time to Value

- Platform allows quick implementation of new analytics to make better informed decisions

Utility questions on analytics strategy

Which solutions will **integrate with my existing systems** most easily?

How will my analytics solutions **work together**?

What analytics choice gives me the best **time to value**?

How do I extract **actionable insight** from my data?

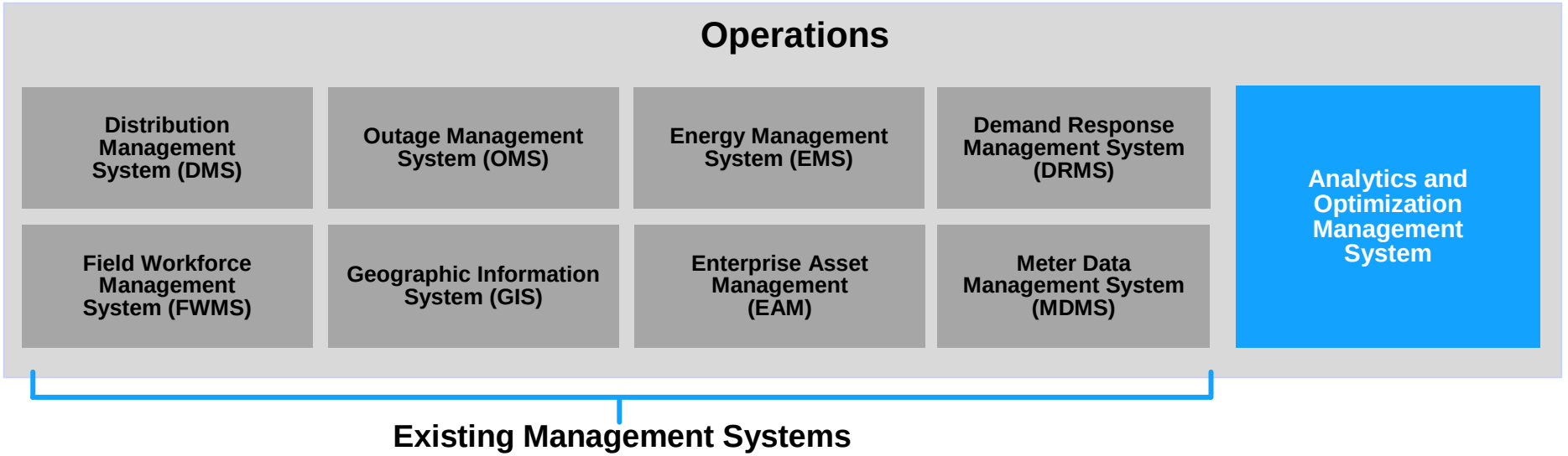
What analytics choices do I make that will **scale** to future needs?

Do I have to **integrate my data** with each new application?

How can I make discoveries in my **data** that may lead to new **analytics** ?

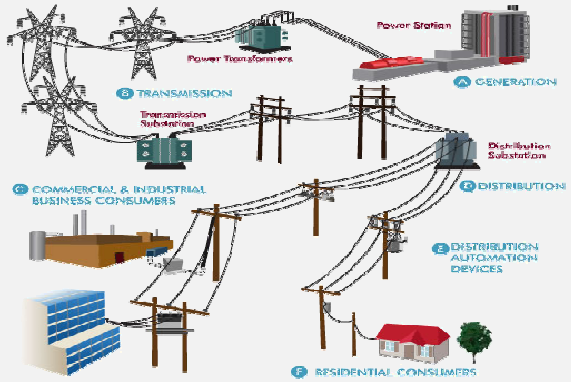
Analytics and Optimization Management System answers

- A new management system built for utility operations
- A platform of modular software to apply analytics and optimization to business problems
- Designed to capture business value by applying analytics to “Big Data” from existing distributed information-based systems



Utility View

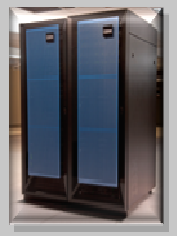
A grid has unique properties, operational objectives, and challenges

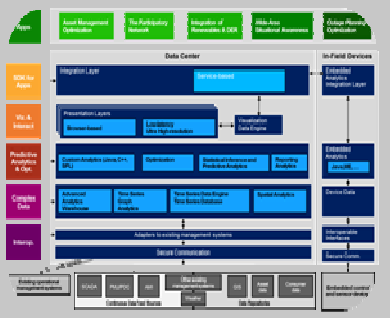


Computational environments must provide performance and flexibility

- Hierarchical Graph Analytics technology for network analysis
- Time Series technology for ultra-fast data ingestion
- Streaming technology for decisions on the fly
- Dynamic and interactive high performance visualization
- Predictive and prescriptive analytics

These computational requirements drive the definition





Design Principles

Enable a Portfolio of Advanced Analytics Applications for Utilities

* Asset management optimization *Integration of renewables and DER
*Wide area situational awareness *Outage planning optimization *Participatory network

Ease of Modern Application Development (Composability)

* Easily build and integrate multiple applications on one system
* Allow iterative refinement of re-usable software components

Performance-Optimized Stack

* Develop and test as a single layer of pre-integrated software
* Support complex data, advanced analytics, and high performance visualization
* Built on world-leading capabilities in Big Data analytics and commercial software products

