



UNITED STATES
DEPARTMENT OF TRANSPORTATION

Commercial Vehicle V2V Communications for Safety Research

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National Highway Traffic Safety Administration

Connected Vehicle Truck Safety Meeting
Chicago, IL
August 4, 2011

Vehicle Safety Communications

Connected Vehicle Environment



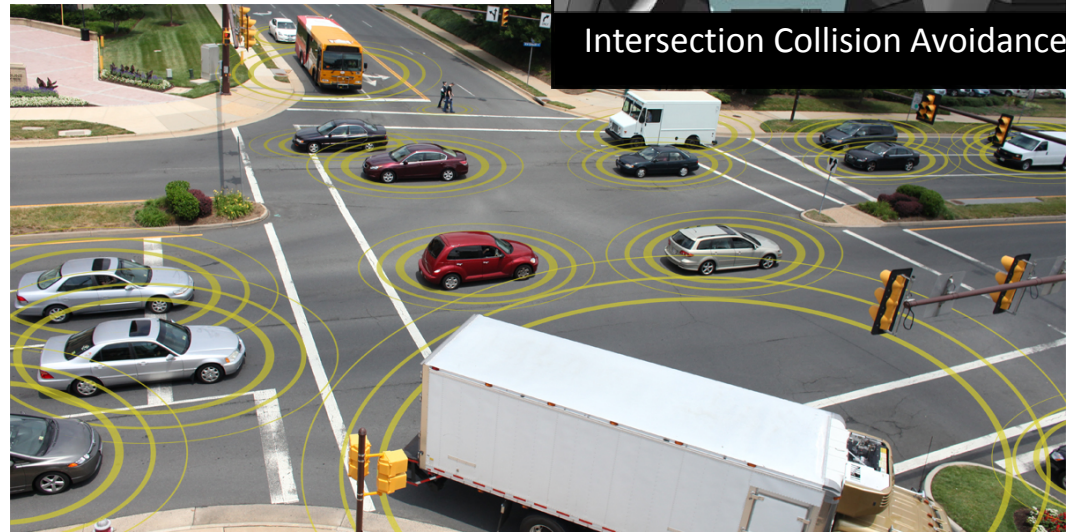
Vehicle Safety Communications

Greater situational awareness

- Your vehicle can “see” nearby vehicles and knows roadway conditions you can’t see.

Vehicle-to-Vehicle (V2V) can reduce or mitigate crashes

- Driver advisories
- Driver warnings
- Vehicle control



Vehicle safety communications have the potential to address approximately 80% of crash scenarios for unimpaired drivers



Commercial Vehicle V2V Research Plan

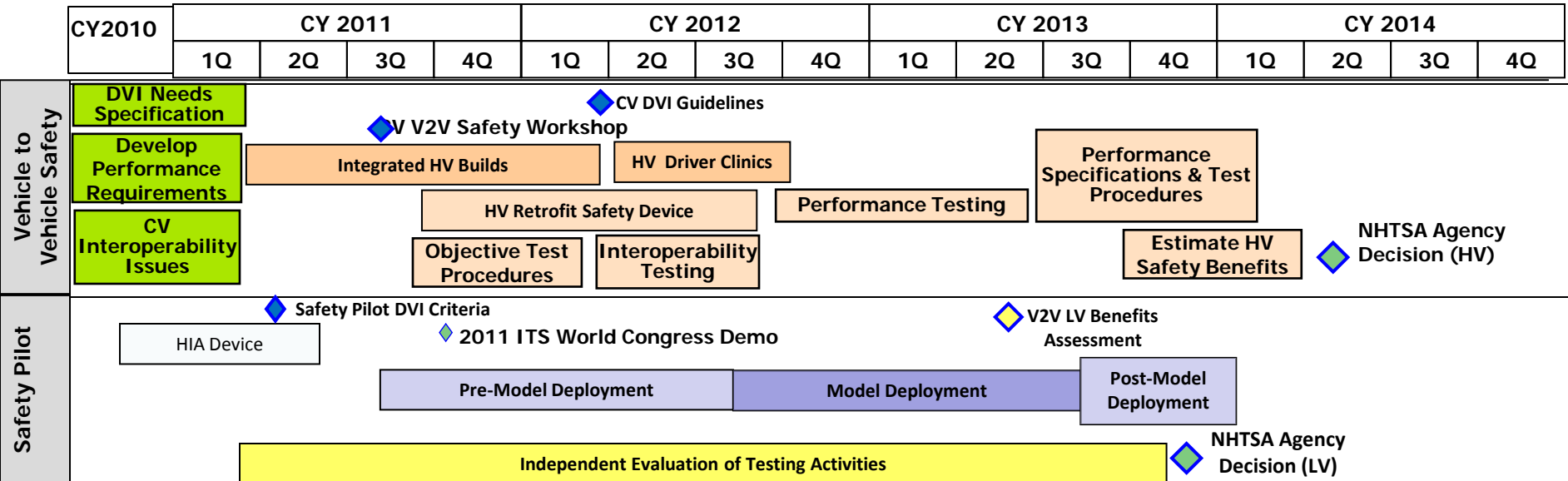
Objective – Resolve technical issues necessary for deployment of Vehicle-to-Vehicle (V2V) systems on commercial vehicles (CV) and conduct research on areas of policy concerns.

Key Tasks

- Identify priority CV crash scenarios.
- Select priority safety applications / determine performance requirements.
- Identify CV specific interoperability issues.
- Identify CV specific human factors / DVI issues.
- Build prototype vehicles and develop objective test procedures
- Conduct Driver Acceptance Clinics.
- Participate in Safety Pilot to gain “real world” experience.
- Estimate safety benefits.
- Identify CV policy issues and coordinate with overall program
- Support NHTSA Agency decision in 2014 for heavy vehicles



Commercial Vehicle V2V and Safety Pilot Roadmap



Research Completed to Date

- Driver Vehicle Interface Needs Identification
- Development of Performance Requirements for Safety Applications
- Identify CV Interoperability Issues

Upcoming Research

- Build Prototype Truck Tractors with Integrated V2V Applications
- Participate in Safety Pilot
 - Conduct CV Driver Acceptance Clinics
 - Model Deployment





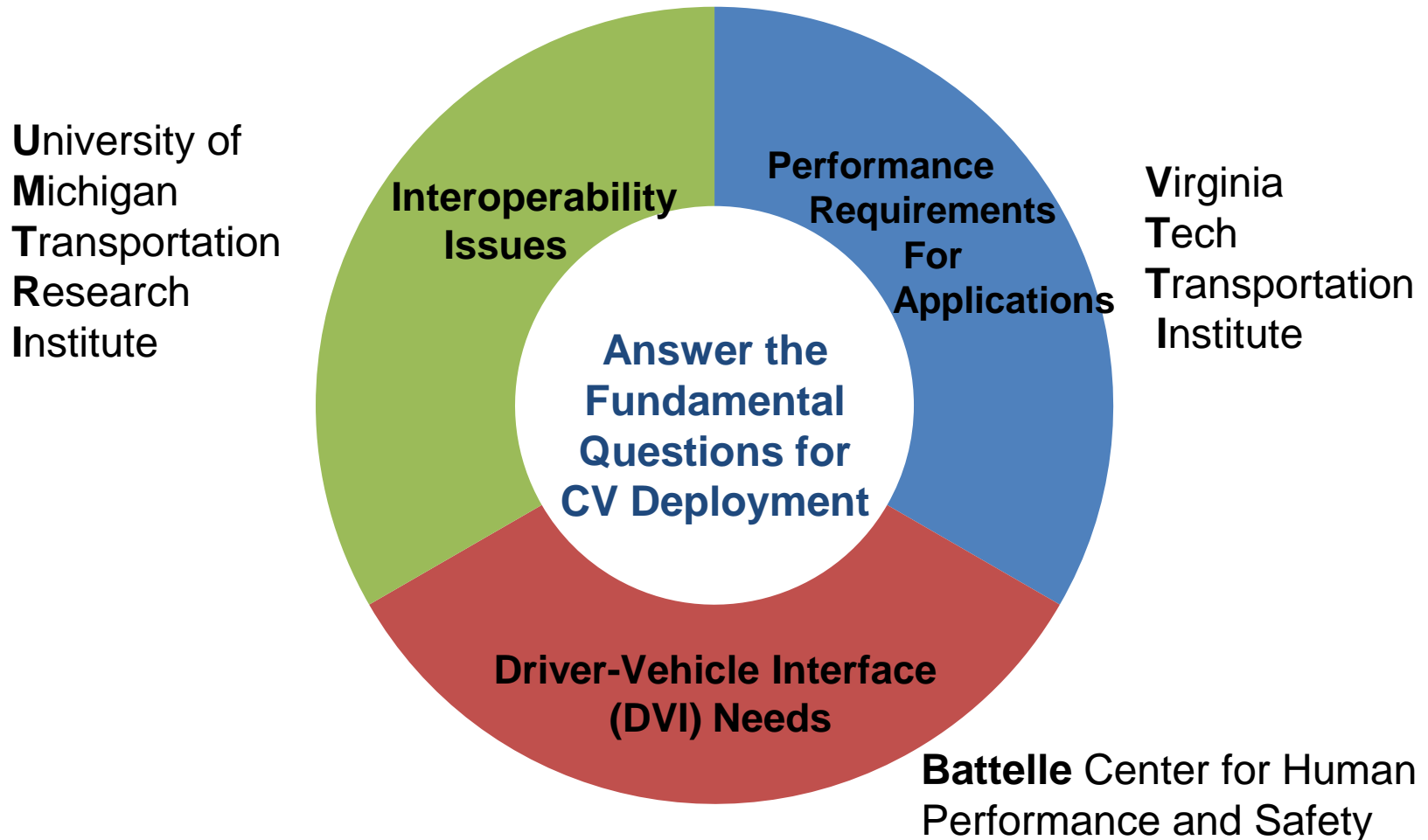
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Commercial Vehicle V2V Results To Date

