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Michigan Traffic Safety Summit

Connected Vehicles & Autonomous Trucks Traveling a Roadway Near You

Alan Korn

March 24, 2015

Fully Autonomous Trucks

When??

Not Today!!

Presentation Overview

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- Heavy Truck Crash Facts
- General Transportation Challenges
- Automation Levels
- Active Safety Systems
- Vehicle Communications
- Higher Automation Levels & Challenges

Meritor WABCO

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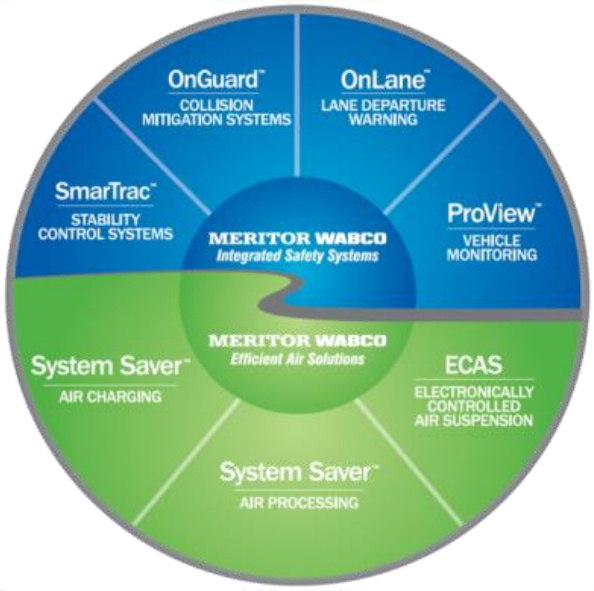
- JV between Meritor and WABCO VCS
- Established in 1990 to service NA Commercial Vehicle Market
- Approximately 200 employees
- A leader in advanced integrated commercial vehicle safety systems
- Air Solutions engineered for optimized performance with less energy consumption



2012 US Large Truck Crash Statistics

- 333,000 large truck DOT reported crashes (76% PDO)
- 3,802 trucks involved in fatal crashes
  - 66% combination vehicles
  - 69 large trucks involved in fatal crashes in MI
- 3,921 fatalities - 697 truck occupants
  - 3.7% increase in total fatalities over 2011
- 104,000 injuries - 25,000 truck occupants
- Fatalities / 100 million miles traveled 1.46 (+3.5% from 2011)
  - 37% reduction from 2002
- Alcohol involved in 2% of large truck fatal crashes (BAC>0.08)
  - Alcohol involved in 23% of passenger car fatal crashes
- Ref: 33,561 fatalities from all US motor vehicle crashes
  - 3.2% increase over 2011
  - 1.13 Fatalities / 100 million miles traveled
  - 938 in MI

Large Truck Fatal Crashes 2000-2012

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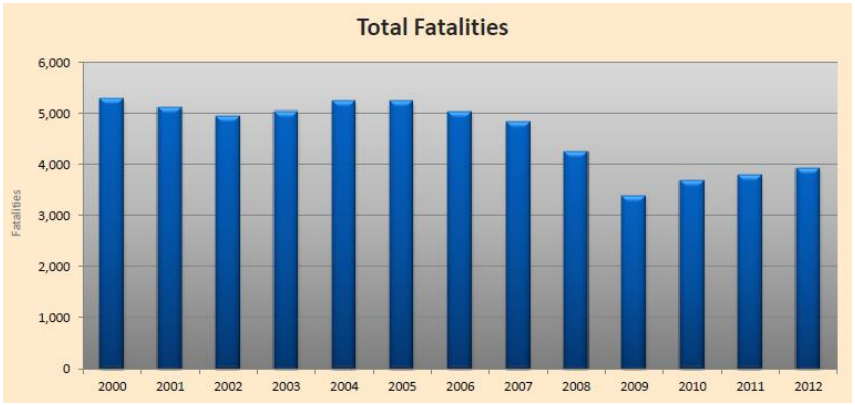