Integration to Existing Management Systems

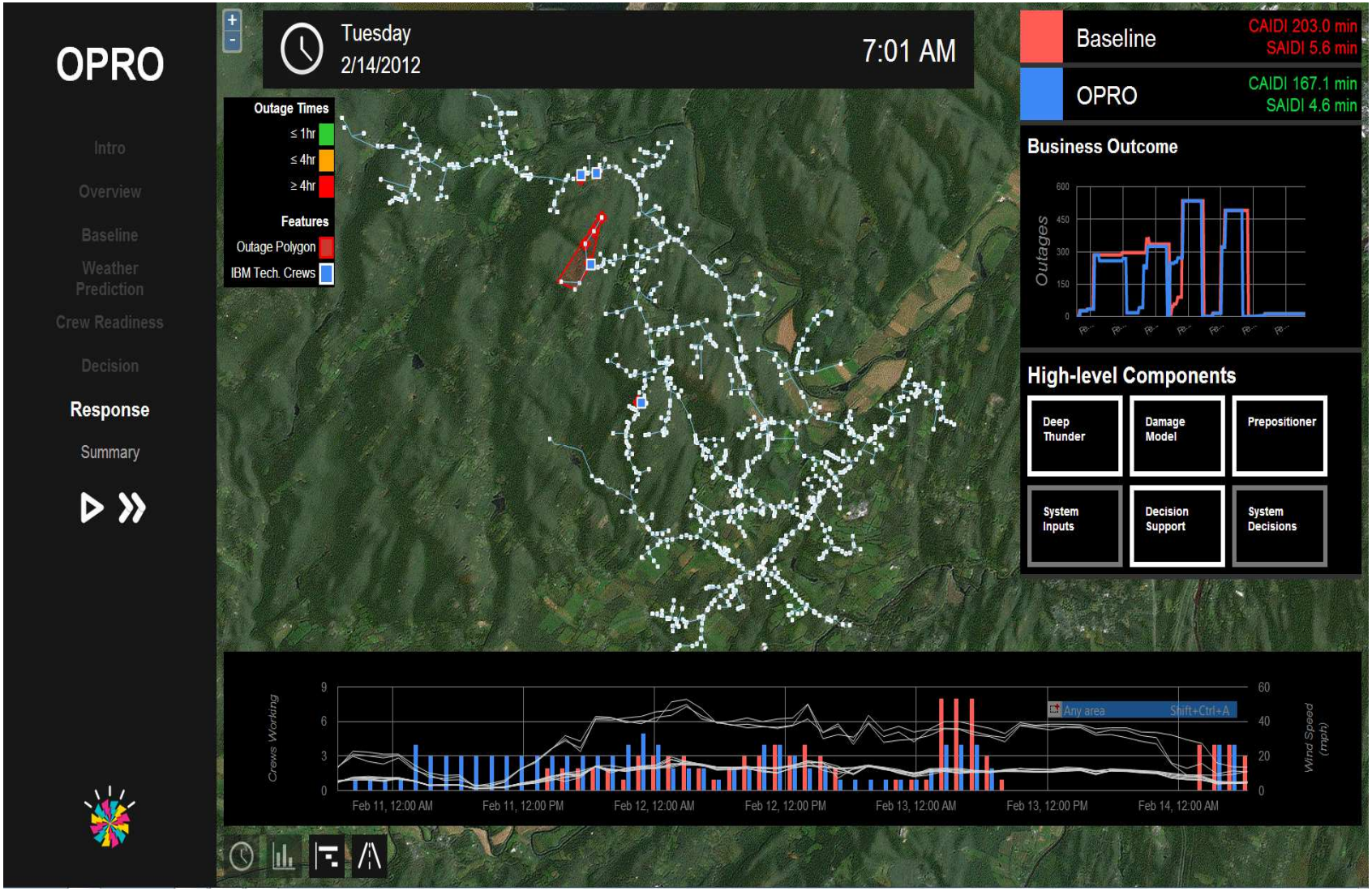
* Supporting standardized data models for easier integration and fewer proprietary lock-in points

Outage Prediction and Response Optimization

- OPRO uses advanced weather prediction, predictive damage estimates, and optimized crew positioning and response planning to improve a utility's preparation for and response to weather-related power outages.

- With more than $14B in total annual lost value of service due to storms in the U.S. alone, improvements in outage restoration and reduction in operational costs would lead to significant value for the utility, in terms of both economic value and improved customer satisfaction.

Outage Prediction and Response Optimization



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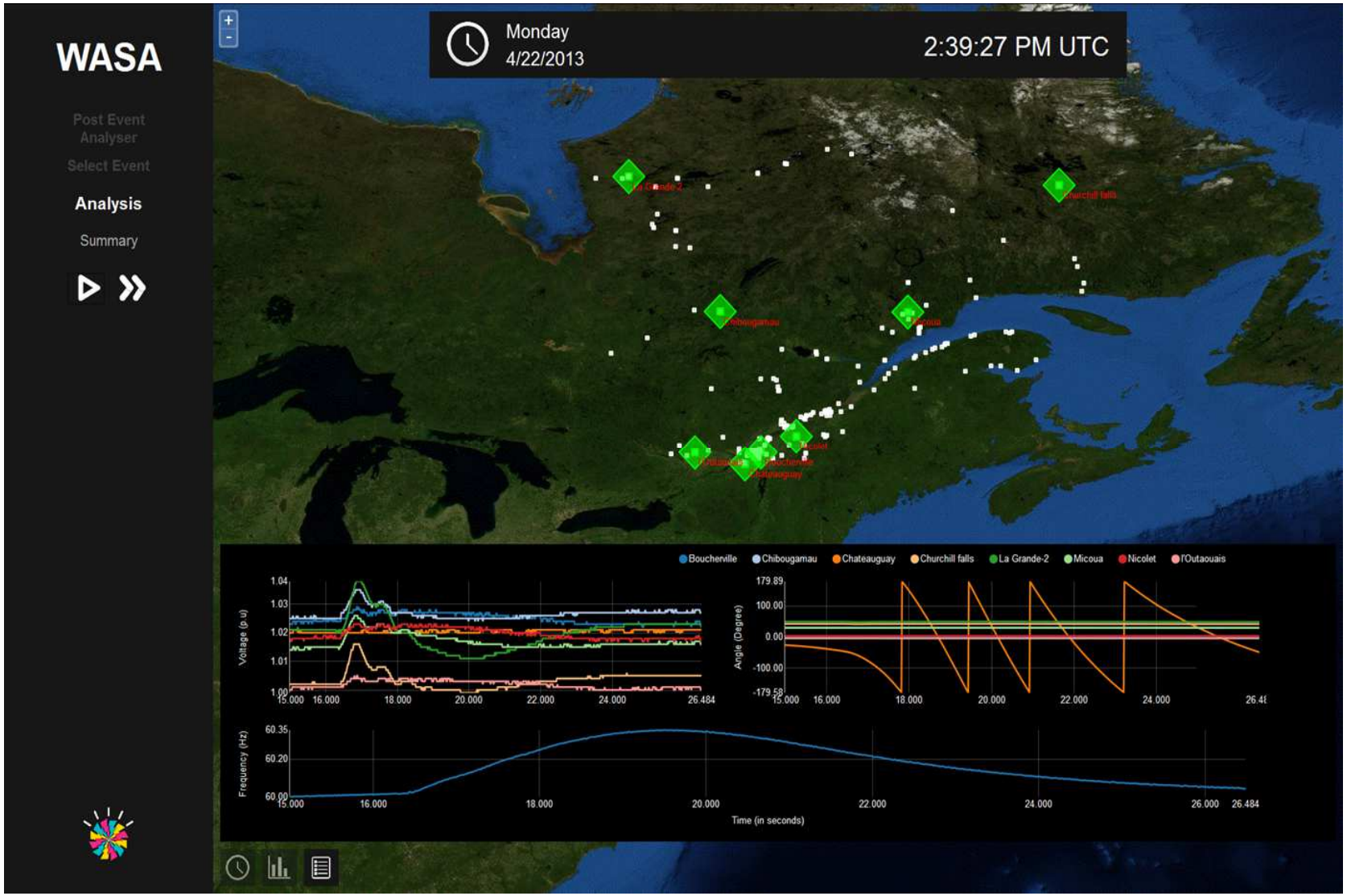
Wide-Area Situational Awareness

- WASA identifies grid anomalies and alerts operators to act before cascading failures that lead to massive black outs. The application provides low latency and high throughput monitoring, archiving, reporting, advanced querying and visualization of the grid state.

- WASA offers significant potential value in helping to avert large-scale blackouts through greater grid state awareness. To provide an example of the magnitude of such events, the 2003 North American blackout had an estimated total economic cost of more than $6 billion.

Wide-Area Situational Awareness



WASA seeks to rapidly identify grid anomalies and alert operators to act before cascading failures that lead to massive black outs. The application will also provide low latency and high throughput monitoring, archiving, reporting, advanced querying and visualization of the grid state.