**Connected Vehicle Truck Safety
Meeting
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Commercial Vehicle V2V Research

Completed CV V2V Research Projects initiated in 2010



CV Driver-Vehicle Interface Needs



Battelle identified specific CV DVI needs. Prepared a reference document to be used for the future development of DVI guidelines.

Unique to CV Driver:

- Cab environment
- Workload
- Duration



CV Driver-Vehicle Interface Needs

Guidance for DVI Design

- Format, modality, location, and timing of messages, alerts, and warnings
- Strategies for minimizing false and nuisance alerts
- Integrating multiple subsystems
 - Prioritizing messages presented to driver
- Status, particularly as it relates to automated vehicle control functions
- Mitigating driver distraction
- Maintaining compatibility between message design and the desired driver response
- Special requirements of CV drivers



CV V2V Safety Applications

VTTI developed performance requirements for CV V2V and V2I safety applications that map to real-world crash scenarios for heavy vehicles.



CV Safety Applications

VTTI summarized performance requirements for the following CV safety applications:

- Cooperative Forward Collision Warning (FCW)
- Emergency Electronic Brake Light (EEBL)
- Blind Spot Warning (BSW) / Lane Change Warning (LCM)
- Control Loss Warning (CLW)
- Wrong Way Direction Warning (WWDW)
- Do Not Pass Warning (DNPW)
- Cooperative Stop Sign Violation Warning (CSSVW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Cooperative Traffic Signal Violation Warning (CTSVW)



Pre-Crash Scenarios and Safety Applications

Pre-crash Scenarios		Safety Applications	V2V					V2V and V2I			
			Cooperative FCW	EEBL/ERS	BSW/LCW	CLW	WWDW	Do Not Pass Warning	Cooperative Stop Sign Violation Warning	IMA	Left Turn Assist
Rear-end	Lead vehicle stopped	•	•								
	Lead vehicle decelerating	•	•								
	Lead vehicle moving	•	•								
	Striking maneuver	•	•		•						
	Lead vehicle accelerating	•	•								
Lane change	Changing lanes/same direction			•							
	Turning/same direction	•							•		
	Drifting/same direction			•	•						
Opposite direction	No maneuver	•			•	•					
	Maneuver	•					•				
LTAP/OD	Non-signal	•							•		
	Signal	•								•	
Junction Crossing	SCP at non-signal	•							•		
	Turn at non-signal	•							•		
	Turn right at signal	•							•		
TCD Violation	Running red light	•			•				•		•
	Running stop sign	•			•			•	•		

Annual CV Crashes Addressable by V2V

Pre-crash Scenario	Crash Count
Rear-end/lead vehicle stopped	31,598
Rear-end/lead vehicle decelerating	17,568
Rear-end/lead vehicle moving	14,251
Rear-end/striking maneuver	4,687
Rear-end/lead vehicle accelerating	1,222
Turning/same direction	27,922
Opposite direction/no maneuver	13,352
Opposite direction/maneuver	978
LTAP/OD at non-signal	5,257
LTAP/OD at signal	5,430
Straight crossing paths (SCP) at non-signal	22,452
Turn at non-signal	4,299
Turn right at signal	2,782
Running red light	9,404
Running stop sign	1,441

2005-2008 GES

Total

185,095



Crash Scenario – Rear End Collisions

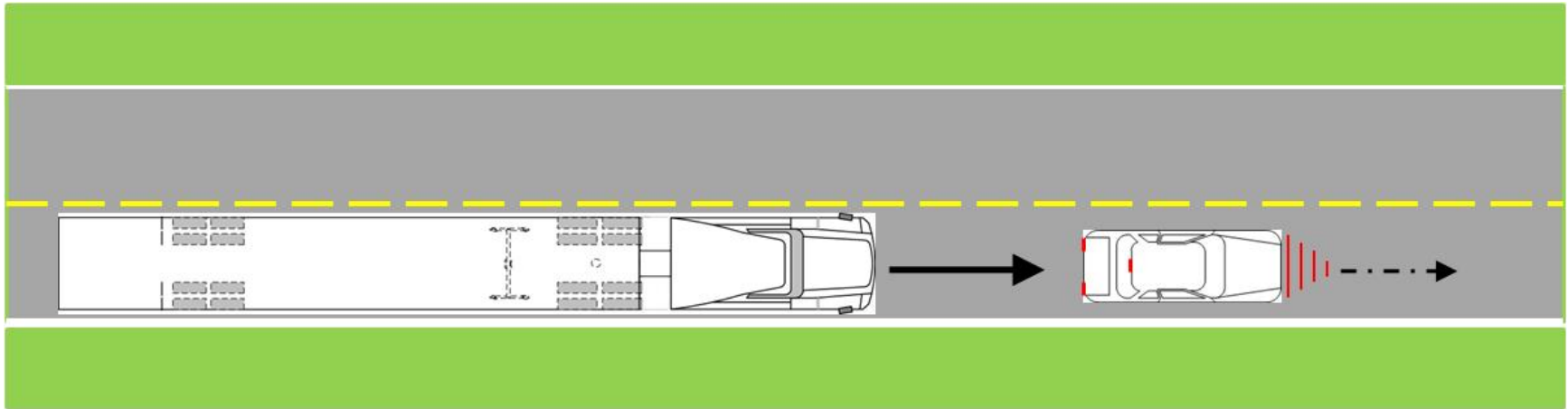
Crashes that could be addressed by V2V safety applications

Pre-crash Scenario	Count	Percent
Rear-end/lead vehicle stopped	31,598	45.6
Rear-end/lead vehicle decelerating	17,568	25.3
Rear-end/lead vehicle moving	14,251	20.6
Rear-end/striking maneuver	4,687	6.8
Rear-end/lead vehicle accelerating	1,222	1.8
Total	69,326	100.0

