TRACK CIRCUIT MONITORING TOOL - AN APTA RECOMMENDED PRACTICE FOR TRANSIT SYSTEMS USING TRACK CIRCUIT TECHNOLOGY

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Bob MacDonald, TSE Engineering, Inc.
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A Software Based Monitoring Tool for Secondary Train Tracking and Evaluation.

A System to recognize Loss Of Shunt conditions

Recommended Practices for a Software Based Track Circuit Monitoring (TCM) Tool

Abstract: The Recommended Practices offers guidelines necessary to integrate a software based tool to monitor track circuit occupancies and identify abnormal operation of track circuits

Project Initiative

- Address NTSB Recommended Practice # R-09-6 and R-09-7

    - *R-09-6: Urgent to WMATA – Enhance safety redundancy by evaluating track occupancy and automatically generate alerts.*

    - *R-09-7: Urgent to FTA – Advise all transit operators with systems that can monitor train movement. Add redundancy by evaluating track occupancy data on a real time basis to automatically generate alerts and speed restrictions to prevent train collisions.*

- Support to APTA Recommended Practice

Background

Modern track circuits represent the latest generation in a long line of train detection systems that identify train location, provide information regarding train maximum allowable speed, and assists in the detection of broken rail.

These systems during their life cycle require constant vigilance to assure standards for safety and reliability are maintained:

- In order to assure a lifecycle of safe and reliable operation there is a need for a technologically experienced labor force.

- Maintenance employees working on these systems should be empowered with the ability, when necessary, *to stop train movements or implement appropriate speed restrictions to prevent collisions. [Red is QUOTE from NTSB R-09-6 Urgent]*

These technical and safety responsibilities are often challenging to the operating entity and line maintenance employees so the ability to contain the decision process by making it immediately available to operations and engineering management would be a major help in assuring safe and reliable train operation.

TCM Objectives

Provide a Practical and Cost Effective Solution to Transit Agencies that addresses APTA Recommended Practice

- Provide a secondary train tracking evaluation based on any track occupancy detection system
- Provide enhanced algorithms to monitor integrity of track circuit indications and train progressions
- Categorize abnormal events in notifications, warning, and safety critical alerts
- Initiates Stop of train movements or appropriate Speed restrictions to prevent collisions. [*QUOTE from NTSB R-09-6*]
- Enabling long-term perspective for improved asset management
- Improve Track Circuit reliability and transportation safety

TCM helps identifying System problems

Potential to detect occupancy failures in Train Monitoring and Control Systems, regardless, if ATC system or other infrastructure systems failure. Examples include:

Failures to detect train occupancy:

- Circuits out of Adjustment
- Corrugated Rail
- Damaged Bonds
- Broken rail clamps
- Loose connectors
- Rusty Rail
- Short circuits protected by LOS timer

False occupancy:

- Circuits out of Adjustment
- Damaged Bonds
- Broken rail
- Traction Power Imbalance
- Dissimilar Rail
- Autumn leaves

The TCM Tool has been found to be a significant asset in the analysis, detection, and identification of track circuit and systems anomalies, improving the reliability and safety of Train Monitoring and Control Systems.

Systems Concept and Program Approach

Provide a secondary train tracking evaluation based on track occupancy data on a real time basis
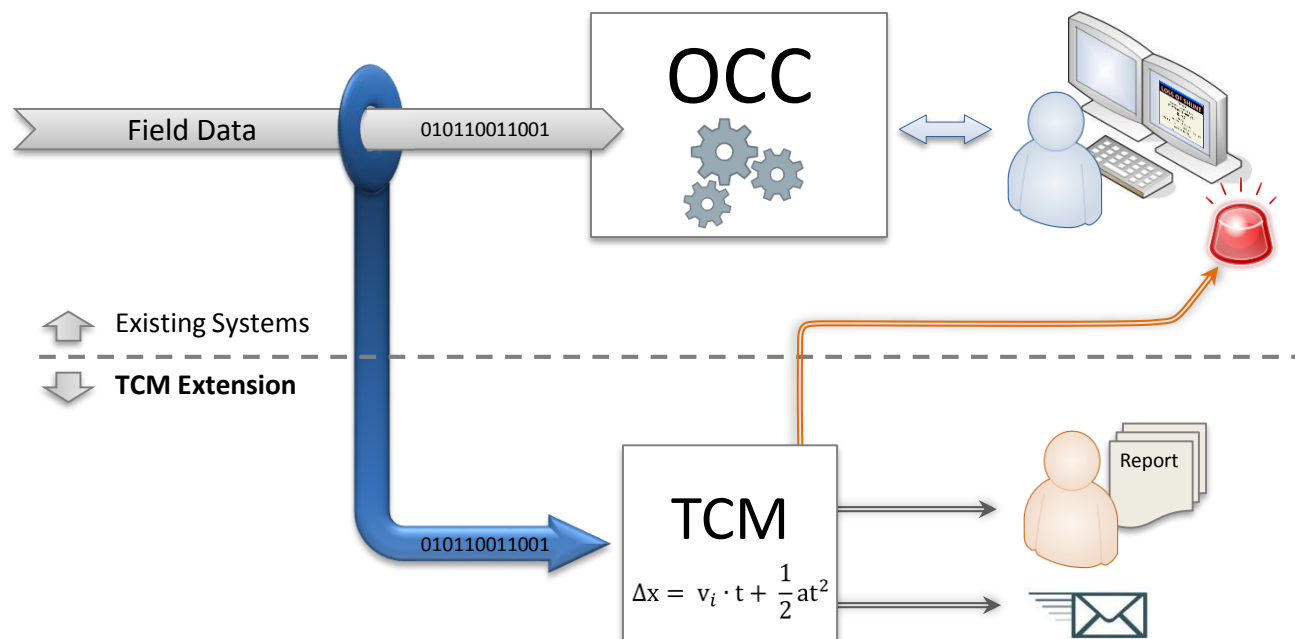
The Track Circuit Monitoring Tool utilizes track circuit status information and analyzes this information – in real time – to detect irregular operation and potentially unsafe conditions. TCM separates and alerts only those conditions, creating potentially unsafe conditions and affecting the reliability and of rail systems.
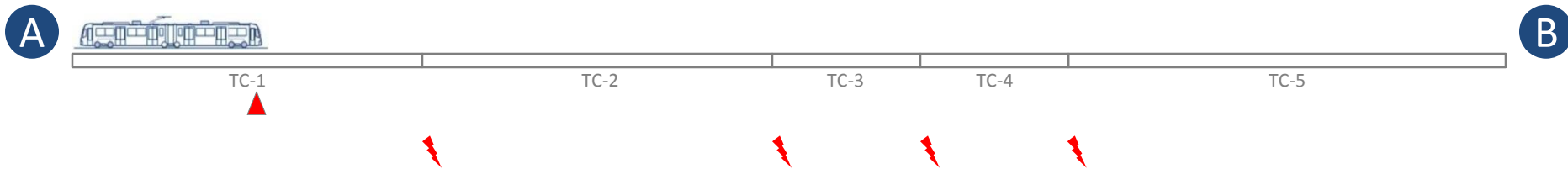
TCM Algorithms

