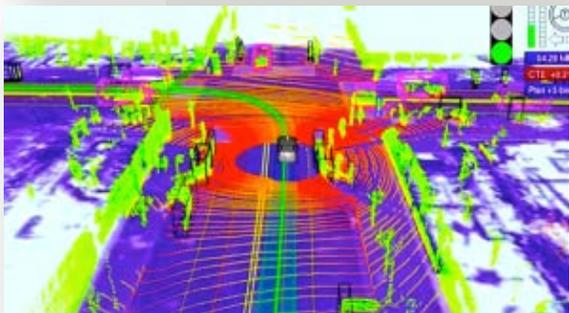




California Road Charge Pilot Program
Technical Advisory Committee

Redefining Mobility: Connected/Increasingly Automated Vehicles



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California Polytechnic State University, San Luis Obispo
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March 27, 2015

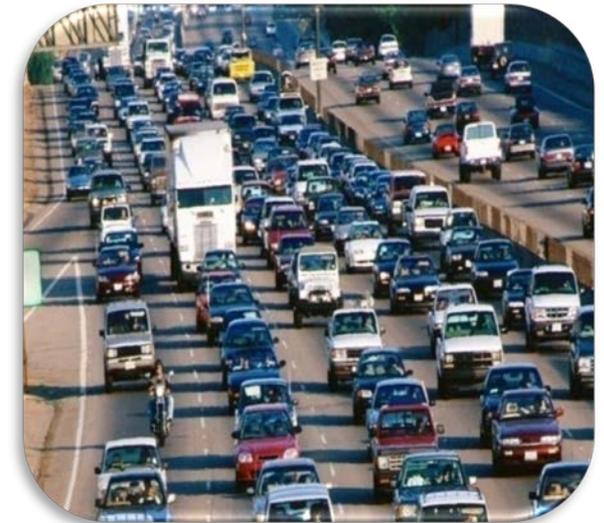
Safety

- 32,719 fatalities in 2013 (-3% from 2002)
- 1.10 fatalities per 100 MVMT (2.9 trillion VMT)
- 10.35 fatalities per 100,000 population
- 2.3 million injuries in 2013
- 5.7 million crashes in 2013
- \$230 billion total cost
 - \$32 billion medical cost
 - \$51 billion for impaired driving
- Leading cause of death for ages 4 to 34



Accessibility, Reliability and Mobility

- 4.8 billion hours of travel delay (34 hours per auto commuter)
- \$115 billion cost of urban congestion

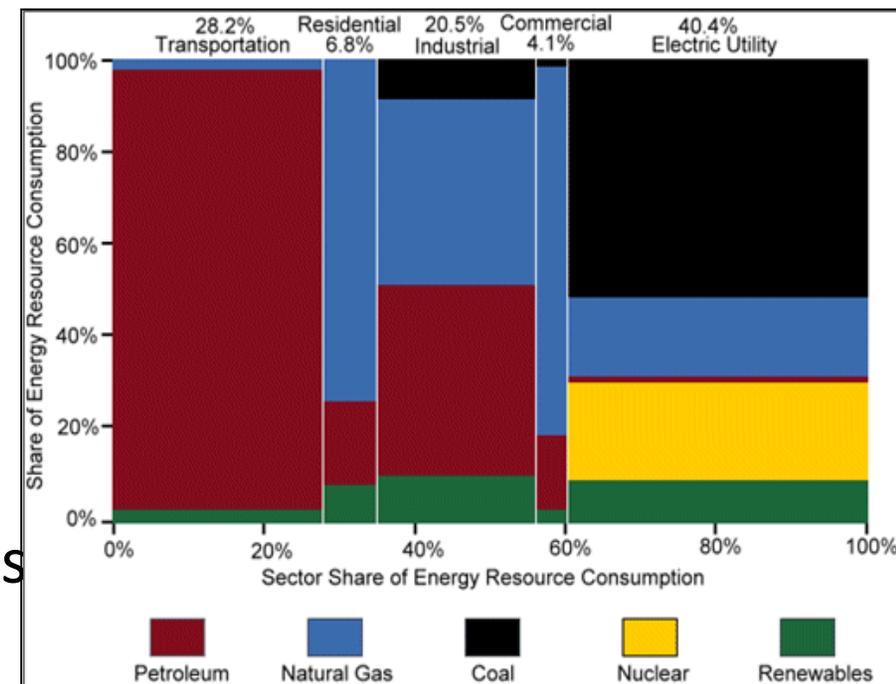
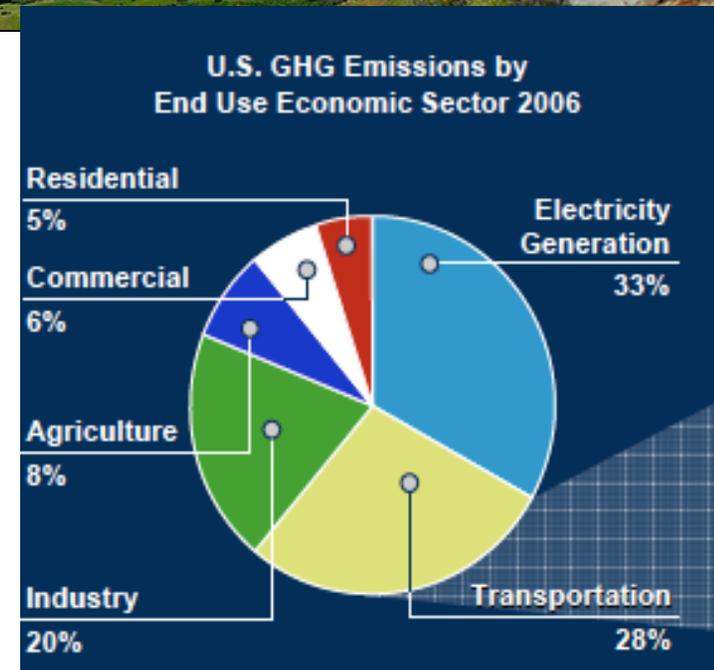


