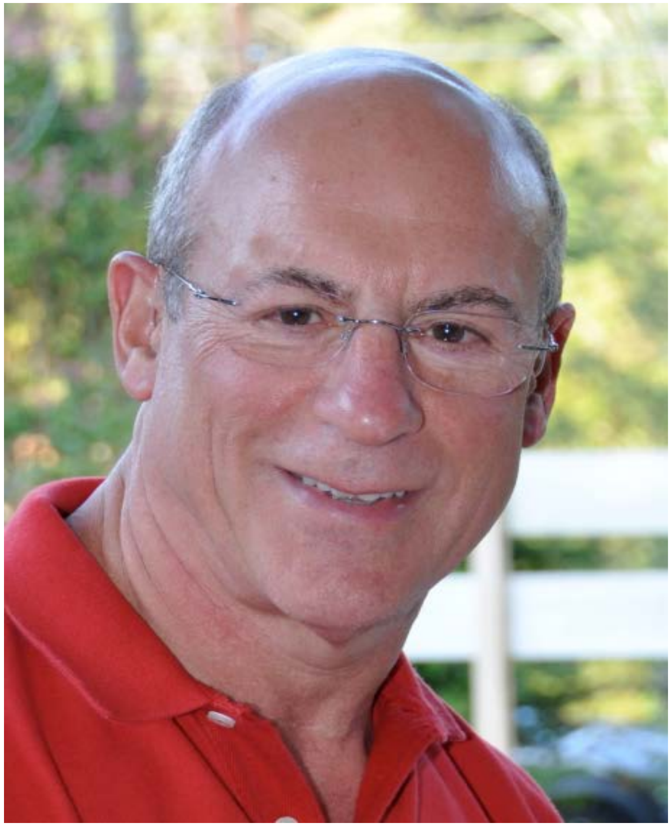
STANDARDS ITS TRAINING
TRANSIT

WELCOME

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology

Module:18
Transit and the Connected/Automated Vehicle Environment/Emerging Technologies, Applications, and Future Platforms

Instructor



Jerome M. Lutin, PhD, PE

Senior Director of Statewide and Regional Planning (Retired)

New Jersey Transit

Learning Objectives

Define relationships between **connected vehicle and automated transit vehicle** functionality

Describe potential for **autonomous bus guidance** for safety, access, and capacity

Describe development of **automated collision avoidance technologies** for buses and paratransit vehicles

Explain potential for AV/CV technologies to support **first mile/last mile** connections

Describe **fundamentals of rail transit system** connected/automated operation

Learning Objective 1

Define the **relationships** between **connected** vehicle and **automated** transit vehicle functionality

Distinguishing Automated Vehicles from Connected Vehicles

Defining Terms

Automated or autonomous?

- **Automated** - perform a task using machinery or computers rather than humans
- **Autonomous** – having the power to control oneself, make decisions

Two types of connectivity

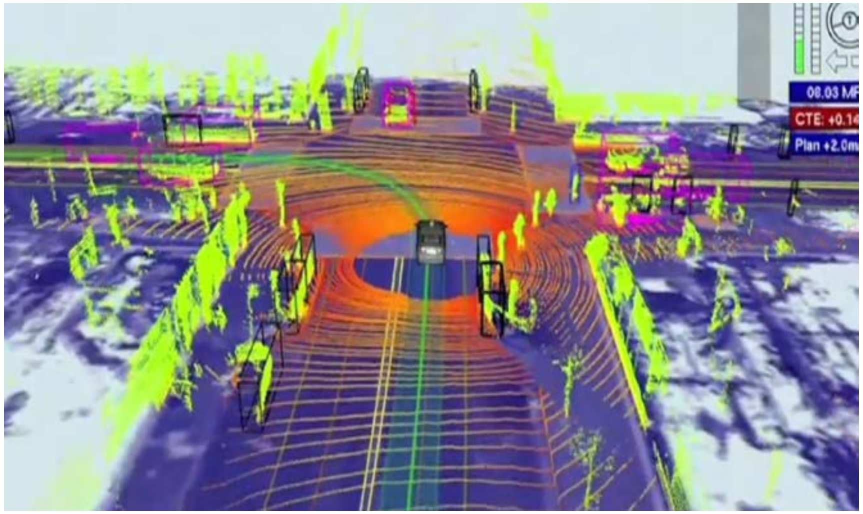
- Connect by using **Dedicated Short Range Communications** technology (DSRC) for Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications
- Connect vehicles as the Internet of Things (IoT) using commercial **Wi-Fi** and **cellular** technology

SUPPLEMENT

Distinguishing Automated Vehicles from Connected Vehicles

Autonomous Vehicles – How do they work?

- Sensors
- Mapping
- Perception
- Communication



Review of Module 11 Learning Objectives

Module 11:Transit and the Connected Vehicle Environment/Emerging Technologies, Applications, and Future Platforms

Learning Objectives

1. Describe the connected vehicle environment
2. Identify and evaluate the potential communications technologies that may be used in a transit connected vehicle environment
3. Identify the ITS standards that support the transit connected vehicle environment
4. Describe the applications being developed in a transit connected vehicle environment
5. Identify the challenges to the successful deployment of a transit connected vehicle environment
6. Describe strategies and approaches for deploying a transit connected vehicle environment

Additional Resources for Understanding the Connected Vehicle Environment

Connected Vehicles 101 Objectives

- What is meant by “connected” vehicles?
- What are the terms/jargon related to connected vehicles?
- What technology is used for connected vehicles?
- Which applications are available for connected vehicles? What is the pertinent USDOT research related to connected vehicles, including applications and technologies?
- What issues may you face in preparing for connected vehicle implementation?
- How can you become or stay involved?

Additional Resources for Understanding the Connected Vehicle Environment

Connected Vehicles 102: Applications and Implementation

1. Connected Vehicles: Introduction and Current Status
2. Preparing to Implement Connected Vehicle Applications
3. Safety Applications
4. Mobility Applications
5. Environmental Applications
6. Implementing Connected Vehicle Applications

Additional Resources for Understanding the Connected Vehicle Environment

Connected Vehicles 201: Developing a Plan for Implementing Connected Vehicle Projects

(will be available online in 2017)

1. Planning for CV Deployment
2. Concept Development
3. System Requirements
4. Comprehensive Deployment Plan

Challenges and Opportunities – Report from GAO

Intelligent Transportation Systems Vehicle-to-Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist

http://gao.gov/products/GAO-15-775

Why Government Accountability Office (GAO) Did This Study:

- USDOT key milestones for the year 2040
    1. 90 percent of the U.S. light duty vehicle fleet is DSRC enabled
    2. 80 percent of all traffic signals are DSRC equipped
    3. DSRC exists at up to 25,000 additional safety-critical roadway locations.
- There are a variety of challenges that may affect the deployment of V2I technologies

Challenges and Opportunities – Report from GAO

What GAO Found

- Possible sharing of frequency spectrum for V2I with other wireless users could adversely affect V2I technologies' performance
- States and local agencies lack resources to deploy and maintain V2I technologies
- Technical standards need to be developed to ensure interoperability
- Need to develop and manage data security and address public perceptions related to privacy
- Need to ensure that drivers respond appropriately to V2I warnings
- Need to address the uncertainties related to potential liability issues posed by V2I
- The full extent of V2I technologies' benefits and costs is unclear

USDOT Joint Program Office (JPO) ITS Strategic Plan

Strategic Priorities and Themes

Realizing Connected Vehicle (CV) Implementation

- Builds on progress made in recent years on design, testing, and planning for CVs

Advancing Automation

- Shapes the ITS Program around research, development, and adoption of automation-related technologies

Relationship Between Connectivity and Automation

Program Category – Advancing Automation

- **Potential Benefits of Automation**
  - Reducing the number and severity of crashes
  - Reduction of aggressive driving
  - Expanding the reach of transportation modes to disabled and older users
  - Providing “last mile” connectivity service for all users
  - Increasing the efficiency and effectiveness of existing transportation systems
  - Providing guidance to state and local agencies to help them understand the impacts of automated vehicles

Federal Automated Vehicles Policy

"Accelerating the Next Revolution In Roadway Safety"

Released September 2016

National Highway Traffic Safety Administration (NHTSA) of the US Department of Transportation

https://www.transportation.gov/AV

- Vehicle Performance Guidance for Automated Vehicles
- Model State Policy
- NHTSA's Current Regulatory Tools
- New Tools and Authorities

Levels of Road Vehicle Automation – NHTSA, SAE, BASt

Why are there Levels of Automation?

- Identify driving levels from “no automation” to “full automation”
- Base definitions on functional aspects
- Describe distinctions for step-wise progression through levels
- Consistent with current industry practice
- Eliminate confusion; useful across numerous disciplines (engineering, legal, media, and public discourse)
- Clarify drivers’ role while driving automation system is engaged

NHTSA – National Highway Traffic Safety Administration
SAE – Society of Automotive Engineers International
BASt - Bundesanstalt für Straßenwesen - Federal Highway Research Institute (Germany)

(NHTSA) Adopts SAE Levels of Automation

- Level 0, human driver does everything;
- Level 1, automated system can sometimes assist human with some parts of the driving task;
- Level 2, system can conduct some parts of driving task, while human monitors driving environment and performs rest of the driving task;
- Level 3, system can conduct some parts of driving task and monitor the driving environment in some instances, but human must be ready to take back control when system requests;
- Level 4, system can conduct driving task and monitor driving environment, but system can operate only in certain environments and under certain conditions;
- Level 5, system can perform all driving tasks, under all conditions

Standards Development Organizations (SDOs) Active in the Automated/Connected Space

American Public Transportation Association (APTA)

- Bus Procurement and Transit Communications Interface Profiles (TCIP)

American Society of Civil Engineers (ASCE)

- Automated Transit Systems

American Society of Testing and Materials International (ASTM)

- Telecommunications Networks

Association of American Railroads (AAR)

- Positive Train Control (PTC)

SUPPLEMENT

Standards Development Organizations (SDOs) Active in the Automated/Connected Space

Institute of Electrical and Electronics Engineers (IEEE)
- Automated and Connected Vehicles

Institute of Transportation Engineers (ITE)
- Standards Training

International Organization for Standardization (ISO)
- Data Communications for V2X
- Vehicle Dynamics

Society of Automotive Engineers SAE International (SAE)
- Vehicle Automation Taxonomy
- Reference Architecture for Vehicle Automation

SUPPLEMENT

Enabling and Emerging Standards

Emerging Standards for Automated and Connected Vehicles

- ASCE Standard 21-13 Automated People Movers
- IEEE P2040 Standard for Connected, Automated, and Intelligent Vehicles
- ISO 19091 Intelligent transport systems -- Cooperative ITS -- Using V2I and I2V communications for applications related to signalized intersections

Enabling and Emerging Standards

Emerging Standards for Automated and Connected Vehicles - SAE

- SAE J3016 Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems

- SAE J3018 Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)

- SAE J3092 Dynamic Test Procedures for Verification & Validation of Automatic Driving Systems (ADS)

- SAE J3131 Automated Driving Reference Architecture

ACTIVITY

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U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

Question

In a NHTSA Level 3 automated vehicle, the driver is:

Answer Choices

a) expected to be available for control in certain areas

b) not expected to be available for control during the trip

c) responsible for monitoring and available to resume control

d) in complete and sole control

Review of Answers

a) expected to be available for control in certain areas

Incorrect. This describes driver's role in Level 4.

b) not expected to be available for control during the trip

Incorrect. This describes driver's role in Level 5.

c) responsible for monitoring and available to resume control

Correct! Driver must monitor and be able to take control.

d) in complete and sole control

Incorrect. This describes driver's role in Level 0.