1. Determine actual train location based on the laws of physics

2. Calculate severity of abnormal track circuit behavior

3. Alerts and reports findings (based on configurable parameters)

→ Improves timely reaction to potentially safety critical incidents
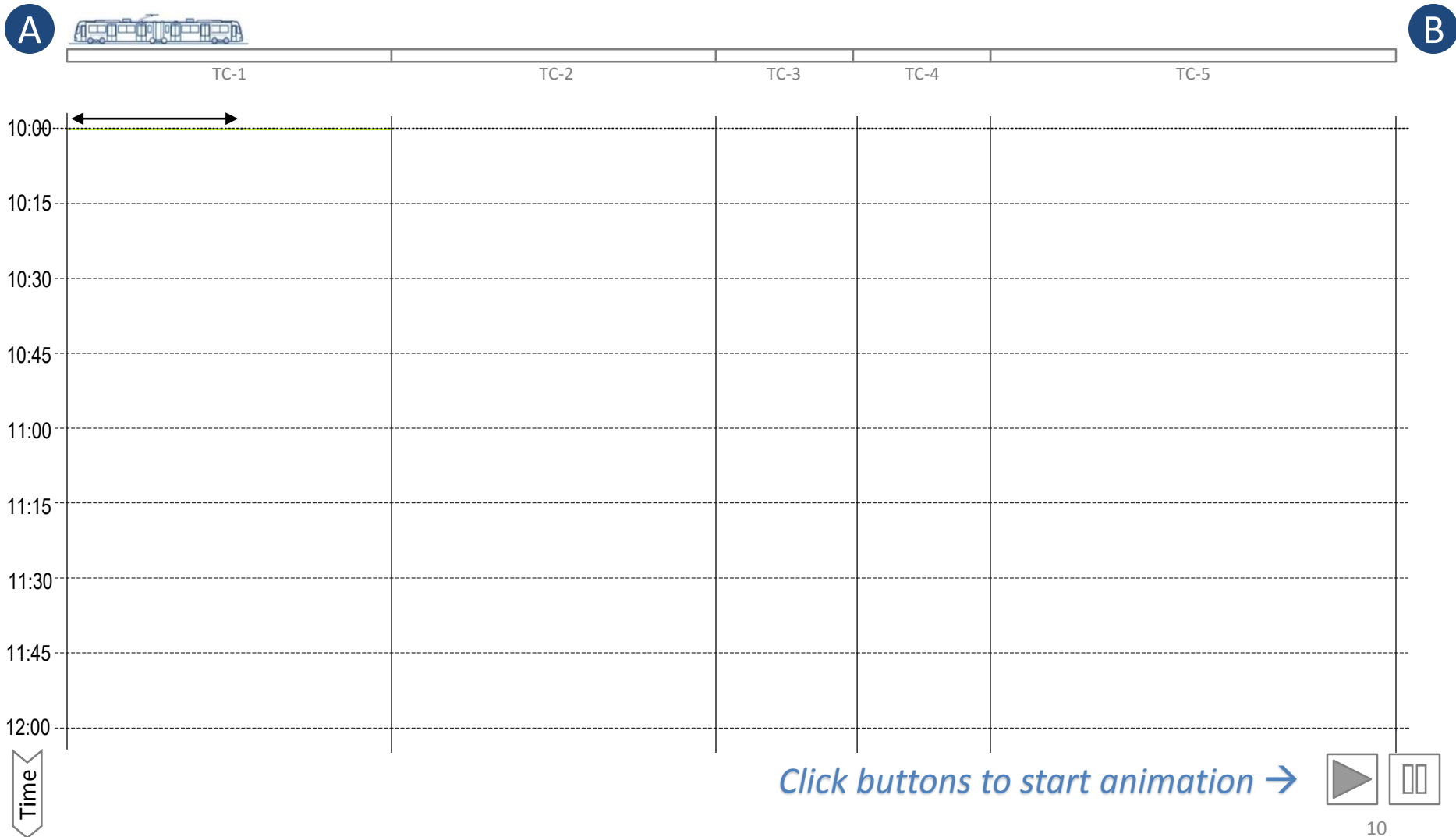
Illustration

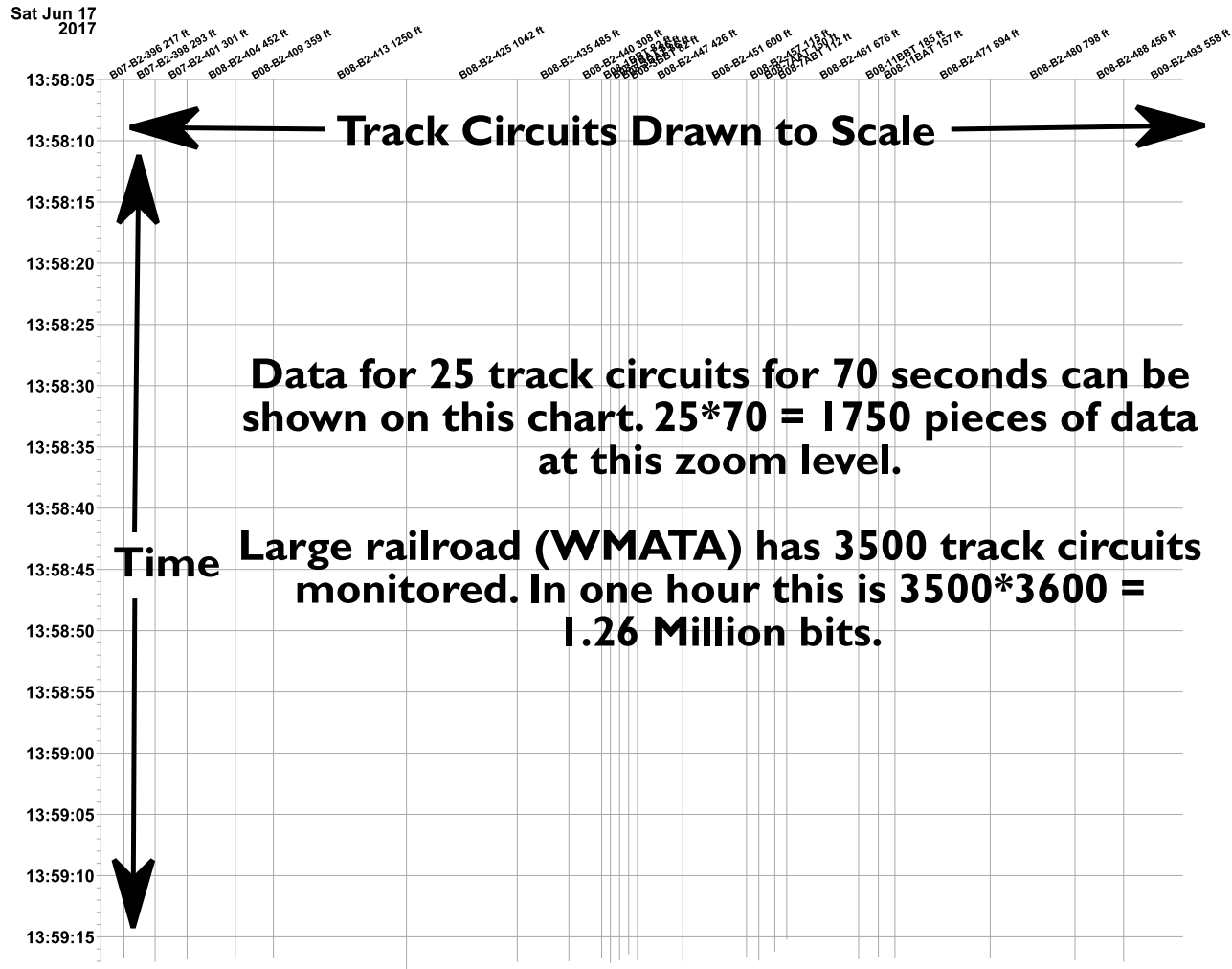## Train progression monitoring and verification with TCM

$$\text{Calculation of Train Progression} = f\left\{ L_{train},\ +a,\ -a,\ v_{max},\ L_{TC},\ TC_\infty \right\}$$
(based on Laws of Physics)

- Validates Track Circuit indications based on physical constraints of Train Consist, Alignment data, and Laws of Physics

