AUTOMATED TRAFFIC SIGNAL PERFORMANCE MEASURES: Critical Infrastructure Elements for SPMs

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
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AASHTO TECHNOLOGY IMPLEMENTATION GROUP

ITE Webinar Series on Automated Traffic Signal Performance Measures (SPMs)

- Critical Infrastructure Elements for SPMs

  June 11, 2014, 12:00 pm to 1:30 pm. Eastern

Automated Traffic Signal Performance Measures

Technology Implementation Group: 2013 Focus Technology

http://tig.transportation.org

Mission: Investing time and money to accelerate technology adoption by agencies nationwide

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Your Speakers Today

Shane Johnson, UDOT

Dr. Chris Day, Purdue

Howell Li, Purdue

Questions for the audience

- How many signals are under your jurisdiction?
- What types of vehicle detection are used at your intersections?
- Are there any communication infrastructure connecting your cabinets?
- What operating system platform(s) do you use (Windows, Linux, Mac)?
- What are some of your biggest challenges for enabling performance metrics in your area?

CRITICAL INFRASTRUCTURE ELEMENTS: Background

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014

PRESENTED BY DR. CHRIS DAY

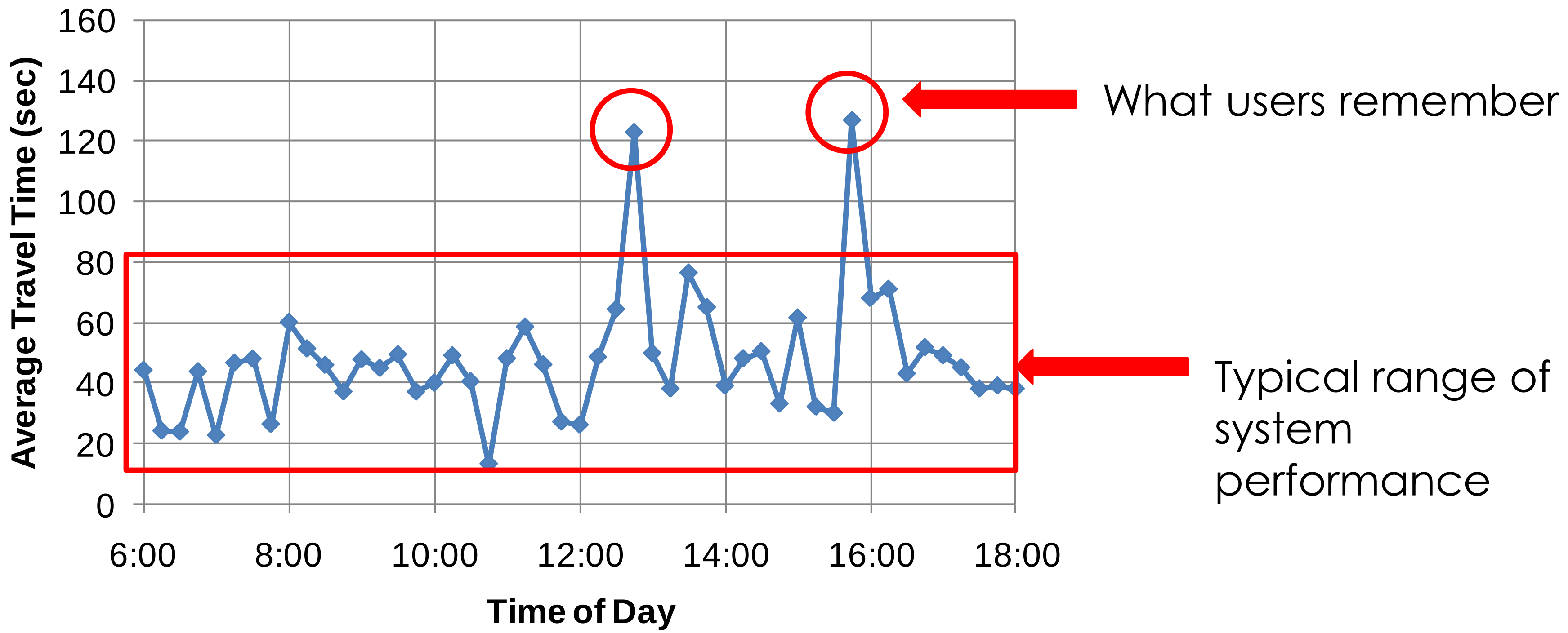
Overview

- Background on Automated Traffic Signal Performance Measures
- Hierarchy of Infrastructure Requirements
  - Communications
  - Detection
- Data Infrastructure for Agency Implementation
  - Utah DOT
  - Indiana DOT

Why Measure Traffic Signal Performance?

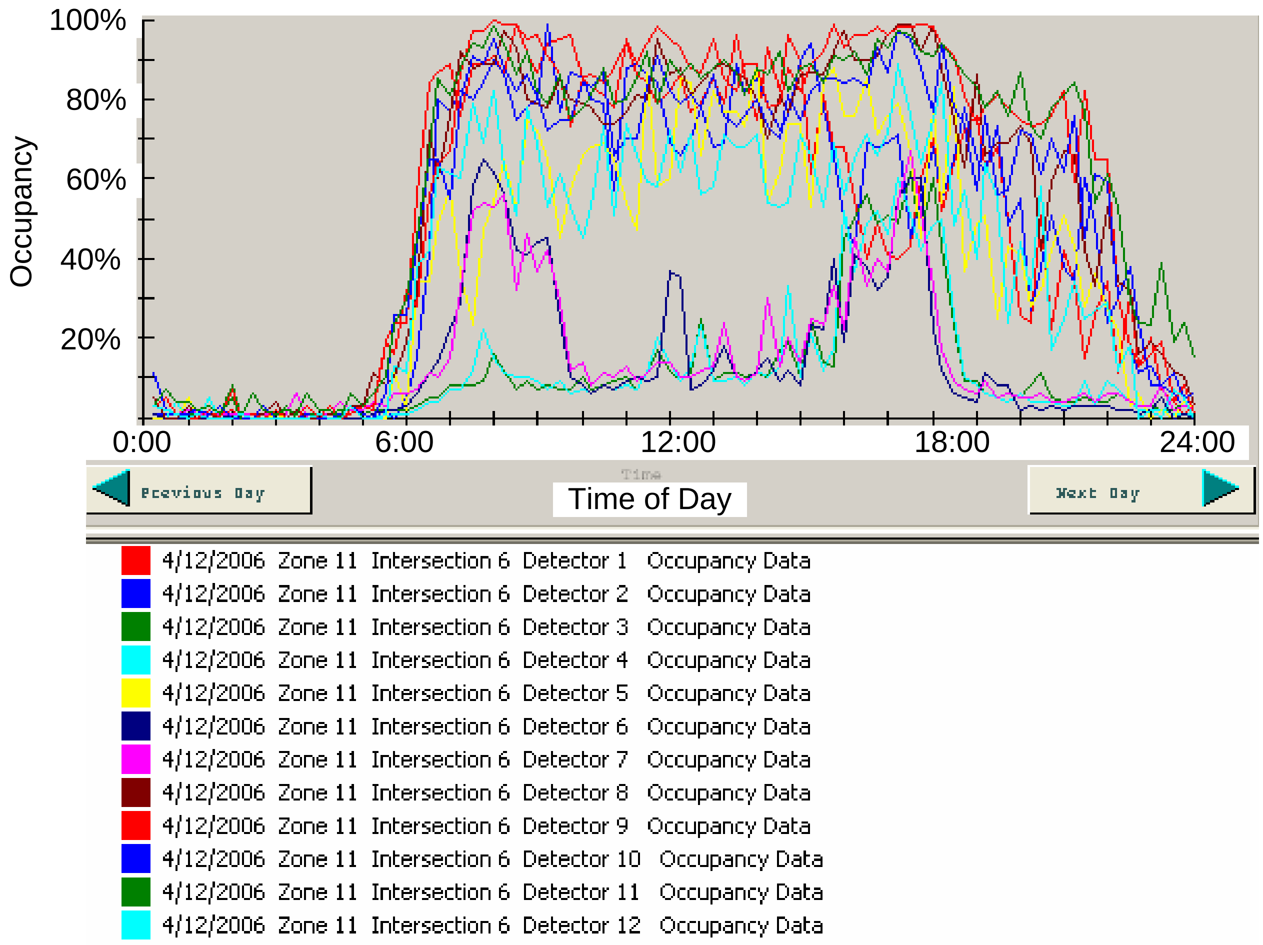
- Better respond to user complaints
  - Verify whether reported problems occur
  - Identify solutions
- Proactively identify and correct operational and maintenance inefficiencies
  - Improve quality of progression
  - Improve capacity allocation

Motivation

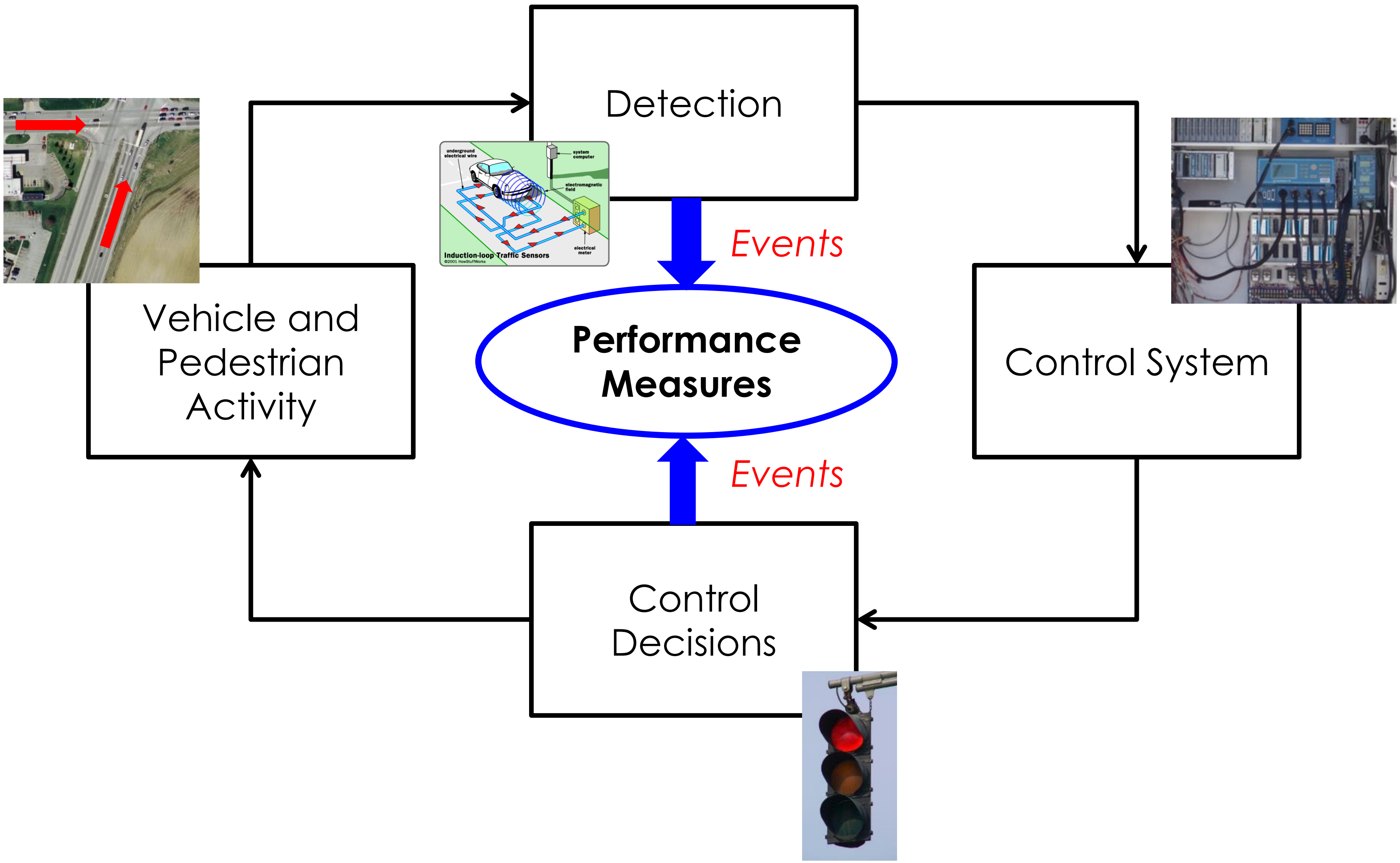


- **Average values** versus **full event timeline**
- When is intervention needed?

Legacy Data Collection: 15-Minute Average Detector Occupancy



What Is "High Resolution" Data?



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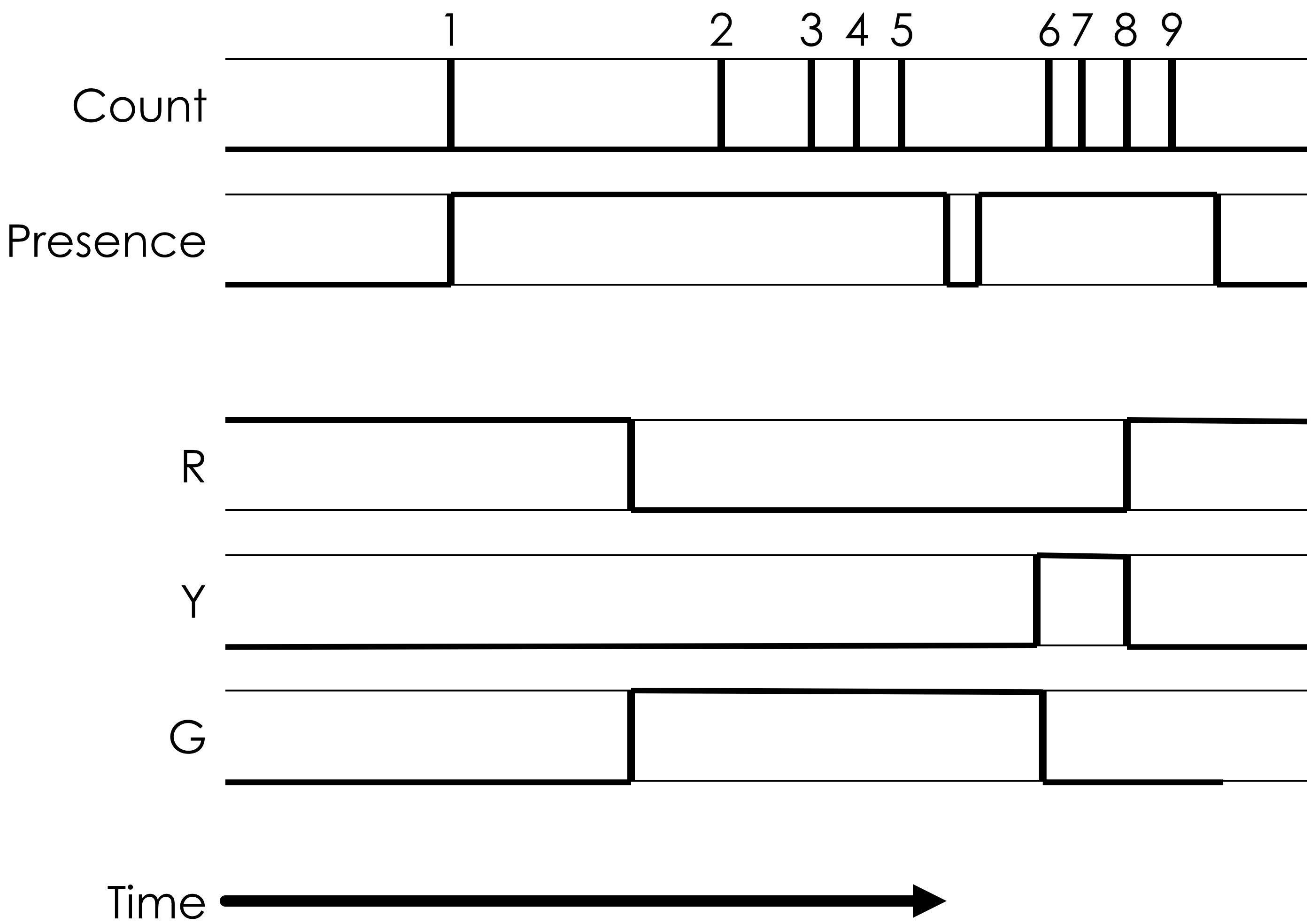

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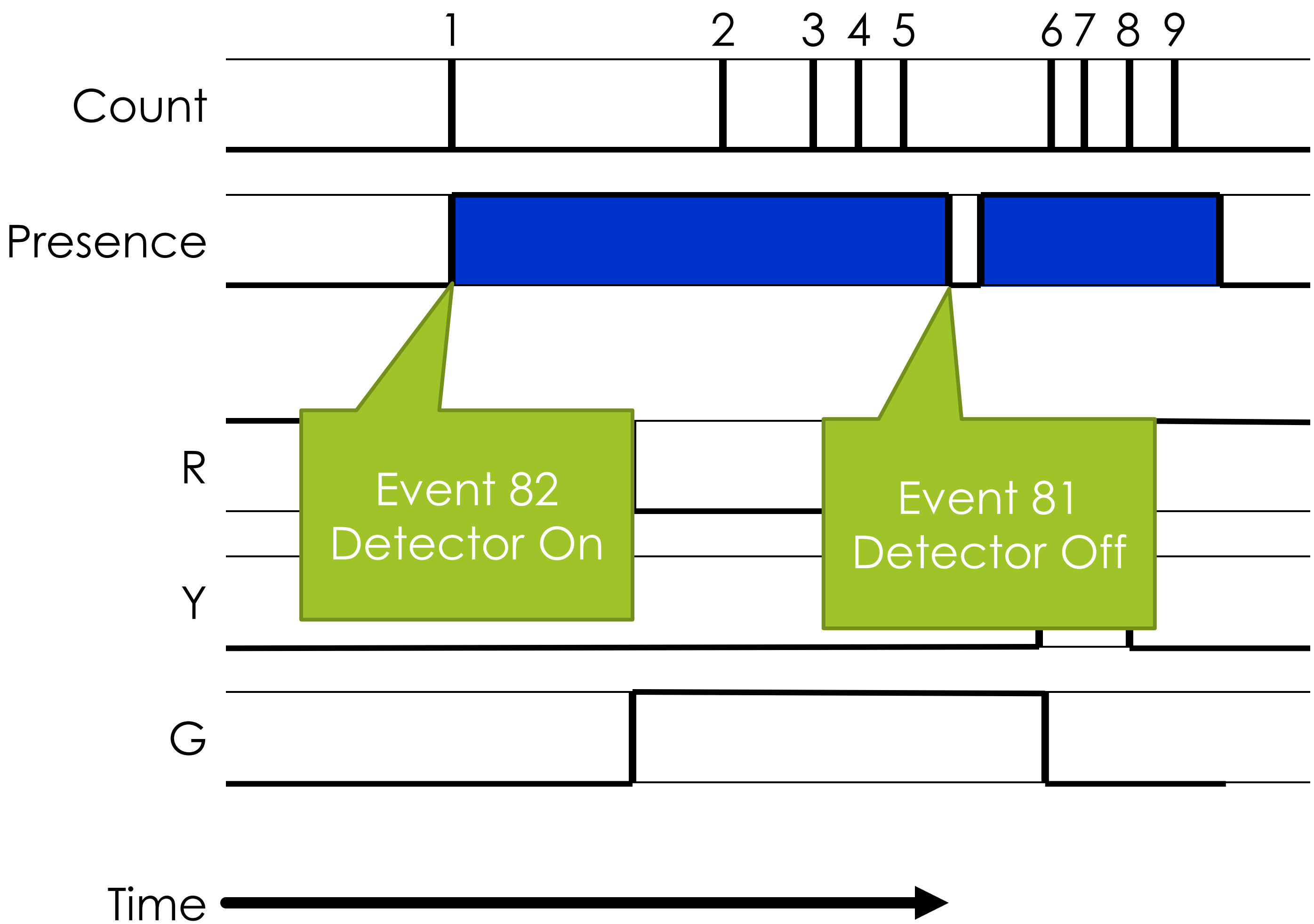

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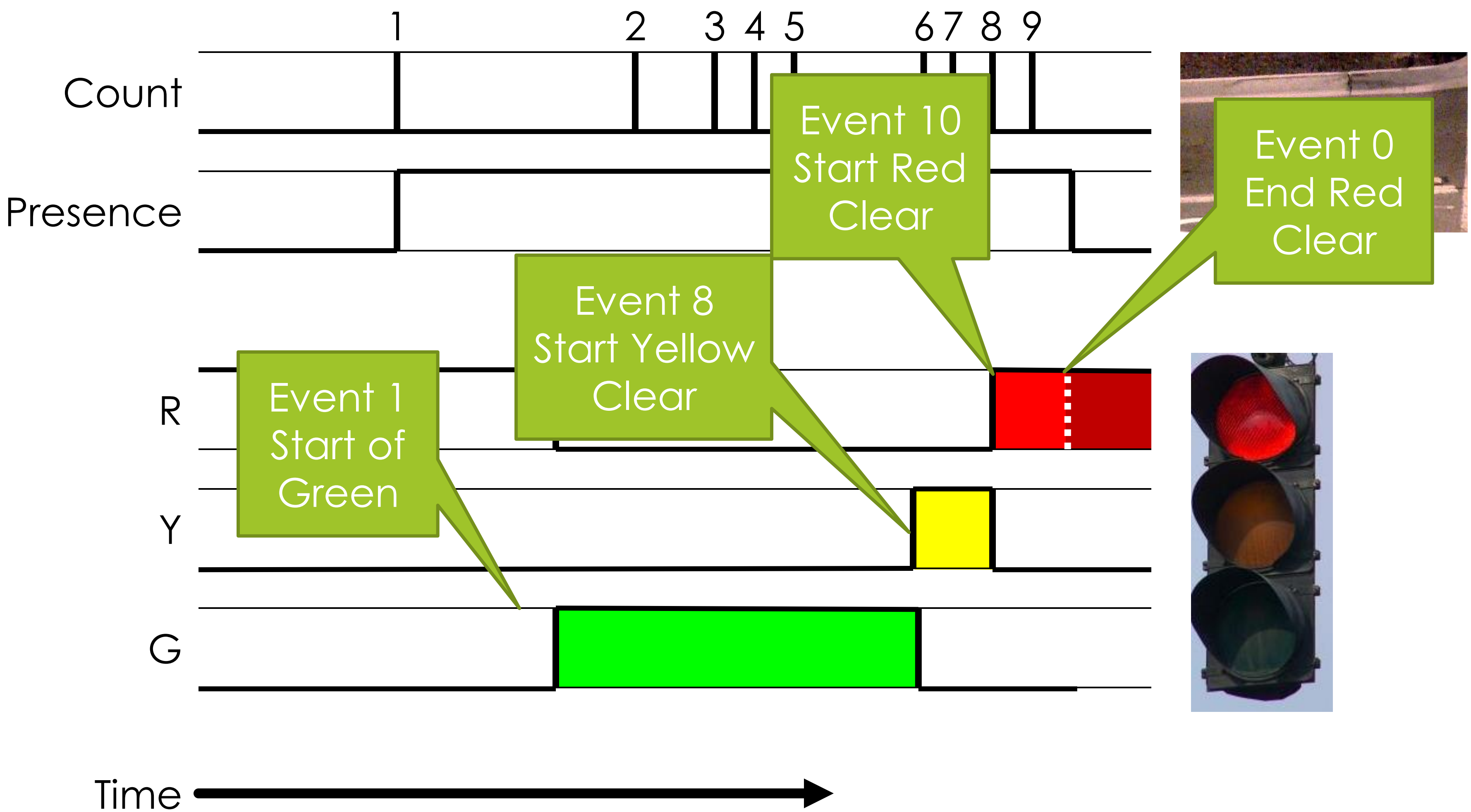

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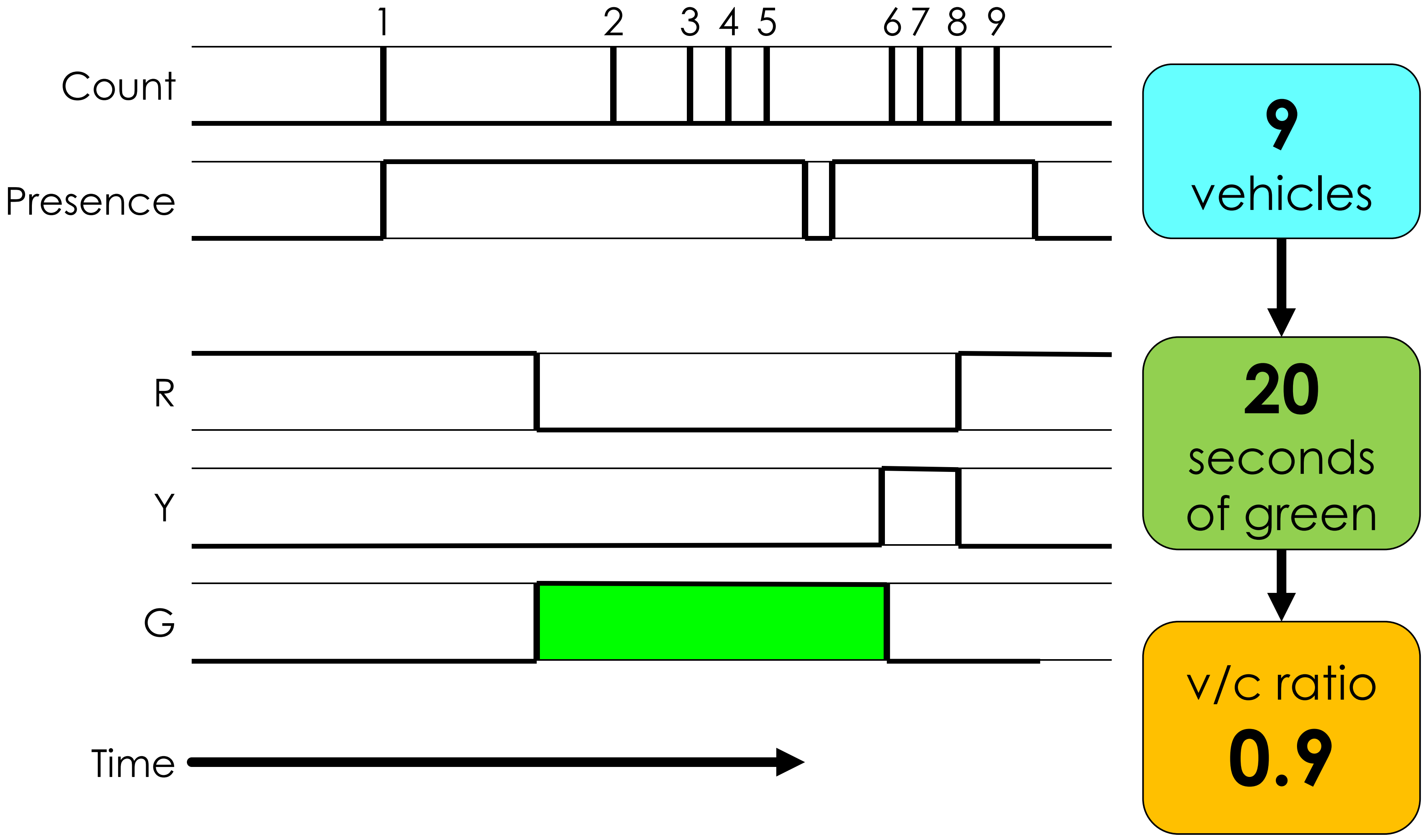
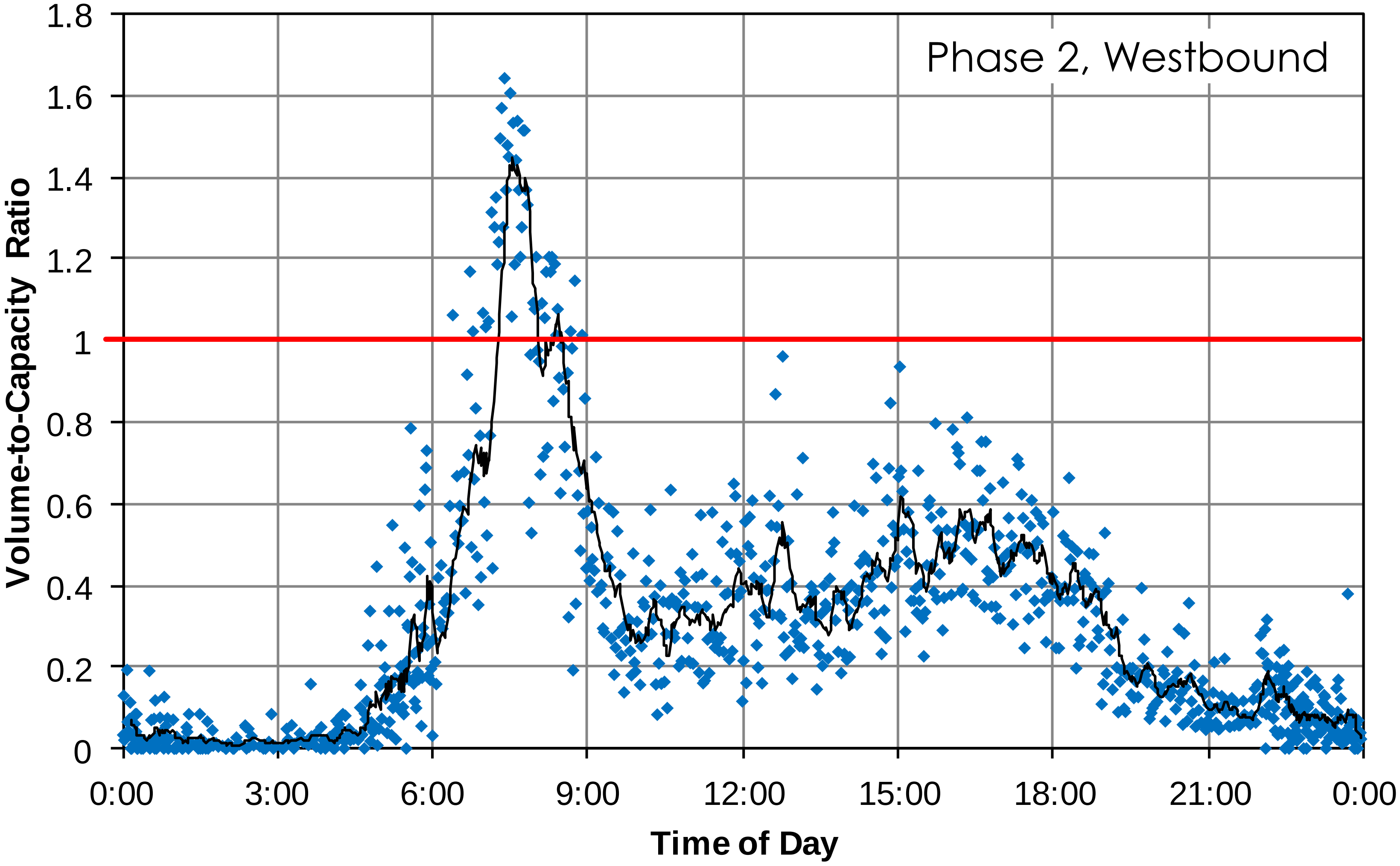
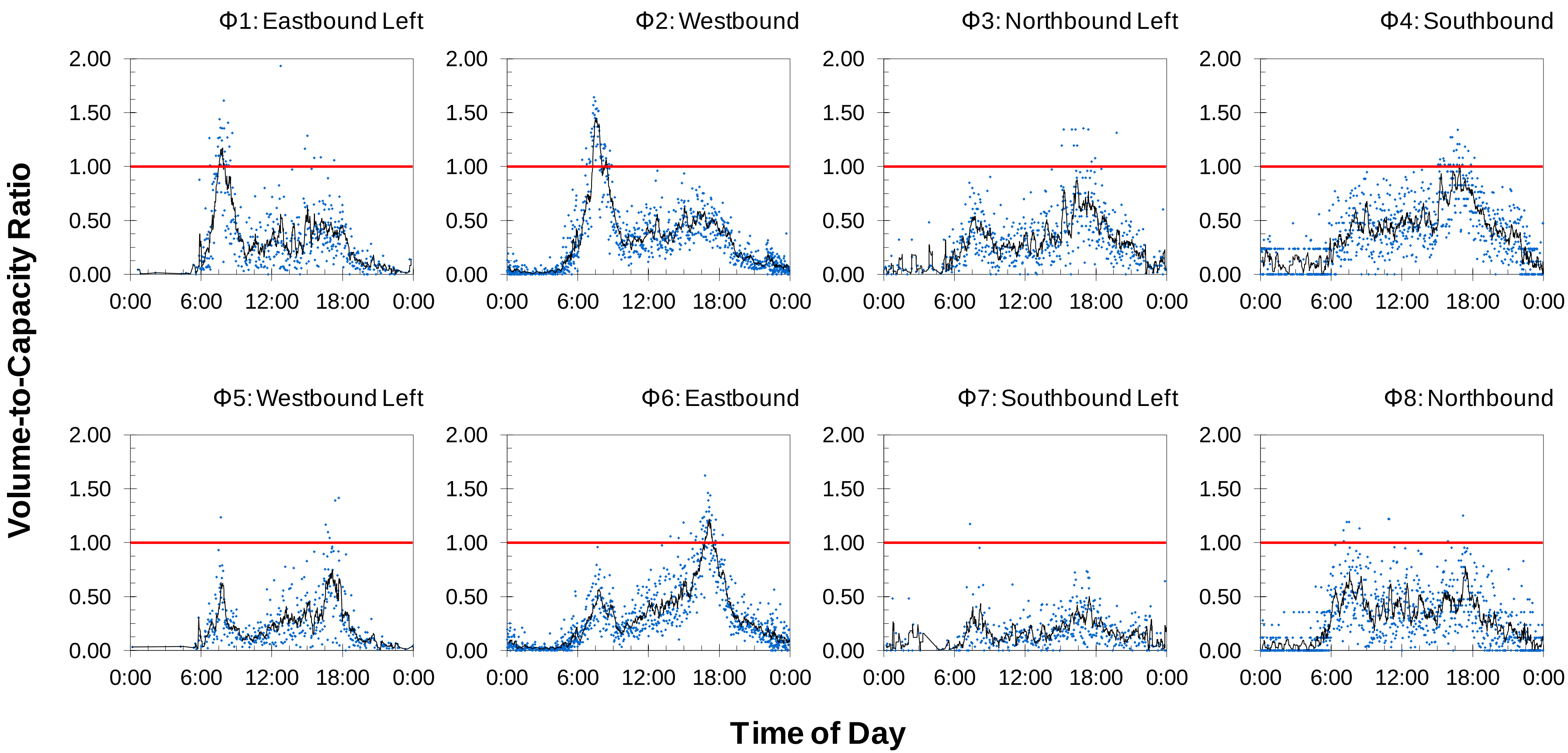


