U.S. Department of Transportation
Federal Railroad Administration

OFFICE OF RESEARCH DEVELOPMENT & TECHNOLOGY
FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT

Autonomous Track Geometry Measurement System

Technical Development & Short Line Demonstration

Edited from presentation delivered at American Short Line and Regional Railroad Association (ASLRRA) on April 24, 2017

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Federal Railroad Administration,
Office of Research, Development & Technology

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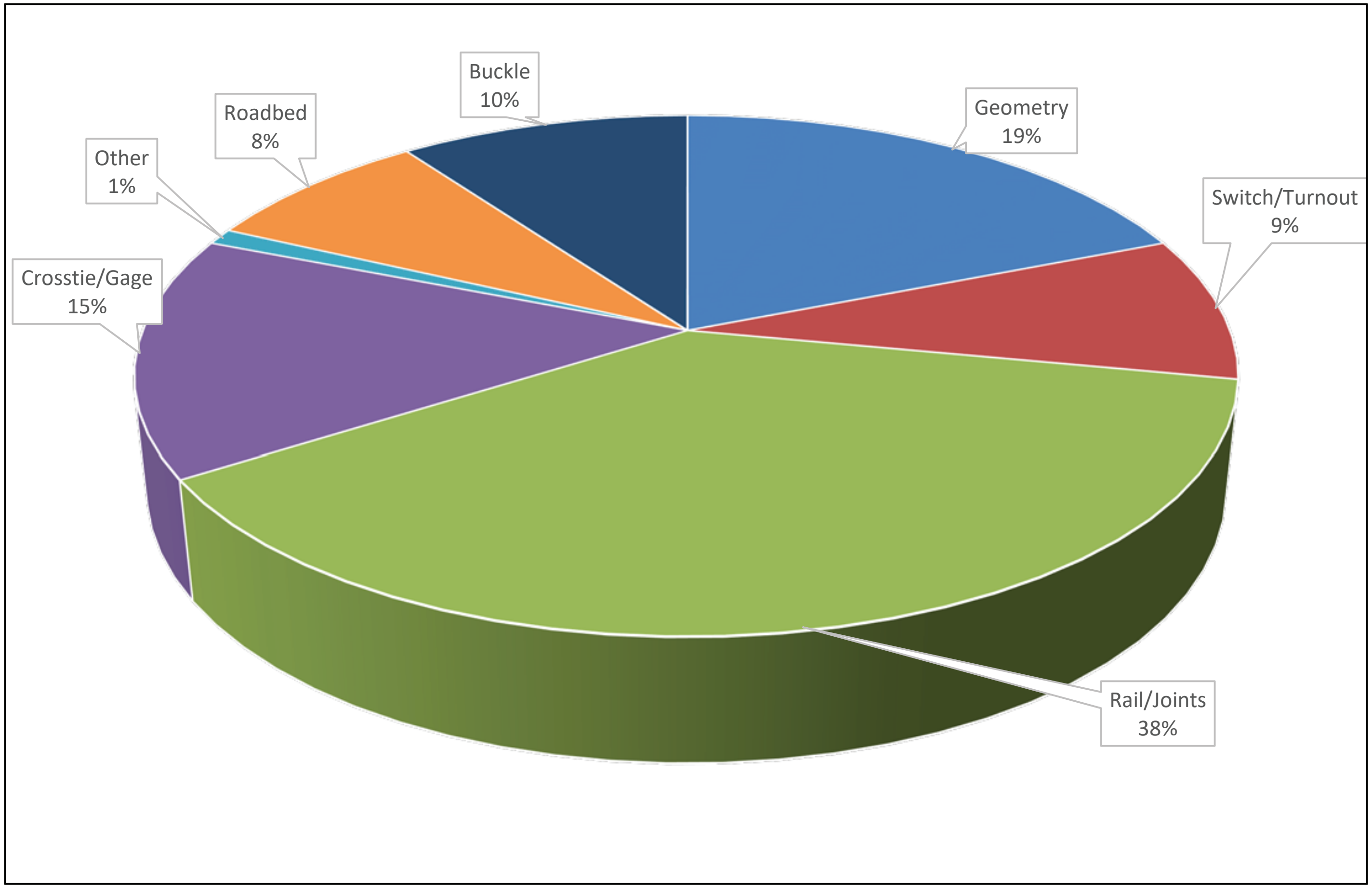
Outline

- Program Vision & Objectives
- Technical Development
- Freight Service Demonstration
- Demonstration Results & Lessons Learned
- Future Plans

Safety Impact

2016 Damage Share by Cause Category

Source: FRA



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What is Autonomous Inspection?

Autonomous Inspection – Process of inspecting the track from revenue service trains using unattended instrumentation with minimal direct involvement.

Autonomous Track Geometry Measurement System (ATGMS) technology is designed to <u>enhance</u>, not replace, traditional inspection methods.

ATGMS – Program Vision

To augment field inspections with state-of-the-art tools that can provide greater coverage and highlight safety risks

ATGMS: A relatively low cost Track Geometry System that is self-powered and adaptable to a wide range of rail vehicles

- Reduces the life-cycle costs of measurement operations
- Eliminates interference with revenue operations
- Increases inspection frequencies and productivity
- Collects data of the highest quality possible—available over the Internet

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ATGMS – Key Benefits

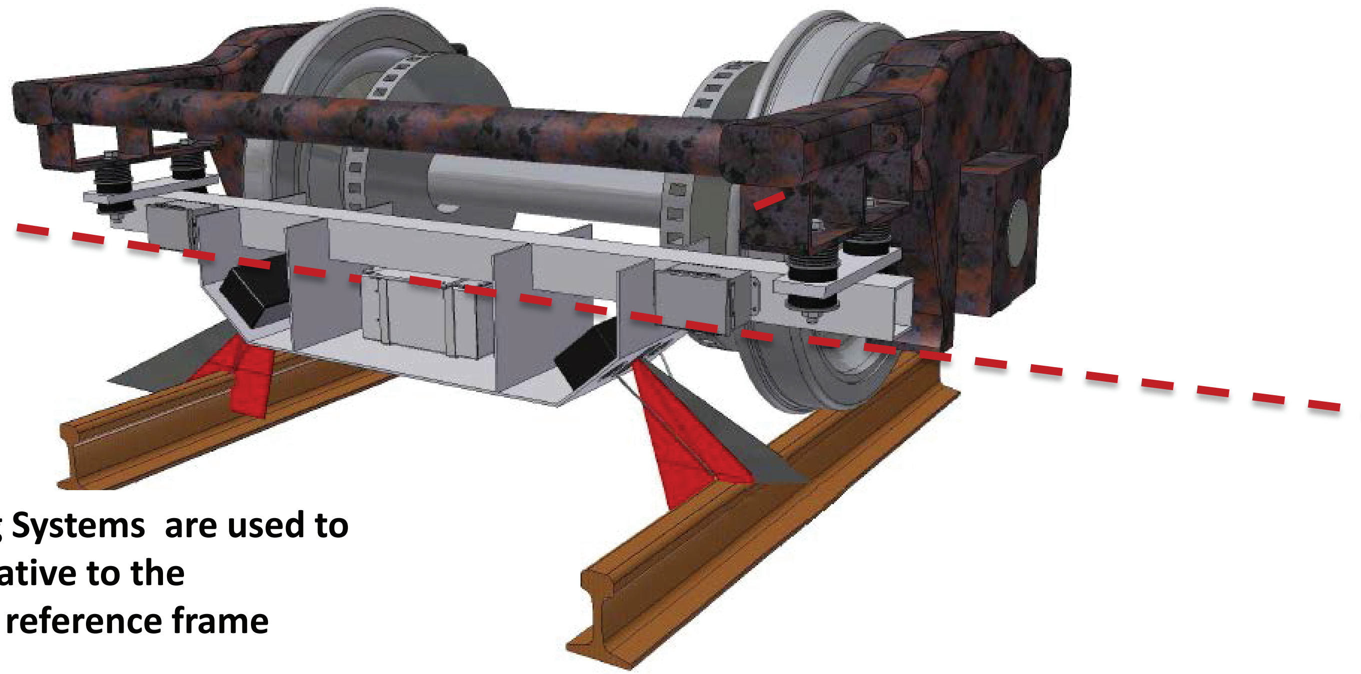
- Earlier identification of anomalies through more frequent inspections.
- More efficient inspections at much lower overall costs.
- Planned maintenance instead of reactive maintenance, resulting in fewer emergency repairs or slow orders.
- Automatic notifications through internet/email.

Every train movement presents an opportunity to assess the vehicle and track system . . . .

Measurement Technique

Inertial Sensors are used to locate the measurement reference frame in space relative to the track

Reference Frame



Laser Scanning Systems are used to locate rails relative to the measurement reference frame

Technology Development Process

Stage 1

Stage 2

Stage 3

Stage 4

Stage 5

- Long-term Pilot w/ Standard Technology - Amtrak Auto Train (2008–2011, 460k miles)
- Standard Service Simulation - DOTX 221 with DOTX 220 (2011–2013, 40k miles)
- Advanced Measurement Technology - Amfleet, Northeast Corridor [NEC] (2012–2013, 50k miles)
- Development of Energy Harvesting Technology - Solar, Methanol Generator
- Freight Service Demonstration (2016–2017, 13k miles)

