Emerging Applications of Waveform and Synchro-Waveform Data Analytics in Electric Utilities

Panel Session: Synchro-Waveforms Data Analytics and Data-Driven Applications

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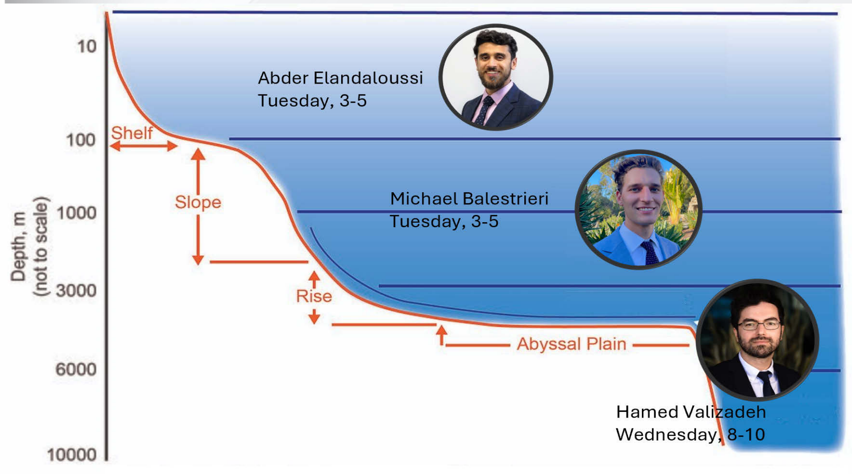
Outline

- Distribution Waveform Analytics (DWA) project introduction
- Challenges of detecting and locating grid anomalies
- Waveform analytics and feature engineering for anomaly detection and classification
- Real experiences and application



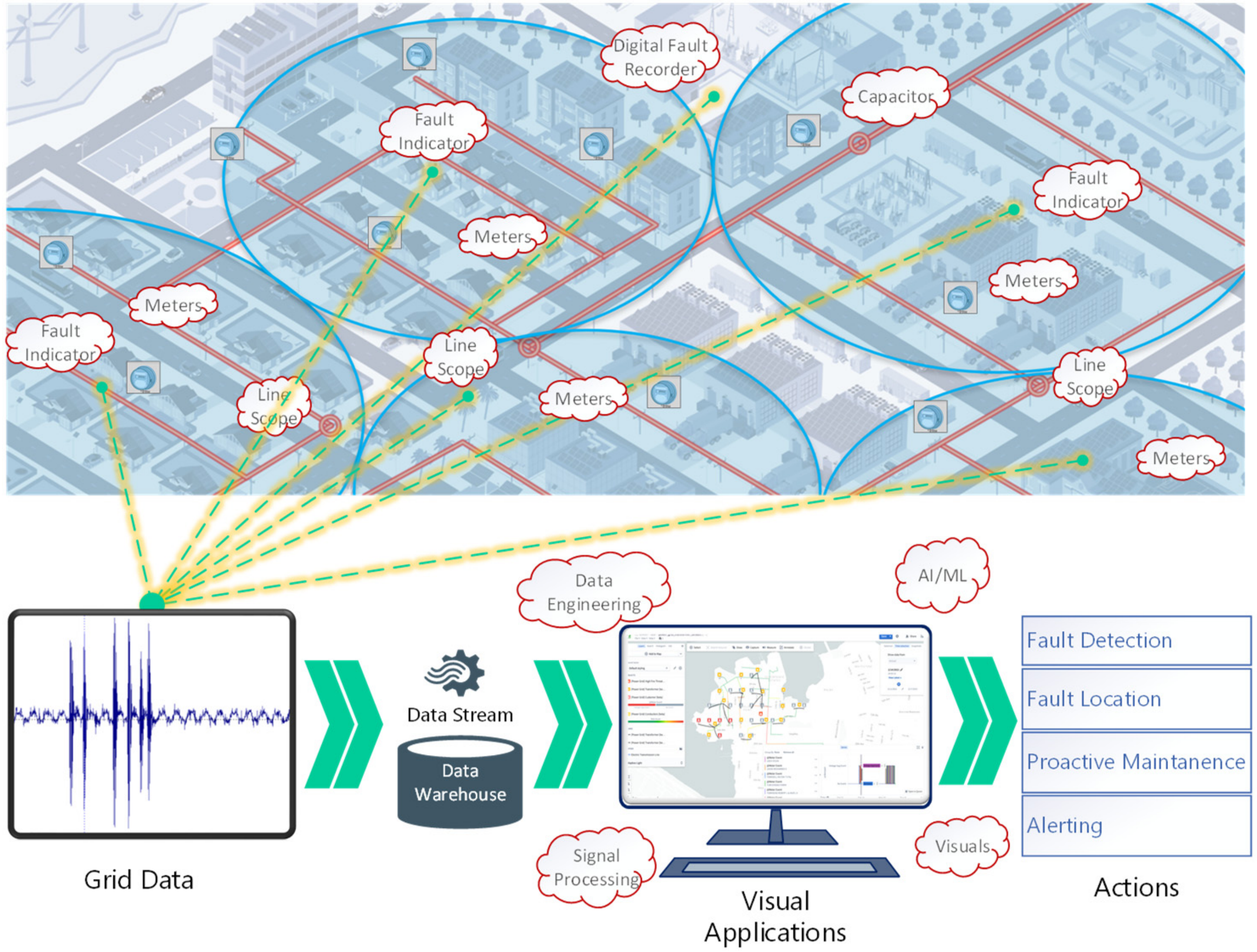
Distribution Waveform Analytics (DWA)

Business Objective: Provide situational awareness to incipient events that could potentially spark a wildfire.