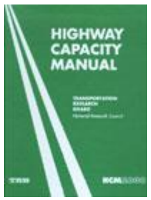
Cycle-by-Cycle Performance Measures



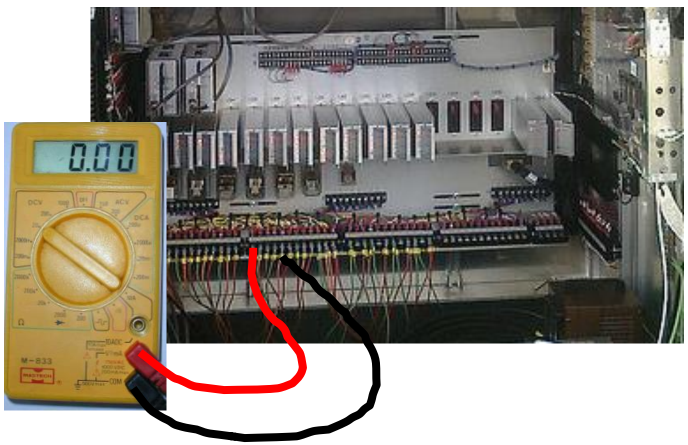
Cycle-by-Cycle Performance Measures



History of Development




- Manual Data Collection
  - 5, 15 minute averages



- Monitoring Load Switch Circuits
  - High-resolution data
  - Latency and clock drift issues
  - **“Do-it-yourself” data collection**


- Embedded Controller Data Collector
  - Record controller events that do not correspond to circuit closures
  - **Required vendor buy-in**

Hardware-in-the-Loop Simulation

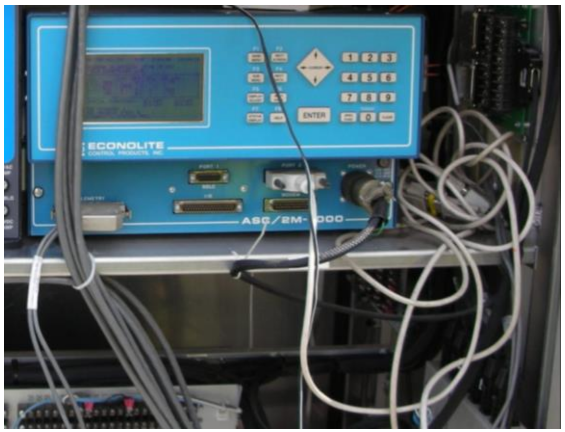
Controller on Shelf

Simulation

Data:

- **Signal Indications**
- **Detector Events**
- **Coordination Events**

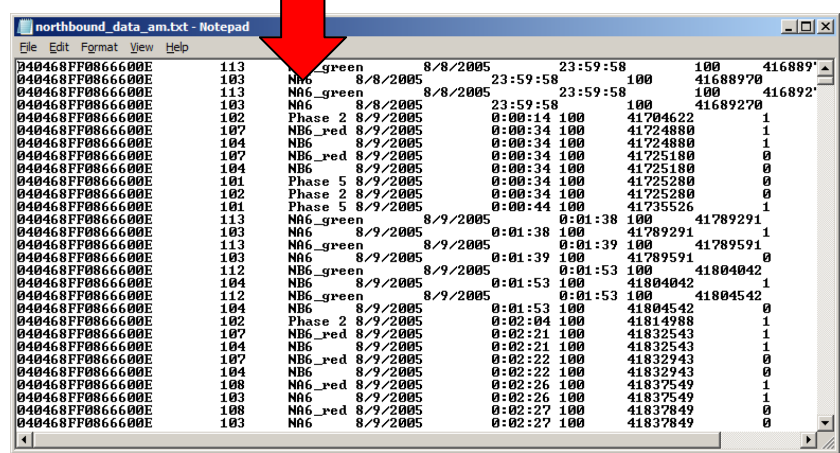
Field Data Collection Using Industrial I/O Equipment



Controller in Cabinet

Data:

- **Signal Indications**
- **Detector Events**
- **Coordination Events**

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040468FF0866600E    113    _green   8/8/2005    23:59:58    100    416889'
040468FF0866600E    103    NA6      8/8/2005    23:59:58    100    41688970
040468FF0866600E    113    NA6_green   8/8/2005    23:59:58    100    416892'
040468FF0866600E    103    NA6      8/8/2005    23:59:58    100    41689270
040468FF0866600E    102    Phase 2  8/9/2005    0:00:14 100    41704622    1
040468FF0866600E    107    NB6_red  8/9/2005    0:00:34 100    41724880    1
040468FF0866600E    104    NB6      8/9/2005    0:00:34 100    41724880    1
040468FF0866600E    107    NB6_red  8/9/2005    0:00:34 100    41725180    0
040468FF0866600E    104    NB6      8/9/2005    0:00:34 100    41725180    0
040468FF0866600E    101    Phase 5  8/9/2005    0:00:34 100    41725280    0
040468FF0866600E    102    Phase 2  8/9/2005    0:00:34 100    41725280    0
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040468FF0866600E    104    NB6      8/9/2005    0:01:53 100    41804042    1
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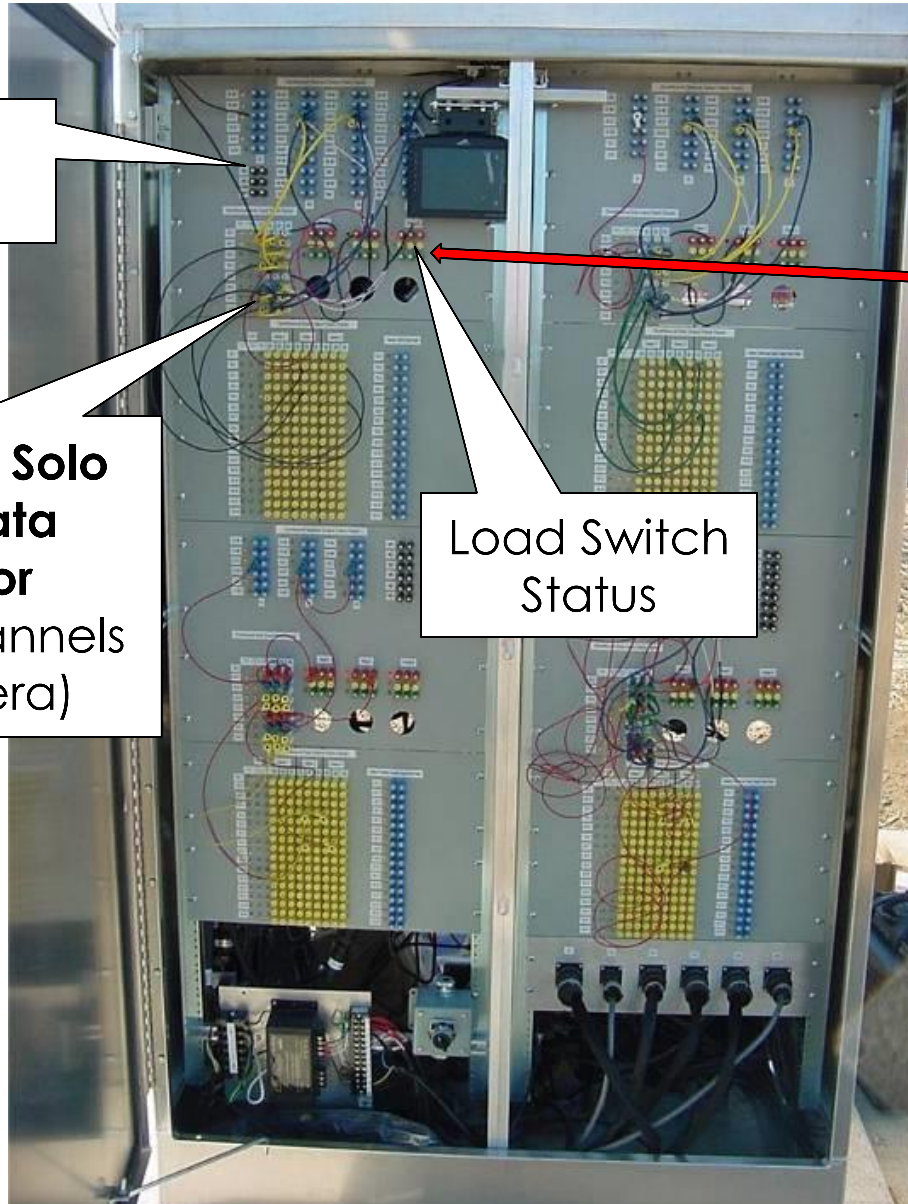
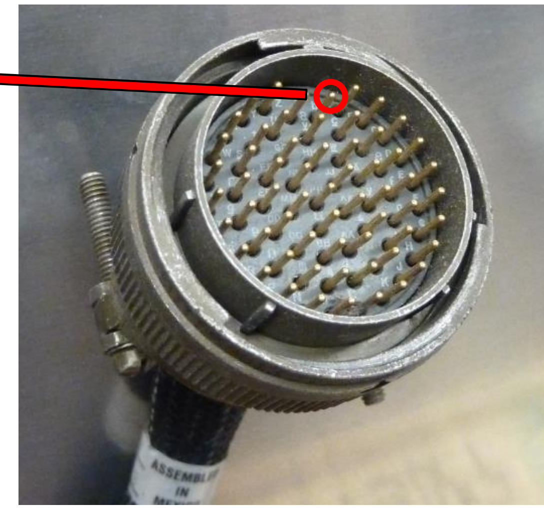
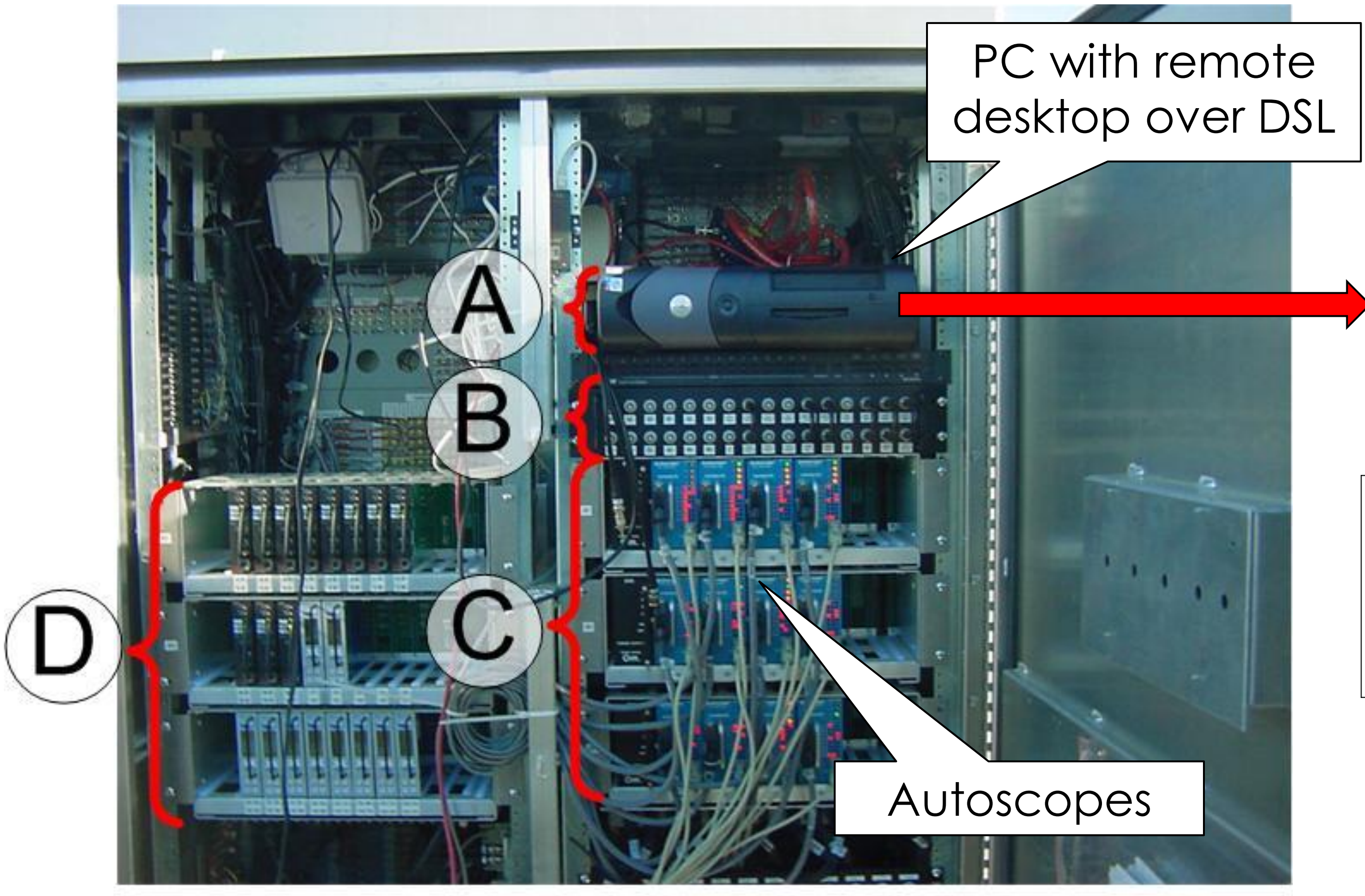
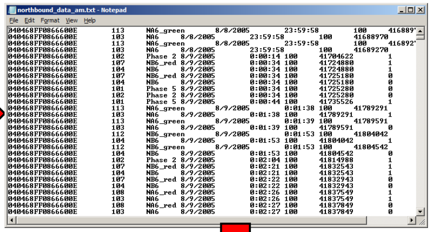
Field Data Collection Cabinet

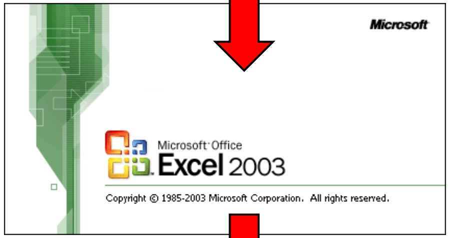


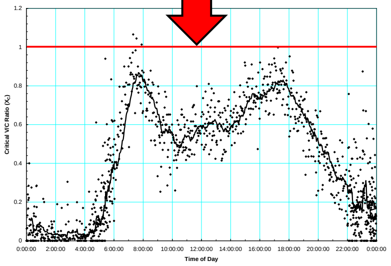


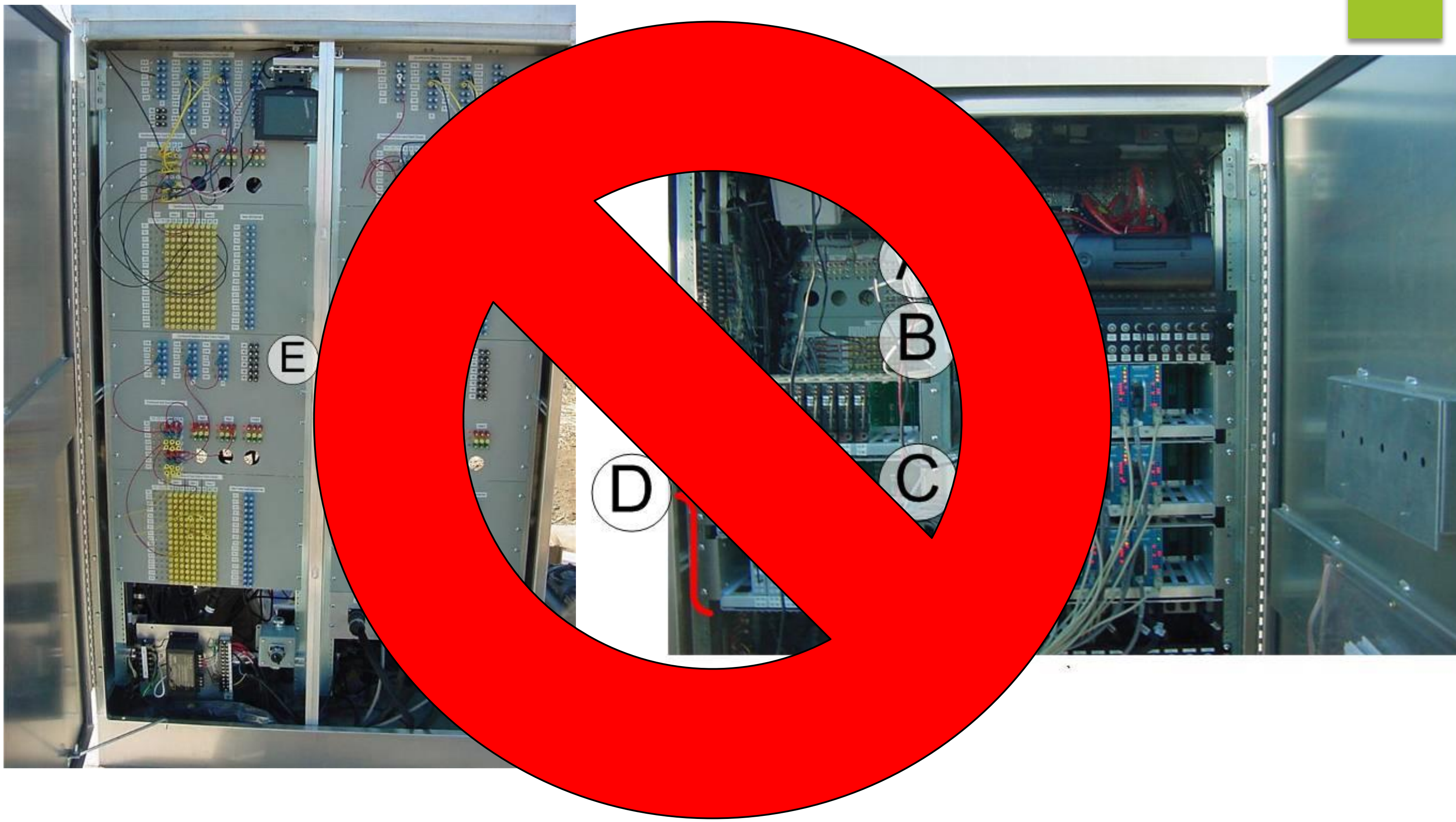
Field Data Collection Cabinet





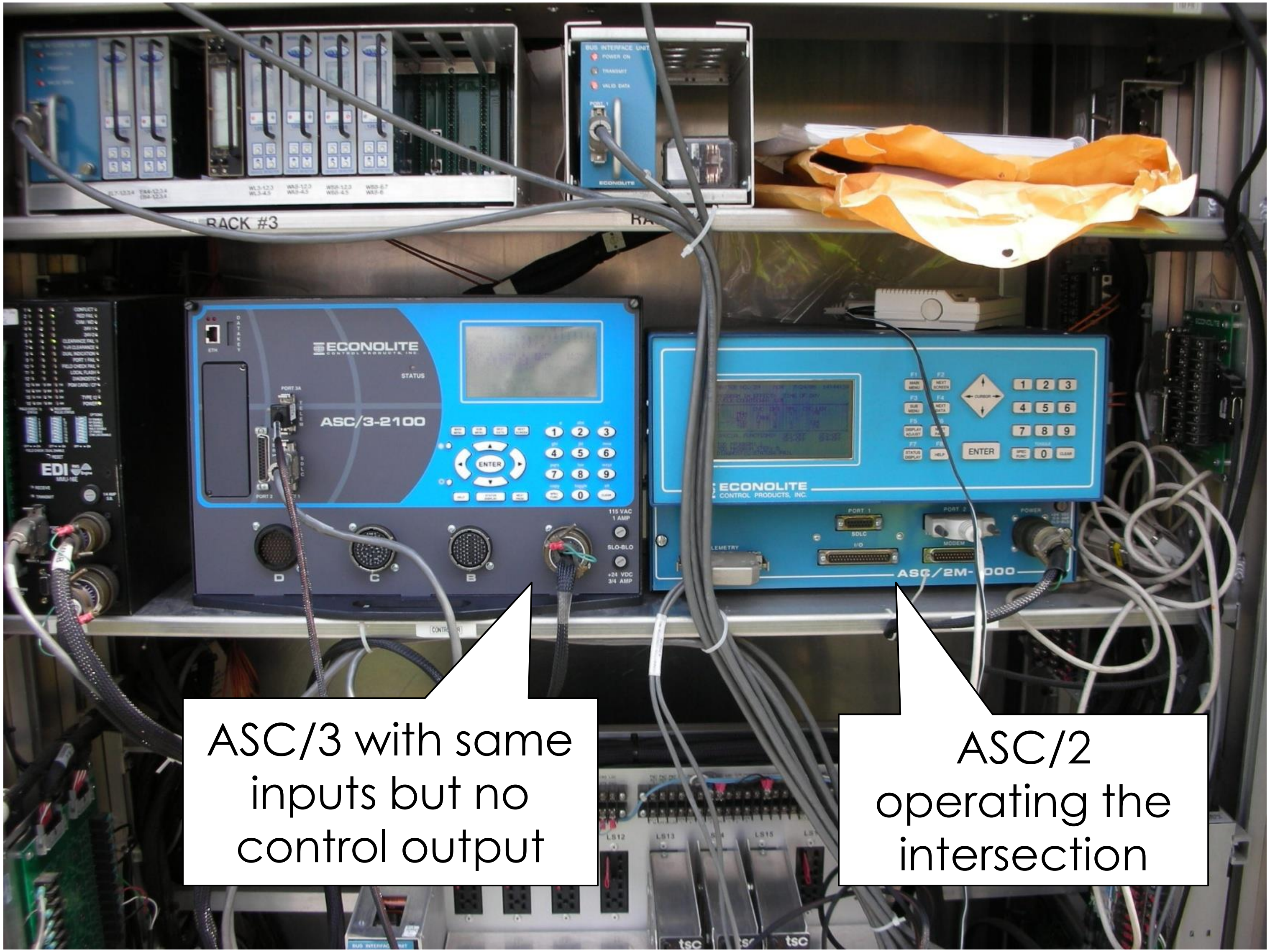




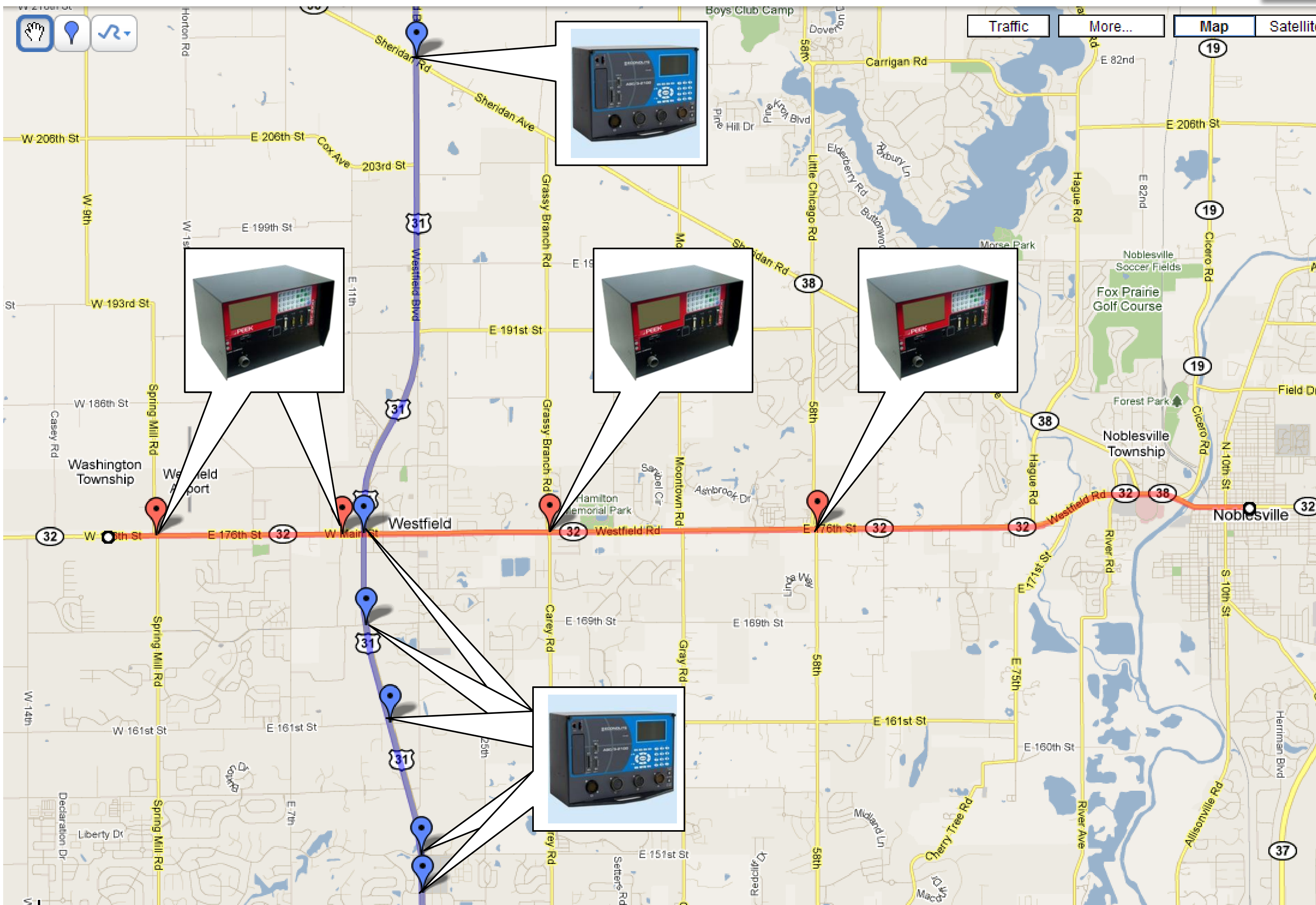


OBSOLETE

Pilot Test of Controller Data Logger (Fall 2006)



Objective: Vendor Neutrality



Development of Controller Data Enumerations

- Want to ensure that a "Phase 2 Green" is written down the same way in every vendor's controller
- Invited controller manufacturers to collaborate to agree on a specification for the data
- Three vendors initially participated
- Today, five vendors have implemented a controller data logger

Active Phase Events:

0	Phase On
1	Phase Begin Green
2	Phase Check
3	Phase Min Complete
4	Phase Gap Out
5	Phase Max Out
6	Phase Force Off
7	Phase Green Termination
8	Phase Begin Yellow Clearance
9	Phase End Yellow Clearance
10	Phase Begin Red Clearance
11	Phase End Red Clearance

Detector Events:

81	Detector Off
82	Detector On
83	Detector Restored
84	Detector Fault- Other
85	Detector Fault- Watchdog Fault
86	Detector Fault- Open Loop Fault

Preemption Events:

101	Preempt Advance Warning Input
102	Preempt (Call) Input On
103	Preempt Gate Down Input Received
104	Preempt (Call) Input Off
105	Preempt Entry Started

Controller Enumerations

Event Code, Event Description, Parameter

06/27/2013 01:29:51.1	10	8
06/27/2013 01:29:51.1	82	5
06/27/2013 01:29:52.2	1	2
06/27/2013 01:29:52.2	1	6
06/27/2013 01:29:52.3	82	2
06/27/2013 01:29:52.8	82	4
06/27/2013 01:29:52.9	81	4
06/27/2013 01:29:53.3	81	6
06/27/2013 01:29:54.5	81	2
06/27/2013 01:30:02.2	8	2
06/27/2013 01:30:02.2	8	6
06/27/2013 01:30:02.2	33	2
06/27/2013 01:30:02.2	33	6
06/27/2013 01:30:02.2	32	2
06/27/2013 01:30:02.2	32	6
06/27/2013 01:30:06.1	10	2
06/27/2013 01:30:06.1	10	6
06/27/2013 01:30:08.1	1	8
06/27/2013 01:30:13.1	32	8
06/27/2013 01:30:15.8	81	5
06/27/2013 01:30:18.5	82	6
06/27/2013 01:30:27.5	81	6
06/27/2013 01:30:30.4	8	8

Detector 5 ON

Phase 8 GREEN

Detector 5 OFF

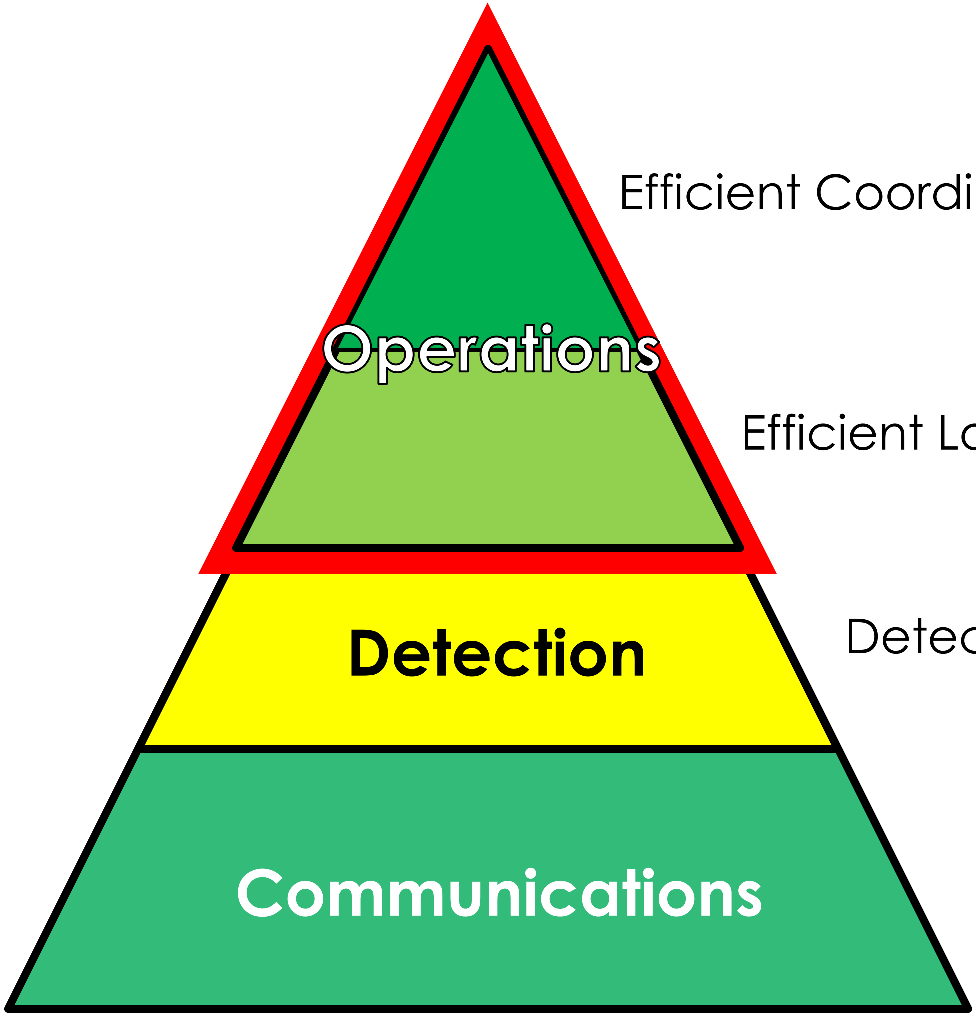
High-resolution Data

Timestamp, Enumeration Code, Parameter

Controllers with High Resolution Data Loggers (As of 2014)

- Econolite
- Peek
- Siemens
- Intelight
- Trafficware (Naztec)

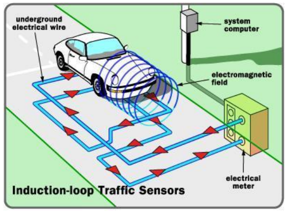
Hierarchy of Infrastructure Needs



Efficient Coordination

Efficient Local Control

Detector Health



Working Communications

System Requirements

High-resolution Controller

Communications

1) Get *.dat* Files

2) Translate Files

.dat → *.csv*

3) Store in Database

Server

1) Query Database

2) Display Graphs

Website

Detection
(optional)