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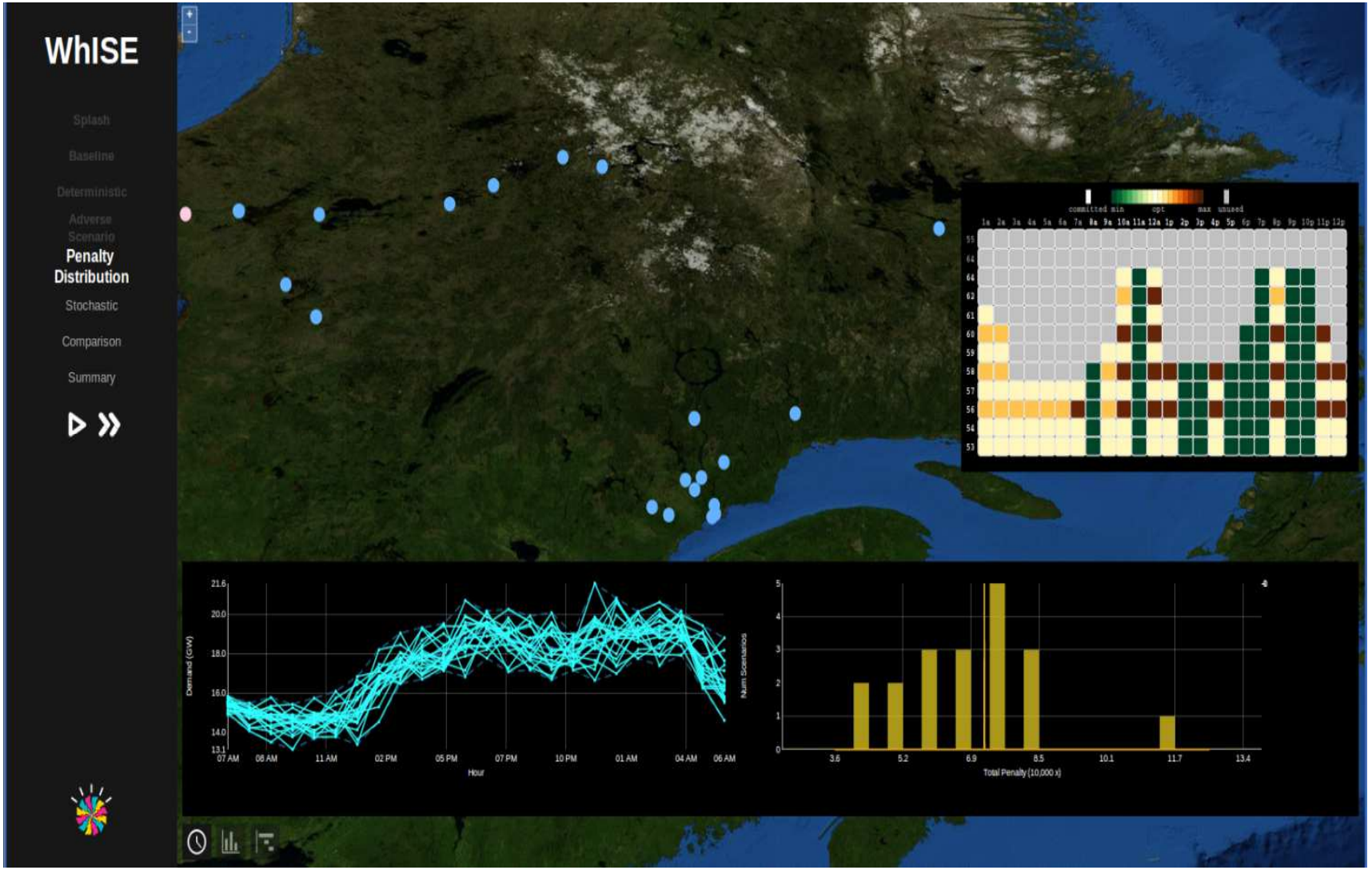
Wind and Hydro Integrated Stochastic Engine

- WhISE is an energy generation planning solution that enables a high percentage of renewable integration. It models the uncertainty of renewables and helps trade off the impact of demand mismatch with the cost of generation unit commitments.

- Current practices rely on high levels of reserves to ensure power availability across all reasonable scenarios. The WhISE approach allows for significant reductions in reserves with better demand matching resulting in cost savings.

Wind and Hydro Integrated Stochastic Engine



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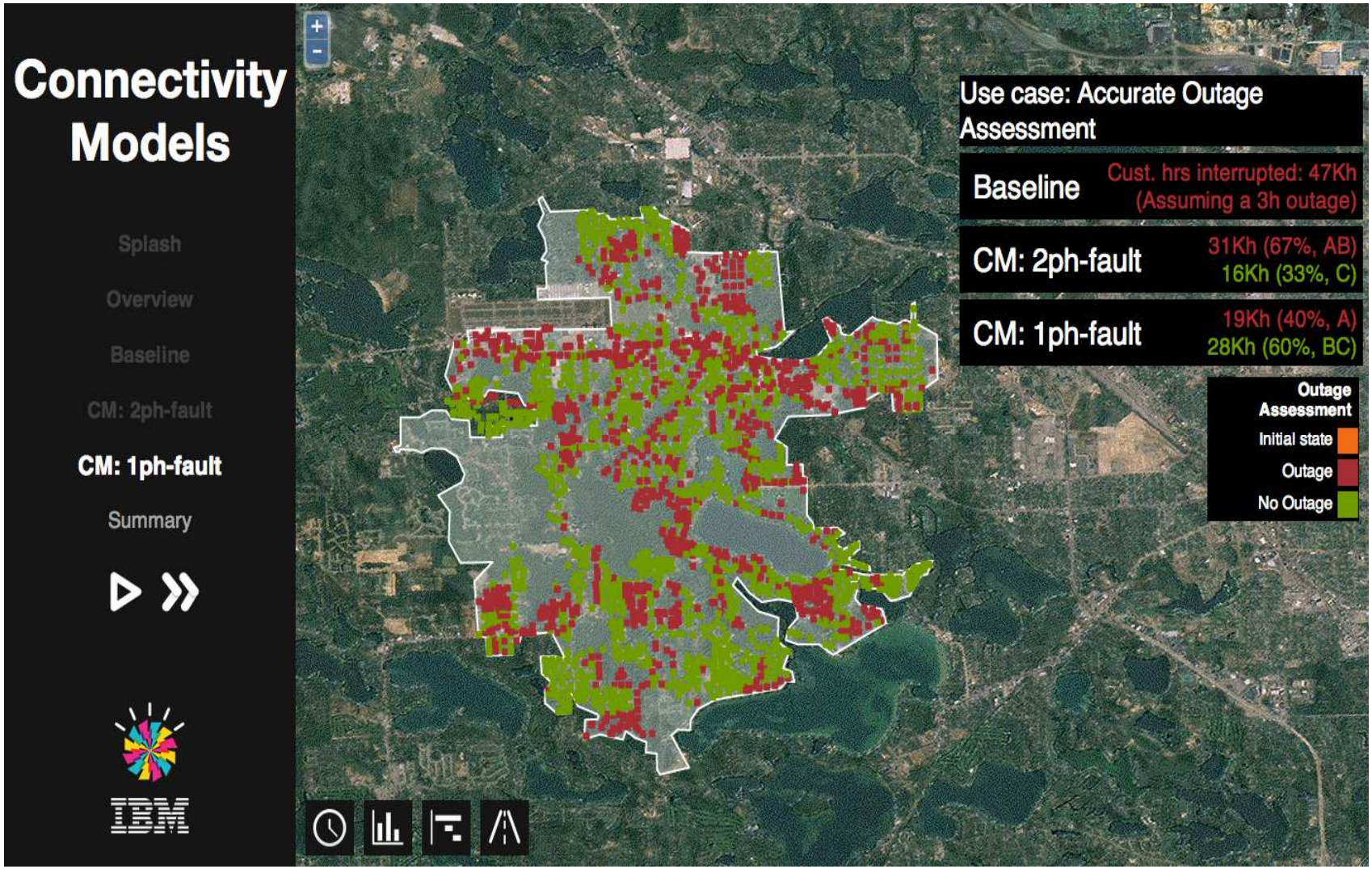
Connectivity Models

- Using advanced analytics on meter measurements, the Connectivity Models application infers customer phase and customer-to-transformer connectivity, which is generally inaccurate or unknown.