- Determines Severity of Inconsistencies and issues Alerts

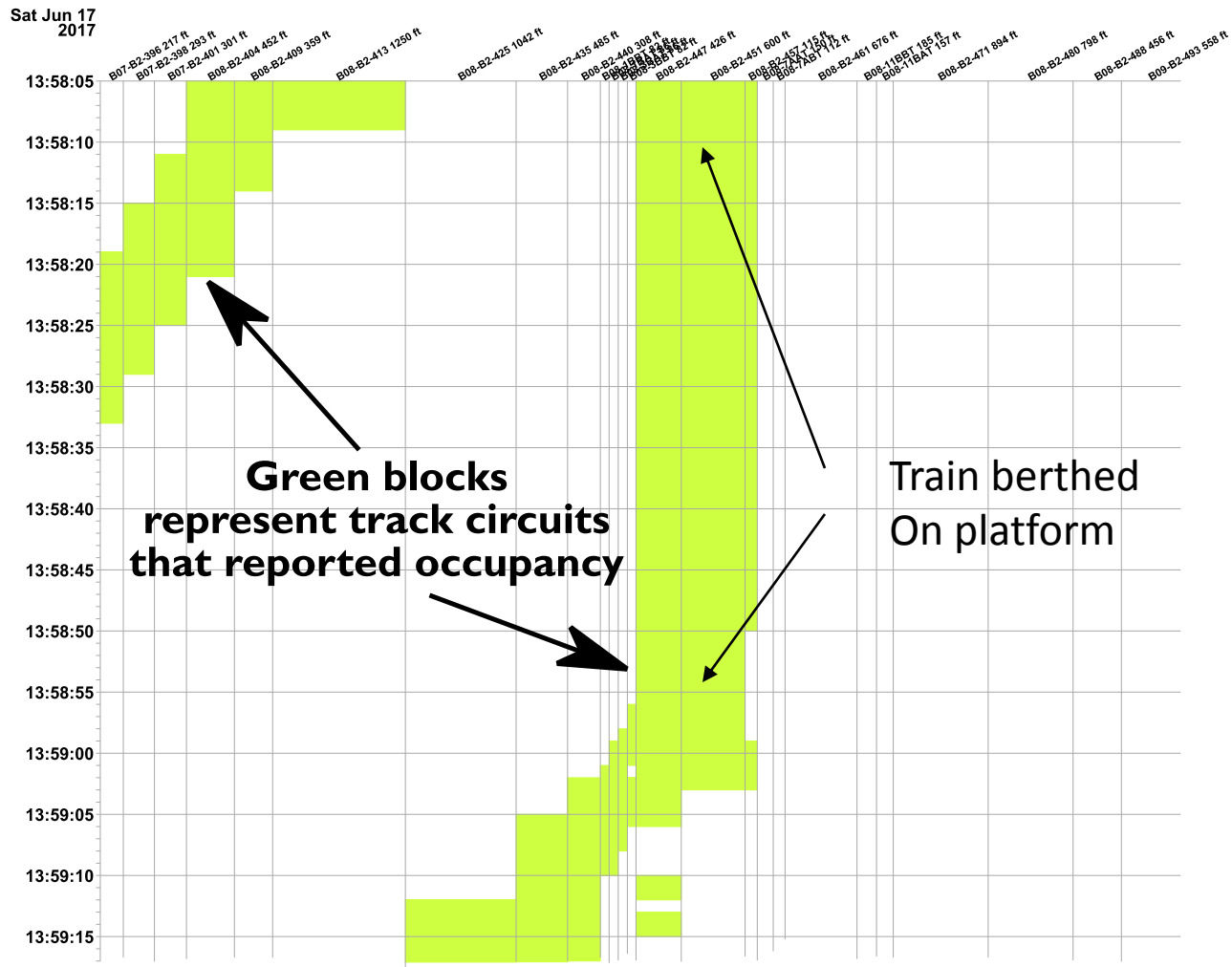- Provides Archive Functionality to enable Historic Analysis of Incidents

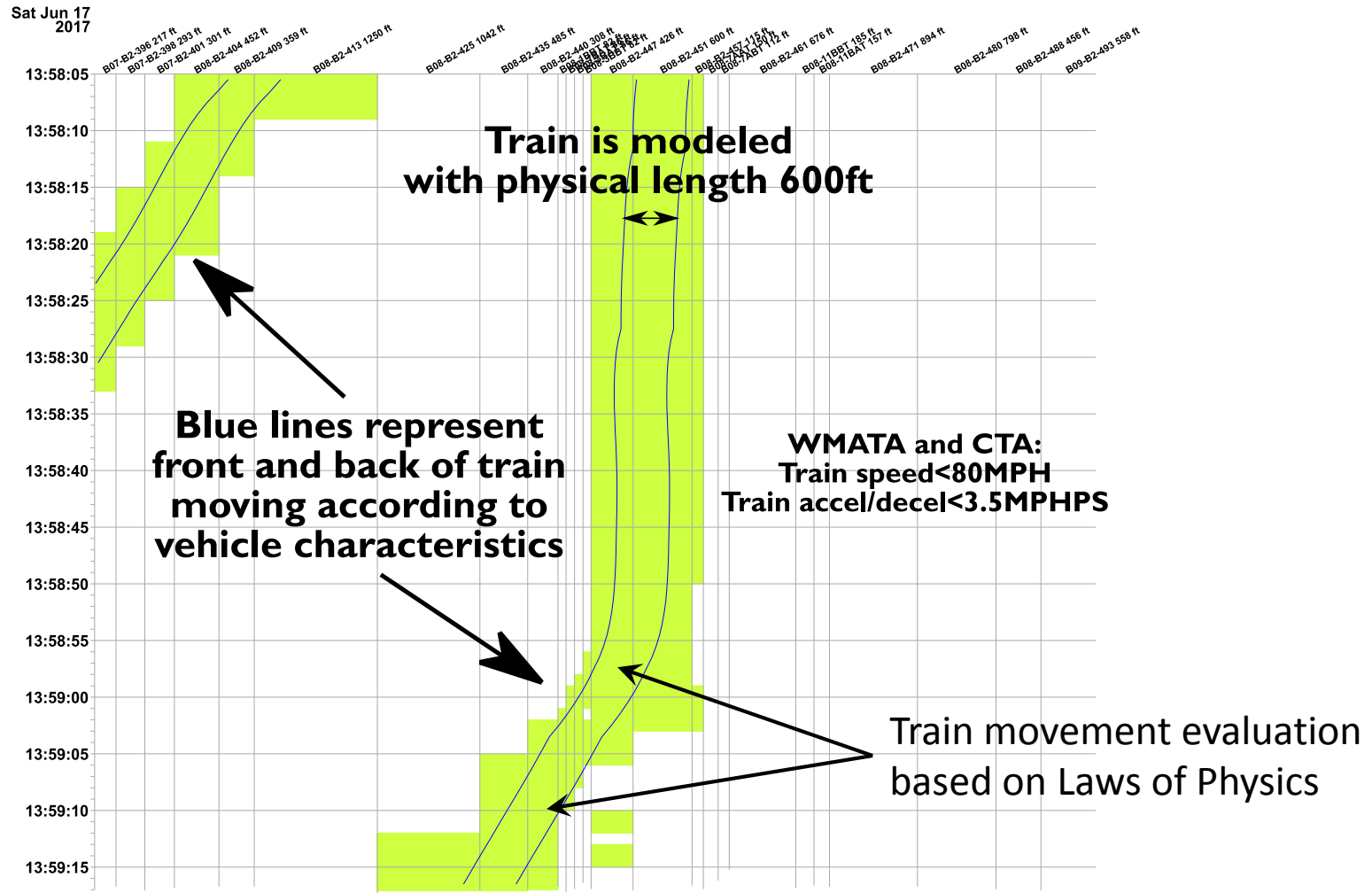# TCM Evaluation in Track Occupancy Chart