Photo courtesy of the Indiana Department of Transportation

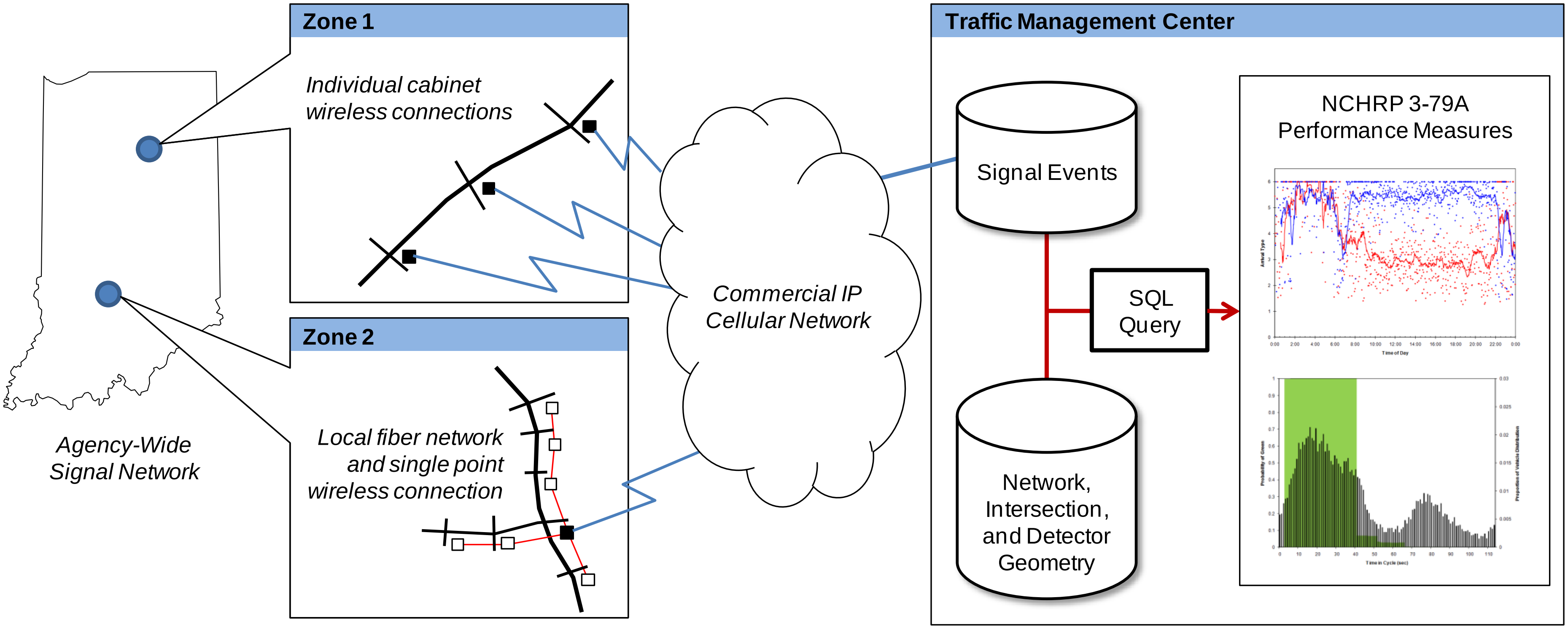
Communications

- Needed to bring data from the field to the office to develop performance measures

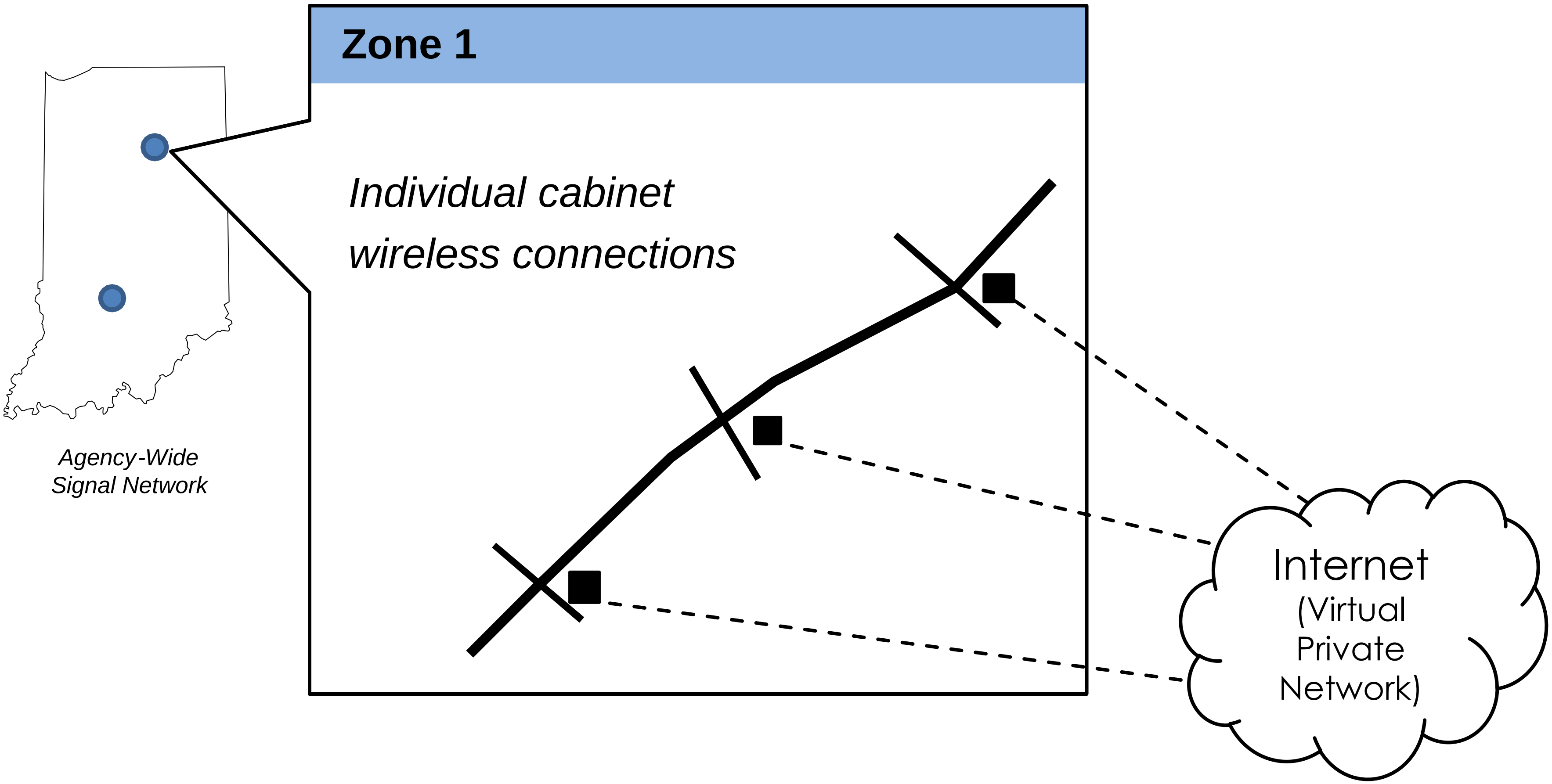
Communications

- Methods of Data Transport
  - Fiber Interconnect
  - Cellular Modem
  - “Sneaker-net”

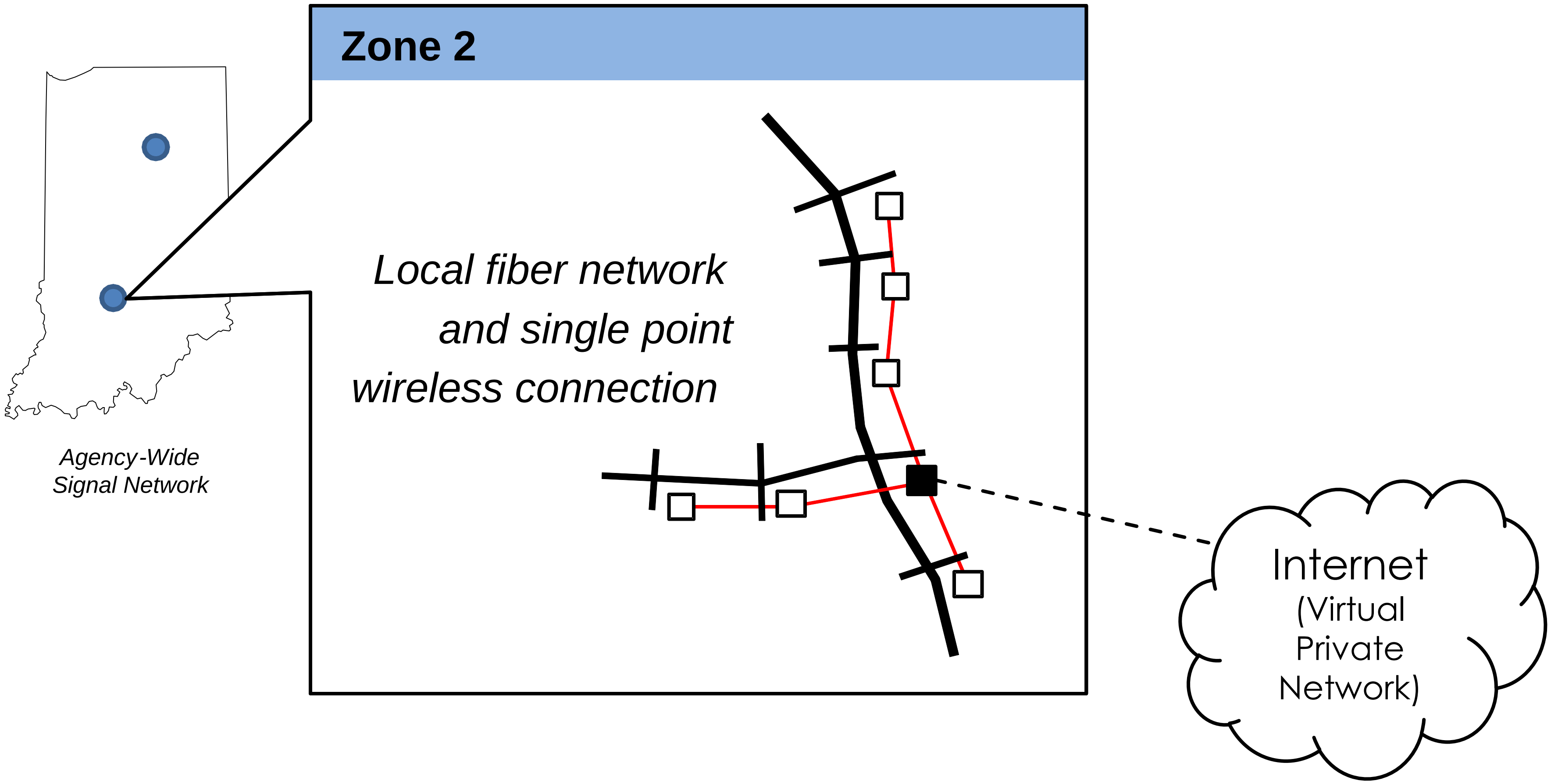
Example Communications Infrastructure



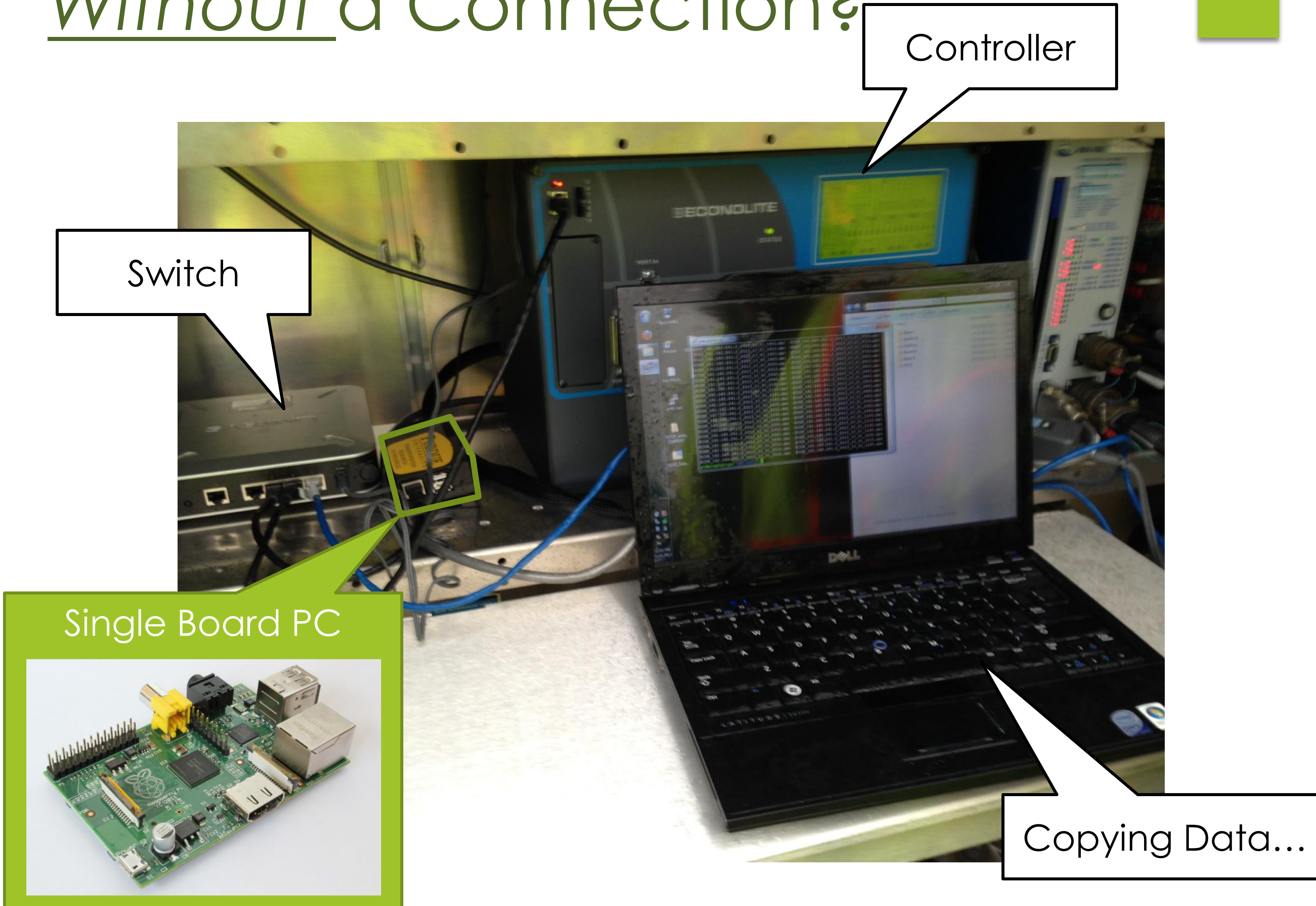
Example Communications Infrastructure



Example Communications Infrastructure

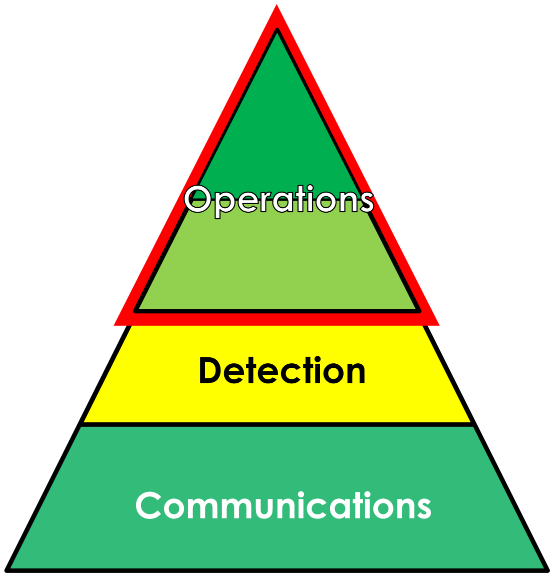


What About Locations *Without* a Connection?



Detection Requirements

- Need some kind of detection on each movement that is desired to be analyzed
  - Any detection technology can be used (provided that it works)
- Flexible – Existing detection is often adequate
- Count detection allows more detailed analysis, but not required



Stopbar versus Advance Detection

- Stop bar detection
  - Measure vehicles as they are served
  - Useful for measuring utilization of capacity for individual movements
- Advance detection
  - Measure vehicles as they arrive at the intersection
  - Needed to evaluate progression
  - Can also evaluate utilization of capacity

Presence versus Count Detection

- When detection zone is longer than the length of a typical vehicle
- **Option 1 – Presence Only**
  - Measure detector occupancy
- **Option 2 – Presence with Count**
  - May require special detector equipment (e.g., count amplifier for loops)
  - Measure volume of vehicles

Detection Types That Have Been Used

- Inductive Loop
- Radar
- Video
- Magnetometer


Metrics & Detection Requirements

Controller high-resolution data only

Purdue Phase Termination

Split Monitor

Advanced Count Detection (~400 ft behind stop bar)

Purdue Coordination Diagram

Approach Volume

Platoon Ratio

Arrivals on Red

Approach Delay

Executive Summary Reports

Advanced Detection with Speed

Approach Speed

Lane-by-lane Presence Detection

Split Failure (future)

Lane-by-lane Count Detection

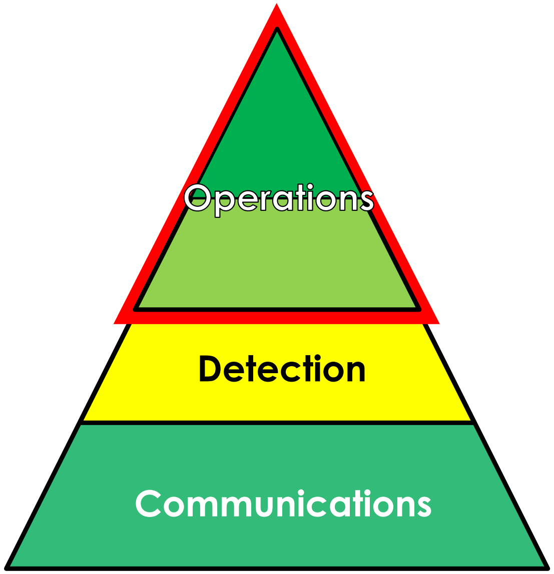
Turning Movement Counts

Probe Travel Time Data (GPS or Bluetooth)

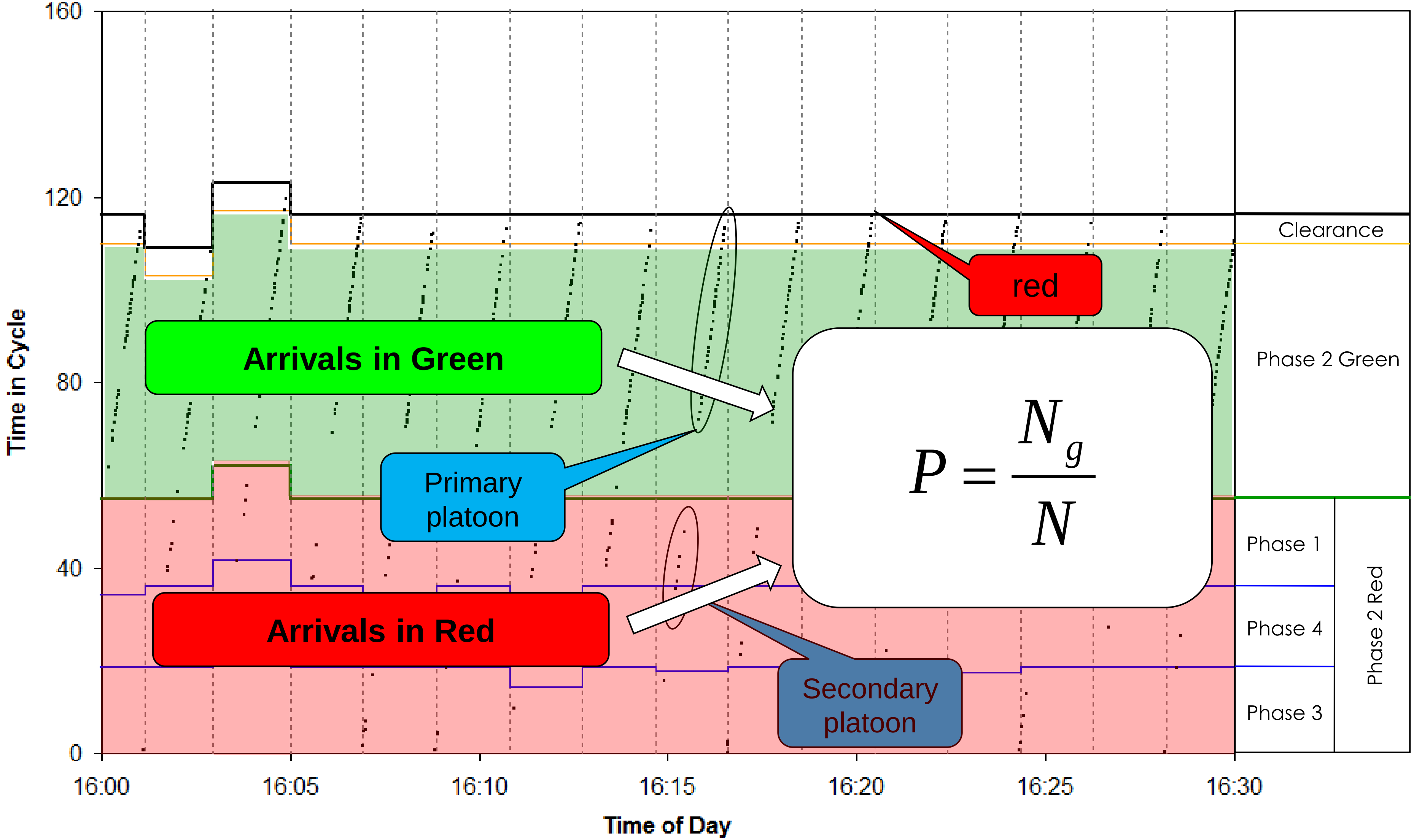
Purdue Travel Time Diagram

Example Applications of Performance Measures

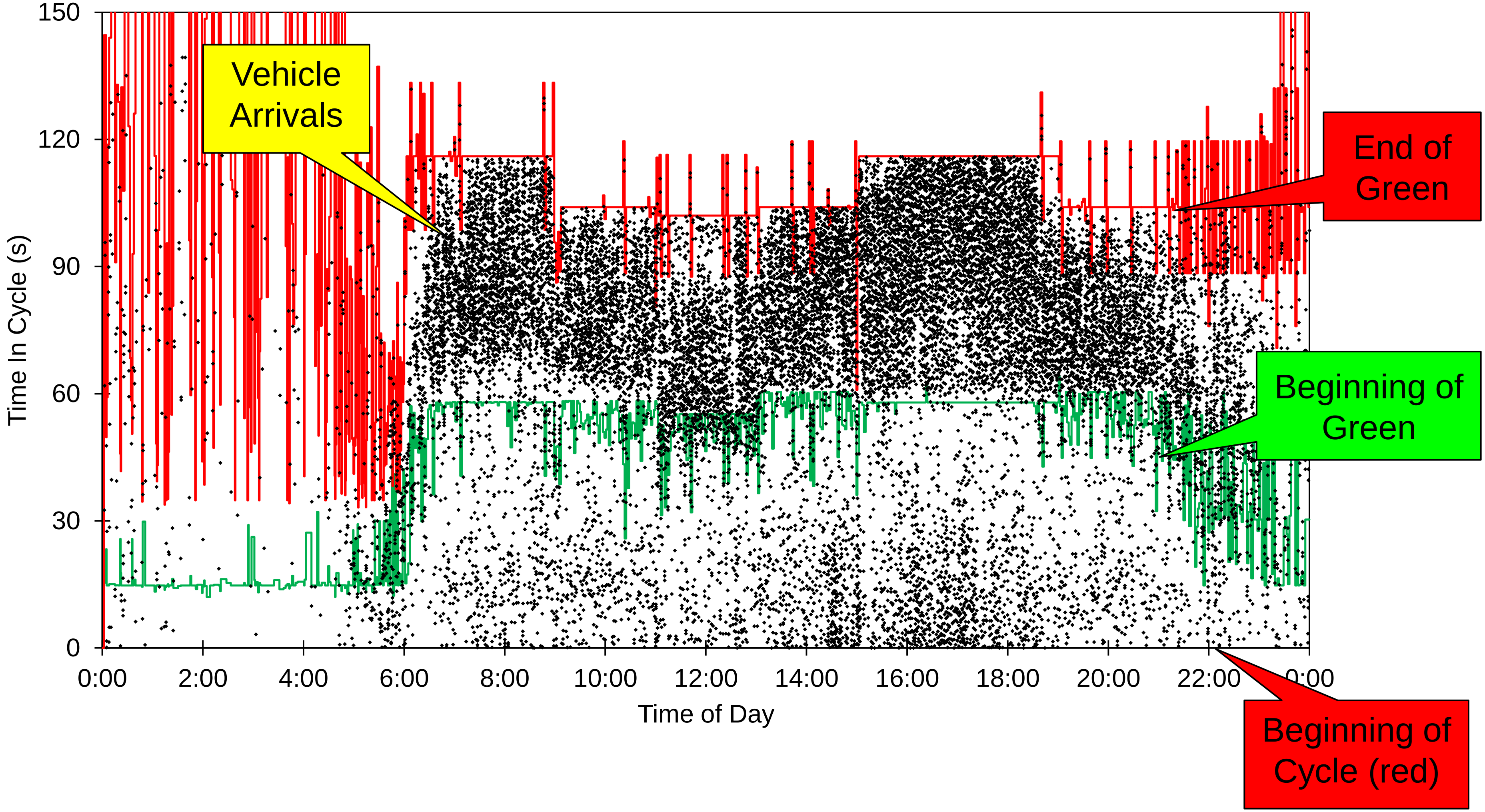
- 1. Capacity Allocation
  - Split Failure and Split Adjustment
- 2. Quality of Progression
  - Offset Optimization