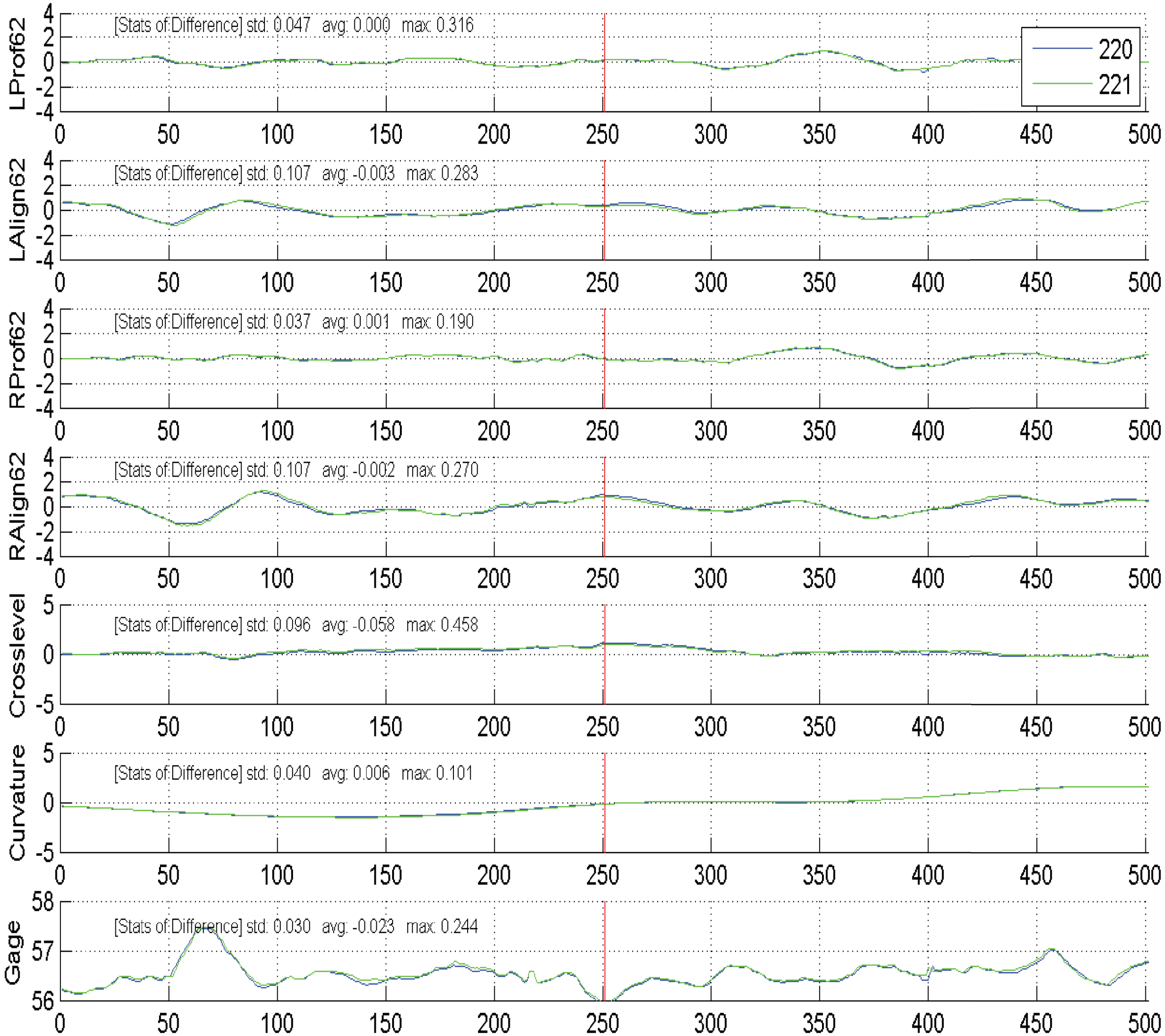
Stage I – Long-Term Pilot with Standard Inspection Technology

- Ruggedized truck-mounted pilot system using commercial-off-the-shelf (COTS) equipment
- Onboard automated processing for exceptions to Track Safety Standards
- Cellular communication and transmission of exceptions
- Powered from train
- Amtrak Auto Train - 460,000 test miles

Stage II – Service Simulation

- Real Time Data - Cellular transmission of all sensor data to processing server
- Onboard self-diagnostics & auto-recovery features
- Web application for added data quality assurance and geometry exception validation
- Documented system accuracy through comparison of FRA's DOTX 221 and DOTX 220 data
- 40,000 test miles

Stage II – Service Simulation (cont.)

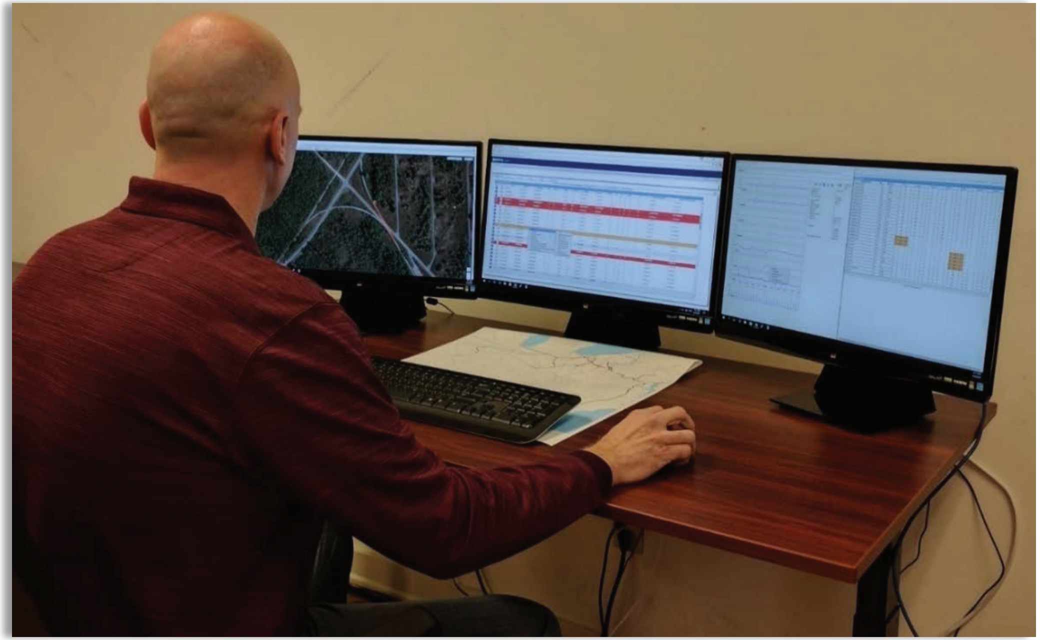


Good agreement between foot-by-foot measurements collected by systems mounted on two different vehicles

62 ft. mid-chord offset measurements collected by manned and autonomous systems over switch, 31 mph

Remote Editor Desk

- Data Quality Check
- System Control
- Exception Validation
- Distribution of Results



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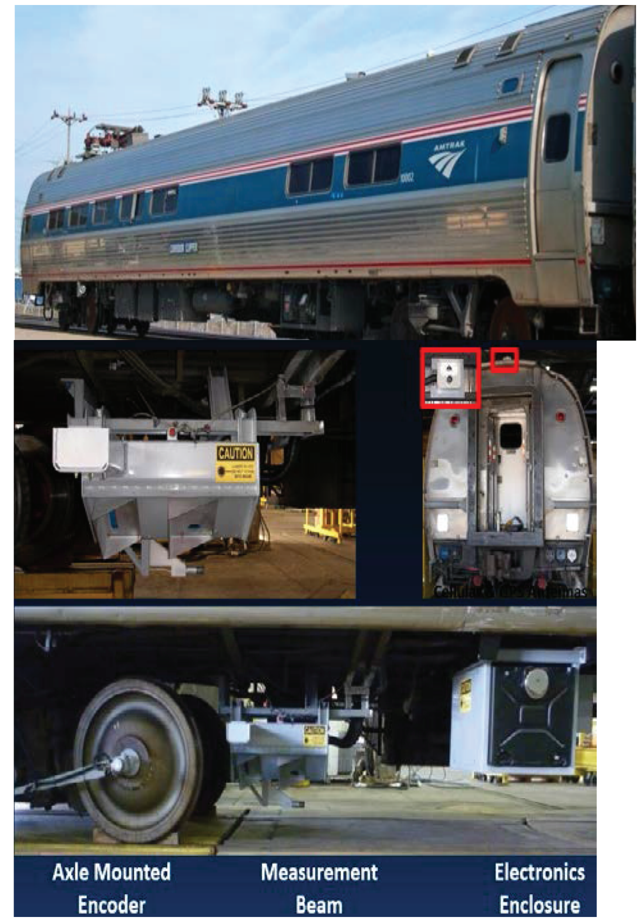
Stage III – Advanced Measurement Technology

- Carbody-mounted ATGMS
  - Minimizes interference with truck/wheel set maintenance
  - Protects against flying debris/mud
  - Modular design
- Back-to-back runs on NEC
  - Amtrak 82602 (ATGMS)
  - Amtrak 10002 (Manned geometry car)
- 50,000 test miles

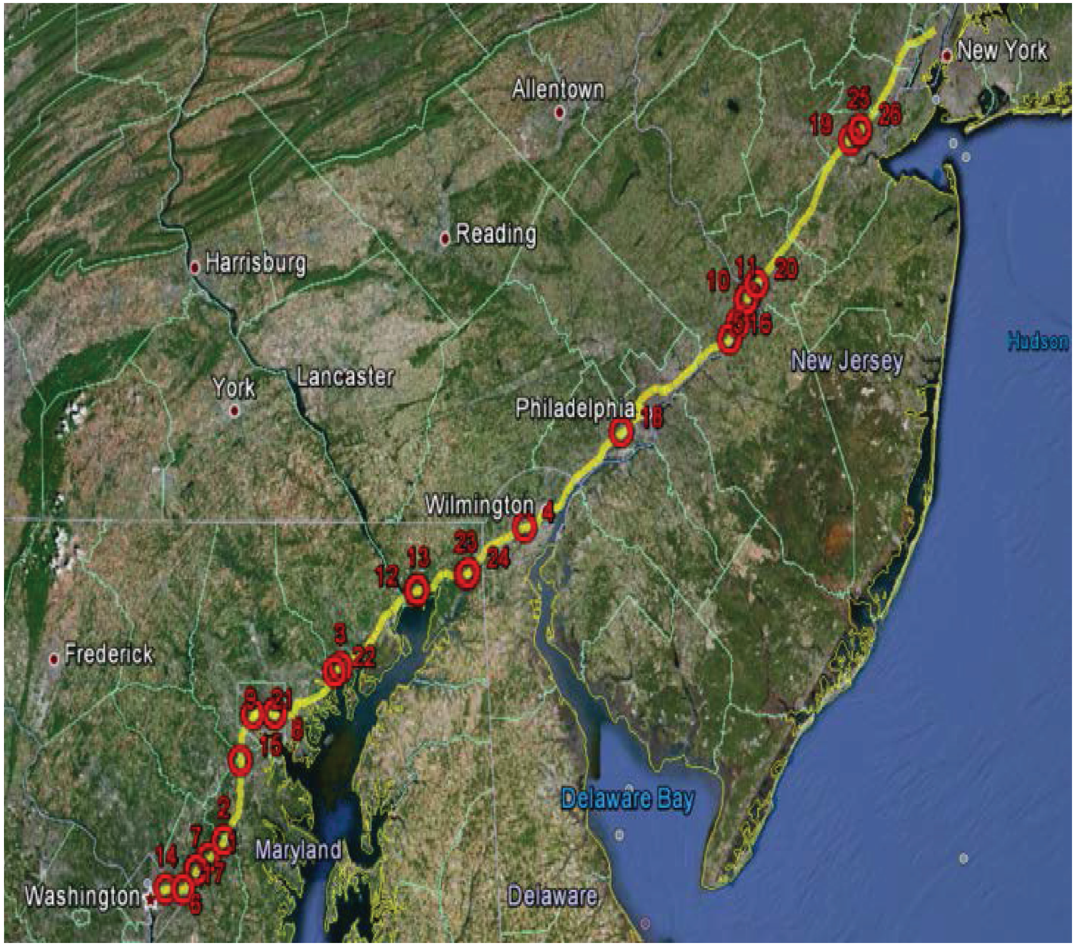


Stage III – Advanced Measurement Technology (cont.)