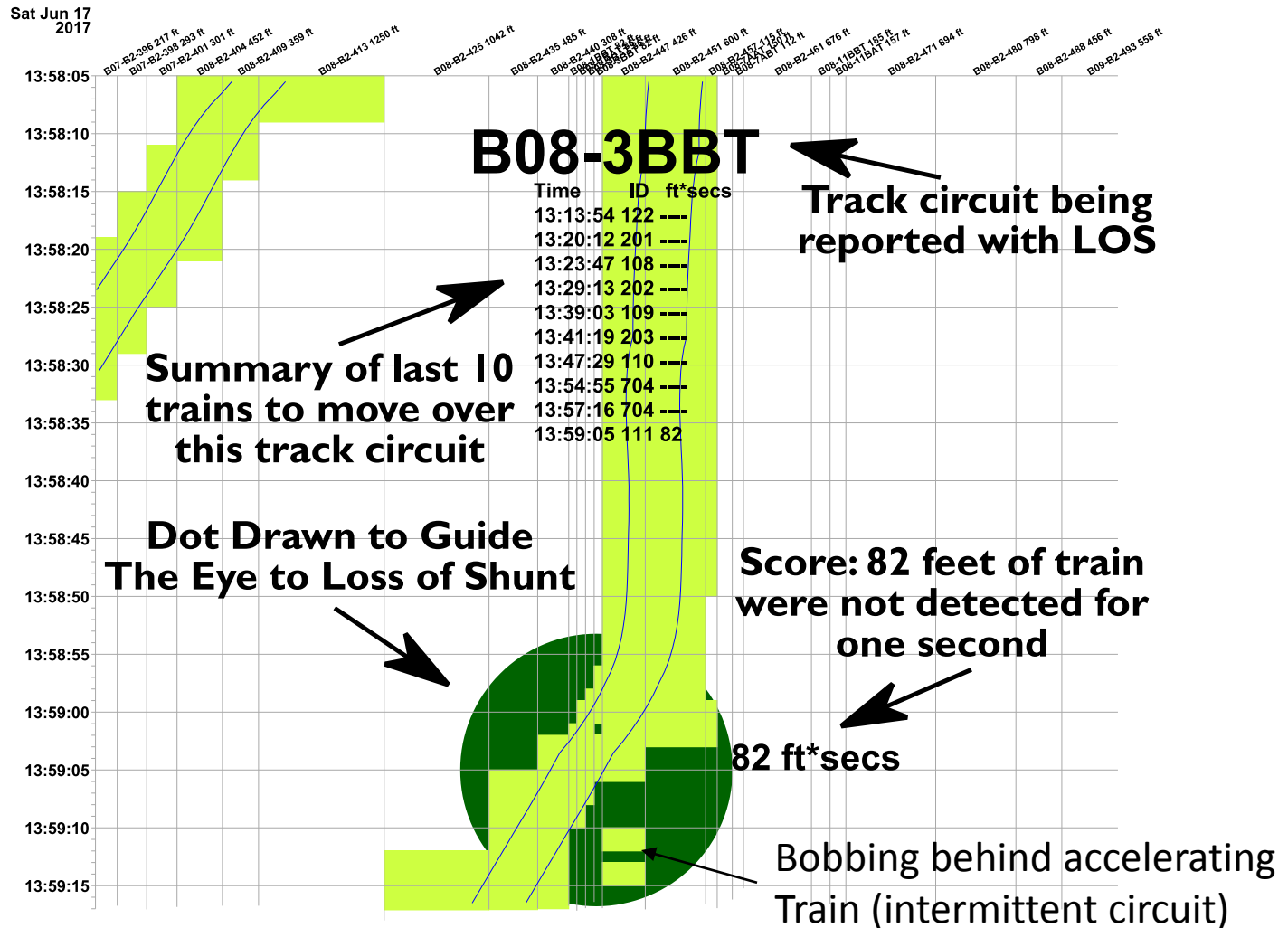TC-1   TC-2   TC-3   TC-4   TC-5

10:00

10:15

10:30

10:45

11:00

11:15

11:30

11:45

12:00

Time

Click buttons to start animation → ▶ ⏸

Sat Jun 17 2017

Track Circuits Drawn to Scale

Time

Data for 25 track circuits for 70 seconds can be shown on this chart. 25*70 = 1750 pieces of data at this zoom level.

Large railroad (WMATA) has 3500 track circuits monitored. In one hour this is 3500*3600 = 1.26 Million bits.

Train is modeled
with physical length 600ft

Blue lines represent
front and back of train
moving according to
vehicle characteristics

WMATA and CTA:
Train speed<80MPH
Train accel/decel<3.5MPHPS

Train movement evaluation
based on Laws of Physics

B08-3BBT

Time	ID	ft*secs
13:13:54	122	----
13:20:12	201	----
13:23:47	108	----
13:29:13	202	----
13:39:03	109	----
13:41:19	203	----
13:47:29	110	----
13:54:55	704	----
13:57:16	704	----
13:59:05	111	82

Track circuit being reported with LOS

Summary of last 10 trains to move over this track circuit

Dot Drawn to Guide The Eye to Loss of Shunt

Score: 82 feet of train were not detected for one second

82 ft*secs

Bobbing behind accelerating Train (intermittent circuit)

CTA Data: Blue Line Track Occupancy Chart

Fri Oct 2 2015

Intermittent Track Circuit
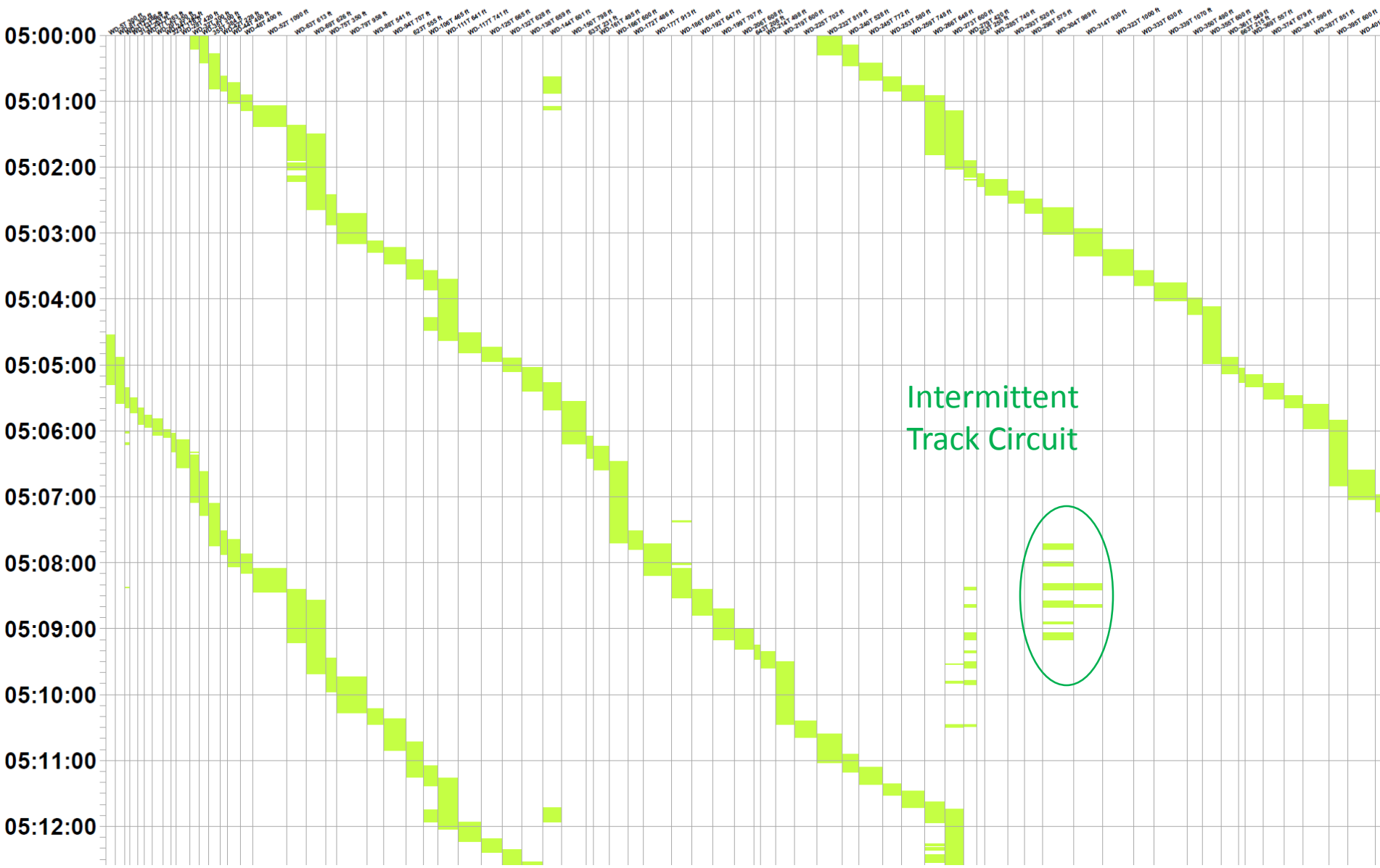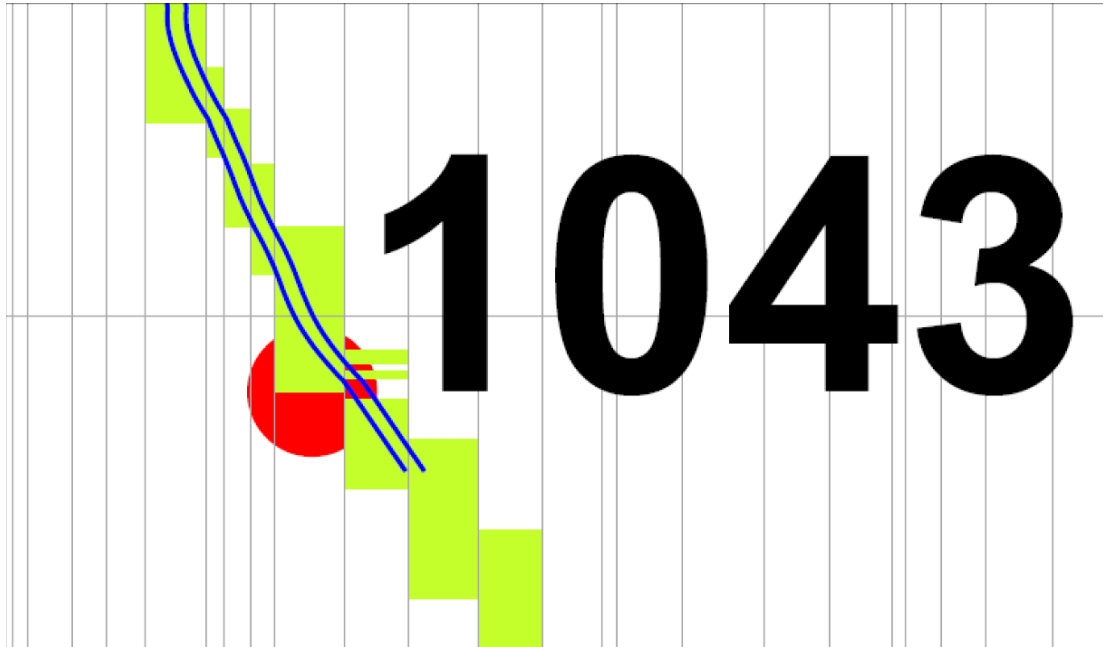
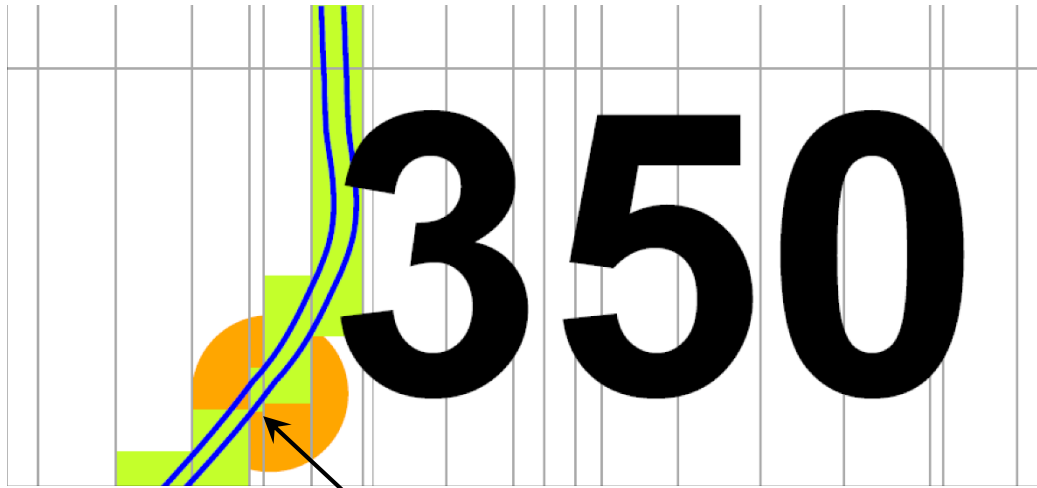# Typical TCM Chart – Westbound traffic