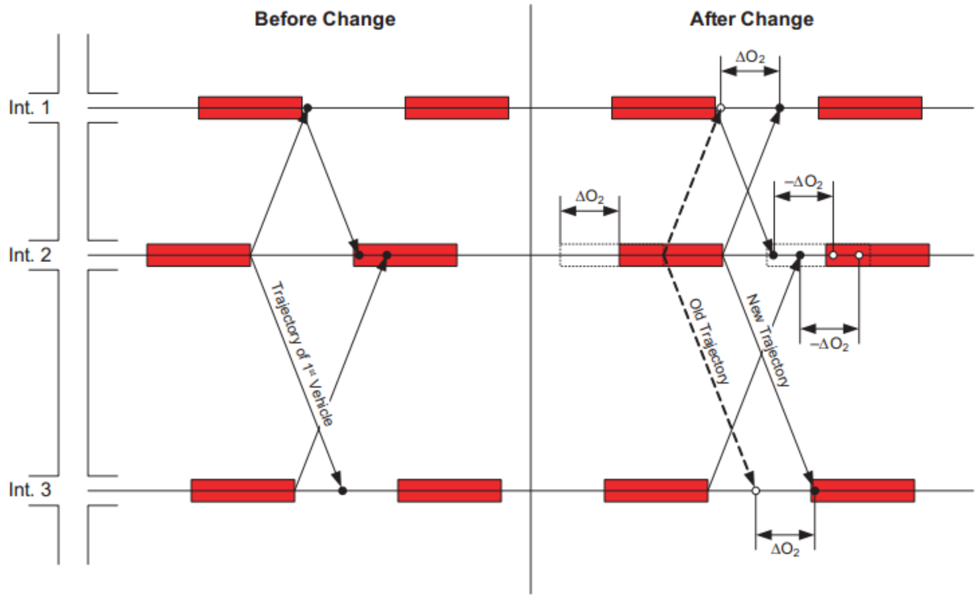
Coordination Diagram

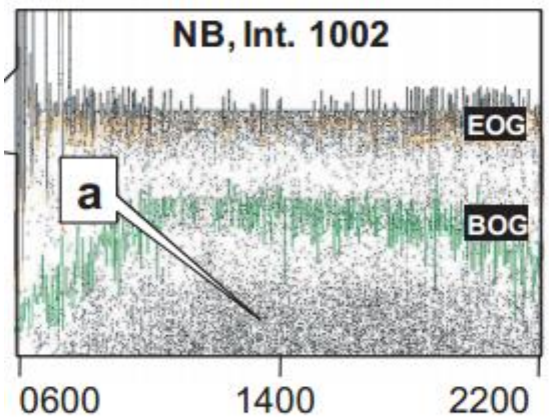


Coordination Diagram 24-Hour View

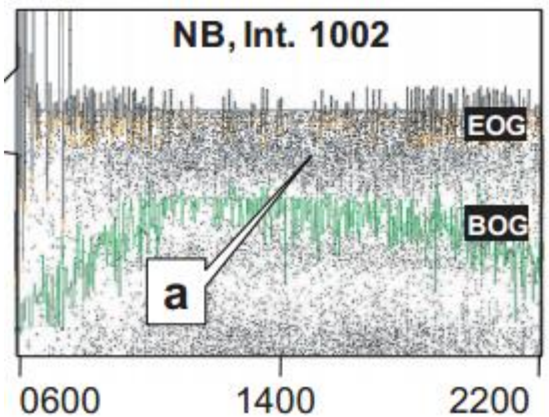


Modeling Changes to Offset

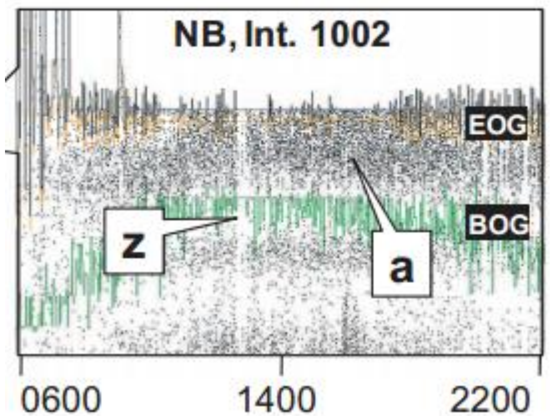




BEFORE

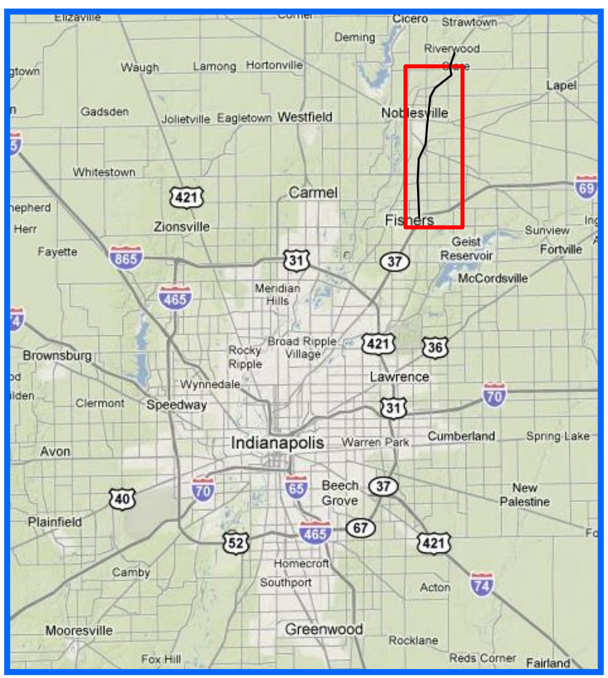


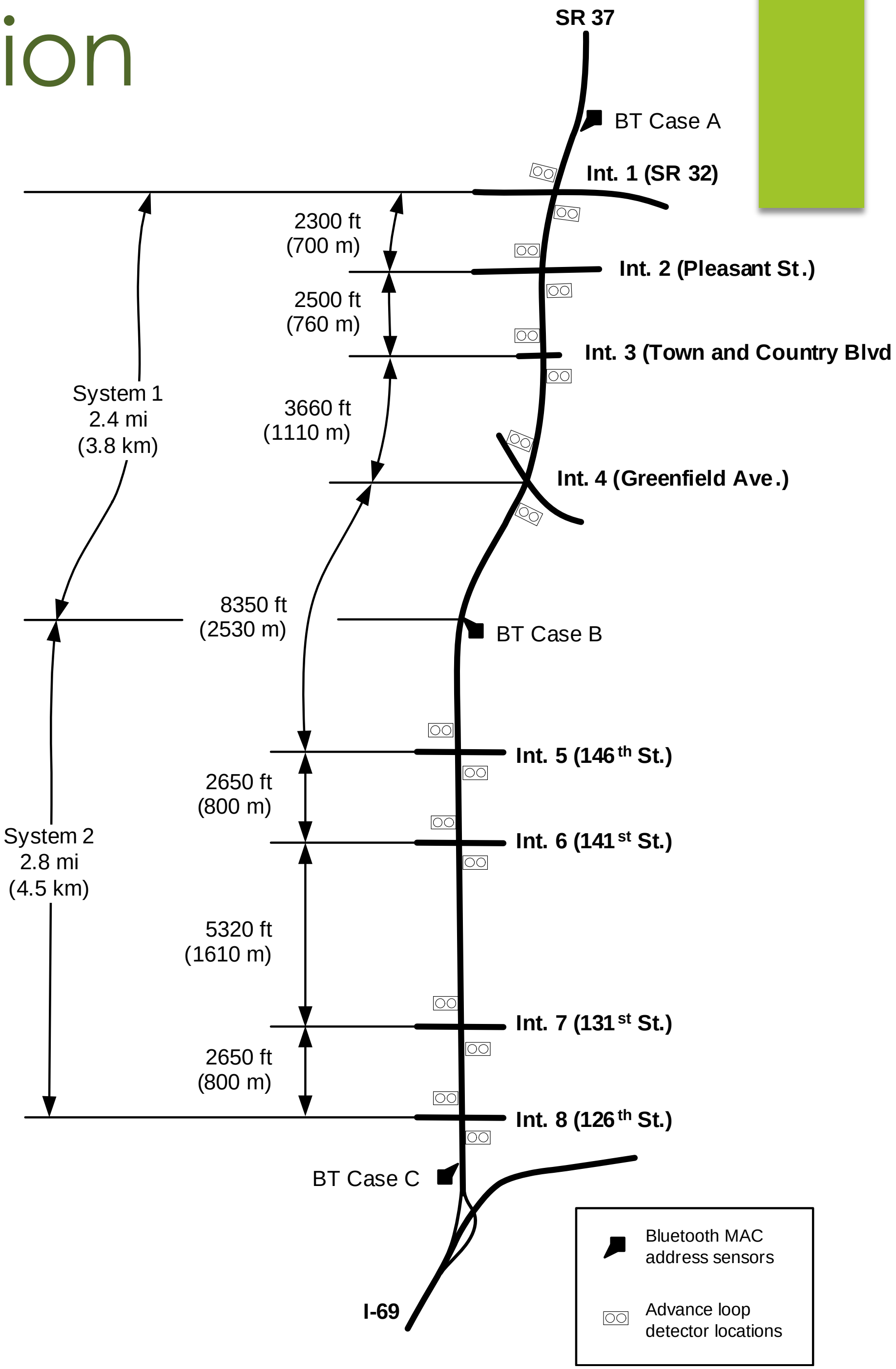
PREDICTED



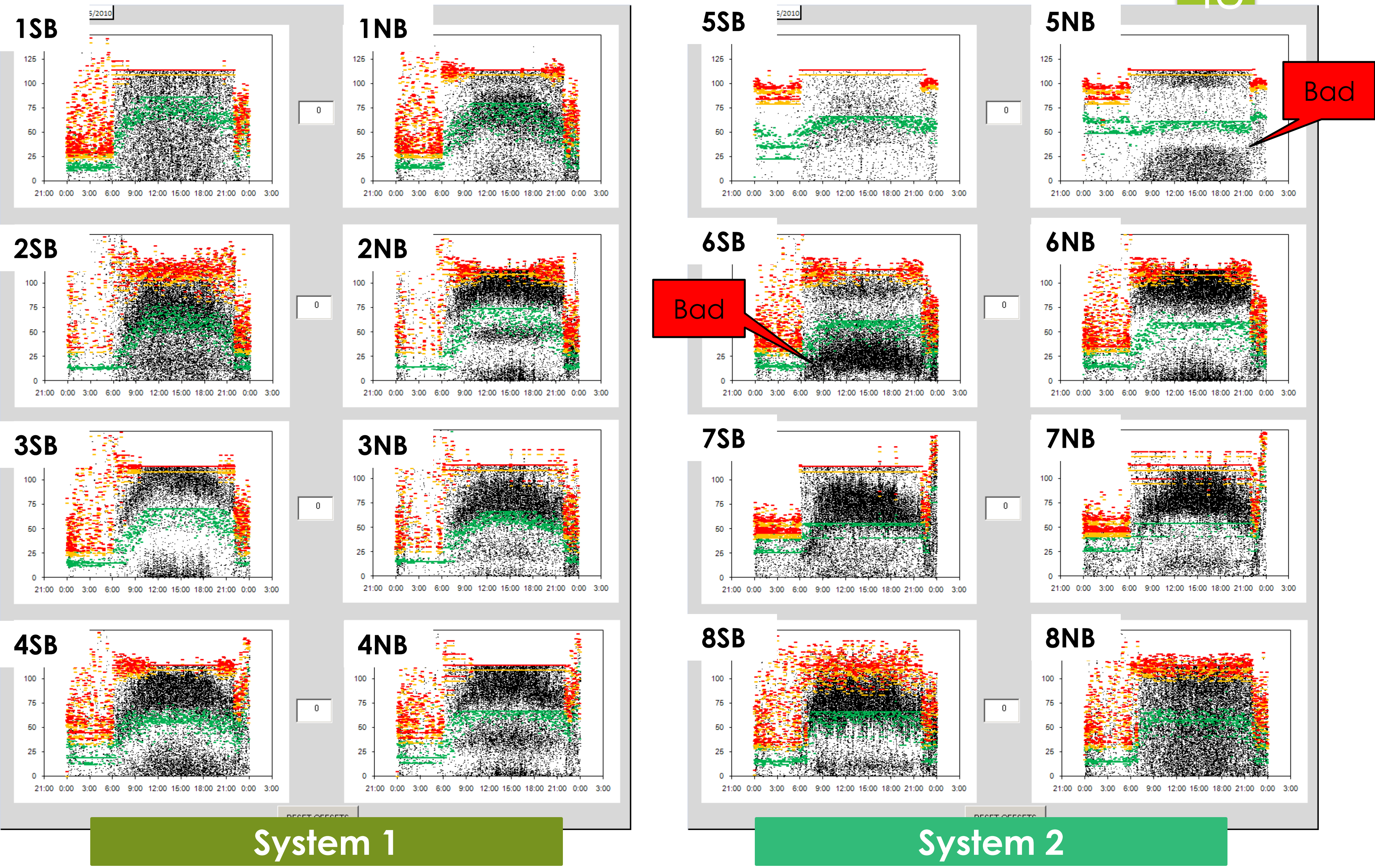
AFTER

Offset Optimization Case Study

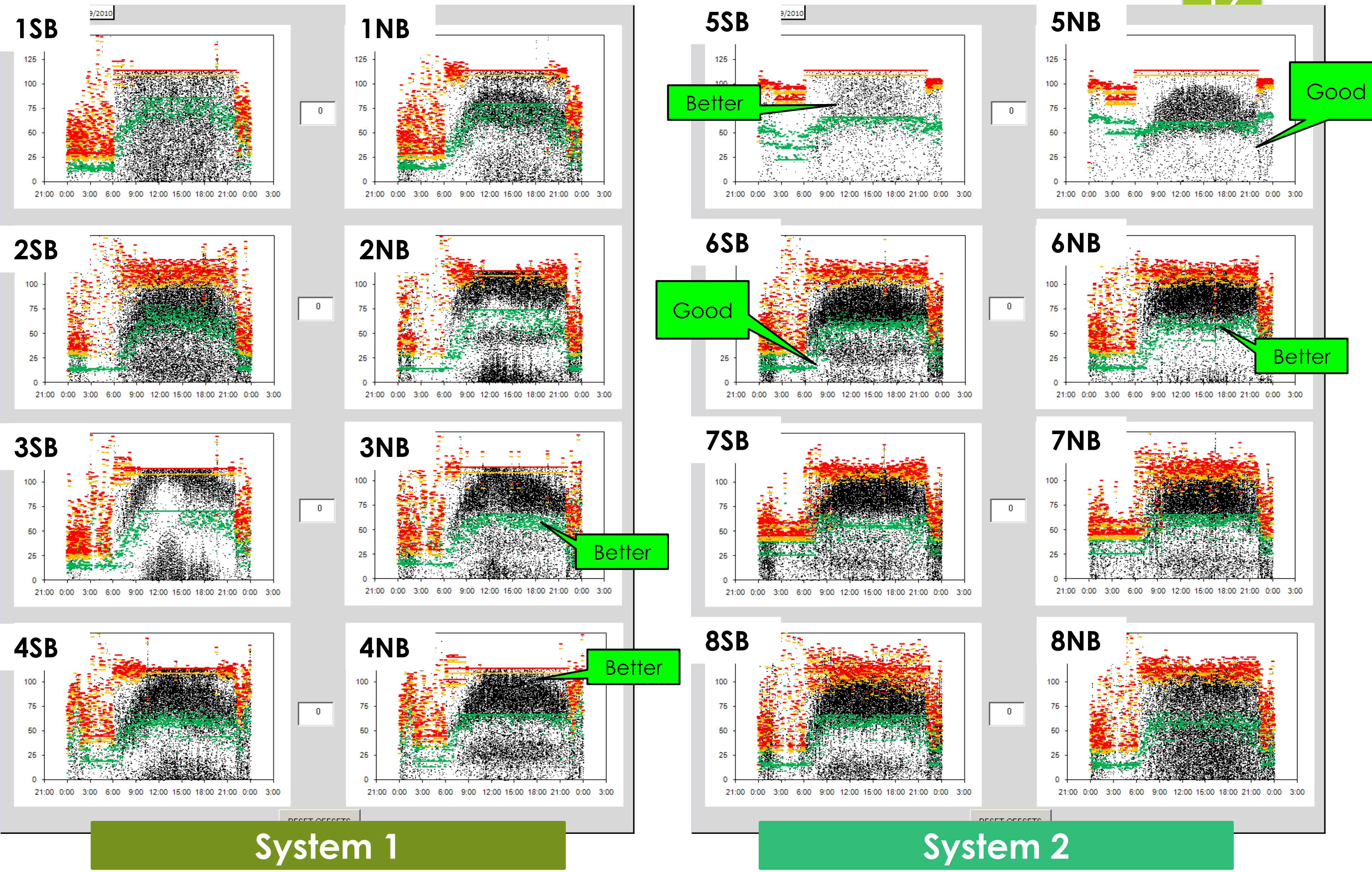




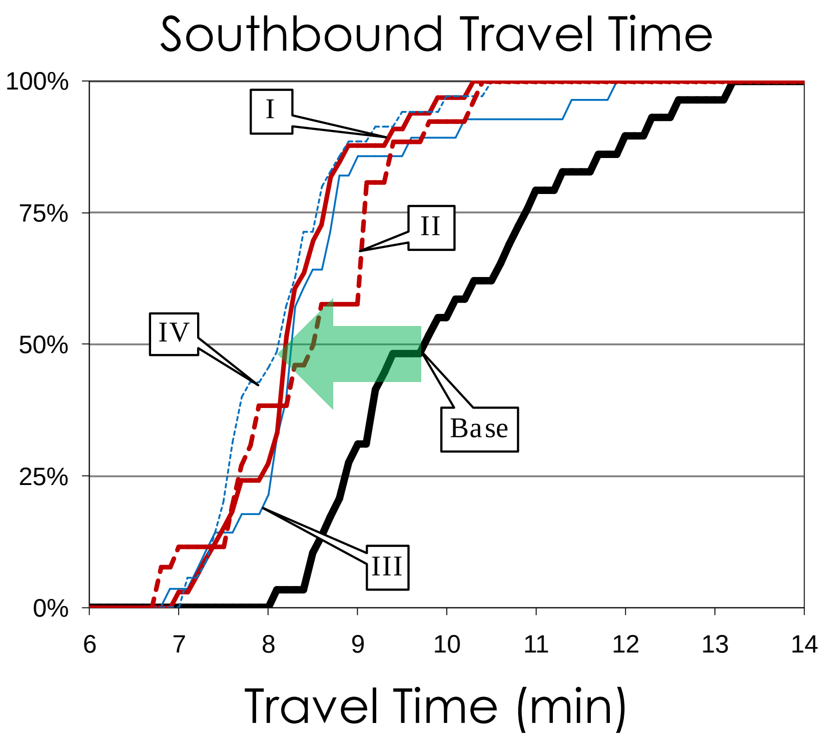
Offset Optimization – BEFORE

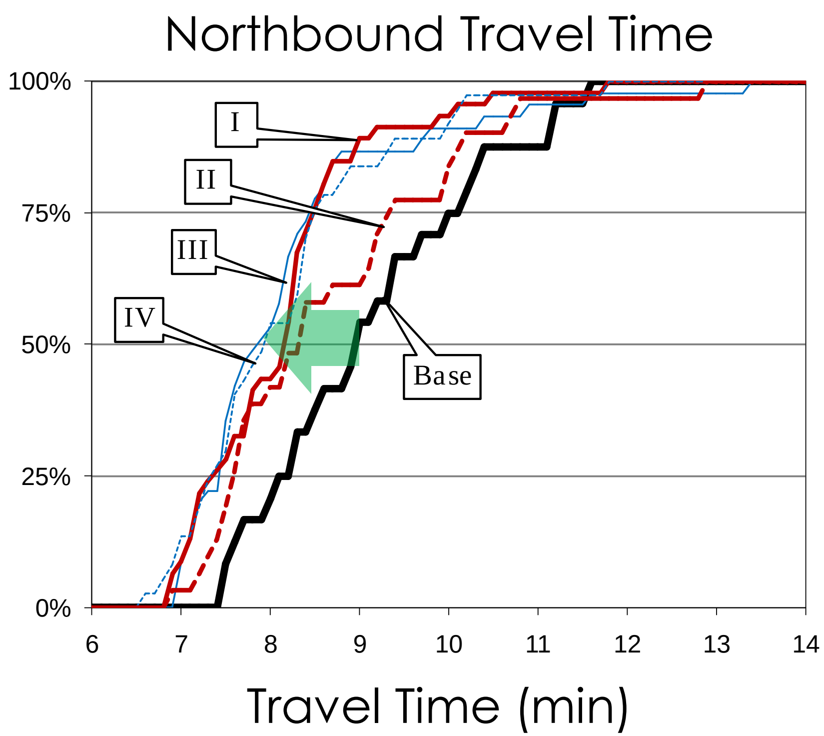


Offset Optimization – AFTER



Impact on Travel Times



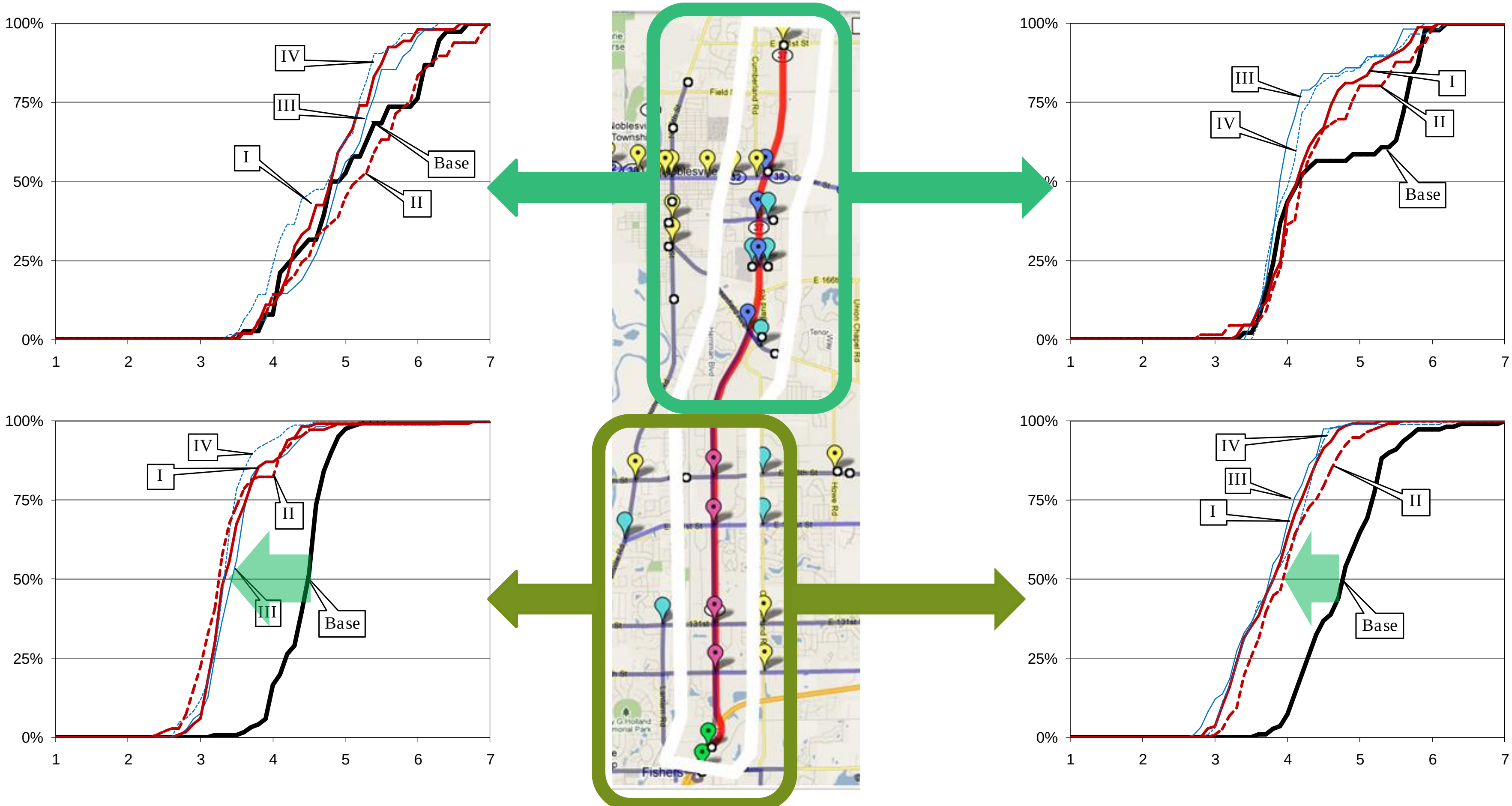


I. Min Delay
II. Min Delay / Stops
III. Max Arrivals on Green
IV. Max Arrivals on Green with Queue Clearance

Impact on Travel Times

Southbound Travel Time

Northbound Travel Time



Travel Time (min)

Travel Time (min)

Estimation of User Benefit

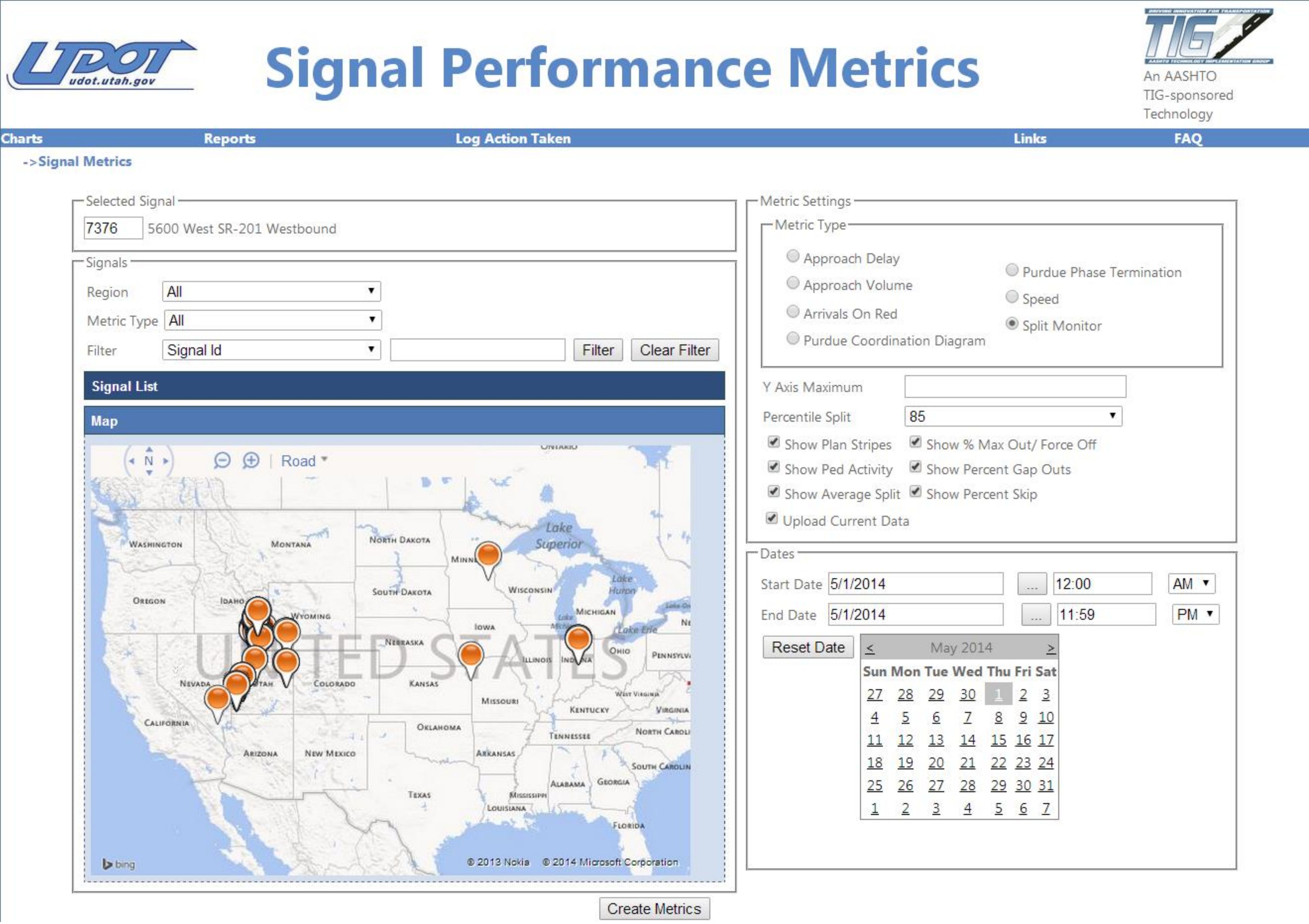
Objective		Daily: Total Time Saved (veh-min)	Daily: CO_2 Emission Reduction (tons)	Daily: CO_2 Savings	Daily: User Benefits	Multi-plier	Annual: CO_2 Emission Reduction (tons)	Annual: CO_2 Savings	Annual: User Benefits
(a) System 1, Northern Section									
I	Min Delay	5032	0.71	$16	$1,697	52	37	$810	$88,233
II	Min Delay and Stops	3813	0.54	$12	$1,286	52	28	$614	$66,864
III	Max N_q	1760	0.25	$5	$593	52	13	$283	$30,855
IV	Alt. Max N_q	7883	1.11	$24	$2,658	52	58	$1,268	$138,229
(b) System 2, Southern Section									
I	Min Delay	24386	3.43	$75	$8,223	52	178	$3,924	$427,614
II	Min Delay and Stops	25327	3.56	$78	$8,541	52	185	$4,075	$444,111
III	Max N_q	25147	3.54	$78	$8,480	52	184	$4,046	$440,962
IV	Alt. Max N_q	26338	3.70	$81	$8,882	52	193	$4,238	$461,845
(c) System 1 and System 2, Arterial									
I	Min Delay	29418	4.14	$91	$9,920	52	215	$4,733	$515,847
II	Min Delay and Stops	29140	4.10	$90	$9,826	52	213	$4,689	$510,976
III	Max N_q	26907	3.78	$83	$9,073	52	197	$4,329	$471,817
IV	Alt. Max N_q	34221	4.81	$106	$11,540	52	250	$5,506	$600,073

Impact of going from arrivals in red to arrivals in green

CRITICAL INFRASTRUCTURE ELEMENTS: UDOT Implementation

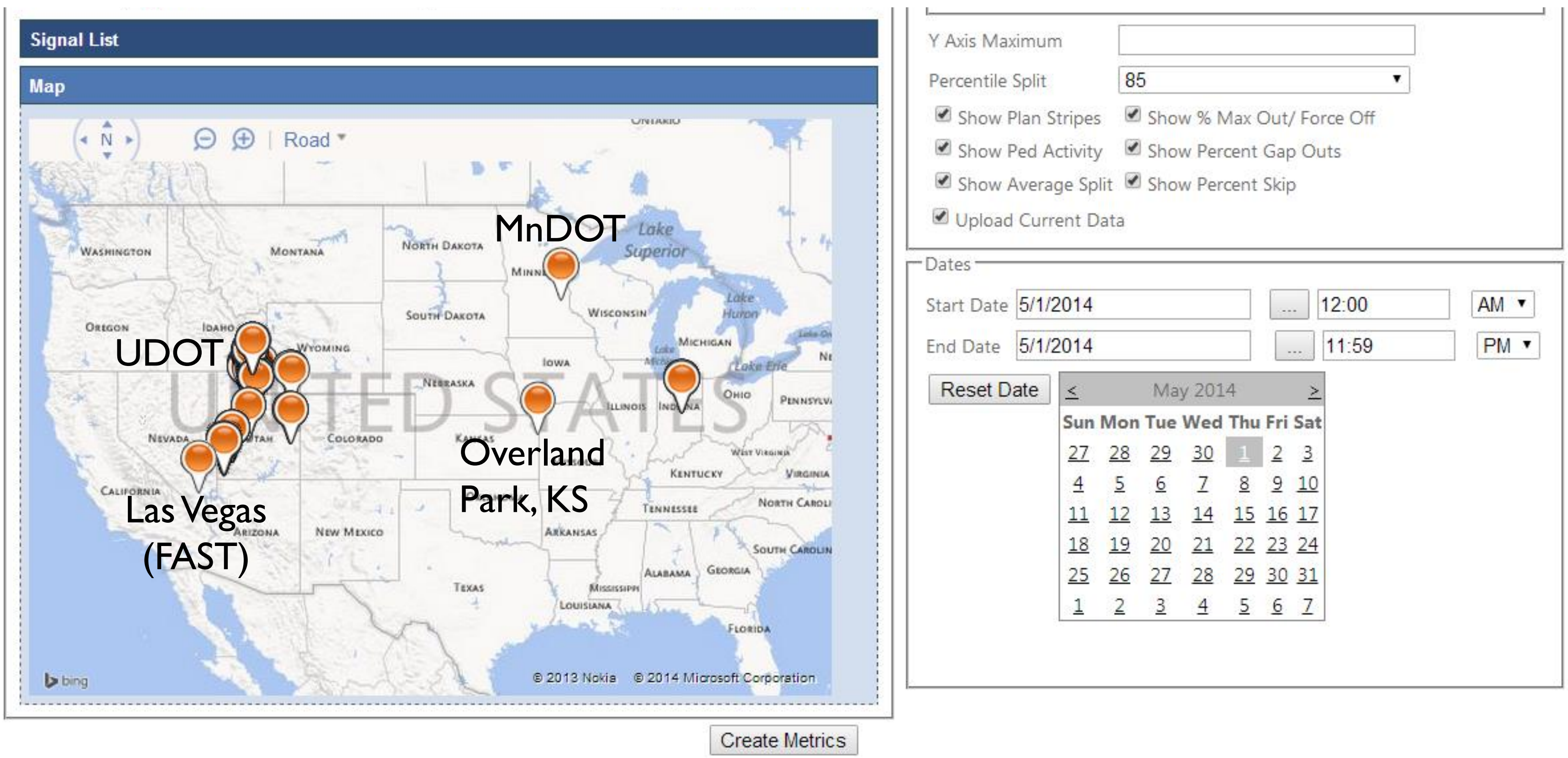
INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014

PRESENTED BY SHANE JOHNSON



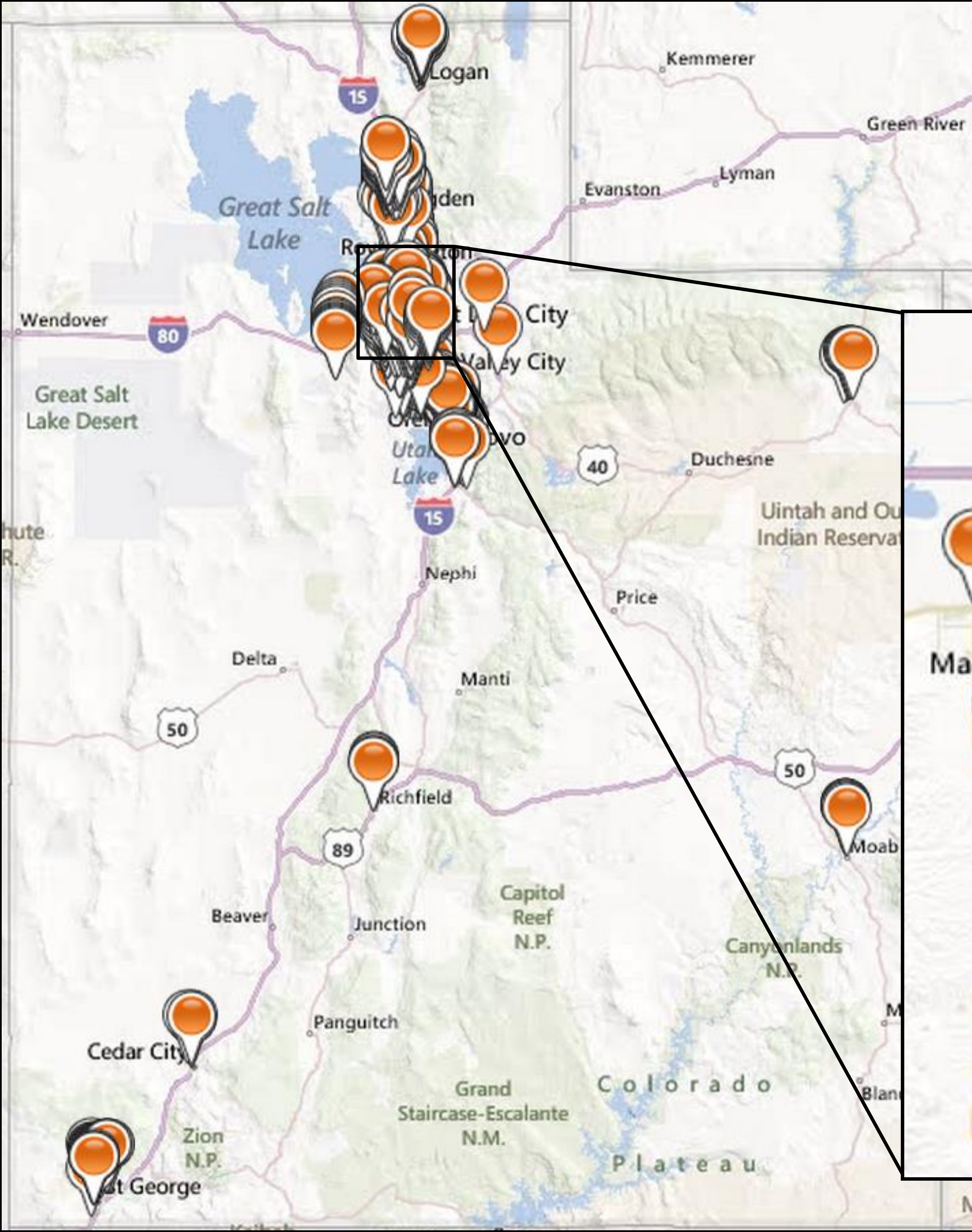
http://udottraffic.utah.gov/signalperformancemetrics