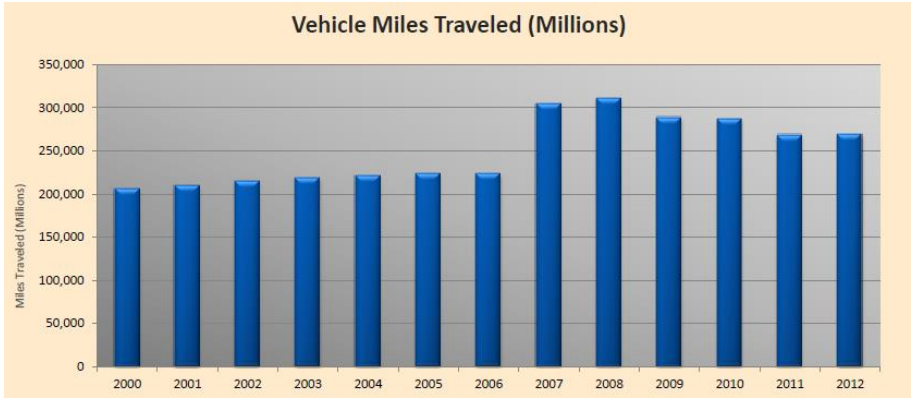

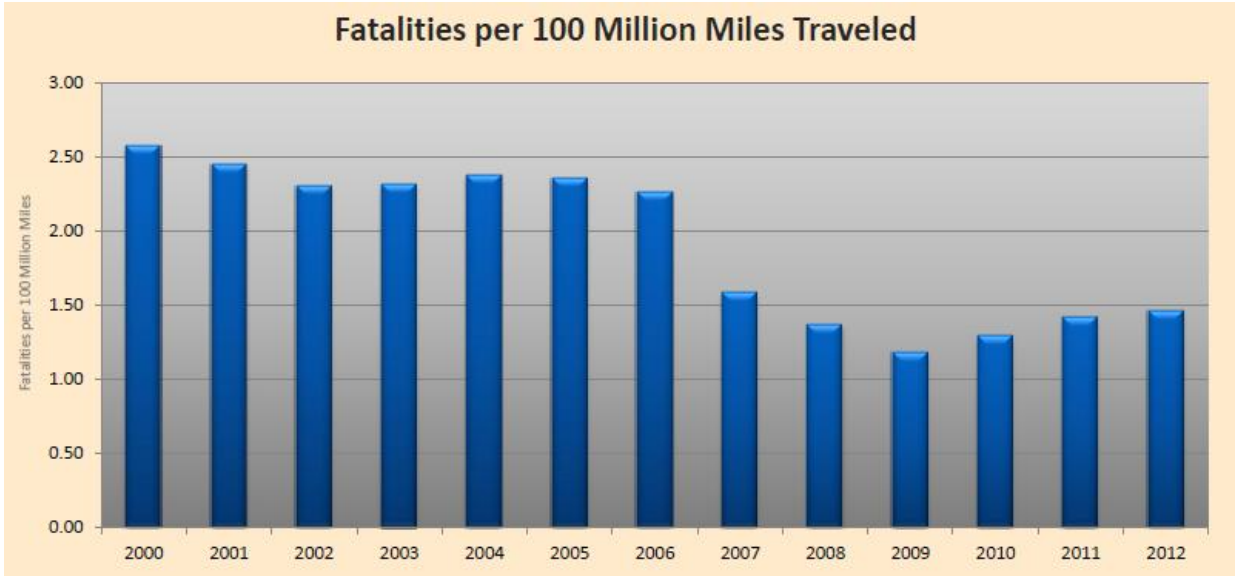

2013 Motor Vehicle Crashes

- NHTSA released an overview of 2013 vehicle crashes in December 2014
  - 32,719 total fatalities from roadway vehicular crashes
  - 3.1% reduction over 2012
- 3,964 fatalities from large truck crashes
  - 0.5% increase over 2012
  - Due to an increase in vehicle miles traveled, large truck crash fatality rate (1.441 fatalities / 100 million miles traveled) decreased 1.6% from the 2012 level
    - First decrease since 2009

General Transportation Challenges

Safety

- 33,561 highway deaths in 2012
- 3,921 fatalities from large truck crashes in 2012
- Leading cause of death for ages 4, 11-27

Mobility

- 5.5 billion hours of travel delay
- $121 billion cost of urban congestion

Environment

- 2.9 billion gallons of wasted fuel
- 56 billion lbs. of additional CO_2

Additional Trucking Challenge

- Motor Carriers are for-hire or private business entities involved in freight transport
- Overarching Goal: Moving freight from location A to B in the safest, most efficient manner possible

- Technologies / automation providing improved safety and efficiency with acceptable paybacks are readily adopted

Table 9: Share of Total Average Marginal Cost, 2008-2012

Motor Carrier Costs	2008	2009	2010	2011	2012	2013
Vehicle-based						
Fuel Costs	38%	28%	31%	35%	39%	38%
Truck/Trailer Lease or Purchase Payments	13%	18%	12%	11%	11%	10%
Repair & Maintenance	6%	8%	8%	9%	8%	9%
Truck Insurance Premiums	3%	4%	4%	4%	4%	4%
Permits and Licenses	1%	2%	3%	2%	1%	2%
Tires	2%	2%	2%	2%	3%	2%
Tolls	1%	2%	1%	1%	1%	1%
Driver-based						
Driver Wages	26%	28%	29%	27%	26%	26%
Driver Benefits	9%	9%	10%	9%	7%	8%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Elements Driving Safety Improvement