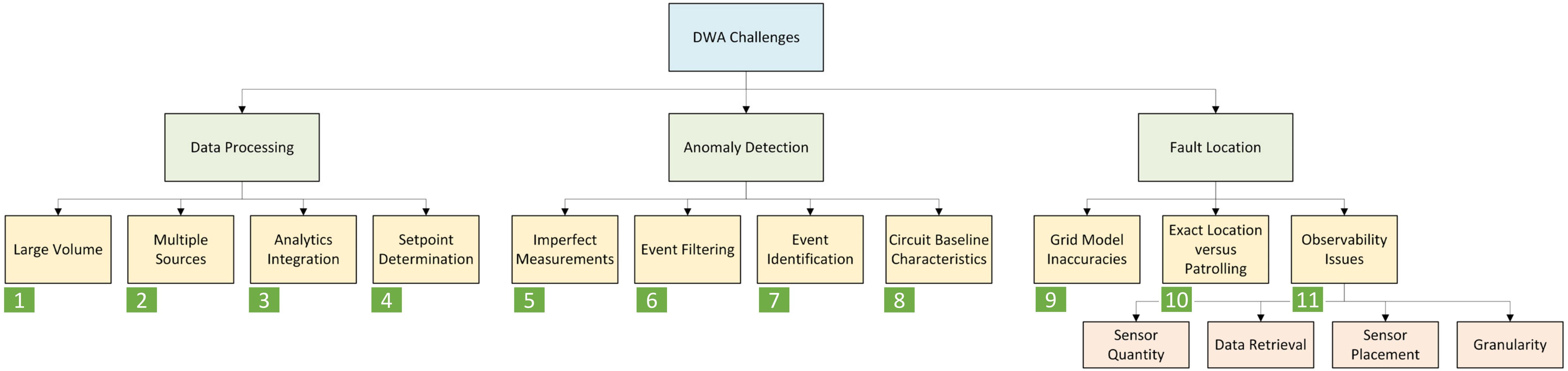
Technical Objective: Integrate disparate grid data sources from existing equipment into a single analytics platform and run analytics.

Devices in Scope:

- Digital Fault Recorder (DFR): Records high-resolution data at the feeder head that can record up transient events
- SCADA Devices: Switches, interrupters, capacitors, and fault indicators that record status events and system conditions
- Smart Meters (AMI): Customer meters provide real-time events at the endpoint level