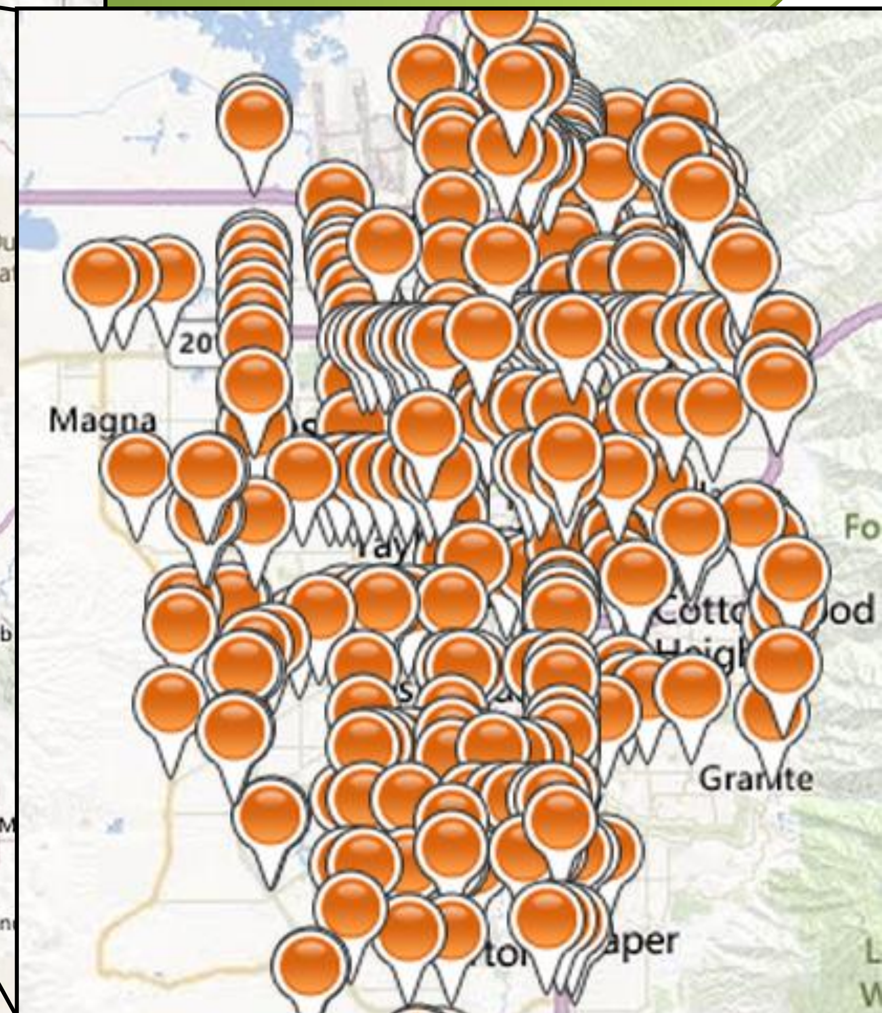
Agencies using UDOT software for SPMs

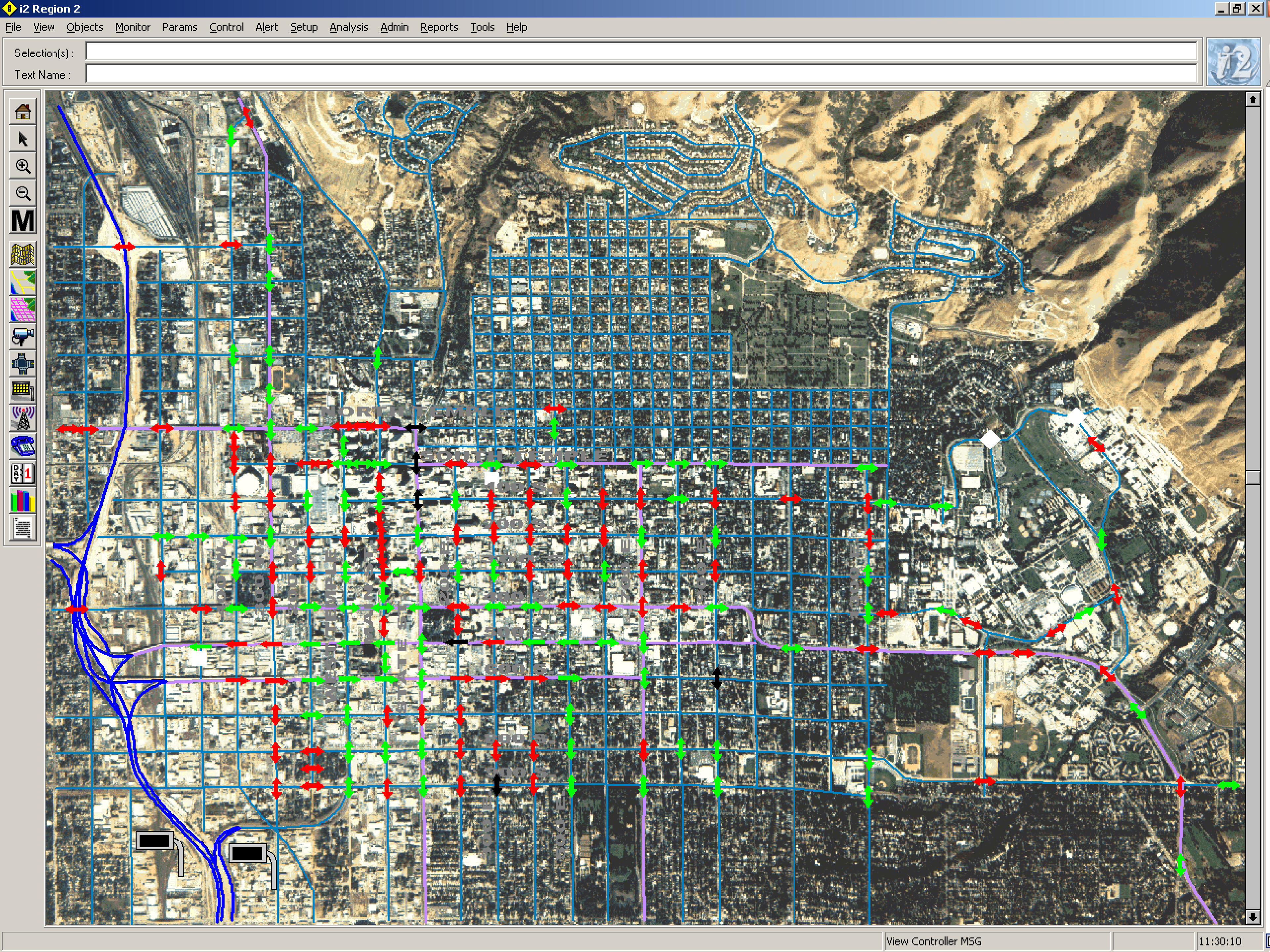


http://udottraffic.utah.gov/signalperformancemetrics

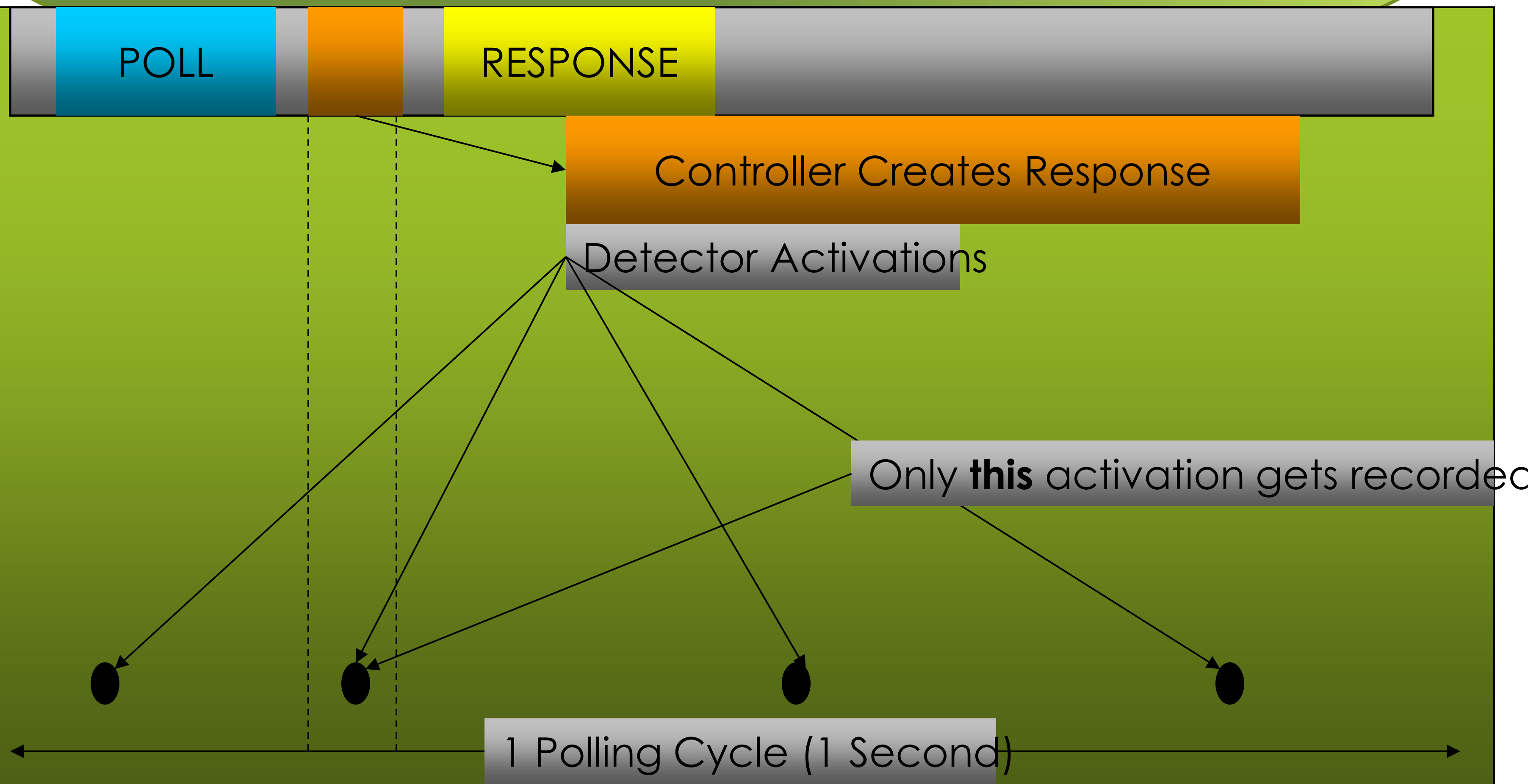
Salt Lake Valley



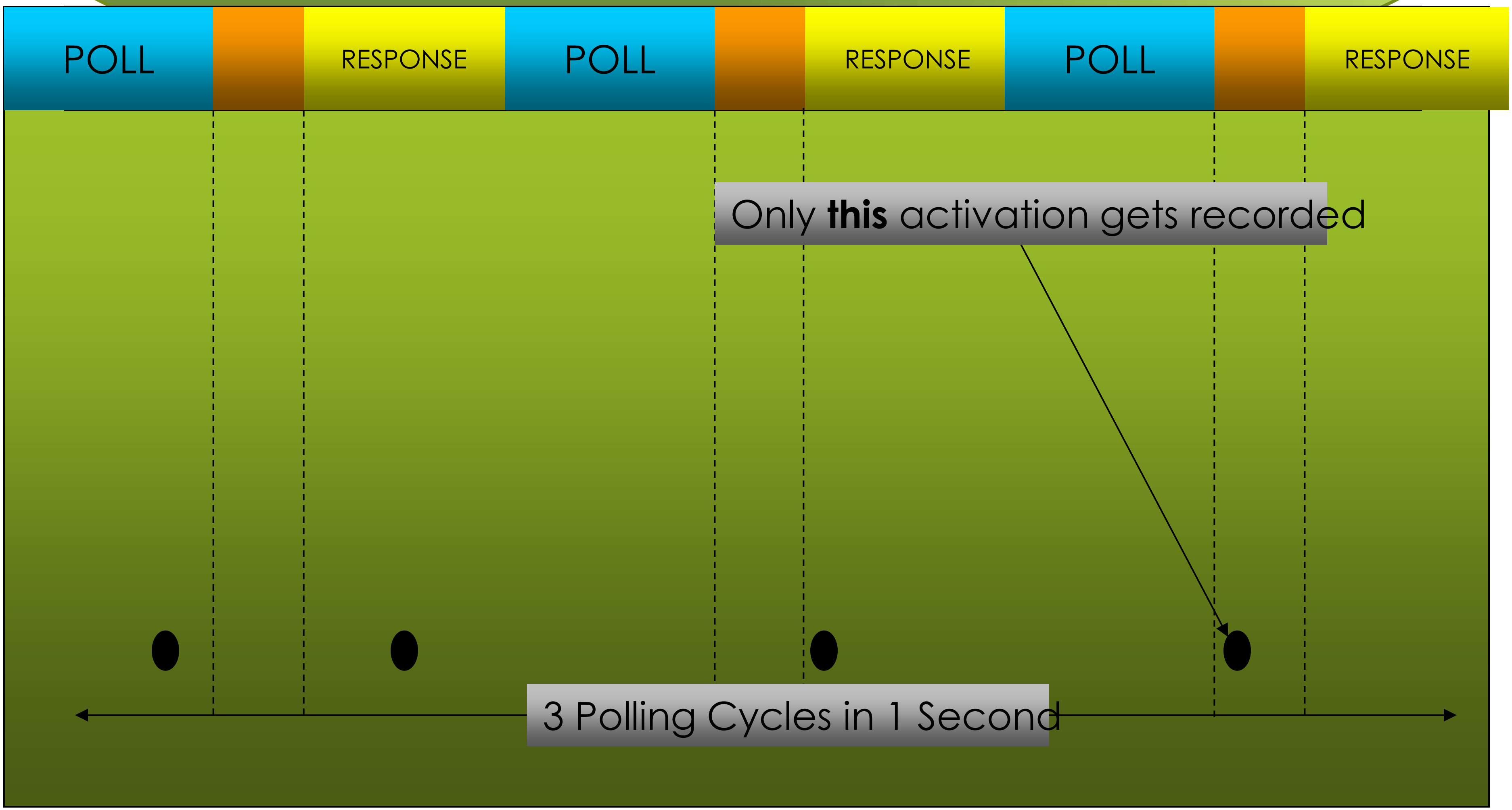



i2 Region 2
File View Objects Monitor Params Control Alert Setup Analysis Admin Reports Tools Help
Selection(s) :
Text Name :
View Controller MSG
11:30:10

Detector Activations and Poll Rates.



Detector Activations and Poll Rates.



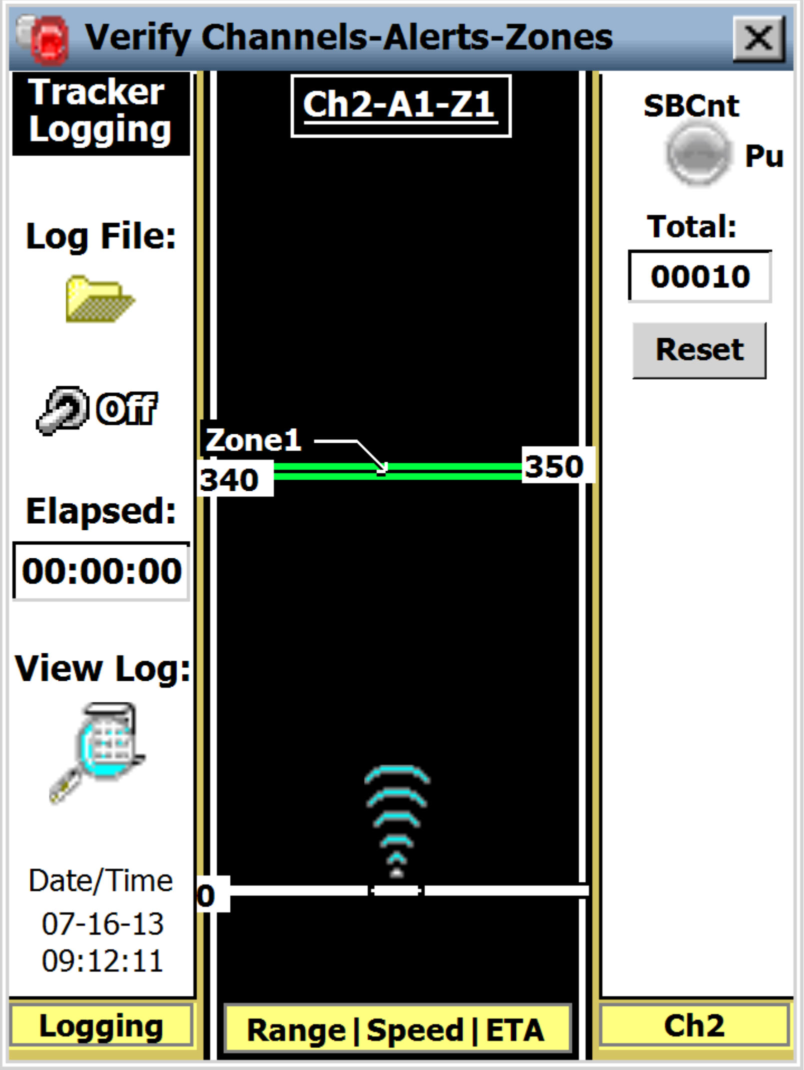
The Econolite ASC3 Controller

- Collects events at 1/10 second resolution
- Stores the collected events in binary log files for maximum storage efficiency
- The files are retrieved over FTP
- UDOT uses APP version 2.54 and OS version 1.14.03.

Detection Technologies

<u>Setback Count Detectors</u>

- Wavetronix Advance
- Used to timestamp vehicle arrivals
- 10' count zone placed ~350' behind stop bar
- No additional expense if already in place for dilemma zones
- May undercount dense traffic

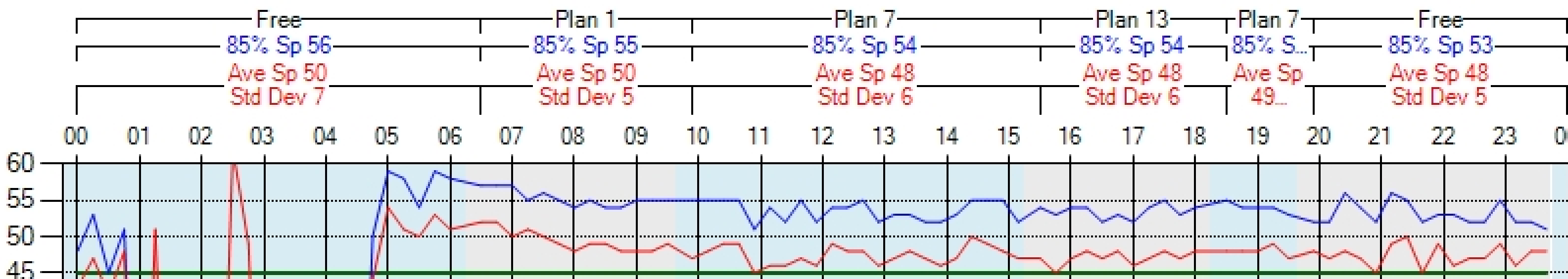


Detection Technologies

Loops

- We have one site that uses loops for advanced detection.
- The loops come in on separate detection channels. They are combined together in the SPM software to give accurate counts.

Detection Technologies



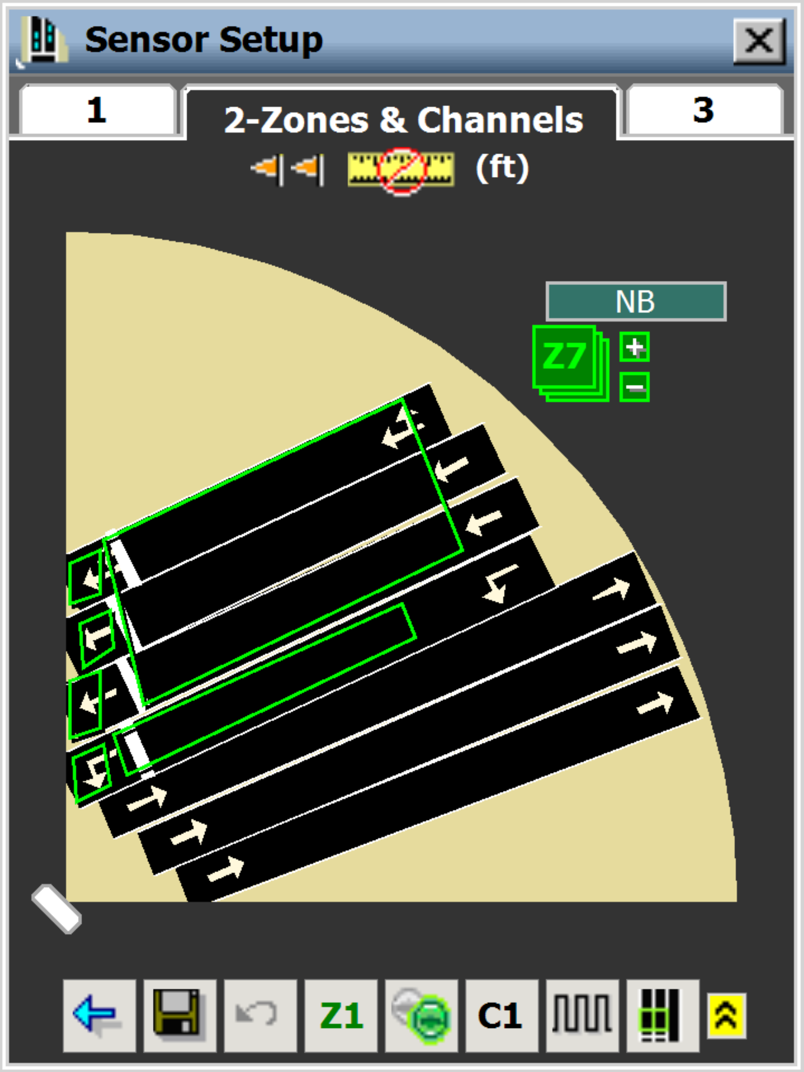
Speed Detection

- Uses the Wavetronix Advance
- The detector sends the recorded MPH, KPH, timestamp and detector ID to a server.
- The server records the information to the database for use in the charts.

Detection Technologies

Wavetronix Matrix detectors

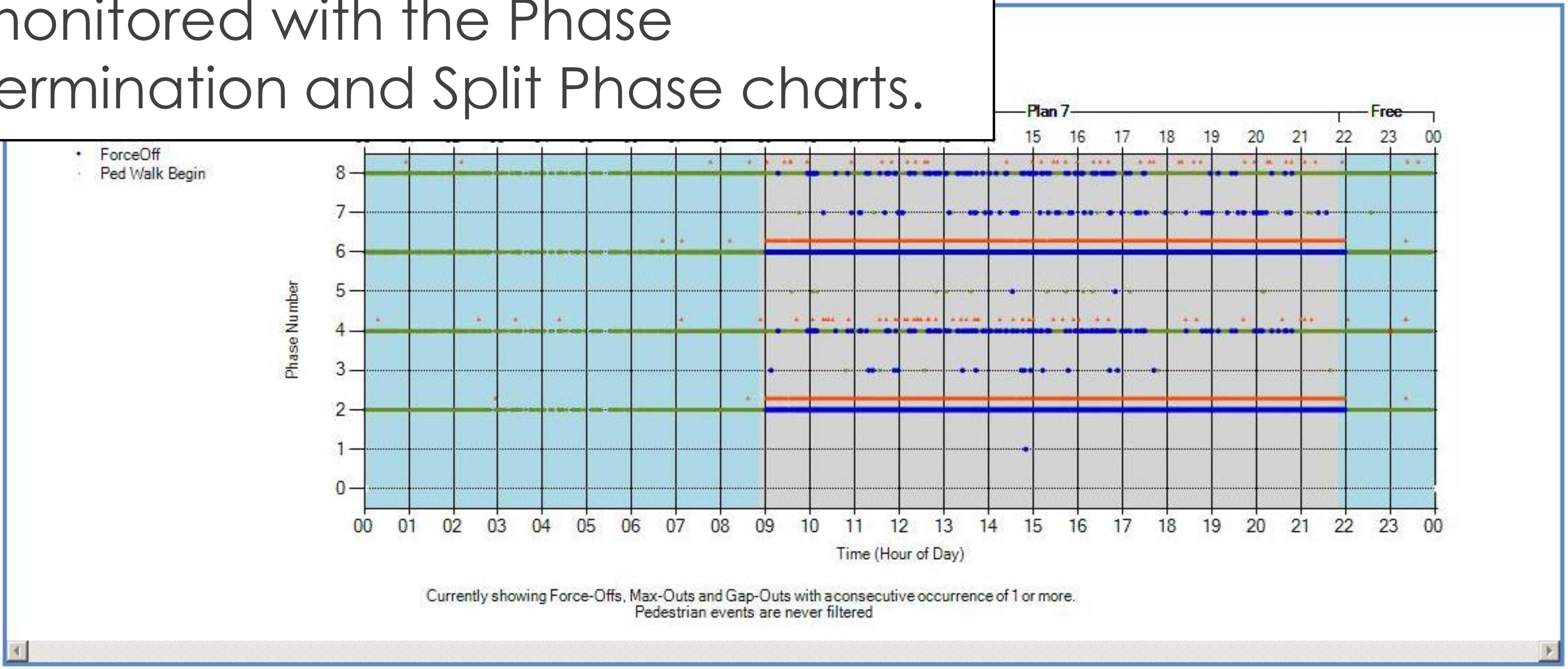
- Used for turning movement counts
- Lane-by-lane detection zones in front of stop bar
- Requires detection rack card for every two zones ($$$$$$)
- Wavetronix is expected to release a new high-capacity detector BIU in June, 2014.



Detection Technologies

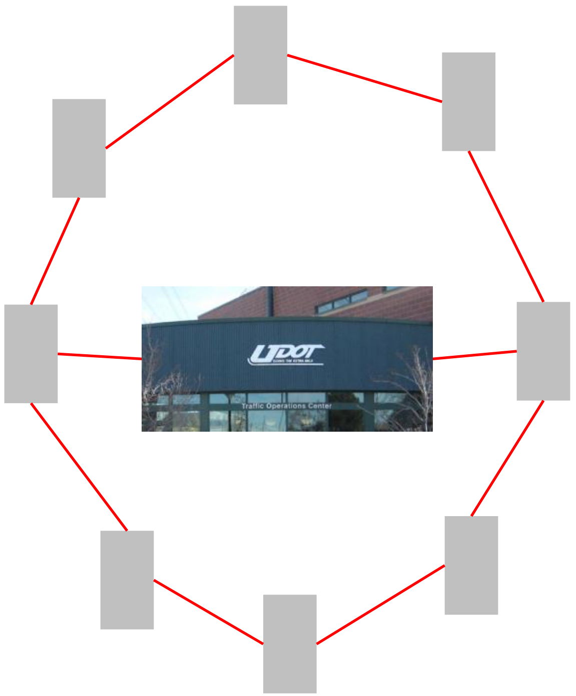
Standard stop bar detection

- The intersection can still be monitored with the Phase Termination and Split Phase charts.



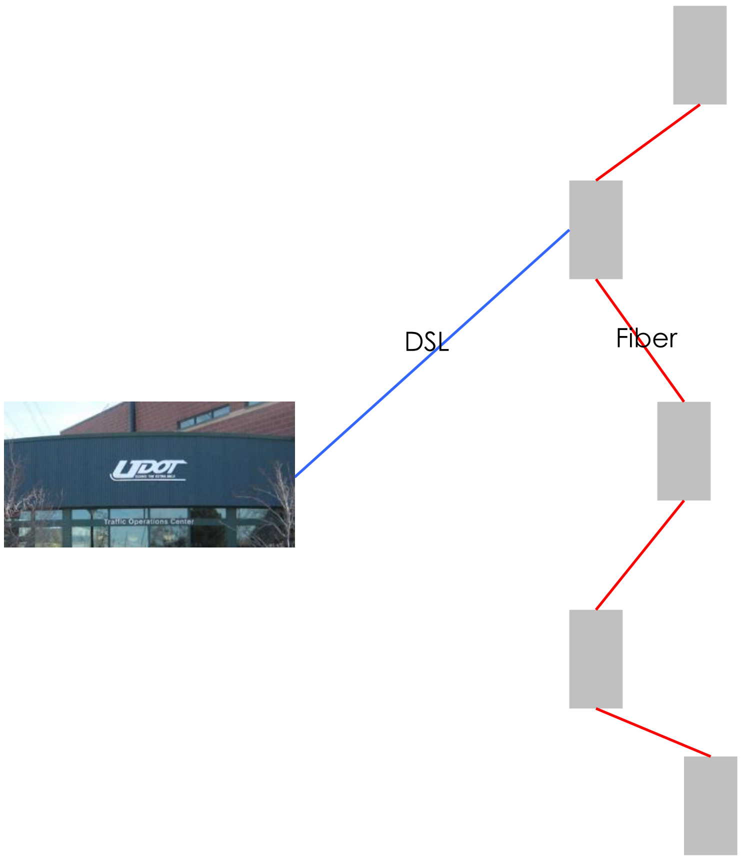
Communication

- UDOT has the advantage of fiber Ethernet to nearly every signal cabinet in the state.
- This provides fast and reliable communication, making the wide-scale rapid collection of hi-res data feasible.
- Even so, event collection is typically 7-10 minutes behind real time.



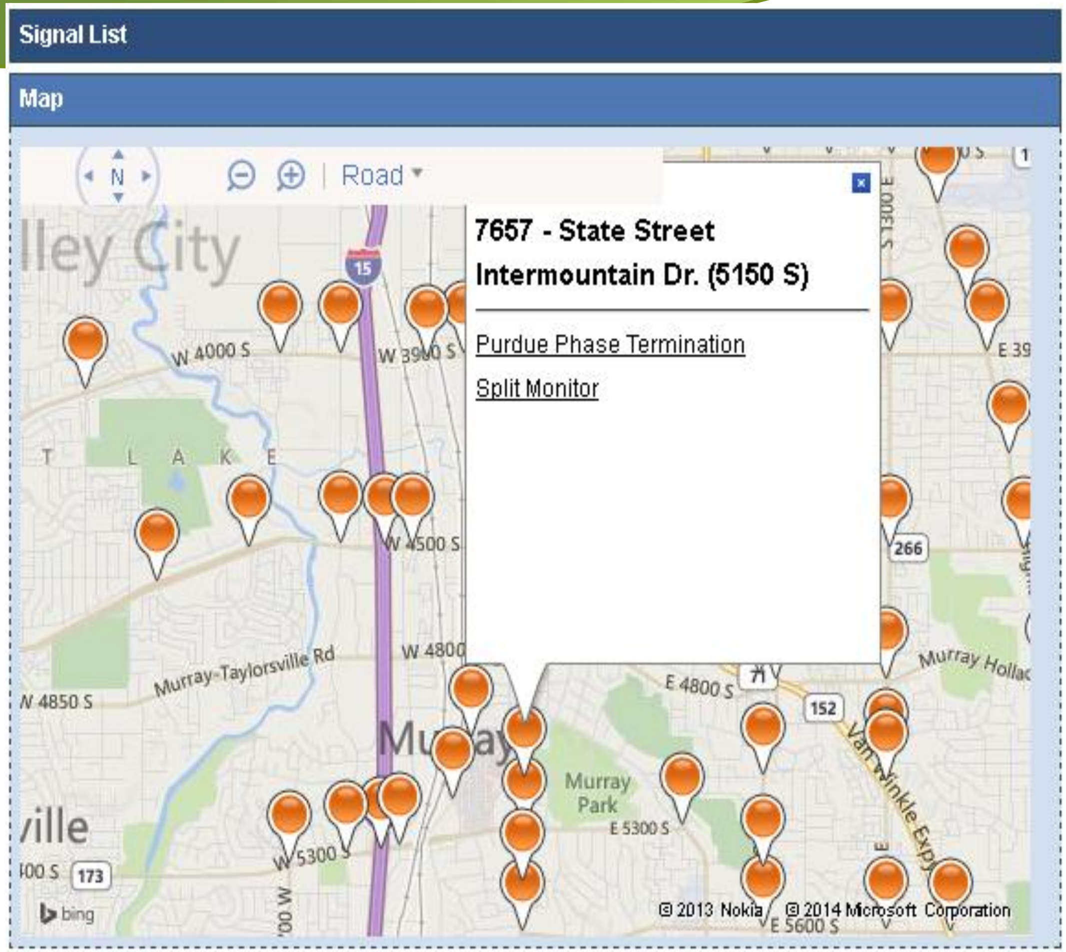
Communication

- In the locations we lack fiber, DSL provides a connection to a fiber channel.
- In the few sites that remain, we are investigating “Sneaker-Net” solutions, such as the Raspberry Pi.



Signal Identifier

- Each intersection must have a unique identifier.
- UDOT uses 4-digit ID numbers that have been assigned by region to every intersection in the state.



Time Synchronization

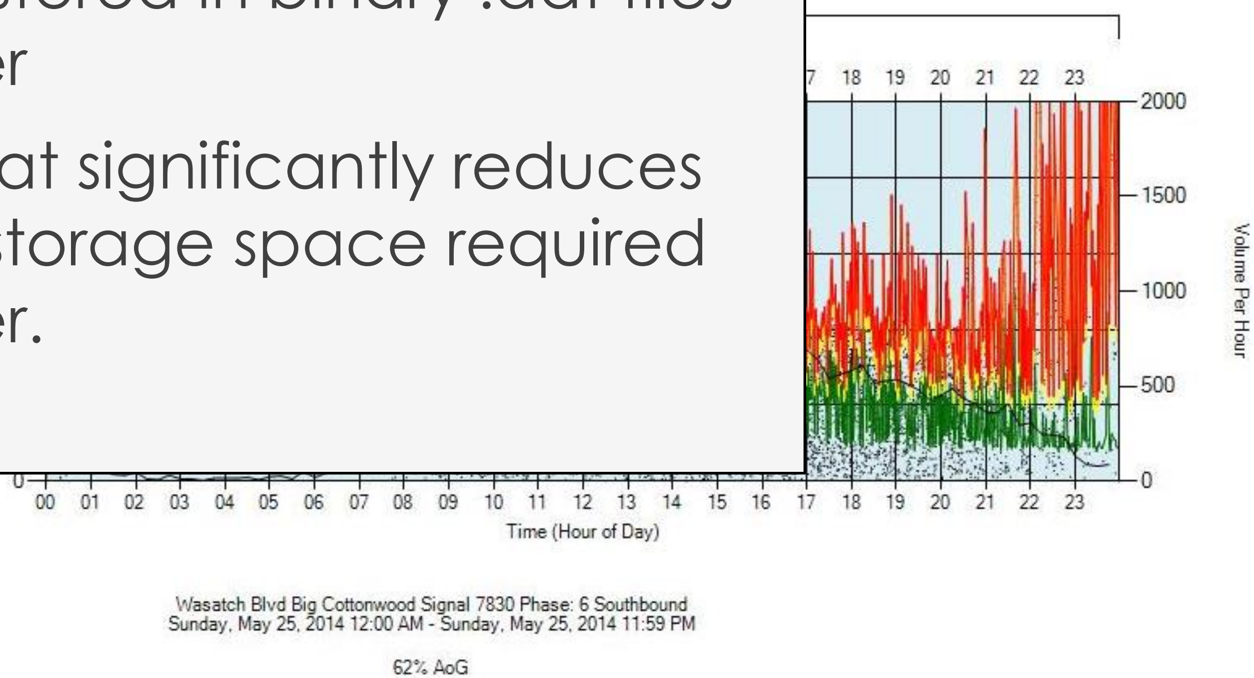
- The controller times must be synched, or the events do not make much sense.
- It is possible to synchronize the time on NTCIP controllers without a central signal system.

Enabling the Hi-Res Logger

- Logging on the ASC3 controllers can be enabled and disabled over SNMP. There is no option for it through the front panel.
- VOIT logging, if enabled, must be disabled first.
- If the controller is reset, logging must be enabled again.

Data retrieval and storage

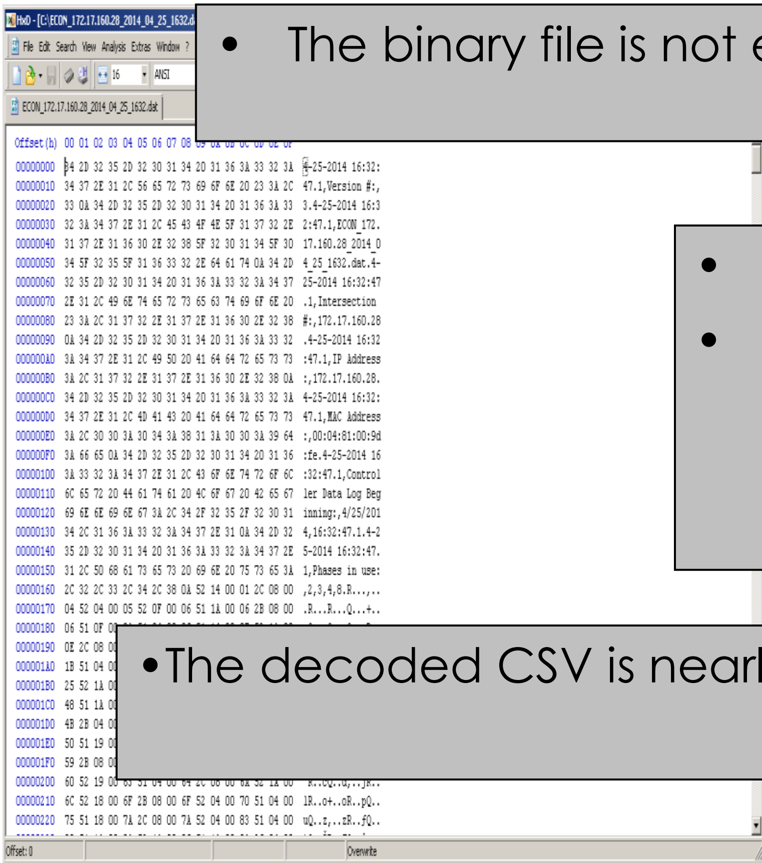
- The ASC3 records each event in 1/10 second resolution.
- The events are stored in binary .dat files on the controller
- The binary format significantly reduces the amount of storage space required on the controller.