- Easily adapts to different car types (freight and passenger)
- Higher clearance
- Simpler design
- Reduced capital cost of technology

Stage III – Advanced Measurement Technology (cont.)

- Comparison of 26 locations between Washington, DC, and New York
- Various track features



Stage III – Advanced Measurement Technology (cont.)

Statistics of Differences Between Foot-by-Foot Geometry Measurements

Geometry Parameter	Mean Difference (Inches)	Standard Deviation (Inches)
L Profile 31' (Inches)	0.00004	0.0215
L Profile 62' (Inches)	-0.00003	0.0238
L Profile 124' (Inches)	0.00068	0.0306
L Alignment 31' (Inches)	0.00000	0.0213
L Alignment 62' (Inches)	-0.00003	0.0297
L Alignment 124' (Inches)	-0.00030	0.0557
R Profile 31' (Inches)	-0.00002	0.0255
R Profile 62' (Inches)	-0.00007	0.0278
R Profile 124' (Inches)	0.00028	0.0340
R Alignment 31' (Inches)	0.00010	0.0327
R Alignment 62' (Inches)	0.00015	0.0401
R Alignment 124' (Inches)	0.00009	0.0669
Crosslevel (Inches)	-0.03984	0.0751
Curvature (Deg/100')	0.01097	0.0130
Gage (Inches)	0.05499	0.0274

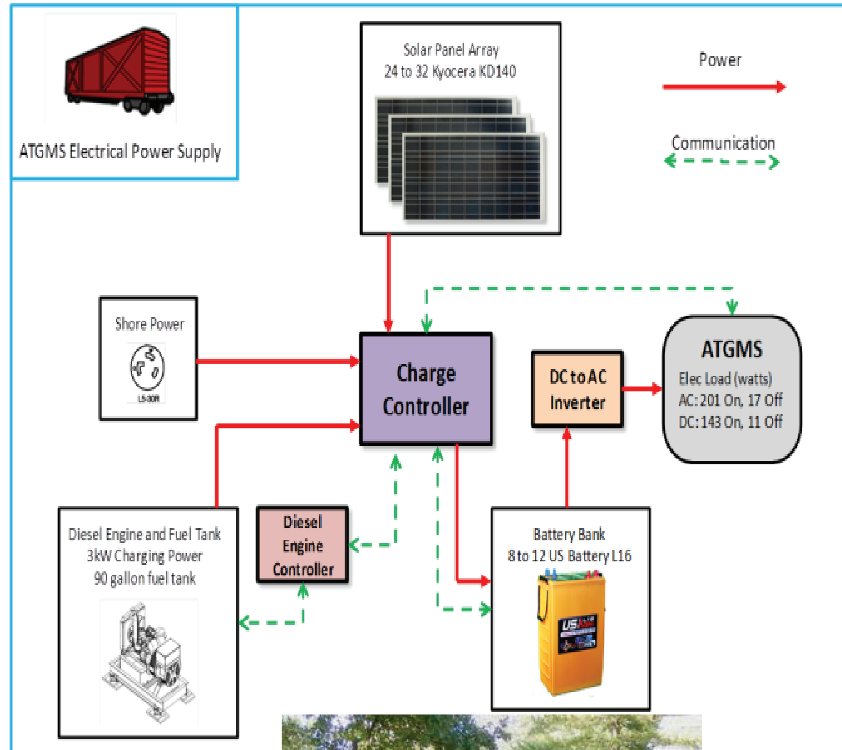
82602 ATGMS compared to 10002 Manned - April 3, 2013

Repeatability Thresholds for Foot-by-Foot Geometry Measurements

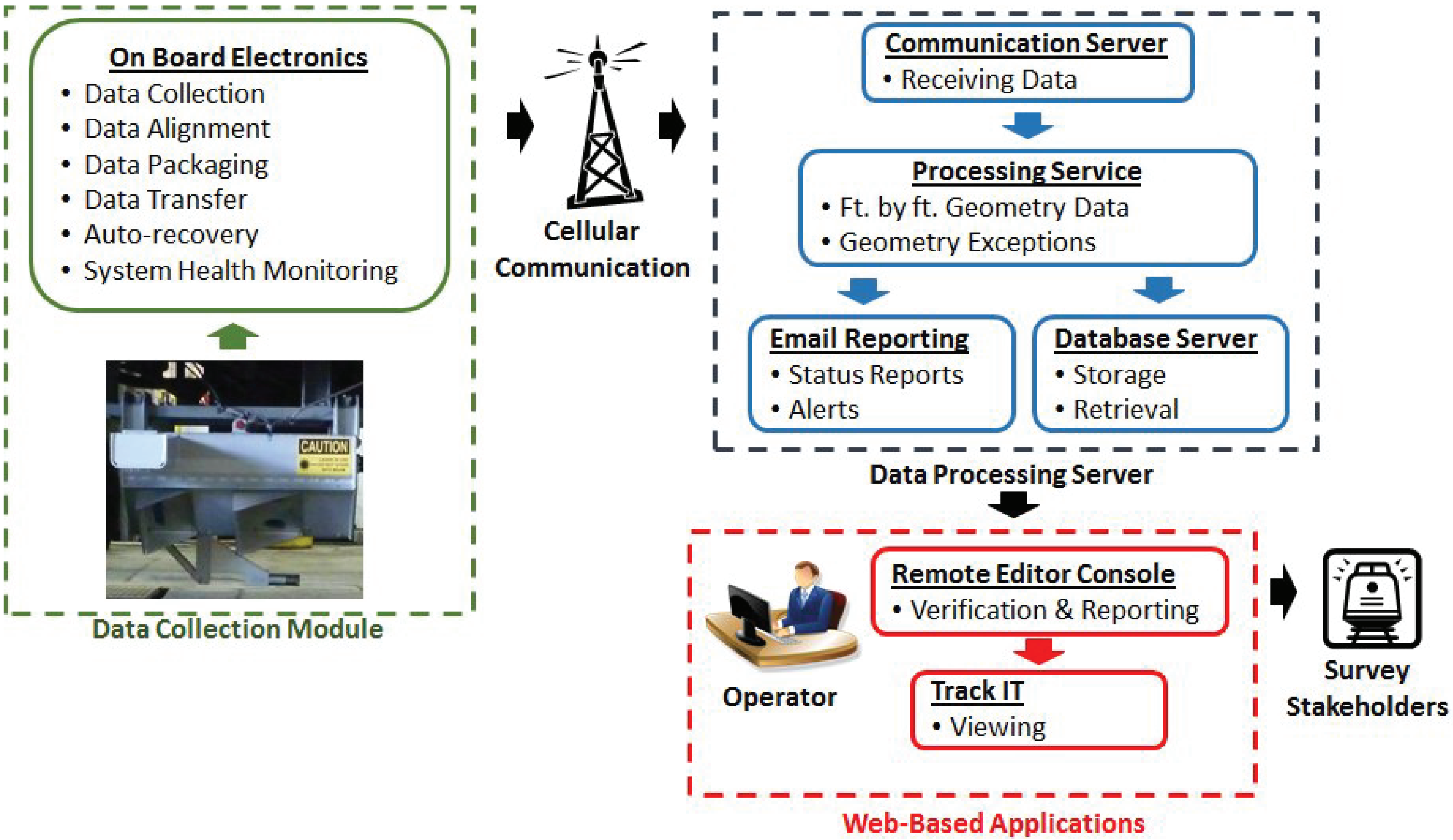
Geometry Parameter	Standard Deviation (Inches)
Profile (Inches)	0.08838
Alignment (Inches)	0.17675
Crosslevel (Inches)	0.08838
Curvature (Deg/100')	0.21210
Gage (Inches)	0.08838

Stage IV – Energy Harvesting Technology

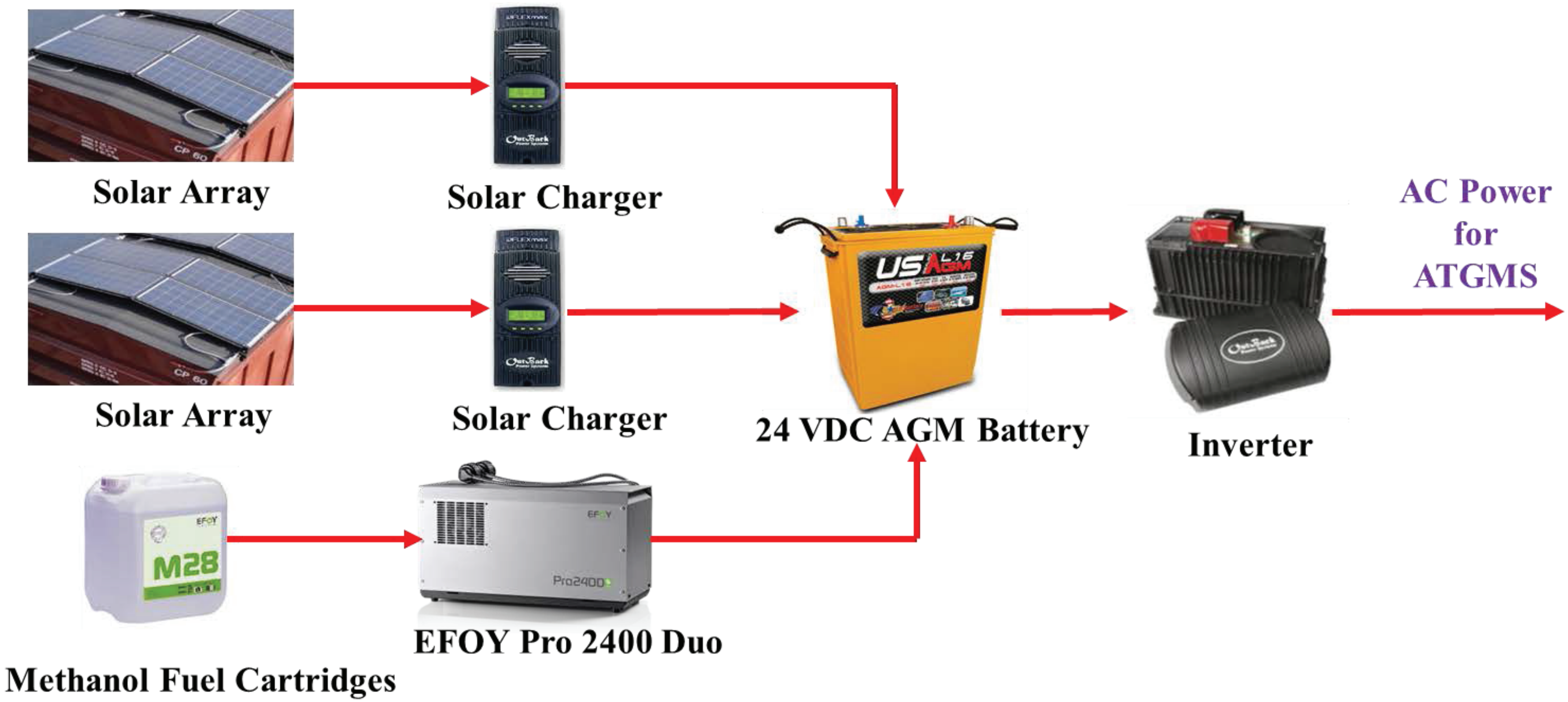
- Evaluated solar, wind, and fossil fuel power sources under different operational and environmental conditions.
- Identified operating temperature, mechanical, electrical, and safety requirements to maximize use of off-the-shelf components.
- Explored alternatives to diesel generators – fuel cells.
- Ruled out wind energy as an efficient source of power generation.