Learning Objective 2

Describe the potential for **autonomous bus guidance** for safety, access, and capacity

CASE STUDY

STANDARDS ITS TRAINING TRANSIT

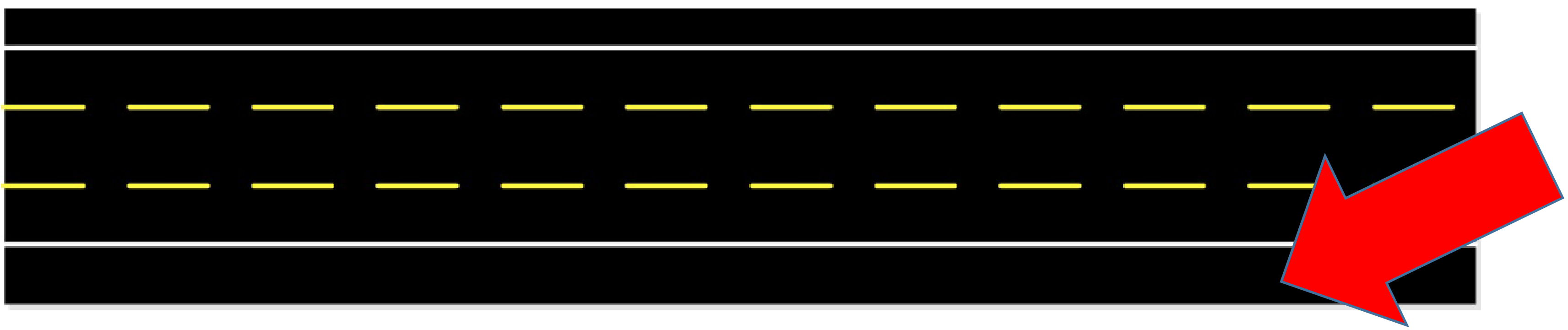
U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

Minnesota Bus on Shoulders

Bus Rapid Transit Technologies:

Assisting Drivers Operating Buses on Road Shoulders

Bus on shoulder makes more **efficient use of roadway**

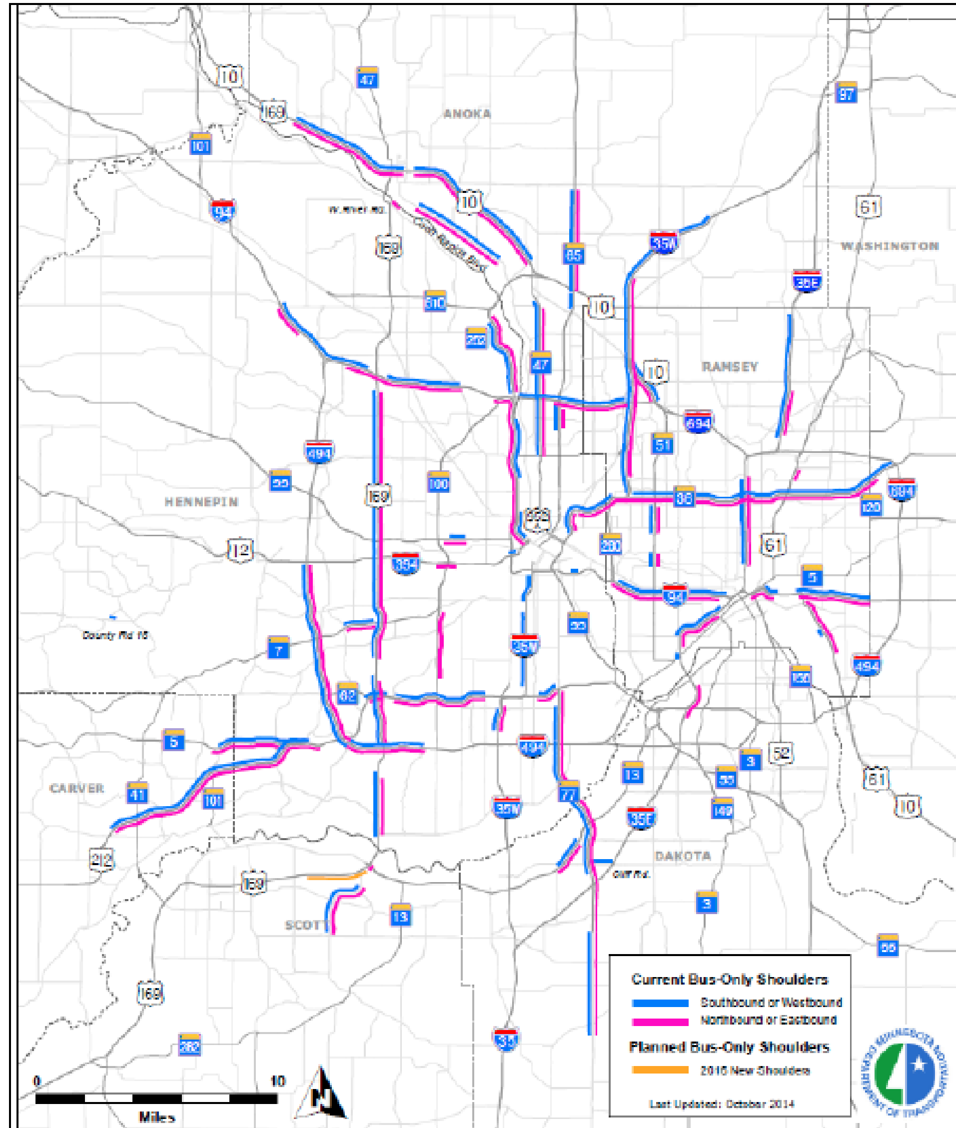


- Consider 3 lanes, 2 shoulders (12 foot-wide lanes, 10-foot wide shoulders)
- Only 64% of paved surface used to move people and goods
- Using only one shoulder (of two available) increases usable surface by 28%
- Capacity increased by 28% with minimal investment!

Minnesota Bus on Shoulders

Minneapolis - St. Paul

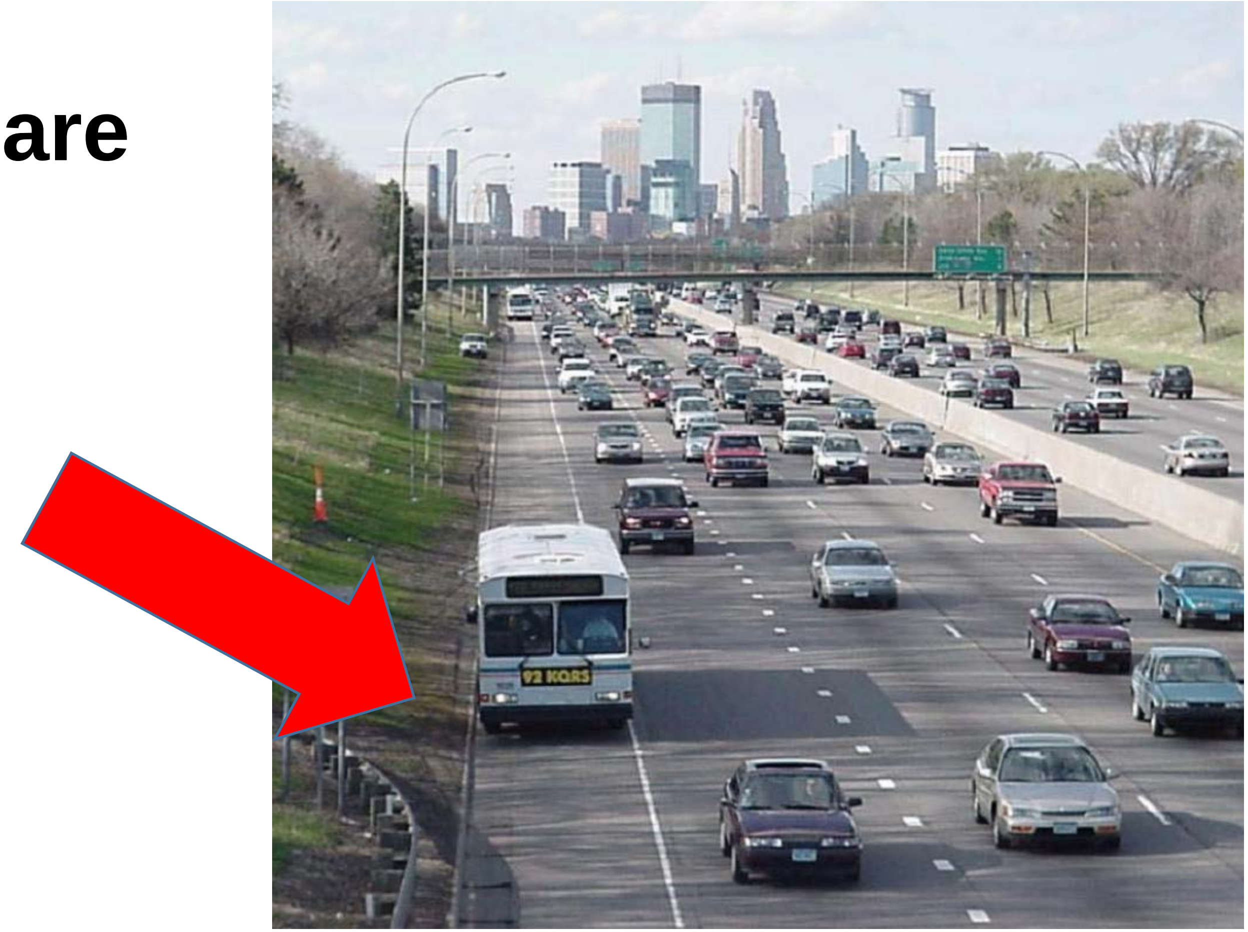
295 mi (476 km)



Minnesota Bus on Shoulders

Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders

Shoulders are narrower
than lanes



Minnesota Bus on Shoulders

Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders

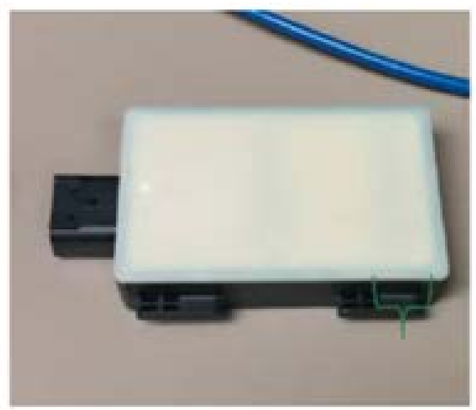
2010: 10 Minnesota Valley Transit buses equipped with driver assist systems

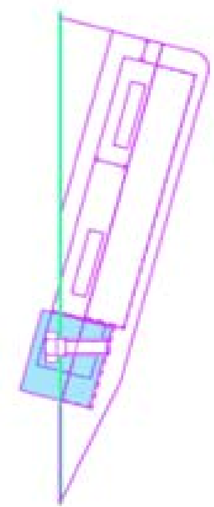
- Lane keeping
- Lane departure warning
- Forward collision awareness
- Side collision awareness
- Comprehensive driver interface – Graphical, tactile (active seat), haptic (steering feedback)

2016: 11 new buses will receive Driver Assist System and existing 10 will be upgraded to same specs –incorporate lessons learned

Minnesota Bus on Shoulders

Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders: Tech Upgrades

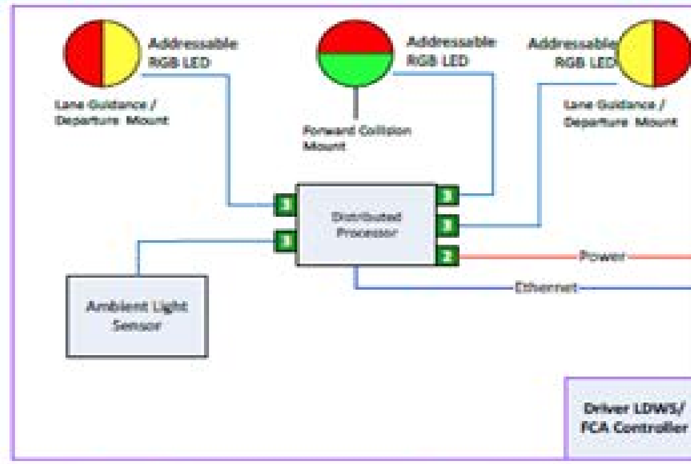


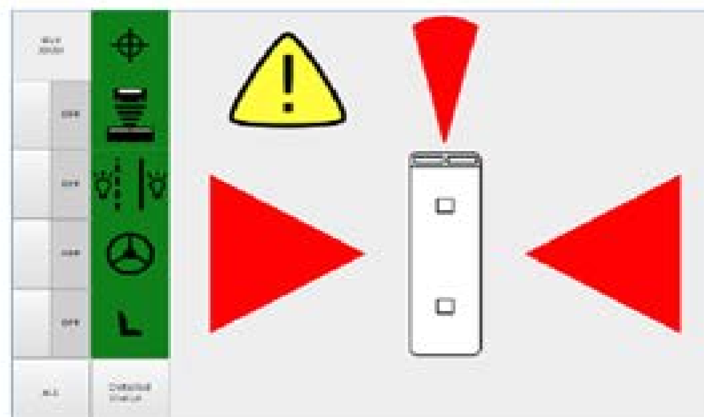


Minnesota Bus on Shoulders

Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders: Tech Upgrades

2010	2015





Minnesota Bus on Shoulders

Bus Rapid Transit Technologies: Assisting Drivers Operating Buses on Road Shoulders

LRT vs. BoSS. BoSS with automation provides robust service in all-weather at significant capital cost savings.