2005-2008 GES



Rear- End with Lead Vehicle Crashes



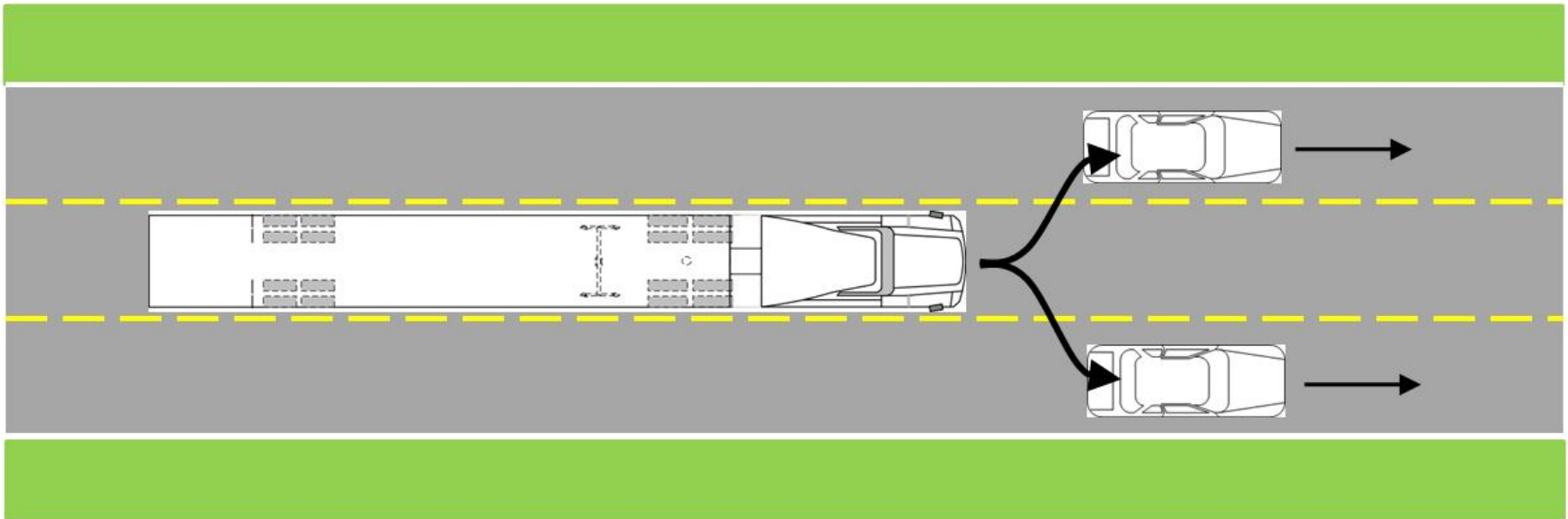
Subject vehicle that is proceeding straight closes in on a lead vehicle

Variations:

- Lead Vehicle Stopped
- Lead Vehicle Moving at a Slower Constant Speed

Applications: FCW, EEBL

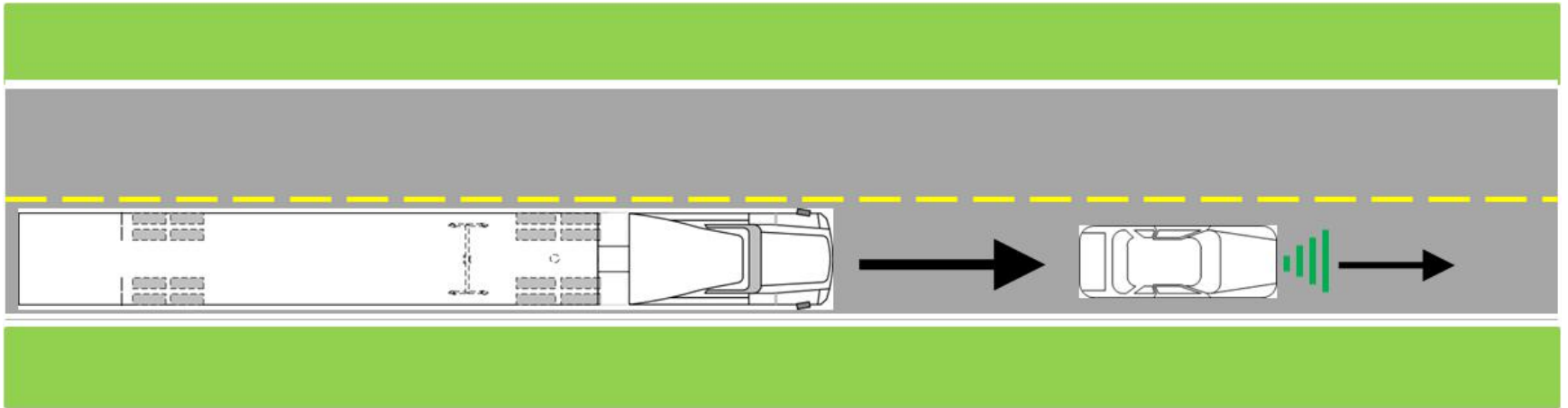
Rear-End – Striking Maneuver



Subject vehicle that is changing lanes or passing, and then closes in on a lead vehicle

Applications: FCW, EEBL, CLW

Rear-End / Lead Vehicle Accelerating



Subject vehicle proceeding straight closes in on an accelerating lead vehicle

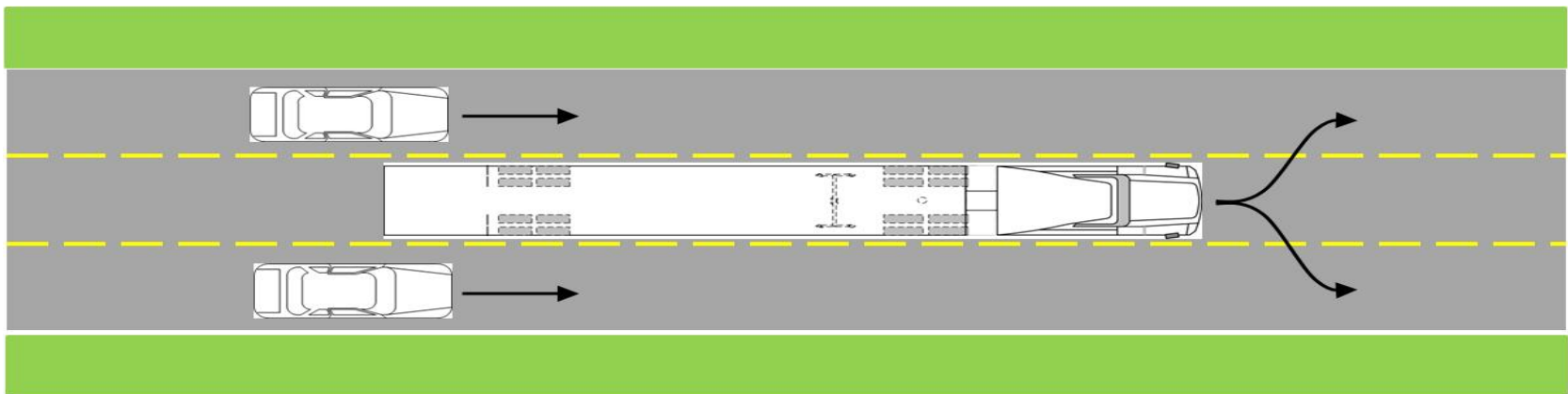
Applications: FCW, EEBL

Lane Change Crash Scenarios

Crashes that could be addressed by V2V safety applications

Pre-crash Scenario	Count	Percent
Changing lanes/same direction	50,690	51.6
Turning/same direction	27,922	28.4
Drifting/same direction	19,703	20.0
Total	98,315	100.0