ATGMS System Architecture

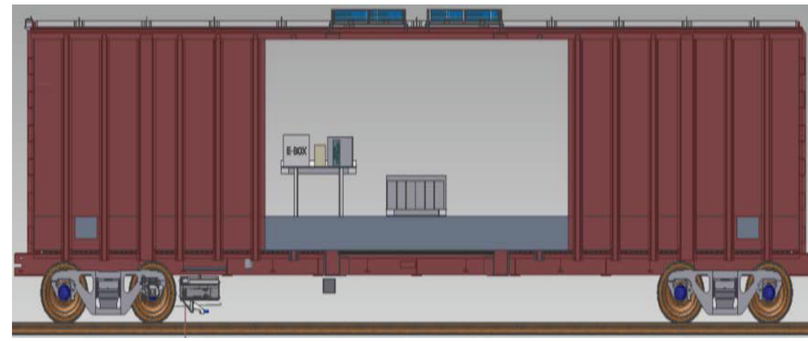


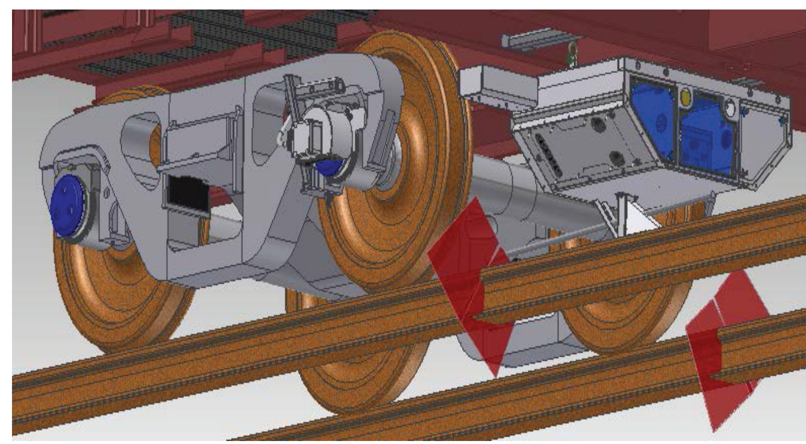
ATGMS Power System Architecture



Stage V – Freight Service Demonstration

- Challenges:
  - Modular ATGMS electrical power system using solar energy and direct methanol fuel cell (DMFC) technology as primary and secondary sources of power.
  - Remote monitoring/control of ATGMS electrical power system.
  - Can we use standard waybill procedures to complete the survey?





DOTX 225 – ATGMS Performance Specifications

- Plate C, Class 5 – 80mph

Parameter	Standards (Std. Dev.)	ATIP Truck-Mounted System (STD)	Carbody-Mounted System (STD)	Speed Limit
Gage [in]	0.0625	0.015~0.025	0.02~0.035	0 - max
Curvature [deg]	0.15	0.006~0.06	0.006~0.06	0 - max
Crosslevel [in]	0.0625	0.03~0.06	0.04~0.075	0 - max
Profile MCO62 [in]	0.0625	0.015~0.03	0.02~0.045	5mph – max
Alignment MCO62 [in]	0.125	0.02~0.04	0.03~0.055	15mph - max

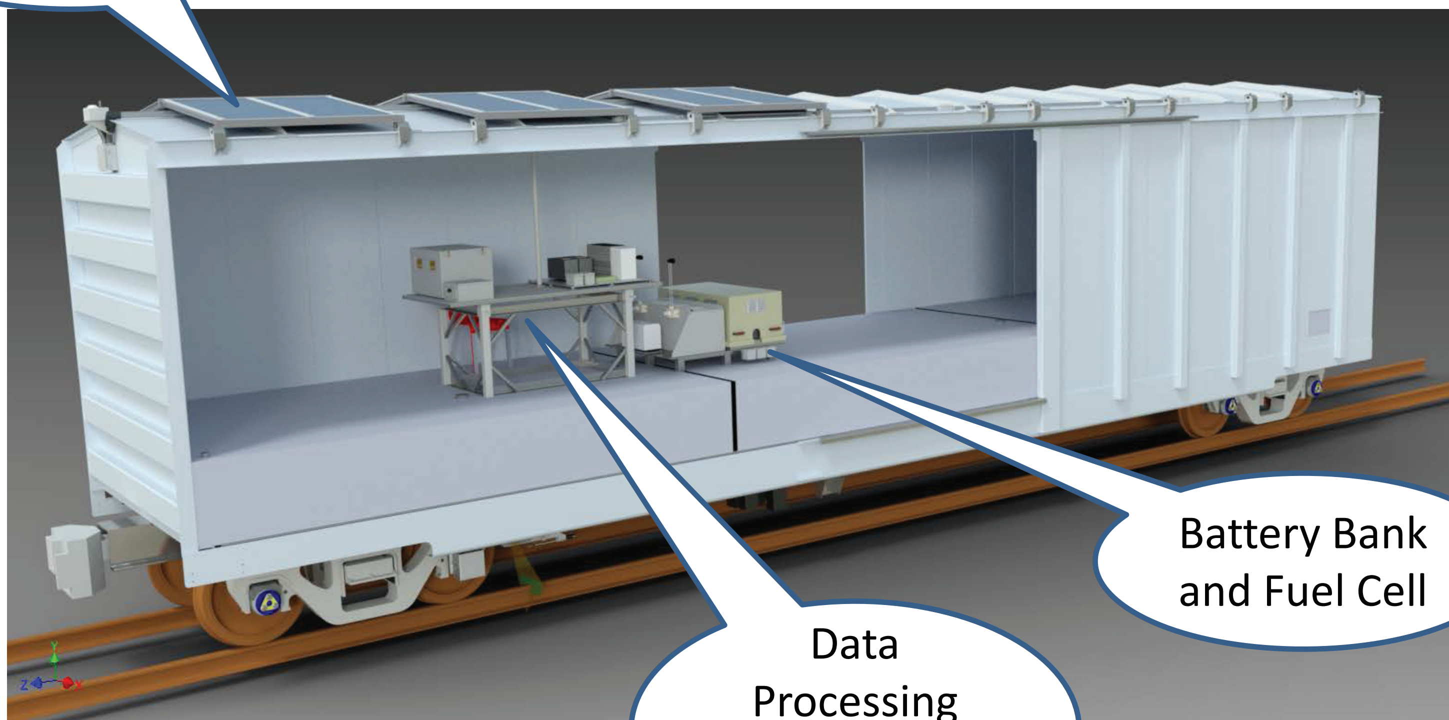
ATGMS – Freight Car

- Paper service boxcars purchased and refurbished for ATGMS service.
- Special thanks to Escanaba and Lake Superior Railroad for cars and rehab work.

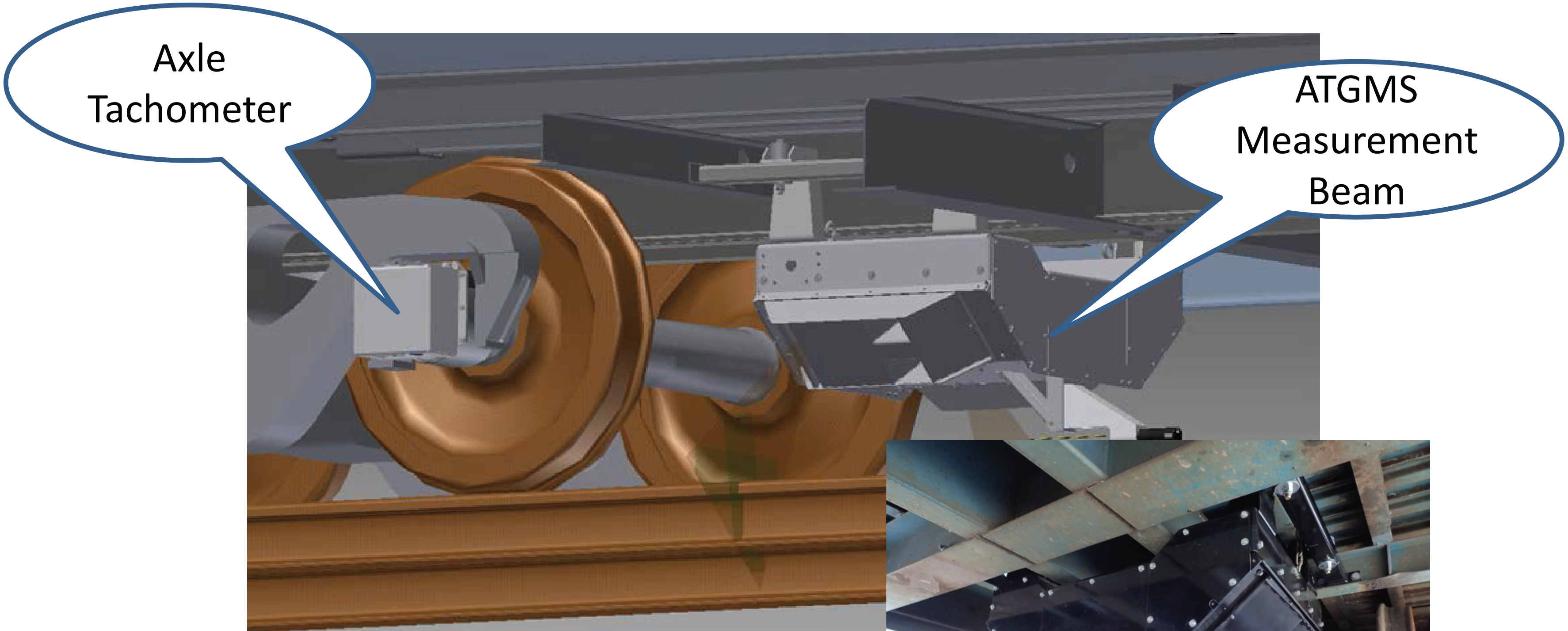
DOTX 225 – Features

- 1978, 70 ton, paper service
- Ballast: Fiber-reinforced concrete (22”)
- Weight: ~200,000 lbs on rail
- Truck-mounted brake conversion
- Refurbished trucks and suspension
- Drains, vents, ladders, safety rails, mounting rails