Household Market Basket

- Second biggest monthly expense, after housing

Impact on Environment

- 28% of U.S. GHG emissions
 - 78% of CO
 - 58% of NO_x
 - 36% of VOCs
- Contributions to particulates
- 29% of U.S. energy consumption, almost all petroleum
- 70% of U.S. petroleum consumption
 - 60% of oil imported → 68% in 2020
 - >40% of imported oil from OPEC nations
- 3.9 billion gallons of wasted fuel annually
- About half of all Americans live in areas that exceed air quality standards for at least one pollutant



Five Leg Stool - GHG Reductions

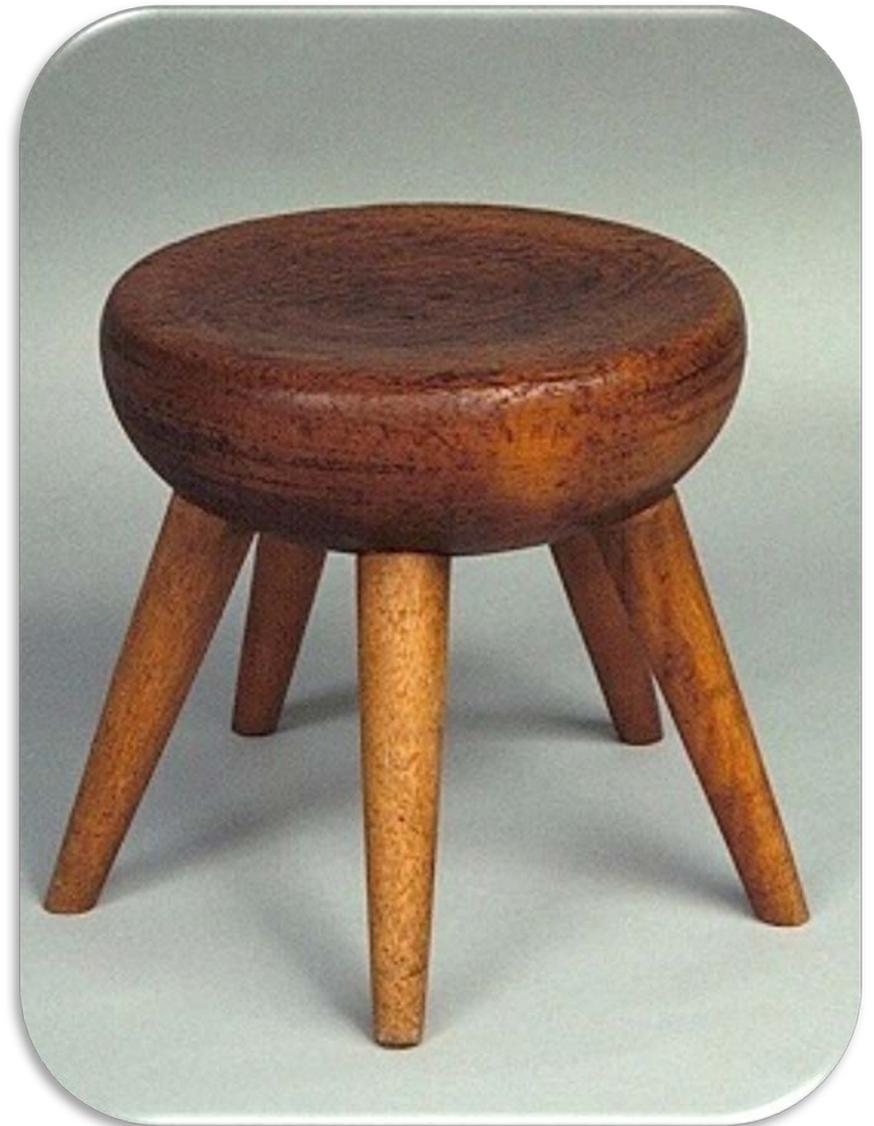
Vehicle
Technology