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NHTSA Levels of Automation

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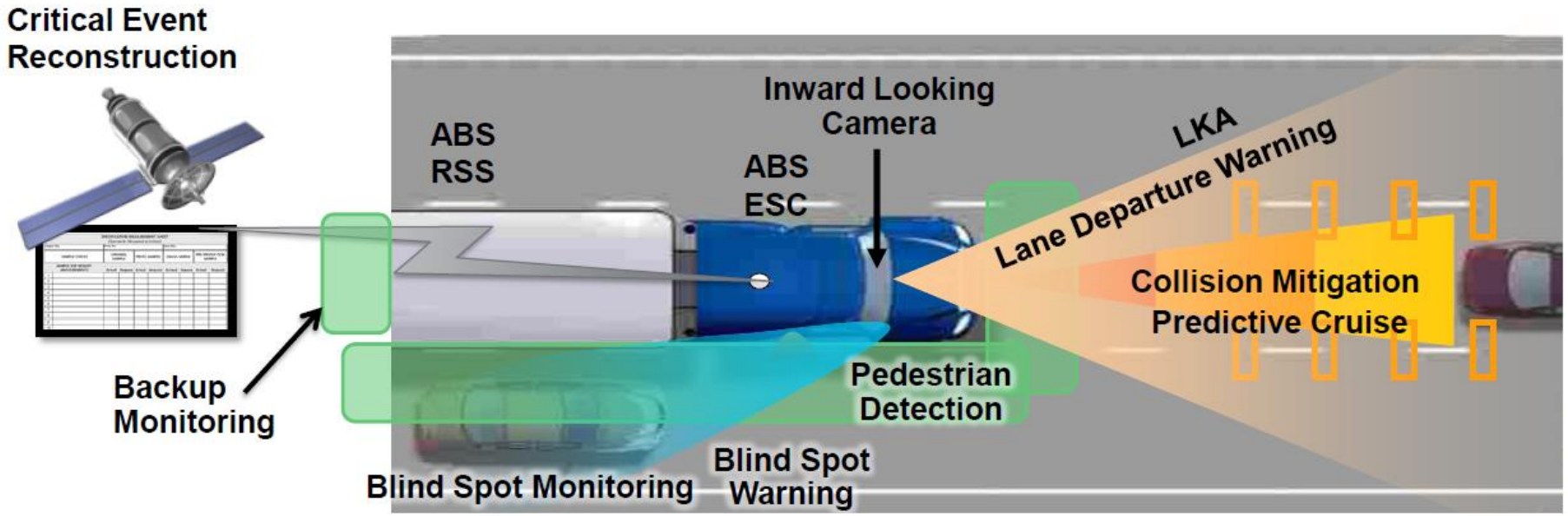
- Level 0: Driver in complete & sole control of vehicle; braking, steering, throttle
- Level 1 Function Specific: One or more systems that automatically assists driver with a primary vehicle control function
- Level 2 Combined Function: Two or more primary control functions combined to work in unison to relieve driver of control of these functions
- Level 3 Limited Self Driving: Enable driver to cede full control under certain conditions. When necessary, system automatically transitions control back to driver
- Level 4 Full Self Driving
- Today's well equipped large trucks are at Level 1

Today's (Near Term) Truck Automation

- NHTSA Automation Levels One and Two
- Discrete active safety systems designed to ASSIST driver in maintaining control of vehicle and reducing crash risk
  - Driver constantly responsible for at least one of the vehicle's primary control functions (usually steering)



Hardware & Performance Integration

- ABS foundation for advanced safety systems
  - Regulated technology
  - Helps prevent high levels of wheel slip (wheel lock) during braking

- Stability Control provides architecture to allow control system to automatically apply service brakes
  - Reduces risk of untripped rollovers and loss of control events

SmartTrac Stability Control

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Collision Mitigation Systems

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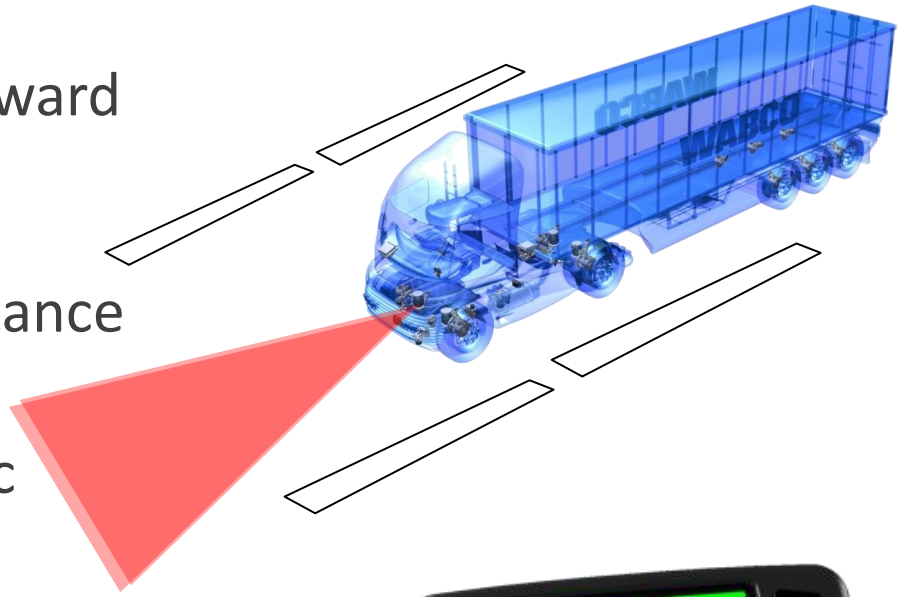
- Active braking system designed to reduce / mitigate truck striking forward collisions
- Uses forward-looking radar sensor technology to monitor speed / distance to target vehicle
- Provides audible, visual and haptic forward collision warnings
  - Re-engage driver
- Active braking to provide ACC and assist driver avoiding or mitigating rear end collisions
- Integrates collision safety system with ABS and stability control



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One Second

CMS Intervention Sequence

Potential rear end collision detected

Hard braking required to prevent collision

Avoidance maneuver not possible

t0 t1 t2 t3 t4 time

Object Tracked

Distance Alert: Visual and Audible

Collision Warning: Haptic (Short Brake Pulse)

Automatic Braking to Assist Driver in Collision Mitigation

Crash Prevented or Mitigated

System Reactions:

Warning Tone and Lamp

Engine Torque Limitation

Haptic Warning

Brake Activation

Collision Mitigation – Slower Moving Target
50 MPH / 20 MPH

Collision Mitigation – Slower Moving Target
50 MPH / 20 MPH

Lane Departure Warning

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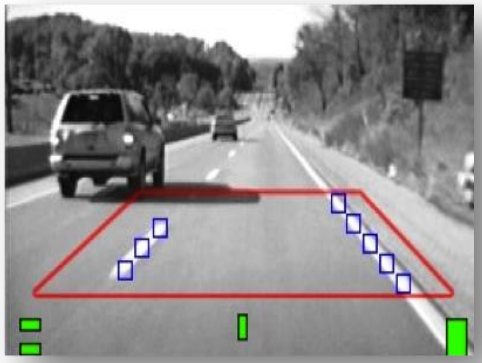
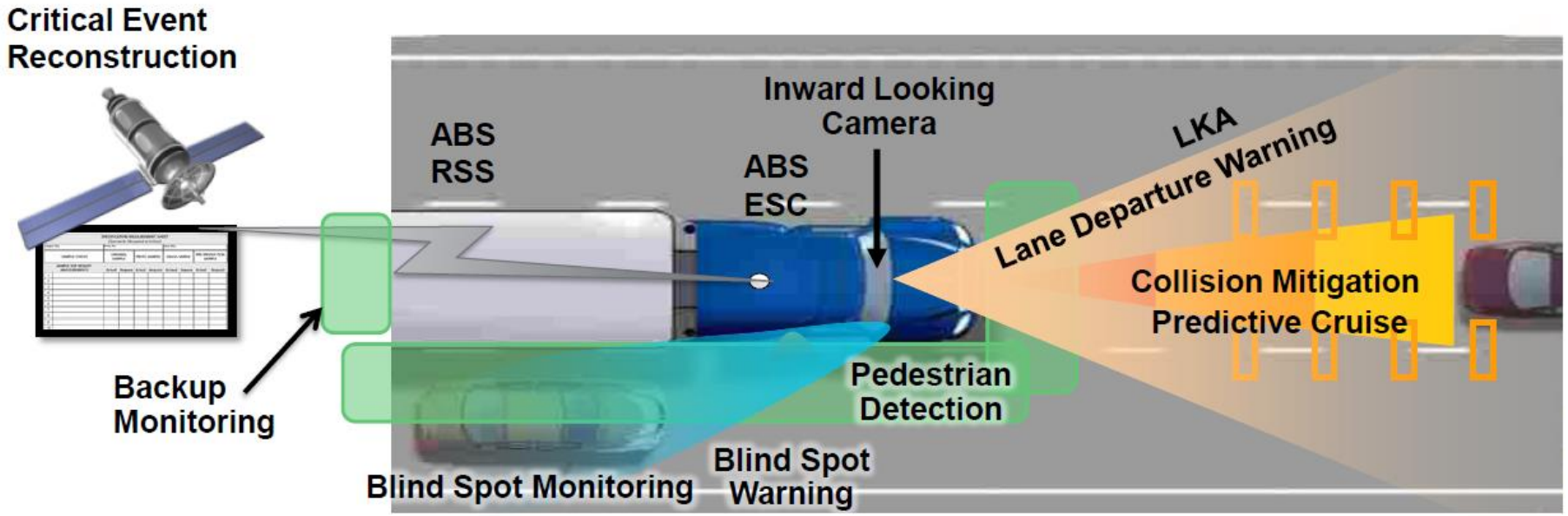
- Vision based technology
- Detects and classifies lane markers
- Tracks and projects lane ahead of truck
- Provides audible warnings
  - Lane change made without turn signal indicator – rumble strip warning
  - Above 40 MPH
  - Driver Alertness Warning
- Critical Event Video option
  - 10 seconds before, 5 seconds after trigger, up to 20 clips
  - Manual download via PC based software