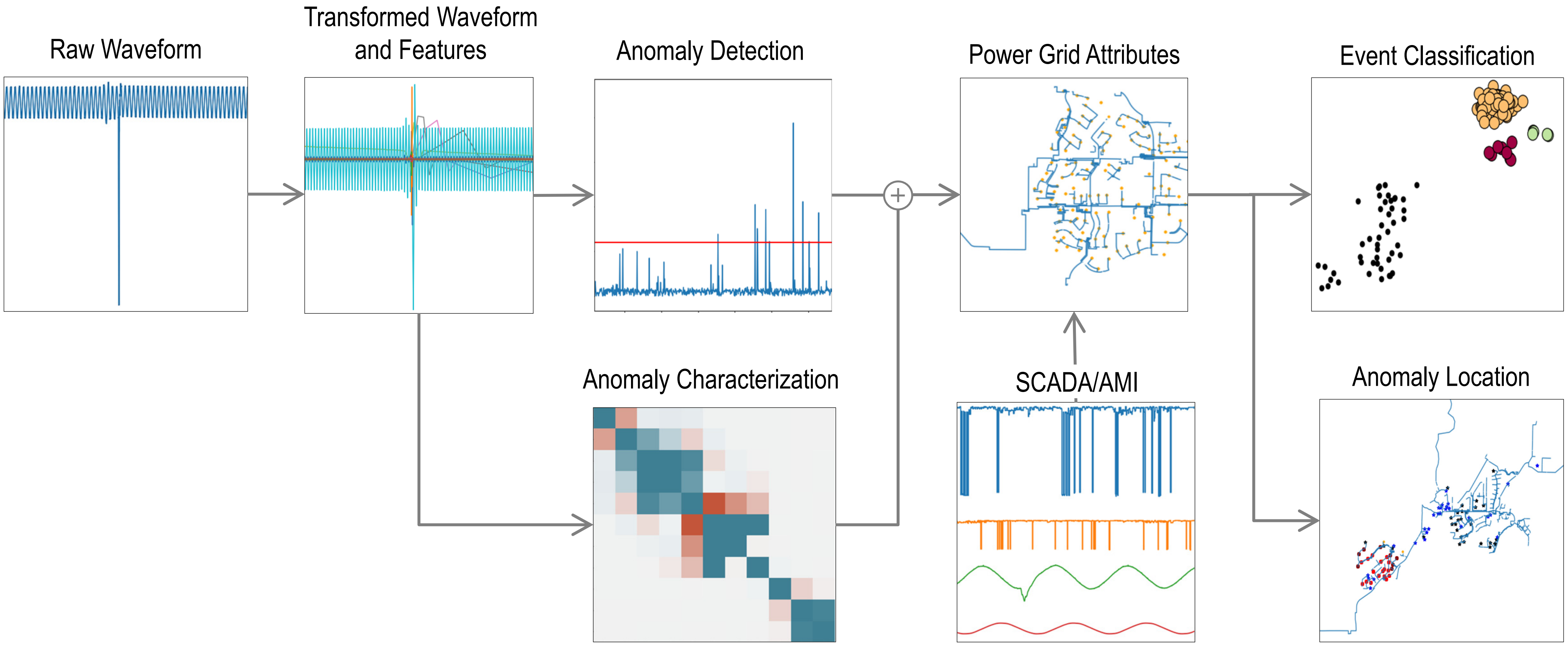


Challenges



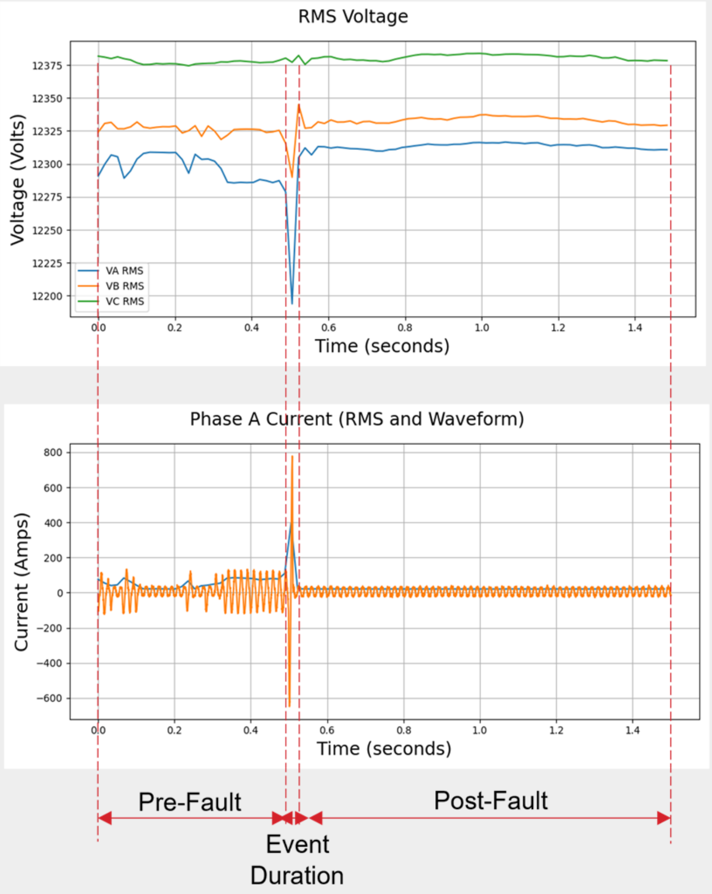
1) A waveform recorder produces roughly 1 GB of continuous point-on-wave data per day per circuit with event data ranging 0-1 GB per day
2) Inconsistencies between various measurements and sensors
3) Data silos between systems (DFR, SCADA, AMI), and operational data in separate databases with no singular analytics platform
4) Determination of settings for selective sensor communications
5) Currently available grid edge measurements are imperfect
6) Prioritization of actionable issues
7) Profile of a fault voltage and current can vary across different fault types and grid layouts
8) Circuit characteristics influence anomaly detection and setpoints
9) The performance of the methods that rely only on the accuracy of the grid impedance parameters are not consistent due to the high sensitivities and imperfect data management
10) Inconsistencies between various measurements and sensors
11) Measurements lack in quantity, placement, and granularity, and data retrieval is sub-optimal at best with the aging wireless networks in place

Waveform Analytics and Feature Engineering for Applied Anomaly Detection

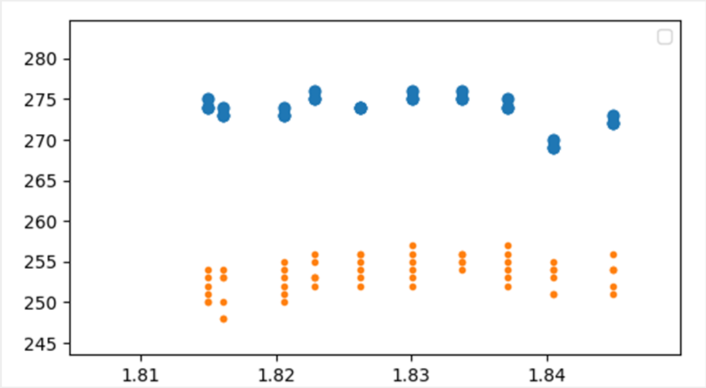


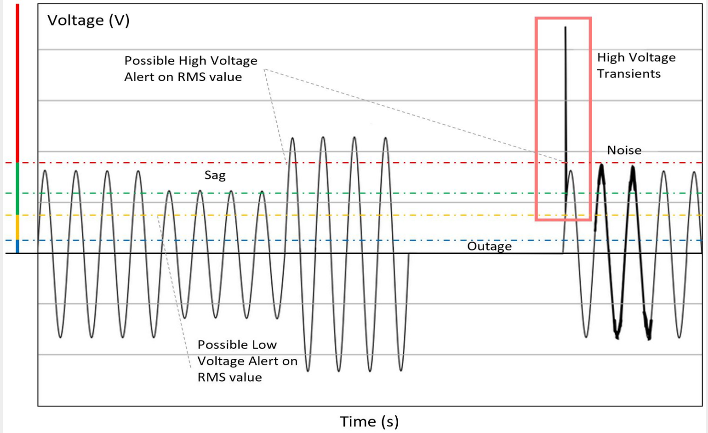
Example Data Types

Digital Fault Recorder creates transient and extended continuous oscillography at the substation

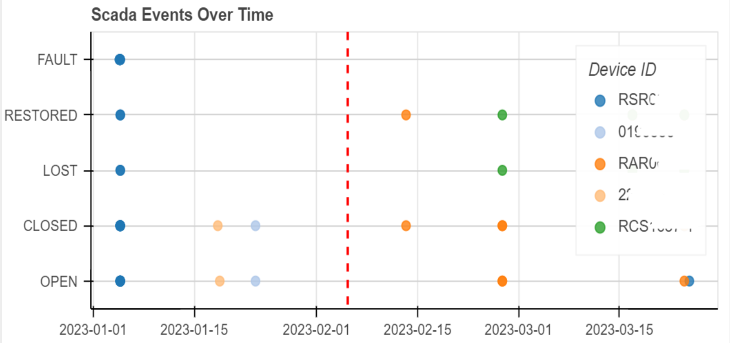


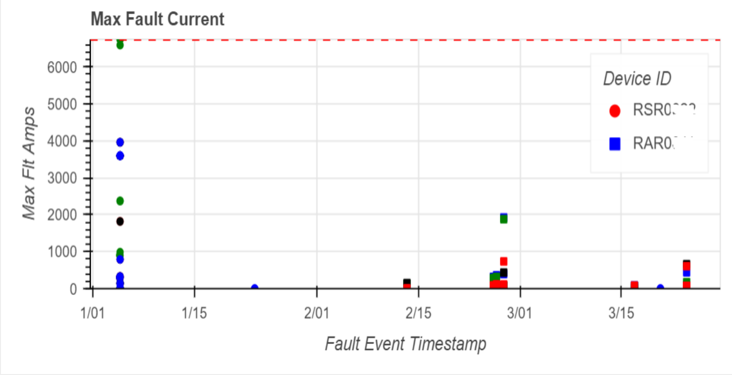
AMI voltage alerts indicate that voltage has exceeded or dipped below or above a preset threshold for at least 1 second