Low Carbon Fuel
Technology

Vehicle Miles
Traveled

Vehicle/System
Operations

Construction/Maintenance/
Agency Operations



Intelligent Vehicle in 2014

2014 Ford Focus

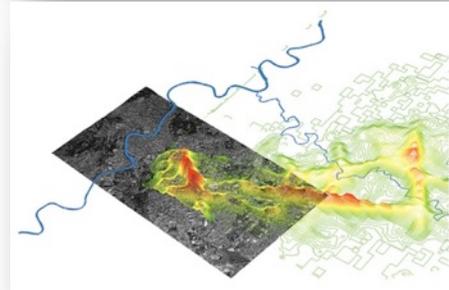
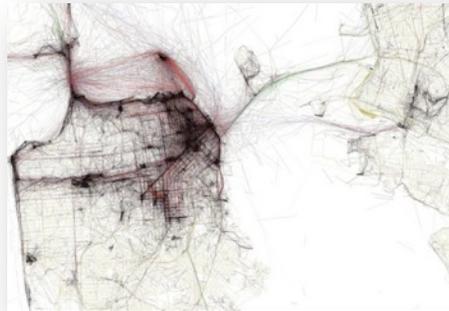
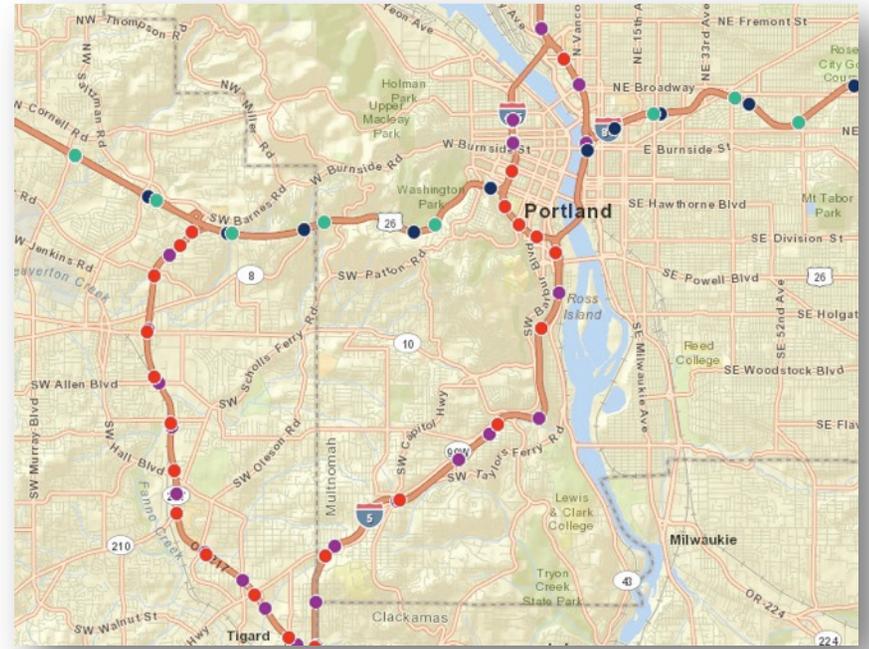
- \$21,900
- EPA Rating 22 City/34 Highway
- Adaptive Cruise Control with Forward Collision Warning
- Blind Spot Information System (BLIS) with Cross-Traffic Alert
- Rear View Camera
- Lane-Keeping System
- Active Park Assist
- 911 Assist
- Traffic Sign Recognition
- Driver Alert
- Pedestrian Alert Kit and Active City Stop