- An accurate and sustainable connectivity model is a key enabler of capabilities needed to improve the reliability and efficiency of the distribution grid. Utility efforts to build and verify their connectivity models are labor and resource intensive. The analytics approach will help to radically lower the cost of such processes.

Connectivity Models



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Real-time and interactive analytics

Technical: Supporting **real-time and interactive** analytical queries with **visualization** for millions of meter reads

Example: Last gasp ingestion following large outage

***10:55pm**	2M meters send last gasp message
*11:00pm	Regular 10M meter read cycle processed
*11:10pm	Ingested and merged last gasps and regular reads and first analytical queries can be performed

Available Queries

(1) Find all meters with last gasps and a missing read

(2) Find all meters without last gasps and missing reads

(3) Feed outcomes of (1) & (2) into advanced algorithm to determine root cause

Visualize affected areas and root cause estimates on geospatial grid representation on control room wall and allow interactive analytics queries

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Analytics Application Integration

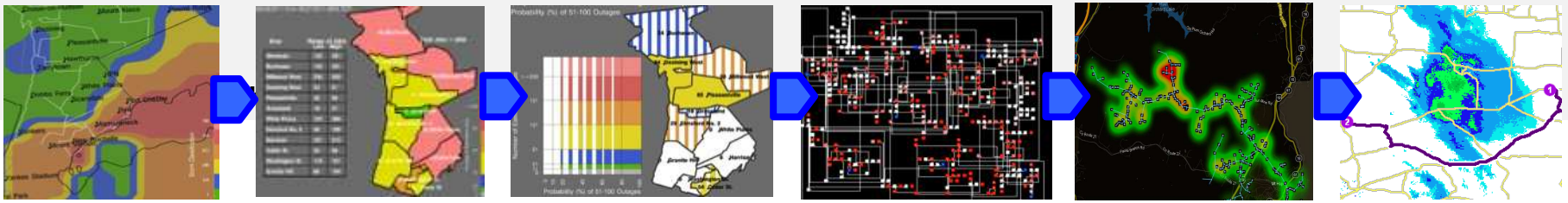
Technical: Enable faster and easier integration of high-performance analytics applications

Example: Outage Prediction and Response Optimization

Transform the decision making process by using coupled predictive modeling, prescriptive analytics, and optimization to address key metrics e.g. SAIDI, CAIDI…

Coupled Models

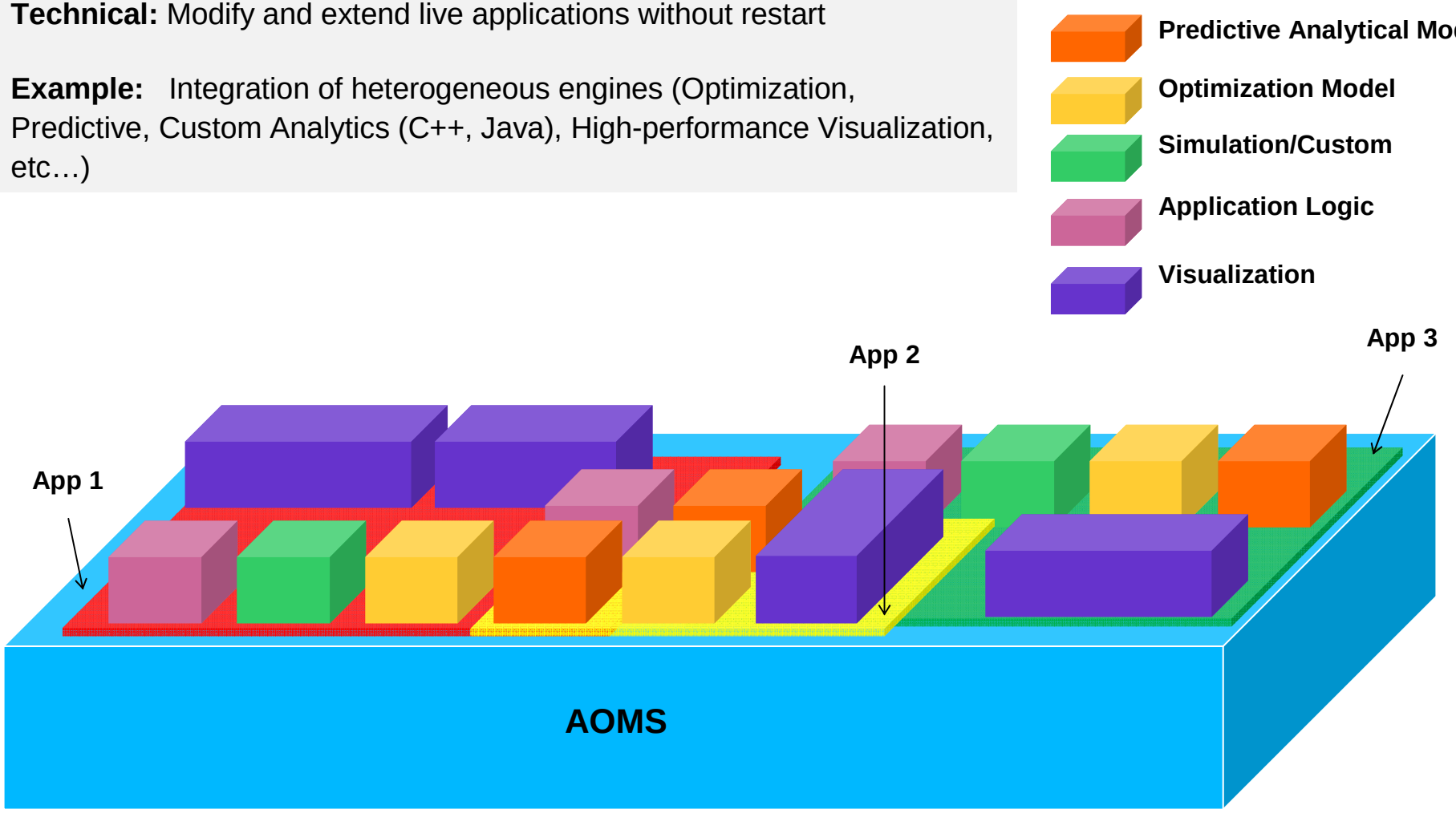
Customized Weather Model	Predictive Damage and Outage Model	Probabilistic Restoration Prediction	Continuous Data Assimilation	Outage Detection	Resource Plan



