

The 6th Man (Always on Duty)

Line Operations, fault data retrieval & analysis system

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Transmission Reliability
Dominion VA Power

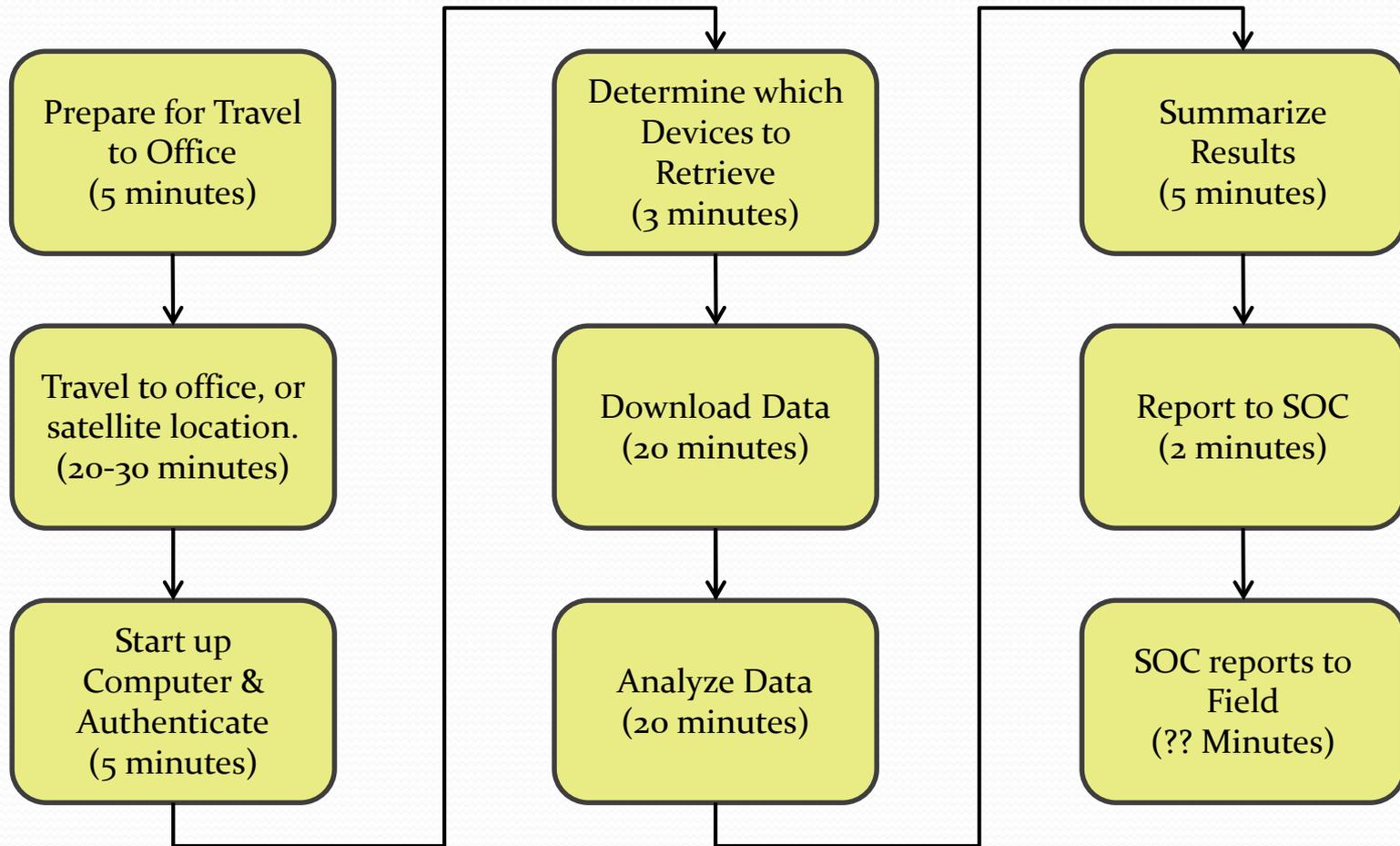
Need for Accurate, Prompt Fault Data has increased from 10 years ago.

- Customer tolerances have decreased to long sustained outages
- Regulatory agencies have become more aware and thus more involved in long sustained outages to transmission facilities.
- Populations reliance on electrical infrastructure has increased.

System Protection Fault Analysis' part in the response

- Typical Response Time
 - Working Hours: 20-25 minutes
 - Non Working Hours: 60-90 minutes
 - *Improved with efficiencies in remote communications*
 - *Could have been up to 3 hours before remote communications*

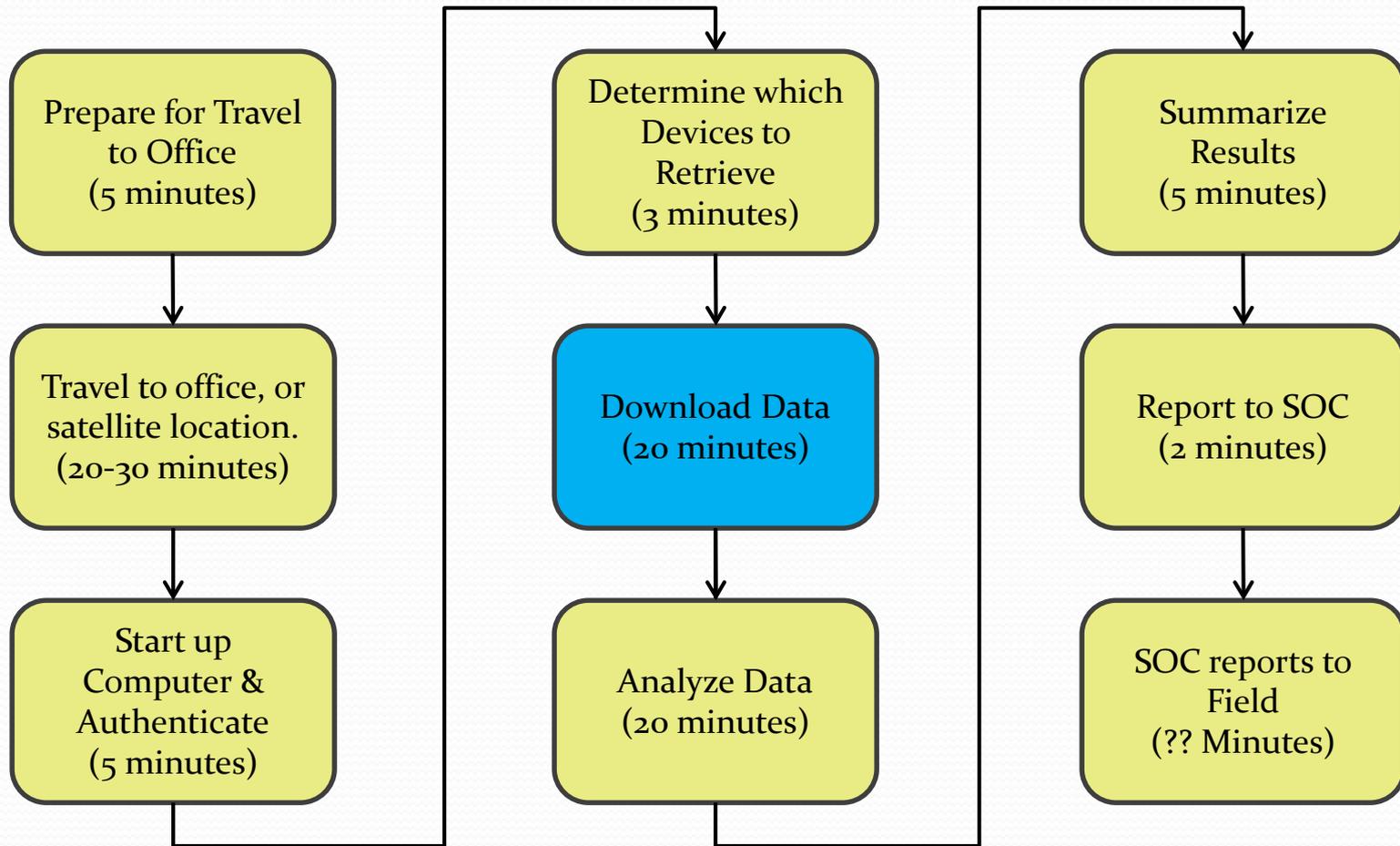
What takes so long?