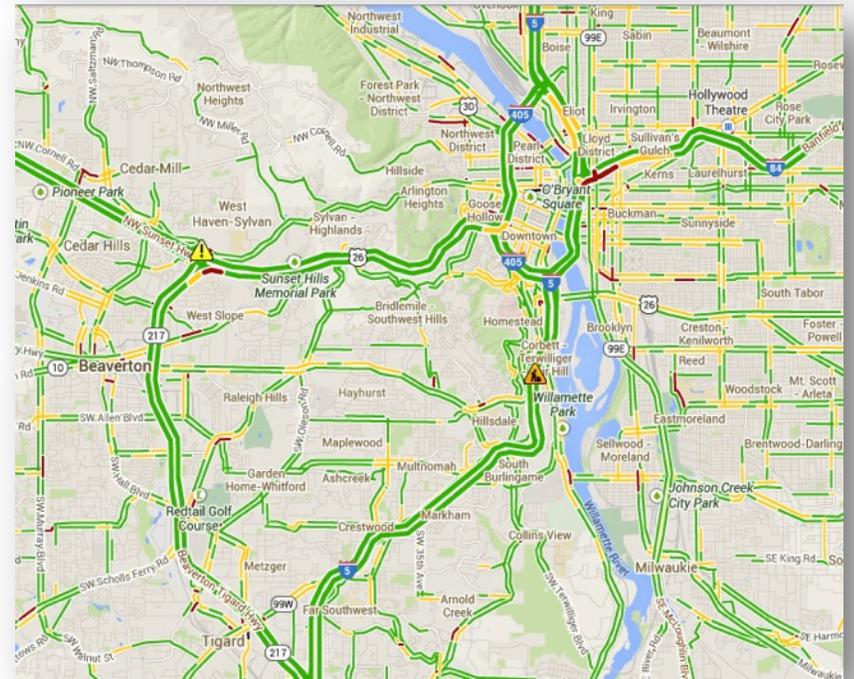
Data Revolution



From a desert...



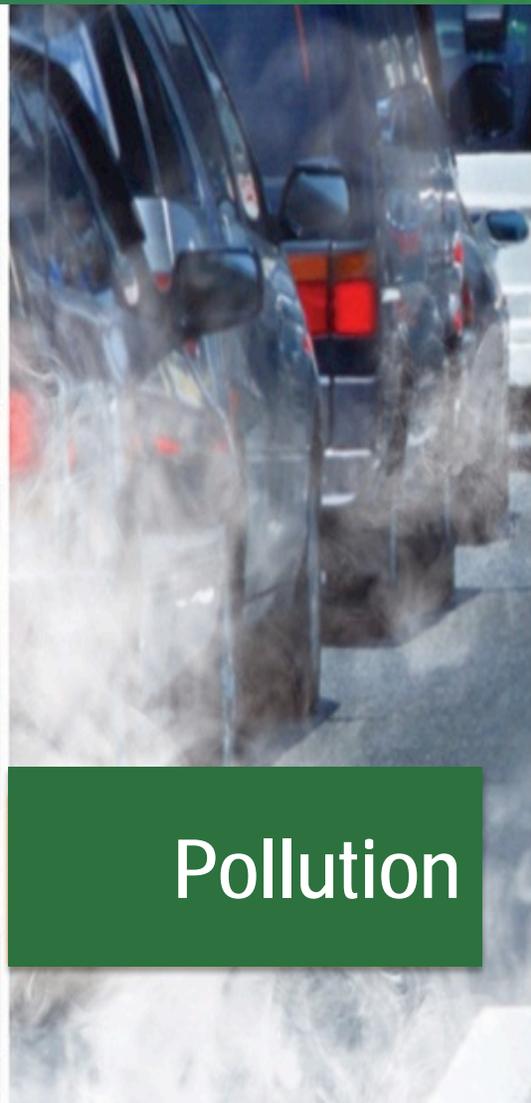
...to an ocean!



