Findings from the NYCT - FTA Wheel/Rail Analytics Project

A Research Project Overview

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Outline

- The project and team

- Some findings

- Project evaluation criteria

- Future R&D activities

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Wheel/Rail Research Project

2 Year SRER Research Project Lasting > 3 Years

- Collaborative Approach
- Multiple organizations – with strengths in the required areas
- Multiple Technologies – *Strength in Diversity*
- Leveraged prior Machine Vision Experience at NYCT
- Supported Team Analytics
- Balanced Transit Agency and Technology Company "NEEDS" & Benefits

Research Project Report

Final Report Submitted

Two Research Efforts will extend beyond the Period of Performance of the Original Research:

- Experimental Wheel Profiles on the DCC
- TOR Friction Management

Integrated Wheel/Rail Characterization through Advanced Monitoring and Analytics

FTA Project Number: NY-26-7113

Grantee Agency: New York Metropolitan Transportation Authority

Source: New York City Transit

**Final Project Report for a Collaborative Research Demonstration Effort by:**

KLD Labs
Dayton T. Brown
Plasser-American
National Research Council Canada
New York City Transit Subway Group
New York City Transit Office of Strategic Innovation and Technology

November 30, 2018

Monitor New York City Transit (NYCT) 7 Line

- 27.5 miles of track;
- 525,000 passengers/weekday;
- Captive Vehicle Fleet of 506 cars
- Up to 27 trains per hour in each direction;
- Elevated tracks and tunnels;
- 24/7 operation requires an optimized maintenance
- 7 partners, 3 years total
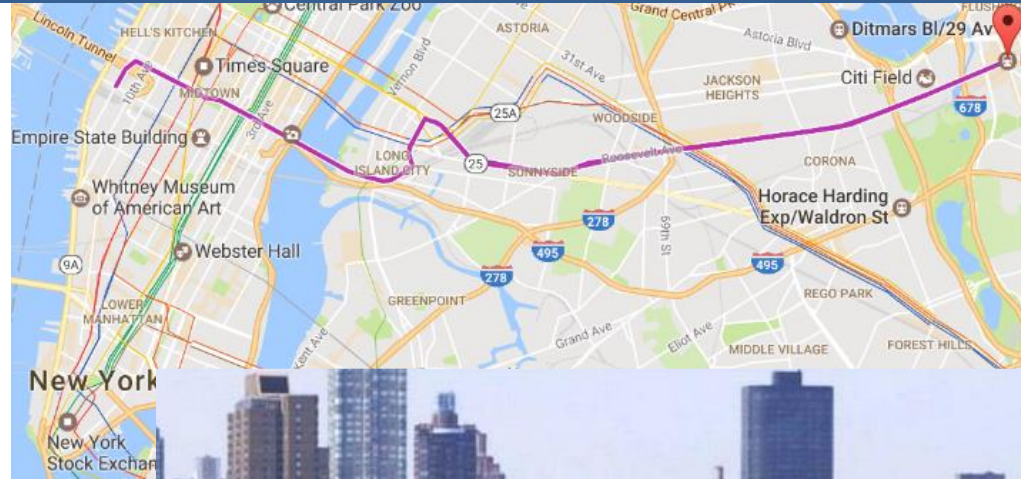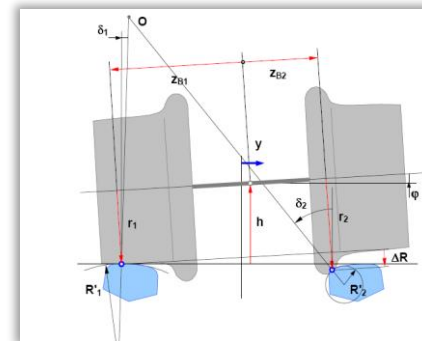
Introducing...

THE TEAM

NYCT WheelScan System

Plasser American

- **Effective Conicity analytics**
- **RFID position reading on TG car**

On-Vehicle Data Acquisition

Data Collection Consist (DCC)

2 instrumented wheelsets (IWS)