Application Composability

Technical: Modify and extend live applications without restart

Example: Integration of heterogeneous engines (Optimization, Predictive, Custom Analytics (C++, Java), High-performance Visualization, etc…)

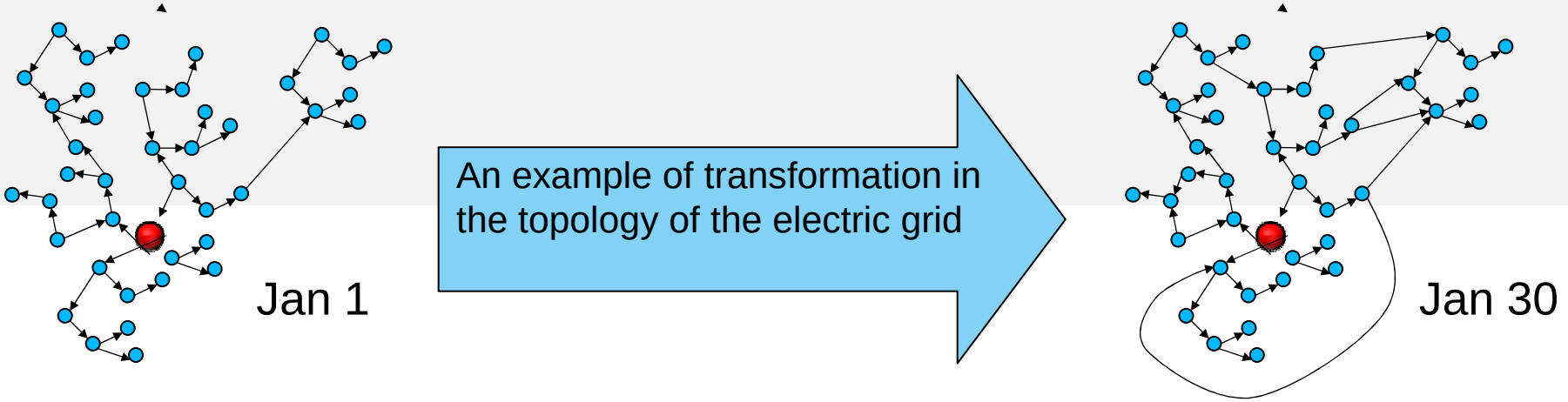


Time-Series Graph Analytics

Technical: High-performance graph analytics on a time-varying grid topology (across 100k+ entities in seconds).

Example: Using analytics to estimate utilization of a transformer as connectivity changes over time

By retrieving grid topology states for a given time range (switch state changes, equipment install/removal), analytics can infer the transformer's utilization

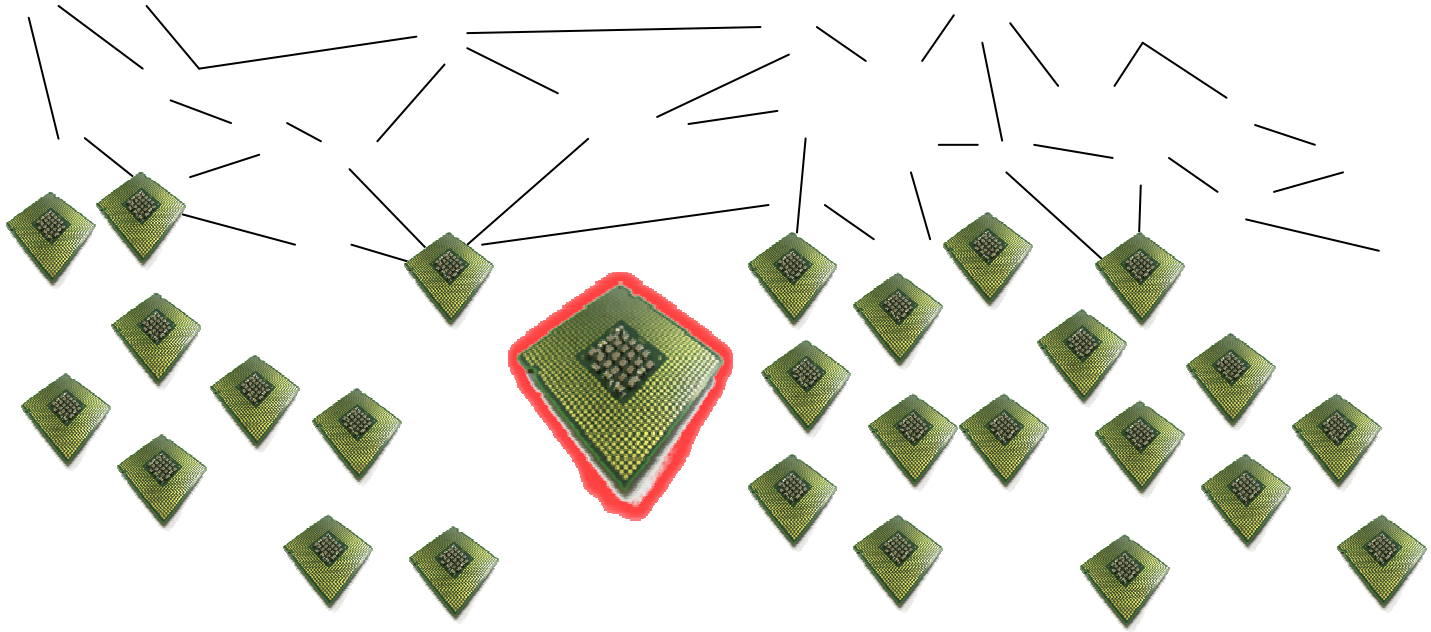


Scalability

Technical: Ability to scale in data volume and computational power with massive parallelism

Example: Fine-grain load forecasting for hundreds of customer segments

Hundreds of statistical models evaluated in parallel across nodes in a compute cluster

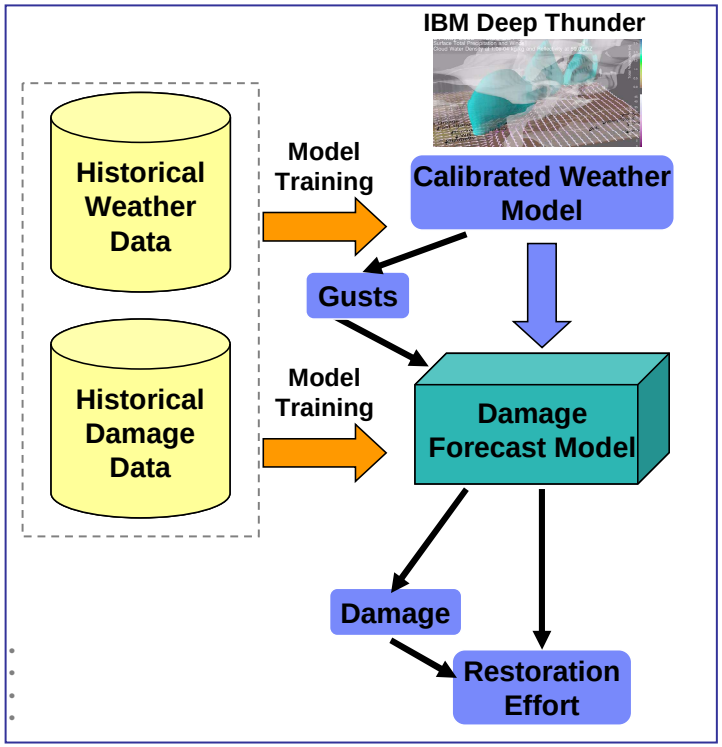


The Business of Weather

- Customizable and highly accurate weather prediction
- Forecasts impacts and integrates with applications for weather-sensitive operations up to three days ahead
- Local, high-resolution weather predictions