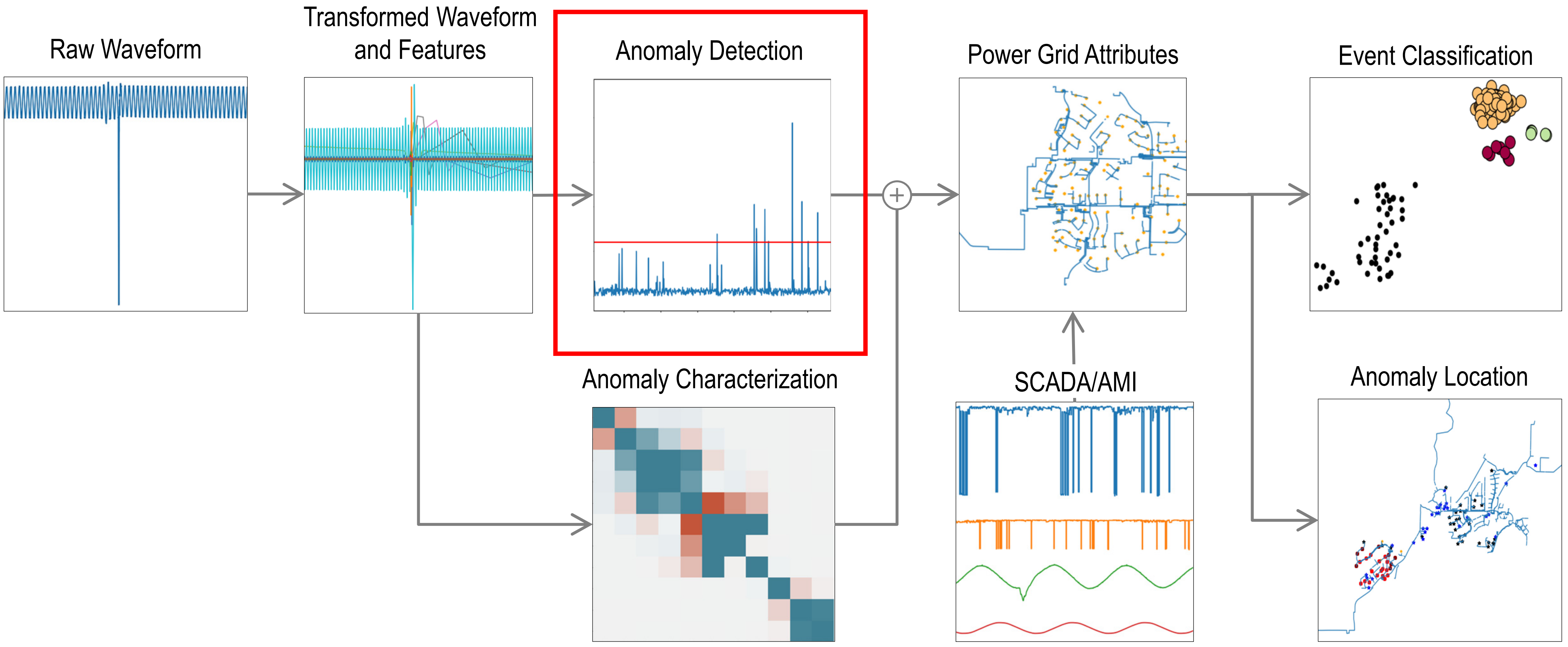


SCADA events, metadata, and fault data varies across different devices and provide device statuses and lower fidelity fault intelligence from the field





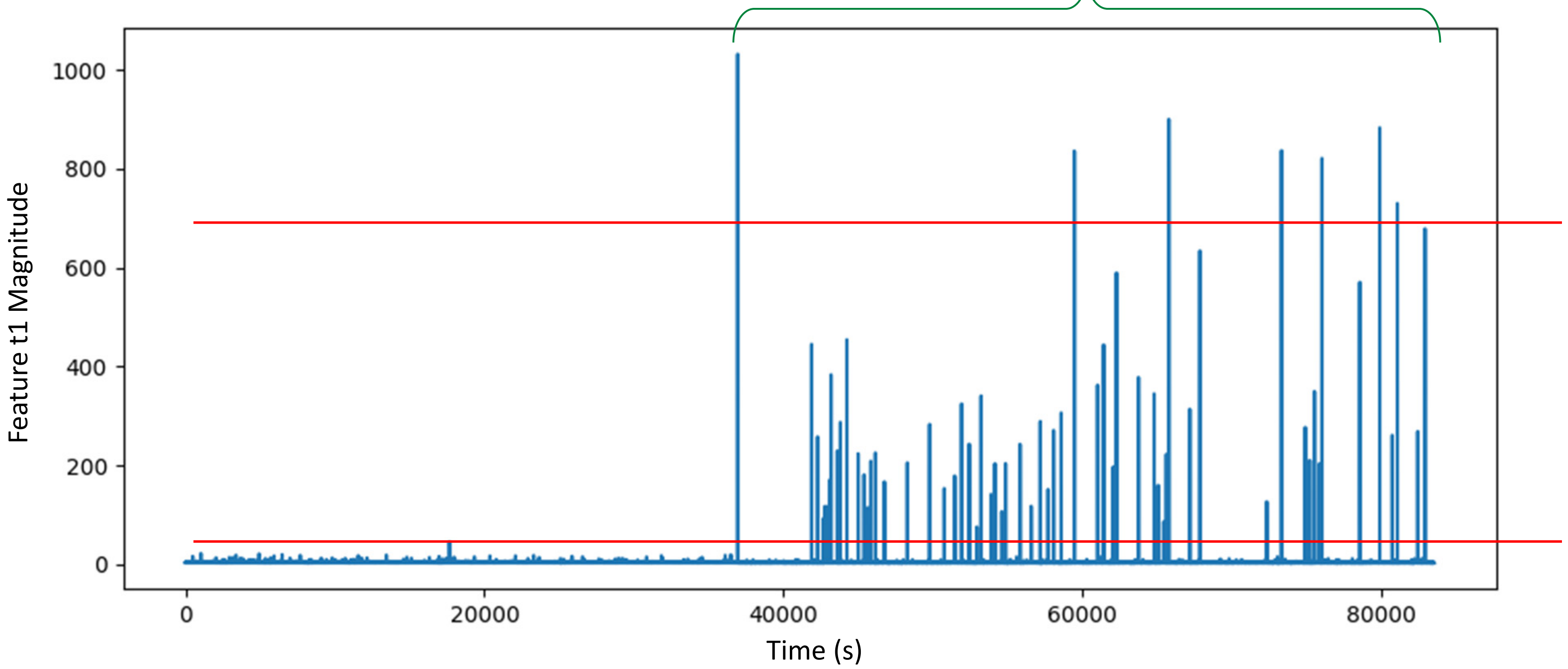
Waveform Analytics and Feature Engineering for Applied Anomaly Detection



Waveform Features for Anomaly Detection

- A threshold is intended to detect when something is abnormal. Abnormalities aren't always problems.
- Any alert you set on a metric exceeding what you think is a normal threshold is going to fire a lot.
- A monitoring system needs to know the difference between an unusual state and a real problem, and this isn't possible with <u>only</u> a threshold.