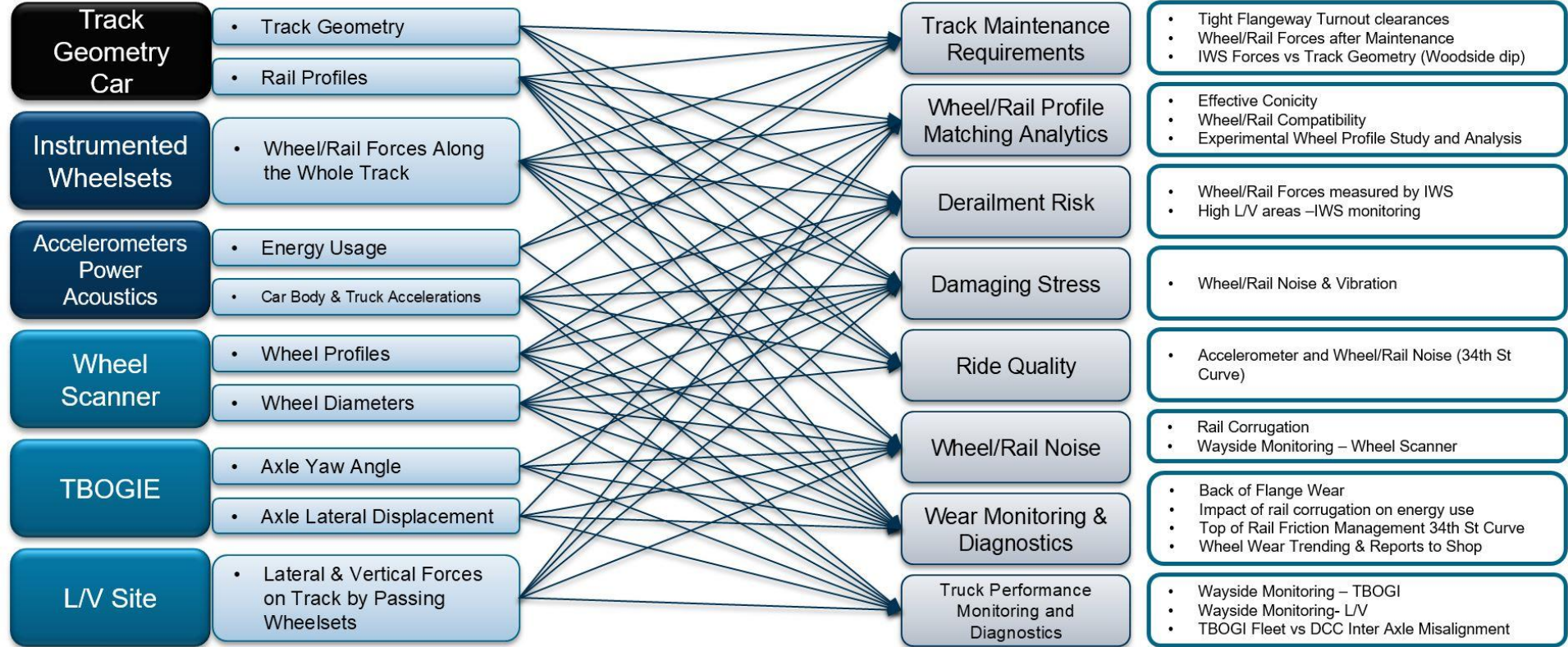- Provides accurate measurements of wheel/rail contact forces (vertical, longitudinal, lateral)
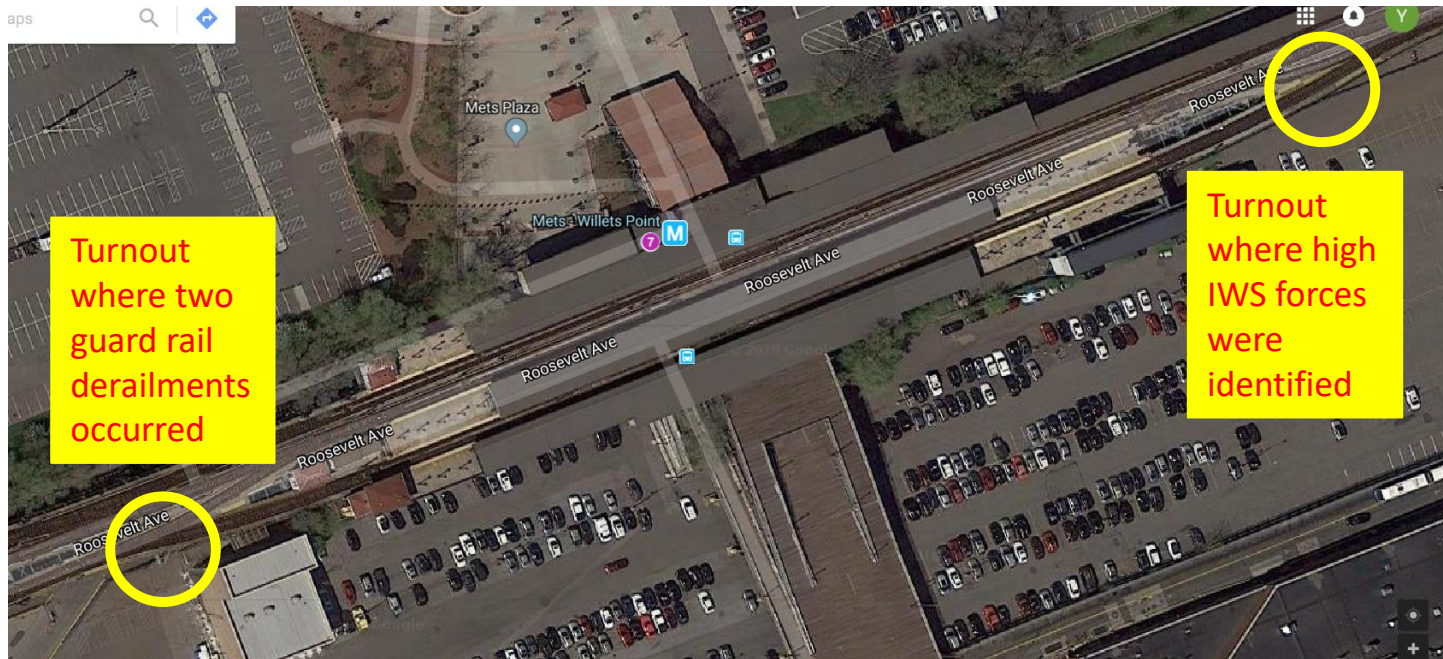
Consist Data Acquisition