Record Retrieval

- Created an in house program, that will download from all device platforms using FTP.
 - Downloads for IP based communications
 - Downloads from Phone line connected devices
- Once connect to device, 4 operations are performed
 - Collects all new or updated Pre calculated fault summary files
 - Collects all new RMS and oscillography files
 - Collects all new or updated SER files
 - Collects any updated configuration files
- Parses files and places relevant information into a SQL database

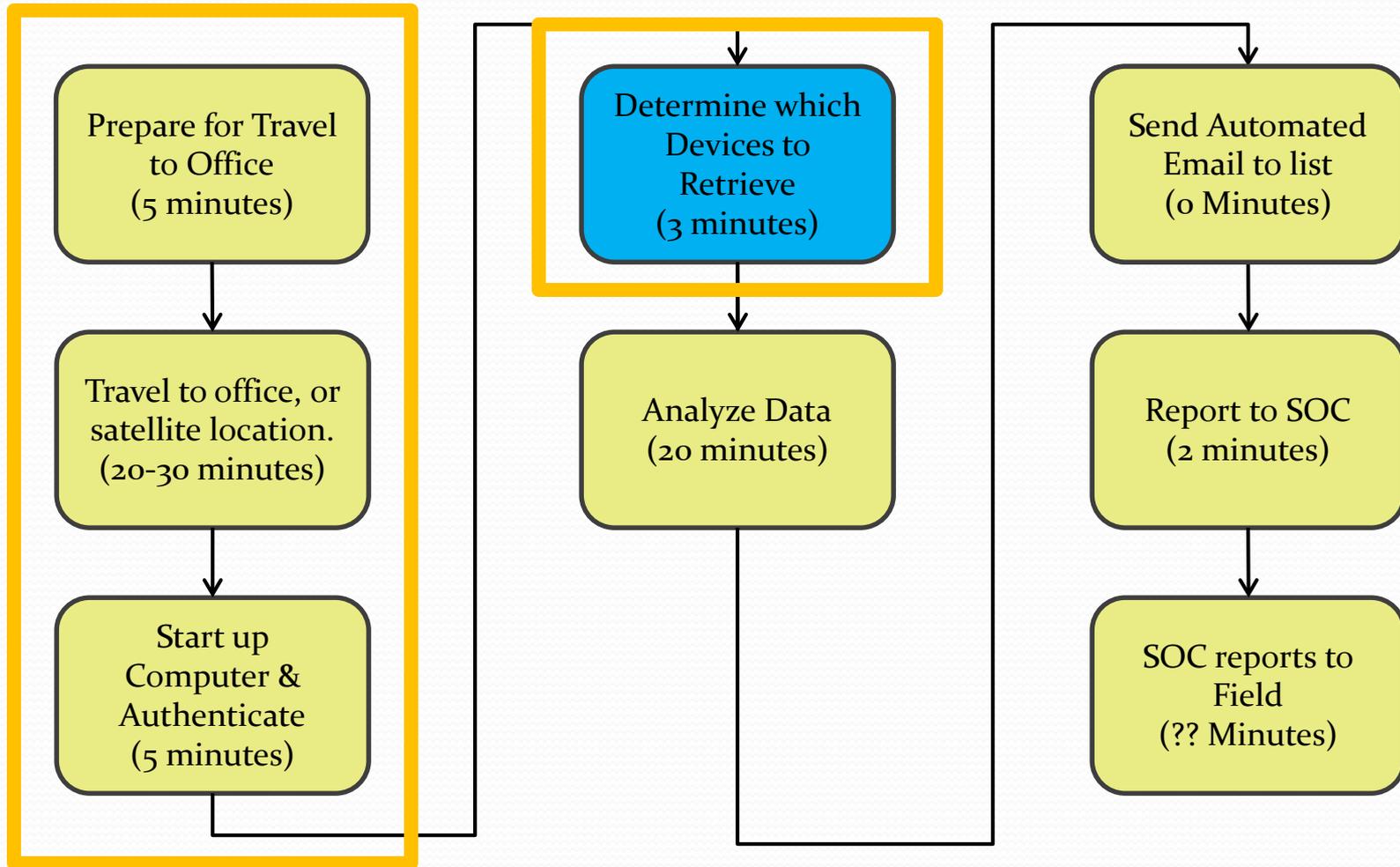
What takes so long?



Auto Configuration Update

- Reads the setting files downloaded from each machine.
- Parses those files and updates the configuration database.
- The system is aware of what devices are monitoring which pieces of equipment.
- Runs comparisons to notify group of when items are changed.
- Runs comparisons against other databases to check for inconsistencies.
 - Line Zo and Z₁
 - Line CT Ratios (coming soon)