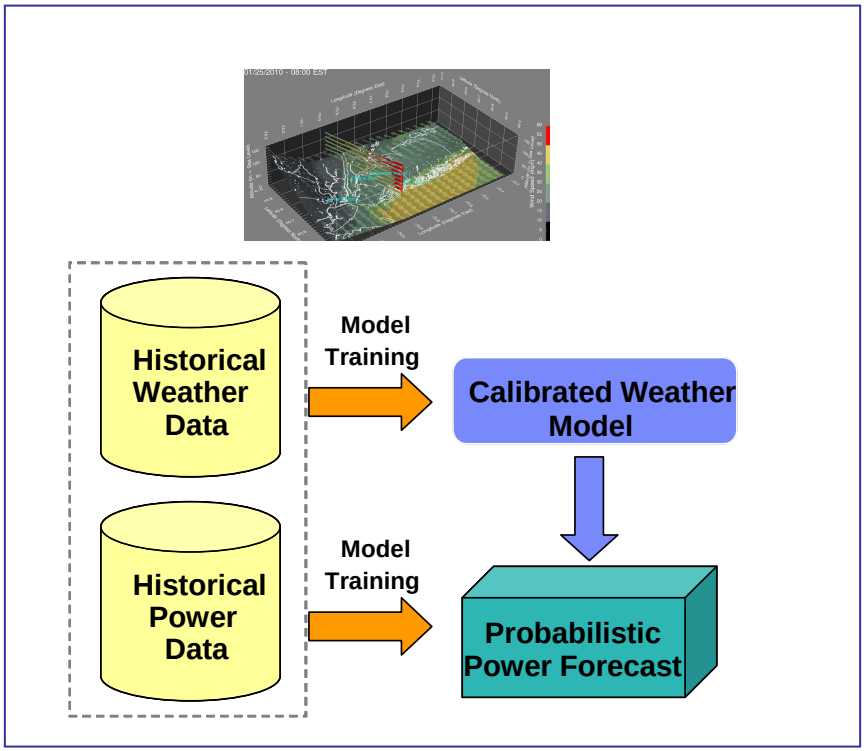
Coupled Weather and Impact Modeling

Custom Modeling for Predictions of Outages



Coupled Weather and Renewable Power Forecasting

Custom Modeling for Power Predictions



Analytics Applications

Outage Planning Optimization

Transforming outage response through prediction and response optimization

Asset Management Optimization

Maximizing Capital Expenditure and Operational Expenditure Return On Investment

Integration of Renewables & DER

Optimizing the use of increasingly distributed and dynamic energy resources

Wide-Area Situational Awareness

Provide high-fidelity real-time predictive and prescriptive analysis of the power grid

The Participatory Network

Enable customers to make informed decisions about their energy use

Design to enable a portfolio of analytics & optimization applications

Analytics and Optimization Management System

Software Development Kit for Streamlined Application Creation
To enable and accelerate application development and deployment

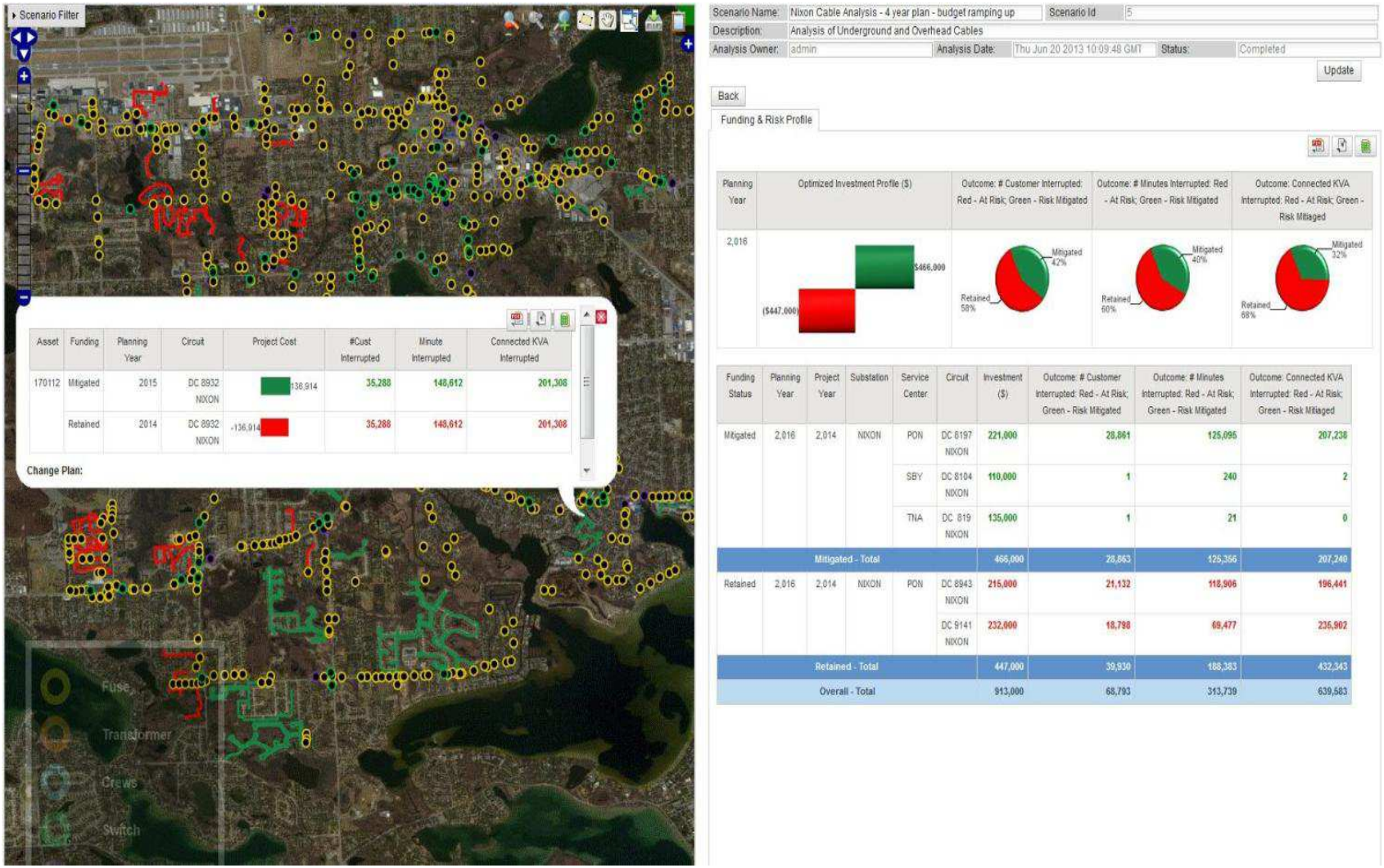
Visualization & Interactivity
To provide interactive browser-based and high performance visualization system rendering

Predictive Analytics and Optimization
To provide a portfolio of reusable analytics engines for utilities to know what's happening next

Complex Data
To ingest, store and query massive heterogeneous real-time and historical data sources

Interoperability
To connect to existing management systems & other data sources

Asset Risk Management and Optimized Repair-Rehab-Replace



ARMOR^3 applies predictive and prescriptive analytics on big data from equipment to identify, quantify and ultimately optimize infrastructure maintenance and planning for all electrical assets including transformers, cables, poles, circuits. ARMOR^3 converts data into information, insight and foresight with the aim of providing decision support across the complete electric infrastructure.