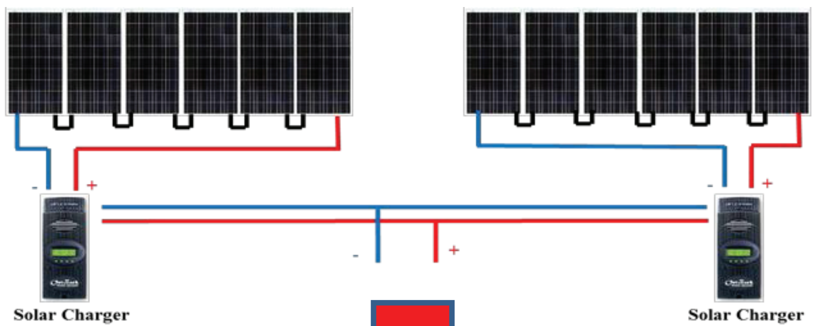
DOTX 225 – System Layout



DOTX 225 – Under Car Equipment



DOTX 225 – Power System



Solar Charging System
12 panels –140J, 17.5V, 8A, 140W

24 Volt DC Supply
12 x 6volt AGM
22kWh capacity

Reserve Charging System
Methanol Fuel Cell - 110W

DC – AC
Inverter

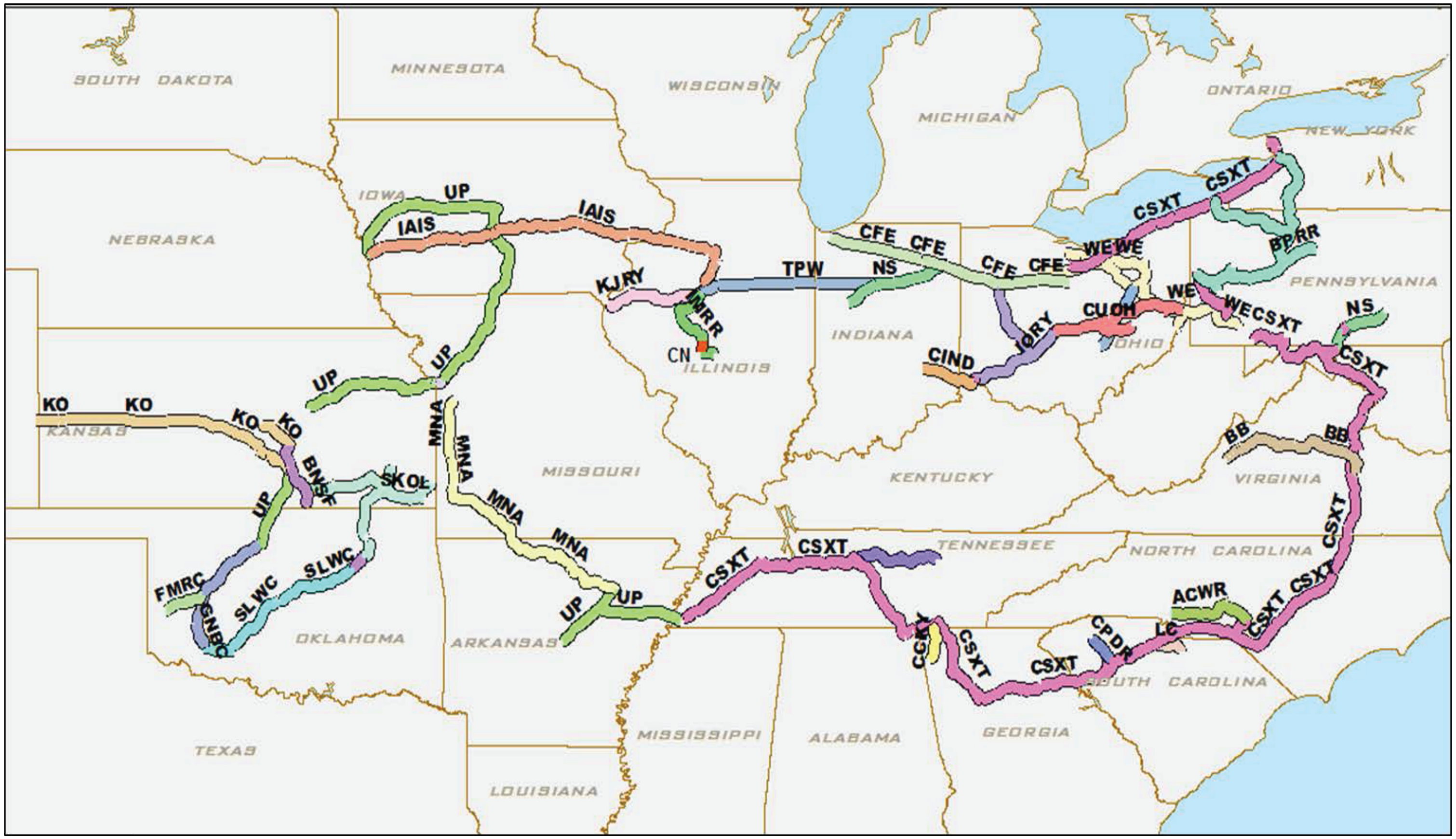
ATGMS Load ~130 watts

Why Choose Short Lines for the Demonstration?

- Strong interest from ASLRRA membership during technology development
- Significant track mileage available
  - 50,000 track miles: ~40% of US total
  - Normally not included in FRA's Automated Track Inspection Program (ATIP) routes
- Good scheduling and logistics challenge for the program
  - Difficult routing
  - Many different stakeholders
  - Many unique track conditions

ATGMS Freight Service Demonstration
April 2016 – January 2017

29 Railroads (4 Class I, 25 Short Line) - 12,787 Test Miles



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Participants

CSX	CSX Transportation
BB	Buckingham Branch Railroad
BPRR	Buffalo & Pittsburgh Railroad
WLE	Wheeling & Lake Erie Railway
OHCR	Ohio Central Railroad
CUOH	Columbus & Ohio River Rail Road
OSRR	Ohio Southern Railroad
IORY	Indiana & Ohio Railway
CIND	Central Railroad of Indiana
CFE	Chicago, Fort Wayne & Eastern Railroad
NS	Norfolk Southern Corporation
TPW	Toledo, Peoria & Western Railroad
KJRY	Keokuk Junction Railway
TZPR	Tazewell & Peoria Railroad
IMRR	Illinois & Midland Railroad
CN	Canadian National Railway
IAIS	Iowa Interstate Railroad
UP	Union Pacific Railroad
GNBC	Grainbelt Corporation
FMRC	Farmrail Corporation
SLWC	Stillwater Central Railroad
SKOL	South Kansas & Oklahoma Railroad
KO	Kansas & Oklahoma Railroad
MNA	Missouri & Northern Arkansas Railroad
NERR	Nashville & Eastern Railroad
CCKY	Chattooga & Chickamauga Railway
CPDR	Carolina Piedmont Railroad
LC	Lancaster & Chester Railway
ACWR	Aberdeen, Carolina & Western Railway

ATGMS – Output Reports

- Advisory Exception Report
  - Near Real-Time
- Track Condition Report
  - Line Segment Summary
- Data Strip Charts
  - Post-Test

Advisory Exception Report

FRA R&D Freight ATGMS Advisory: [redacted]

File Message ADOBE PDF Tell me what you want to do

Mon 1/16/2017 9:32 AM

no_reply_rtgms@atip.fra.dot.gov

FRA R&D Freight ATGMS Advisory: [redacted] Twist 31 1.38 [redacted]

To

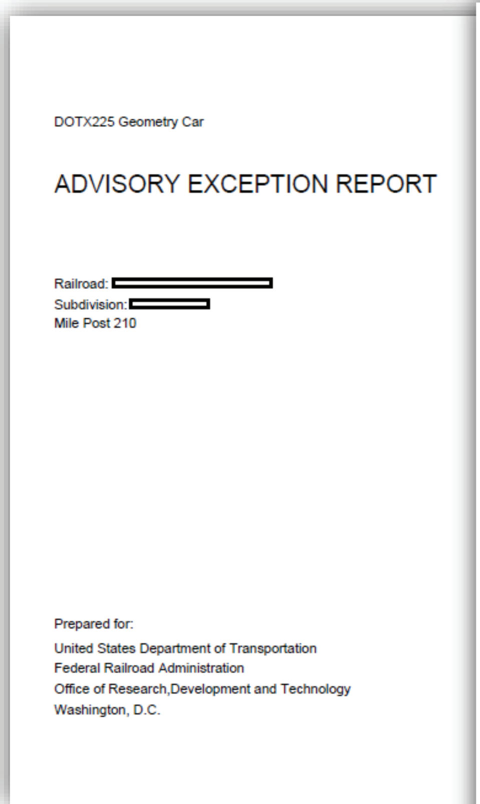
DOTX225 Exception R...
208 KB

RailRoad: [redacted]
Subdivision: [redacted]
Exception Type: Twist 31
Exception Value: 1.38
Length: 8
MilePost: 210
Foot: 3370
Train Speed: 37
Limited Class: 2
Track Number: 2
GPS Location: http://maps.google.com/maps?&q=35.042007,-78.892137&t=h&z=15

Dear Sir or Madam:

Under the Federal Railroad Administration (FRA) Research, Development & Technology (R&D) Freight Autonomous Track Geometry Measurement System (ATGMS) Demonstration Project, the FRA is providing you an Advisory Exception Report (AER) generated from an FRA geometry car coupled in a freight train. An AER provides a snapshot of track geometry conditions that are likely noncompliant with the Federal Track Safety Standard parameters in accordance with its implied track classification. This data is provided for your information only, and is not considered to be an Automated Track Inspection survey.

Advisory Exception Report (cont.)