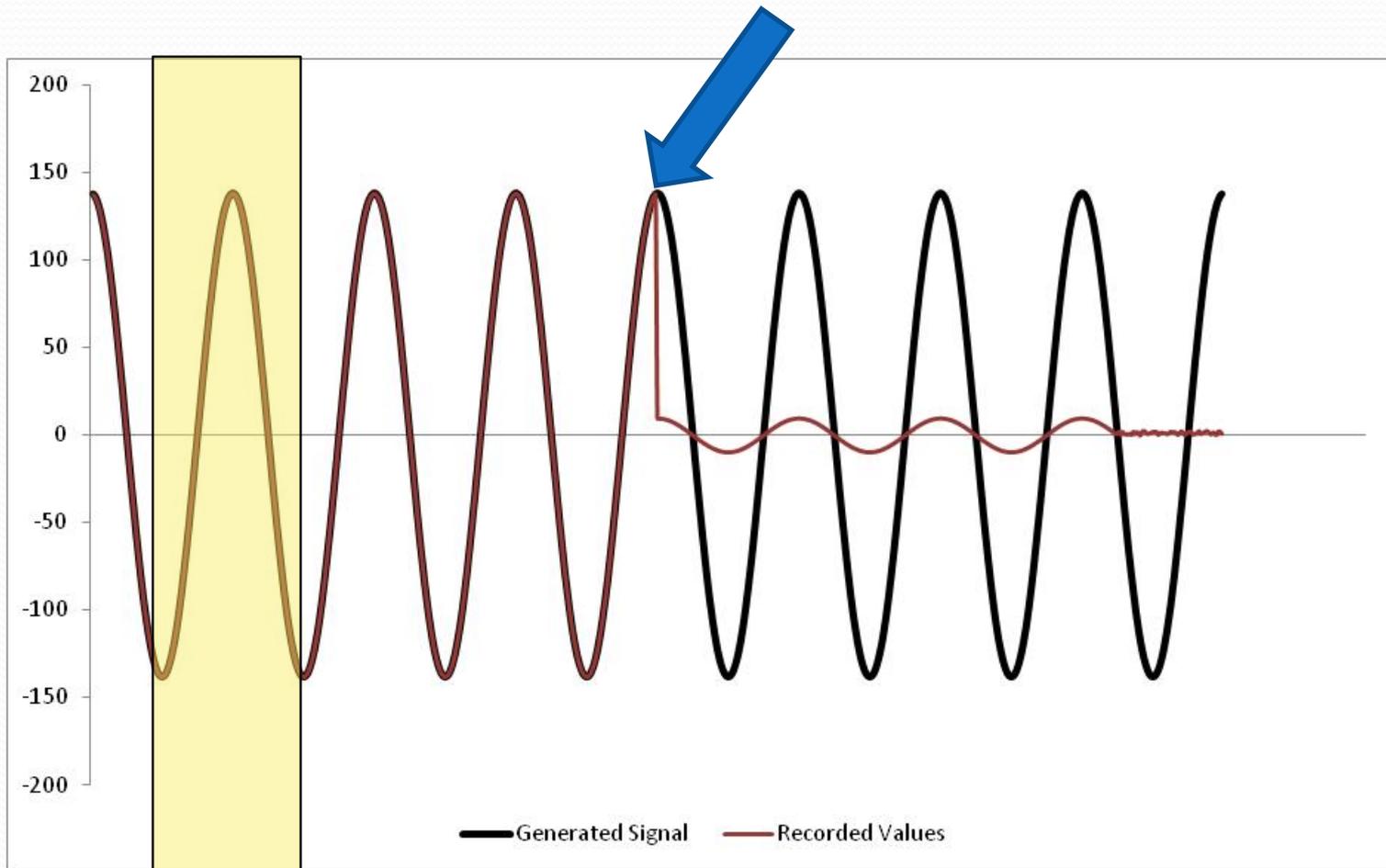
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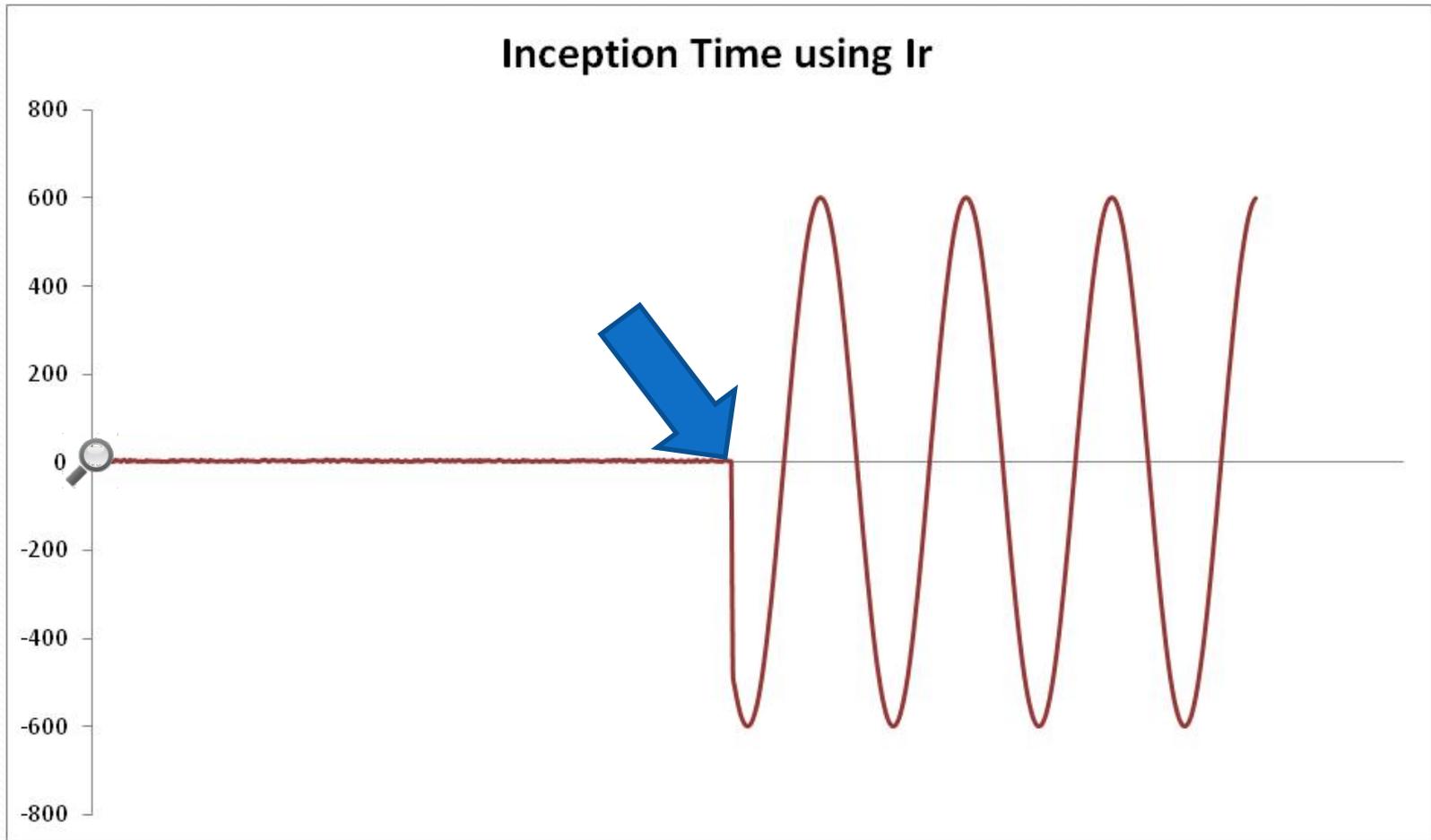
What needs to be done to provide a fault location?

1. Calculate Locations using Data From Fault Recorders
 1. ~~Automatically Generated Locations~~
 2. Manually Generated Locations
 3. Manually Generated Doubled Ended Locations
2. ~~Get any relay targets and Locations~~
3. ~~Review Locations from TWS System~~
4. Get Timestamp and review FALLS for Lightning correlations
5. Run a comparison against the fault model (ASPEN).

Fault Inception Time using Voltage



Fault Inception Time using IR



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Calculating Single Ended Methods

- Uses data loaded into memory from the inception time module.
- Finds the first stable point in the fault to take the rms sample.
- Performs up to 4 different single ended algorithms to locate the fault.
 - Simple
 - Reactance
 - Takagi
 - Modified Takagi
- After review only the reactance method is currently loaded into the data for use later in the output reports

If we can do one end, why not both?

- When the single ended module runs, the program will look for data from the opposite end. When the second terminal is processed it locates the data from the remote terminal and can now process the IEEE double ended algorithm.

$$\text{abs}\left(\frac{V_{2N} - V_{2F} + Z_{1L} * I_{2F}}{Z_{1L} * (I_{2N} + I_{2F})}\right)$$

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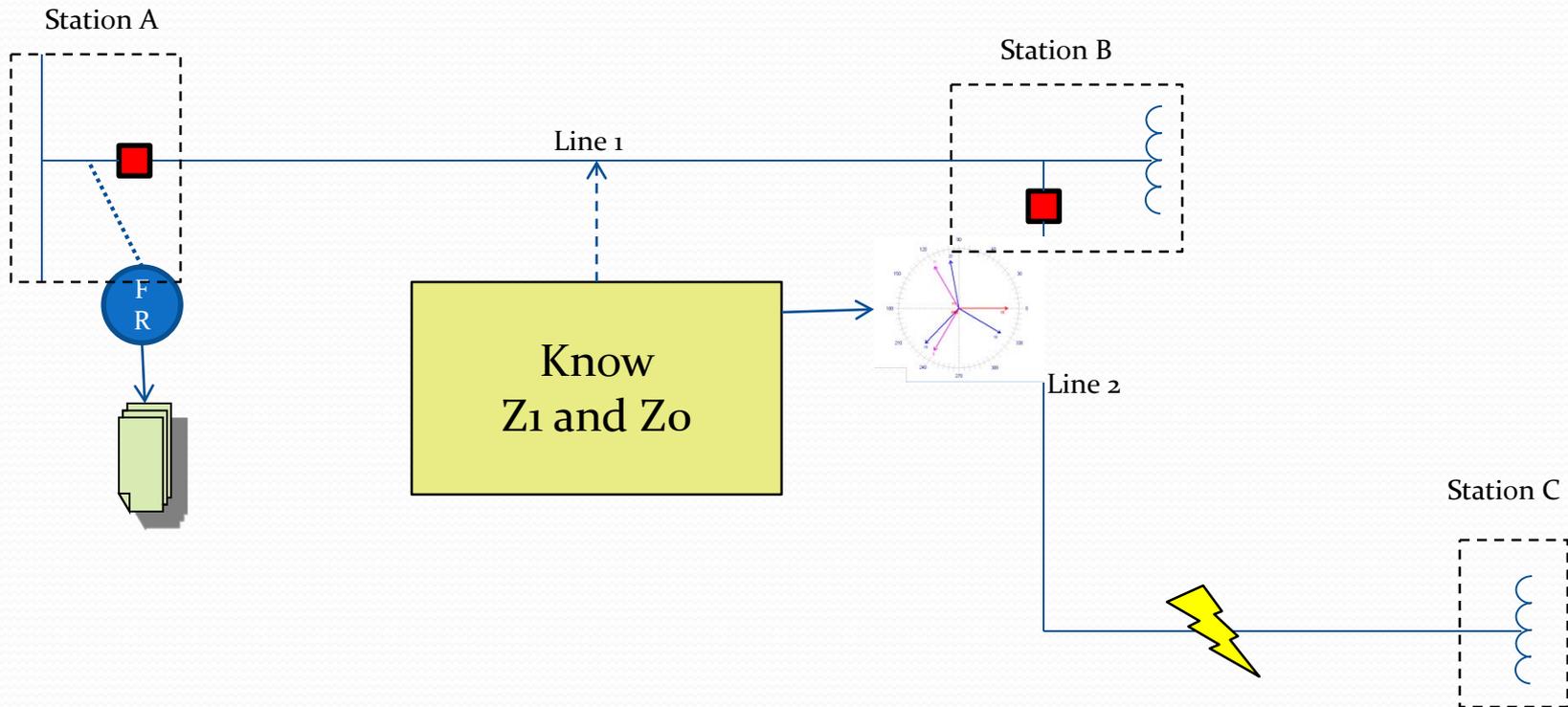
Comparison to Fault Model