345 ft*secs
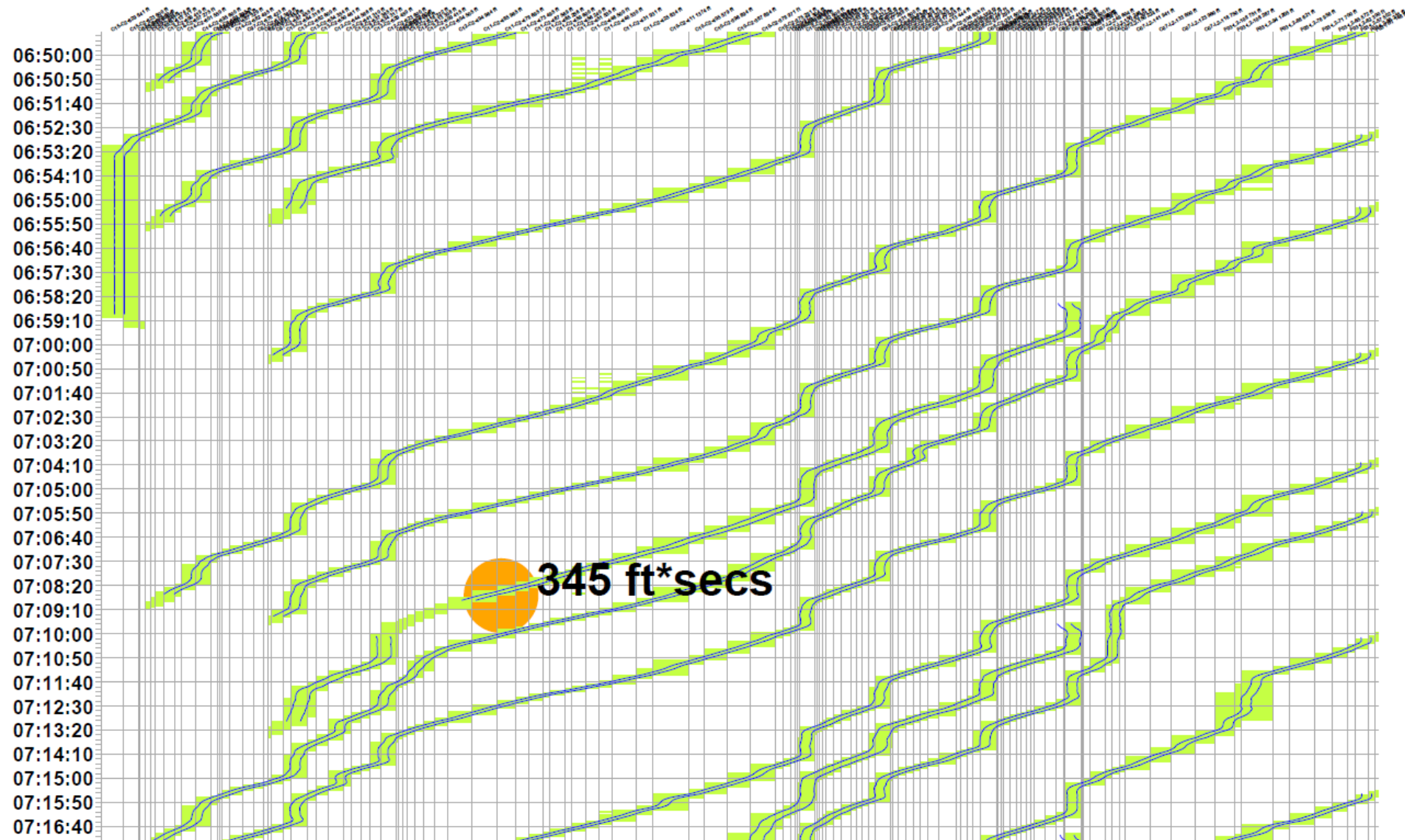
CTA Data: July 18, 2017
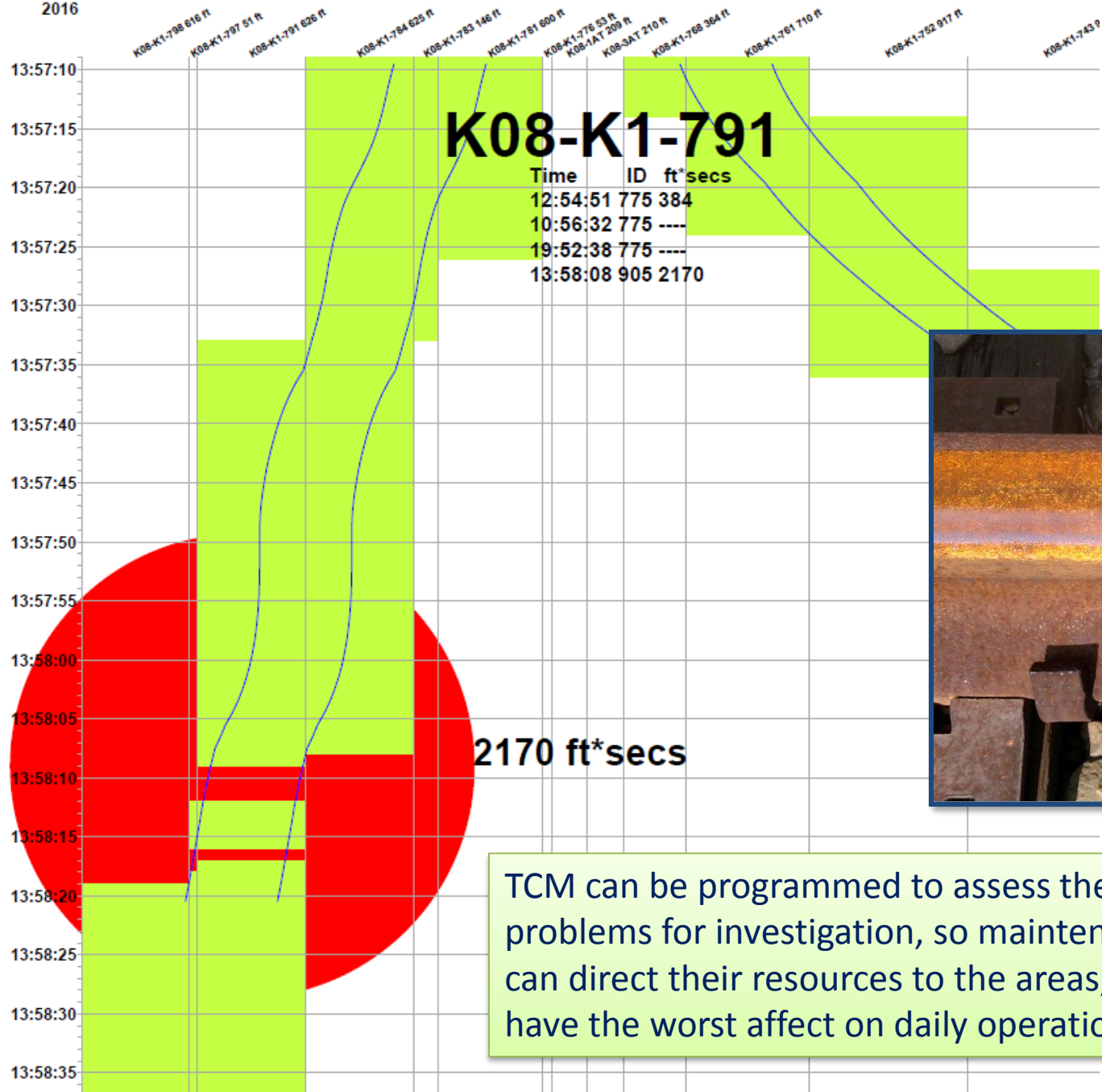
CTA Data: July 18, 2017