The Econolite binary file

Before:

After:



- The binary file is not easily readable.

- It can be translated to csv.
- Econolite has created a log translator program.

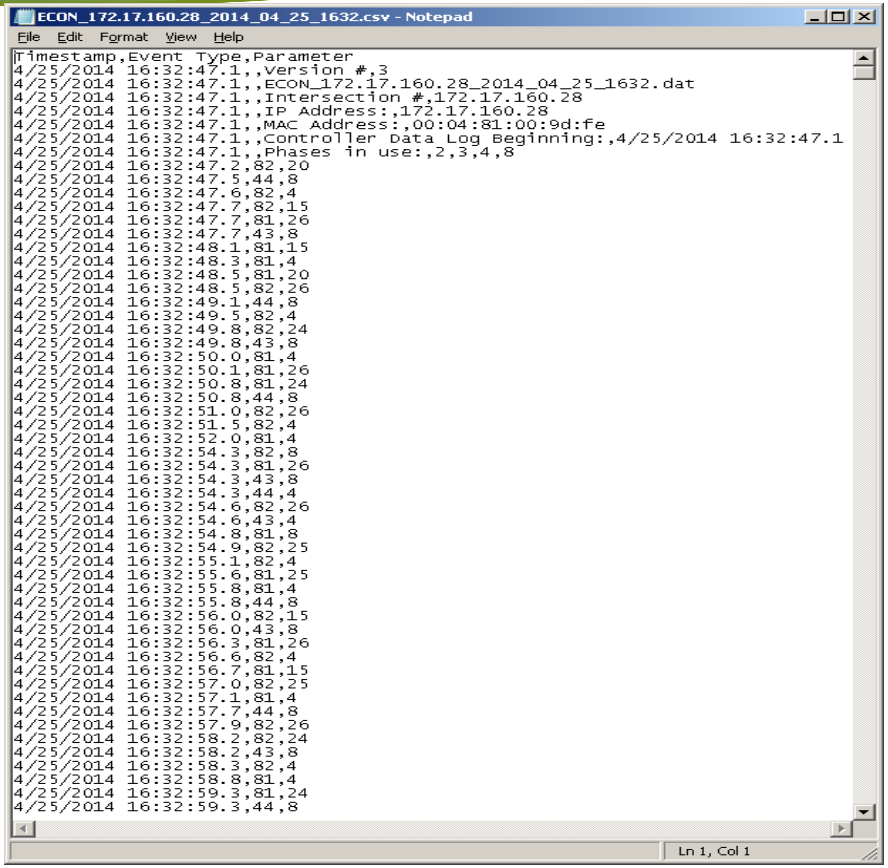
- The decoded CSV is nearly 8 times larger than the encoded binary file.

Retrieving the binary file

- The ASC3 controllers have FTP servers.
- The .dat files are located in the /SET1 directory.
- A program periodically collects the .dat files from the controller using FTP, and stores the files in on the database server.

The .CSV file

- The controller does not know its own ID.
- Therefore, the Signal ID is no where in the .csv file.
- That information must be added to the record before it is added to the database


ECON_172.17.160.28_2014_04_25_1632.csv - Notepad

File Edit Format View Help

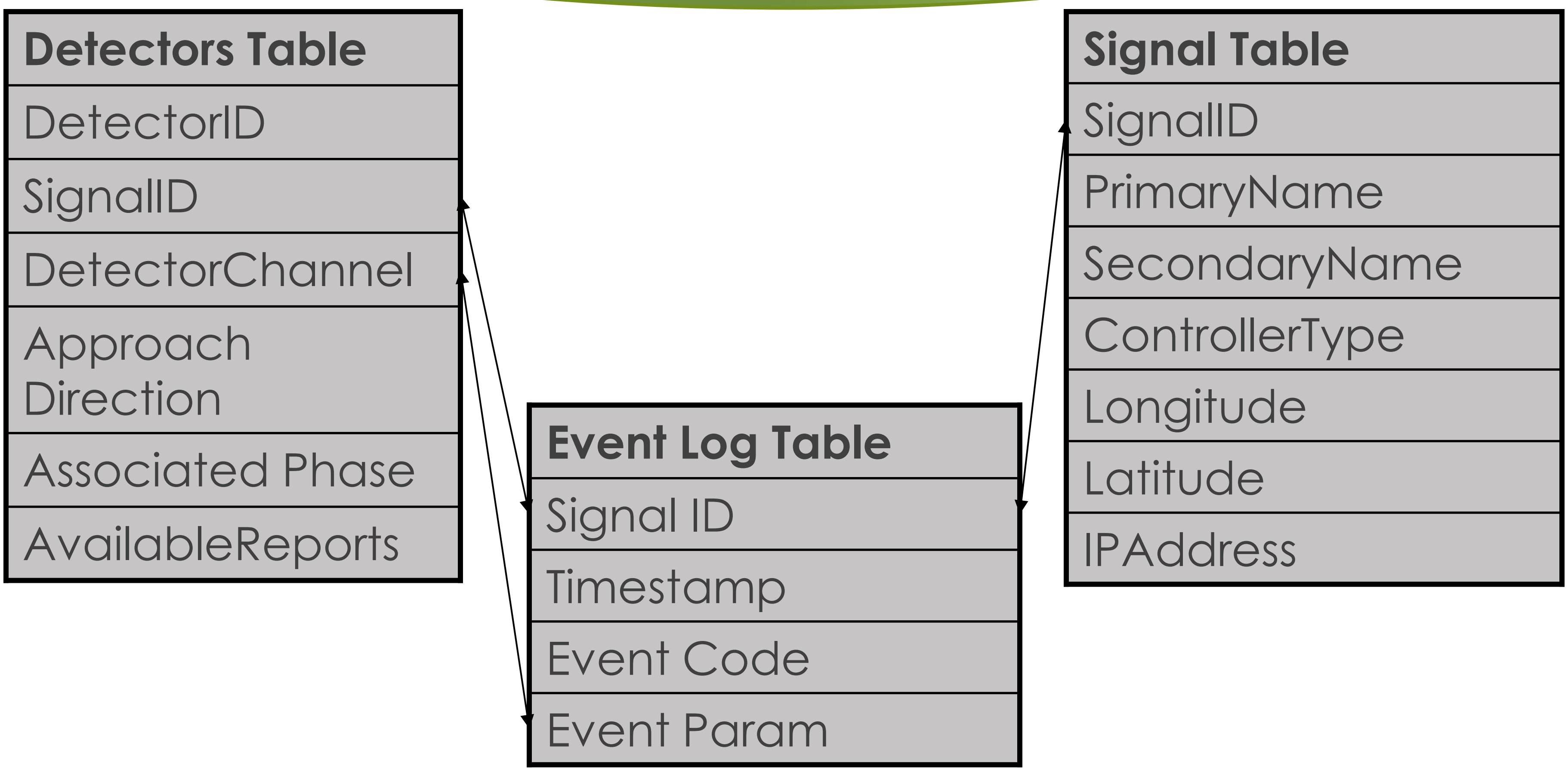
```
Timestamp,Event Type,Parameter
4/25/2014 16:32:47.1,,Version #,3
4/25/2014 16:32:47.1,,ECON_172.17.160.28_2014_04_25_1632.dat
4/25/2014 16:32:47.1,,Intersection #,172.17.160.28
4/25/2014 16:32:47.1,,IP Address:,172.17.160.28
4/25/2014 16:32:47.1,,MAC Address:,00:04:81:00:9d:fe
4/25/2014 16:32:47.1,,Controller Data Log Beginning:,4/25/2014 16:32:47.1
4/25/2014 16:32:47.1,,Phases in use:,2,3,4,8
4/25/2014 16:32:47.2,82,20
4/25/2014 16:32:47.5,44,8
4/25/2014 16:32:47.6,82,4
4/25/2014 16:32:47.7,82,15
4/25/2014 16:32:47.7,81,26
4/25/2014 16:32:47.7,43,8
4/25/2014 16:32:48.1,81,15
4/25/2014 16:32:48.3,81,4
4/25/2014 16:32:48.5,81,20
4/25/2014 16:32:48.5,82,26
4/25/2014 16:32:49.1,44,8
4/25/2014 16:32:49.5,82,4
4/25/2014 16:32:49.8,82,24
4/25/2014 16:32:49.8,43,8
4/25/2014 16:32:50.0,81,4
4/25/2014 16:32:50.1,81,26
4/25/2014 16:32:50.8,81,24
4/25/2014 16:32:50.8,44,8
4/25/2014 16:32:51.0,82,26
4/25/2014 16:32:51.5,82,4
4/25/2014 16:32:52.0,81,4
4/25/2014 16:32:54.3,82,8
4/25/2014 16:32:54.3,81,26
4/25/2014 16:32:54.3,43,8
4/25/2014 16:32:54.3,44,4
4/25/2014 16:32:54.6,82,26
4/25/2014 16:32:54.6,43,4
4/25/2014 16:32:54.8,81,8
4/25/2014 16:32:54.9,82,25
4/25/2014 16:32:55.1,82,4
4/25/2014 16:32:55.6,81,25
4/25/2014 16:32:55.8,81,4
4/25/2014 16:32:55.8,44,8
4/25/2014 16:32:56.0,82,15
4/25/2014 16:32:56.0,43,8
4/25/2014 16:32:56.3,81,26
4/25/2014 16:32:56.6,82,4
4/25/2014 16:32:56.7,81,15
4/25/2014 16:32:57.0,82,25
4/25/2014 16:32:57.1,81,4
4/25/2014 16:32:57.7,44,8
4/25/2014 16:32:57.9,82,26
4/25/2014 16:32:58.2,82,24
4/25/2014 16:32:58.2,43,8
4/25/2014 16:32:58.3,82,4
4/25/2014 16:32:58.8,81,4
4/25/2014 16:32:59.3,81,24
4/25/2014 16:32:59.3,44,8
```

Ln 1, Col 1

The Event Database

- Each record in the CSV must have the signal ID added to it.
- The record can then be added to the database.
- On average, each intersection will need 11MB per day.
- UDOT requires 11 GB per day to hold the collected controller events.

Database Schema



Why the Schema Matters

- The Event log contains four pieces of information:

SignalID, Timestamp, Event Code and Event Parameter

- The entry for a detector activation would look like:

1001,01/01/2014 12:37 33:20, 82, 12

- The last two values are the Event code (82) and the Event Parameter (12)

- Event Code 82 indicates a detector activation on detector channel 12 (the Event Parameter)

Event Log Table
Signal ID
Timestamp
Event Code
Event Param

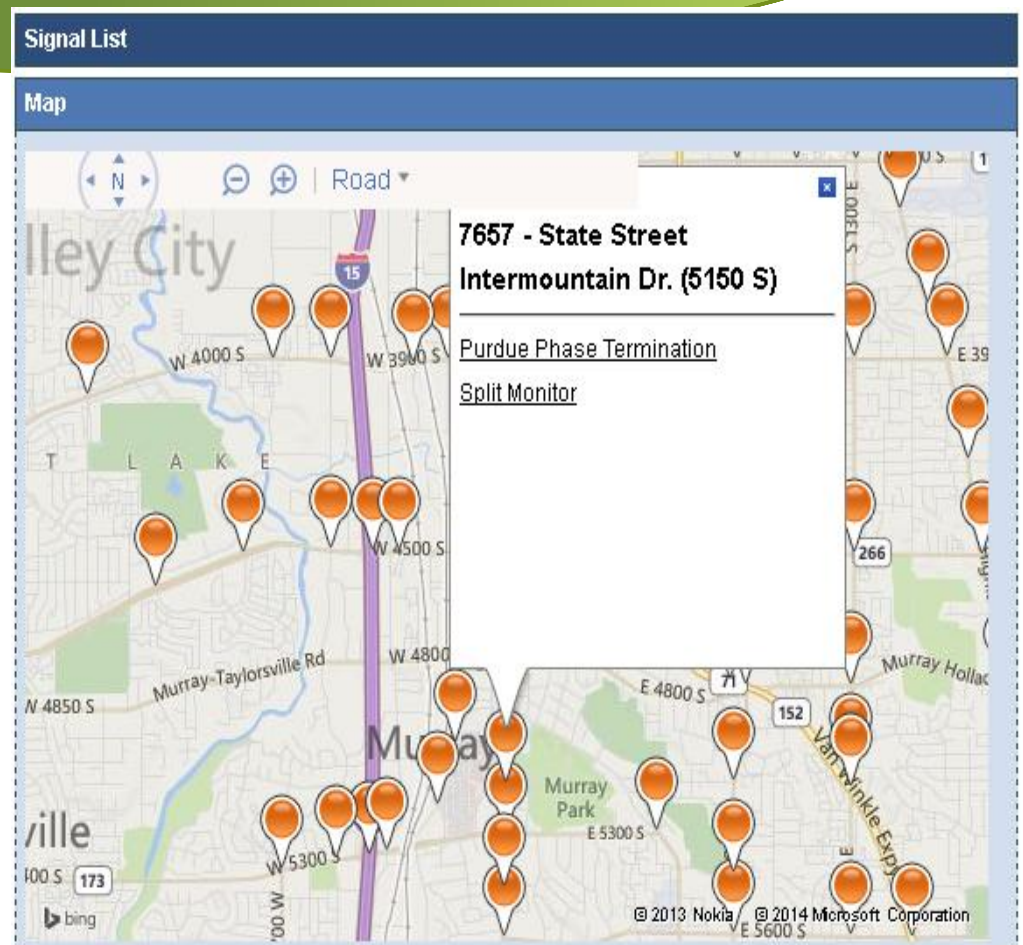
Why the Schema Matters

- We need a way to relate signal ID and detector channel to approach direction and phase number.
- The controller does not have this information.
- That is why we need a list of Detectors

Detectors Table
DetectorID
SignalID
DetectorChannel
Approach Direction
Associated Phase
AvailableReports

Why the Schema Matters

Signal Table
SignalID
PrimaryName
SecondaryName
ControllerType
Longitude
Latitude
IPAddress



What you will need

- A Database server
- Microsoft SQL server 2008 or later
- Microsoft Windows server 2008 R2 or later
- Disk space requirements will vary, but you will want a lot (We started with 8 TB, and we are running out)
- The more processors you can get, the happier you will be.

What you will need

- A Web Server
- Windows Server 2008 R2 or later
- Internet Information Server 7.0 or later
- Faster processors and more RAM will provide a more responsive experience.
- Hard drive requirements for the web server are minimal

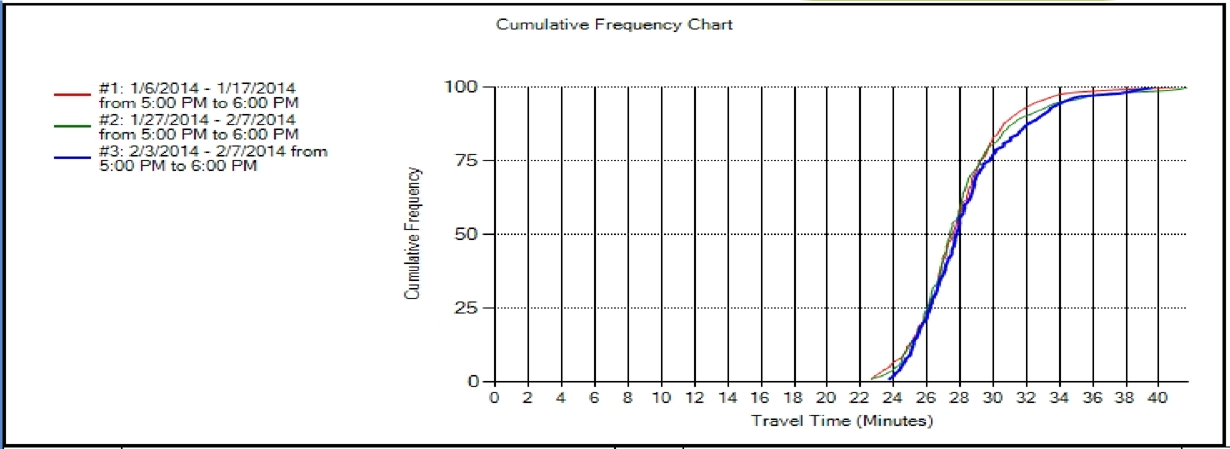
Hardware Mitigation

- Reduce storage requirements by deleting old data. (Do you really need to know when a car crossed a detector 3 years ago?)
- Archive old records to tape or other media, and restore it when needed. (It might be best to do this in a .CSV format instead of a database backup)

Hardware Mitigation

- The UDOT SPM system can be hosted on multiple smaller computers, instead of one large and expensive one.
- The hard drive requirements will still be large, however.

Probe Data



TMC Code	TMC Name	Range ID	Time Range	TMC Length	Avg. Travel Time	Std. Dev.	% Good Bins	Avg. Confidence Score
116+05735	Bangerter From: 12600 S To: 9000 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	4.6	6.04	0.51	94%	30
116+05735	Bangerter From: 12600 S To: 9000 S	2	1/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	4.6	5.95	0.43	92%	30
116+05735	Bangerter From: 12600 S To: 9000 S	3	2/3/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	4.6	6.18	0.47	93%	30
116+05736	Bangerter From: 9000 S To: 7800 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	1.46	1.75	0.20	84%	30
116+05736	Bangerter From: 9000 S To: 7800 S	2	1/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1.46	1.77	0.26	65%	30
116+05736	Bangerter From: 9000 S To: 7800 S	3	2/3/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1.46	1.78	0.22	69%	30
116+05737	Bangerter From: 7800 S To: 7000 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	1	1.27	0.16	91%	30
116+05737	Bangerter From: 7800 S To: 7000 S	2	1/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1	1.30	0.30	77%	30
116+05737	Bangerter From: 7800 S To: 7000 S	3	2/3/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1	1.35	0.36	83%	30
116+05738	Bangerter From: 7000 S To: 6200 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	0.92	1.23	0.20	88%	30
116+05738	Bangerter From: 7000 S To: 6200 S	2	1/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	0.92	1.37	0.43	79%	30
116+05738	Bangerter From: 7000 S To: 6200 S	3	2/3/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	0.92	1.49	0.55	89%	30
116+05739	Bangerter From: 6200 S To: 5400 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	1.04	1.39	0.13	89%	30
116+05739	Bangerter From: 6200 S To: 5400 S	2	1/27/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1.04	1.43	0.17	81%	30
116+05739	Bangerter From: 6200 S To: 5400 S	3	2/3/2014 - 2/7/2014 From: 5:00 PM To: 6:00 PM	1.04	1.45	0.19	92%	30
116+05740	Bangerter From: 5400 S To: 4700 S	1	1/6/2014 - 1/17/2014 From: 5:00 PM To: 6:00 PM	1.01	1.30	0.15	92%	30

Executive-Level Reports

Executive Summary

5/25/2014 to 5/25/2014

Statewide Summary

Arrival on Red		Delay		Volume	Intersections	
Percent	Platoon Ratio	Daily Average Per Approach (hrs)	Average Per Veh (sec)	Daily Average Per Approach	Total	Number Of Approaches
29 %	2.72	0.01	6.18	4,761	375	773

Region Summary

Region	Arrival on Red		Delay		Volume	Intersections	
Name	Percent	Platoon Ratio	Daily Average Per Approach (hrs)	Average Per Veh (sec)	Daily Average Per Approach	Total	Number Of Approaches
1	20 %	14.47	0.00	1.68	731	94	182
2	29 %	1.50	0.03	6.45	6,606	168	364
3	26 %	18.87	0.01	5.96	992	104	208
4	17 %	1.23	0.10	1.56	4,190	9	19

Trivia and Statistics

- The UDOT SPM system is written in C#, Javascript and ASP.NET
- At last count, more than 90,000 lines of code went into the system (that includes the auto-generated files that must be maintained)
- As of June 1st, 2014, there were more than 53 billion records in the UDOT SPM Database

Trivia and Statistics

- Our database server, purchased in 2011, cost about $15,000. 80% of that cost was for hard drives.
- We are adding another 12 TB of drive capacity, which we hope will provide another 3.5 years of record storage.
- We estimate we have saved the state 1.5 million dollars so far, based on our ability to find broken detectors, optimize offsets and collect count information.

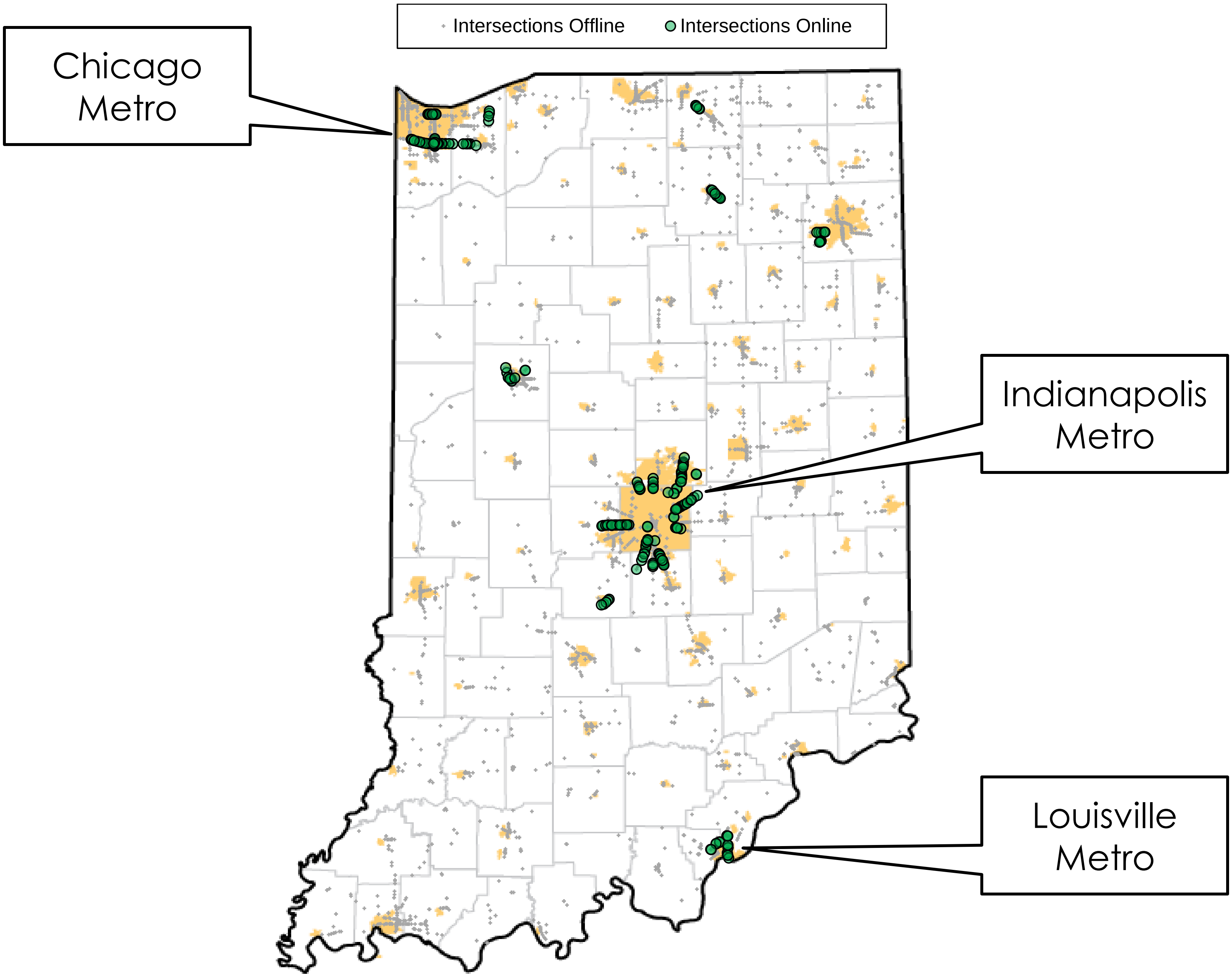
CRITICAL INFRASTRUCTURE ELEMENTS: INDOT Implementation

INSTITUTE OF TRANSPORTATION ENGINEERS WEBINAR PART 3 – JUNE 11, 2014

PRESENTED BY HOWELL LI

INDOT Signal Systems Network

- 2505 signals
- 196 signals with high-resolution data enabled
  - Mixed cellular, wireless, and fiber infrastructure
- Vendor-neutral system
- Open source software for back office
- Joint INDOT-Purdue software development

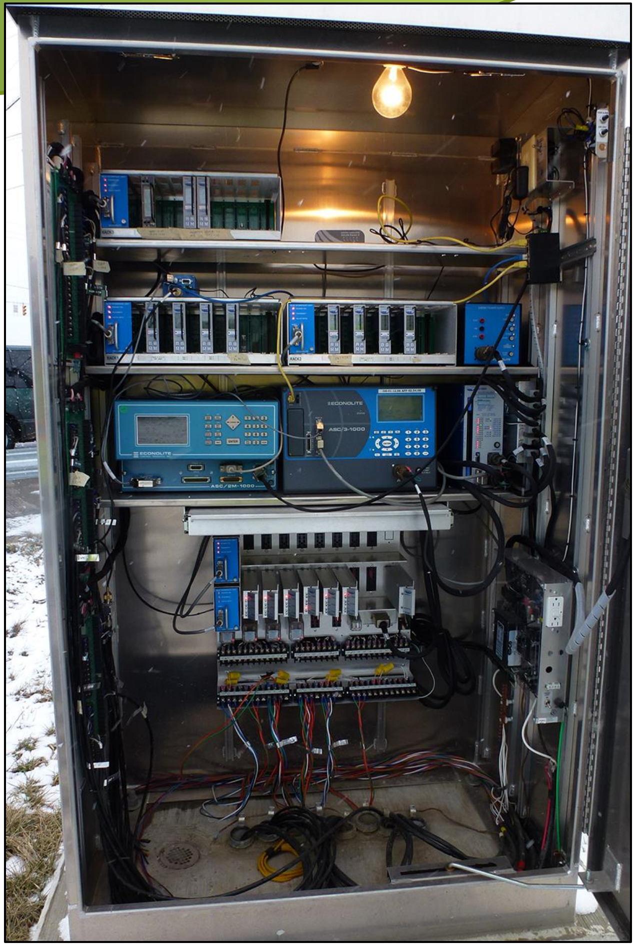


Intersections Offline
Intersections Online
Chicago Metro
Indianapolis Metro
Louisville Metro

Cabinets and Controllers

- All performance measure-enabled cabinets are NEMA standard

Make	Num. Connected
Econolite	188
Peek	7
Siemens	1
Total	**196**



Detection

Cut or pave-over loops

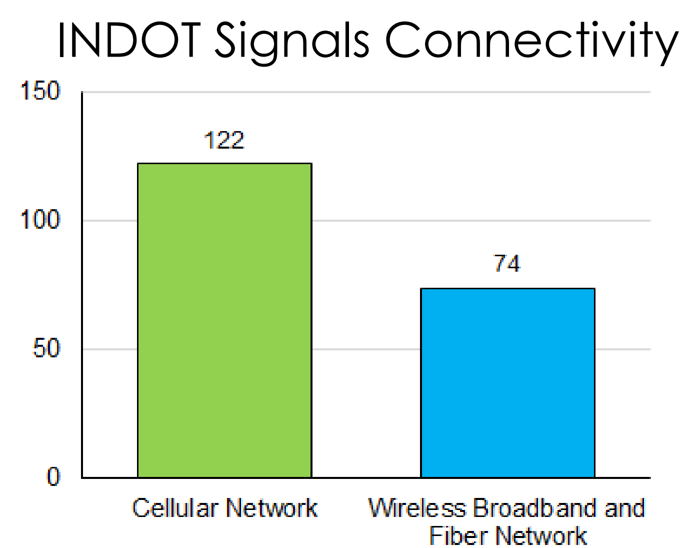
SDLC interface

Connection Methods

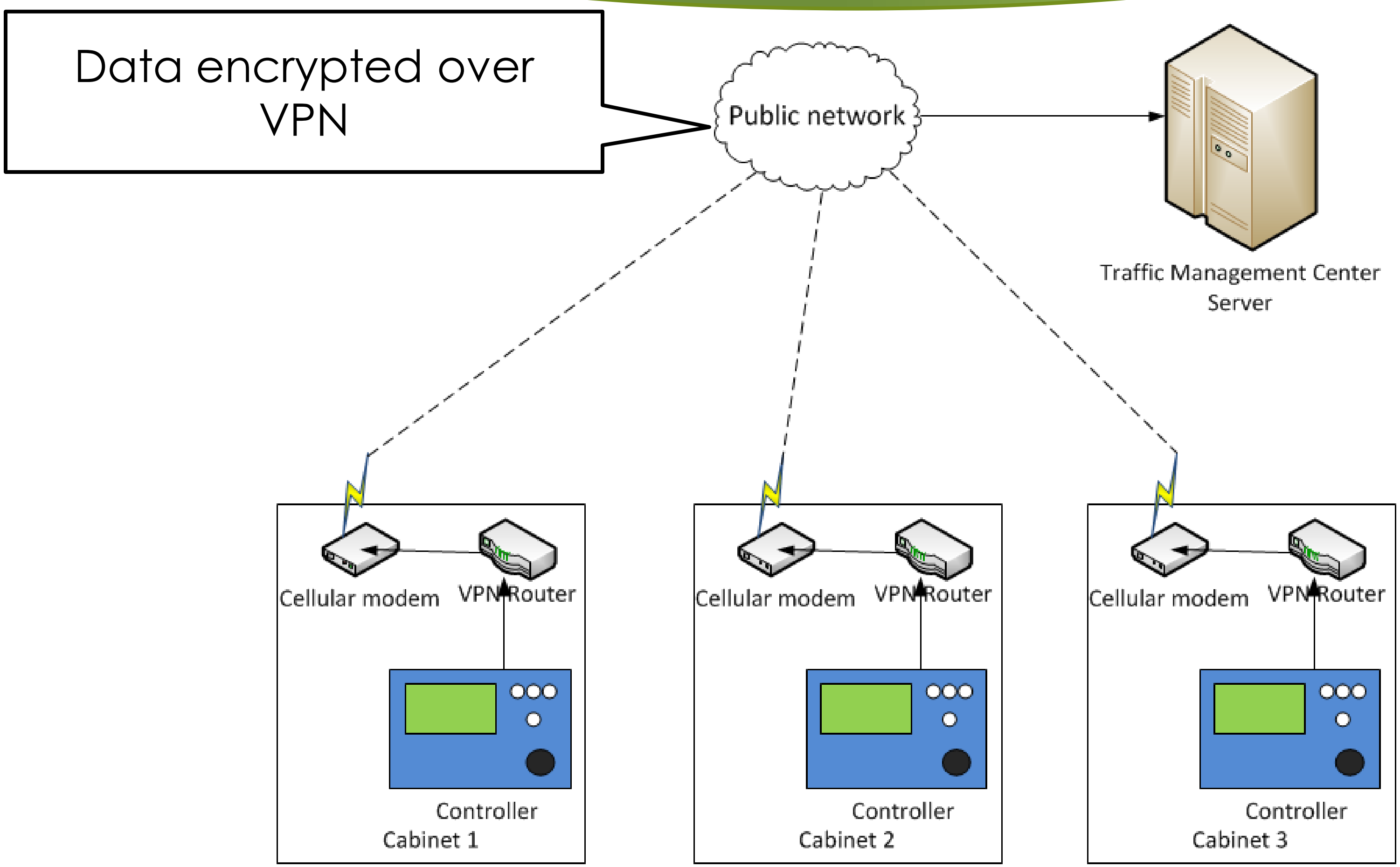
- **Hauling data back to the TMC**
  - Commercial cellular networks (public network)
    - Each subscription costs $34.99/mo
    - Recommend separate Virtual Private Network (VPN)
  - Wireless broadband and fiber backbone (private network)

- **Hauling data between cabinets**
  - Localized longitudinal fiber
  - Broadband or 900 mhz Ethernet radios