- Created a module which faults every 1% of every transmission line in the fault model. It performs a 3 phase fault and phase to ground fault both in a radial and network configuration. The program then inserts all the fault currents calculated into an SQL table. The values are updated every Saturday at midnight.
 - If fault data is only available from one terminal, then the program attempts to match the fault current to the modelled flows from the terminal. The closest match is selected as the location.
 - If fault data is available from both terminals, then the program will attempt to find the best match to the ratio between the two terminals.
- This module will not run if angle between the current and voltage is less than 40 degrees.
- Care needs to be applied to this method, and excluded if the system was not in a normal configuration at the time of the fault.

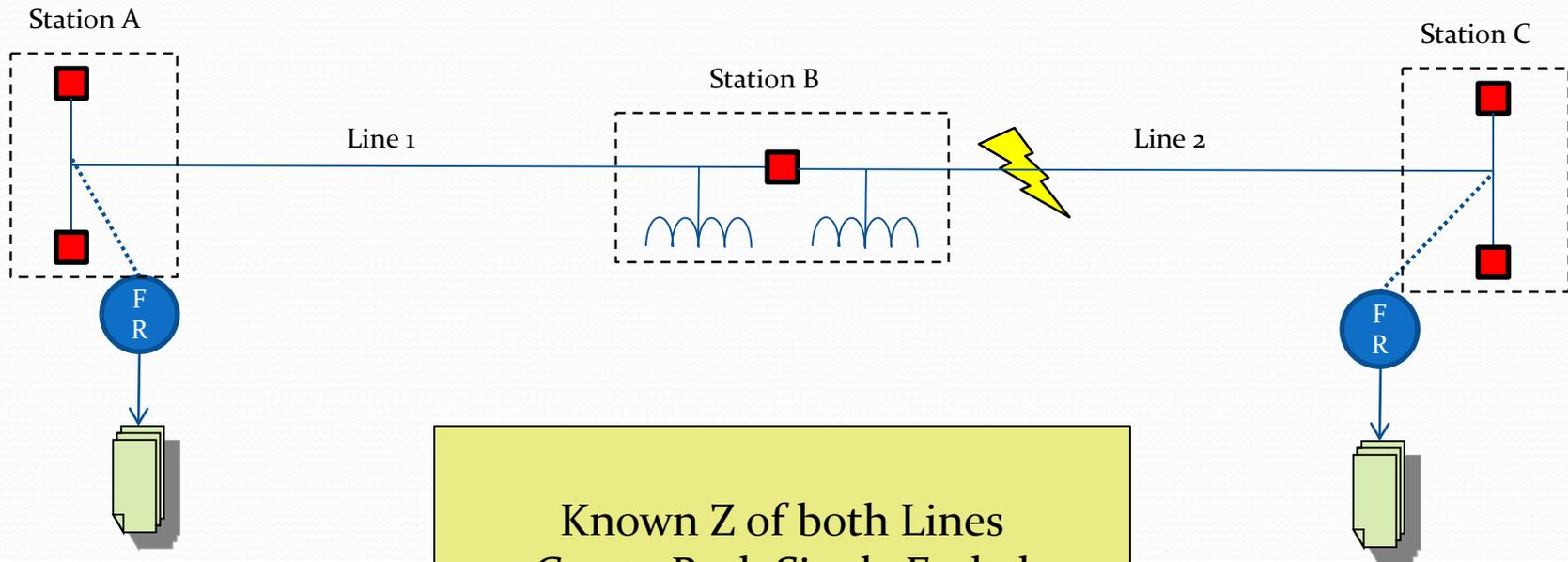
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What if there is no recording device at the terminal in question?



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Known Z of both Lines
Create Both Single Ended
Locations From Station B and C,
and a Double Ended Location
between Station B and C.

Confidence Range & Filtering

- Use a ± 2 sigma window to exclude any outliers from consideration.
- New standard deviation is now computed.

Standard Deviation	Classification
≤ 0.5 miles	High Confidence
≤ 1 miles	Confident
≤ 1.5 miles	Low Confidence
> 1.5 miles	No Confidence