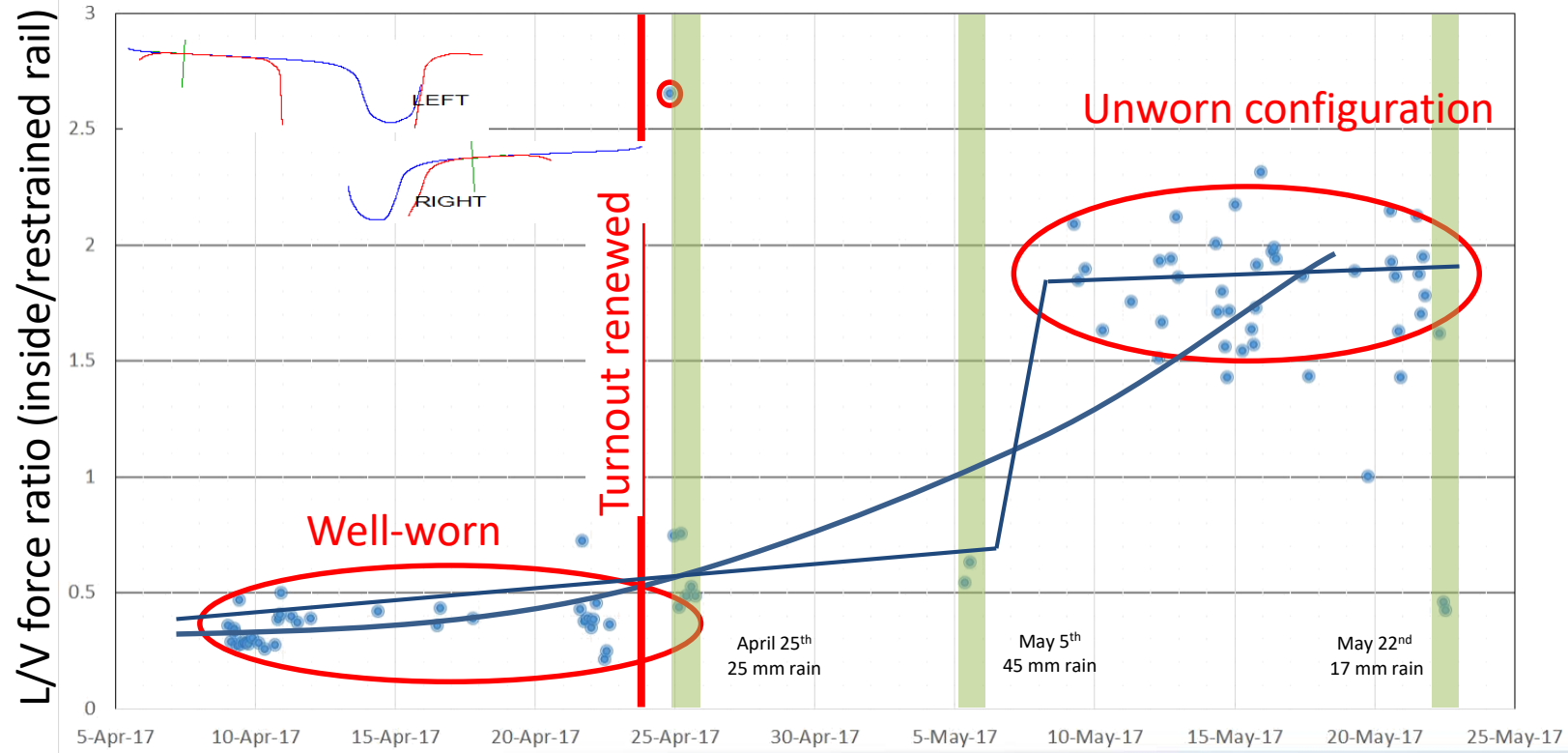- Accelerometers, acoustic recording equipment and propulsion energy recording equipment

Part of an 11 car consist in revenue service

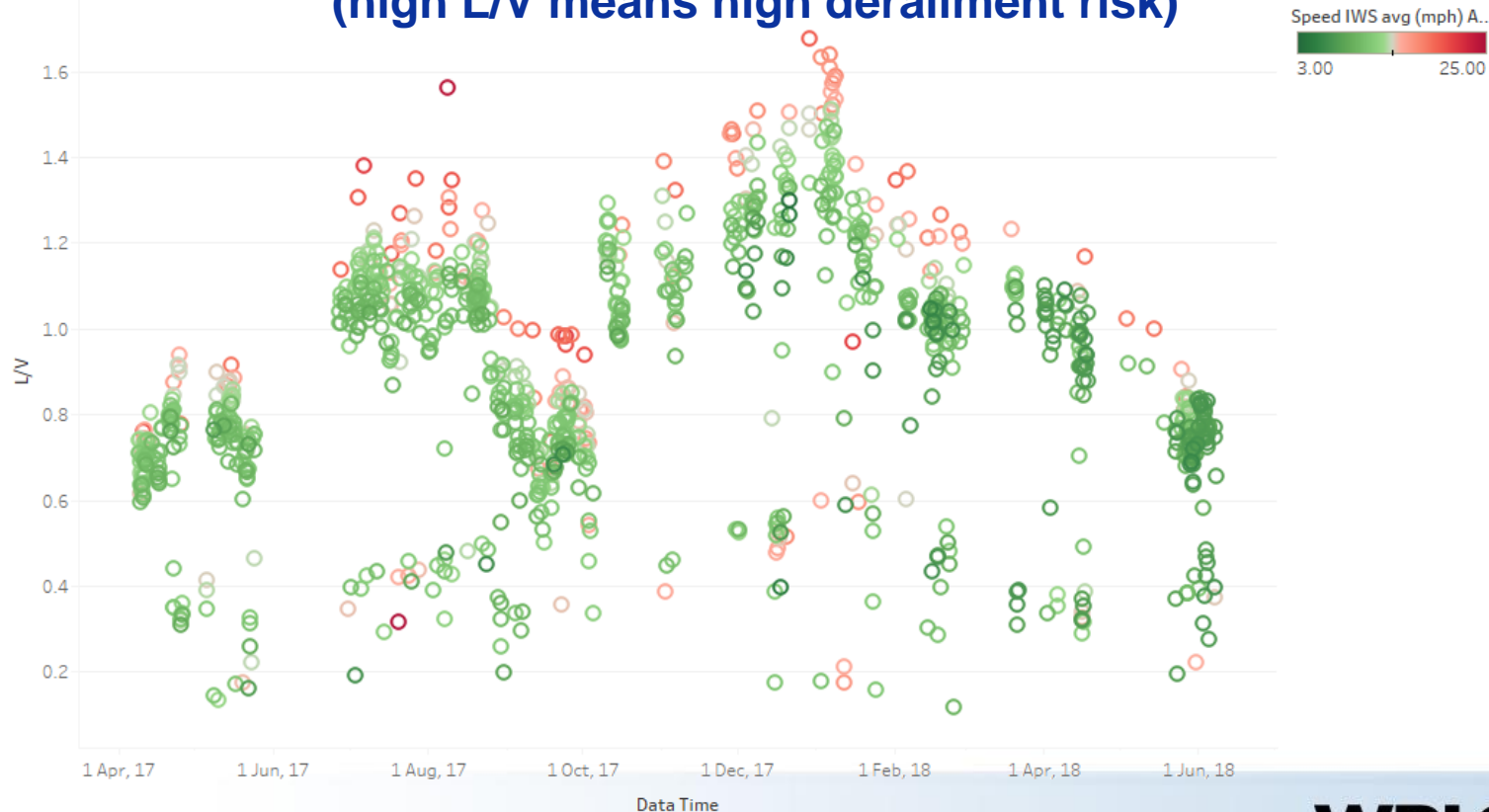- Daily dedicated real-time performance data acquisition