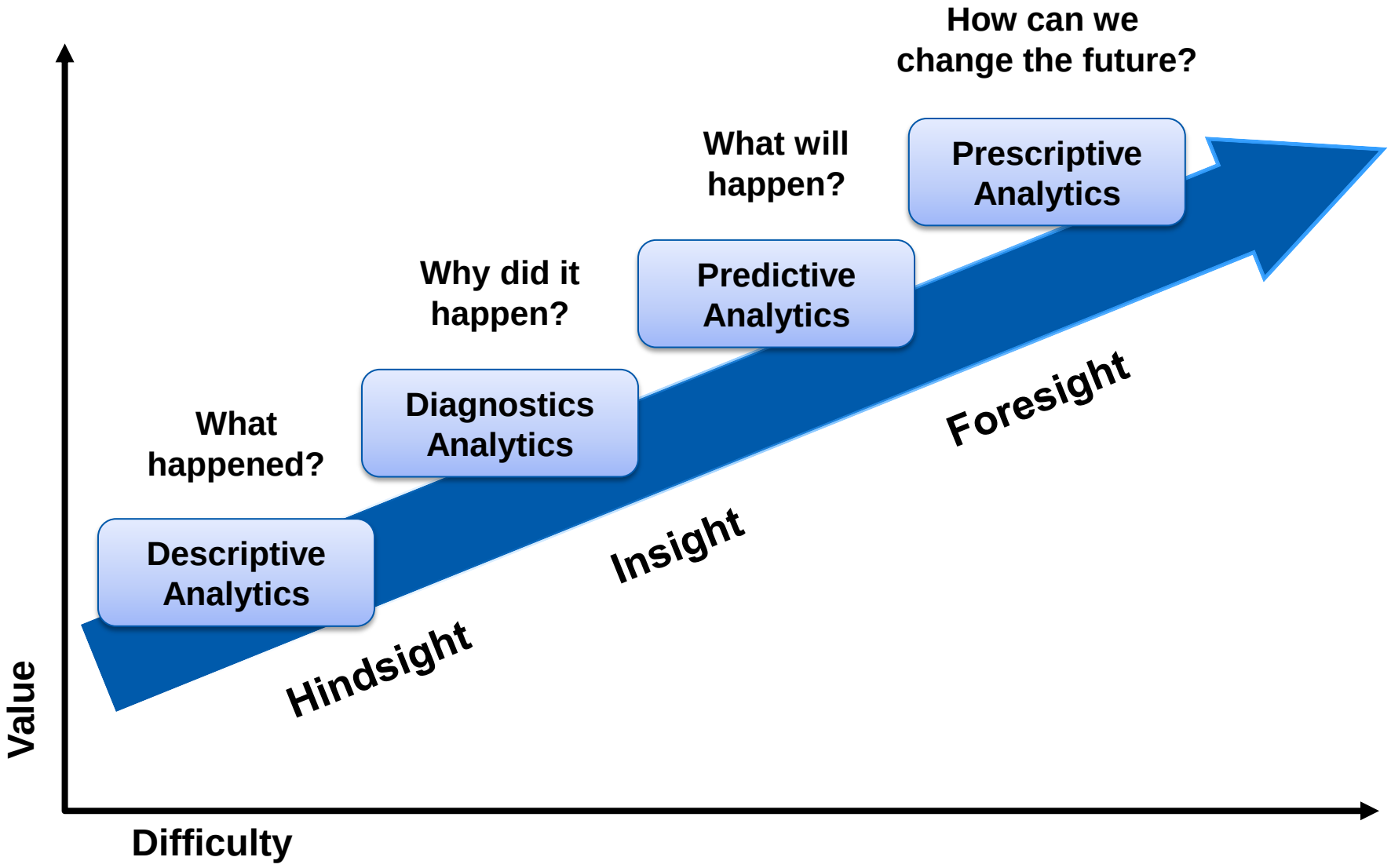


Fleet Performance



Integrated Safety System	ABS, Stability Control, Collision Mitigation, LDW, Side Sensing	Vehicle Approach
Fleet Performance System	Inward / Outward Looking Camera, Video Data Analytics	Program Approach

Then, Now, & Where We're Going



Gartner

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“Predictive” Video Data Analytics

Active Safety Systems

MW System Inputs
- ABS, ATC, ECS, CMS, LDW, Blind Spot

MW Sensor Inputs
- Wheel Speed Sensor
- Brake Apply Pressure Sensor
- Lateral Accelerometer
- Steering Angle Sensor
- Yaw Rate Sensor
- CMS Radar Sensor
- LDW Camera
- Side Sensor
- Rear Sensor

Other Inputs
- Vehicle Diagnostic Info
- Vehicle Speed
- Fuel Economy
- Accelerator Pedal Position

+

Video Monitoring

- In-Cab Driver Feedback
- Camera / Video Capture
- Video / Data Analysis
- GPS Data
- Cellular Data Off-load
- Driver Input Device
- Web Portal Infrastructure

=

Data Analytics

- Driver Management Safety / Driving Efficiency
- Behavioral Change
- Vehicle Monitoring
- Critical Alerts
- Accident Reconstruction

Safety Monitoring + **Efficiency Monitoring**

Video Analysis and Feedback

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Future Automation

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Where are we going in the future? Connected World!

- **Limited Self Driving** (NHTSA Level 3)
  - A completely integrated control system with 360° situational awareness
  - Driver cedes full control of all driving functions under certain traffic and environmental conditions
  - Driver expected to regain control within a comfortable transition time when environmental conditions change (GM Supercruise – 2017 Cadillac)
  - Will payback be adequate for trucking industry?
- **Autonomous Driving** (NHTSA Level 4)
  - Vehicle designed to perform all driving functions (throttle, braking, steering full time)
  - Driver provides destination input, but is not expected to provide control at any time during trip (Google car).