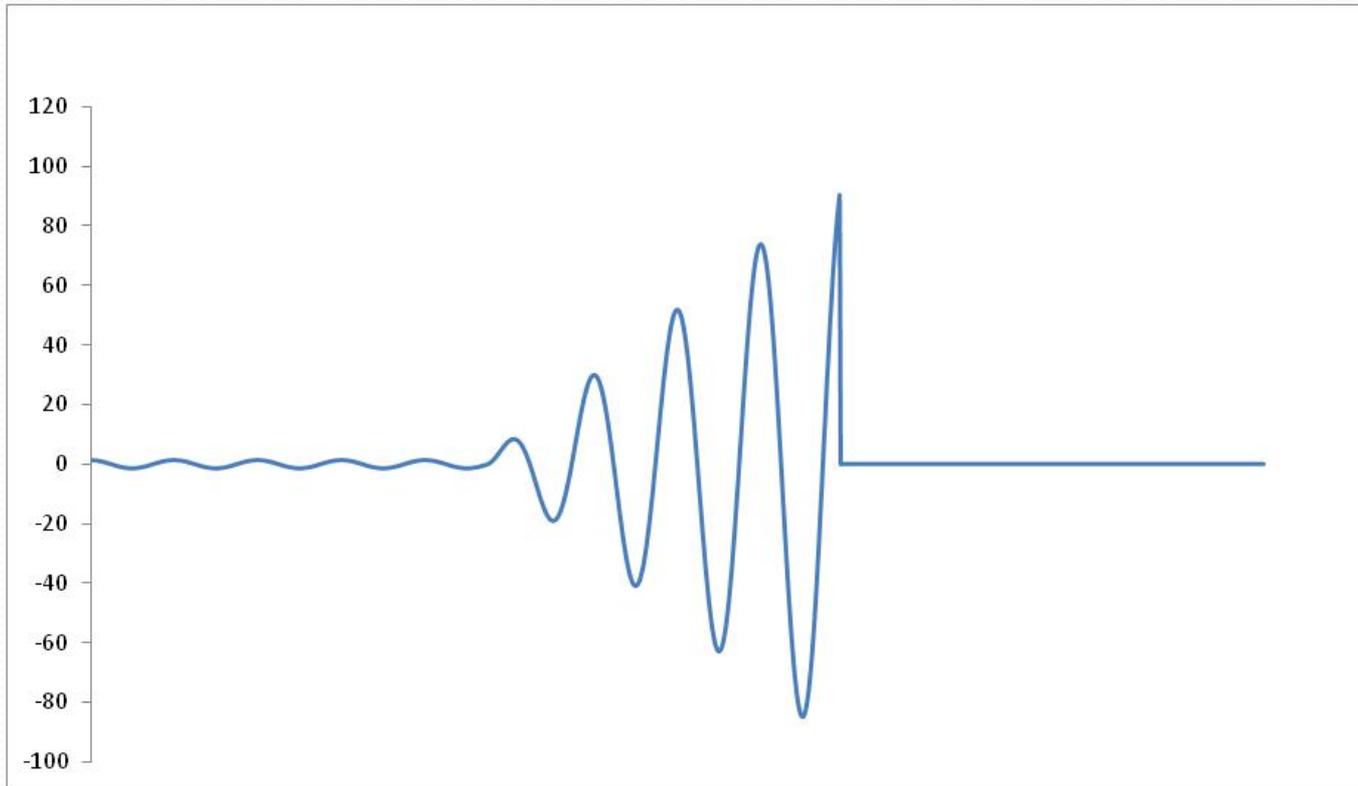
Which location do we provide

- Now have 7 different methods of fault locations
 - FALLS (Lightning)
 - Travel Wave System (TWS)
 - Double End Algorithm (DFR Data)
 - Single Ended Algorithms (DFR Data)
 - Relay provided SCADA Data
 - Model Comparison Double Ended
 - Model Comparison Single Ended
- Pick the distance from the closer terminal

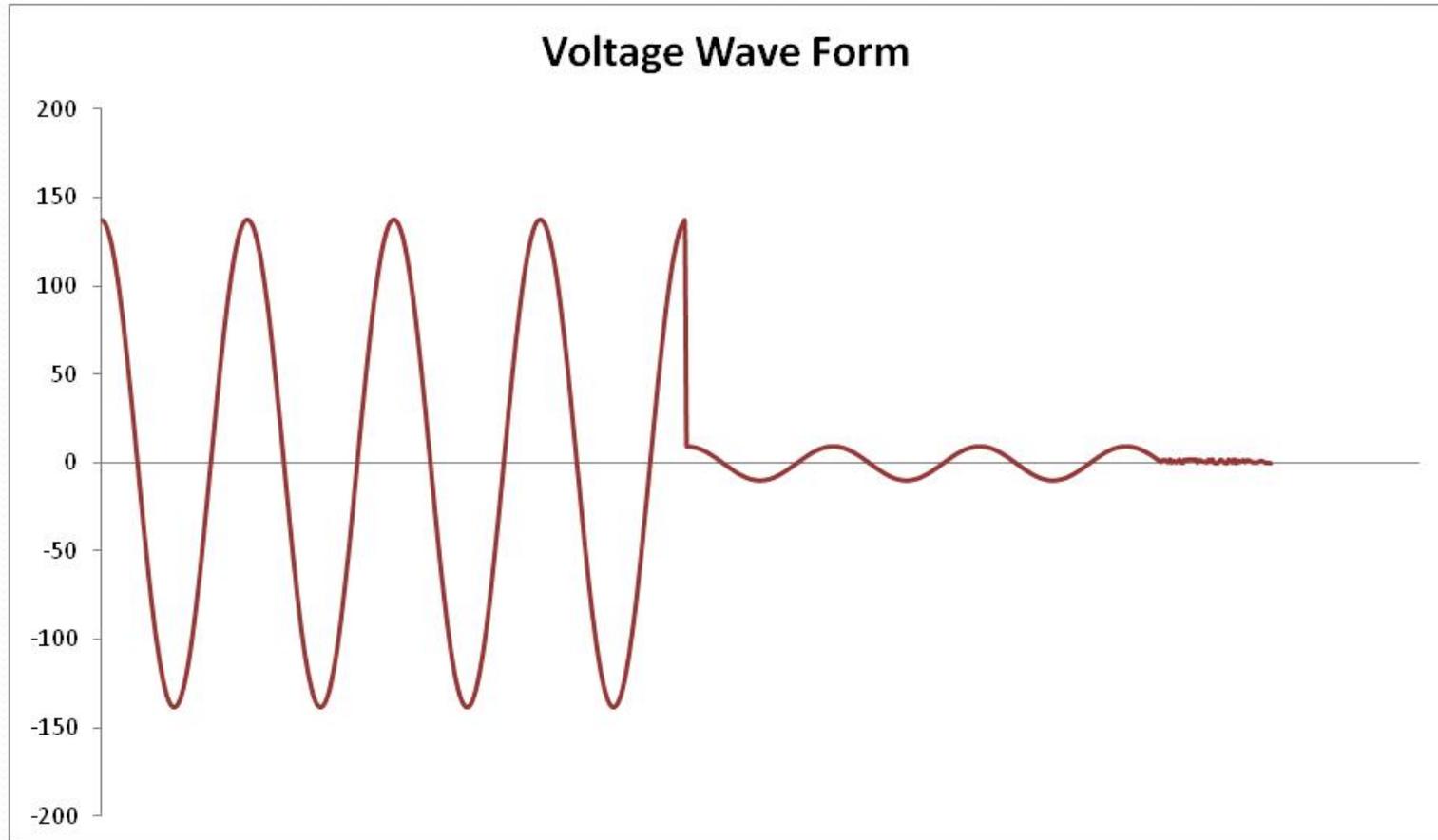
Wave Form Analysis

- 3 Built in signature detection algorithms.
 - Tree Signature
 - Contamination/Insulation Failure
 - Resistive Faults
 - Disables Fault Model Comparison