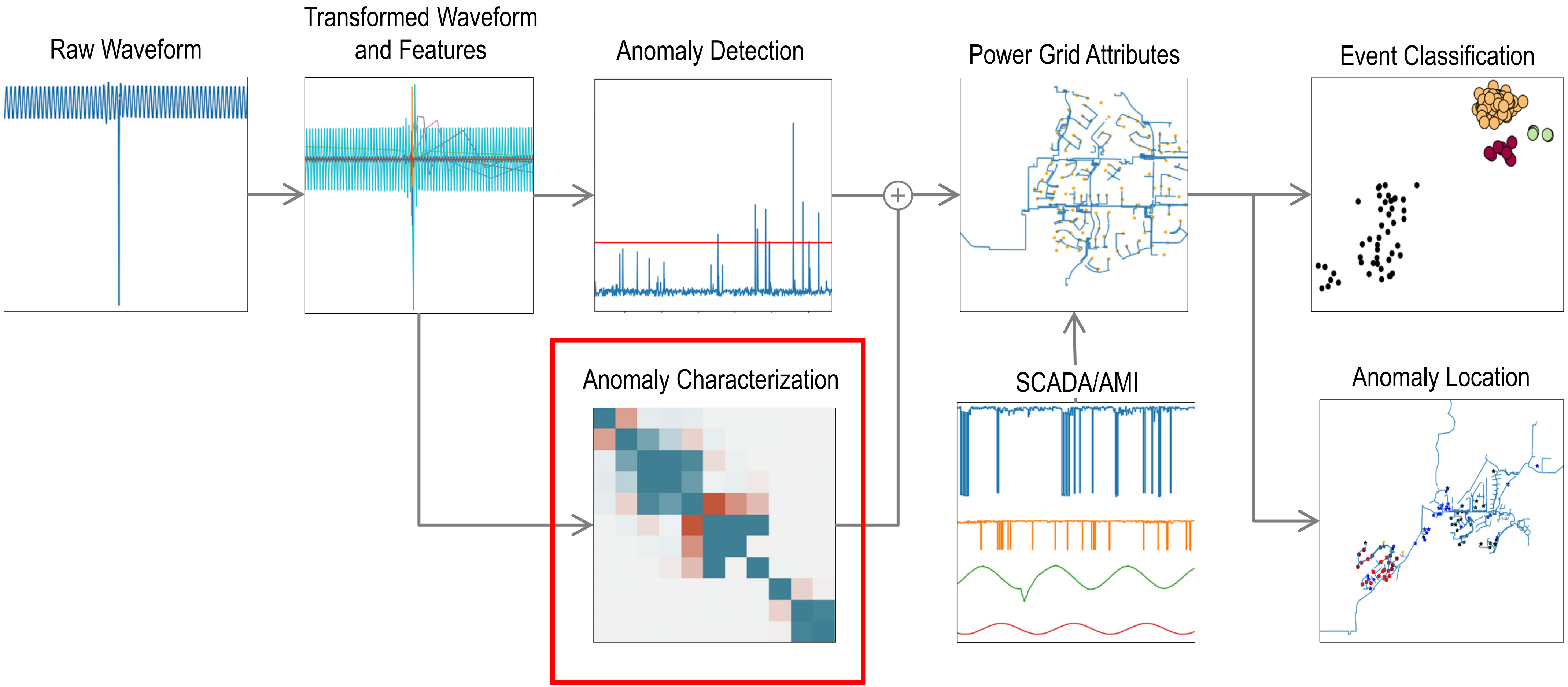
Incipient Signatures of an UG Equipment Failure Together with Other Grid Issues



Features have dynamic range to allow for setting/using varying levels of thresholds for varying levels of actionability (basic filtering of anomaly and event-types)

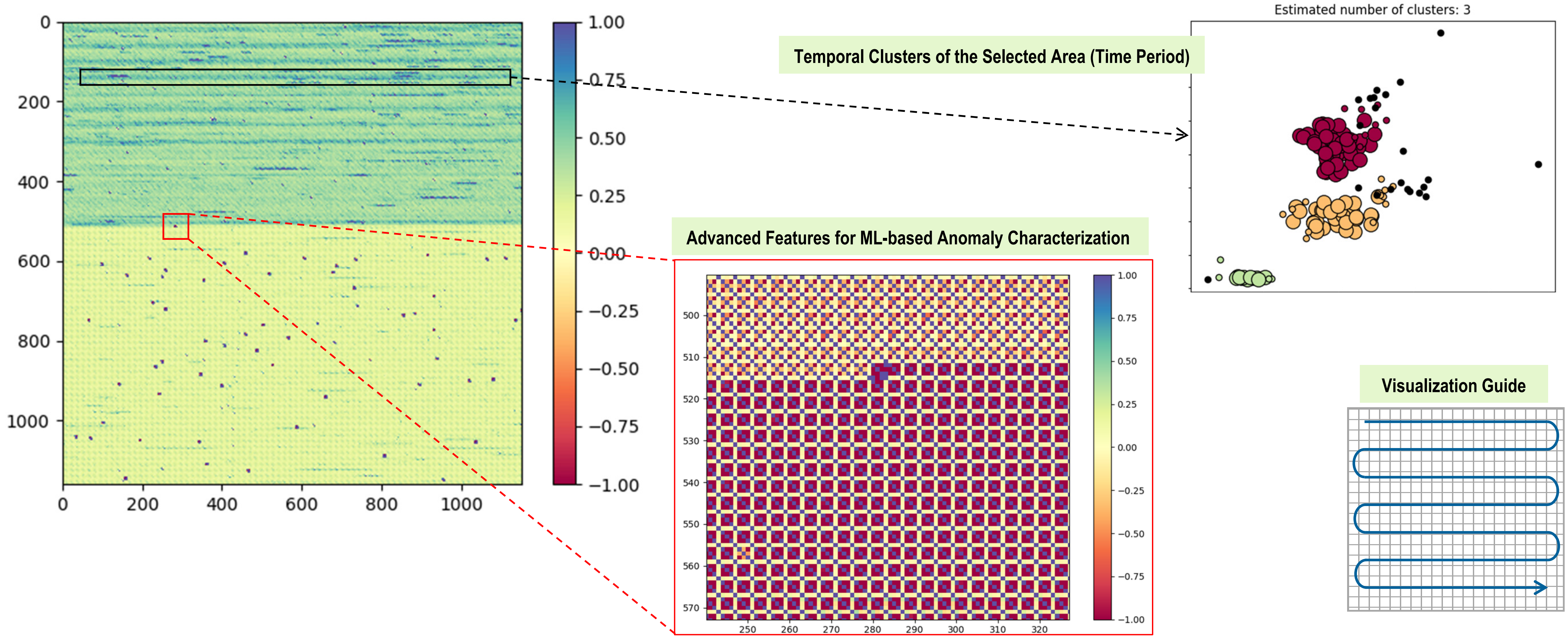
Features are very sensitive to anomalies (anomaly characterization prevents repeated triggering)