2005-2008 GES

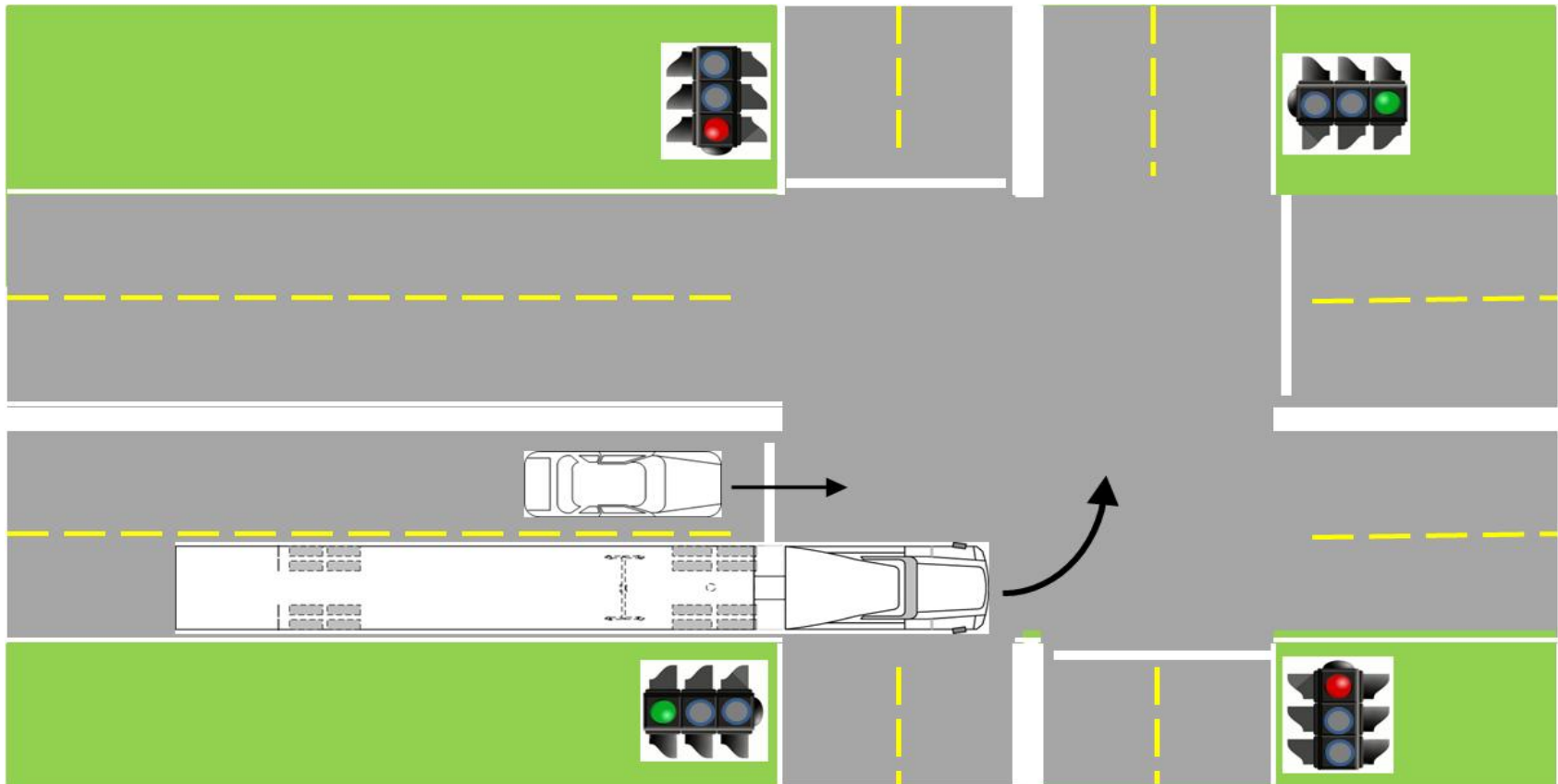


Subject vehicle changing lanes then encroaching into another vehicle traveling in the same direction

Applications: BSW/LCW



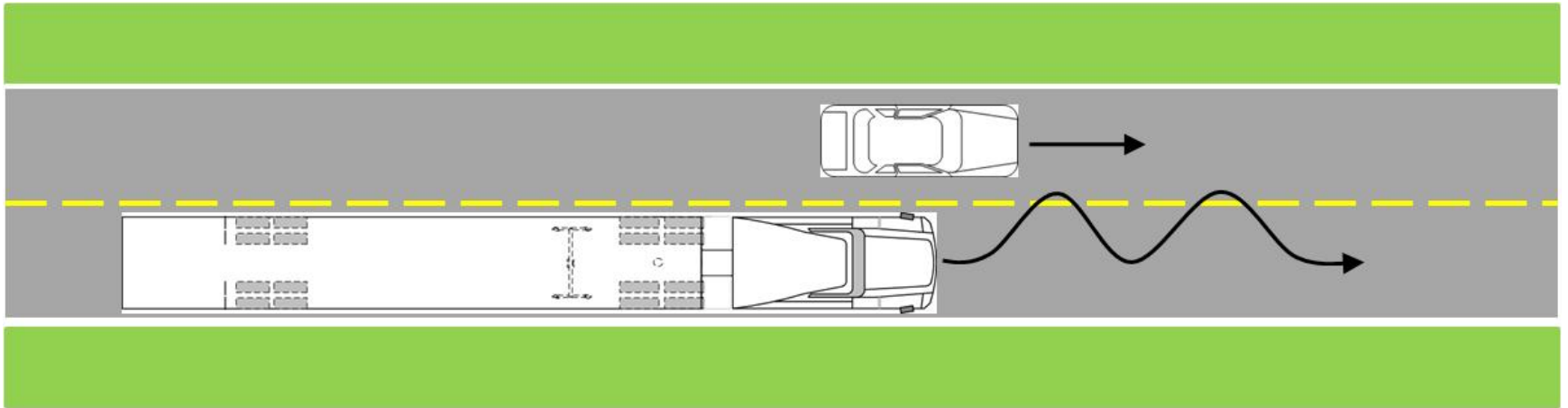
Turning / Same Direction



Subject vehicle turning left at an intersection cuts across the path of another vehicle initially traveling in the same direction

Applications: FCW, LTA

Drifting / Same Direction



Subject vehicle proceeding straight drifts into an adjacent vehicle traveling in the same direction

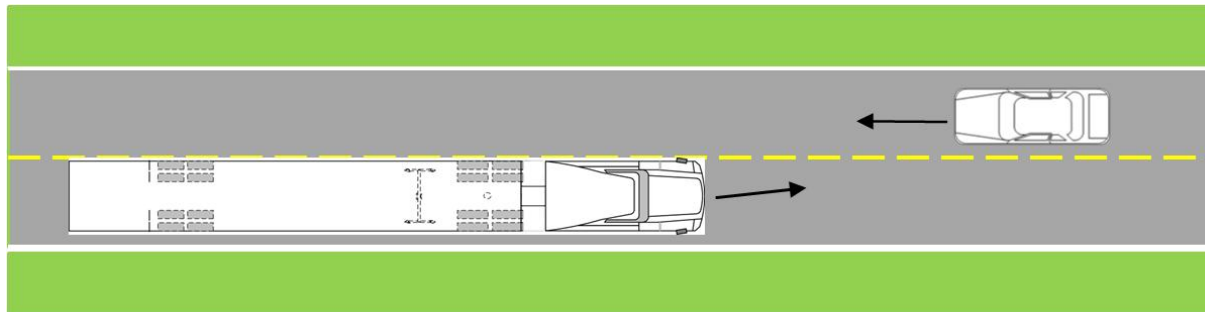
Applications: BSW/LCW, CLW

Opposite Direction Crashes

Crashes that could be addressed by V2V safety applications

Pre-crash Scenario	Count	Percent
Opposite direction/no maneuver	13,352	93.2
Opposite direction/maneuver	978	6.8
Total	14,330	100.0

2005-2008 GES



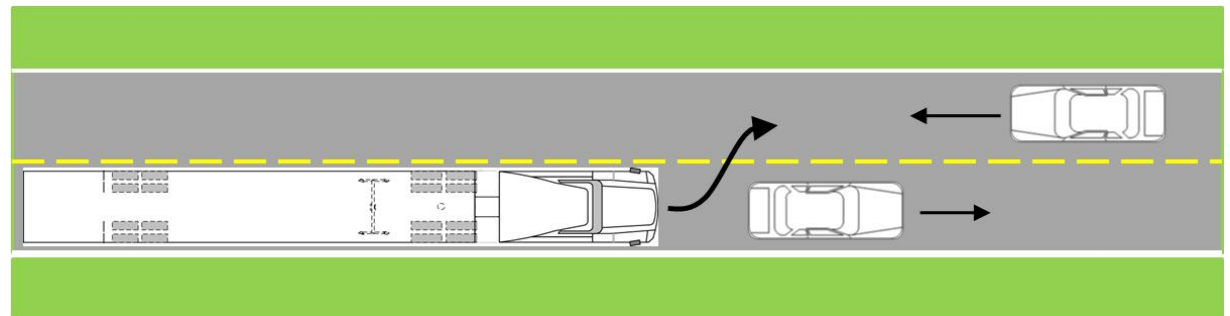
No Maneuver

Applications: FCW, CLW, WWDW

Subject vehicle traveling straight drifts into another vehicle traveling in the opposite direction