Track Geometry Car
- Track Geometry
- Rail Profiles

Instrumented Wheelsets
- Wheel/Rail Forces Along the Whole Track

Accelerometers Power Acoustics
- Energy Usage
- Car Body & Truck Accelerations

Wheel Scanner
- Wheel Profiles
- Wheel Diameters

TBOGIE
- Axle Yaw Angle
- Axle Lateral Displacement

L/V Site
- Lateral & Vertical Forces on Track by Passing Wheelsets

Track Maintenance Requirements
- Tight Flangeway Turnout clearances
- Wheel/Rail Forces after Maintenance
- IWS Forces vs Track Geometry (Woodside dip)

Wheel/Rail Profile Matching Analytics
- Effective Conicity
- Wheel/Rail Compatibility
- Experimental Wheel Profile Study and Analysis

Derailment Risk
- Wheel/Rail Forces measured by IWS
- High L/V areas –IWS monitoring

Damaging Stress
- Wheel/Rail Noise & Vibration

Ride Quality
- Accelerometer and Wheel/Rail Noise (34th St Curve)

Wheel/Rail Noise
- Rail Corrugation
- Wayside Monitoring – Wheel Scanner

Wear Monitoring & Diagnostics
- Back of Flange Wear
- Impact of rail corrugation on energy use
- Top of Rail Friction Management 34th St Curve
- Wheel Wear Trending & Reports to Shop

Truck Performance Monitoring and Diagnostics
- Wayside Monitoring – TBOGI
- Wayside Monitoring- L/V
- TBOGI Fleet vs DCC Inter Axle Misalignment

Turnout where two guard rail derailments occurred

Turnout where high IWS forces were identified

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Trending L/V Ratio with Date and Speed
(high L/V means high derailment risk)

Willets Point Derailments

| Contributing factor	Monitoring tool
Renewed track geometry	IWS
Wheel profile wear	Wheelscan
Back of flange geometry	Wheelscan
Effect of speed	IWS
Friction conditions	IWS, TGC video system
Flangeway clearance	IWS, TG Car
Position in trainset	L/V TBOGIE
Track geometry perturbations	Accelerometers