Waveform Analytics and Feature Engineering for Applied Anomaly Detection

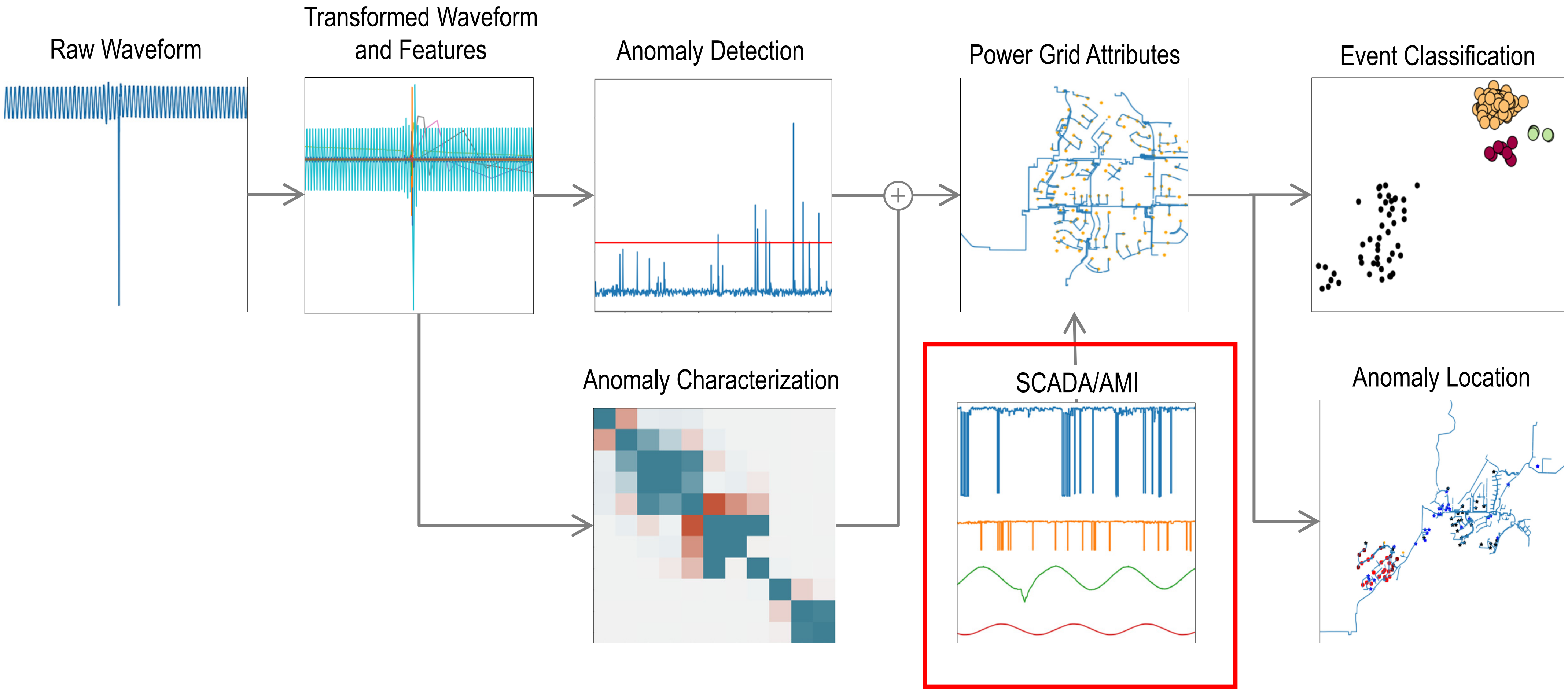


Waveform Features for Anomaly Characterization

- Anomaly characterization (by temporal clustering) is developed together with the anomaly detection.