- **Customize on location needs and costs**



Commercial Cellular Networks

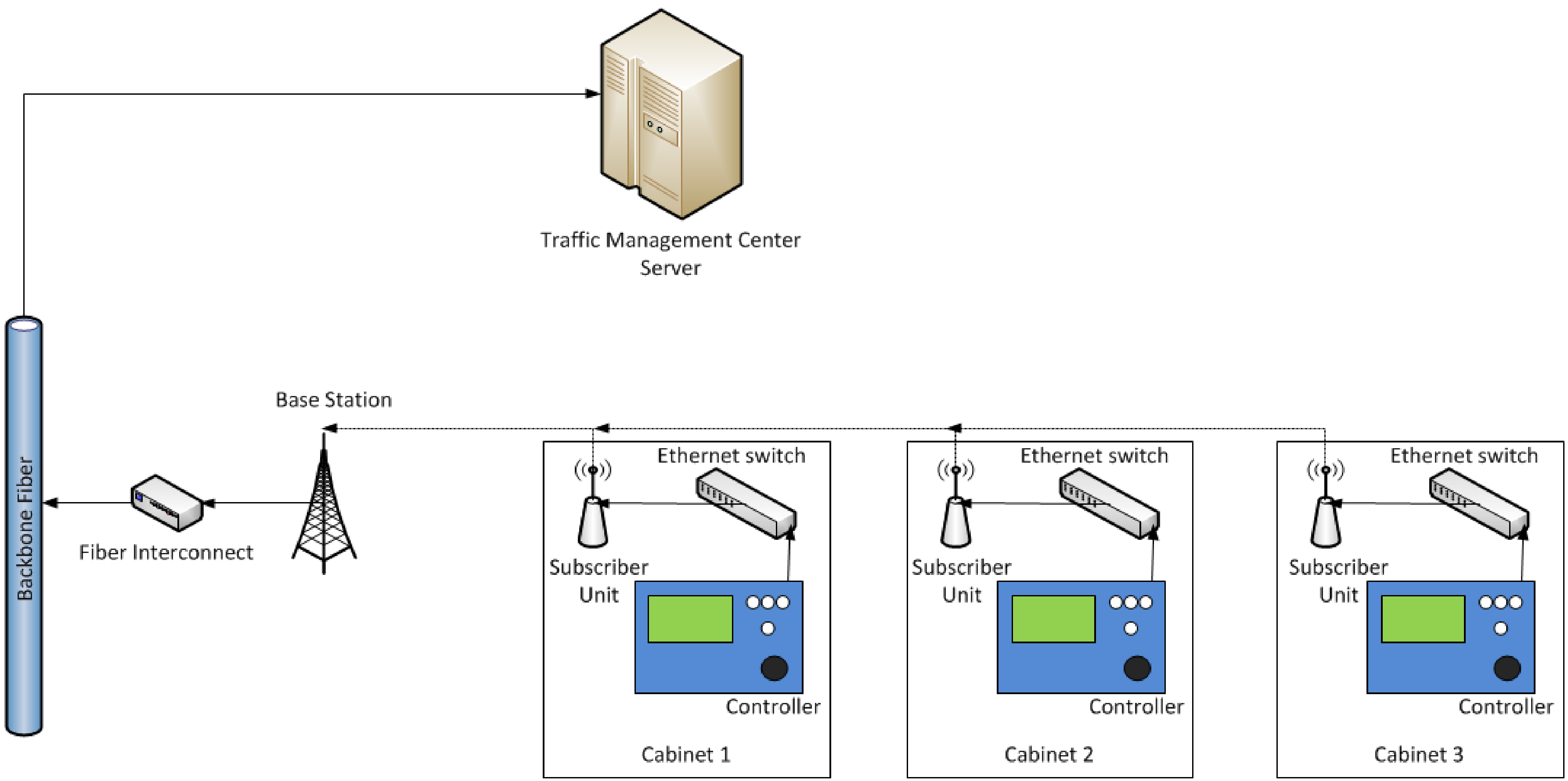


Commercial Cellular Networks

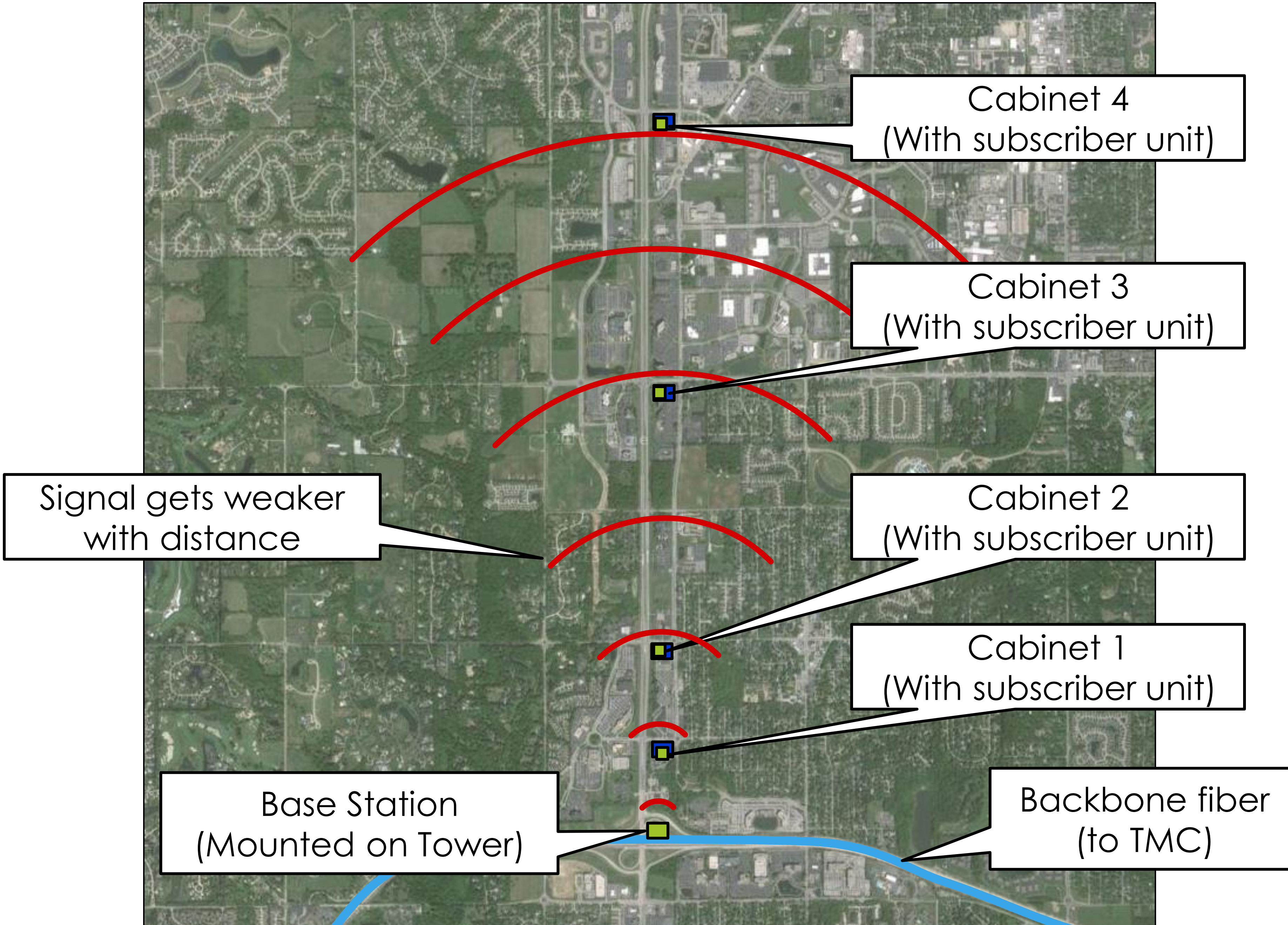
RavenX Cell modem

VPN router (now integrated with RavenX)

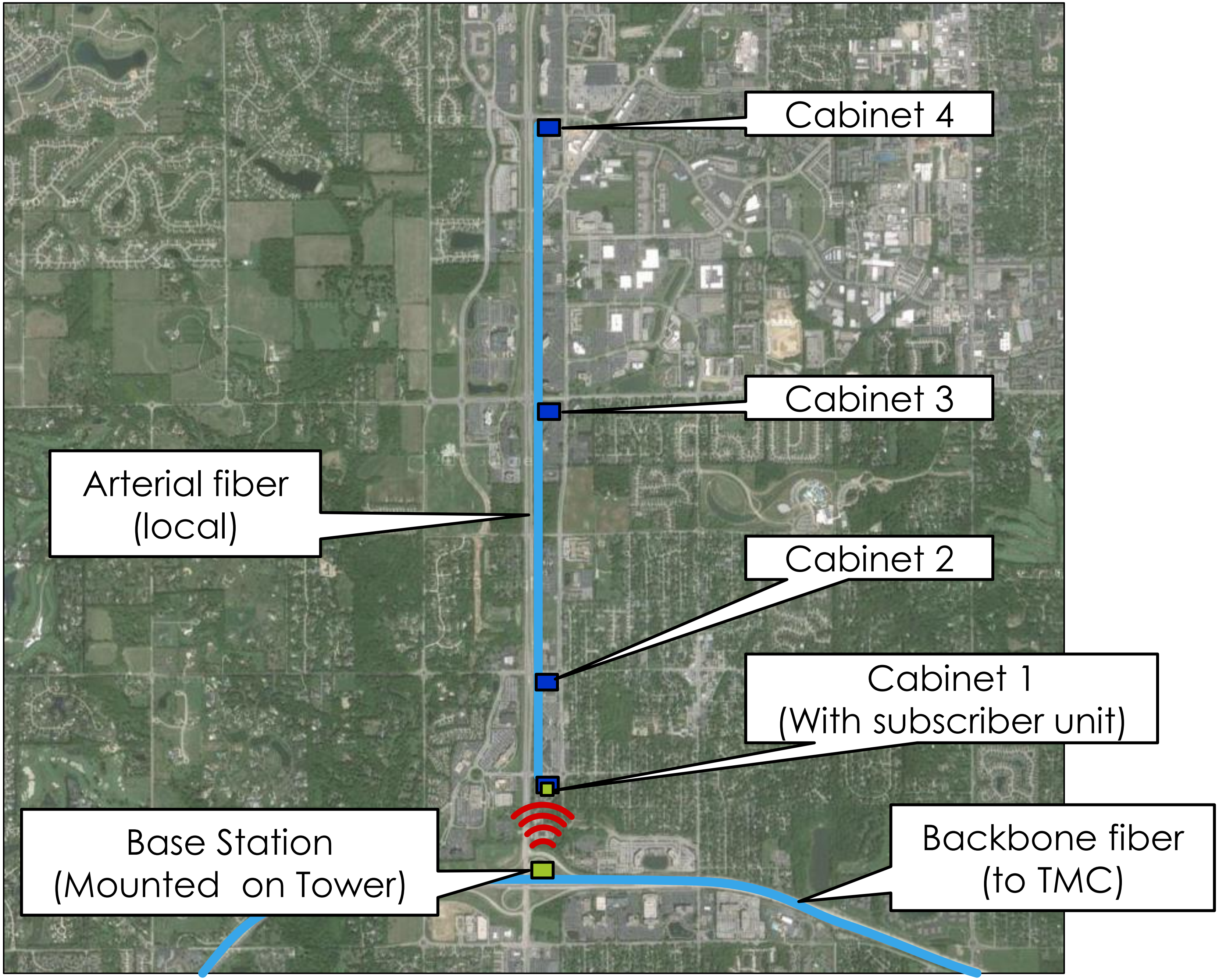
Wireless Broadband and Fiber (no arterial fiber)



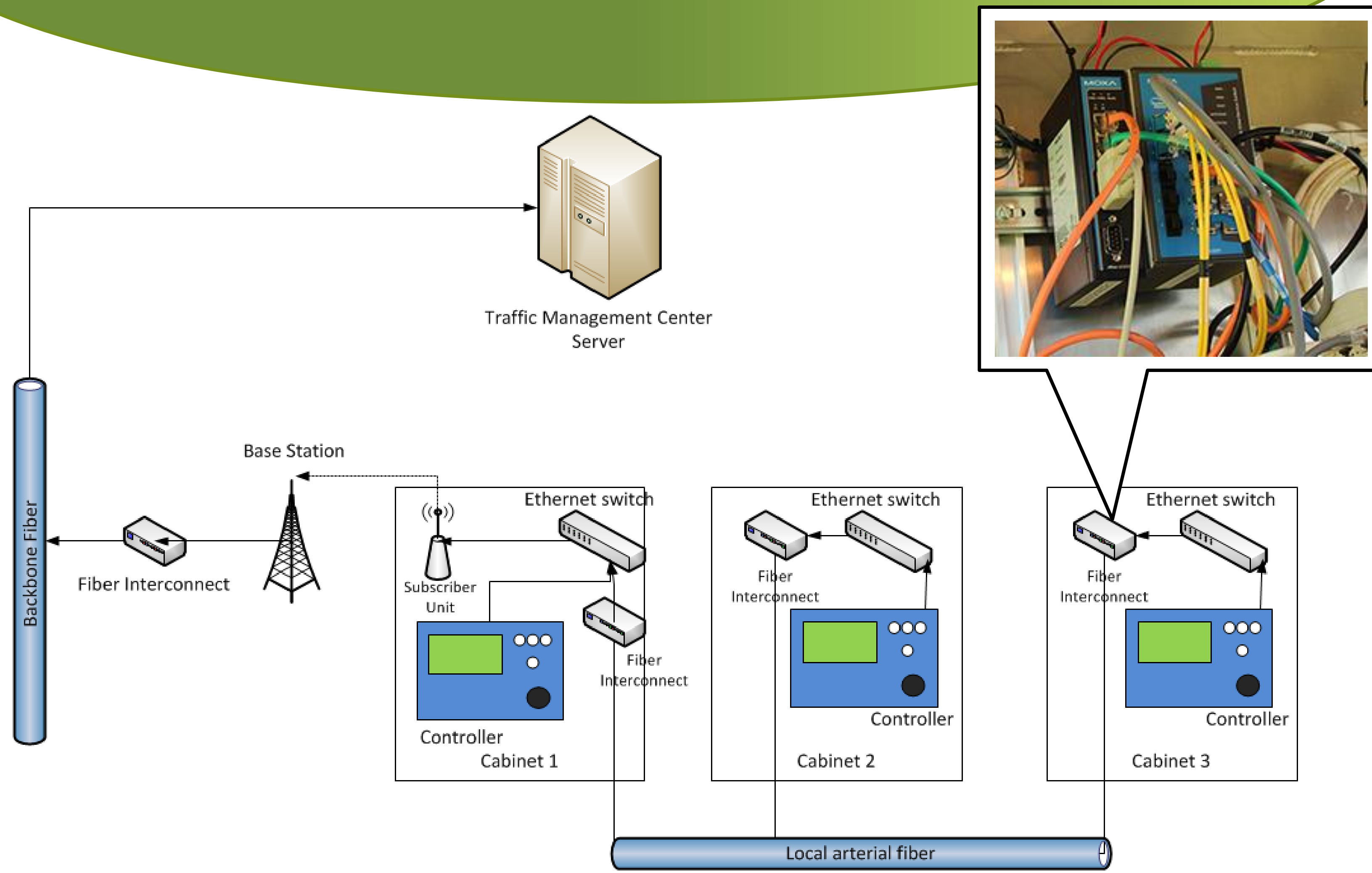
Wireless Broadband and Fiber Backbone



Wireless Broadband and Fiber Backbone

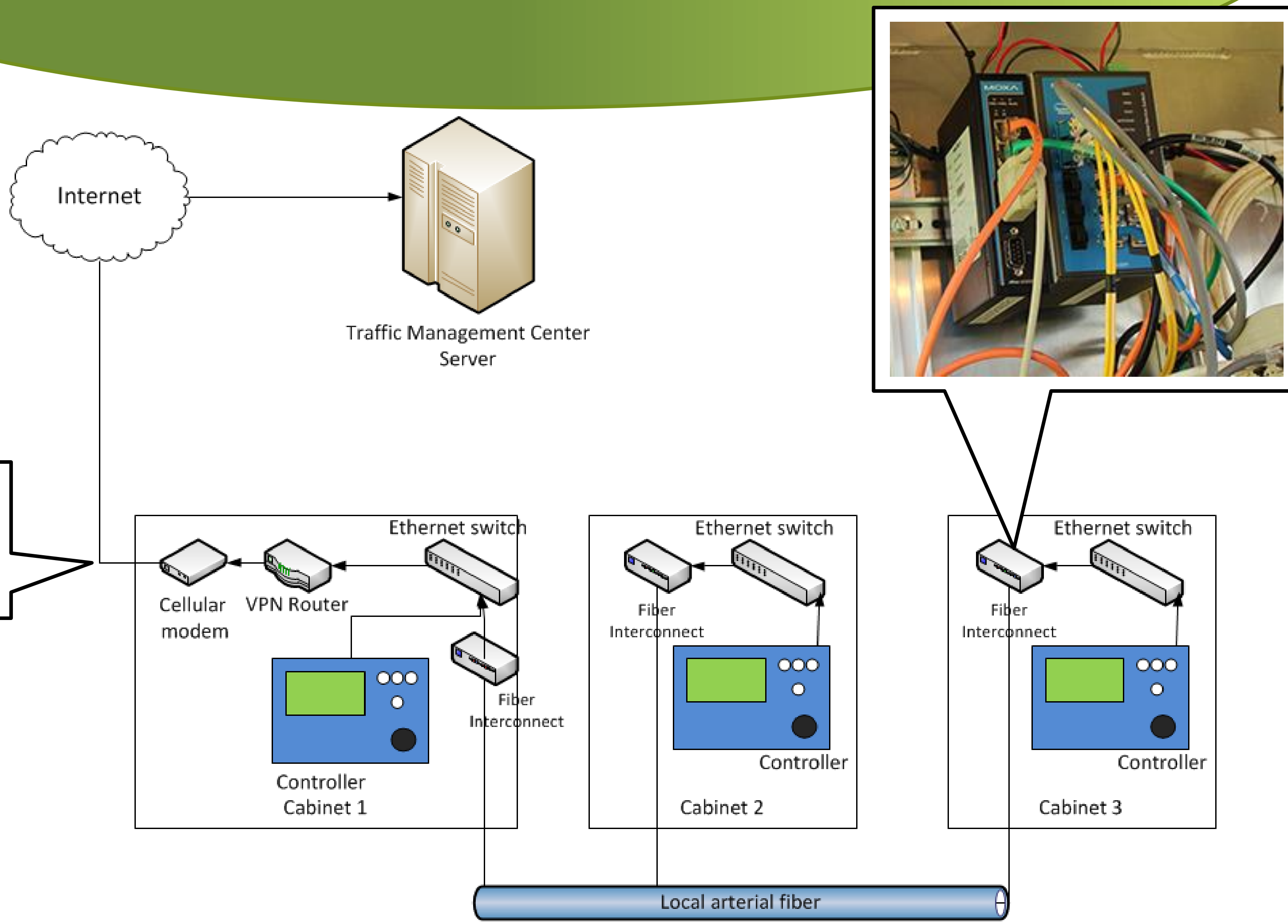


Wireless Broadband and Backbone Fiber

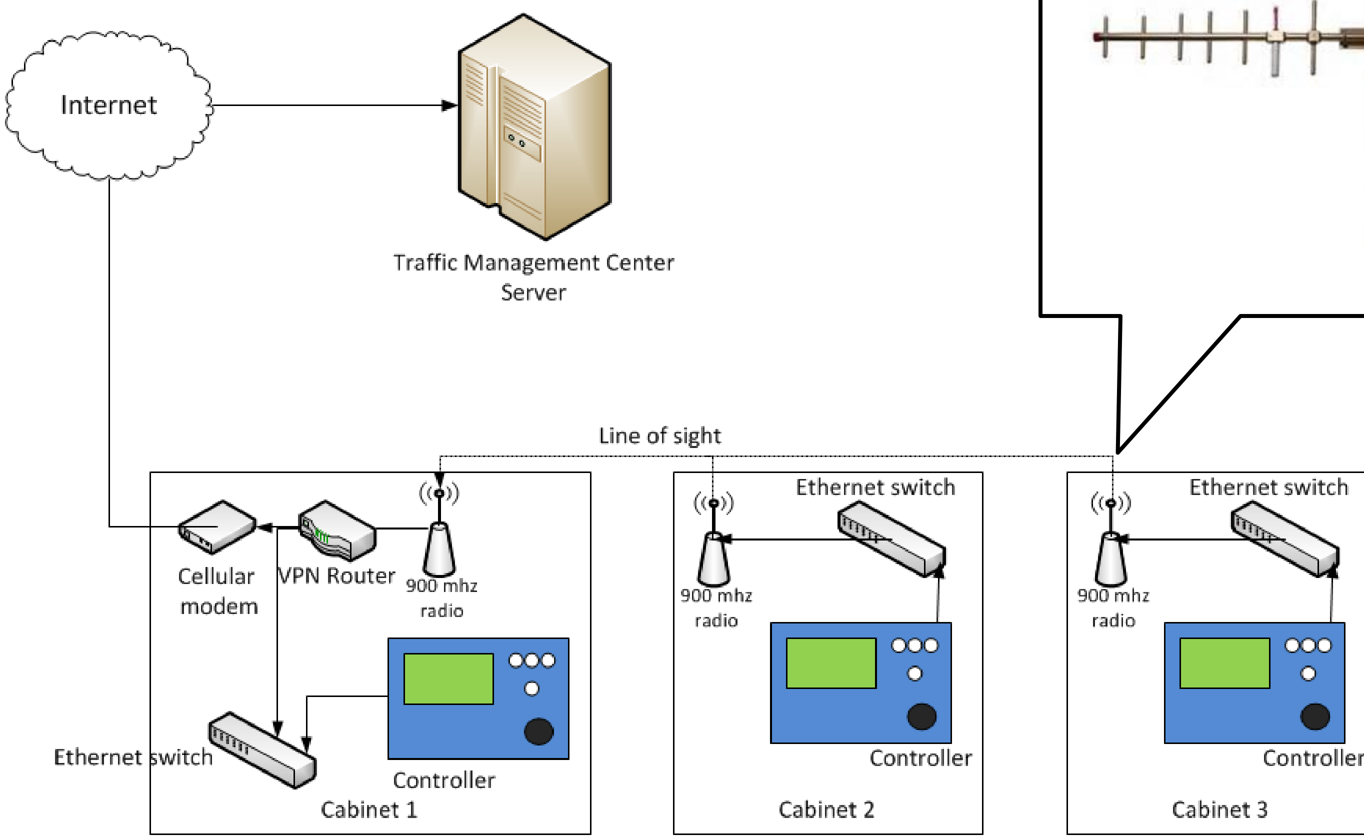


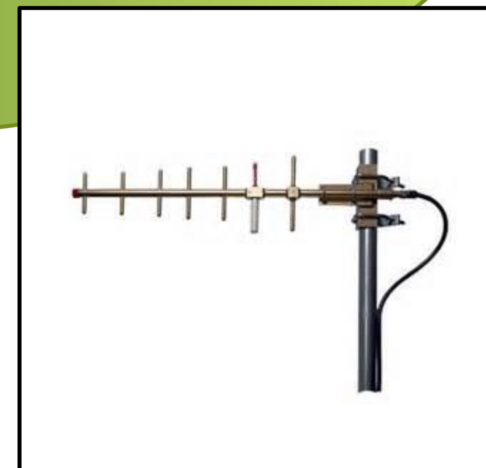
Longitudinal Fiber with Cellular Backhaul

Replaced with cellular backhaul



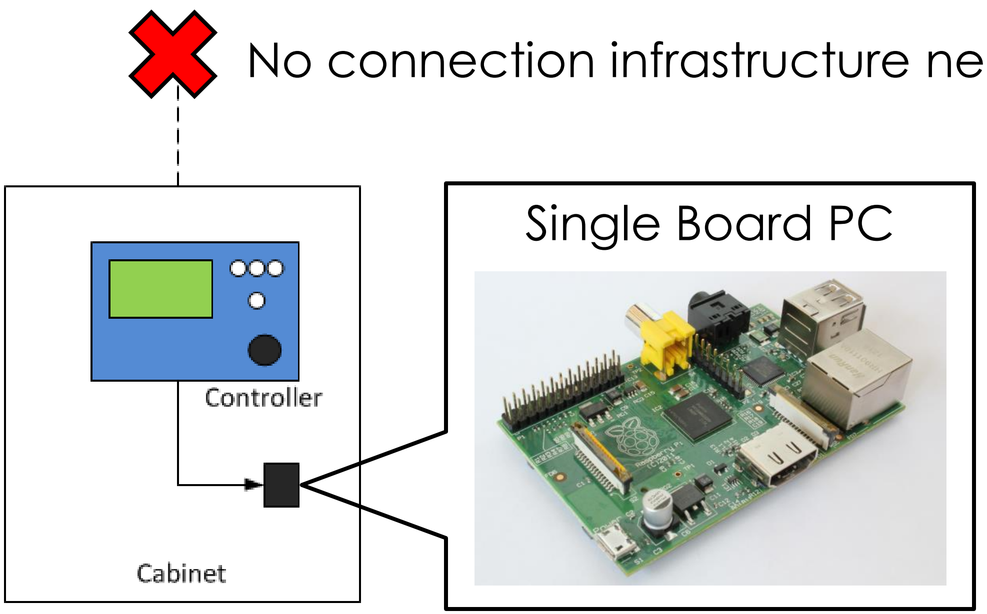
900 mhz Ethernet radio with Cellular Backhaul





“Sneaker Net”

No connection infrastructure needed



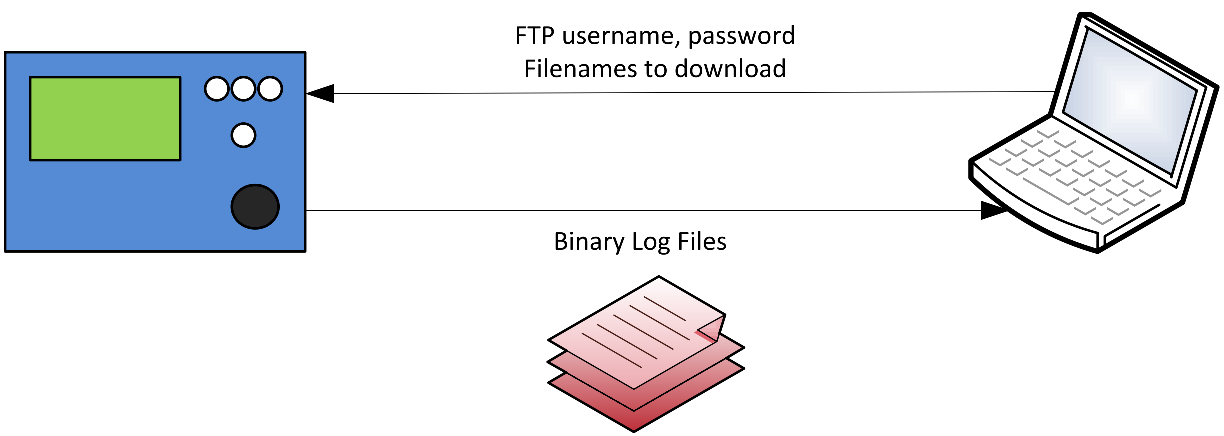
- Cost-effective solution to get data needed by performance measures
- Saves data on SD memory card (up to the size of the card)
- Requires occasional field visits for retrieval

FTP File Retrieval

- FTP – File Transfer Protocol
  - Connect using FTP Client software (e.g. FileZilla)
  - Use FTP Client API to download files
    - API – Application Programming Interface
    - Automation
    - To include as part of a larger data processing system

Field testing

Production systems



Servers for a Production System

- **Processing Server**
  - Retrieves data files from controllers via FTP
  - Data decoding and massaging
  - Saves processed data to Database Server
- **Database Server**
  - Stores and distributes high-resolution data
- **Web Server**
  - Client-side interface
  - Generates performance measures

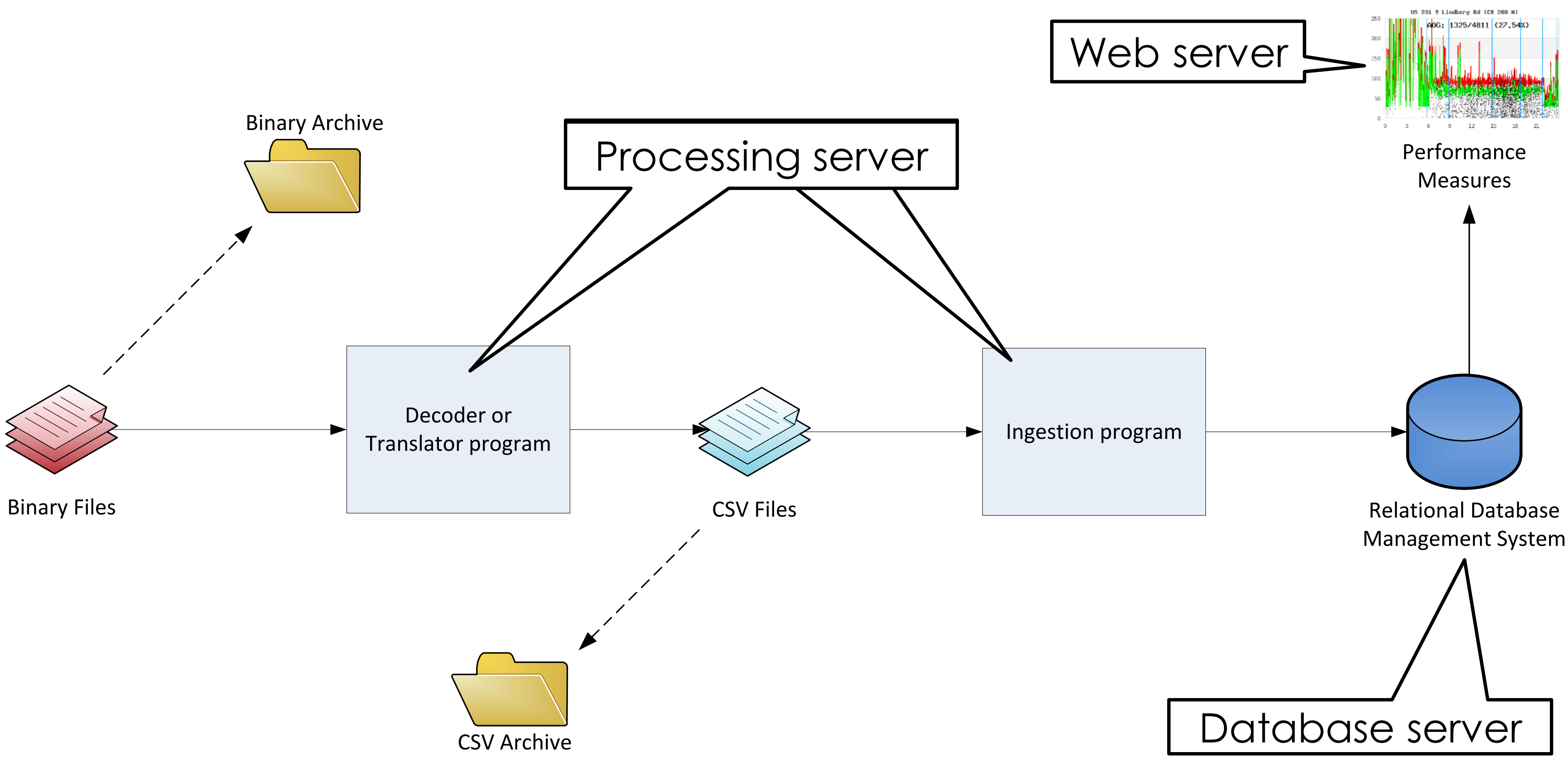
- Hardware Specification
  - Dell PowerEdge R710
  - 2x Quad-Core Intel Xeon Processors
  - 96 GB of RAM
  - 3TB – 12TB disk storage (10,000 RPM drives, RAID)

Software – All open source

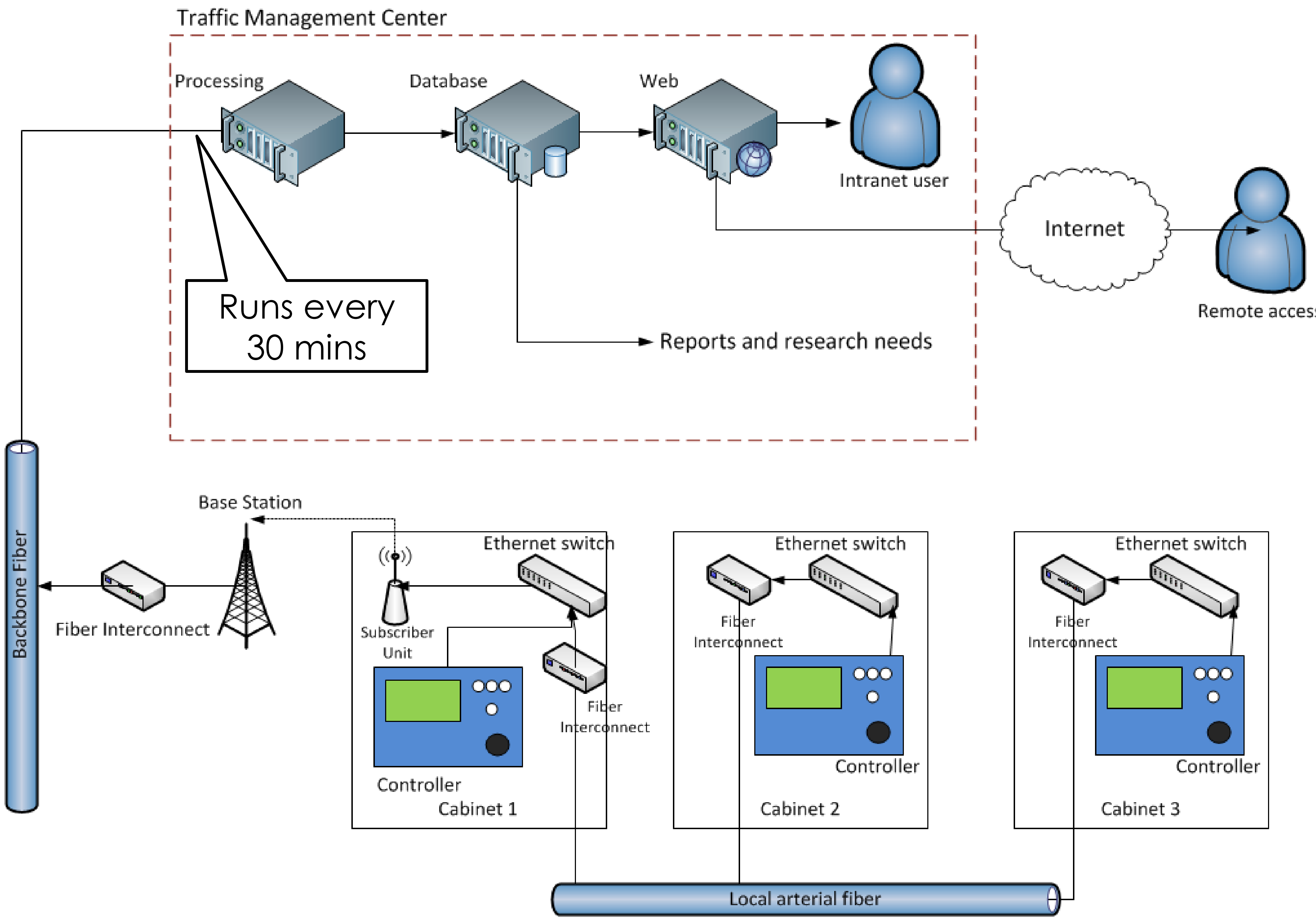
- **Operating System**
  - Ubuntu Linux (version 12.04 LTS)