Maneuver

Applications: FCW, DNPW

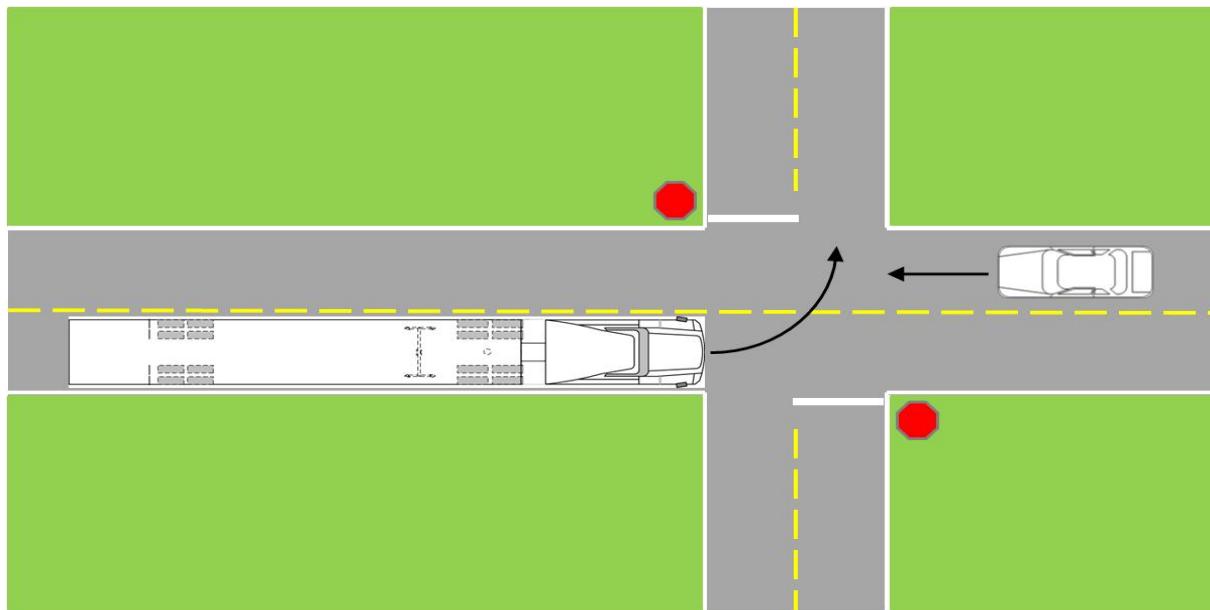


Left Turn Across Path Opposite Direction

Crashes that could be addressed by V2V safety applications

Pre-crash Scenario	Count	Percent
LTAP/OD at non-signal	5,257	49.2
LTAP/OD at signal	5,430	50.8
Total	10,687	100.0

2005-2008 GES



Subject vehicle turning left at an intersection cuts across the path of another vehicle crossing from an opposite direction

Variations:

- Traffic signal controlled intersection

Applications: FCW, IMA, LTA

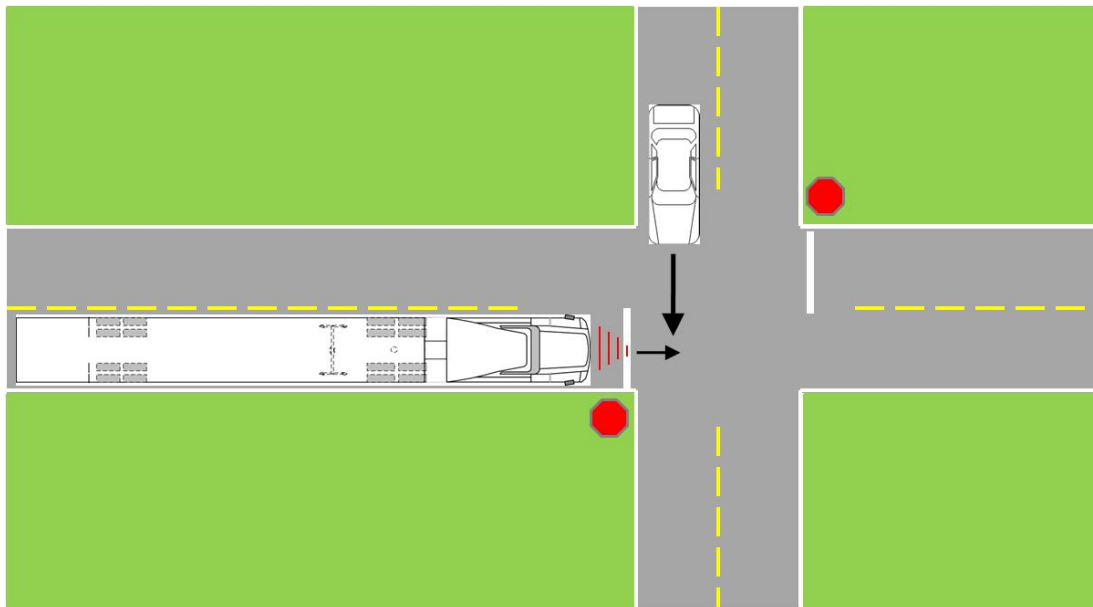


Junction Crossing Crashes

Crashes that could be addressed by V2V safety applications

Pre-crash Scenario	Count	Percent
SCP at non-signal	22,452	76.0
Turn at non-signal	4,299	14.6
Turn right at signal	2,782	9.4
Total	29,533	100.0