Quantified Operational Risks:
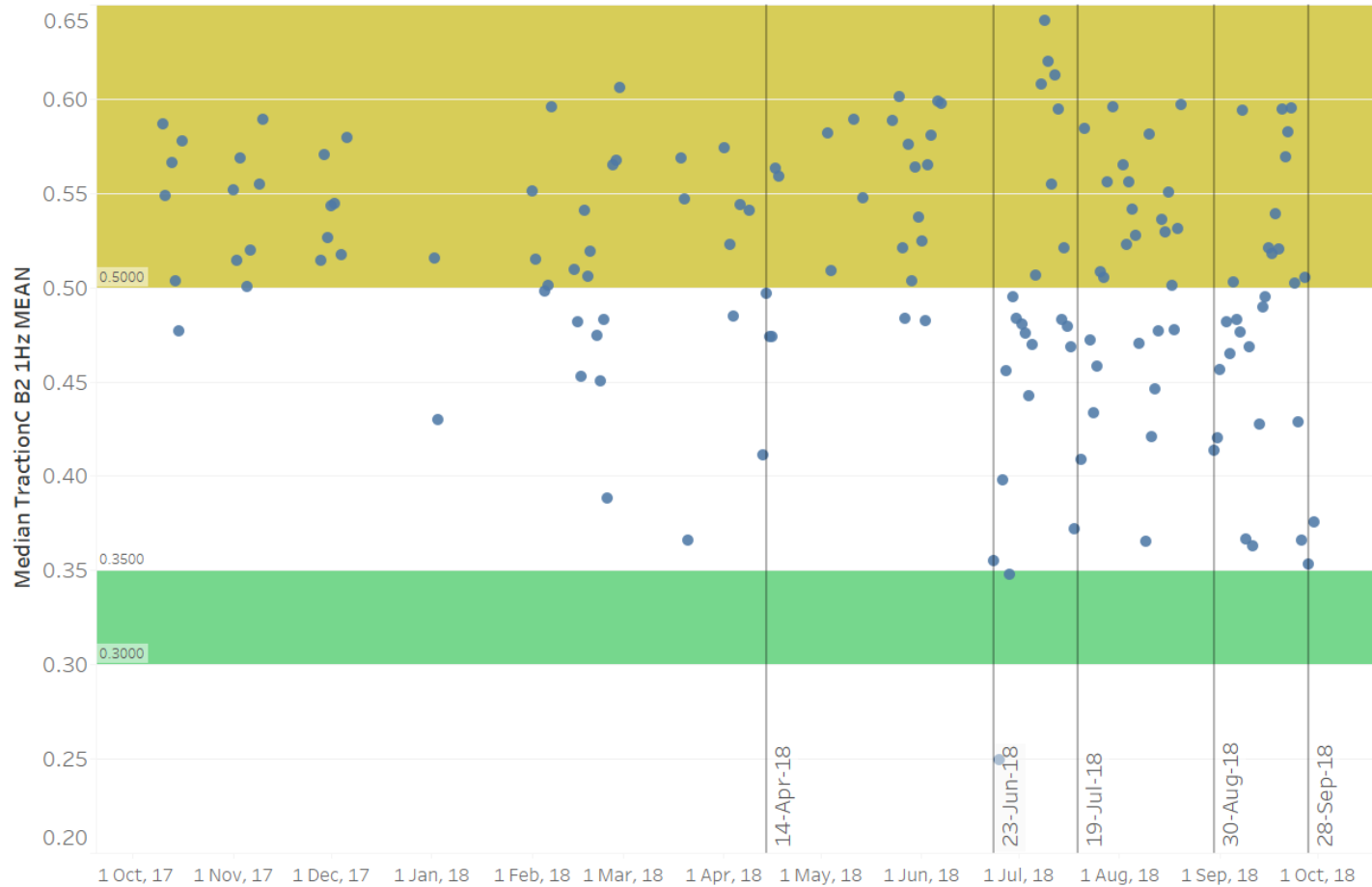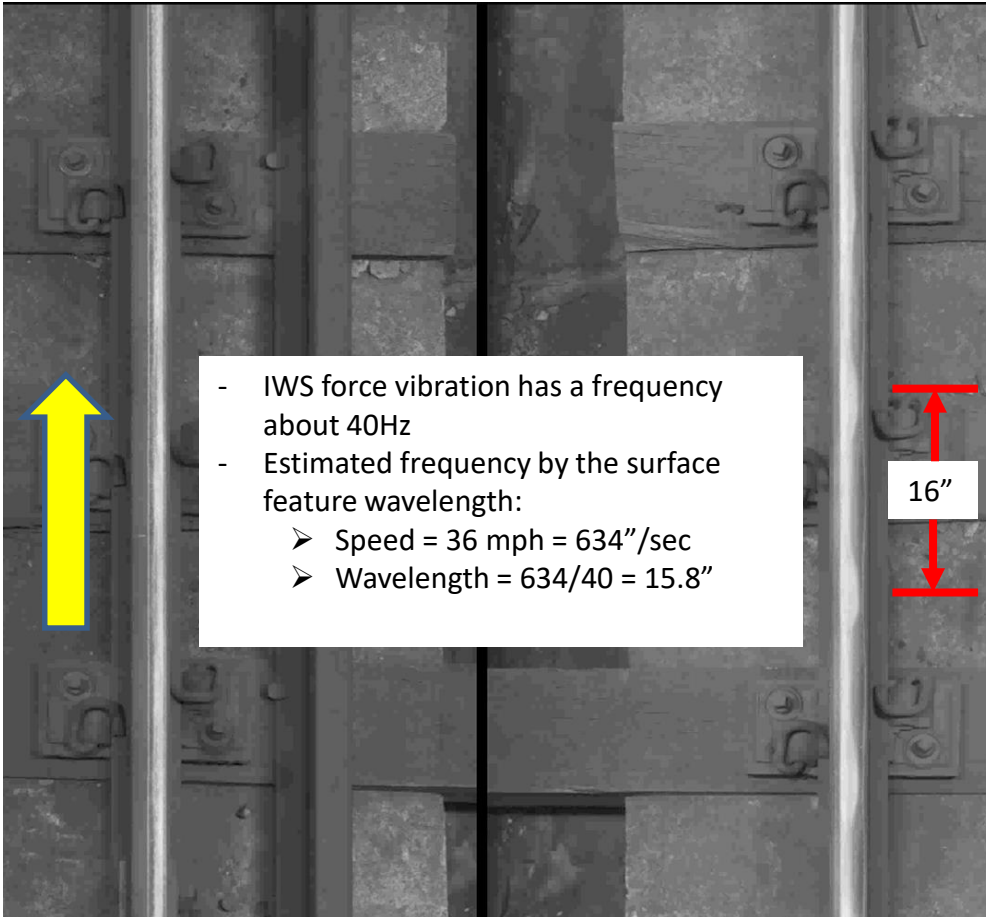# 60 m radius Restrained Curve
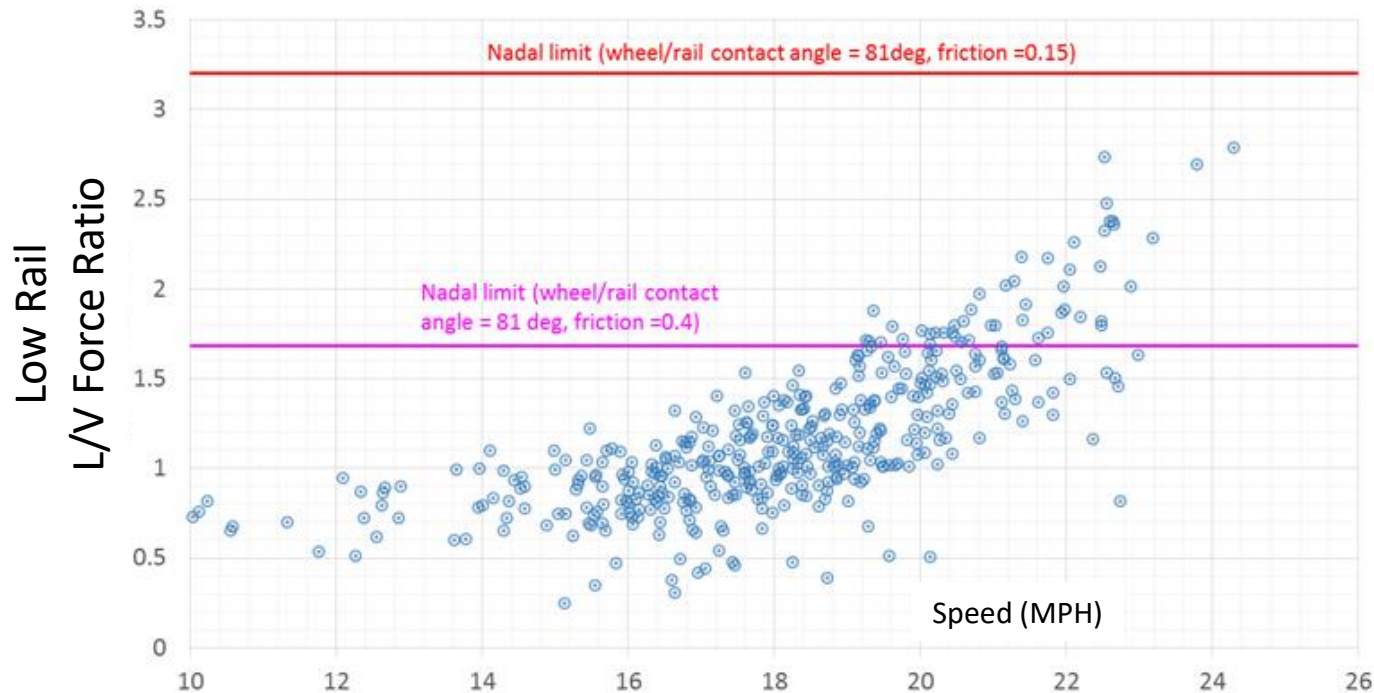
Effectiveness of Friction Management