Vehicle to Vehicle / Infrastructure Communications

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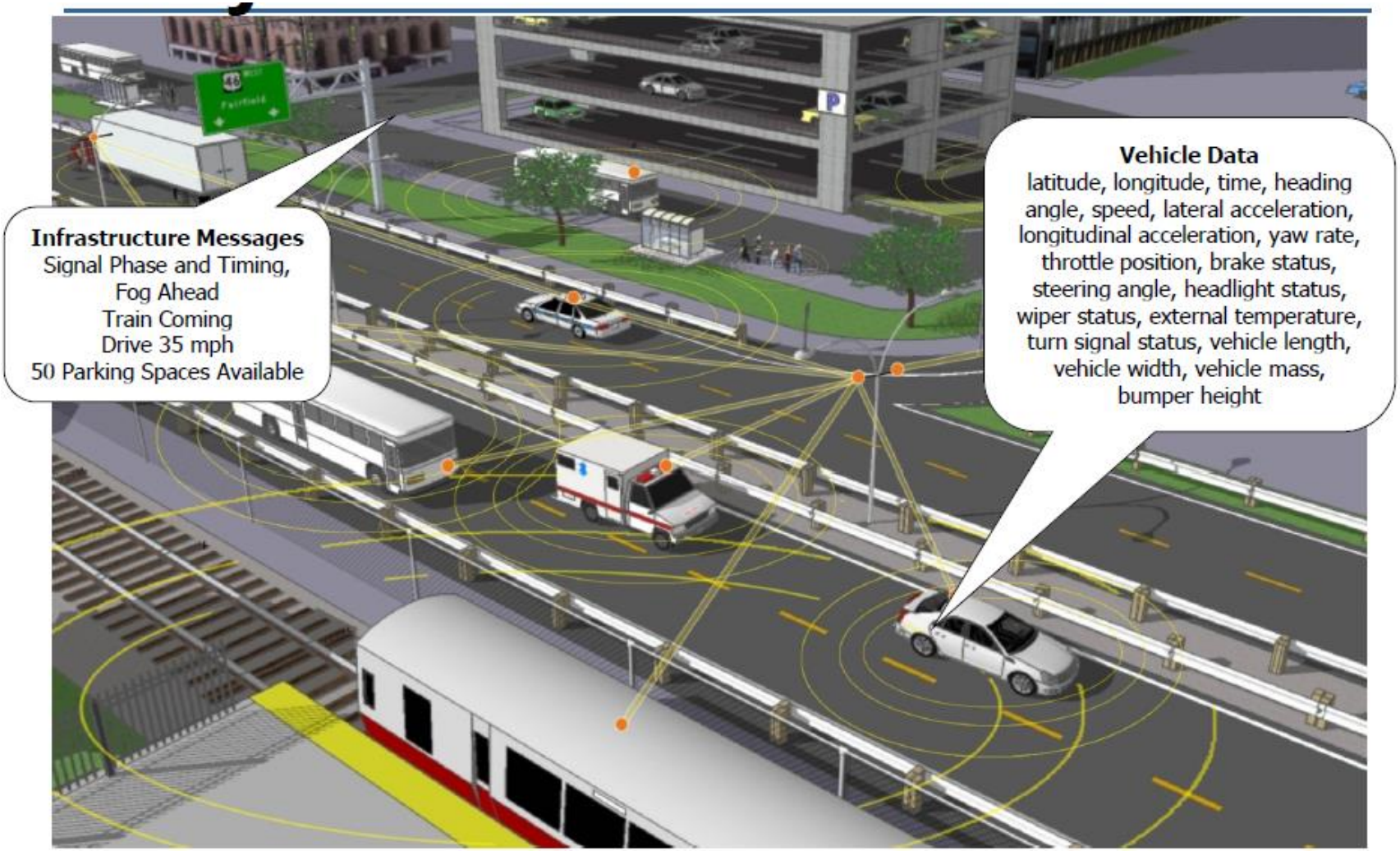

U.S. Department of Transportation

V2V / V2I / V2X Communications

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- Dynamic wireless exchange of data between nearby vehicles and infrastructure – Dedicated Short Range Communication
- All vehicles on public roads broadcast a Basic Safety Message regarding location, direction and speed
  - "Here I Am" data messages, 10 Hz, 1600 foot range
- Vehicles sense threats with 360° awareness
- System only provides warnings
- NHTSA estimates safety applications have potential to address approx 80% of crashes for unimpaired drivers

Active Safety Systems vs DRSC V2V

- Active Safety Systems
  - Designed to ASSIST driver maintaining control of vehicle and reducing crash risk
  - Contains on-board sensors, actuators and algorithms to warn and enable the automatic intervention of one or more of the vehicles primary control functions (braking, steering, throttle) when calculated safety thresholds are exceeded
    - ABS, Stability Control, Collision Mitigation
- DSRC V2V
  - Designed to ASSIST driver maintaining control of vehicle and reducing crash risk, provides data from vehicles, infrastructure, other devises
  - Contains on-board GPS, vehicle information and communication capability to warn drivers when calculated safety thresholds are exceeded
  - Capable of warning on potential collisions not visible to current active safety systems
  - Relies on other vehicles in traffic stream having similar capabilities