Category	LRT*	BOS**
Capital Costs	$1.7B	$150 M
Operational Cost / Year	$12 - $17M	$18.1M

* Metropolitan council estimates, 2011

**
- 46K miles per bus per year
- 4 MPG per bus (Diesel)
- 120 buses
- Fuel consumption: 1.4M Gallons
- Fuel Cost (at $5 per gallon): $6.9M
- Maintenance: $10K per bus per year - $1.2M
- Driver salary: $10M ($40/hr, 8 hrs/day)

CASE STUDY

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

Lane Transit District BRT Automated Docking

Lane Transit District Emerald Line (EmX) Bus Rapid Transit (BRT) – Eugene Oregon Pilot Opened 2007

- Four mile line between Eugene and Springfield
- 10-15 minute headways
- 1.6 miles of dedicated right of way


Lane Transit District BRT Automated Docking

Bus Rapid Transit Issues Today

- **Customers** demand high-quality transit services
- Agencies need a **safer** and more **cost-effective** transit system
- **Insufficient funding** for building and operating new light or heavy rail systems
- **Space limitations** for installing bus-only lanes in existing ROW
- **Drivers complain** about driving in narrow, bus-only lanes

Lane Transit District BRT Automated Docking

Vehicle Assist and Automation (VAA) Technologies for BRT

- **Functions to be tested:**
  - Magnetic lane guidance for dedicated BRT lane
  - Precision docking

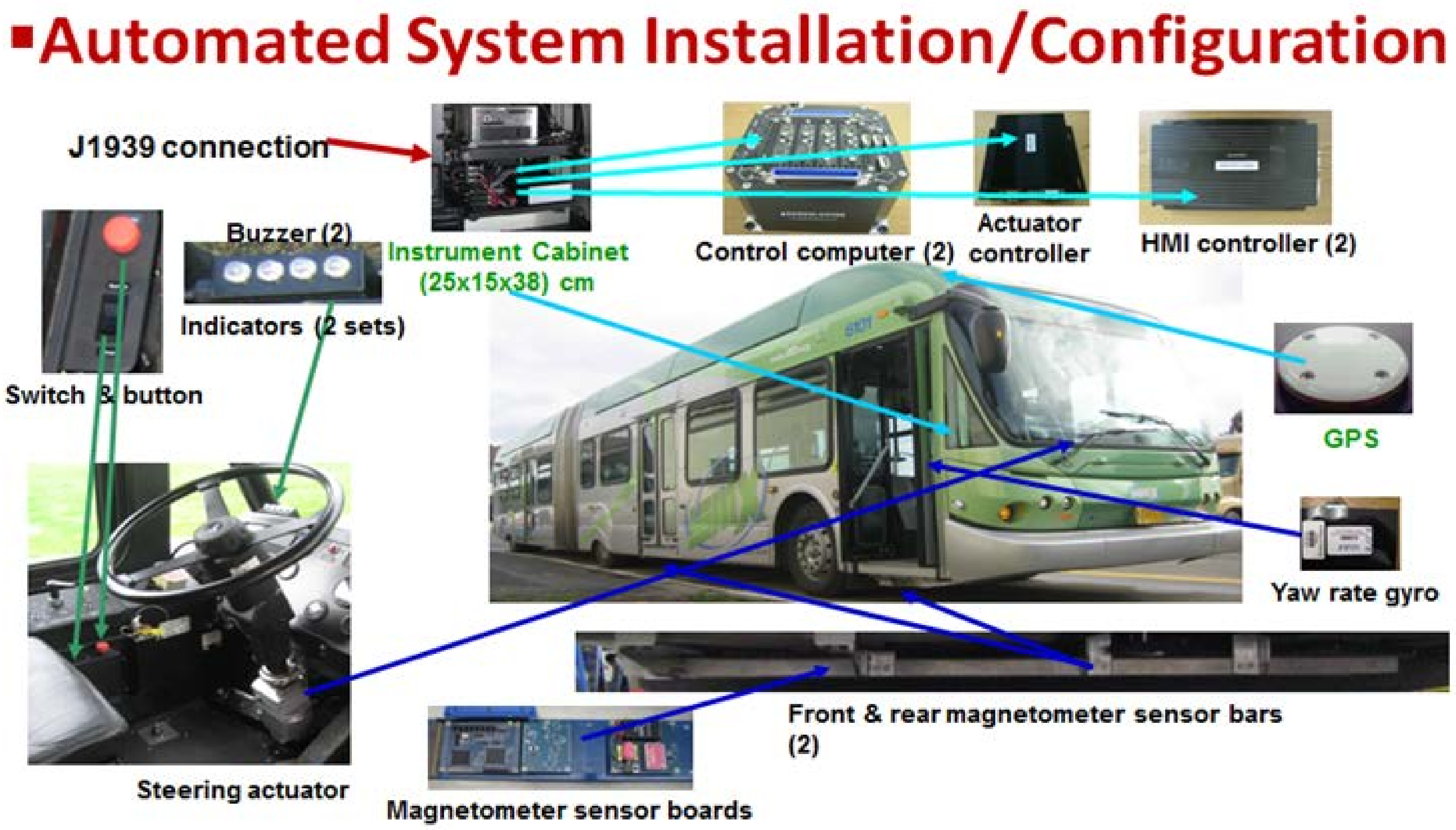
- **Testing to determine potential benefits**
  - Reduced right-of-way requirements and infrastructure build-out costs
  - “Rail-like” operations
  - Smoother and faster travel
  - Reduced operating and maintenance costs
  - Reduced accidents

Lane Transit District BRT Automated Docking

Vehicle Assist and Automation (VAA) Technologies for BRT

- **23 mile BRT line**
  - 3 miles of magnets installed
- **LTD maintenance yard test track**
- **One 60’ New Flyer bus equipped**
  - Two sensor bars
  - Steering actuator
  - Computer controller
  - Human-Machine Interface display

Lane Transit District BRT Automated Docking



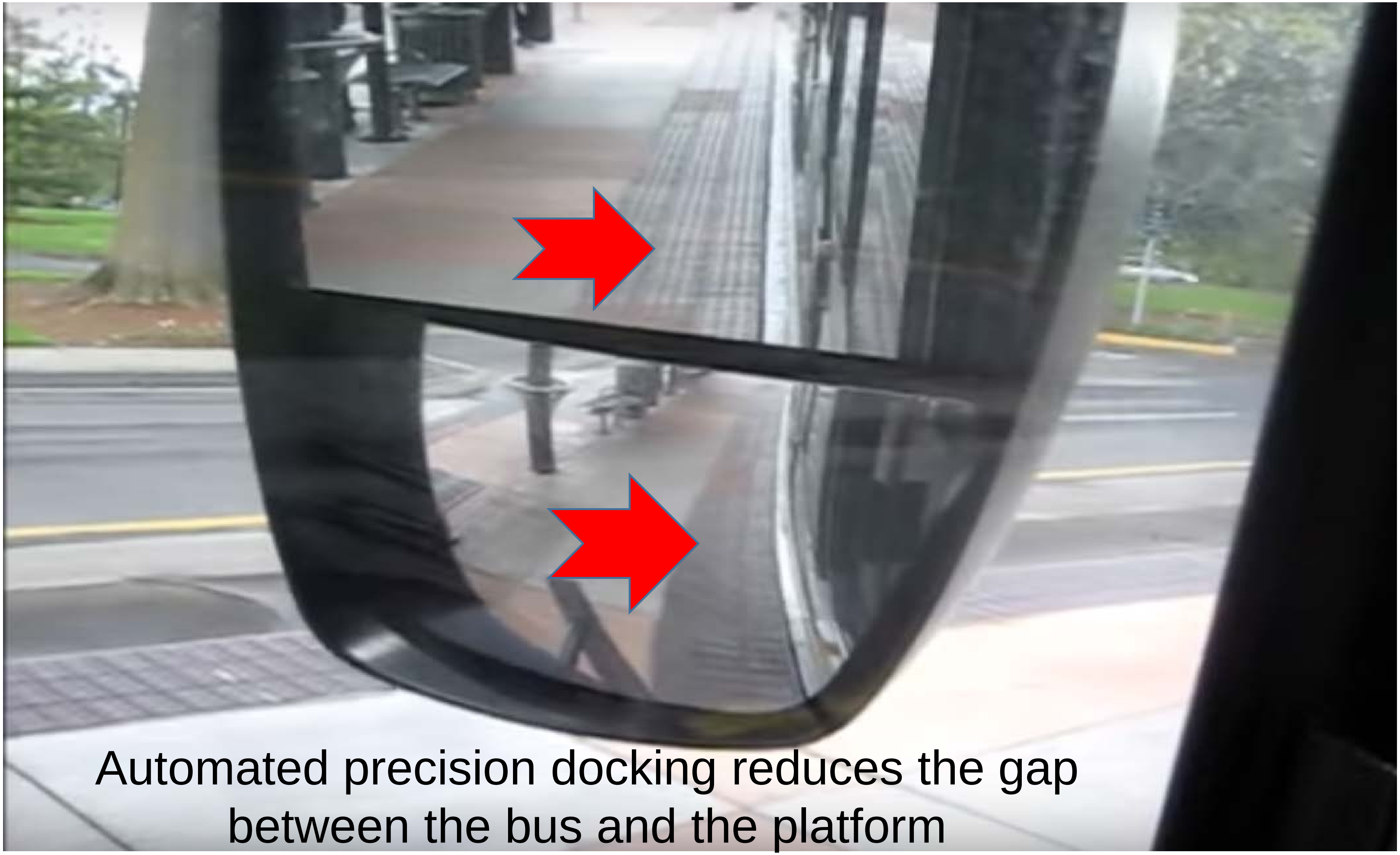
SUPPLEMENT

Lane Transit District BRT Automated Docking

The magnetometer (in the right hand) is used on the bus to follow the path created by a series of magnets (in the left hand)

The bottom photo shows the magnets being installed in holes drilled in the pavement

Lane Transit District BRT Automated Docking



Automated precision docking reduces the gap between the bus and the platform

Lane Transit District BRT Automated Docking

VAA Field Operational Test (FOT) in Revenue Service – Design & Development for Deployment

Revenue service elevates design requirements of automated control

- Apply product development methodologies (reliability + maintainability)
- Emphasis on safety design (redundancy + fault detection/management) Fail-safe and fail-soft

Deployment requires professional installation

- Installation not to degrade bus normal operations
- Normal maintenance to be straightforward (visual inspection, fault reporting, data collection)
- Most repairs could be conducted by transit personnel (spare part replacement)

Lane Transit District BRT Automated Docking

VAA FOT Revenue Service – Design and Development for Deployment

- **Deployment requires the handling of all operational modes**
  - Work in all possible operational conditions and scenarios (different drivers, speeds, weather, traffic conditions, transition methods, …)
  - Detect and manage all (known) faults

- **Revenue service demands addressing any (new) issues**

  Work through operational and other issues (e.g., policy, legal, institutional) with transit agencies

Potential for Bus Platooning

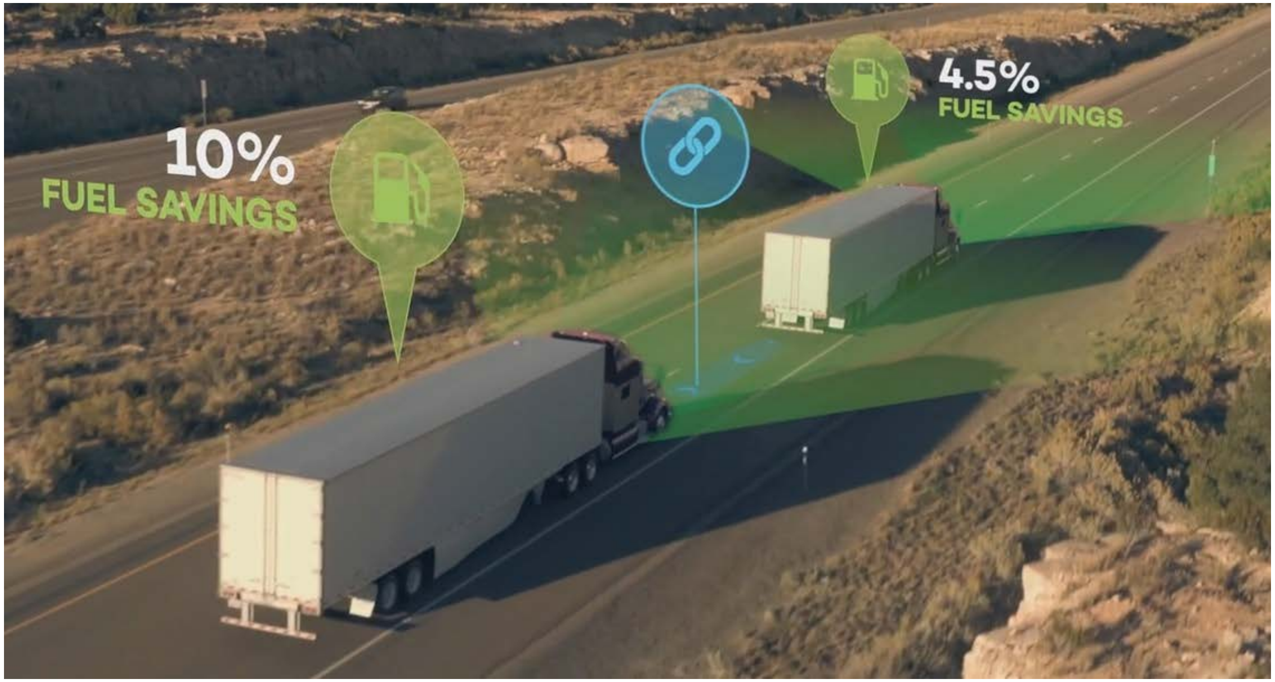
Bus Platooning Concept Introduced in Demo ’97

- Part of **automated highway demonstration** (Demo‘97) sponsored by USDOT National Automated *Highway System Consortium (NAHSC)*
- Mandated by 1991 ISTEA legislation
- Two Houston Metro low-floor New Flyer **buses** were equipped with **full automation**
- **Magnetic nails** embedded in pavement provided guidance

Potential for Bus Platooning

Guidance Technology has been upgraded Since 1997

- **V2V communications** allow cooperative adaptive cruise control (CACC)
- Commercial truckers see **truck platoons** as a way to improve safety and **reduce fuel consumption**



Potential for Bus Platooning

New Starts projects for transit often compare Bus Rapid Transit (BRT) with Light Rail Transit (LRT)

- BRT ride quality is not as smooth as LRT
- BRT does not match potential LRT capacity
- Automated/Connected operation using Cooperative Adaptive Cruise Control (CACC) enables buses on BRT to improve both ride quality and capacity, offering potential for less expensive infrastructure

Potential for Bus Platooning

Potential to Add Peak Period Capacity at Less Cost

< connected>

Bus #2 Follower - No Operator on Board

Bus #1 Leader – Operator on Board

Peak Period

Bus 2 Parked

Off-Peak

Bus 1 Operates as Single Unit

Potential for Bus Platooning

Potential to Increase Capacity in High Volume Bus Corridors

Potential for Bus Platooning

Potential Increased Capacity of Exclusive Bus Lane (XBL) Through Decreased Separation Using Cooperative Adaptive Cruise Control (CACC) (Assumes 45 foot (13.7 m) buses each with 57 seats)					
Average Interval Between Buses (seconds)	Average Distance Between Buses (ft.)	Average Distance Between Buses (m)	Buses Per Hour	Seated Passengers Per Hour	Increase in Seated Passengers per Hour from Base
1	6	2	3,600	205,200	164,160
2	47	14	1,800	102,600	61,560
3	**109**	**33**	**1,200**	**68,400**	**27,360**
4	150	46	900	51,300	10,260
5 (Base)	**212**	**64**	**720**	**41,040**	**-**

ACTIVITY

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U.S. Department of Transportation
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Question

Which of the following bus pilot technologies is most reliant on connected vehicle (V2V) technology?