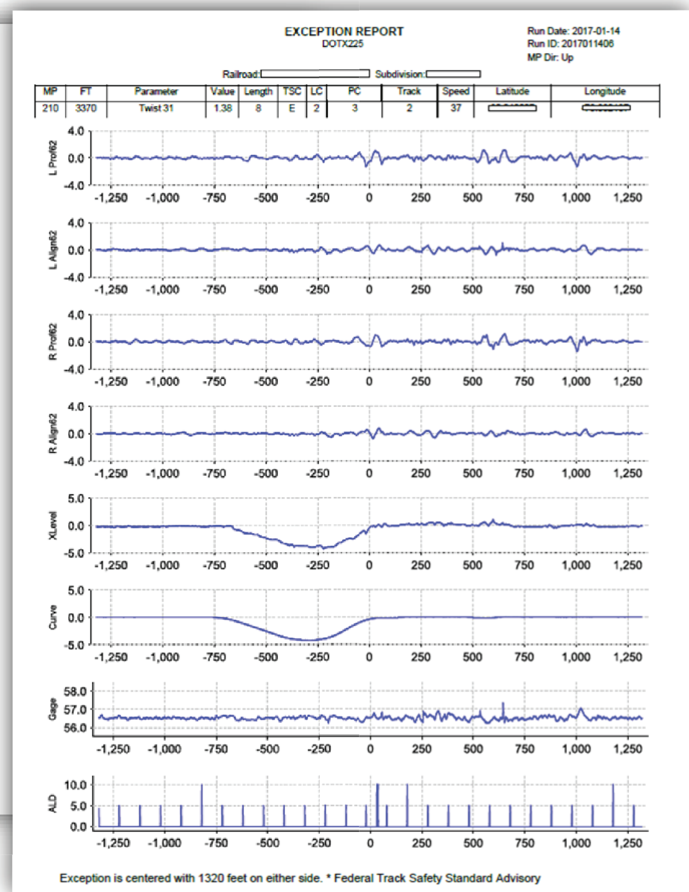
DOTX225 Geometry Car

ADVISORY EXCEPTION REPORT

Railroad: [redacted]
Subdivision: [redacted]
Mile Post 210

Prepared for:

United States Department of Transportation
Federal Railroad Administration
Office of Research,Development and Technology
Washington, D.C.



EXCEPTION REPORT
DOTX225

Run Date: 2017-01-14
Run ID: 2017011406
MP Dir: Up

Railroad: [redacted] Subdivision: [redacted]

MP	FT	Parameter	Value	Length	TSC	LC	PC	Track	Speed	Latitude	Longitude
210	3370	Twist 31	1.38	8	E	2	3	2	37	[redacted]	[redacted]

Exception is centered with 1320 feet on either side. * Federal Track Safety Standard Advisory

Track Condition Report

DOTX225 Report: [redacted] 2017-01-15; [redacted] to...

File Message ADOBE PDF Tell me what you want to do

Tue 1/17/2017 2:22 PM

no_reply_rtgms@atip.fra.dot.gov

DOTX225 Report: [redacted] 2017-01-15; [redacted] to [redacted]

To

[redacted] 2017011511 -...
9 KB

Dear Sir or Madam:

Under the Federal Railroad Administration (FRA) Research, Development & Technology (R&D) Geometry Measurement System (ATGMS) Demonstration Project, the FRA is providing you an (TCR) generated from an FRA geometry car coupled in a freight train. The TCR provides a tabu track geometry conditions resulting from the autonomous testing conducted, in accordance w classification. This data is provided for your information only, and is not considered to be an A survey.

Run ID: 2017011511

DOTX225 Geometry Car

TRACK CONDITION REPORT

[redacted] to [redacted]

Railroad: [redacted]

Prepared for:
United States Department of Transportation
Federal Railroad Administration
Office of Research, Development and Technology
Washington, D.C.

Prepared by:
ENSCO, Inc.
5400 Port Royal Rd
Springfield, VA 22151

Track Condition Report (cont.)

Exception Report
Exception List Section

Page 1 of 1
Run Date: 01/15/2017
Run ID: 2017011511

[redacted] to [redacted]

MP	FT	Parameter	Value	Length	Speed	TSC	LC	PC	Track	Latitude	Longitude
70	2319	**Lmt Speed 4**	53.00	865	9	C		3	1	[redacted]	
88	4245	**Lmt Speed 4**	49.00	977	19	C		3	1	[redacted]	
90	2495	**Lmt Speed 4**	60.00	888	22	C		4	1	[redacted]	
130	4165	**Lmt Speed 4**	54.00	3914	44	C		4	1	[redacted]	

Notes:

* Federal Track Safety Standard Advisory
+ Maximum curve speed is limited at qualified cant deficiency.
However, actual cant deficiency does not exceed 1-inch grace allowed under 49 CFR 213.57(b).

Exception Report
Exception Summary Section

Page 1 of 1
Run Date: 01/15/2017
Run ID: 2017011511

[redacted] to [redacted]

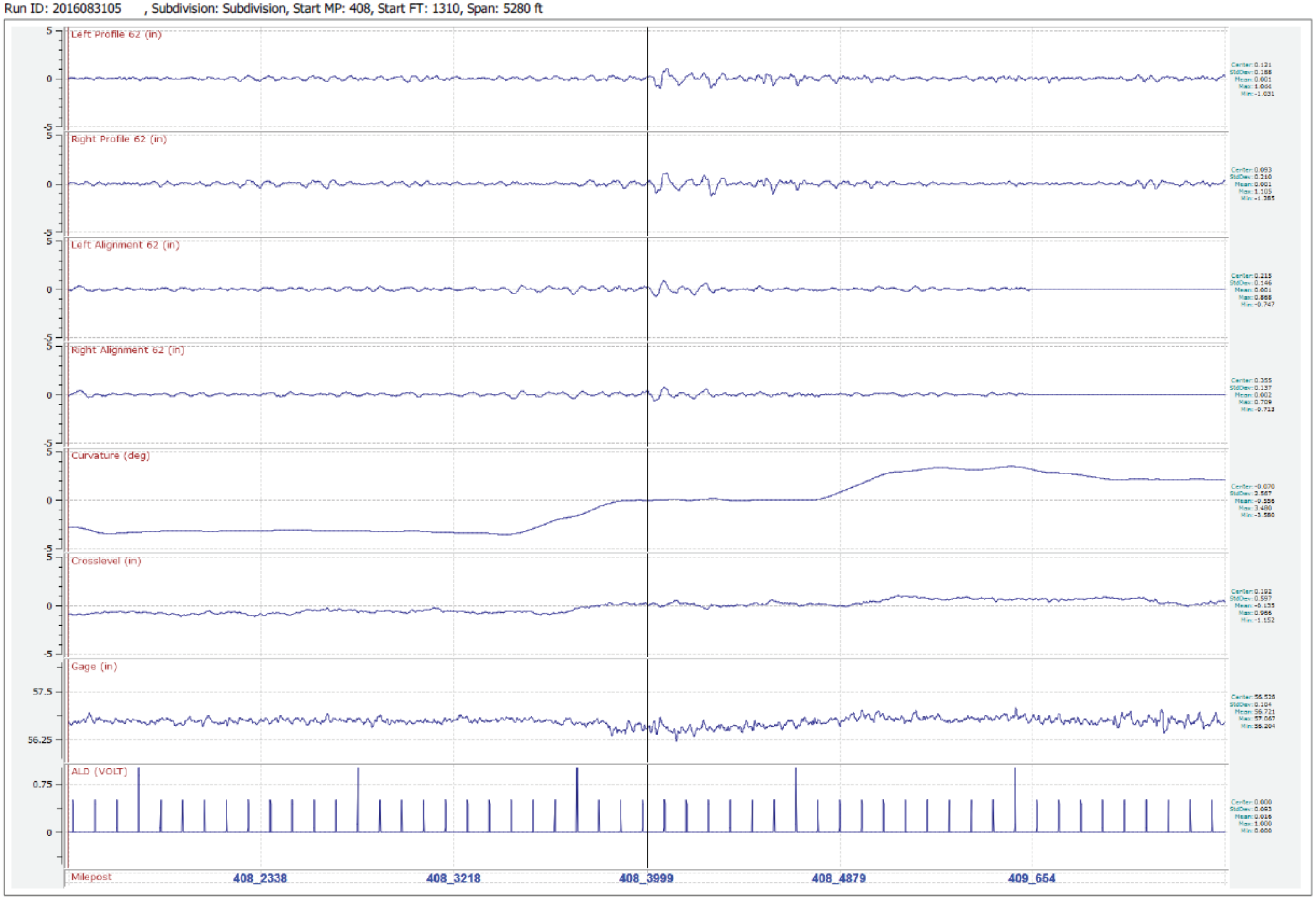
		Wide Gage			Tight Gage		Alignment			Crosslevel		
		Tot	Exc	2 Cl	Tot	Exc	Tot	Exc	2 Cl	Tot	Exc	2 Cl
MP	FT	EXC	FT	Drop	EXC	FT	EXC	FT	Drop	EXC	FT	Drop
70		-	-	-	-	-	-	-	-	-	-	-
88		-	-	-	-	-	-	-	-	-	-	-
90		-	-	-	-	-	-	-	-	-	-	-
130		-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-

	Rockoff			Profile			Run Off			Warp			Twist-31			Lmt Spd			
	Tot	Exc	2 Cl	Tot	Exc	2 Cl	Tot	Exc	2 Cl	Tot	Exc	2 Cl	Tot	Exc	2 Cl	Tot	Lim	Pst	
MP	EXC	FT	Drop	EXC	FT	Drop	EXC	FT	Drop	EXC	FT	Drop	EXC	FT	Drop	EXC	Cls	Cls	Trk
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	3	1
88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	3	1
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	4	1
130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0	4	1
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4			

Total Miles: **88.70**
Exceptions per 100 Miles: **4.51**
CY14 National Average Exceptions per 100 miles: 11.5

Data Strip Charts

Run ID: 2016083105 , Subdivision: Subdivision, Start MP: 408, Start FT: 1310, Span: 5280 ft