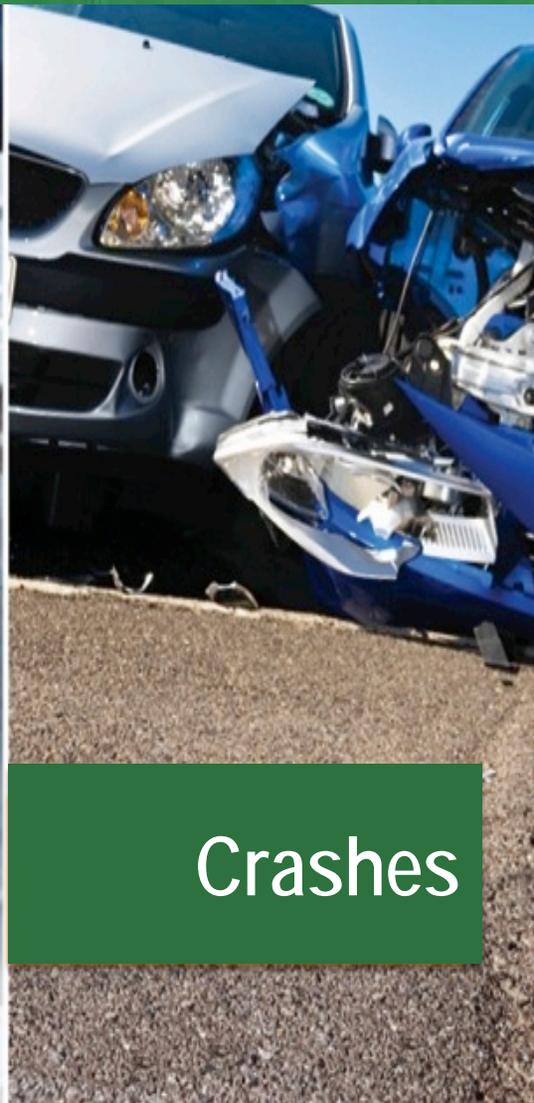
Connected Vehicles 101



Traffic



Pollution



Crashes



Weather

Vision for Connected Future

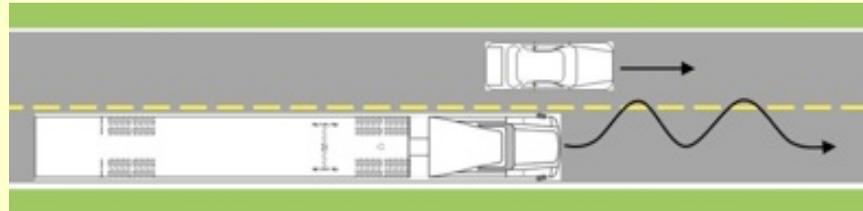


Solutions for 80% of Crashes

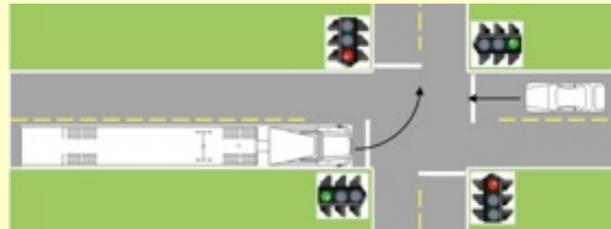
Rear End Warning 28%



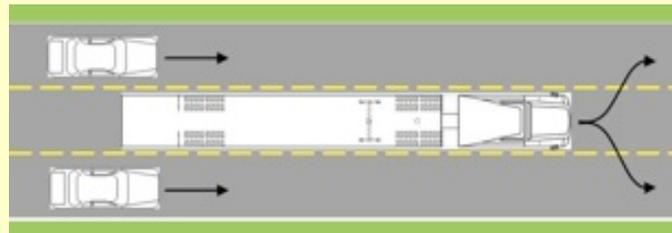