Answer Choices

a) Automated Docking

b) Bus on Shoulder

c) Hybrid Propulsion

d) Bus Platooning

Review of Answers

a) Automated Docking

Incorrect. Used mainly magnetic guidance.

b) Bus on Shoulder

Incorrect. Used mainly radar and GPS.

c) Hybrid Propulsion

Incorrect. Hybrid propulsion not mentioned in the pilots.

d) Bus Platooning

Correct! Bus spacing mainly relies on communication.

Learning Objective 3

Development of
automated collision avoidance technologies
for buses and paratransit vehicles

National Transportation Safety Board (NTSB) Report on Forward Collision Avoidance

Special Investigation Report – The Use of Forward Collision Avoidance Systems to Prevent and Mitigate Rear End Crashes – 2015

“The NTSB has no authority to regulate, fund, or be directly involved in the operation of any mode of transportation."

National Transportation Safety Board (NTSB) Report on Forward Collision Avoidance

"currently available forward collision avoidance technologies for passenger and commercial vehicles … could reduce rear-end crash fatalities."

NTSB recommendations:

- Manufacturers - install forward collision avoidance systems on all newly manufactured passenger and commercial motor vehicles
- NHTSA - expand New Car Assessment Program to include graded performance rating of forward collision avoidance systems
- NHTSA - expand or develop protocols for assessment of forward collision avoidance systems

National Transportation Safety Board (NTSB) Report on Forward Collision Avoidance

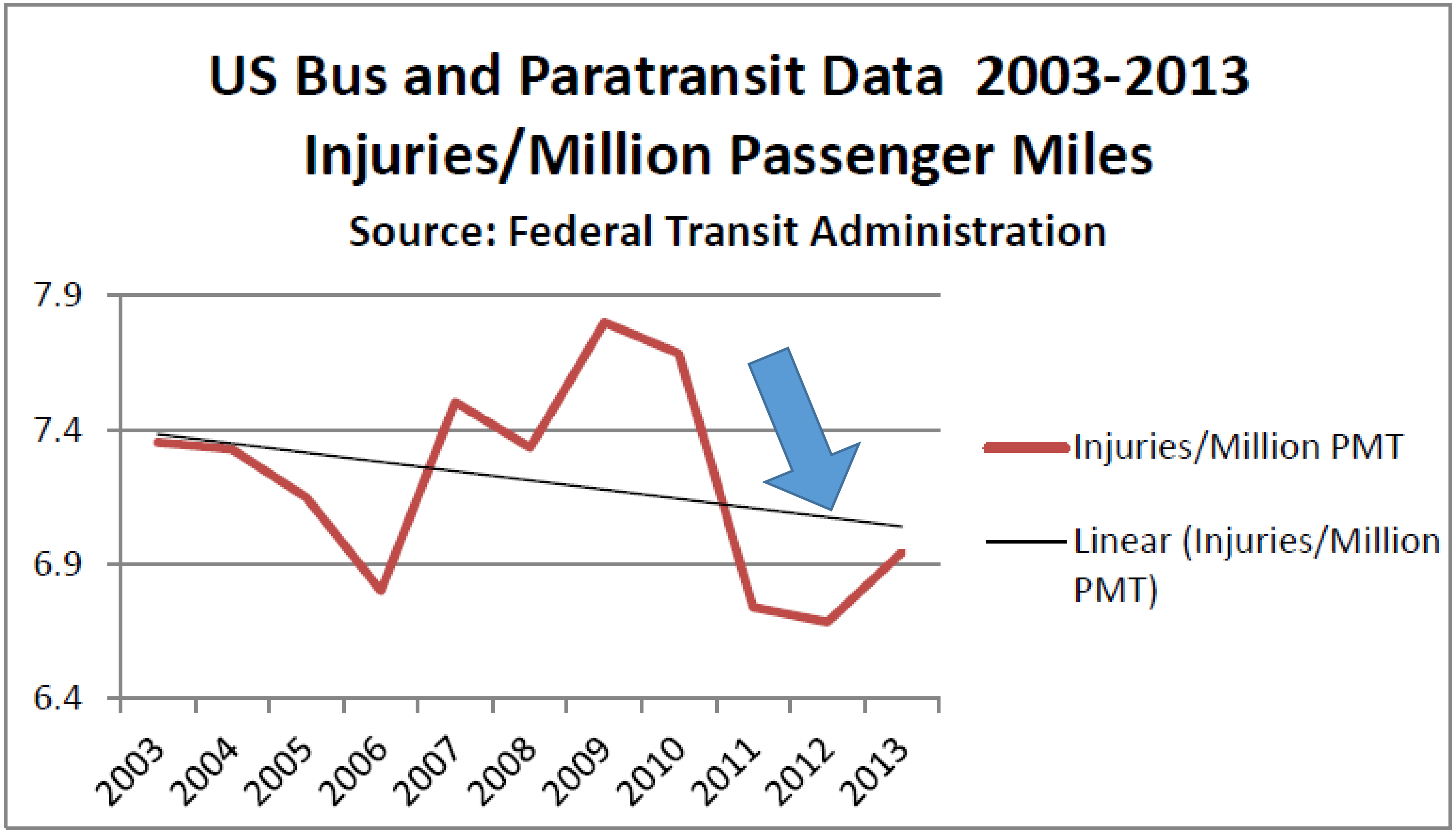
Forward collisions reduced 71% for trucks with collision avoidance systems, (CAS) autonomous emergency braking, (AEB) and electronic stability control (ESC)

NTSB called for immediate action to require these systems on new vehicles

- Transit required to retain buses for 12 + years
- Years before transit benefits from CAS and AEB on new buses
- Need to retrofit existing buses with CAS and AEB
- Need standards for CAS and AEB for retrofits and new buses

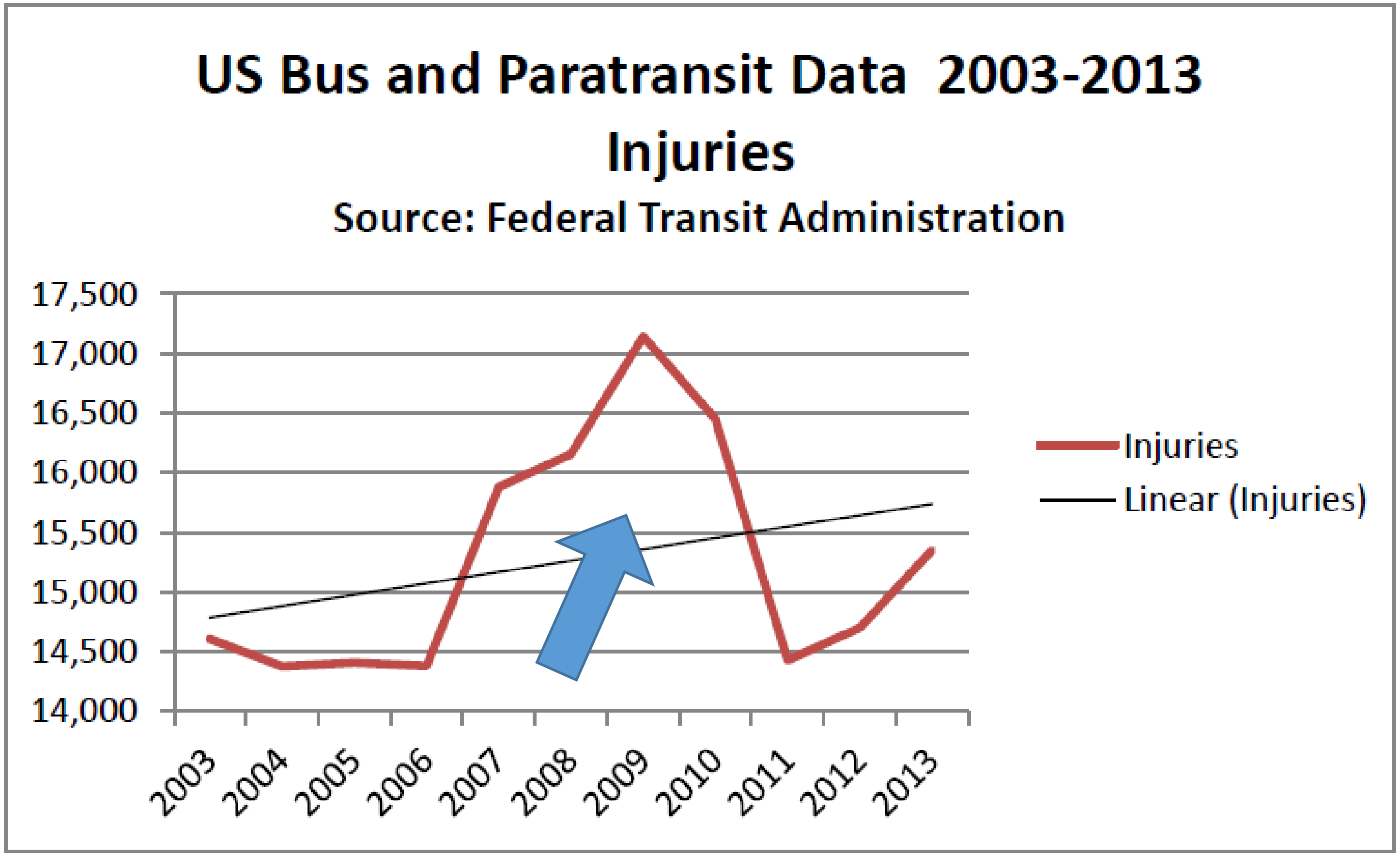
Collision Avoidance – Magnitude of the Problem for Transit

Trend in Rate of Bus and Paratransit Injuries Per Passenger Mile



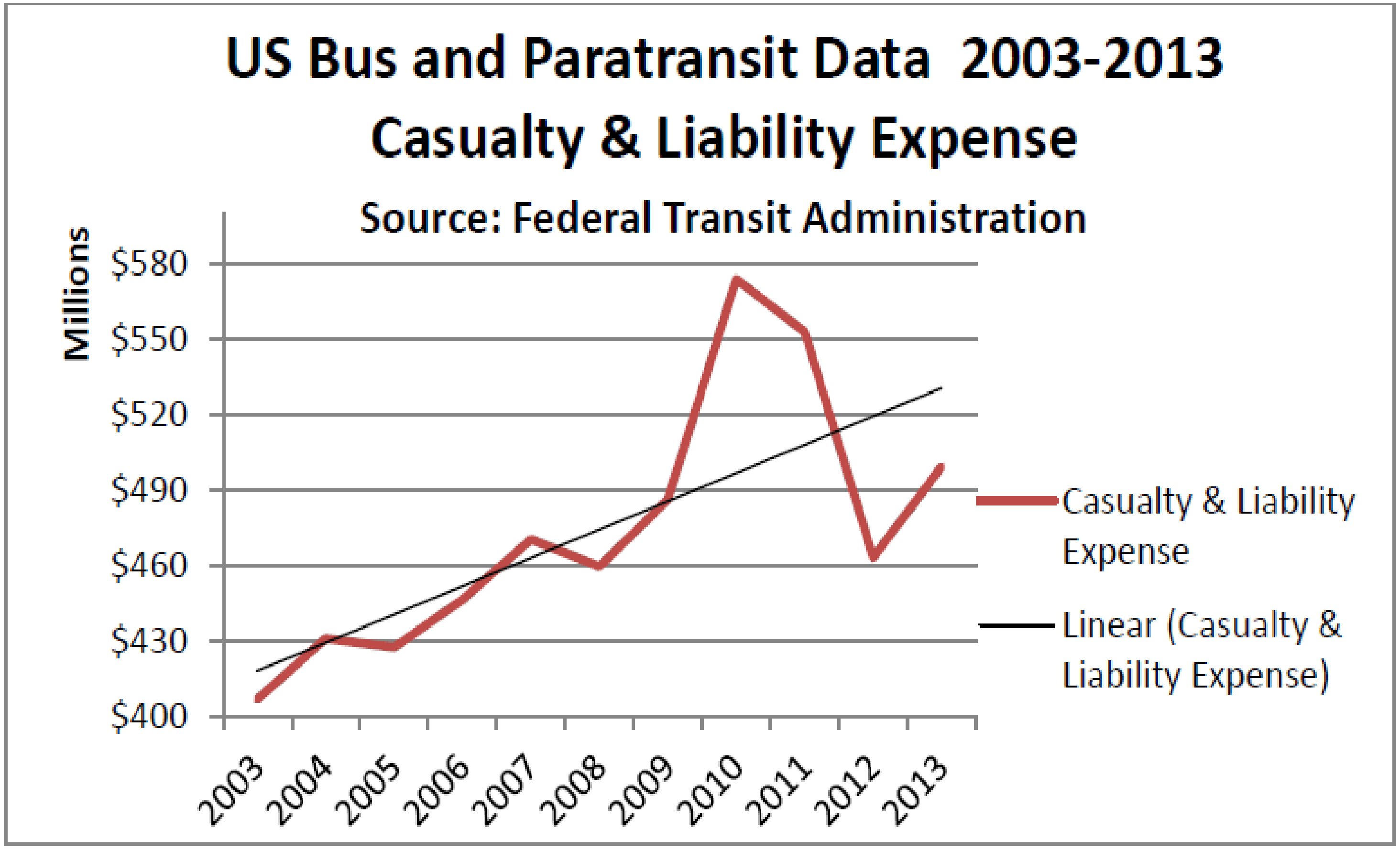
Collision Avoidance – Magnitude of the Problem for Transit