Traction Ratio on Low Rail of 34th Street Curve @CC1 Entry
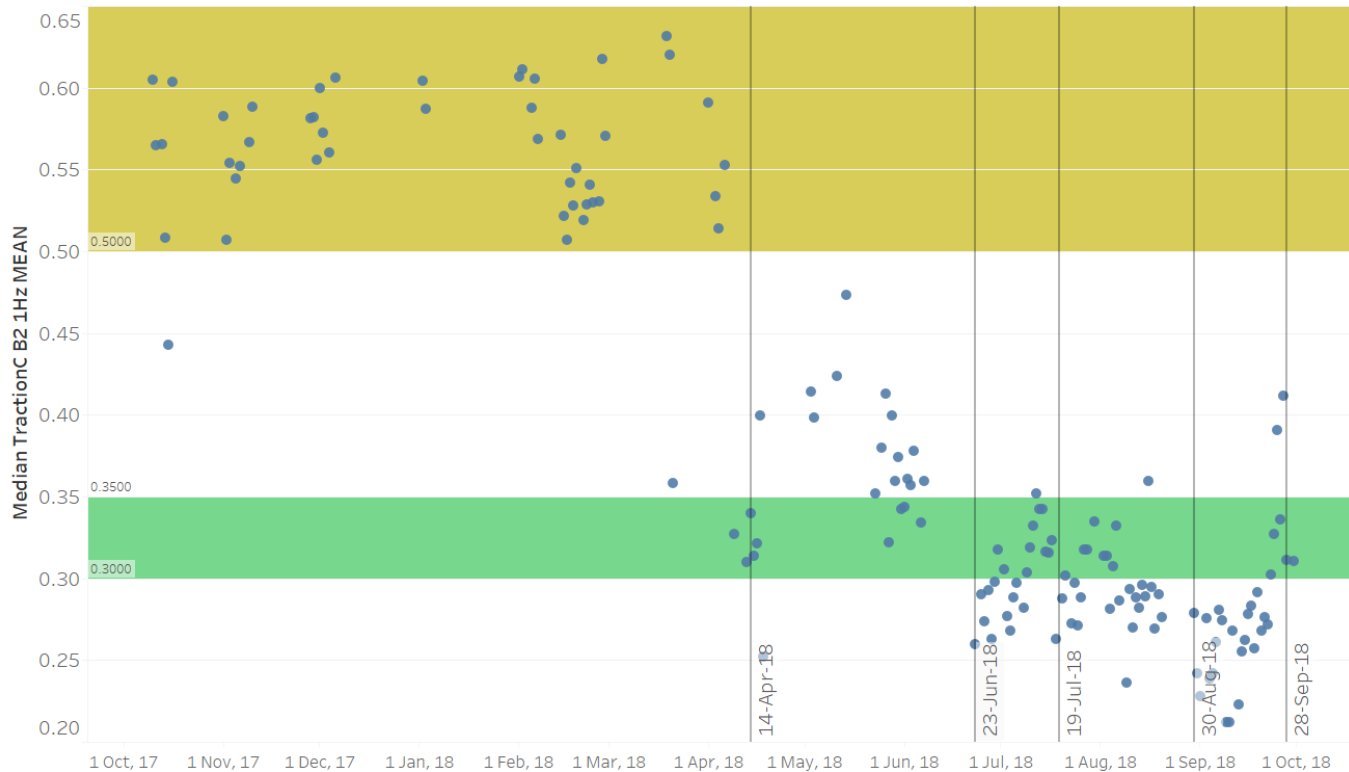
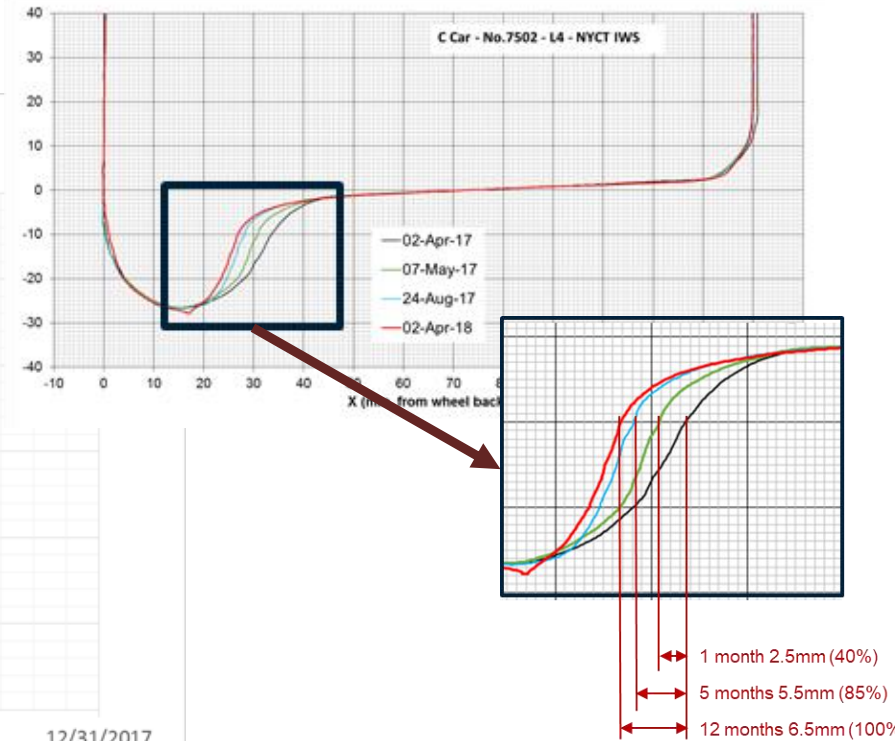Traction Ratio on Low Rail of 34th Street Curve @CC1 - Exit