350
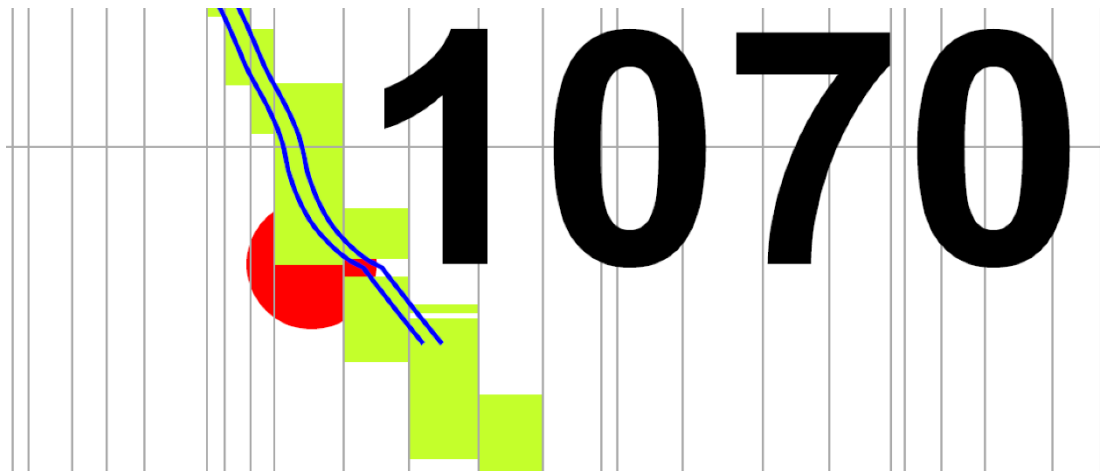
Insufficient overlap

597

TC pickup under Train

K08-K1-798 616 ft
K08-K1-797 51 ft
K08-K1-791 626 ft
K08-K1-794 625 ft
K08-K1-783 146 ft
K08-K1-781 600 ft
K08-K1-776 53 ft
K08-1AT 209 ft
K08-3AT 210 ft
K08-K1-766 364 ft
K08-K1-761 710 ft
K08-K1-752 917 ft
K08-K1-743 9

13:57:10
13:57:15
13:57:20
13:57:25
13:57:30
13:57:35
13:57:40
13:57:45
13:57:50
13:57:55
13:58:00
13:58:05
13:58:10
13:58:15
13:58:20
13:58:25
13:58:30
13:58:35

K08-K1-791

Time	ID	ft*secs
12:54:51	775	384
10:56:32	775	----
19:52:38	775	----
13:58:08	905	2170