Trend in Number of Bus and Paratransit Injuries Per Year



Collision Avoidance – Magnitude of the Problem for Transit

Trend in Bus and Paratransit Casualty and Liability Expenses



Collision Avoidance – Magnitude of the Problem for Transit

Collisions, Fatalities, Injuries, Casualty and Liability Expenses for Bus and Rail Modes

Mode	Reporting Period 2002-2014			Reporting Period 2002-2013
	Collisions	Fatalities	Injuries	Total Casualty and Liability Expenses by Mode
Total Bus, Demand Responsive and Van Pool	85,391	1,340	201,382	$5.75 Billion
Total Rail	6,118	1,303	89,806	$3.17 Billion

Collision Avoidance – Magnitude of the Problem for Transit

Transit Insurance Pool Data Show Major Portion of Injuries, Fatalities, and Claims are Collision Related

Examination of 232 closed claims for Washington State Transit Insurance Pool spanning 2006-2015

- 100% of fatalities (6 total) were collision-related (vehicle, pedestrian, and bicyclist)
- 88% of injuries (335 total) resulted from collisions or sudden stops
- 94% of claims ($24.9 million total) resulted from collisions or sudden stops

MANY OF THESE COULD HAVE BEEN PREVENTED WITH CAS AND AEB

CASE STUDY

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

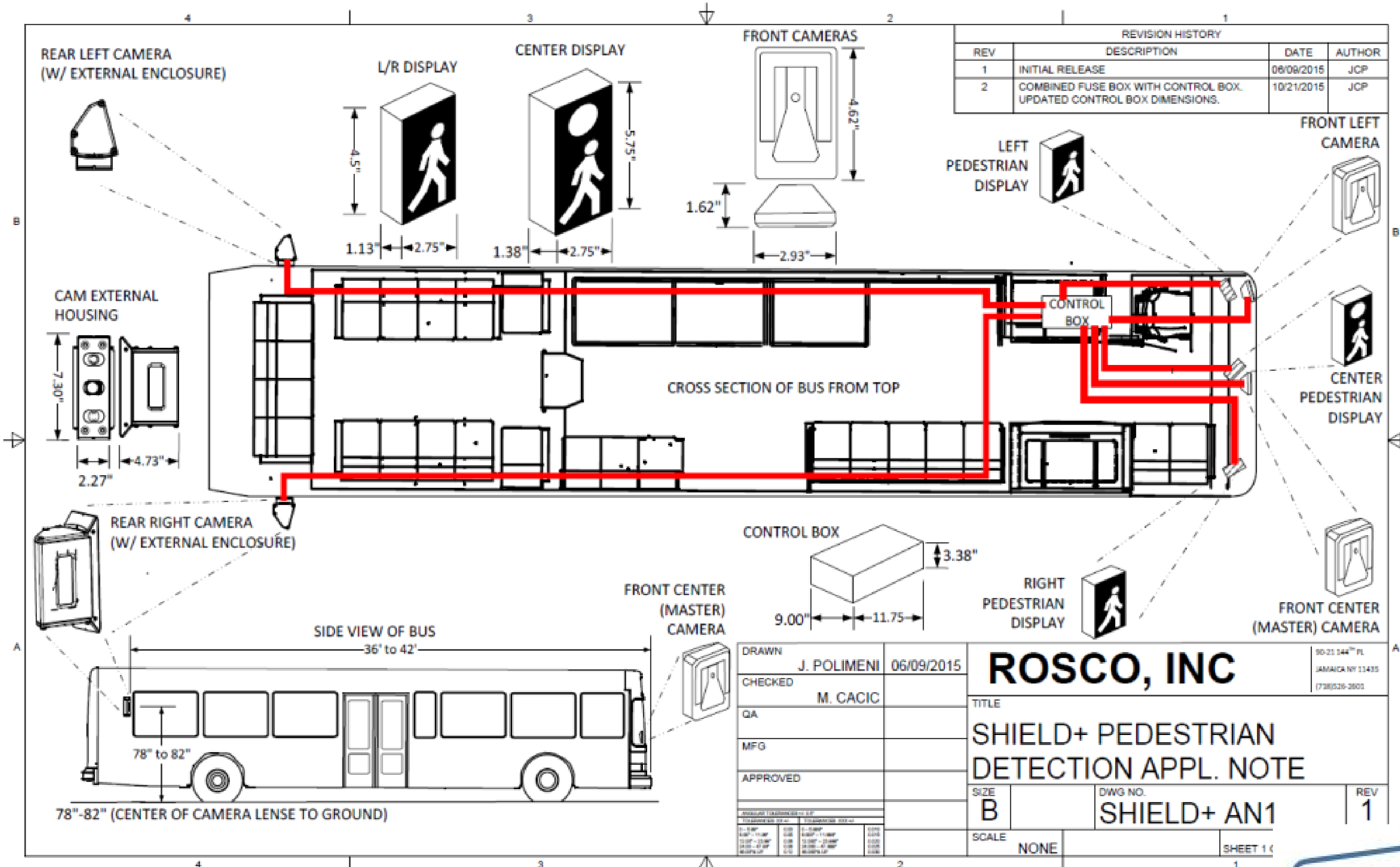
Washington State Transit Insurance Pool Safety Pilot

Innovations Deserving Exploratory Analysis (IDEA) grant awarded by TRB with additional funding from insurance companies

- Equipped 35 transit buses with CAS at seven member agencies and three buses at King County Metro
- Comprehensive examination of total costs for most severe and costly types of collisions
- Evaluate potential for CAS to reduce the frequency and severity of collisions, and reduce casualty and liability expenses
- Does not include autonomous braking in this phase

Washington State Transit Insurance Pool Safety Pilot

System Configuration



SUPPLEMENT

Washington State Transit Insurance Pool Safety Pilot

System Configuration - Alerts and Warning Displays

"MOBILEYE SHIELD+" OPERATOR REFERENCE GUIDE

MOBILEYE®
Our Vision. Your Safety.™

ROSCO® VISION SYSTEMS
OFFICIAL MOBILEYE PARTNER

LEFT SIDE DISPLAY

OFF
- Left Side Pedestrian Display
- For detecting pedestrians and cyclists who are near left front corner of bus or left side of bus.

DETECTION
- Yellow illumination with no sound
- Informs the operator a pedestrian or cyclist has been detected near the left front or left side of bus.
- Operator should exercise additional caution until verifying that the danger of collision has passed.

ALERT
- Red flashing with beeping sound
- Informs the operator a pedestrian or cyclist has been detected in the left front or left side of bus and collision is imminent.
- Operator should take action to carefully stop bus to avoid collision.

CENTER DISPLAY & EYEWATCH

OFF
- Center Display
- Contains the Pedestrian Display and EyeWatch.
- The EyeWatch readouts and explanations can be found below on this document.

DETECTION
- Yellow illumination with no sound
- Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus.
- Operator should exercise additional caution until verifying that the danger of collision has passed.

ALERT
- Red flashing with beeping sound
- Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus and collision is imminent.
- Operator should take action to carefully stop bus to avoid collision.

RIGHT SIDE DISPLAY

OFF
- Right Side Pedestrian Display
- For detecting pedestrians and cyclists who are near right side of bus.

DETECTION
- Yellow illumination with no sound
- Informs the operator a pedestrian or cyclist has been detected near the right side of bus.
- Operator should exercise additional caution until verifying that the danger of collision has passed.

ALERT
- Red flash with beeping sound
- Informs the operator a pedestrian or cyclist has been detected on the right side of bus and collision is imminent.
- Operator should take action to carefully stop bus to avoid collision.

EYEWATCH READOUTS

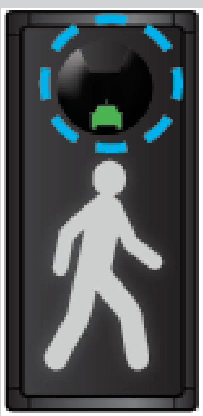
• Solid green dot with hash marks on each side. • System is operational with bus at 0 speed.	• Solid green dot • System is operational.	• Lane Departure Warning (LDW) • Occurs when crossing the lane markers without using turn signal. • Appears as a vertical white hash line on the Eyewatch • A series of sharp warning beeps of short duration. • The hash line will be on the Eyewatch side corresponding to the lane marker crossed. • For pilots this feature is not active	• Speed Limit Indicator (SLI) • Appears when the bus is traveling at least 5 mph (adjustable) over the last posted speed limit sign. • Two vertical white hash lines on each side of the Eyewatch will appear with a white number indicating miles over the last posted speed limit • Has a chime sound. • Operator should reduce speed to keep within the speed limit.	• Headway Monitoring (HMW) • Appears as green car • Indicates detection of a vehicle in the path of the bus. • No number shown if bus is traveling a safe distance behind the vehicle in front or when bus is traveling below 19 MPH.	• Headway Monitoring (HMW) • Appears as green car and number • Indicates how far the vehicle in front of the bus is in seconds. • The 2.5 indicates the seconds until a collision could occur if the front vehicle were to come to a stop. • Operator is advised to reduce speed if time to collision falls below preset seconds and car turns red. • Has a chime sound.	• Headway Monitoring Warning (HMW) • Appears as a red car with an audible chime • Indicates the distance between bus and vehicle in front has fallen below a safe threshold. • Operator is advised to reduce speed to increase distance to a safe level.	• Forward Collision Warning (FCW) • Appears as flashing red car with a high pitched beeping sound • Indicates rear end collision is imminent • Operator must stop the bus immediately

T: 718.526.2601

SUPPLEMENT

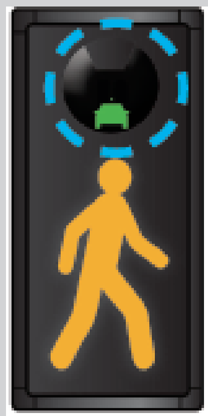
System Configuration – Alerts and Warning Displays

CENTER DISPLAY & EYEWATCH



OFF

- Center Display
- Contains the Pedestrian Display and EyeWatch.
- The EyeWatch readouts and explanations can be found below on this document.



DETECTION

- Yellow illumination with no sound
- Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus.
- Operator should exercise additional caution until verifying that the danger of collision has passed.

ALERT

- Red flashing with beeping sound
- Indicates a pedestrian or cyclist is in front of the moving bus or coming towards the moving bus and collision is imminent.
- Operator should take action to carefully stop bus to avoid collision.

SUPPLEMENT

Washington State Transit Insurance Pool Safety Pilot

Telematics – Monitoring System Performance

- The CAS does not record video
- Additional technology is used to generate data that can be used to evaluate the systems' effectiveness
- Additional cameras record video of events
- Telematics unit captures and transmits data

Washington State Transit Insurance Pool Safety Pilot

Monitoring System Performance with Telematics and Video

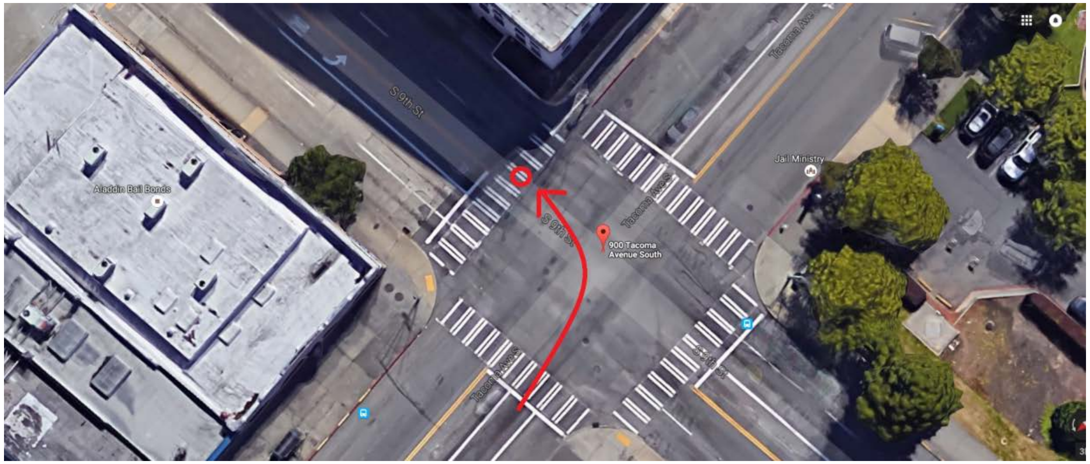
Bus Speed = 0 mph

ROSCO VISION SYSTEMS

MOBILEYE Our Vision. Your Safety.