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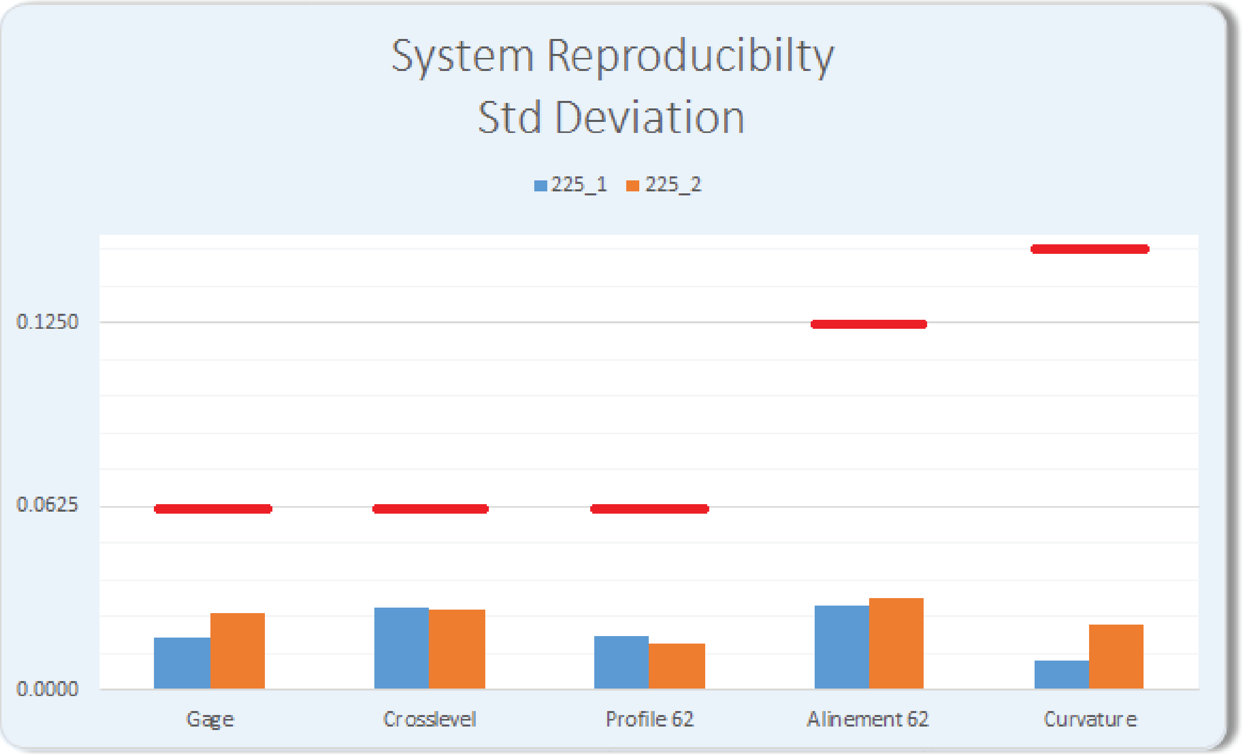
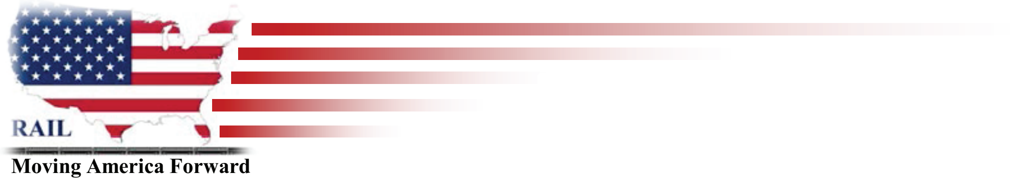
Measures of Success

- 12,787 test miles
  - 74.3 miles data not collected
  - 99.994% success rate
- ~20,000 "points of interest" found
  - End user defined exception thresholds
  - Generally one class higher than posted speed

Measures of Success – Calibration

April 2016 versus January 2017





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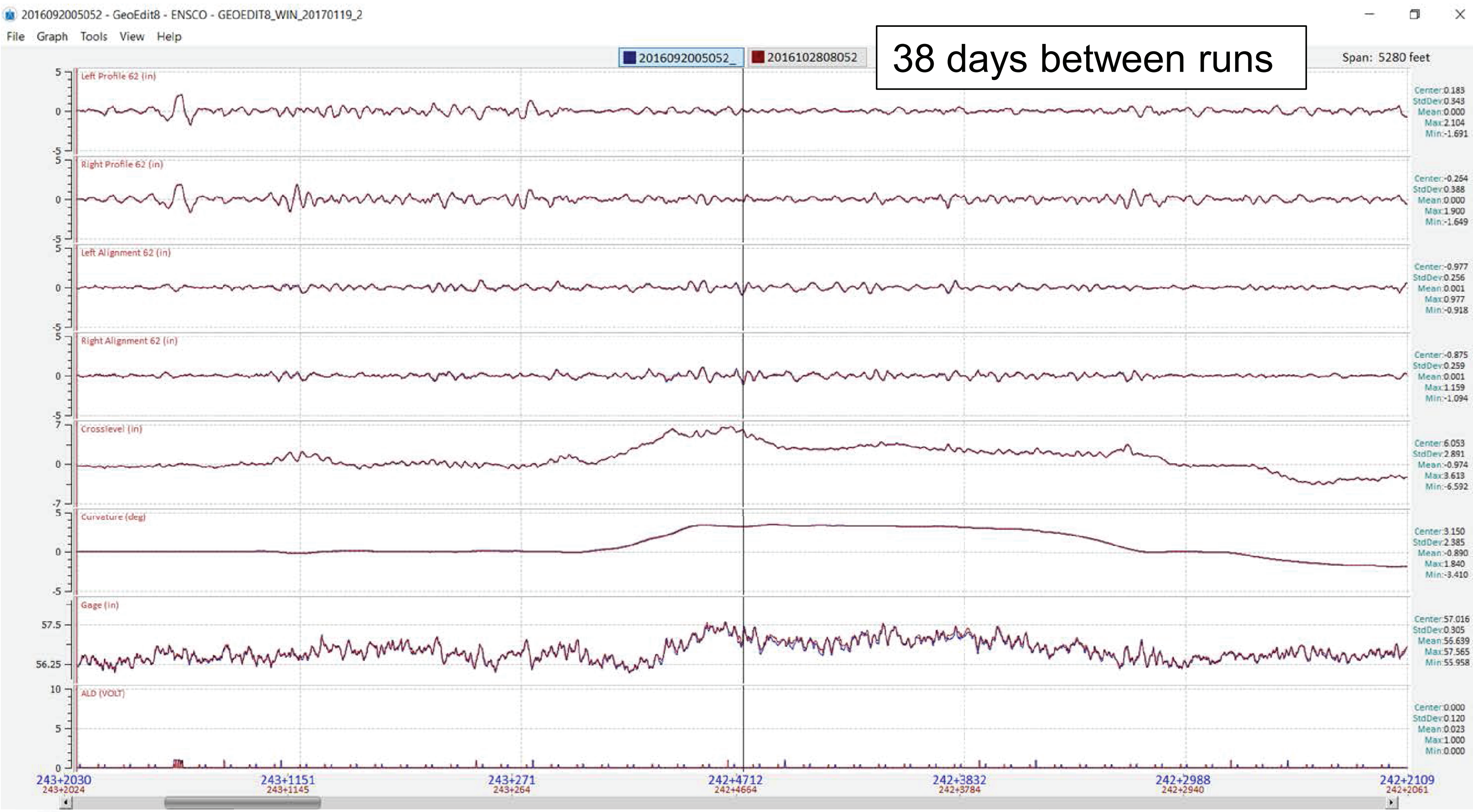
Measures of Success – Repeatability



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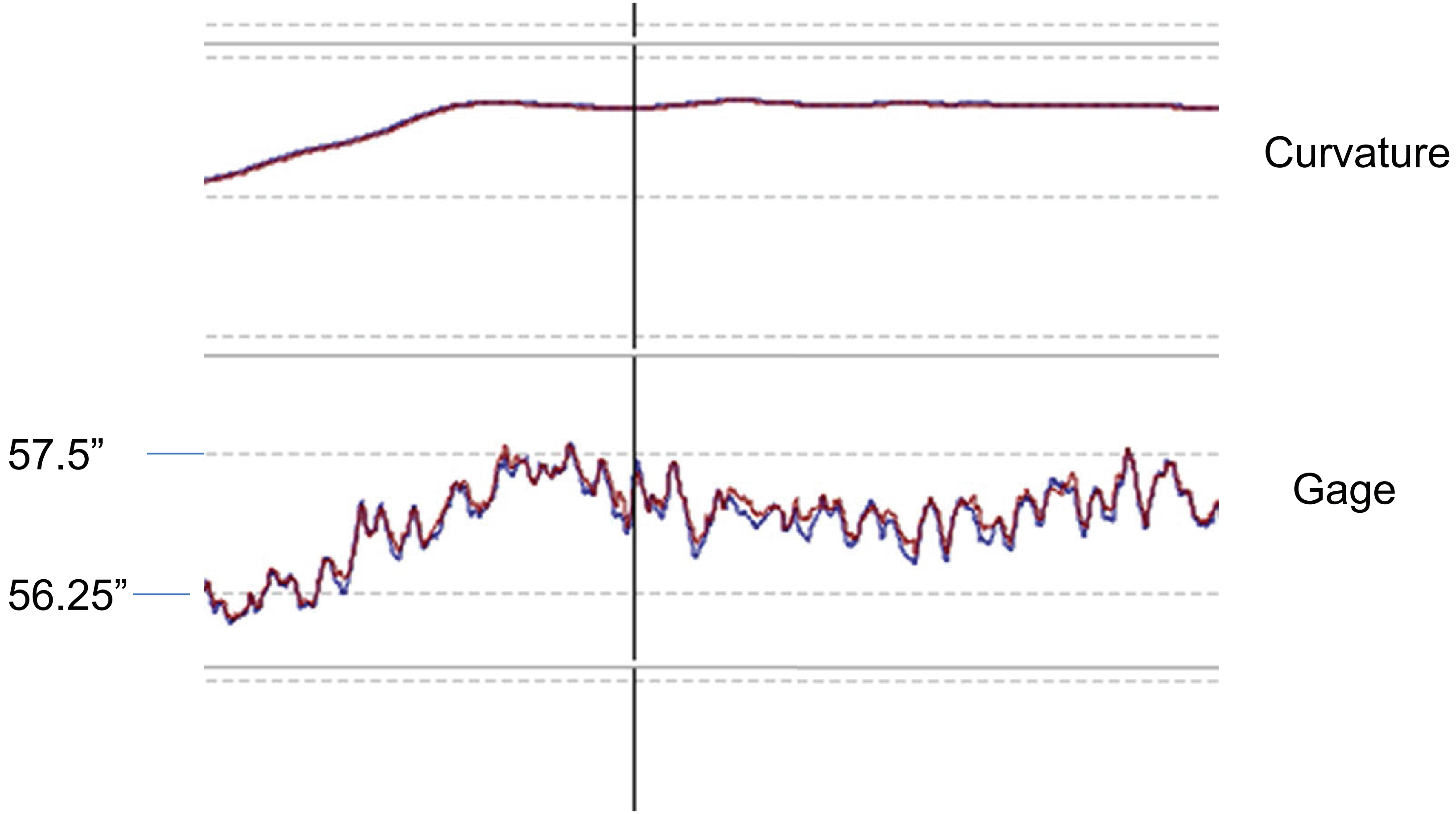
Measures of Success – Repeatability (cont.)