2170 ft*secs
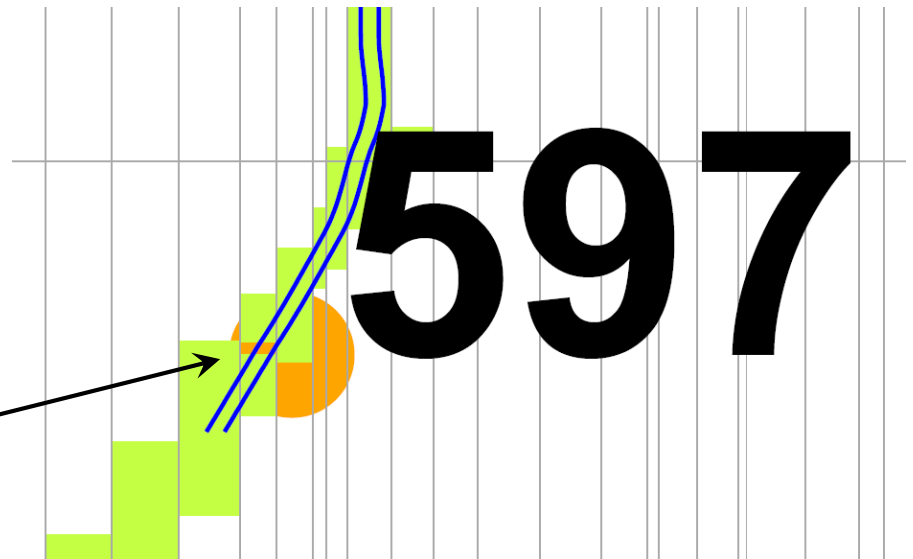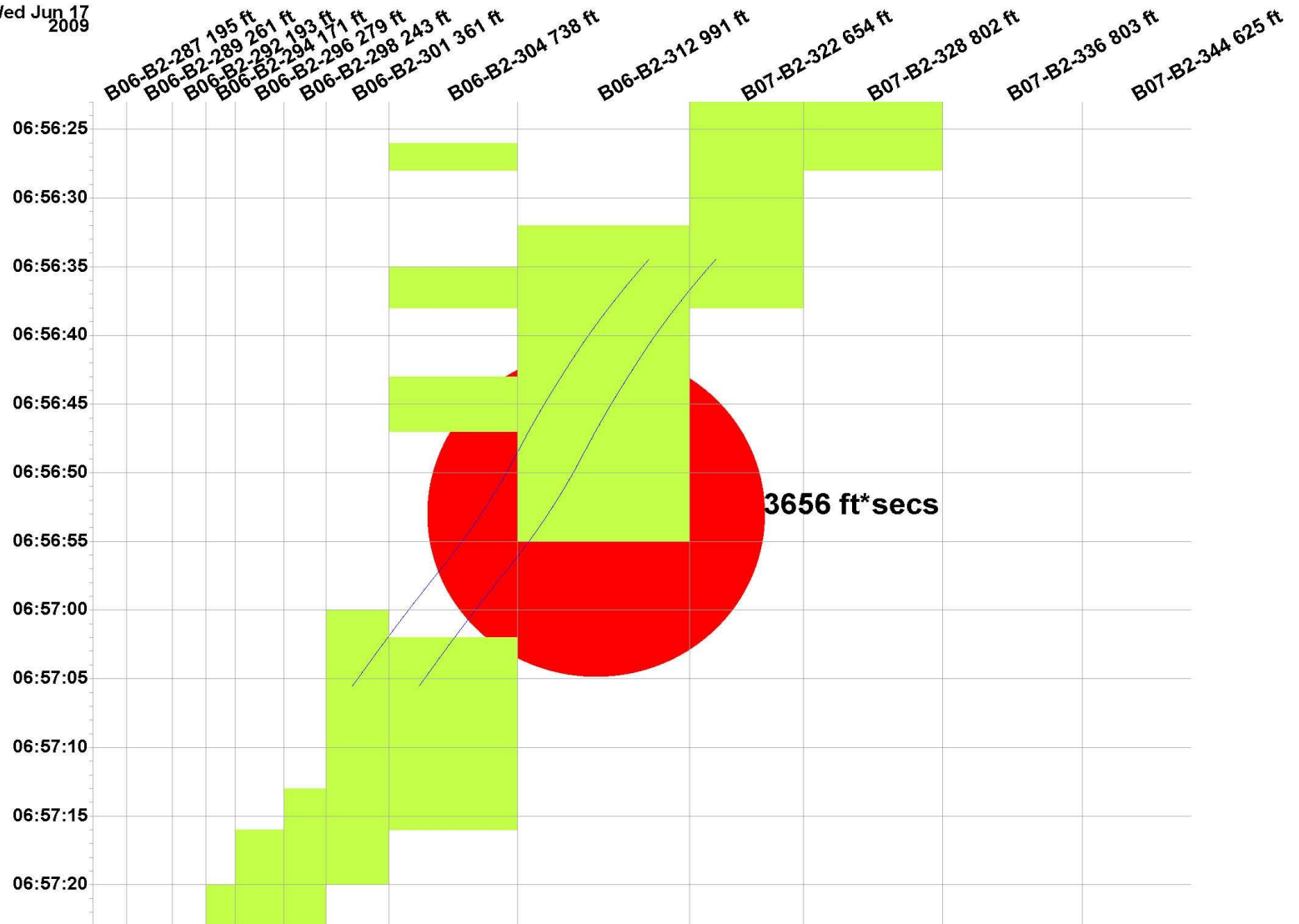
TCM can be programmed to assess the most severe problems for investigation, so maintenance managers can direct their resources to the areas, most likely to have the worst affect on daily operations.

Business Process - WMATA

WMATA has a well-defined business process for responding both to critical loss-of-shunt incidents and more minor maintenance or reliability issues found by TCM.

For the most common causes of track circuit problems, the cycle between TCM report and resolution can be very short.

7:03PM

Reply   Reply All   Forward

Wed 3/2/2016 7:03 PM

ATC Track Circuit Monitoring Tool <tcmt@wmata.com>

PDF fit loss of shunt report

To   Shoppa, Tim; Glansdorp, Johann B.; Shaw, Thomas; Goller, Jeffery L.; Bauer, Cindy L.; Vartani, Varouj; Myers, Colin A.; Croce, Nicholas J.; Kennerly, Manael; Gorelik, Boris; tshoppa@gmail.com; Adams, Dorsey M; Brown, Louis J.; Ruban, Yury; Lynch, Eric; Weingarten, Colby; Newman, David W.; Fitch, Myron; Dougherty, James; Burns, Daniel; Bozic, Zoran; Shaver Christine M; Enyinnia, Adiele; Davis, Robert; Gworlekaju, Robert; Abramovich, Theo; Flanders, Jerry; Bui, Truong D.; Johnson, Carl B.; Hitaffer, Thomas E.

Retention Policy   Delete Emails Older Than 180 Days (6 months)   Expires   8/29/2016

This message was sent with High importance.
We removed extra line breaks from this message.

Message   fit2016Mar2h19.pdf (269 KB)

These are LOS failure-tof-it events picked up LOS fits on server los3 Report runs from Wed Mar 2 09:00:00 2016 to Wed Mar 2 19:03:02 2016

Track circuit 11BBT

Had shown problems

Earlier in day at:

9:00AM

9:42AM

1:53PM

2:03PM

3:30PM

3:39PM

5:09PM (pictured)

Business Process - WMATA

7:22PM

Reply   Reply All   Forward

Wed 3/2/2016 7:22 PM

Bozic, Zoran

Analysis of the 3/02/2016 PM LOS data

To   Sow, Moustapha

Cc   Weingarten, Colby; Lam, Dat; Nguyen, Du; Cox, David W.; Curtiss, Rahim L.; Nguyen, Phule; Relyea, Robert; Carlos, Walter; Shoppa, Tim; Vannatter, Brian K.; DeFilippo, John L.; Le, Thuong Duy; Frazier, Philip A.; Parsons, Louis S.; Shaw, Thomas; Salas, Carlos A.; Kennerly, Manael; Bowman, Shanita; Rogers, Jameel T; Brown, Louis J.; Gregory, Bert; Reikowski, Robert J.; Holzer, Ron; Romero, Steven; Sienkiewicz, Peter G.; Kamal, Said; Beatty, Steven; Bryant, Freddie; Campbell, Eugene A.; Allen, James; Thompson, Michael;

Retention Policy   Delete Emails Older Than 180 Days (6 months)   Expires   8/29/2016

Analysis of the 3/02/2016 PM LOS data report indicates that **one** track circuit currently requires investigation by SMNT:

C10-11BBT

No action required by ROCC.

Zoran Bozic

ATC Engineer & Maximo SME
CTF, Office B-228
Office: 301-618-1320
Cell: 202-603-3721

8:54PM

Reply Reply All Forward

Wed 3/2/2016 8:54 PM

Sow, Moustapha

RE: Analysis of the 3/02/2016 PM LOS data

To   Bozic, Zoran

Cc   Weingarten, Colby; Lam, Dat; Nguyen, Du; Cox, David W.; Curtiss, Rahim L.; Nguyen, Phule; Relyea, Robert; Carlos, Walter; Shoppa, Tim; Vannatter, Brian K.; DeFilippo, John L.; Le, Thuong Duy; Frazier, Philip A.; Parsons, Louis S.; Shaw, Thomas; Salas, Carlos A.; Kennerly, Manael; Bowman, Shanita; Rogers, Jameel T; Brown, Louis J.; Gregory, Bert; Reikowski, Robert J.; Holzer, Ron; Romero, Steven; Sienkiewicz, Peter G.; Kamal, Said; Beatty, Steven; Bryant, Freddie; Campbell, Eugene A.; Allen, James; Thompson, Michael;

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ATC crew 2229-2289 found a loose MCM and a 2ft loop cable connections.
Both connections have been tightened and track circuit 11BBT has been 3 pts verified and returned into service.

Business Process - WMATA

8:59PM

⮐ Reply   ⮐ Reply All   ⮐ Forward

Wed 3/2/2016 8:59 PM

Goller, Jeffery L.

Fwd: Analysis of the 3/02/2016 PM LOS data

To   Shoppa, Tim

Retention Policy   Delete Emails Older Than 180 Days (6 months)   Expires   8/29/2016

Another fine example of the TCMT in action.