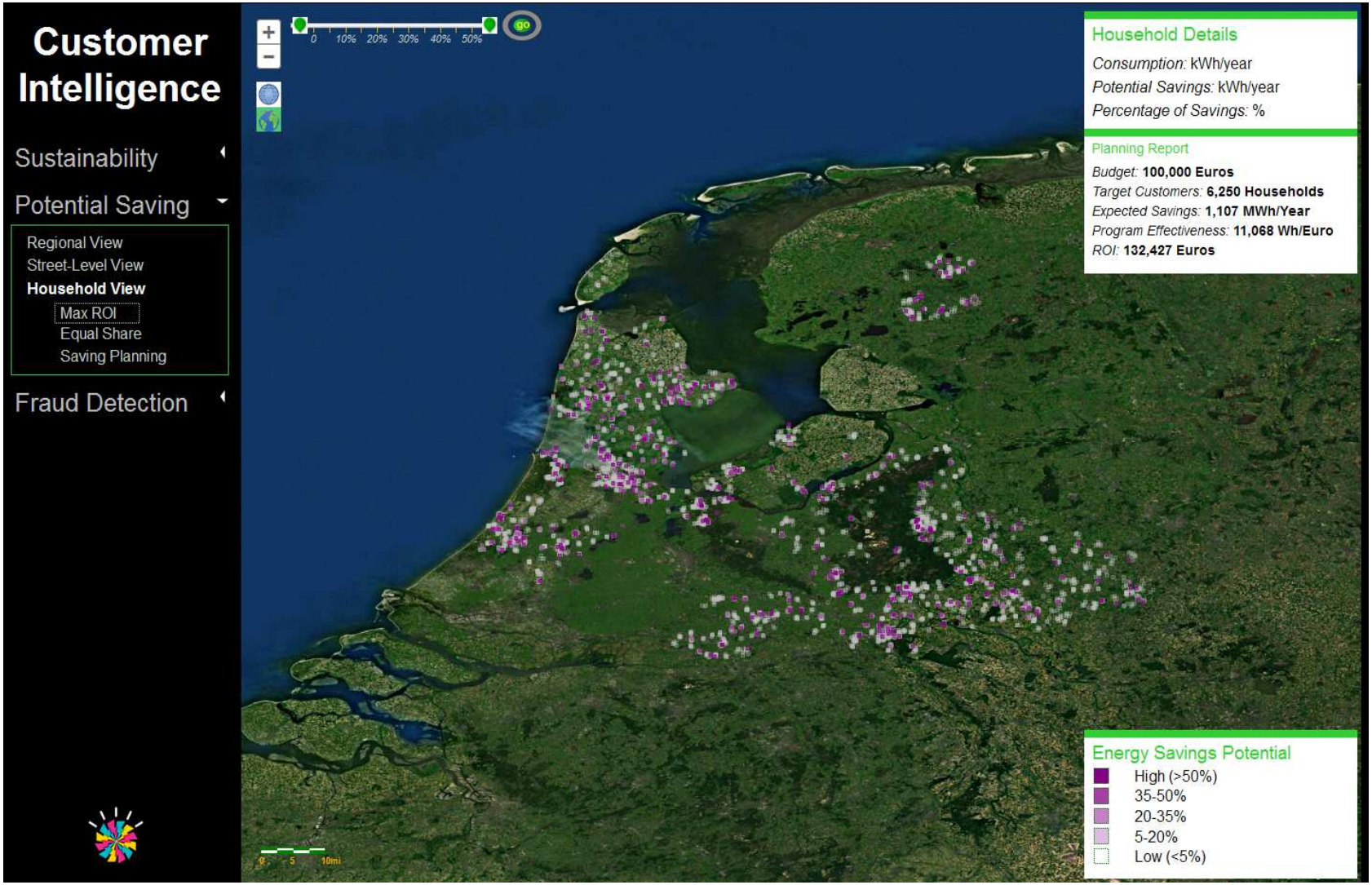
ARMOR^3 provides the ability to run a broad set of scenarios on the same detailed data, prioritizing across multiple teams / groups. It offers predictive maintenance to identify and fix the next failure before it happens, and generates asset risk and investment profiles to enable 100% utilization (useful life) of the asset while taking into account resource constraints.

Optimized Planned Asset Maintenance and Capital Investment

OPAMCI improves visibility into utility asset health conditions based on existing partial instrumentation results and power flow simulation, enabling better asset maintenance, capital investment optimization, and deferment of instrumentation rollout.

OPAMCI aims to reduce the outage cost associated with asset failure by more than 10% through optimizing asset maintenance and replacement schedules. It also aims to reduce the need for expensive instrumentation as an alternative path to such asset health insight.

Customer Intelligence



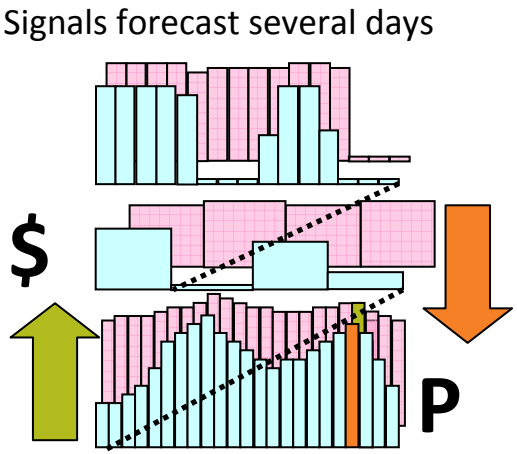
Through data-driven analytics, Customer Intelligence provides advanced customer segmentation capabilities for utilities to better understand their customers and the impact on utility operations.

Such customer insights will help a utility transform the relationship with customers, improving:
- the effectiveness of campaigns and pilot programs by smarter targeting,
- grid stability by understanding changes in customer dynamics such as Demand Response Behavior, Adoption of Renewables and Plug-in Vehicles
- revenue protection by more accurately detecting energy theft.