- IWS force vibration has a frequency about 40Hz
- Estimated frequency by the surface feature wavelength:
  - ➤ Speed = 36 mph = 634"/sec
  - ➤ Wavelength = 634/40 = 15.8"

16"

Trending the Effect of Wheel Wear

Avg Lat Force (360 runs April 9 - Nov 10) C2 Leading High Rail on 46th Bliss St Curve

C Car - No.7502 - L4 - NYCT IWS

- 02-Apr-17
- 07-May-17
- 24-Aug-17
- 02-Apr-18

1 month 2.5mm (40%)
5 months 5.5mm (85%)
12 months 6.5mm (100%)

HOW DID WE DO?

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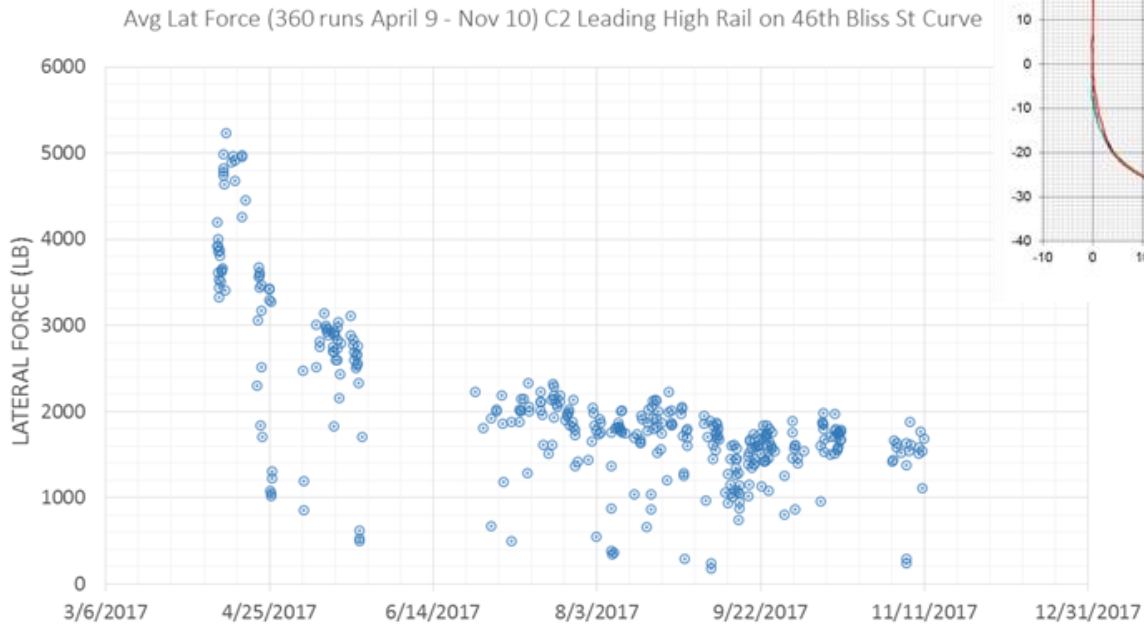
Work Schedule & Key Milestones