Lane Departure 23%



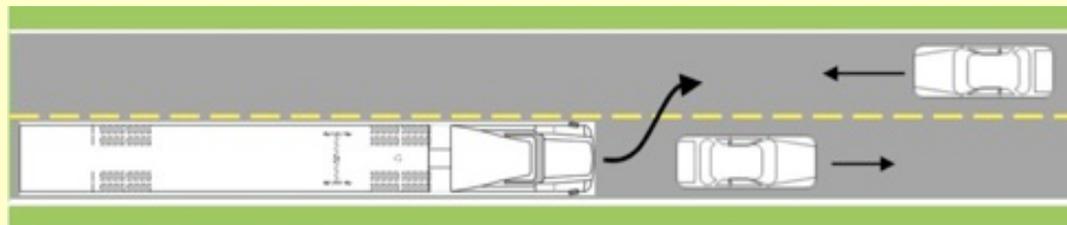
Intersection 25%



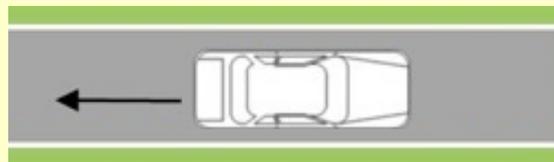
Lane Change 9%



Opposite Direction 2%



Backover 2%



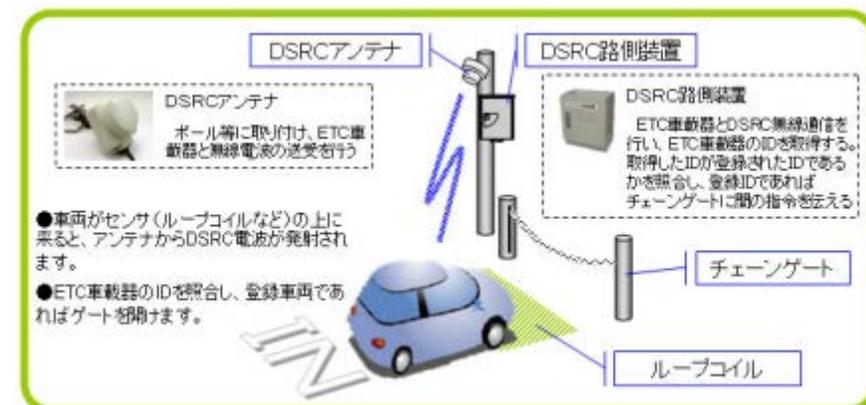
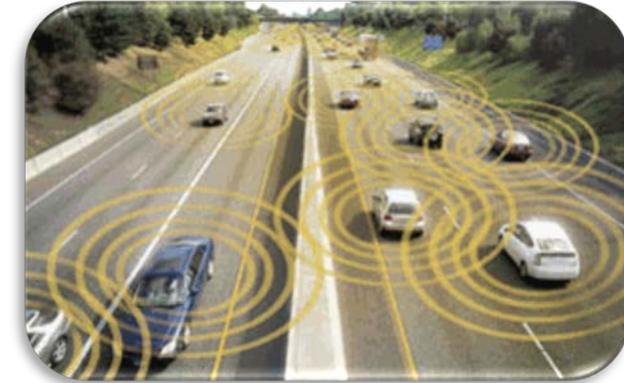
SAE J2735 Basic Safety Message