Washington State Transit Insurance Pool Safety Pilot

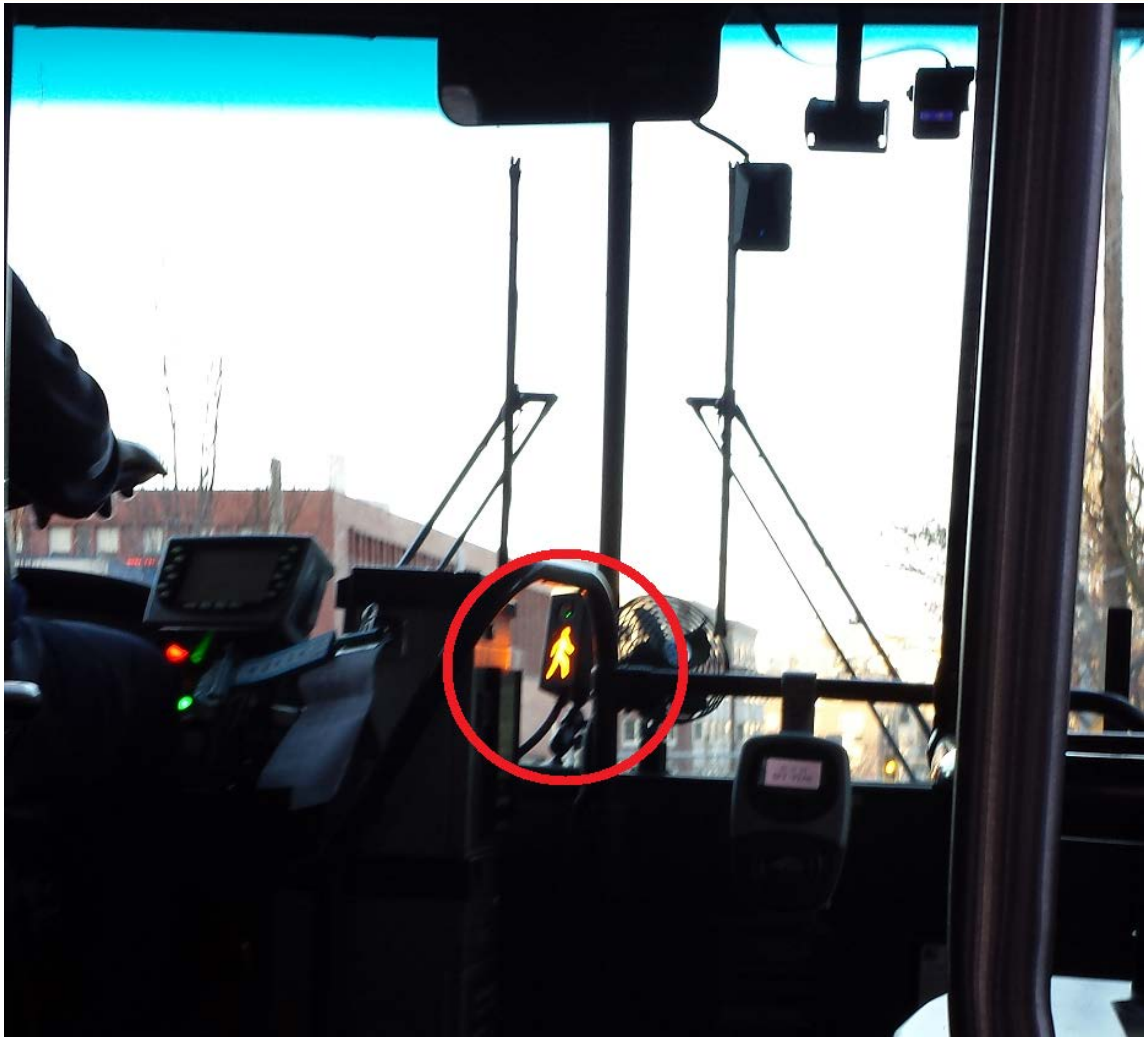
Field Testing the CAS – Mapping Telematics Data



Washington State Transit Insurance Pool Safety Pilot

Field Testing the CAS

Checking System Performance in Revenue Service – comparing real time observations with telematics data



Washington State Transit Insurance Pool Safety Pilot

Field Testing the CAS – Logging Telematics Data

Number of selected vehicles : 1 Information exists for 1 of 1 vehicles selected

Time Period: : 28/03/2016 21:20:00 - 28/03/2016 22:20:59

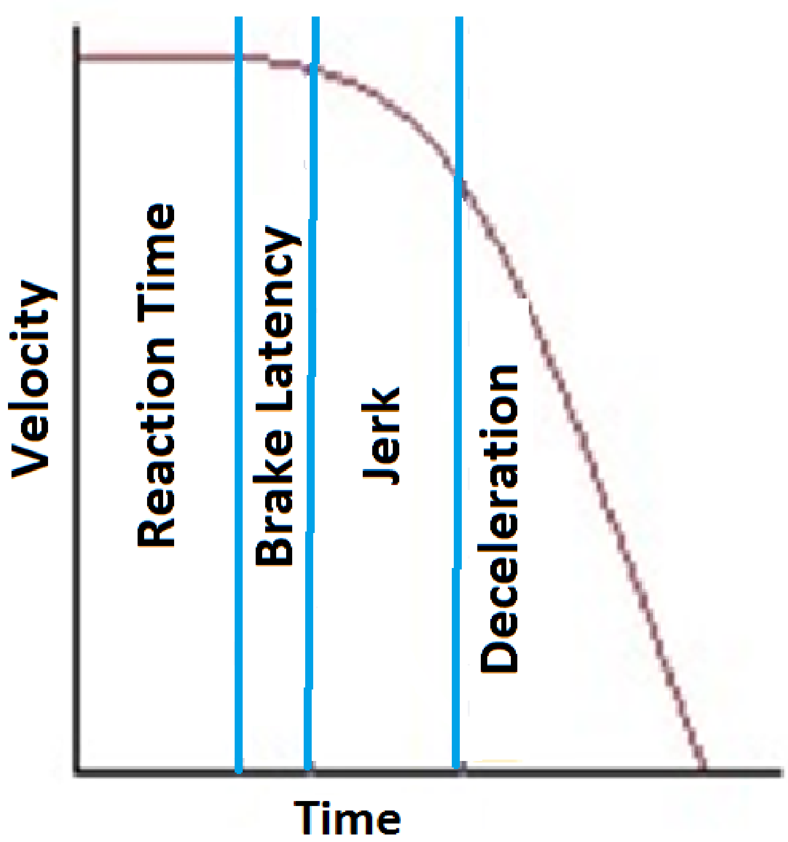
Total Records : 44

Report Name : -	Vehicle name	Heading	Distance In Miles	Driver name	Address	Speed	Status Name	Rule name	POI Original
28/03/2016 21:57:25	KCM #4346	NE	3.29		1333-1367 Madison St, Seattle, WA 98104, USA	14	ME - Pedestrian In Range Warning	ME4 - Pedestrian In Range Warnin	
28/03/2016 21:57:29	KCM #4346	NE	3.29		1368-1398 Madison St, Seattle, WA 98104, USA	14	PDZ-R	ME4 - PDZ - Right	
28/03/2016 22:00:06	KCM #4346	NE	3.73		1349-1397 E Madison St, Seattle, WA 98122, USA	14	ME - Pedestrian In Range Warning	ME4 - Pedestrian In Range Warnin	
28/03/2016 22:00:07	KCM #4346	NE	3.73		1349-1397 E Madison St, Seattle, WA 98122, USA	12	ME-PCW		
28/03/2016	KCM #4346	NE	3.73		1350-1398 E Madison St	11	ME -	ME4 -	

Autonomous Emergency Braking (AEB) – Need for Standards and Testing

The Need for Autonomous Braking

- The curved line shows velocity of the bus when braking



Autonomous Emergency Braking (AEB) – Need for Standards and Testing

The Need for Standards and Specifications

Transit buses require different CAS-AEB technology than cars and trucks

- Standing passengers could be injured from sudden stops
- Buses in service 12 -18+ years - ability to retrofit is key
- Can not take buses out of service for long periods – standards help design systems for quicker retrofits and maintenance
- Little financial incentive for bus OEM's to do R&D for CAS – transit is being left behind
- Most buses purchased through competitive bidding requiring detailed specifications for CAS-AEB

Autonomous Emergency Braking (AEB) – Need for Standards and Testing

Standards will need to address unique bus characteristics such as:

- Blind spot locations
- Component replacement and maintenance requirements
- Forces acting on seated and standing passengers
- Operator training and workload
- Proximity of pedestrians and waiting passengers
- Sensor placement
- Vehicle lifespan

ACTIVITY

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

Question

Which of the following statements is true?

Answer Choices

a) Casualty and liability expenses for rail transit far exceed those for bus transit.

b) Driver reaction time is not a factor in avoiding bus collisions.

c) National Transportation Safety Board does not require forward collision warning systems on all new vehicles.

d) Transit buses are currently being delivered with Autonomous Emergency Braking.

Review of Answers

a) Casualty and liability (C&L) expenses for rail transit far exceed those for bus transit
Incorrect. Bus C&L expenses were 80% higher than rail.

b) Driver reaction time is not a factor in avoiding bus collisions
Incorrect. Bus moves at initial velocity during reaction.

c) The NTSB does not require forward collision warning (FCW) systems on all new vehicles
Correct! NTSB recommends, but has no authority to require it.

d) Transit buses are currently being delivered with Autonomous Emergency Braking (AEB)
Incorrect. AEB not currently available for transit buses.

Learning Objective 4

Potential for AV/CV technologies to support **first mile/last mile** transit connections

C A S E   S T U D Y

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

CityMobil2 Demonstrations

CityMobil2 – European Union project to pilot test automated road transit

- Pilot testing driverless shuttle vehicles across Europe
- Funded at €15 million ($19.5 million)
- Two sets of six vehicles supplied by two vendors, Easymile and Robosoft
- Vehicles are battery powered
- Operating speed is typically 8-15 km/hr. (5-9 mph)
- Seating for six with four standees
- Guidance uses GPS and LIDAR

CityMobil2 Demonstrations

CityMobil2 Demonstration Sites

Demo Type	Location	Start Month	End Month	Vehicle Mfr	# of Veh	Route (km)	Stations Served	# of Riders
Large Scale	Lausanne, CH	4/2015	8/2015	Easymile	4	1.5	6	7,000
	La Rochelle, FR	12/2014	4/2015	Robosoft	6			14,660
	Trikala, GR	9/2015	1/2016	Robosoft	6	2.5		12,150
Small Scale	Antibes, FR	1/2016	3/2016	Easymile	4	1.0	5	4,000
	Oristano, IT	7/2014	9/2014	Robosoft	2	1.3	7	2,500
	Vantaa, FI	7/2015	8/2015	Easymile	4	1.0		19,000
	San Sebastian, ES	4/2014		Robosoft	3			3,500
Showcase	Bordeaux, FR	10/2015	10/2015	Easymile	4	1.0	2	
	Leon, ES	9/2014	9/2014	Robosoft	2			
	Warsaw, PO	4/2016						

CityMobil2 Demonstrations

CityMobil2 Vehicles – Exterior of Easymile EZ10 vehicle

SUPPLEMENT

CityMobil2 Demonstrations

CityMobil2 Vehicles – Interior of Easymile EZ10 vehicle

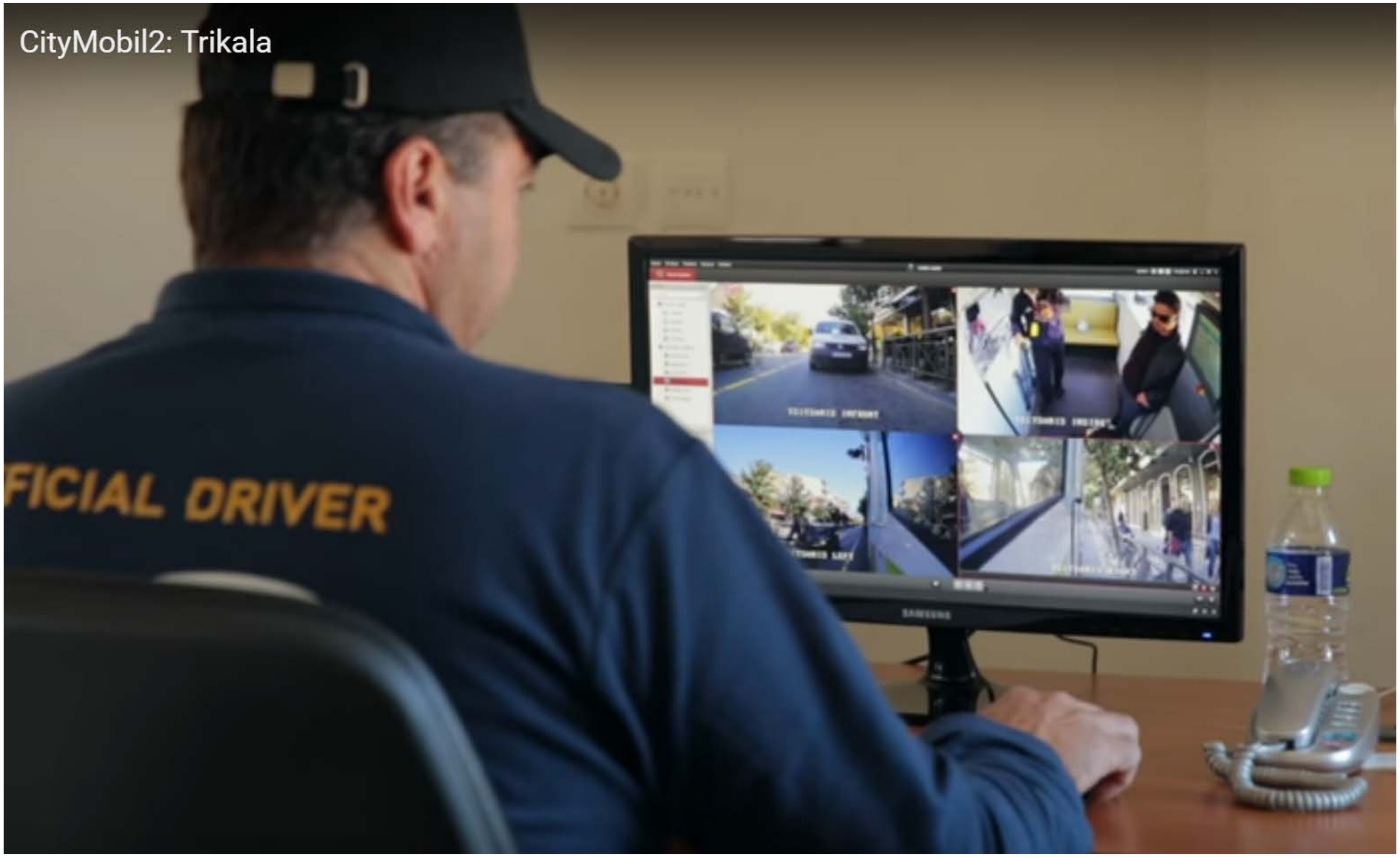
CityMobil2 Demonstrations

CityMobil2 – Robosoft RobuCITY vehicle

SUPPLEMENT

CityMobil2 Demonstrations

CityMobil2 – Remote monitoring of vehicles



CityMobil2 Demonstrations

CityMobil2 Demonstrated Feasibility of Automated Transit for First Mile/Last Mile in Mixed Traffic