Table 1: Project Milestones and Actual Completion Sequence

Mile Stone	Milestones and Interim Milestone Completion Snapshot	Original Start Date	Original Completion Date	Oct 1 2016 Revised Completion Fcst	Jan 1 2017 Revised Completion Fcst	1-Apr-17 Revised Completion Fcst	1-Jan-18 Revised Completion Fcst	1-Apr-18 Revised Completion Fcst	1-Jul-18 Revised Completion Fcst	1-Oct-18 Reviseed Completion Fcst	1-Jan-19 Reviseed Completion Fcst	Actual Completion Date
1	**Notice to Proceed**	**1-Sep-15**										**21-Aug-15**
2	**Phase I: Instrumentation of Vehicles**	**15-Sep-15**	1-Mar-17									
	- Research Consist instrumented with on-board recorders and initiate data collection		1-Feb-16	1-Nov-16	*Completed*							**30-Dec-16**
	-Gate Meeting 1 Month 6 ~ Review of on-train Data Collection Deliverables		15-Apr-16	*Completed*								**25-Aug-16**
	-In-Track Wheel Profile System Commissioned and Wheel Profile Data collection initiated		1-Aug-16	15-Nov-16	25-Jan-17	*Completed*						**19-Jan-17**
	-Way-side L/V anfd TBOGI devices opeational and data collection initiated		1-Sep-16	15-Nov-16	1-Mar-17	20-May-17						
	- Instrumented Wheel Sets instaled and commissioned on DCC		1-Nov-16	15-Feb-17	1-Mar-17	*Completed*						**31-Mar-17**
	- Integrated Wheel Profile, TGC and way-side devices, software integration completed		2-Jan-17	25-Feb-17	1-Mar-17	1-Jun-17	*Completed*					**11/30/2017**
	- Analytics Functionality is ready to support Phase II Data Collection of "As-Is"		1-Mar-17	1-Mar-17	1-Mar-17	1-Jun-17	*Completed*					**11/30/2017**
3	**Phase II Optimization of the Analytics and Data Collection**	**16-Mar-17**	1-May-17									
	- Review of Phase I Deliverables and Establishment of Phase II Objectives		16-Mar-17				*Completed*					**11/1/2017**
	- Phase II "As-Is" Data Collection and Analytics Systems Demonstrations		1-May-17				*Completed*					**11/30/2017**
4	**Phase III: Demonstration of Improved Wheel/Track Management**	**1-May-17**	1-Aug-17									
	-Review of Phase II Deliverables and Establishment of Phase III Objectives		15-May-17				1/10/2018	*Completed*				1/15/2018
	-Phase III Modification A: 34th Street Curve Analytics & System Demonstration		3-Jul-17				3/15/2018	6/30/2018	7/31/2018	11/30/2018	12/30/2018	12/30/2018
	- Phase III Modification B Wheel Profile Change with Analytics & System Demonstration		1-Aug-17				3/15/2018	6/30/2018	9/30/2018	12/10/2018	1/31/2019	1/30/2109
5	**Final Report**	**1-Aug-17**	1-Sep-17				3/31/2018	9/30/2018	9/30/2018	12/15/2018	2/28/2019	2/28/2019

Key Milestones were met, but Schedule Slippage was experienced.

Project Evaluation Criteria

- Operational Safety

- Infrastructure and equipment resiliency

- Reduced energy use

- Increased service life of assets

- Reduced cost of asset ownership

- Improve customer service and customer experience

PEC – Operational Safety

- Rail Corrugations and high lateral forces → trial TOR Friction Management
- Identified back of flange (BOF) wear issues.
- L/V forces ↑ with execution of track maintenance
- Excessive speed ↑ higher risk
- Tight gauge contributes to instability

PEC Reduce Energy Use

- Use of TBOGI to identify "worse performers"
- Effective conicity analytics identify locations at higher risk for hunting.
- DCC traction energy monitoring shows
  - Corrugation increases energy consumed in one curve by 7%.
  - Friction management measurably reduce energy requirements.

PEC: Recapture of Investment (Value Proposition)

Estimated Maintenance Cost Avoidance resulting from Research work:

- Elimination of one fleet wide (506 cars) non-optimum wheel replacement before planned SMS

Break Out of just the SMS Truck related work with estimates for non-optiimum (off-SMS Cycle) wheel work		
LABOR Estimate		**MATERIAL Estimate**
797 Man Hours for Truck Work in SMS Cycle/Car		$55,413 Material Cost/Car for Truck SMS Work
$35.00 Hourly wage estimate		
$27,895 Total Labor Cost/car for Truck SMS		
506 # Cars in #7 Line Fleet		506 # Cars in #7 Line Fleet
$14,114,870 Total SMS Cost just for Labor on Truck Work		$28,038,978 Total Materials Cost just for Truck Work in SMS Cycle
50% Estimate of Labor (%SMS Truck Labor) for Non-Optimum Wheel Change		10.00% Estimate of Wheel and axle costs in SMS Cycle Material
$7,057,435		$2,803,898
Estimated Cost Avoidance of one wheel change between SMS Cycle:		$9,861,333
Avoids one Non-Optimum Wheel Change by end of Year 2 of 6 Year SMS Cycle		

PEC: Recapture of Investment (Value Proposition)

Estimated Maintenance Cost Avoidance resulting from Research work:

- Avoidance of 30 Day Mid-Cycle Manual Wheel Measurements: ~ $250,000/yr.

- Monitoring and Reduction of Wheel/Rail performance associated with Derailment Risk

- Maintenance Cost Reductions associated with increasing data driven Condition-Based Maintenance

PEC: Improve Customer Service and Customer Experience

- Higher noise areas identified by external microphones may prompt intervention (e.g. grinding or friction management
- Excessive noise, truck hunting and vertical vibration may be identified and reduced
- Monitoring permits high force/risk areas to be addressed proactively, increasing reliability

FUTURE APPLICATIONS AND R&D ACTIVITIES

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Asset Management

- Baseline performance (forces, vibration, etc.)

- Establish maintenance limits

- Monitor, trend report on condition/performance

- Recommend/program interventions
  - Wheel retruing
  - Truck inspections
  - Rail grinding (corrugation, profile)
  - Friction management

State of Good Repair

- Requires
  - Metrics for evaluating component and system performance
  - Regular reporting
- Autonomous (performance based) systems
- Programmed metrics over several data streams
- Set (prescriptive and performance-based) maintenance and safety limits
- Automatic/continuous reporting

Other Follow-on Research

- Data Analytics
  - Wear, corrugation, defects, safety, vehicle performance, energy
- Component and system design optimization
  - Root cause analysis for above problems, design solutions
- Data reporting and implementation - programs to visualize and report
  - Automated data collection
  - Rail safety standards
  - State of Good Repair reporting

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Thank you!

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