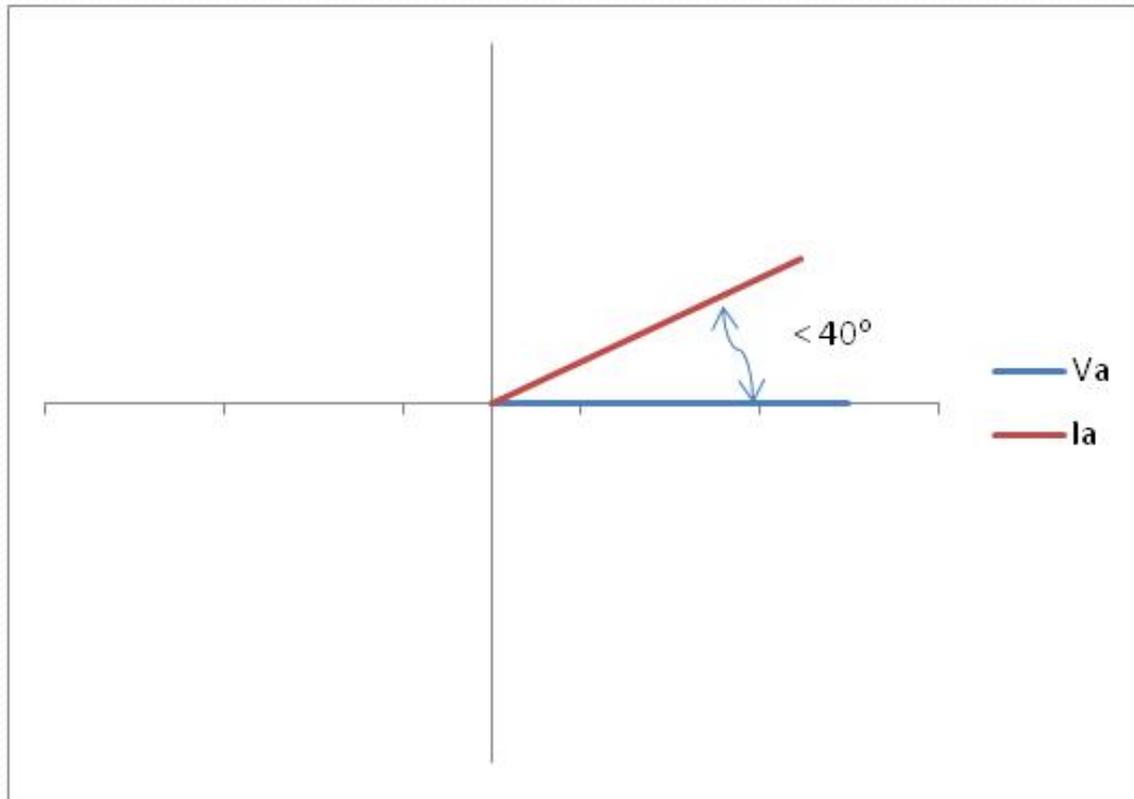
Tree Signature



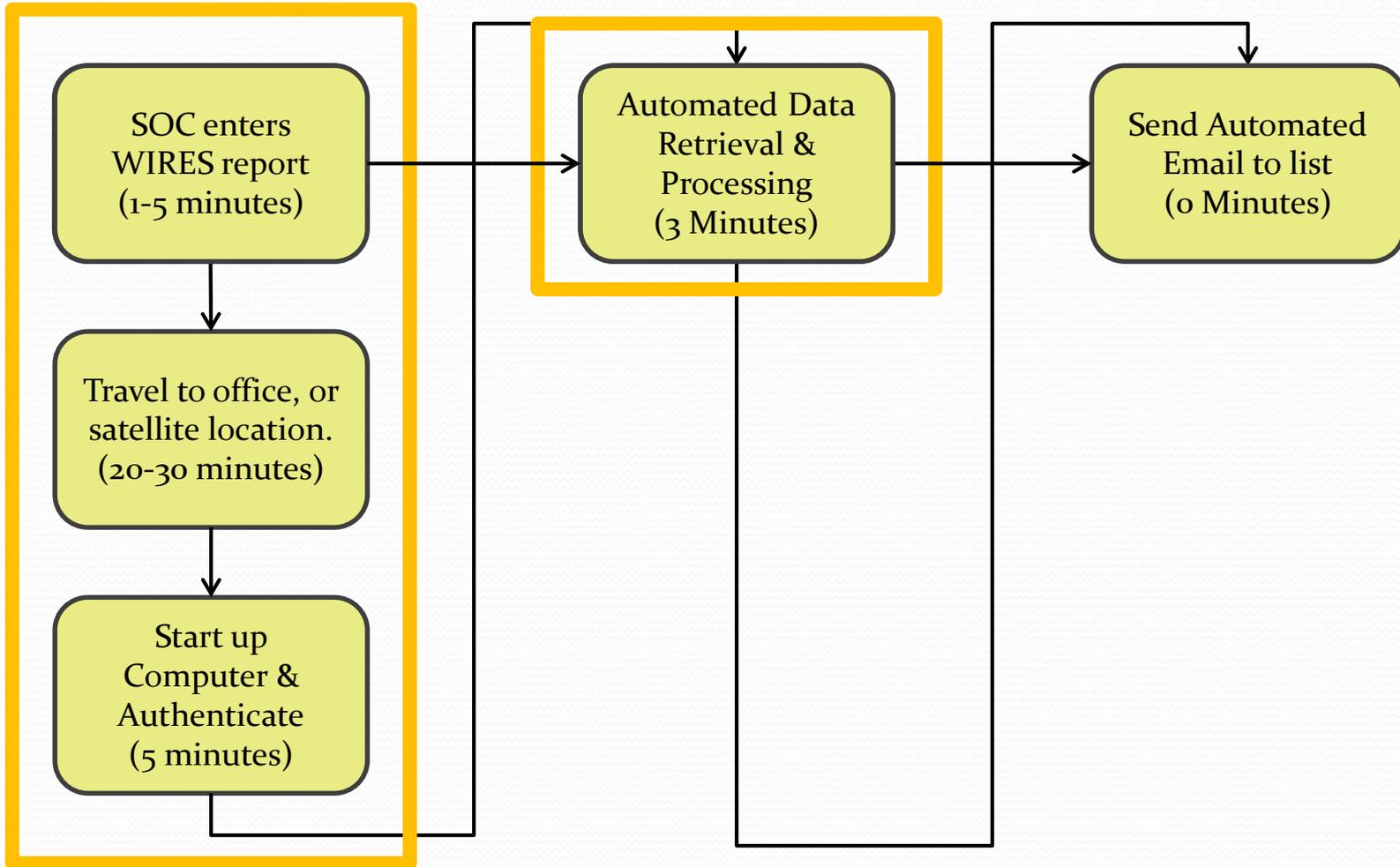
Contamination Signature



Resistive Fault Signature



What takes so short?



System Response Time

- Report should be out no later than 30 minutes from the requested time.
 - Worst Case situation where 2 terminals are on dial up access and a full set of records must be downloaded.
 - If all the records are not back in 30 minutes the system will move on and report on the data currently available.
- Average response time is under 2 minutes from start to finish.

Report Header



Line Operation Quick Summary for Line 136.

Tunis - Earleys (Main Line Length: 14.85 miles)

Operation Date/Time: 12/16/2014 15:45:07.899

Confidential

Responsible Line Crew: Albemarle-Wmstn (ETLE2)

Supervisor: Vernon D 'Doug' Mitchell

vernon.mitchell@dom.com

(O)(252) 809-4137

(M)(252) 661-0040

Manager: William Vernon 'Billy' Gatlin

william.gatlin@dom.com

(O)(434) 447-5506

(M)(804) 337-1833

Director: Mark Steven Allen

mark.allen@dom.com

(O)(804) 257-4711

(M)(804) 240-6147

Fault Location Summary

Tunis

Device	Date Time	Location	Structure	Targets
Tunis\Boykins DFR 1	12/16/2014 15:45:07.899	6.410	136/72	BG*
Tunis\Boykins DFR 1 (Double Ended)	12/16/2014 15:45:07.899	7.579	136/85	BG*
Tunis\Boykins DFR 1 (ASPEN Single Ended)	12/16/2014 15:45:07.899	-27.500		BG*