V2X Warnings

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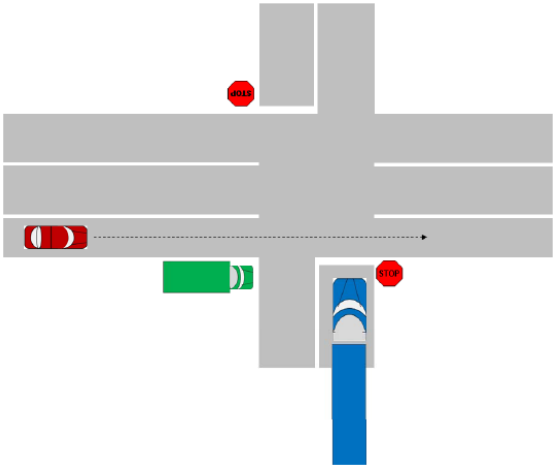
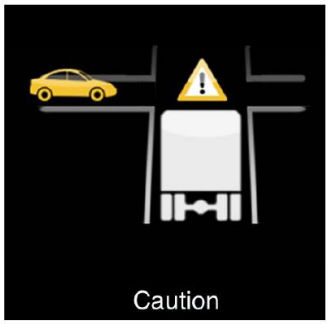
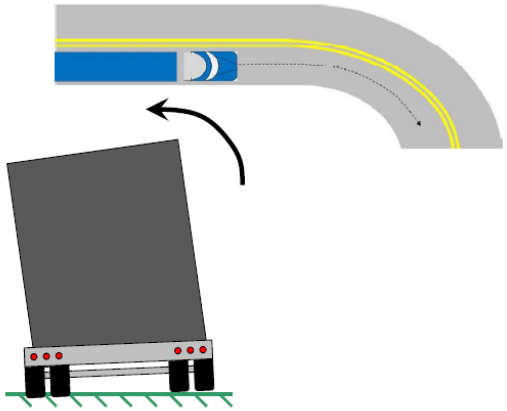
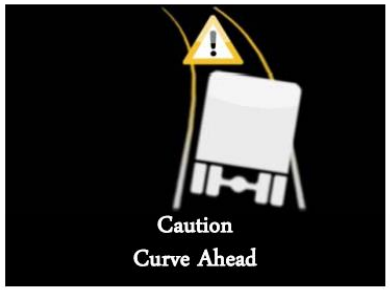
Intersection Movement Assist (IMA)

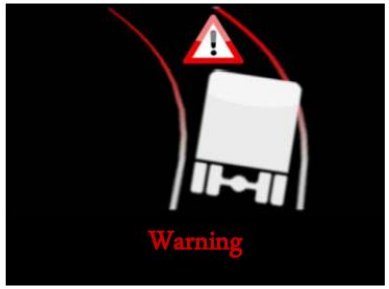




Curve Speed Warning (CSW)







Safety Pilot: Model Deployment

- Model for national deployment of technology
- Determine real world technology effectiveness at reducing crashes & how drivers respond to safety applications
- Deployment began August 2012 in Ann Arbor and continues
- Terabytes worth of data being collected and analyzed by the Volpe Center
  - Report expected in 2015

	Integrated Vehicles	Retrofit/ Aftermarket Devices	Vehicle Awareness Devices	
Passenger Cars	64	300	2200	
Heavy Trucks	3	16	50	
Transit		3	100	
Medium Duty			100	
	67	319	2450	**2836**

ANPRM – V2V Communication

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- NHTSA released ANPRM on Aug 18th requiring V2V communication capability be installed on new light vehicles – FMVSS 150
  - Will create minimum performance requirements for devices and messages
  - Safety apps will not be required – will rely on market driven initiatives to develop
  - Document contained 57 questions requesting information
  - Announced availability of NHTSA's research report, "Vehicle-to Vehicle Communications: Readiness of V2V Technology for Application"
- Motivation for Issuing ANPRM
  - Certain crash scenarios require V2V communication to detect
    - Intersection crashes most serious
  - V2V will not develop absent of regulation / Interoperability
    - Significant number of vehicles on public road must be equipped
- Preliminary hardware costs estimated at $341-$350 per vehicle
- NHTSA received over 900 comments to ANPRM (NHTSA-2014-0022)
- Heavy truck decision expected this year

NHTSA
www.nhtsa.gov

Heavy Truck V2V Challenges

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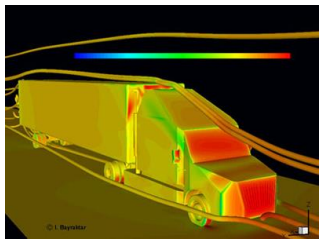
- Trailer presence and length needs to be considered
  - How to automatically supply this data to tractor installed devise?
  - Will a trailer mounted unit also be required?
- Articulated vehicles present additional challenges
  - Intersection clearance, lane changes
- Warnings must be integrated with current active safety systems
  - Cannot have two devises providing similar warnings (CMS, Blindspot)
- Can payback be ensured during the initial years of deployment?
  - Platooning, priority traffic control in certain locations

Platooning Concept – Cooperative Adaptive Cruise Control

- Platooning: A group of trucks traveling at highway speeds with reduced following distances to decrease aerodynamic drag (improve fuel economy) and increase road capacity
- All vehicles fitted with radar based Adaptive Cruise Control / Collision Mitigation Systems
  - ACC attempts to maintain a fixed following distance to lead vehicle by automatic control of engine, engine brake and service brakes
- Vehicle to vehicle communication (DRSC) allow vehicles to react almost simultaneously to braking and acceleration actions of lead vehicle (electronically coupled)
  - Following vehicle reacts prior to a change in headway distance
  - Driver reaction time eliminated



- Drivers able to manually initiate and end platooning
- Drivers in all vehicles control steering and can always override system