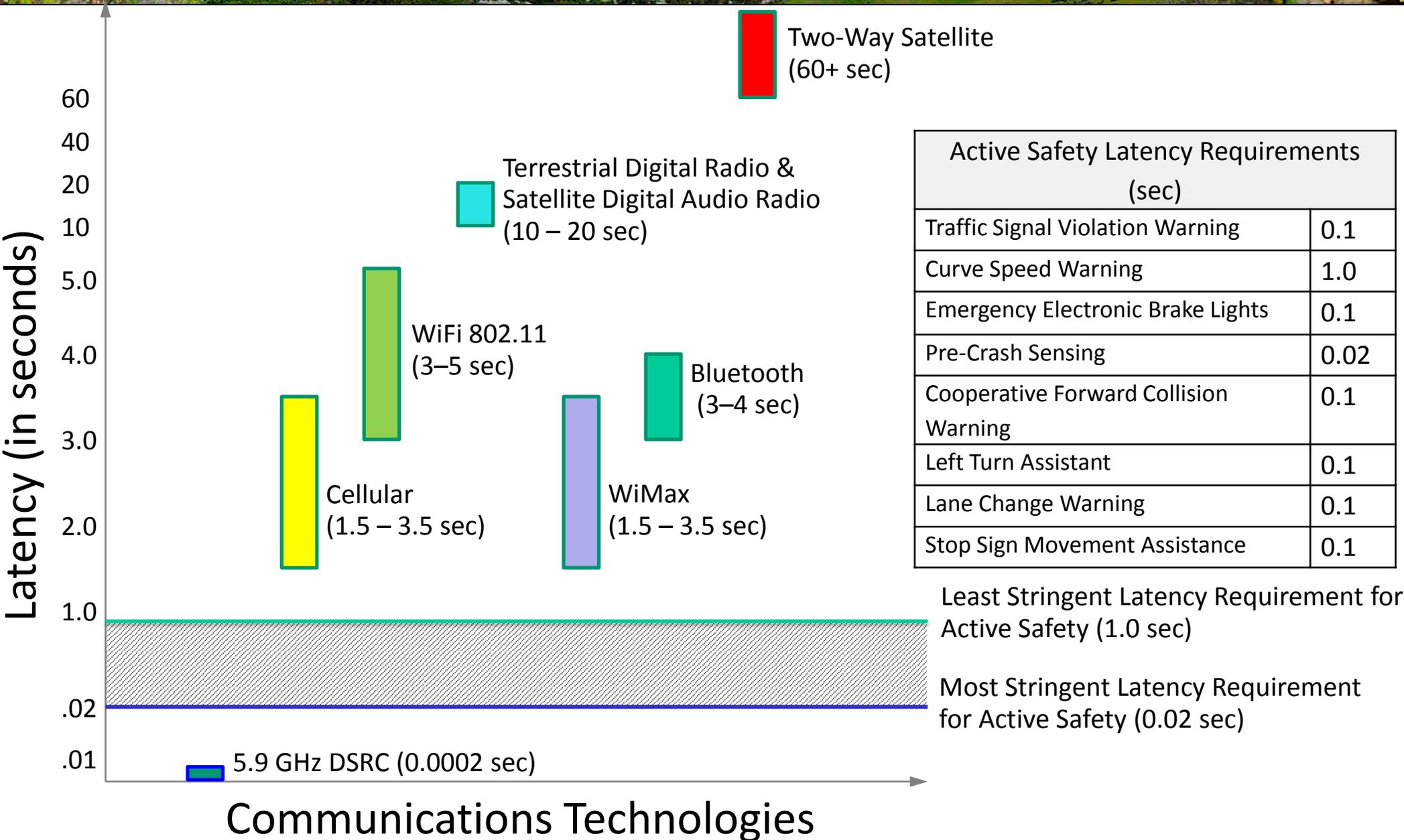


Basic Safety Message
Temporary ID
Time
Latitude
Longitude
Elevation
Speed
Heading
Acceleration
Brake System Status
Vehicle Size

What is DSRC?

- “Dedicated Short Range Communications”
- FCC authorized spectrum at 5.9 GHz for safety applications in 1999 (also Europe and Japan)
- Key ingredients: **standardization** and **interoperability**
- Other applications and other wireless technologies can be accommodated
- Older DSRC systems such as toll tags operate at 900 MH: no standard, several proprietary systems are in place
- Both vehicle to infrastructure and vehicle to vehicle communication environments
- **Complementary** to cellular
- High data transfer rates and **low latency**
- Range up to 1000 m
- Data Rate – 6 to 27 Mbps
- Seven licensed channels





Note: y-axis not to scale for illustration purposes

Data source: Vehicle Safety Communications Project – Final Report

Safety Pilot – 2836 Vehicles



V2V

- Forward Collision Warning
- Emergency Electronic Brake Light
- Intersection Movement Assist
- Blind Spot Warning/Lane Change Warning
- Do Not Pass Warning
- Left Turn Across Path/Opposite Direction
- Right Turn in Front
- V2I
- Signal Phase and Timing
- Curve Speed Warning
- Railroad Crossing Warning
- Pedestrian Detection