2005-2008 GES

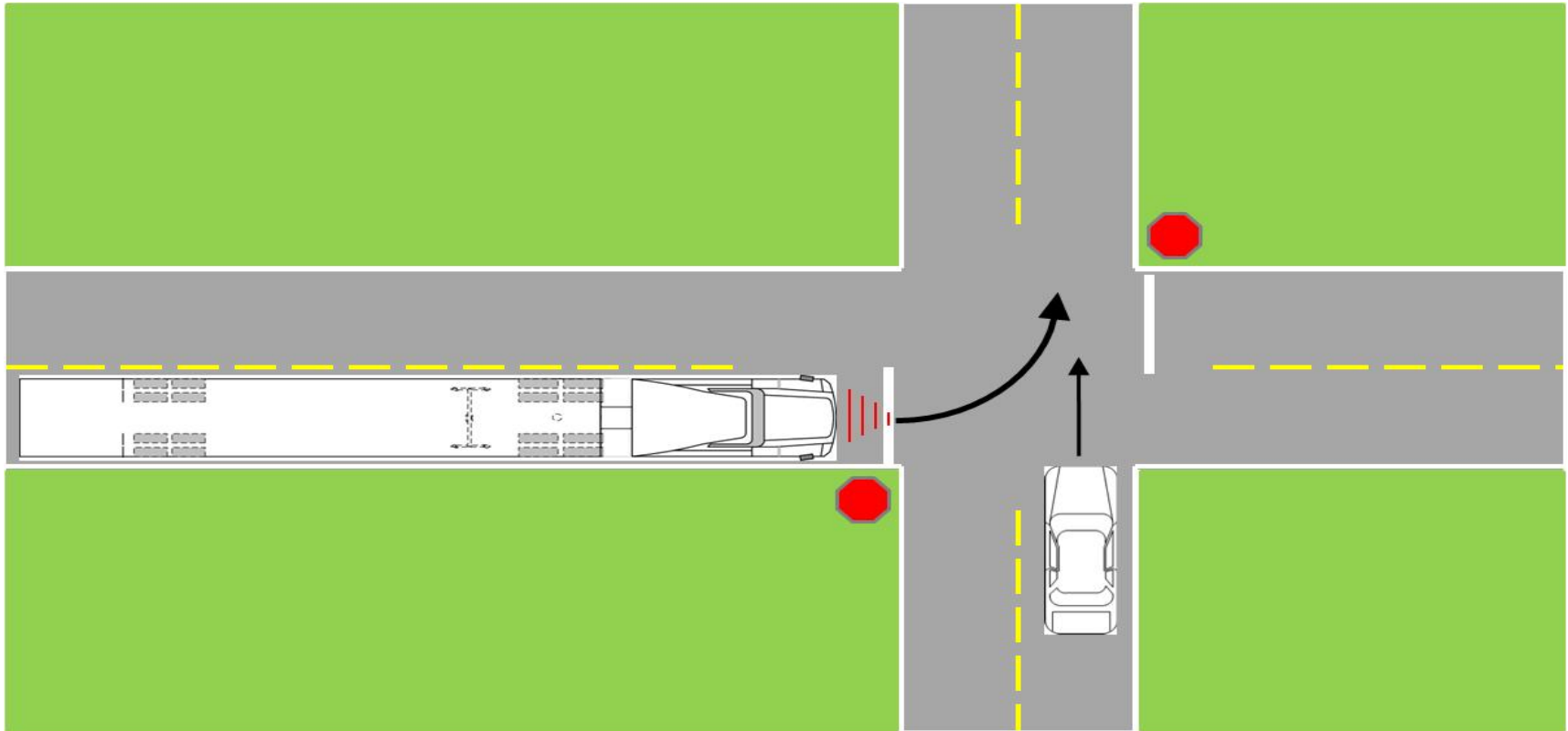


Stopped Crossing Path (SCP) subject vehicle stopping at a road junction then proceeding against lateral crossing traffic

Applications: FCW, IMA



Turn at Non-Signal

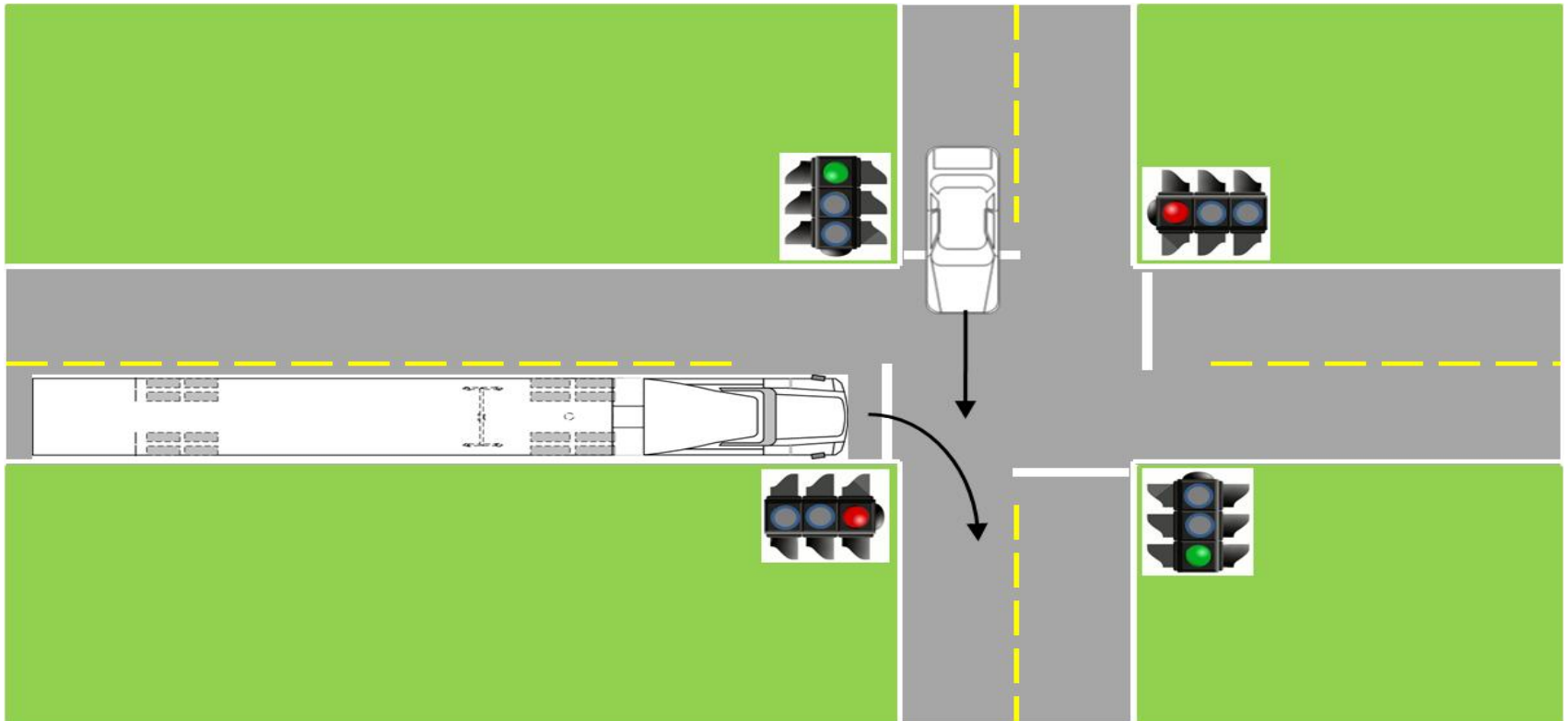


Subject vehicle stops at a road junction and then proceeds to turn left against lateral crossing traffic

Applications: FCW, IMA



Right Turn at Signal



Subject vehicle stops at a signalized intersection then proceeds to turn right into the path of another vehicle crossing laterally from the subject vehicle's initial stop position

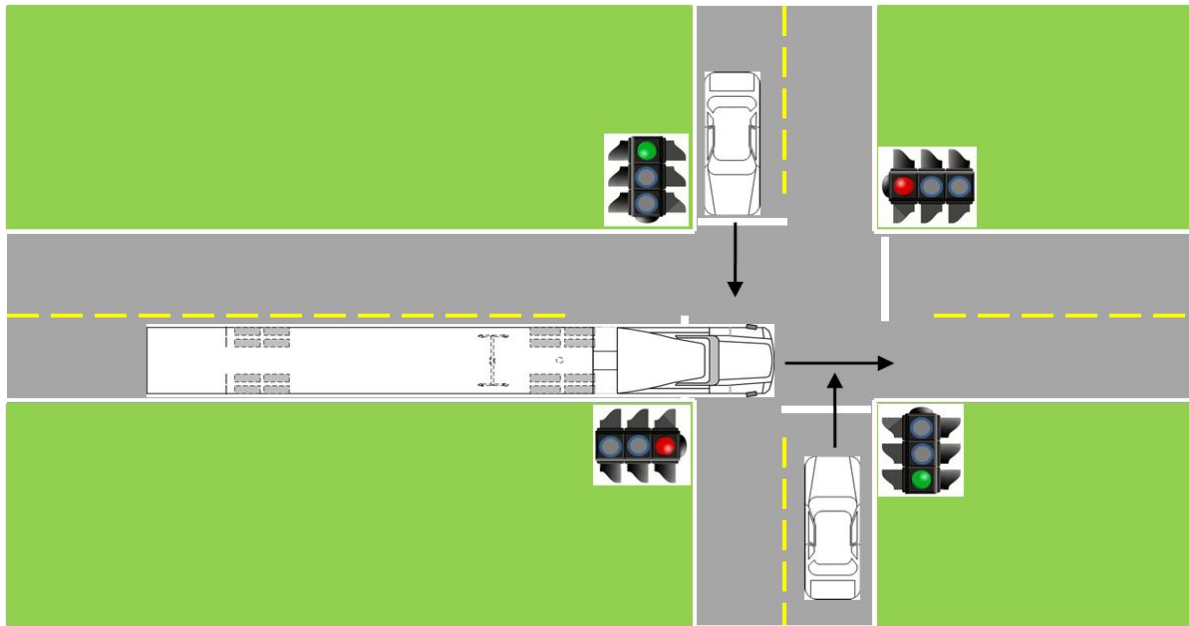
Applications: FCW, IMA

Traffic Control Device (TCD) Violation

Crashes that could be addressed by V2V/V2I safety applications

Pre-crash Scenario	Count	Percent
Running red light	9,404	86.7
Running stop sign	1,441	13.3
Total	10,845	100.0