ACTIVITY

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

Question

Which of the following was not true of the CityMobil2 demonstrations?

Answer Choices

a) The program was funded at about $19.5 million by the European Union

b) Two different contractors each built six robotic vehicles

c) The vehicles traveled at low speed and carried passengers

d) The vehicles required exclusive rights-of-way with no pedestrian or vehicular crossings

Review of Answers

a) The program was funded at about $19.5 million by the European Union

True.

b) Two different contractors each built six robotic vehicles

True.

c) The vehicles traveled at low speed and carried passengers

True.

d) The vehicles required exclusive rights-of-way with no pedestrian or vehicular crossings

False! Vehicles shared roads with people, bicycles, and cars

Learning Objective 5

Fundamentals of rail transit system **connected/automated operation** for transit safety and capacity

CASE STUDY

STANDARDS
ITS
TRAINING
TRANSIT

U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

Communications Based Train Control (CBTC)

Case Study – Implementing CBTC at MTA New York City Transit

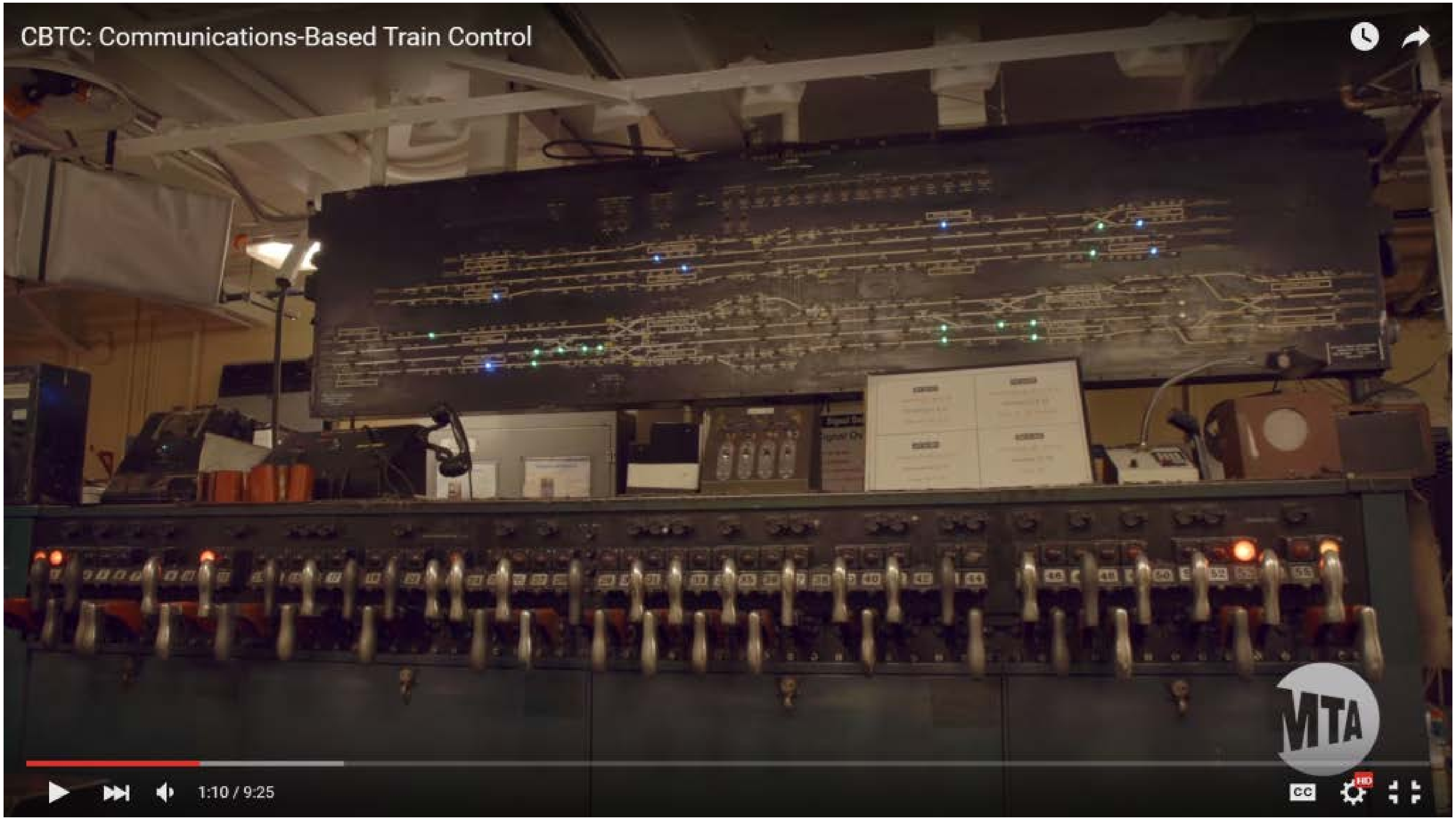
Communications Based Train Control (CBTC)

Fixed Block Signaling – most common form of railway signaling for more than a century

- Sections of rails on track are separated by electrical insulators
- Steel train wheels and axles complete an electric circuit through rails as train passes from one section of rail to the next
- Insulated sections of rail are called “blocks”
- Purpose – to insure only one train at a time is in the block
- When train enters block, electricity passes through the track circuit to illuminate signals like traffic lights, telling oncoming trains to stop, slow, or proceed

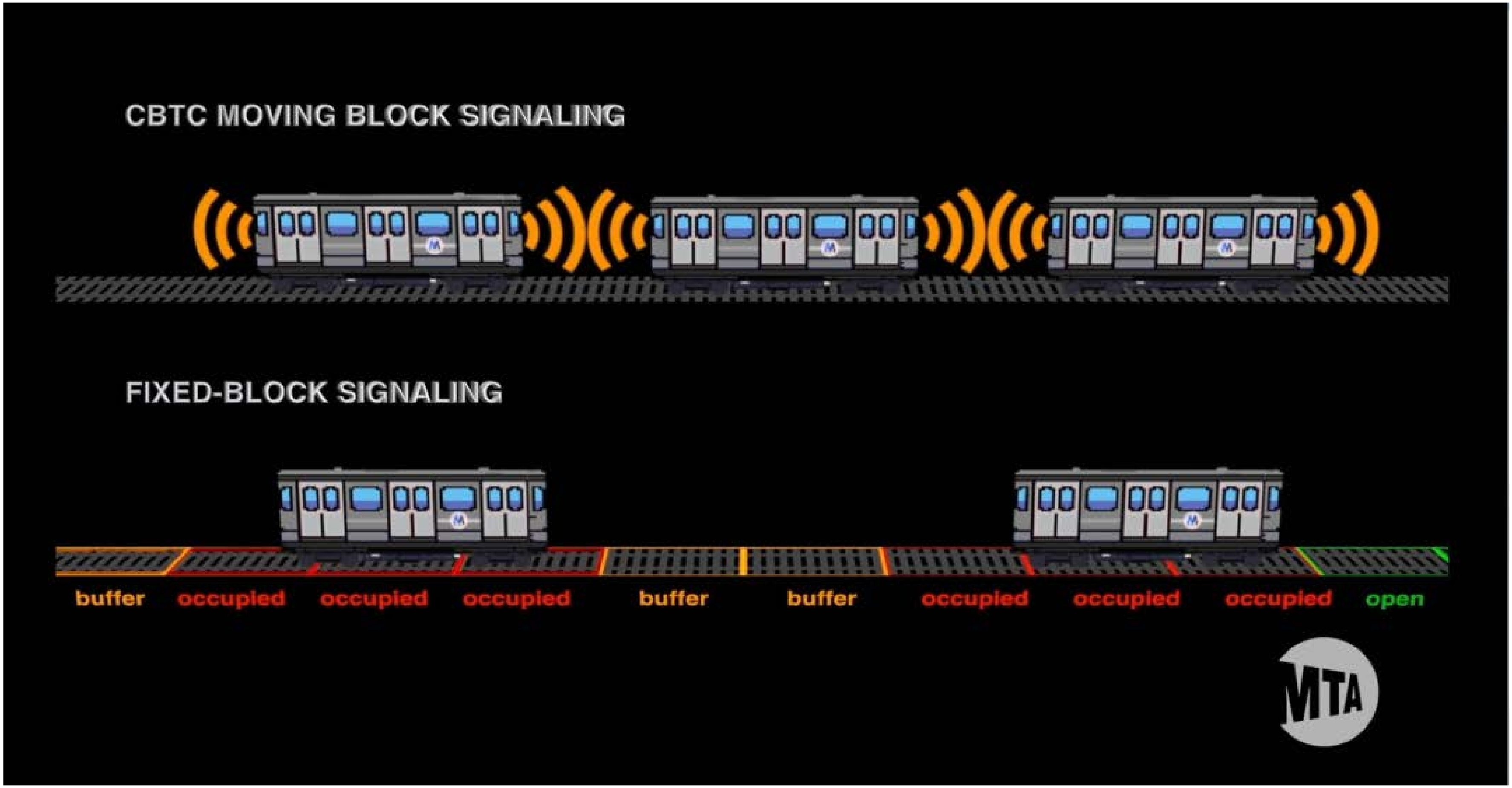
Communications Based Train Control (CBTC)

Fixed Block Signaling at New York City Subway – 1930's equipment still in use



Communications Based Train Control (CBTC)

Moving Block Signaling at New York City Subway



Communications Based Train Control (CBTC)

Key Elements of a Radio – Based CBTC System Architecture

- Transmits train performance data and continuous train position and speed
- Enables dynamic adjustment of train spacing (virtual block length)
- Uses three integrated networks:
  - Backbone network
  - Radio Network
  - Train-to-wayside network – on-board radio and trackside radio access points
- Automatic Train Control (ATC) is on-board and wayside, providing speed control and braking

Communications Based Train Control (CBTC)

IEEE Standards for CBTC

IEEE 1474.1 – worldwide reference technology standard

- **1474.1-2004** - CBTC Performance and Functional Requirements
- **1474.2-2003** - User Interface Requirements in CBTC Systems
- **1474.3-2008** - Recommended Practice for CBTC System Design and Functional Allocations
- **1474.4-2011** - Recommended Practice for Functional Testing of a CBTC System
- **IEEE 802.11a/g/p/n** - protocol (Wi-Fi/WLAN)

Communications Based Train Control

Benefits of CBTC for MTA NYCT

Canarsie Line in operation - Flushing Line being installed - Queens Blvd Line next

- Allows more trains per hour, increasing passenger capacity
- Provides more reliable service; more efficient use of its track and car fleet
- Allows system to recover quickly from delays and restore consistent wait times
- Keeps signaling system in state of good repair, enhances safety
- Can program not-to-exceed speed in work zone, improving track worker safety
- Can provide real-time travel information to customers
- **Canarsie Line ridership up 27 % since CBTC installed in 2007**

Commuter Rail - Positive Train Control (PTC)

Commuter Rail and Positive Train Control

2014 U.S. Commuter Rail Operations

- 23 authorities reporting service
- 3,891 vehicles
- 178,640,234 revenue miles
- 275,663,405 passenger trips

Commuter rail operates over track shared with Amtrak and freight railroads, often mixing with freight trains

Commuter Rail - Positive Train Control (PTC)

What is Positive Train Control?

"Positive train control" (PTC) describes technologies designed to automatically stop a train before certain accidents caused by human error occur."