Jeffrey L. Goller
Engineering Manager - ATC
Acting Deputy Chief Engineer
TIES/CENI-ATC
(office JGB) 202/962-1271
(office CTF) 301/618-7735

Benefits for Wayside Signaling Maintenance

- Automated daily reports on tracking anomalies and irregularities

- Early detection of track circuit malfunction or deterioration

- Maintenance prioritization for faster response to reoccurring problems

- Improved asset reliability and subsequently more reliable service

- Extended useful lifetime of assets

WMATA Performance Data

Smoothed LOS Events per day Jun 2010-Jun 2011
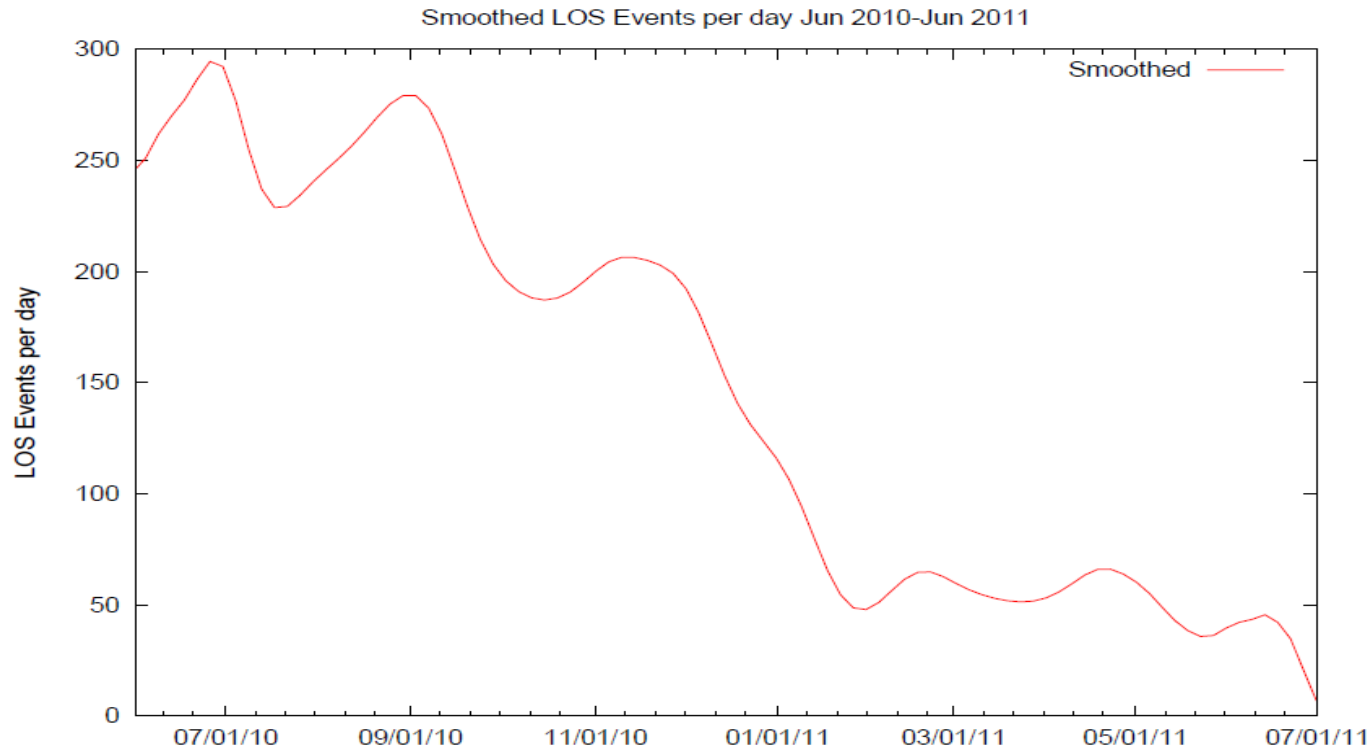
➢ As the tool was refined and the review process between Engineering and Maintenance was applied, the number of alarm events continuously fell from a high of almost 300 per day to about 10 per day over the period July 2010 to July 2011.

Transfer to Practice
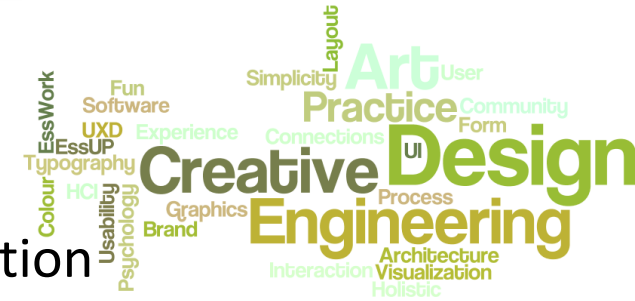
Systems Requirements

- TCM server (two if redundancy is desired)
    - Intel based platform, Entry-level Server (approx. $5,000)
    - Linux Operating System, MySQL database
    - TCM software
- Access to incoming field data (usually centralized via front-end processor)
- Interface to OCC Line Controller console

Systems Design & Engineering

1. Data modeling of initial Track alignment section

2. Data processing of recorded data in offline mode

3. TCM link to OCC for live data processing

4. Setup of OCC alert devices and email/text messaging

5. Incorporating TCM alerts into Agency's Operating Procedures

   a) SOP for critical alarms (e.g. Absolute Block in affected track)

   b) Maintenance task for Warnings and Alerts

   c) Setup of communications regime (Line Controller, Signaling Chief & Mtce. Manager, Transportation Supervisor, GM, etc.)

   d) Definition of Reports and End-user Training

6. Addition of other track alignment sections

Usage status across US transit properties:

1. WMATA: Continuous real-time use since 2010

2. CTA

    ▪ Offline analysis since 2015

    ▪ Real-time analysis since July 2017

3. MARTA

    ▪ Limited amount of offline analysis in 2017/18

    ▪ Real-time analysis in 2018/2019

4. BART (just getting started)

Lifecycle Maintenance Approach

Iterative and continued Improvement of the TCM Tool as more Transit Agencies participate in its deployment

Feed-back

User Forum[*] and Feedback loop to Agencies for upgrades, new version, extended functionality, and maintenance support

[*] Forum consists of program developers, industry experts, and Transit Agency representatives

Summary of Benefits

The Track Circuit Monitoring Tool (TCM) provides a means for a rail system to identify track circuit conditions affecting daily operations, and provides information that allows maintenance and operations managers the ability to prioritize resources and react swiftly to restore the system to normal operation.

- TCM utilizes status information, delivered to a centralized facility to analyze thousands of track circuits in real time to detect irregular operation.

- TCM separates and reports only those issues, causing problems and affecting the reliability and potentially the safety of rail system track circuits.

- Outputs from TCM can alert appropriate personnel in real time to the location and severity of track circuit problems:

    - ✓ That may affect safety allowing immediate action to restrict the area in question until additional resources can further evaluate the problem.

    - ✓ Operating in an erratic manner with the ability to send information to maintenance resources that identifies the severity and location of the problems affecting reliable operation.

- TCM can be programmed to asses the most severe problems for investigation, so maintenance managers can direct their resources to the areas most likely to have the worst affect on daily operations.

- TCM can be used to develop reports showing the affects of erratic track circuit behavior on the daily operation of the transit system for analysis by maintenance and operations.

- TCM's core algorithm was developed by WMATA and is currently operating successfully in Washington DC and Chicago, with ongoing preparation for installation in Atlanta.

Closing Comments

Most issues affecting the safety of a system represent a series of errors, oversights, omissions and poor communications and can culminate in tragic consequences while undermining the integrity of key pieces of rail transportation infrastructure[1].

The TCM software is intended to help identifying the potential for track circuit failure and alerting the operations and maintenance organizations to the potential threat in the shortest possible time.

[1] modified quote from LinkedIn

Acknowledgements

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL ACADEMY OF SCIENCES

APTA AMERICAN PUBLIC TRANSPORTATION ASSOCIATION

Track Circuit Monitoring tool source code sections and algorithms made available by WMATA *(special thanks to Tim Shoppa for his continued support in implementing the tool at CTA and other Transit Agencies)*

Pilot installation and Systems integration support provided by Chicago Transit Authority

Chose Track Circuit Monitoring Tool deployment after several years of inhouse research and development on Track Circuit Monitoring approaches

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QUESTIONS