(*) Post Processed Records

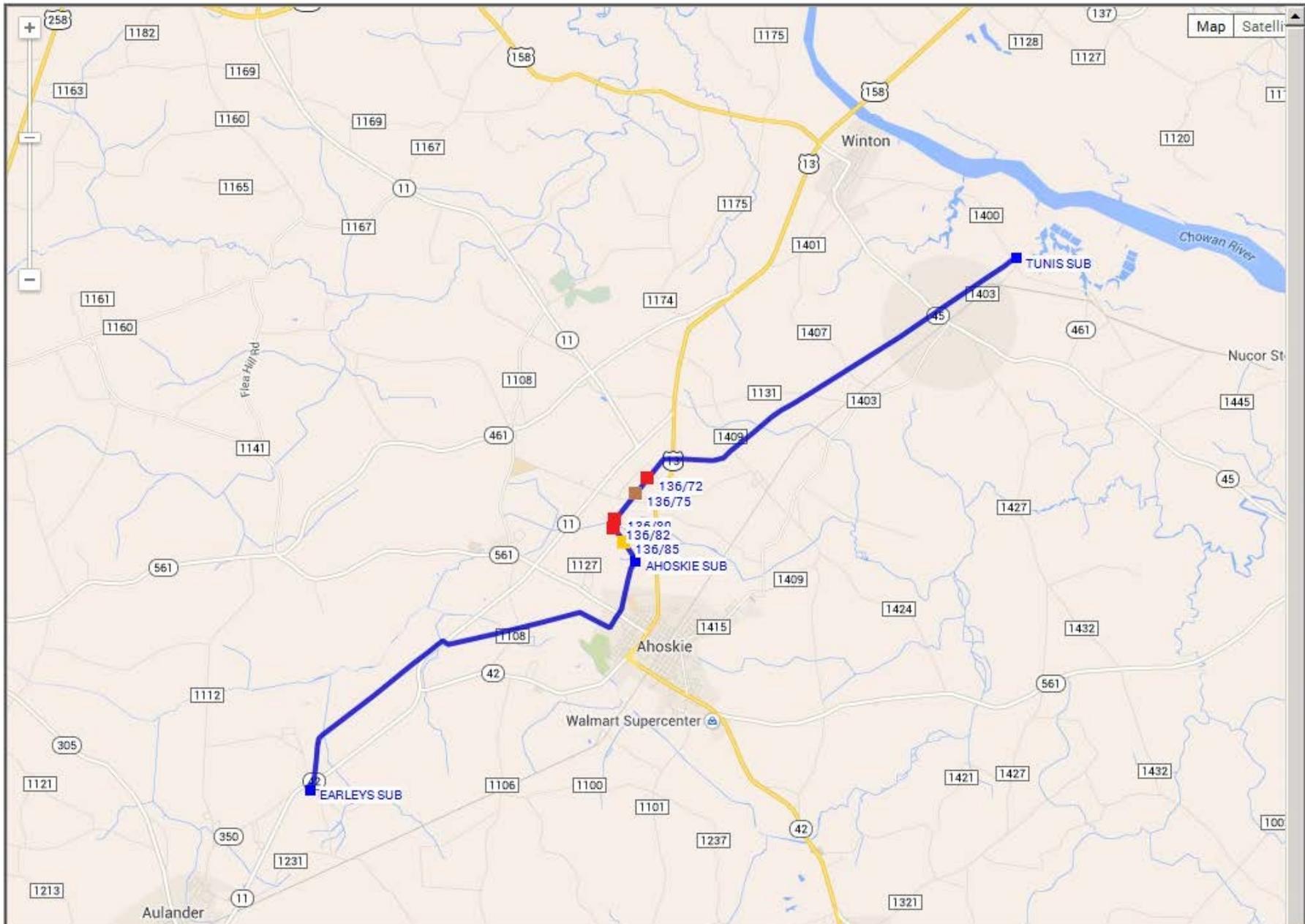
Earleys

Device	Date Time	Location	Structure	Targets
Earleys DFR 1 (ASPEN Single Ended)	12/16/2014 15:45:07.901	7.992	136/75	BG*
Earleys DFR 1	12/16/2014 15:45:07.901	7.531	136/80	BG*
Earleys DFR 1	12/16/2014 15:45:07.907	7.4	136/82	BG