- **Processing Server**
  - PHP scripting (version 5.3)
  - Vendor-supplied decoding software
- **Database Server**
  - PostgreSQL (version 9.1)
    - Relational Database Management System (RDBMS)
- **Web Server**
  - Apache HTTP Server (version 2.2)
  - PHP Scripting (version 5.3)

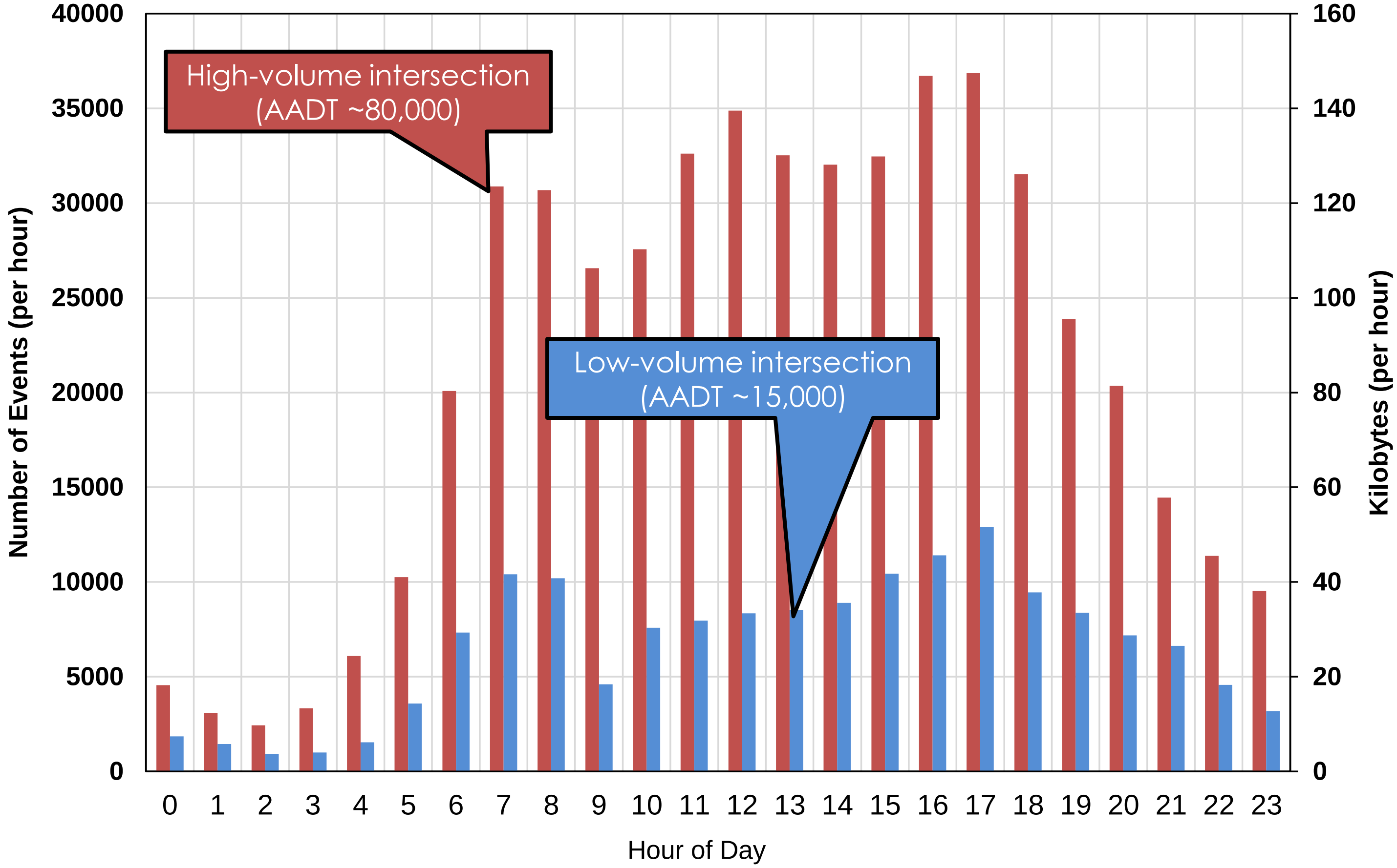
How each server is tasked



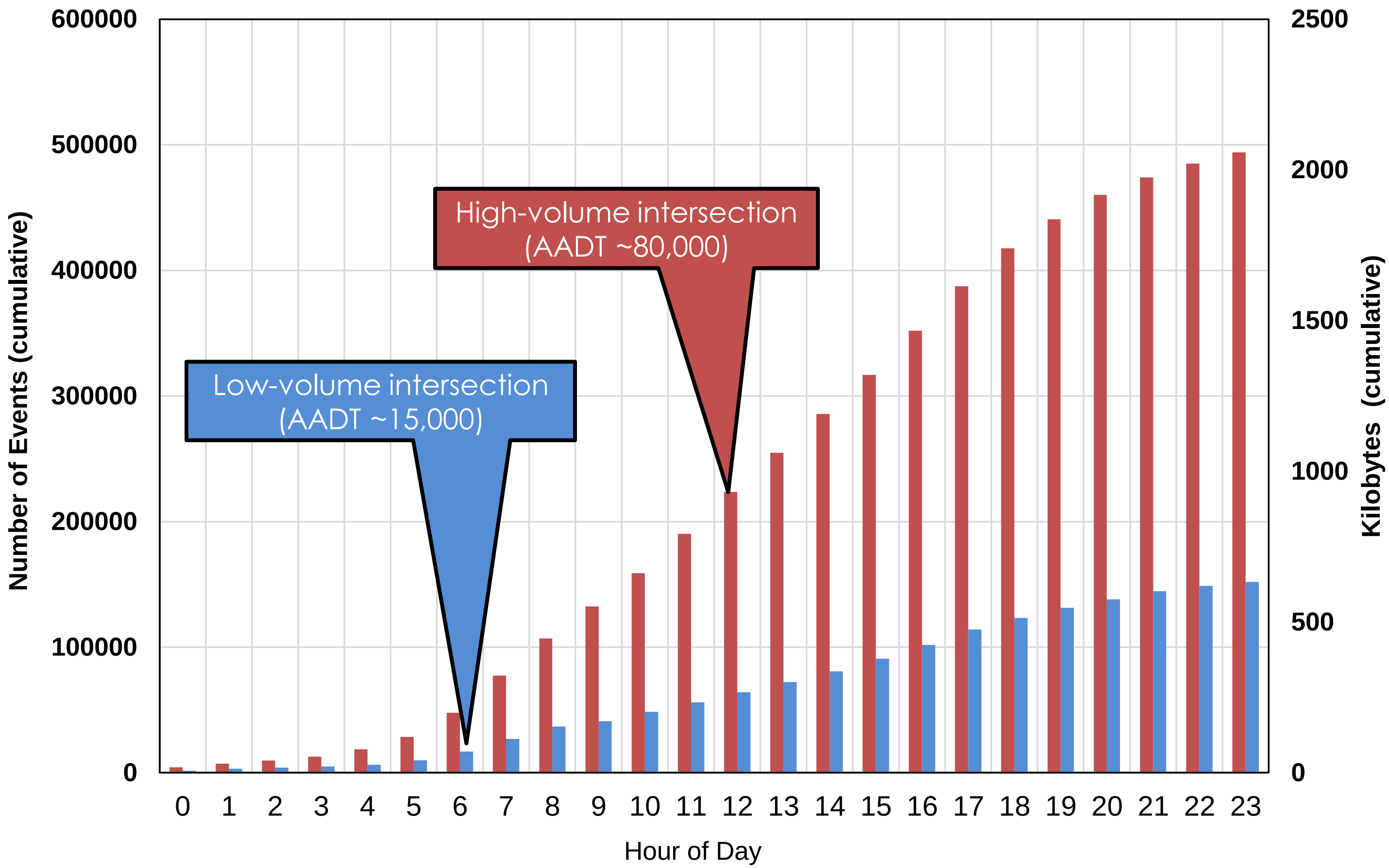
Data Flow – From Field to User



Data Storage Requirements

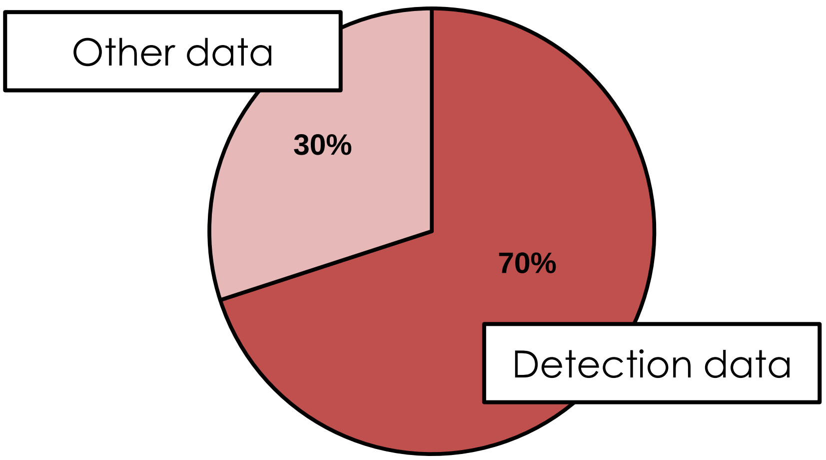


Data Storage Requirements

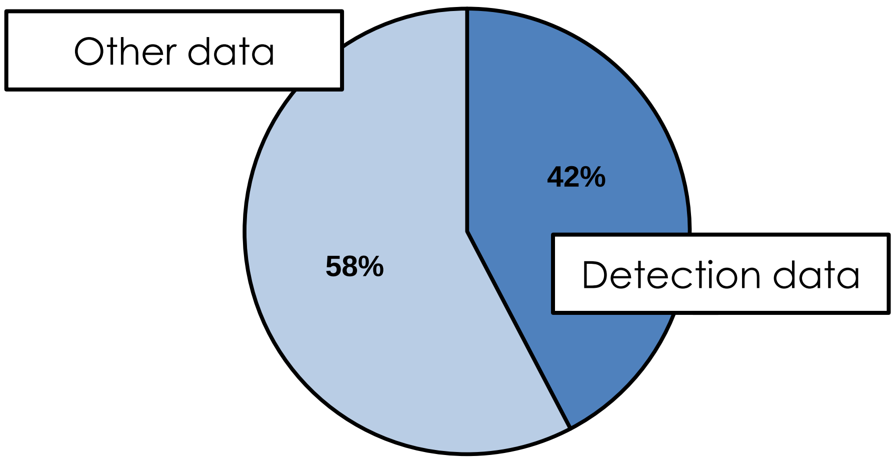


Data Storage Requirements

- Data size contingent on intersection volumes
- Busy intersections = more detections = more data

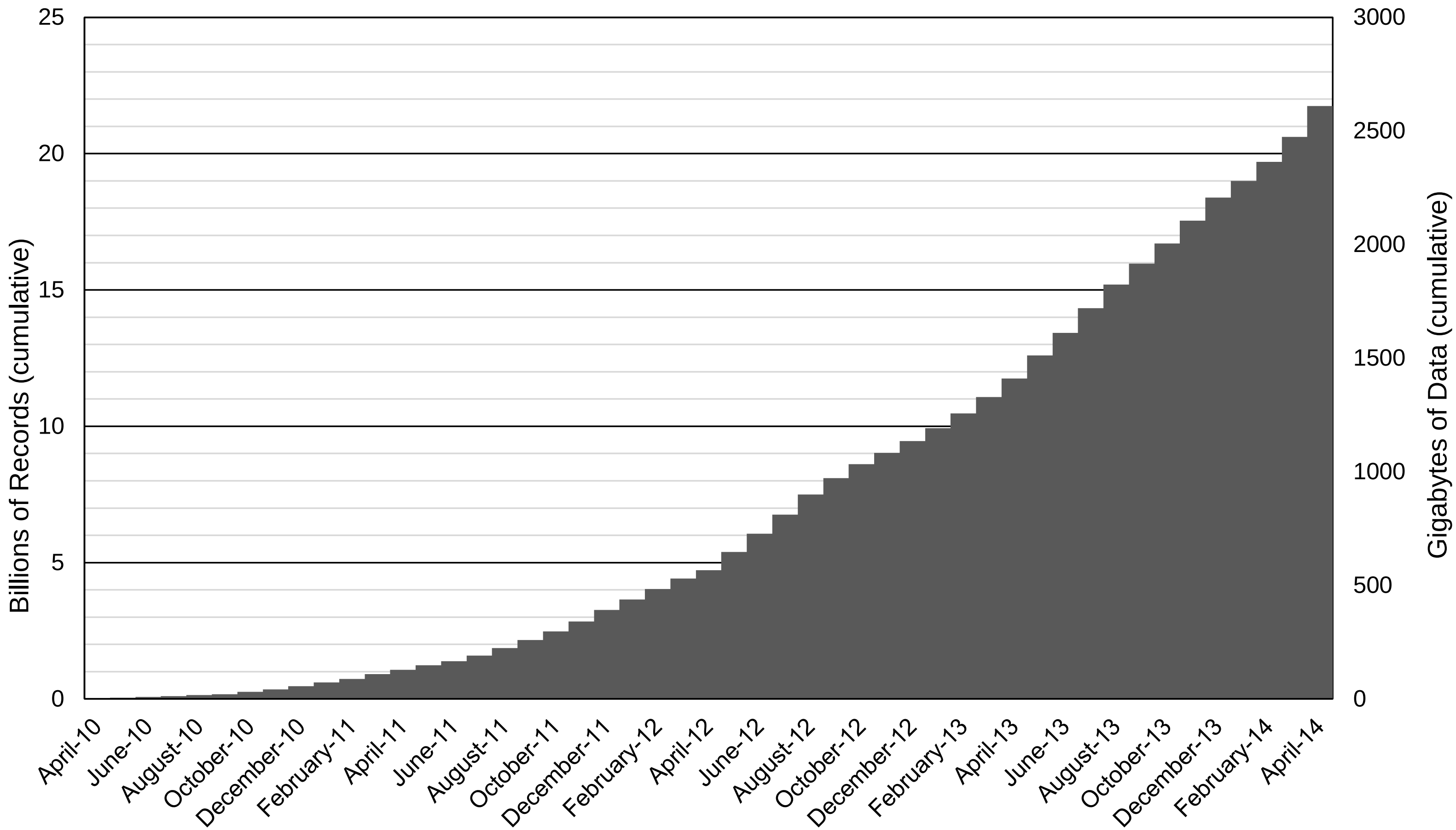


High-volume intersection
(AADT ~80,000)

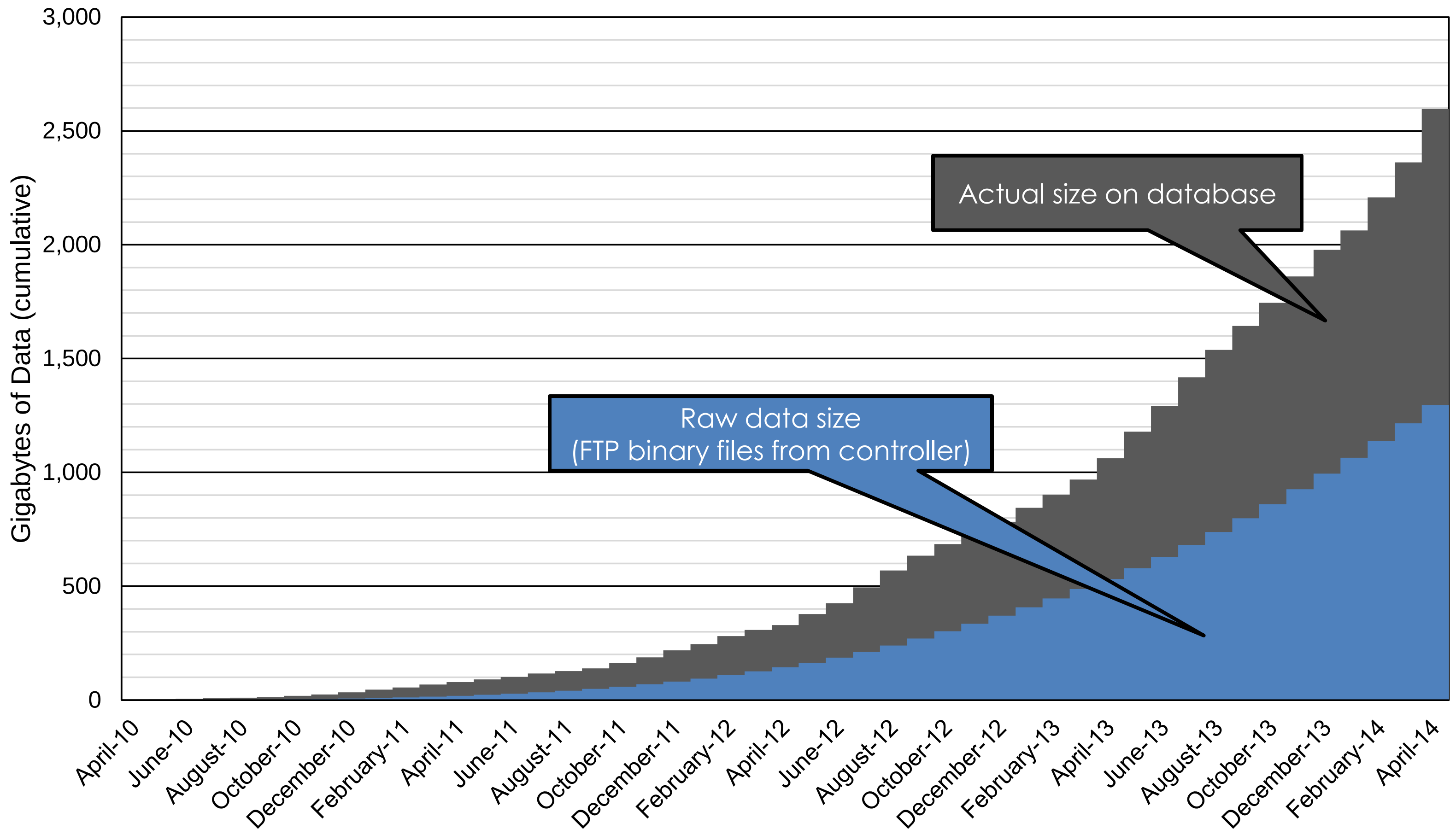


Low-volume intersection
(AADT ~15,000)

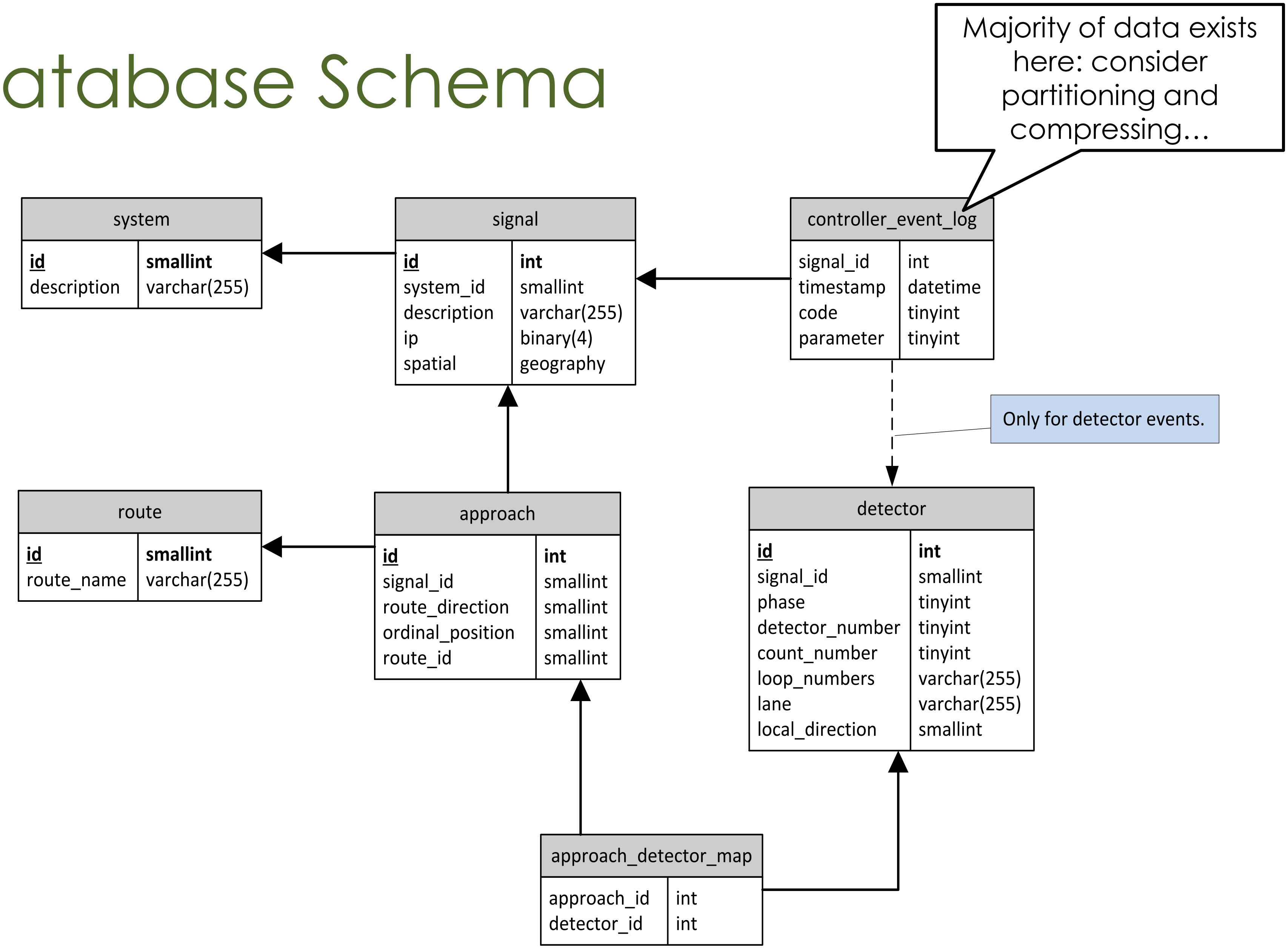
Data Storage Requirements

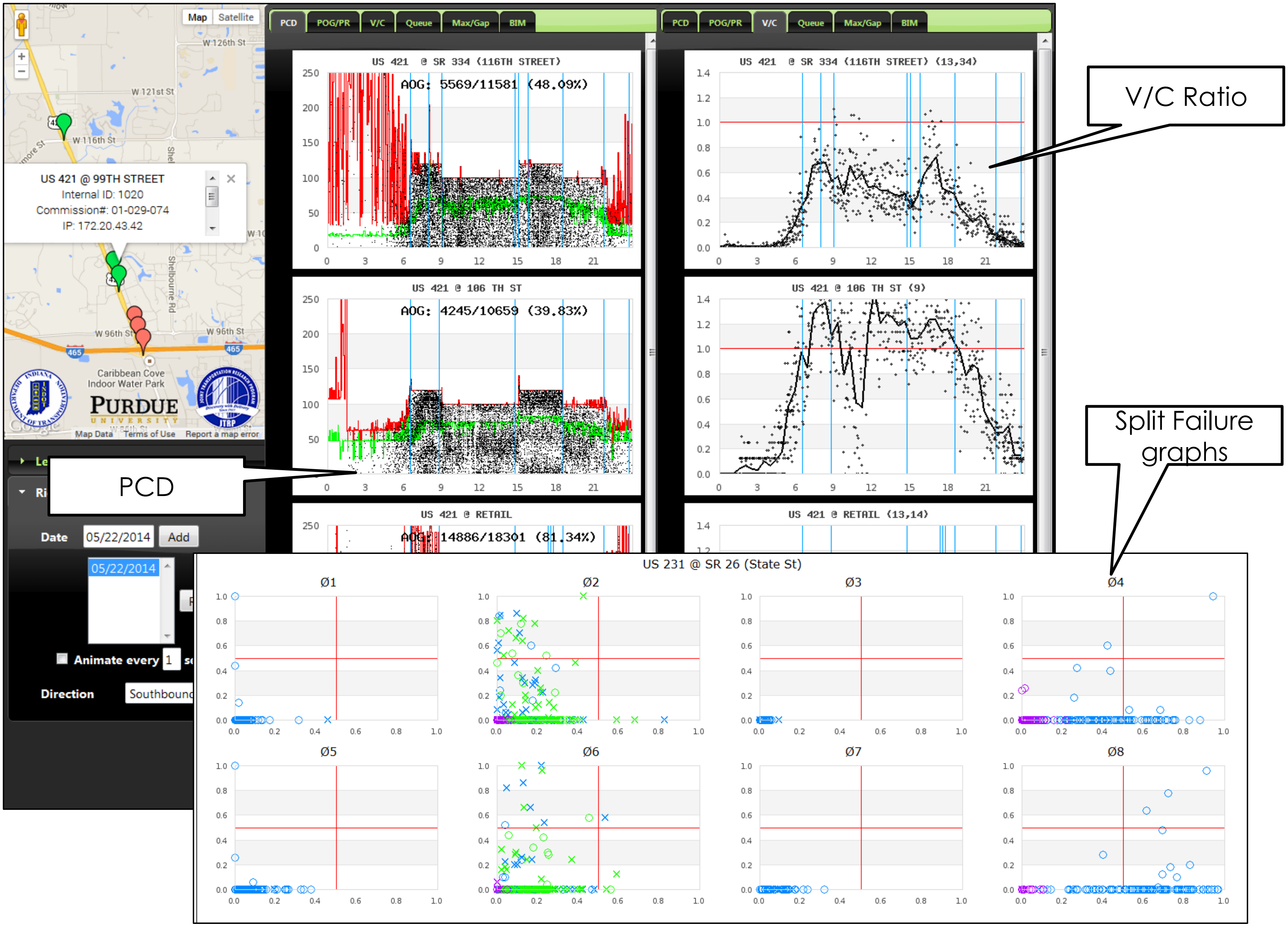


Data Storage Requirements



Database Schema




V/C Ratio
Split Failure graphs
PCD
PCD
POG/PR
V/C
Queue
Max/Gap
BIM
US 421 @ SR 334 (116TH STREET)
AOG: 5569/11581 (48.09%)
US 421 @ 106 TH ST
AOG: 4245/10659 (39.83%)
US 421 @ RETAIL
AOG: 14886/18301 (81.34%)
US 421 @ SR 334 (116TH STREET) (13,34)
US 421 @ 106 TH ST (9)
US 421 @ RETAIL (13,14)
US 421 @ 99TH STREET
Internal ID: 1020
Commission#: 01-029-074
IP: 172.20.43.42
Map
Satellite
W 126th St
W 121st St
W 116th St
W 96th St
Shelbourne Rd
Caribbean Cove Indoor Water Park
PURDUE UNIVERSITY
JTRP
Map Data
Terms of Use
Report a map error
Date
05/22/2014
Add
Animate every
Direction
Southbound
US 231 @ SR 26 (State St)
Ø1
Ø2
Ø3
Ø4
Ø5
Ø6
Ø7
Ø8

Find out more: http://tig.transportation.org

AASHTO TIG

- TIG Home
- About TIG
- Focus Technologies
- Executive Committee
- Feedback
- Additionally Selected Technologies
- TIG-Solicitation
- Lead States Team Guidance

TIG Home

AASHTO > AASHTO Technology Implementation Group > TIG Home

AASHTO's Technology Implementation Group — or TIG — scans the horizon for outstanding ad
technology and invests time and money to accelerate their adoption by agencies nationwide.

Each year, TIG selects a highly valuable, but largely unrecognized procedure, process, software
that has been adopted by at least one agency, is market ready and is available for use by othe

Guided by the vision of "a culture where rapid advancement and implementation of high payoff,
expectation of the transportation community," TIG's objective is to share information with AAS
agencies, and their industry partners to improve the Nation's transportation system.

Recently selected technologies with links to additional information are listed below. Also, you m
and Additionally Selected Technologies categorized by AASHTO subcommittee interest area.

Lead States Team Focus Technologies

2013 Focus Technologies

- Automated Traffic Signal Performance Measures
- UPlan Phase II

Prior Four Years Focus Technologies

- Embedded Data Collector
- Environmental Planning GIS Tools

Additionally Selected T

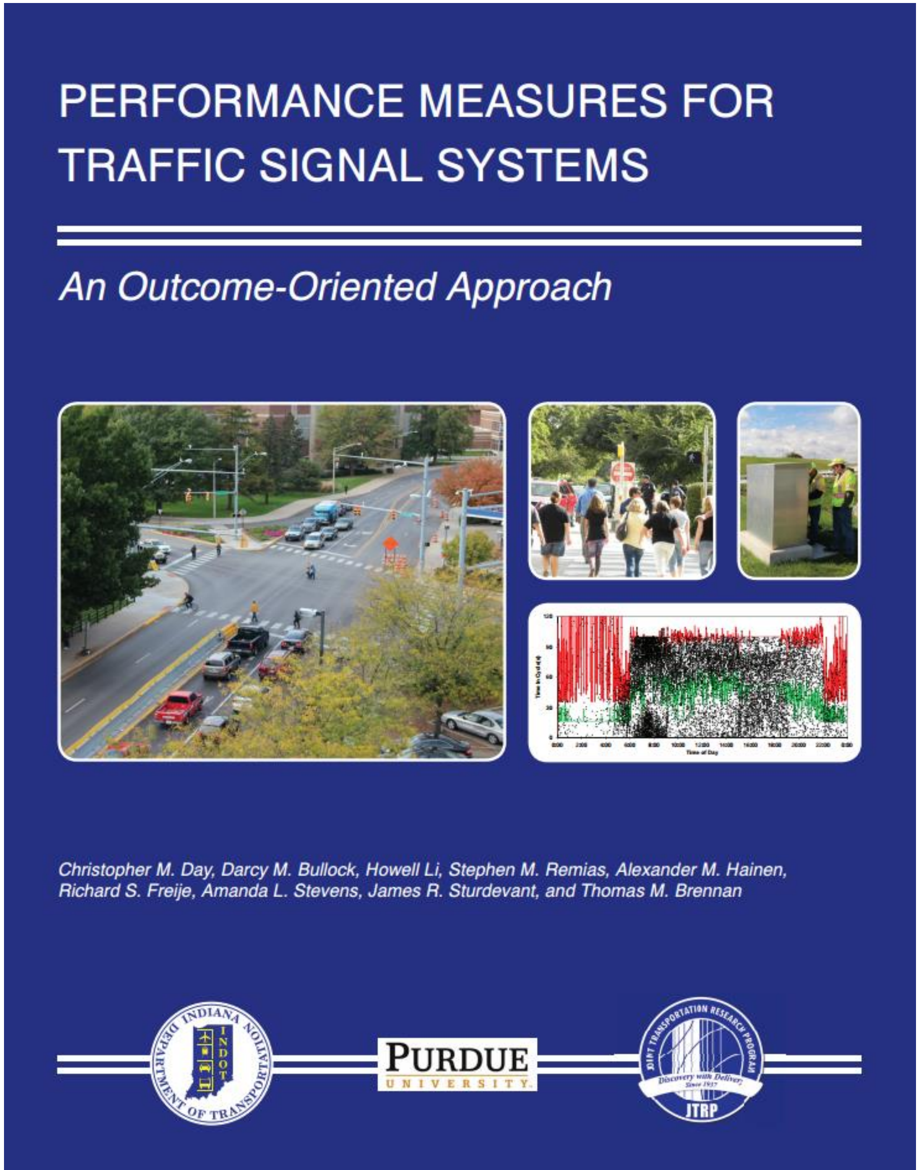
2013 ASTs

- Double Crossover Dia

Prior Four Years ASTs

- Anonymous Wireless Time Data Collection
- Curvature Extension f

Additional Reading



http://tinyurl.com/signalmoe

DOI: 10.5703/1288284315333

Shane Johnson

UDOT

Dr. Chris Day

Purdue

Howell Li

Purdue

Thank you.

COMMENTS OR QUESTIONS?

http://tig.transportation.org

http://tinyurl.com/signalmoe

TIG SPM TEAM CONTACTS

Mark Taylor
Utah DOT
801-887-3714
marktaylor@utah.gov

Jamie Mackey
Utah DOT
801-887-3489
jamiemackey@utah.gov

Steve Misgen
Minnesota DOT
651-234-7835
steve.misgen@state.mn.us

Jim Sturdevant
Indiana DOT
317-899-8603
jsturdevant@indot.in.gov

Richard Denney
FHWA
410-962-4796
richard.denney@dot.gov

Andrew Wimsatt
TTI
979-862-4597
awimsatt@ttimail.tamu.edu