2005-2008 GES

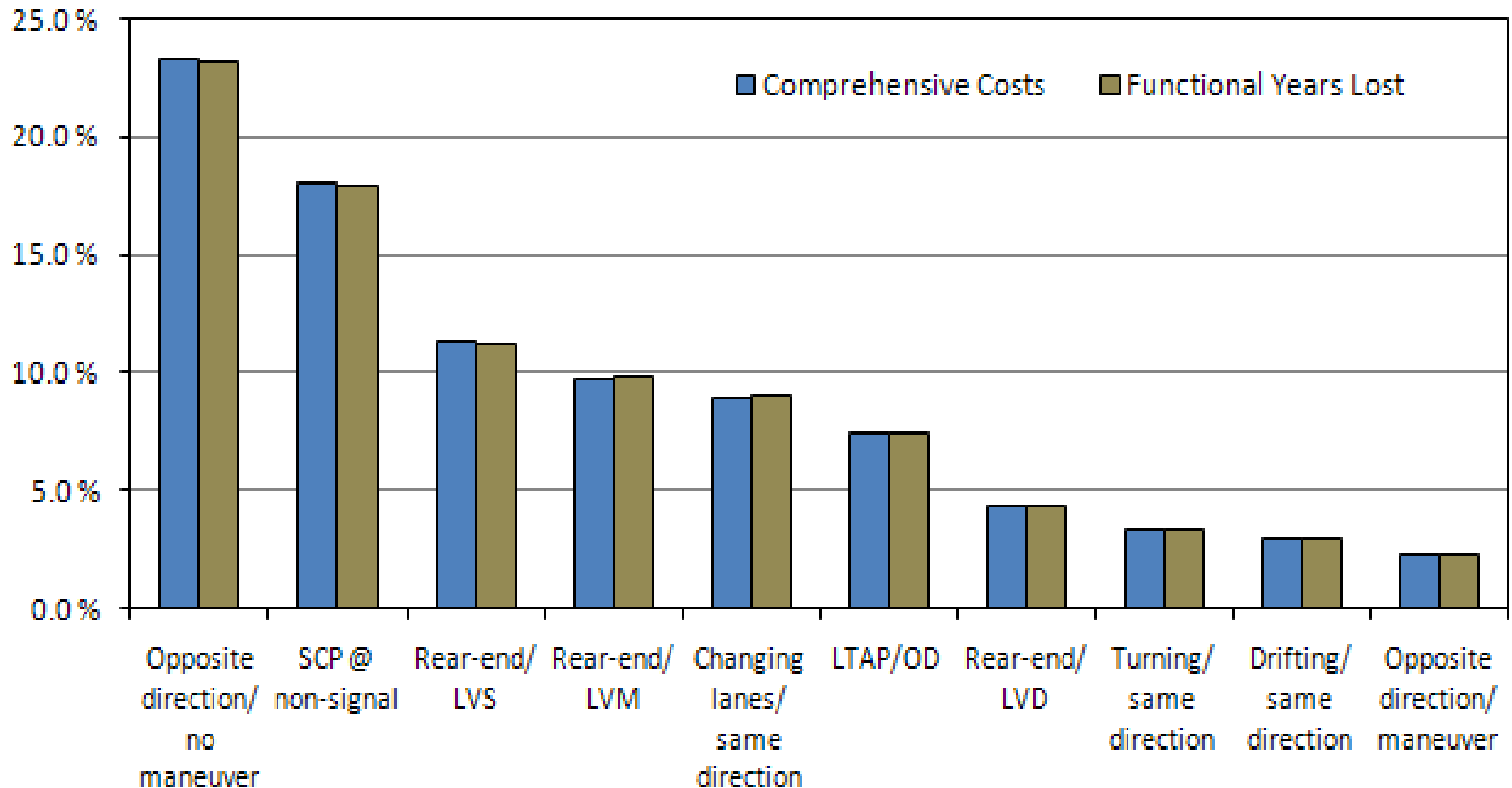


Subject vehicle proceeding through a red light, through the intersection, and colliding with another straight-crossing vehicle from a lateral direction

Applications: FCW, BSW/LCW, IMA, CTSVW, CSSVW



Ranking of Priority CV V2V Crash Scenarios



“Depiction of Priority Heavy Truck Pre-Crash Scenarios for Safety Applications Based on Vehicle-to-Vehicle Communications,” Toma et. Al., Volpe 2010, to be published.

CV Interoperability Issues

UMTRI was tasked with Identifying priority CV interoperability issues that need to be addressed for successful deployment of vehicle safety communications

High Priority

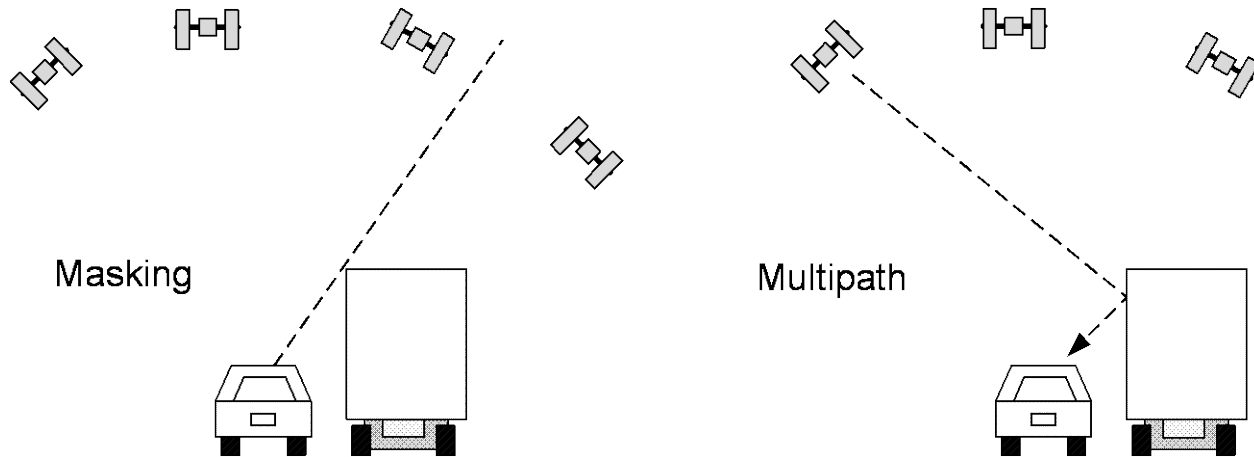
- DSRC performance and CV physical factors
- SAE J2735 basic safety messages (BSM) and articulated vehicles

Mid-Level Priority

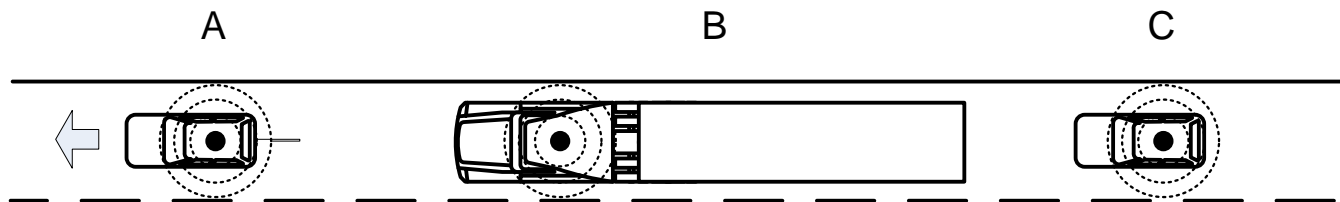
- Aftermarket/retrofit safety devices and J1939 issues
- Scalability: performance in areas of dense DSRC
- Impact of CVs on relative positioning accuracies
- Power unit OBEs knowing trailer parameters
- Certification of onboard equipment
- Engagement of commercial industry in discussions
- Using CVs in objective testing