(*) Post Processed Records

Fault Locations Convergence

Fault Location Standard Deviation 0.43 miles **High Confidence**



Aulander

EARLEYS SUB

Ahoskie

Walmart Supercenter

AHOSKIE SUB

136/72
136/75
136/80
136/82
136/85

TUNIS SUB

Winton

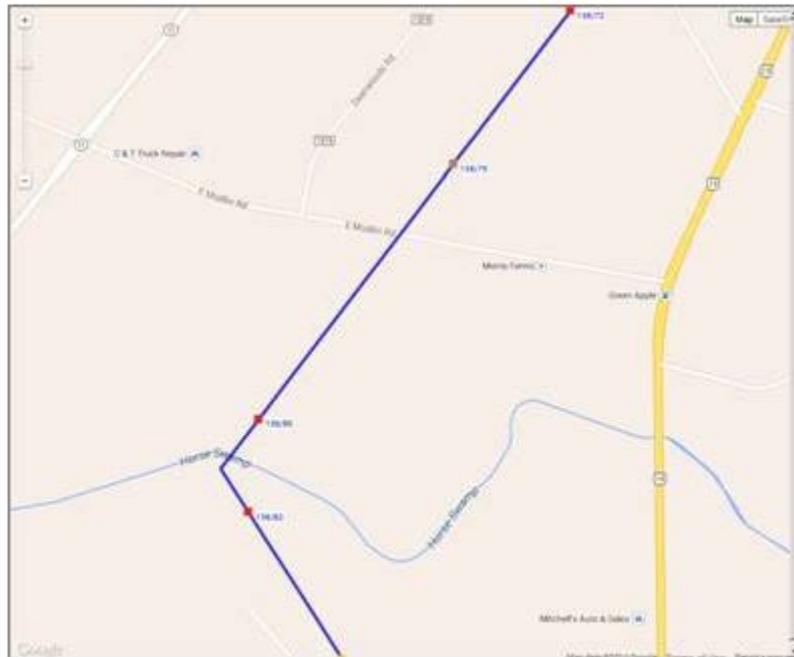
Chowan River

Nucor St

Map

Satellite

Zoomed View

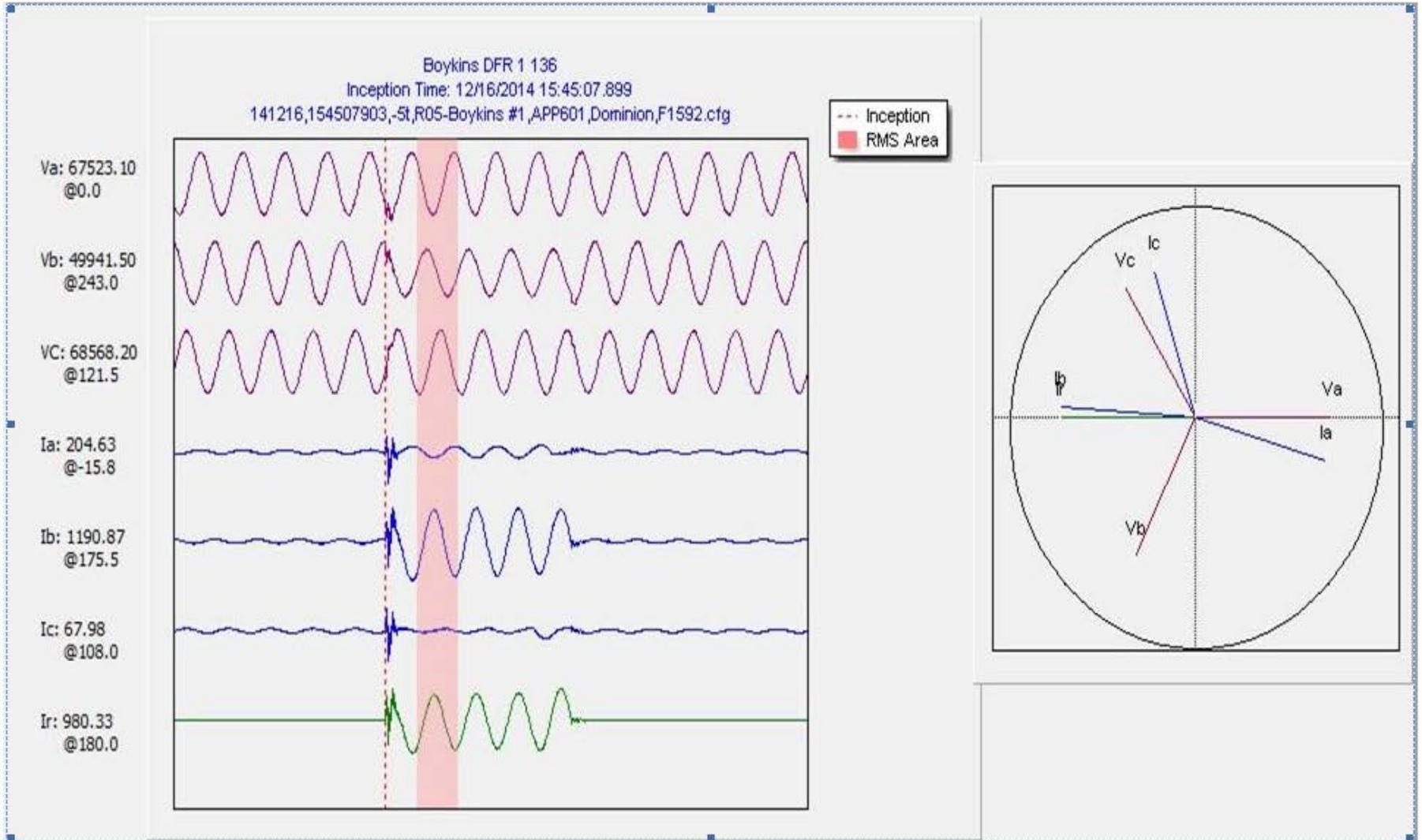


Zoom on Fault View



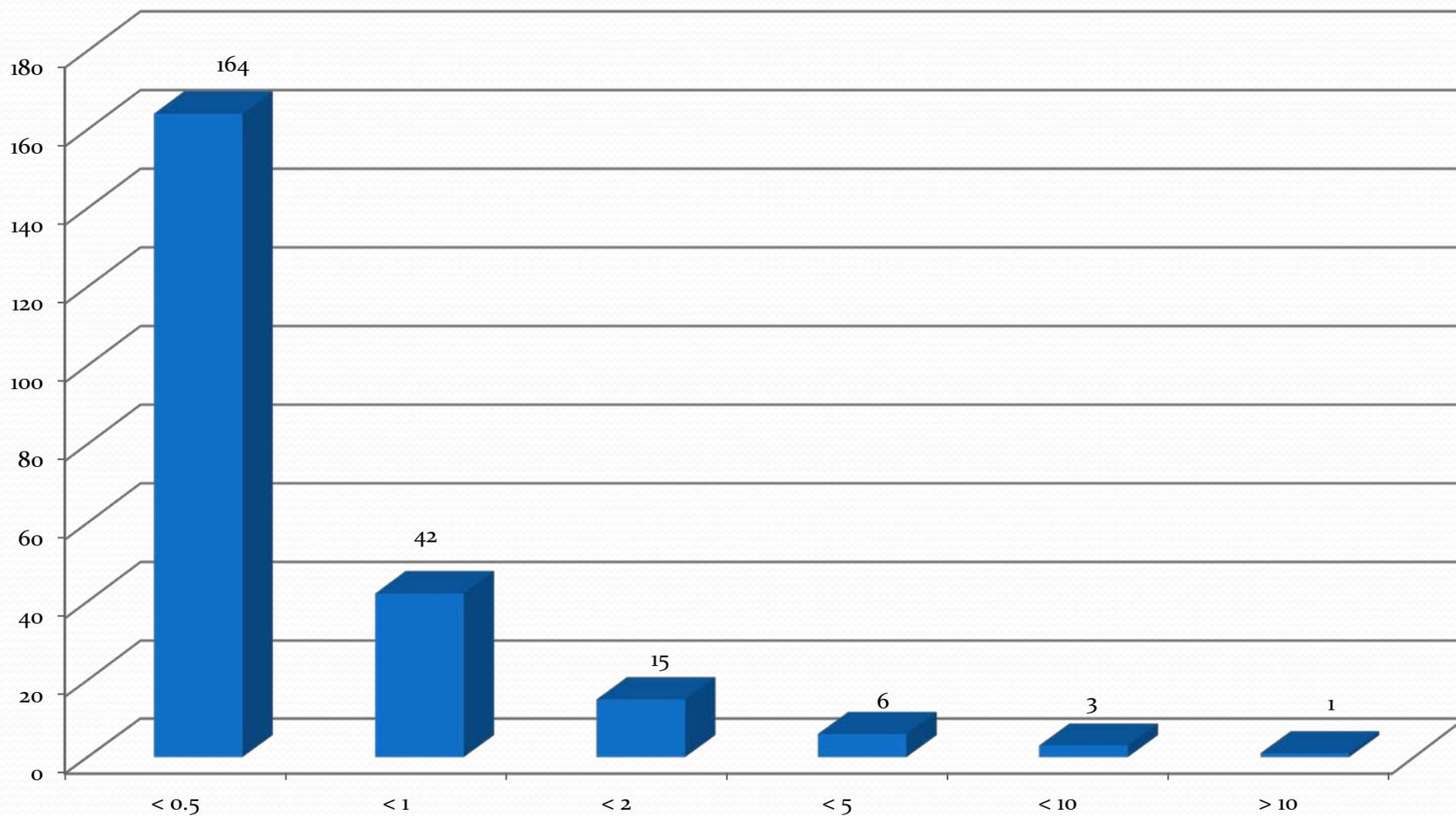
Earth View

Oscillography



Results

Target Accuracy



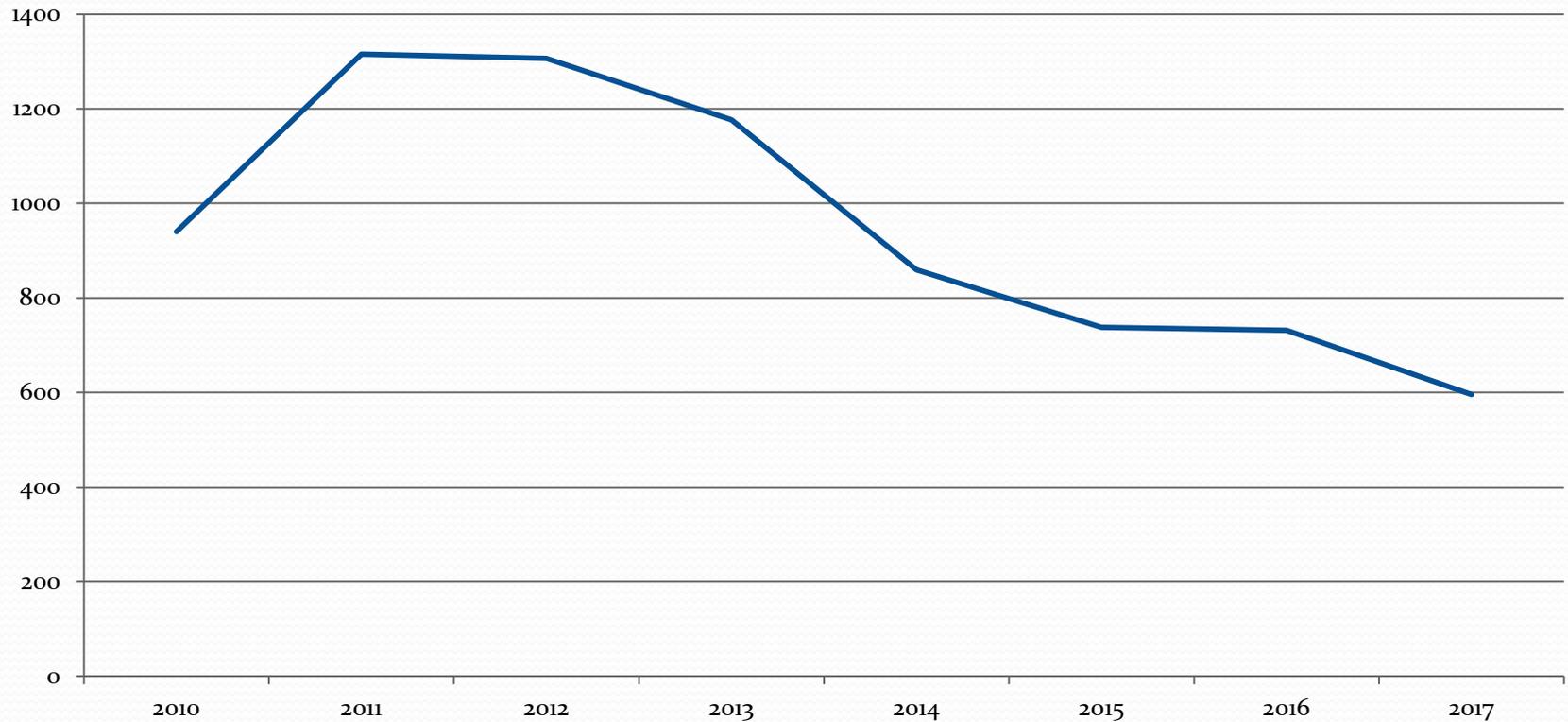
Results

**Terminal Restoration Times, Overhead Lines
3 Year rolling average**



Results

**Total Line Restoration Times, Overhead Lines
3 Year Rolling Average**



Results

Customer Impact