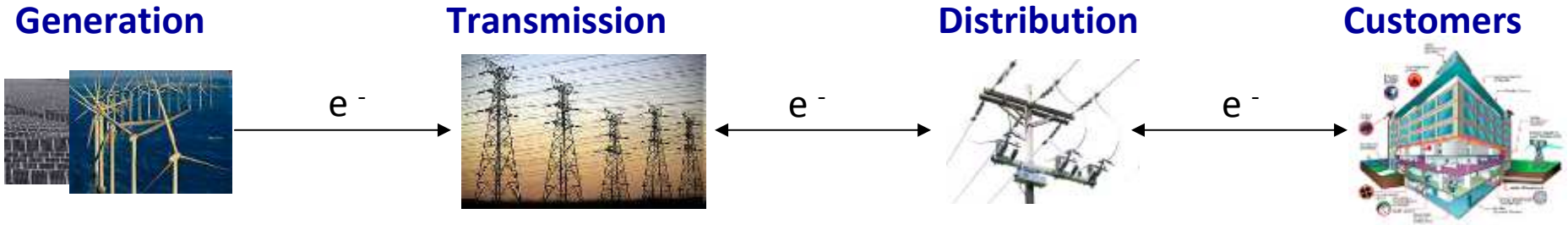
Transactive Energy Definition

A distributed overlay approach utilizing a *cost-based* economic signal as a distributed control system signal.

- All *business* and *operational* objectives and constraints can be assigned a value, and thereby incorporated into the signal.



Transactive Incentive Signal (TIS): reflects true *cost* of electricity at any given point



Transactive Feedback Signal (TFS): reflects anticipated consumption in time

Formulating the TIS

- The Incentive Signal from a node represents the average cost of delivered energy at that node
- Average calculation for interval *n*:

$$TIS_n = \frac{\sum_{a=1}^{A} C_{E,a,n} \cdot \hat{P}_{G,a,n} \cdot \Delta t_n + \sum_{b=1}^{B} C_{C,b,n} \hat{P}_{b,n} + \sum_{c=1}^{C} C_{I,c,n} \cdot \Delta t_n + \sum_{d=1}^{D} C_{O,d,n}}{\sum_{a=1}^{A} \hat{P}_{G,a,n} \cdot \Delta t_n}$$

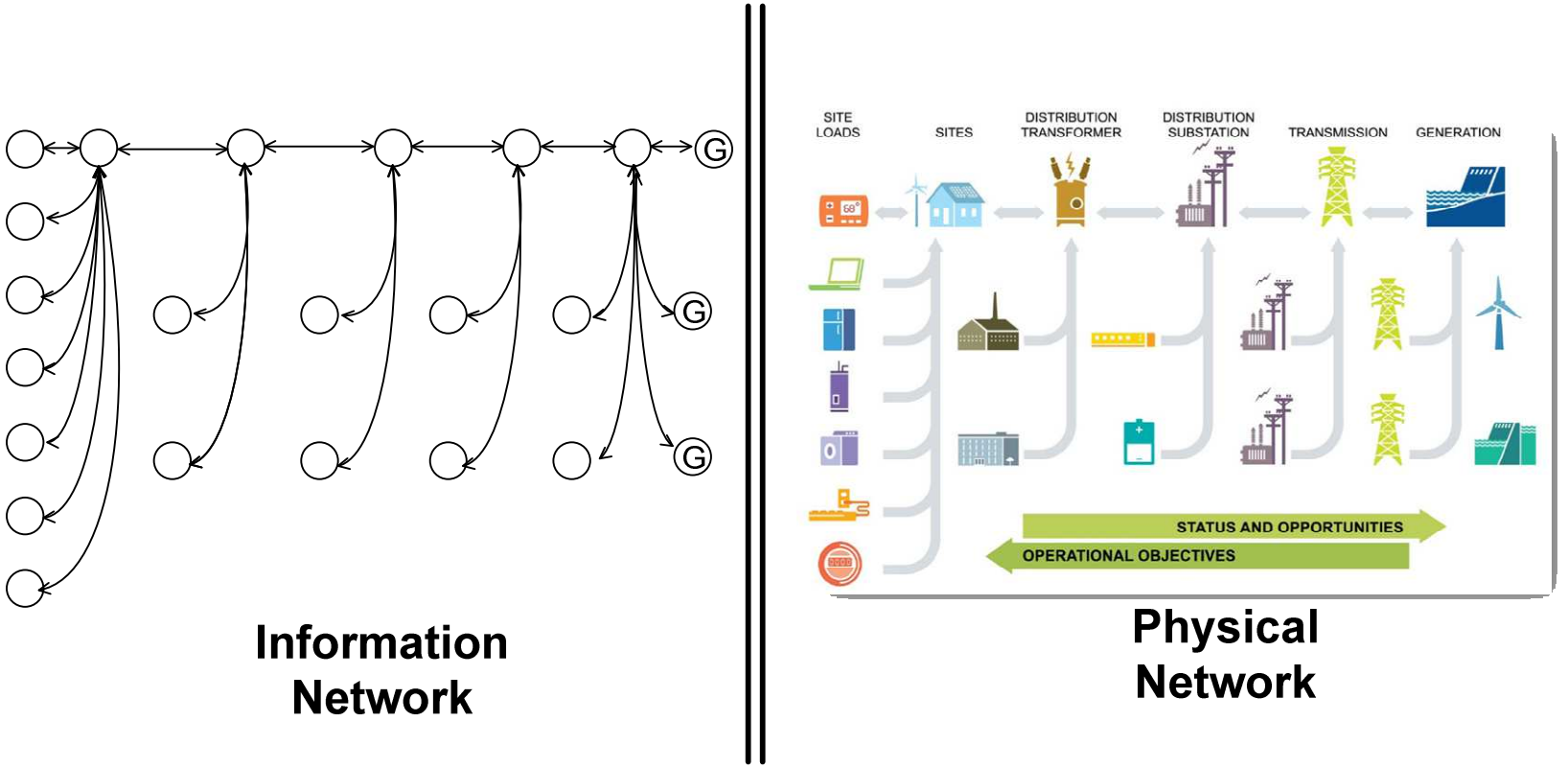
Total supply to node

Component terms:

- Energy (cost per energy) – e.g. marginal supply cost
- Capacity (cost per power) – e.g. capacity penalty
- Infrastructure (cost per time) – any overhead costs
- Other (cost) – additional incentives, one-off charges like excess-demand charge

Propagation of the incentive and feedback signals

Incentive and feedback signals propagate through an information network (the Transactive Control System) that overlays the electrical network; the signals are modified by Transactive Control Nodes (software agents)



Role of a Transactive Control Node

- Responds to system conditions as represented by incoming Transactive Incentive Signals and Transactive Feedback Signals through
  - Decisions about behavior of local assets
  - Incorporation of local asset state and other information
  - Optionally updates both transactive incentive and feedback signals

- Inputs representing objectives are needed from asset-owners to calculate incentive and feedback signals

- Each signal is a sequence of forecasts in a time-series, so inputs will also be sequences of future (forecast/planned) values

Further Insights On-Line

- Analytics and Optimization Management Management System
  - http://www.research.ibm.com/client-programs/seri/
  - Applications are on the lower half of the page, clicked to from the blue button link
    - http://www.research.ibm.com/client-programs/seri/conference.shtml

- Overview video
  - http://www.youtube.com/watch?v=GoT4kBeTXJk

- Other videos in this area
  - http://www.youtube.com/watch?v=hlfxOlkeL-M
  - http://www.youtube.com/user/IBMEnergyUtility/videos

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  - HYbrid Renewable Energy Forecast press release
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