Measures of Success – Maintenance

- 9 months: 3 maintenance visits
  - Resolve computer damage due to humping
  - Tachometer swap (upgrade), system check
  - Resolve computer basic input/output system error
- 129 consecutive days
  - No issues
- Power System Reliability
  - Functioned as designed
  - Minimal use of fuel cell

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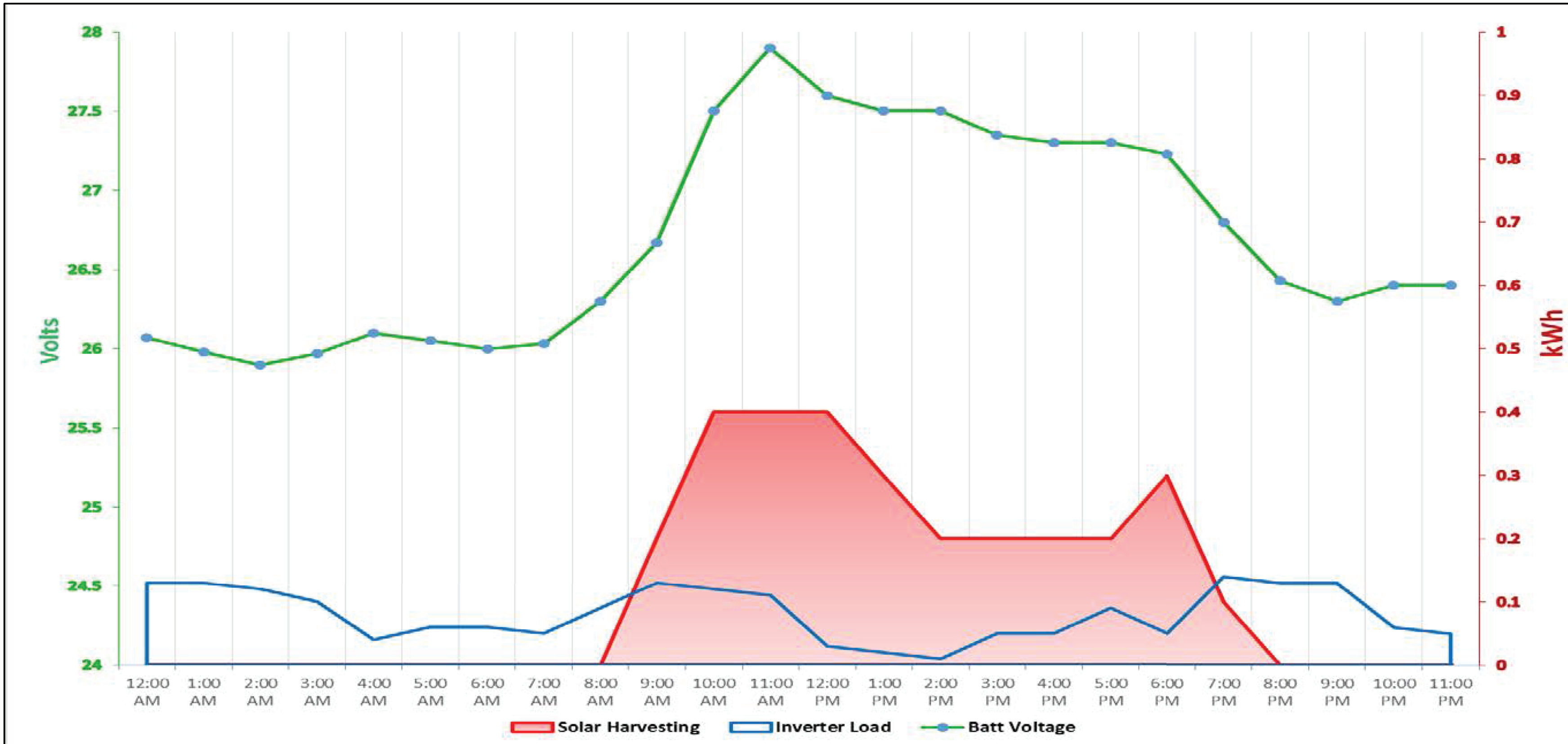
Power System Performance

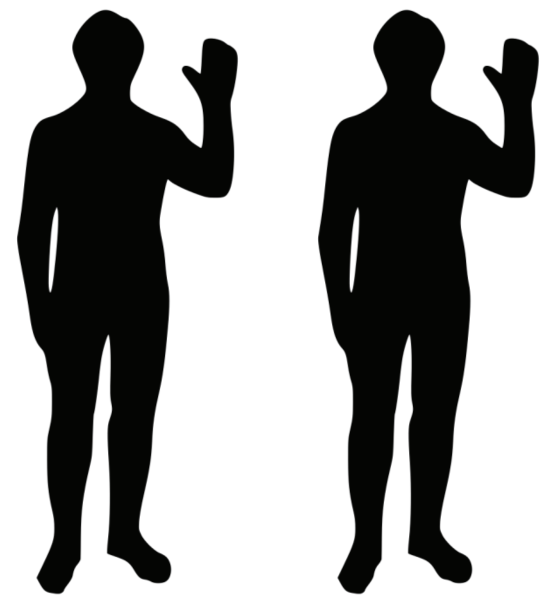


(Fuel cell total run-time over 9 months: ~ 15 hrs, < 1 liter)

Measures of Success

Level of Effort Required

- Scheduling
- Coordinate interchanges
- Gather necessary timetable, track chart, and milepost coordinates to support testing
- Coordinate system maintenance/field work
- Monitor system performance
- Operate Remote Editor Desk (9 a.m. to 5 p.m.)
- Distribute data
- “Support” FRA project sponsor



Room for Improvement

Base Maps

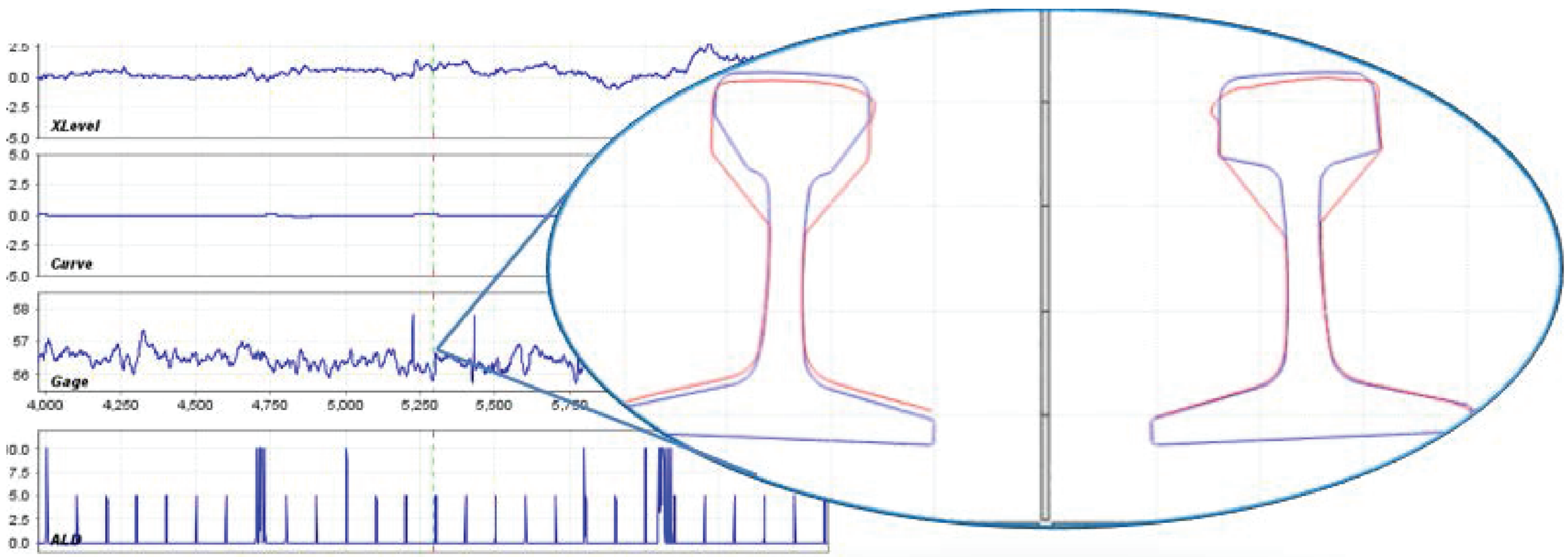
- Track centerlines correlated with Global Positioning Satellite (GPS) coordinates and railroad identifiers:
  - Milepost
  - Track Number & Class
  - Posted Speed – Speed Tables

Narrow Gage = Rail Lip

- May be able to identify lipped rail locations using rail images

Room for Improvement (cont.)

- Narrow gage exceptions caused by rail head flow was a problem for effectively editing/reviewing data at Remote Editor Desk.
- Associate rail image with exceptions.



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Participant Feedback

- ✓ Geometry exception measurements were predominantly accurate and prompted immediate correction.
  - ! A few participants commented about preventing potential derailment.
- ✓ GPS location data was reliable.
- ✓ Receiving geometry exception results without committing track engineering personnel to a test train.
- ✓ Getting a geometry test for the first time or out of cycle.
- ✓ Receiving track geometry exception results via email.
- ✓ Narrow gage exception volume when rail flow existed.
- ✓ Having to rerun segments.
- ✓ PDF not best format for working with exception information.

✓ (green) = Positive Feedback
✓ (red) = Negative Feedback

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Commercial Applications

CP Rail (2014)

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Commercial Applications (cont.)

CSX (2016)

ATGMS – Short Line Acquisition Options

The Advantages:

- COTS technology
- Adaptable to almost any railcar
- Multiple supply sources of similar technology

The Disadvantages:

- Capital cost
- Operating challenges – short runs, connect the dots
- Remote Editor Desk/logistics management probably required

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Short Line Acquisition Options (cont.)

Opportunities

- Team up with other short lines (American Short Line & Railroad Association)
- Partner with Class 1s that have this technology
- Possible service leasing opportunities with 3rd party providers

Special *Thank You*

- Eric Sherrock – Program Manager
- Jennifer Zahaczewski – Technical Project Manager
- Eric Tyson – Demonstration Test Coordinator and Remote Editing Desk Manager

ENSCO Rail

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