DSRC Performance and CV Physical factors

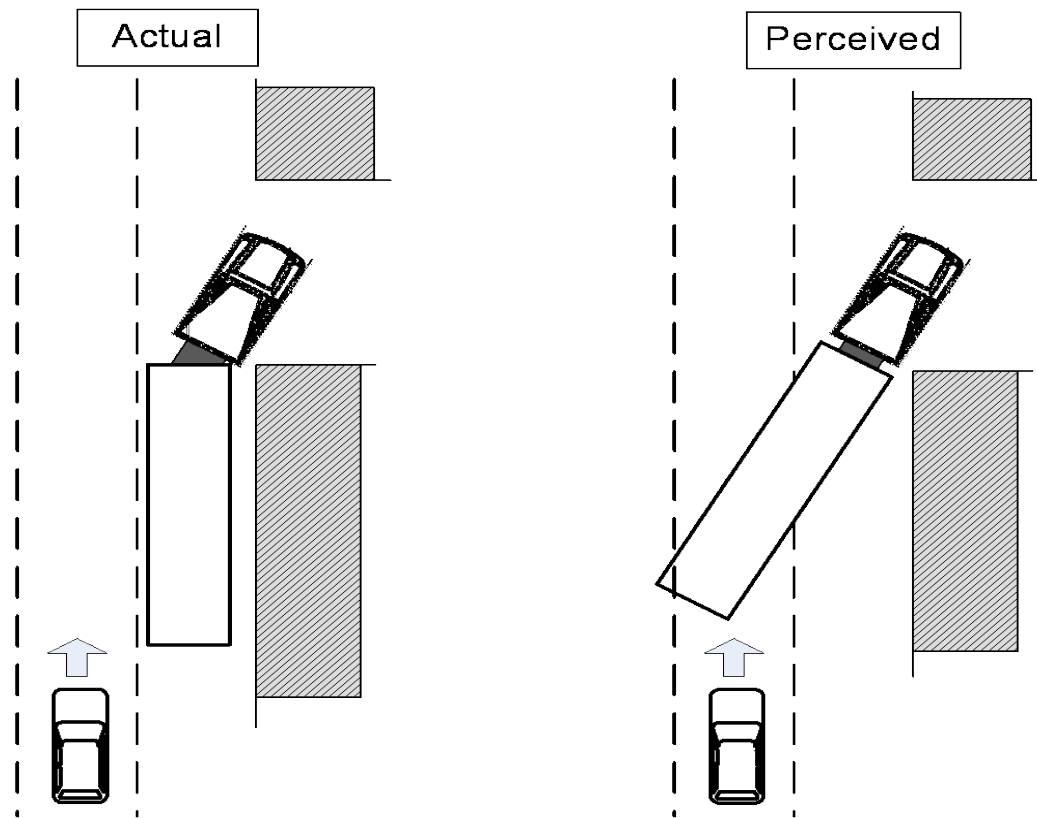


Impact on GPS signals received by a small vehicle adjacent to a large vehicle



Blockage scenarios

SAE J2735 BSM and Articulated Vehicles



SAE J2735 message set does not allow for combination (articulated) vehicles. All data is associated with a single "rigid body" vehicle which could have impacts for safety application performance.

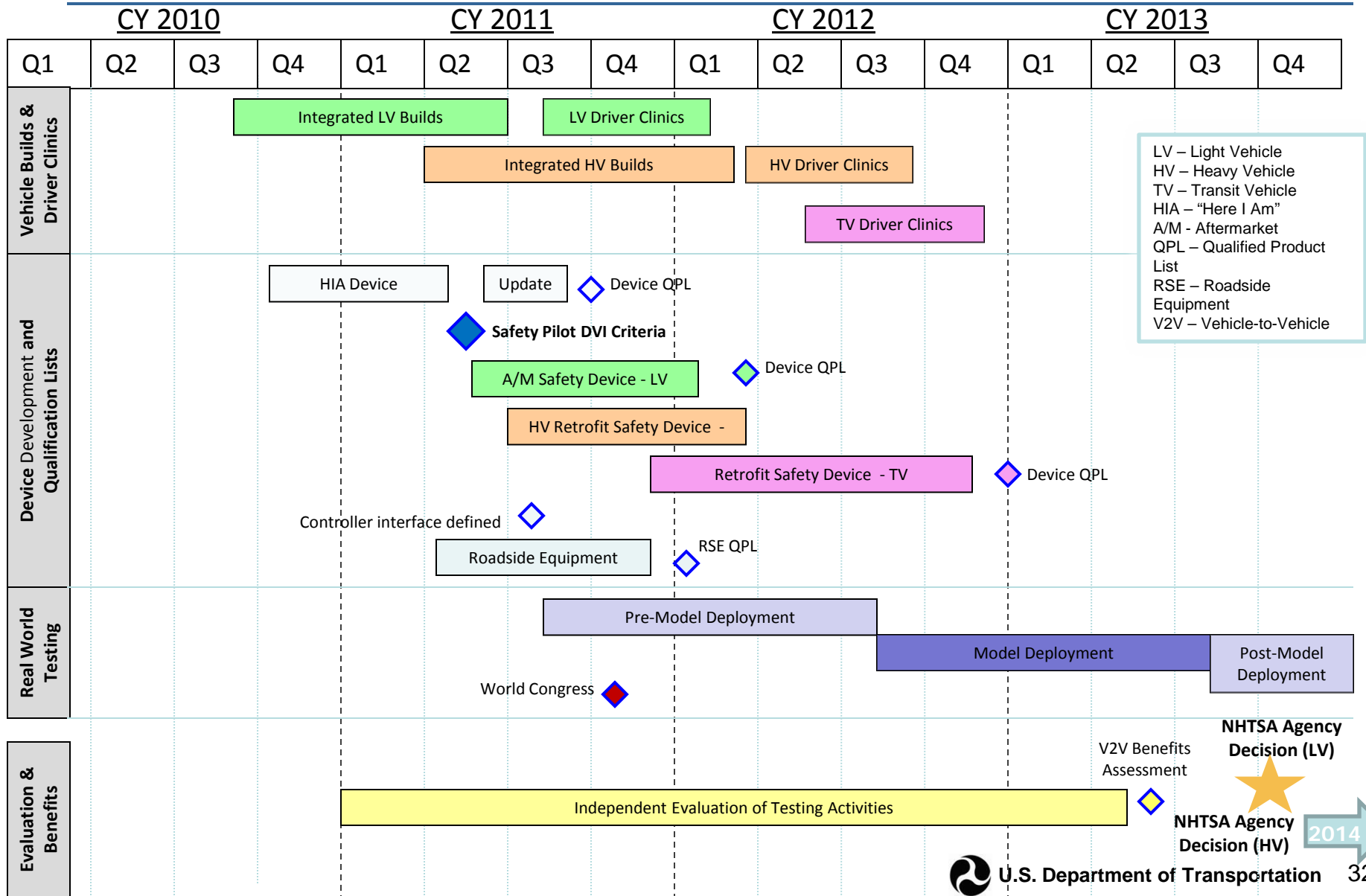


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Current CV V2V Research and Safety Pilot

**Connected Vehicle Truck Safety Meeting
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ITS Safety Pilot Roadmap



Current CV V2V Research – Safety Pilot

- **Connected CV Safety Applications Development**
 - U.S. DOT awarded a contract in April to team led by Battelle to build heavy vehicles with integrated V2V applications
 - 4 - Class 8 tractors (3 sleepers, 1 day cab) and 7 trailers
- **CV Driver Acceptance Clinics**
 - Conduct tests in 2-4 locations in the U.S. to gauge driver acceptance and collect data on systems and applications
 - Select CDL-licensed drivers to participate from local trucking fleets and independents
 - Tests run in a controlled environment with in-cab experimenter
 - On-board data collection and driver surveys



Safety Pilot

- **Model Deployment**

- Full scale test of approximately 3000 vehicles (all types)
- 2-3 Integrated CVs – with safety applications
 - Naturalistic, recruiting “real” truck drivers
- 8 - Retrofit – fleet vehicles
 - Devices same functionality as integrated CVs
- 50 – CVs with basic functionality
- Field test runs from July 2012 – June 2013



Safety Pilot

- **Retrofit Safety Device (RSD) Development**

- Project begins in fall of 2011 – contract to be awarded
- Supplemental to Connected CV Activities
- Develop RSD kits with V2V safety applications
- Increase the number of fully functional CVs in the Model Deployment
- RSD kits installed in Safety Pilot participating fleet CVs
 - Articulated vehicles and straight trucks (Classes 6,7, and 8) that feature J1939 CAN
 - Provide additional CV test data
- Establish a platform for future research



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