Platooning Concept – Cooperative Adaptive Cruise Control

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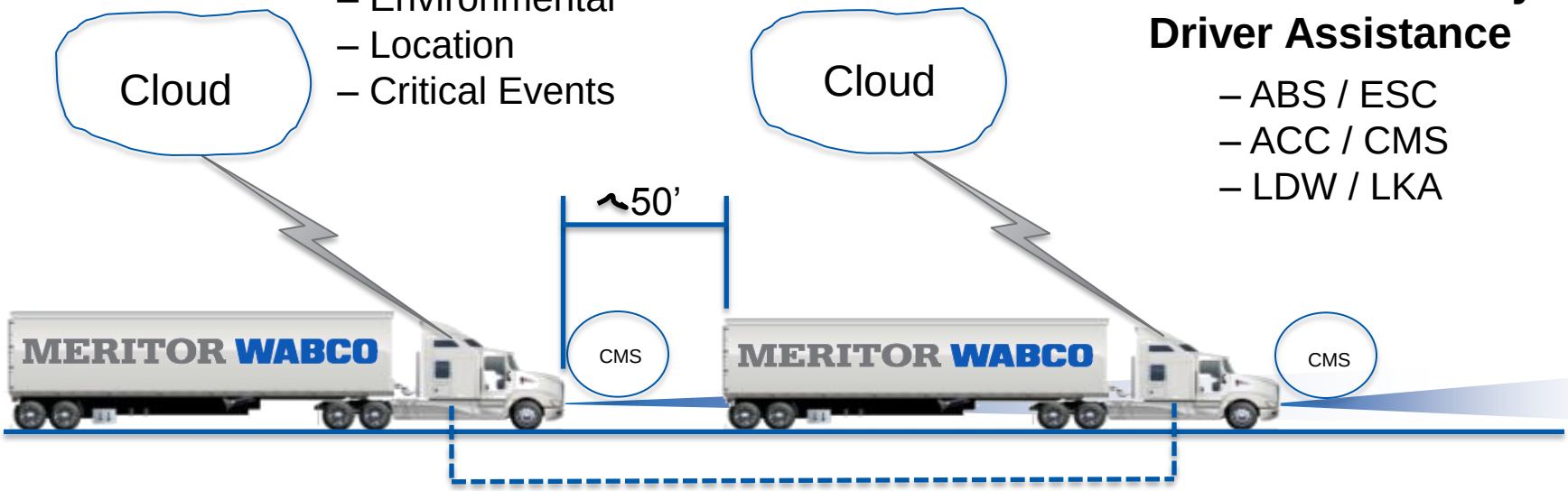
Data

– Environmental
– Location
– Critical Events

Active Safety Systems Provide Necessary Driver Assistance

– ABS / ESC
– ACC / CMS
– LDW / LKA



V2V 5.9 GHz DSRC Link

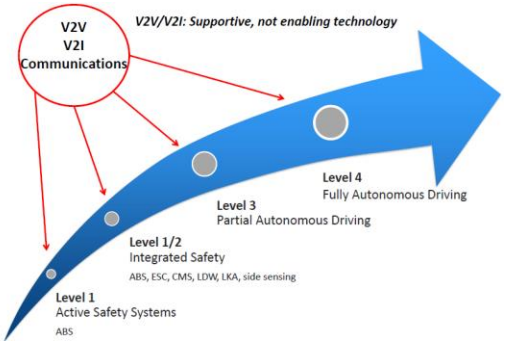
(allows exchange of data between vehicles using wireless communication)

Allows for:
- Synchronized Braking and Acceleration
- Potential video transfer
- Drivers steer both vehicles

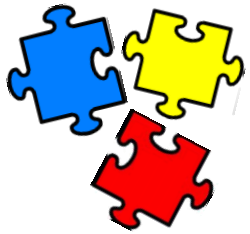
Following vehicle will react to:
- Change in following distance to lead vehicle
- Initiation of lead vehicle braking and acceleration

Next Steps Toward Autonomous Functionality

- Continued development of higher performance sensors, actuators and systems, cost optimized for volume production
- Relieve driver of control functions for discrete time periods
- Adaptive vehicle based active safety systems
  - Integrating traffic stream, environment & infrastructure information – "Big Data"
- Higher software reliability levels and tools to validate
- Cyber security
- V2I private sector payback initiatives
  - Wireless inspection, e-parking, e-tolling, weigh in motion



Pieces are Getting in Place



- Electronic engines allow automatic control of drive torque
- Stability control architecture allows automatic control of the service and engine brakes (longitudinal)
- Electronic steering allows driverless lateral control of the vehicle
- Sensors are being deployed to determine the external environment surrounding the vehicle
- What's missing is the complete integration of a 360^{o} vision of the vehicle's surrounding and the sophisticated algorithm to allow machine control to exceed human control
  - Moore' Law: the number of transistors in an integrated circuit doubles every 2 years (2000: 38 M, 2010: > 1 Billion)

Challenges Moving Toward Advanced Automation Levels

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- Achieving sufficient technology payback
  - Especially Level 3
- Validation requirements
- Potential reduction in driver skills
- Transition from complete system control back to driver – Level 3
  - Will driver be prepared?
- Liability concerns
- Infrastructure improvements
- Mixed vehicle population

Summary

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- Use of heavy truck active safety systems increasing
- Changes in automation level will be evolutionary, not revolutionary
- Integrated active safety system development will continue to progress
  - Significant safety improvements possible and expected
  - For near term, systems will assist drivers, not replace them
- We will get there when the technology is ready
  - The question is WHEN???

Save Lives, Increase Value, Reduce Costs

Cutting edge

"There's a way to do it better – find it."

Thomas Edison

Trendsetting

Thanks!

Novel

Groundbreaking

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