PTC **mandated by Congress** must be designed to prevent

- Train-to-train collisions
- Derailments from excessive speed
- Unauthorized incursions by trains onto track with maintenance activities
- Movement of a train through a track switch left in the wrong position

PTC systems **supplement** rather than replace existing train control systems

SUPPLEMENT

Commuter Rail - Positive Train Control (PTC)

Regulatory History of PTC - Rail Safety Improvement Act of 2008

Chatsworth, CA Sept. 12, 2008

Metrolink train collision with Union Pacific freight train

- 25 killed
- 102 injured
- $12 million in damage

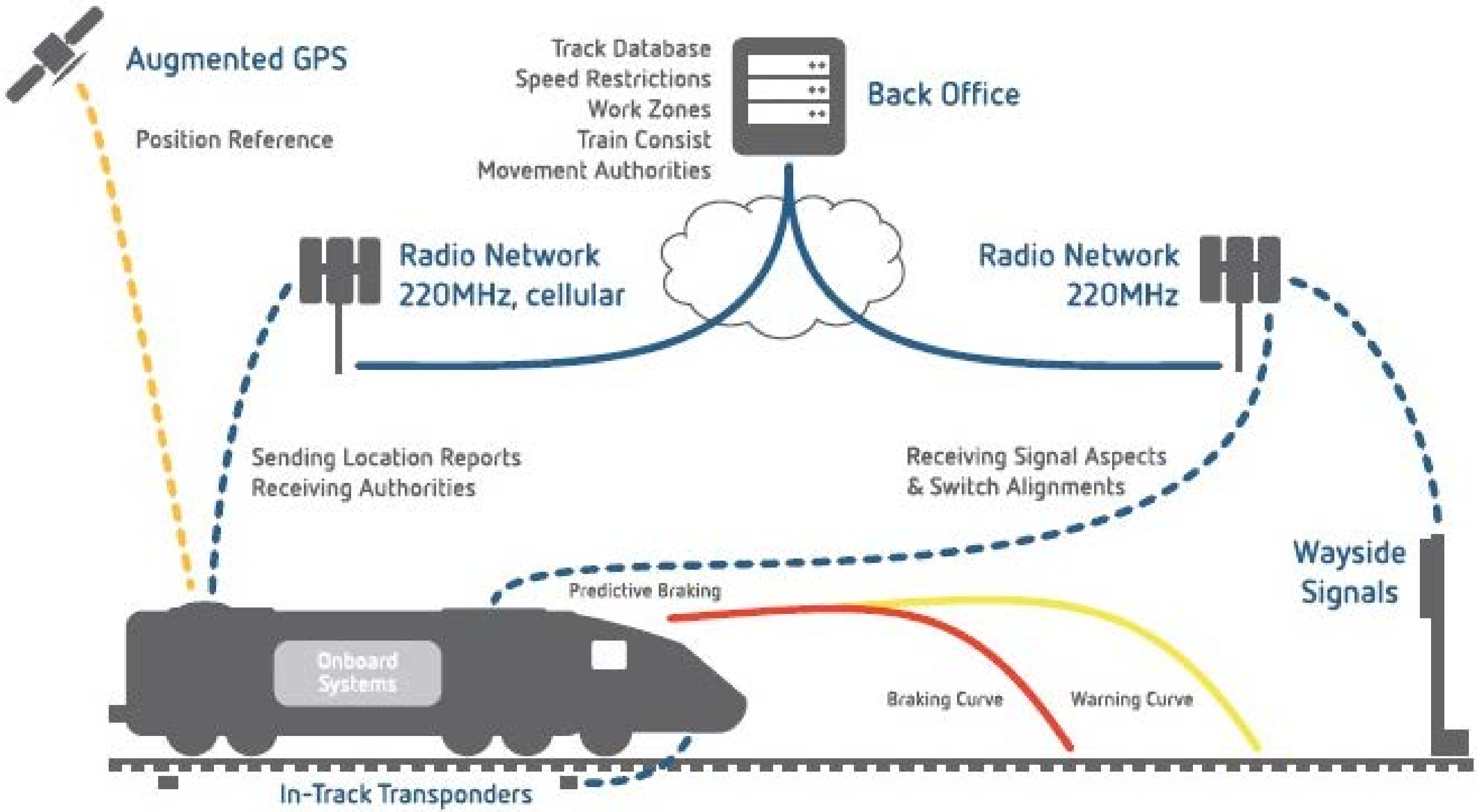
Cause: Metrolink engineer was texting on his phone

Congress: Install PTC by

- Dec. 31, 2015
- Deadline extended to
  Dec. 31, 2018

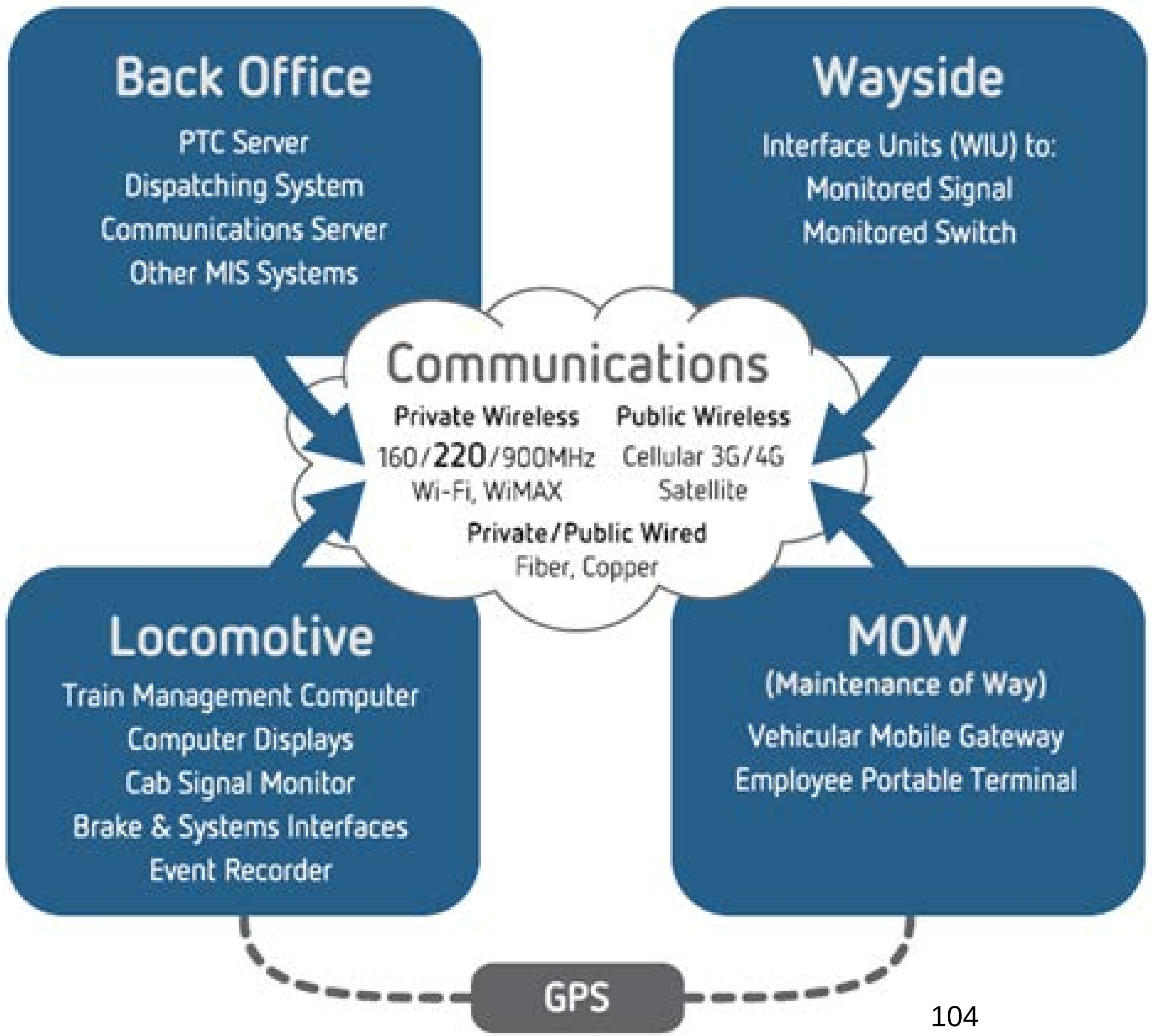
Commuter Rail - Positive Train Control (PTC)

PTC Operation



Commuter Rail - Positive Train Control (PTC)

PTC Architecture



Two major technical architectures

Amtrak NEC – Advanced Civil Speed Enforcement System (ACSES)

ITC – Interoperable Electronic Train Management System (I-ETMS)

Commuter Rail - Positive Train Control (PTC)

Tasks to Complete PTC – Estimated Price Tag – $13 Billion

- Physical survey and geo-mapping for 82,000+ track-miles
- Geo-mapping - 460,000 field assets (mileposts, curves, grade crossings, switches, signals, etc.)
- Installing PTC and new radios on 22,000+ locomotives
- Installing 32,600 “wayside interface units” (WIU) and new radios for connecting locomotives, train dispatching office, signal, and switch locations
- Installing PTC technology on 2,600+ switches in non-signaled territory and signal replacement projects at 15,100 locations
- Developing and deploying a new radio system at approximately 4,000 base stations
- Developing back office systems and upgrading dispatching software

Commuter Rail - Positive Train Control (PTC)

Standards for PTC

- **Unlike most other ITS standards, standards for PTC are based on Federal Law.** The Rail Safety Improvement Act (RSIA) of 2008 mandated the Federal Railroad Administration of the U.S. Department of Transportation issue rules for PTC

- **RSIA key technical mandates:**

  - **All PTC systems must be interoperable** - any railroad's locomotive can operate on any other railroad's track using the same signaling and control systems.

  - **Core objectives defining that PTC system must prevent:**
    - Train-to-train collisions
    - Over-speed derailments
    - Incursions into established work zone limits

Commuter Rail - Positive Train Control (PTC)

FRA Standards for PTC – extensive detail in rulemaking

Subpart I—Positive Train Control Systems
Sec.
236.1001 Purpose and scope.
236.1003 Definitions.
236.1005 Requirements for Positive Train Control systems.
236.1006 Equipping locomotives operating in PTC territory.
236.1007 Additional requirements for highspeed service.
236.1009 Procedural requirements.
236.1011 PTC Implementation Plan content requirements.
236.1013 PTC Development Plan and Notice of Product Intent content requirements and Type Approval.
236.1015 PTC Safety Plan content requirements and PTC System Certification.
236.1017 Independent third party Verification and Validation.
236.1019 Main line track exceptions.
236.1021 Discontinuances, material modifications, and amendments.
236.1023 Errors and malfunctions.
236.1025 [Reserved]
236.1027 PTC system exclusions.
236.1029 PTC system use and en route failures.
236.1031 Previously approved PTC systems.
236.1033 Communications and security requirements.
236.1035 Field testing requirements.
236.1037 Records retention.
236.1039 Operations and Maintenance Manual.
236.1041 Training and qualification program, general.
236.1043 Task analysis and basic requirements.
236.1045 Training specific to office control personnel.
236.1047 Training specific to locomotive engineers and other operating personnel.
236.1049 Training

Commuter Rail - Positive Train Control (PTC)

Association of American Railroads (AAR) Standards for PTC – Manual of Standards and Recommended Practices Section K

- **Part I** – Railway Electronics System Architecture and Concepts of Operations (9000 Series)
- **Part II** – Locomotive Electronics and Train Consist System Architecture (9100 Series)
- **Part III** – Wayside Electronics and Mobile Worker Communications (9200 Series)
- **Part IV** – Office Architecture and Railroad Electronics Messaging (9300 Series)
- **Part V** – Electronics Environmental Requirements and System Management (9400 Series)
- **Part VI** – Railway Data Management and Communications (9500 Series)

SUPPLEMENT

ACTIVITY

STANDARDS ITS TRAINING TRANSIT

U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

Question

Which of the following statements is true?

Answer Choices

a) Positive Train Control standards are voluntary.

b) All Communications Based Train Control Systems must be interoperable.

c) Communications Based Train Control Systems allow only one train in a fixed block at a time.

d) Positive Train Control systems and Communications Based Train Control systems can be overlaid on existing fixed block signal systems.

Review of Answers

a) Positive Train Control standards are voluntary.
False. PTC standards are mandated by FRA rule-making

b) All Communications Based Train Control Systems must be interoperable
False. PTC interoperates across all railroads, but not CBTC

c) Communications Based Train Control Systems allow only one train in a fixed block at a time
False. CBTC systems do not use fixed blocks

d) Positive Train Control systems and Communications Based Train Control systems can be overlaid on existing fixed block signal systems.
Correct! PTC and CBTC can be installed as overlays

Module Summary

What We Have Learned

1. The relationships between connected vehicle and automated transit vehicle functionality, including terminology, and which SDO's are active in the CV/AV space.
2. The potential to improve safety, access, and capacity by using automated guidance for operation on shoulders, for docking at platforms, and for bus platooning.
3. That development of automated collision avoidance technologies for buses and paratransit vehicles can improve operational safety and can save lives, reduce injuries, and reduce costs by avoiding collisions and braking autonomously.
4. How the European CityMobil2 demonstrations showed the potential for automated transit vehicles to provide first mile/last mile serve in mixed traffic with pedestrians, bicyclists, and autos.
5. That Positive Train Control systems and Communications Based Train Control systems can improve safety, capacity and system reliability through automation and connectivity.

Thank you for completing this module.

Feedback

Please use the Feedback link below to provide us with your thoughts and comments about the value of the training.

Thank you