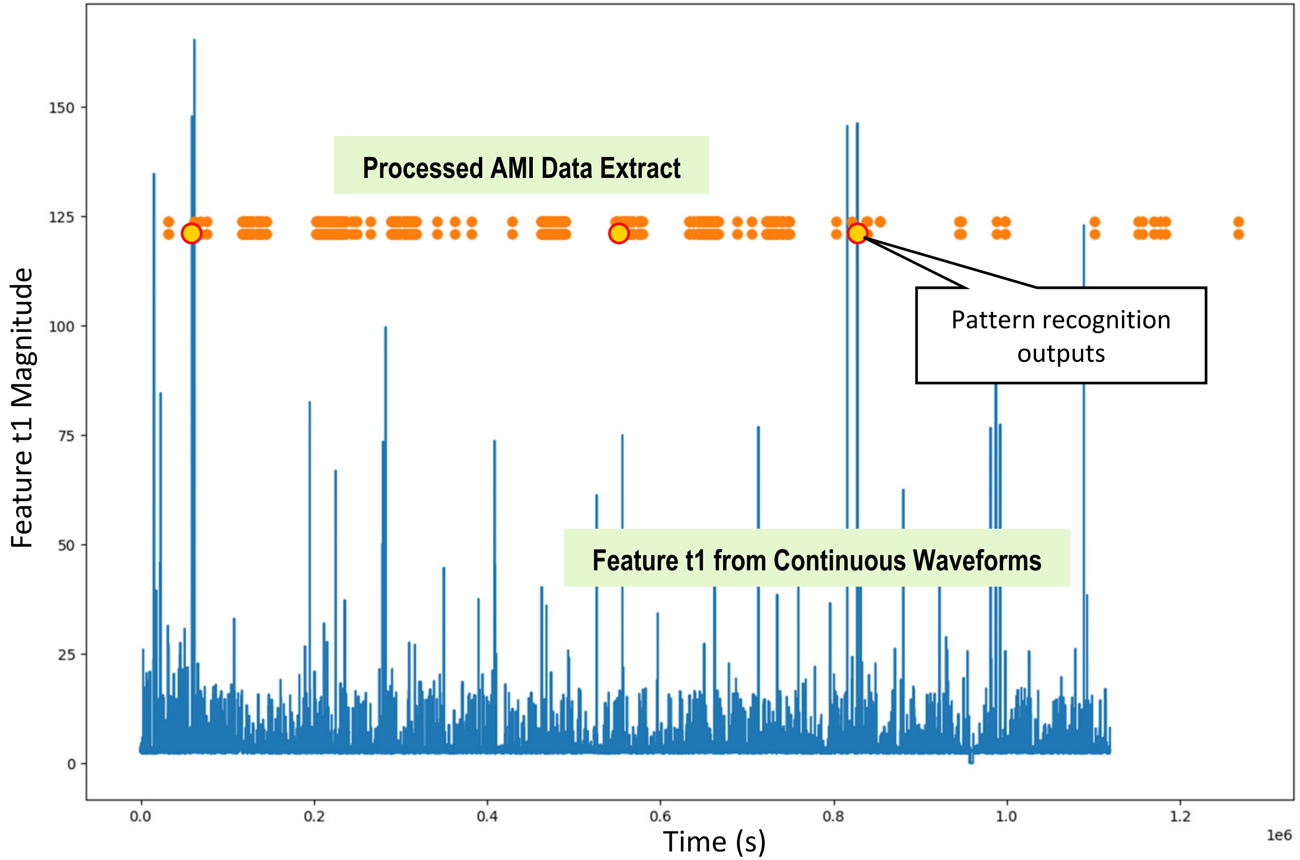


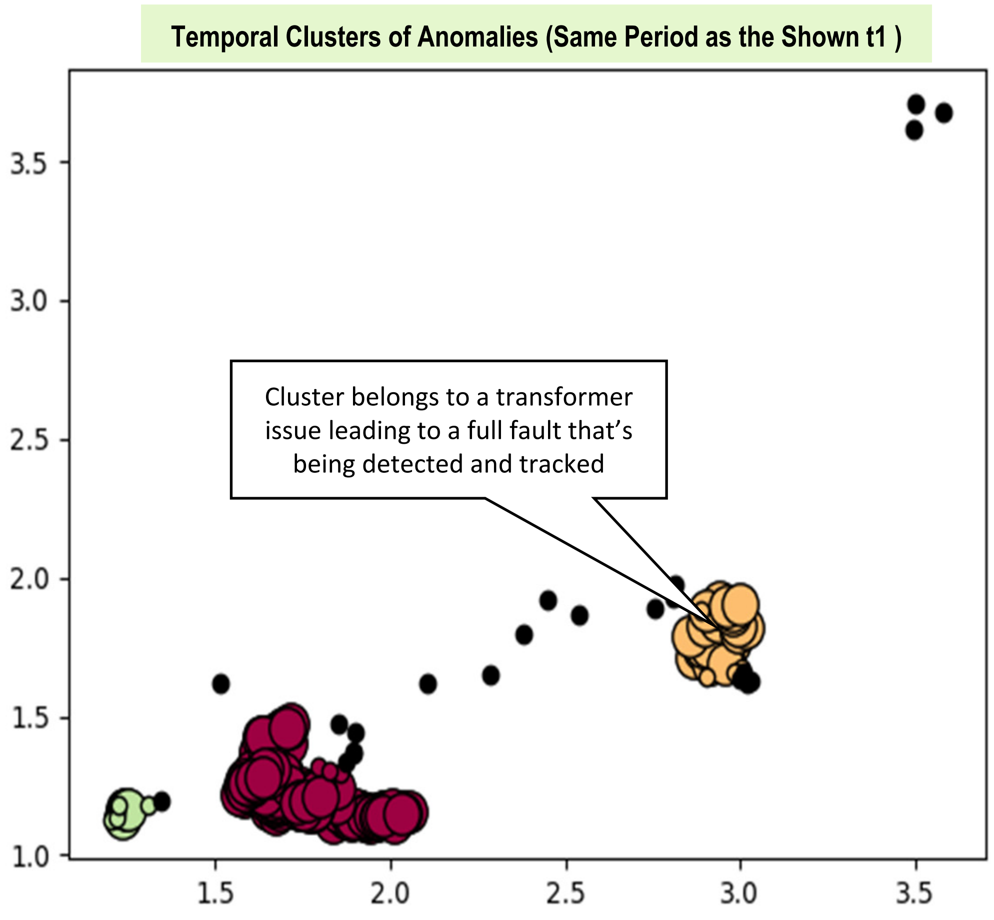
Waveform Analytics and Feature Engineering for Applied Anomaly Detection



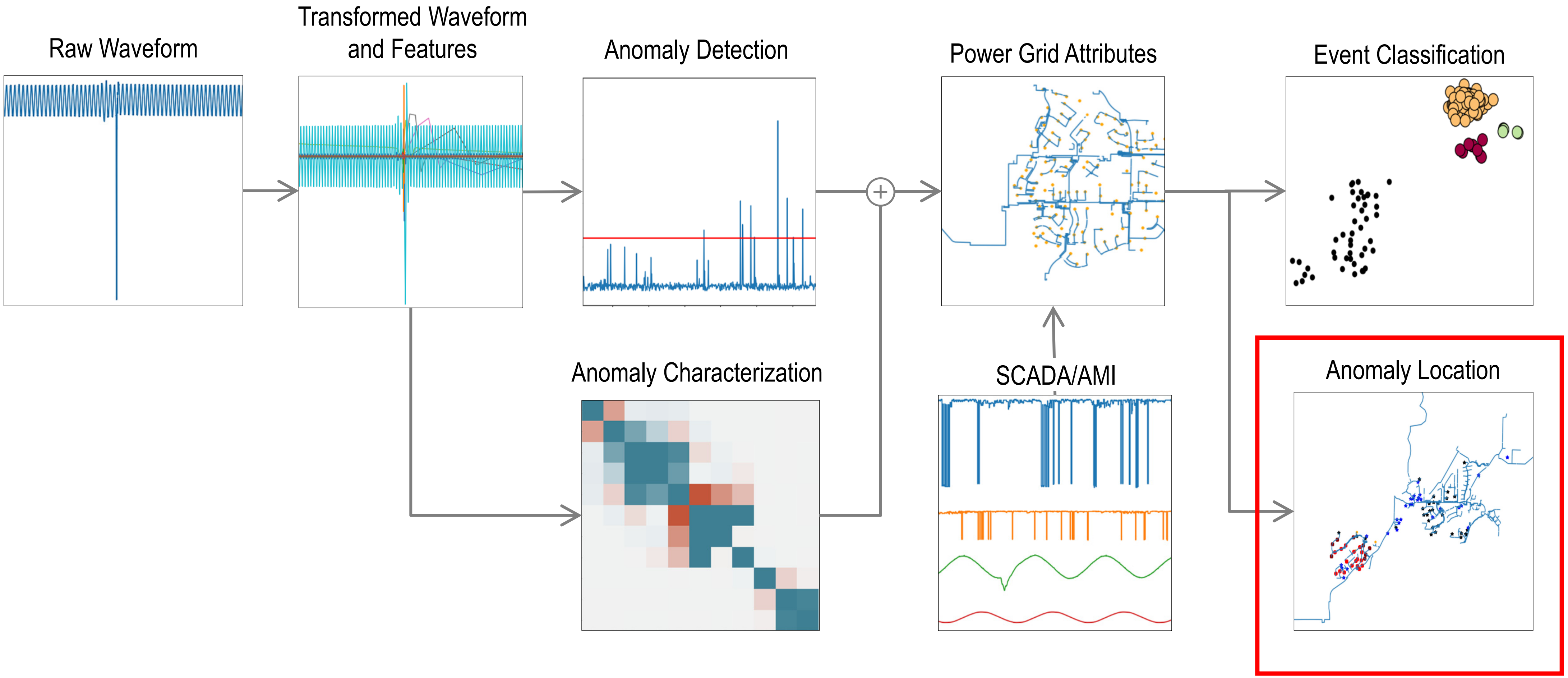
Waveform Features for Anomaly Detection

- AMI-based abnormal voltage recordings help pinpoint fault location via spatiotemporal modeling of imperfect and sporadic measurements
- Frequency of incipient signature occurrence increases over the course of the failure as time passes.



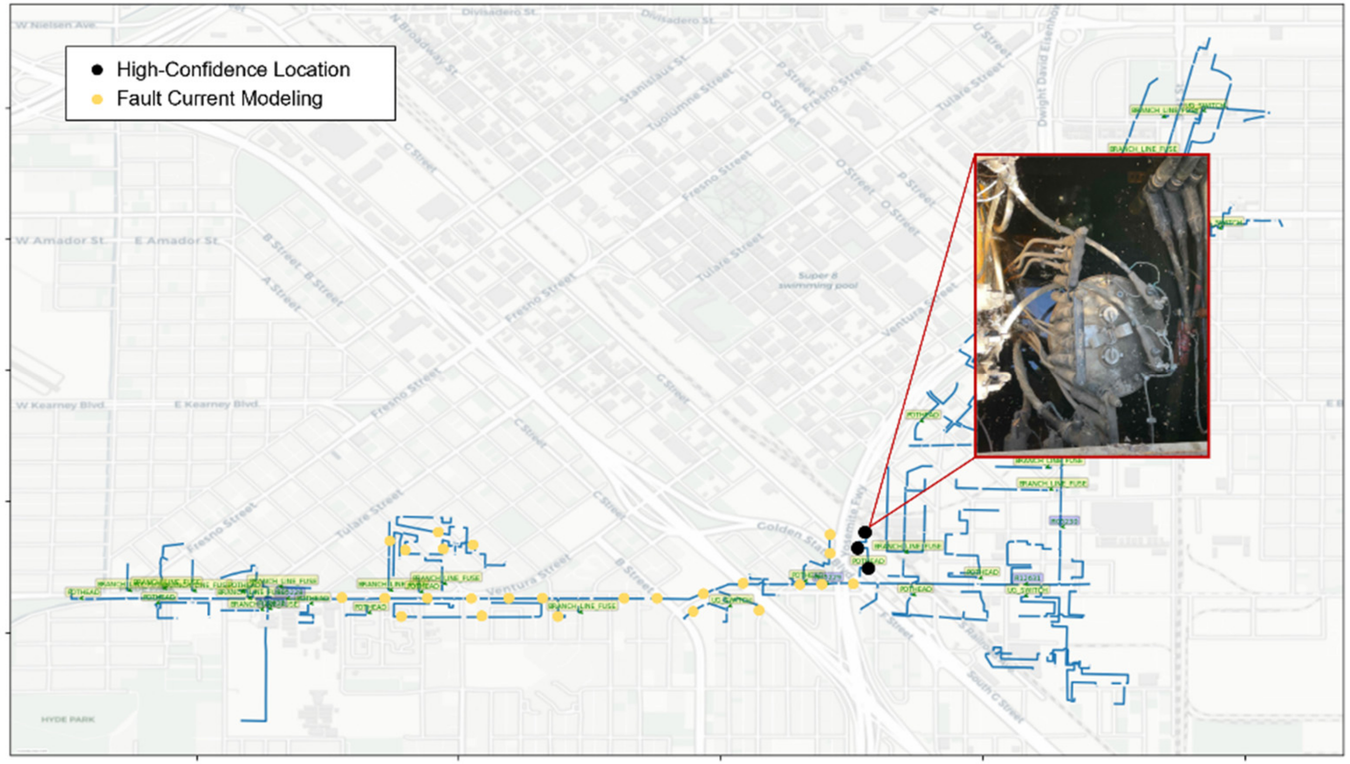


Waveform Analytics and Feature Engineering for Applied Anomaly Detection



Real Example for Location Estimation

- Incipient underground fault
- Signatures started 92 days ahead of the final failure
- Several methods for fault location are implemented. Two methods shown:
  - Waveform-based estimation (yellow dots) relative to the known location
  - Multi-source high confidence estimation (black dots) include the location of final failure
- Multi-source estimation utilizes grid edge voltage alerts from AMI
  - GPS time synchronization is not required. Waveshape synchronization is sufficient
- Detection of event type and protection system awareness are key



The grid layout is slightly modified to remove sensitive information

Conclusions

- **Enhancing Model Performance**: By crafting features that capture the essence of the event, we enable our models to extract meaningful patterns and relationships from the data, leading to more accurate insights.
- **Improving Model Interpretability**: Engineering features that are interpretable, enables transparency and is essential for building trust in machine learning systems and making informed decisions based on model outputs.
- **Handling Complex Data**: Distribution grid data is rarely clean. It often contains missing values and outliers that can hinder model performance.
- **Minimal Need for Labeled Data**: Well-engineered features minimize the requirements for labeled signature libraries. .