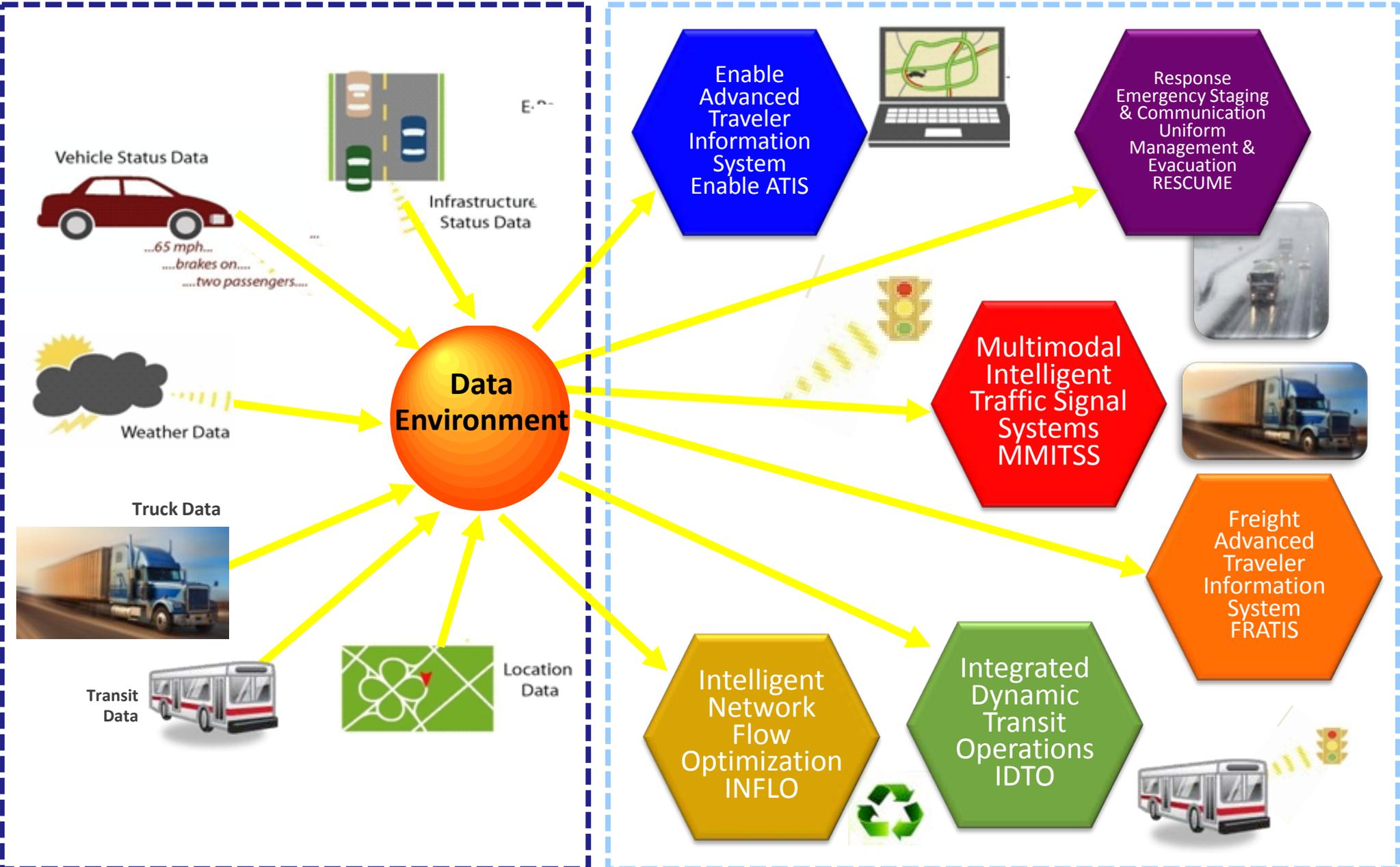


Informed NHTSA Decision February 2014

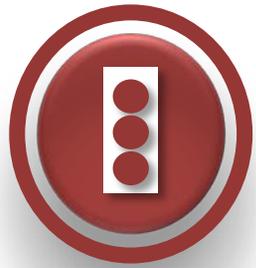
Mobility Program

Real-time Data Capture & Management

Mobility Applications



AERIS OPERATIONAL SCENARIOS & APPLICATIONS



ECO-SIGNAL OPERATIONS

- **Eco-Approach and Departure at Signalized Intersections** (*similar to SPaT*)
- **Eco-Traffic Signal Timing** (*similar to adaptive traffic signal systems*)
- **Eco-Traffic Signal Priority** (*similar to traffic signal priority*)
- **Connected Eco-Driving** (*similar to eco-driving strategies*)
- **Wireless Inductive/Resonance Charging**



ECO-TRAVELER INFORMATION

- **AFV Charging/Fueling Information** (*similar to navigation systems providing information on gas station locations*)
- **Eco-Smart Parking** (*similar to parking applications*)
- **Dynamic Eco-Routing** (*similar to navigation systems*)
- **Dynamic Eco-Transit Routing** (*similar to AVL routing*)
- **Dynamic Eco-Freight Routing** (*similar to AVL routing*)
- **Multi-Modal Traveler Information** (*similar to ATIS*)
- **Connected Eco-Driving** (*similar to eco-driving strategies*)



ECO-LANES

- **Eco-Lanes Management** (*similar to HOV Lanes*)
- **Eco-Speed Harmonization** (*similar to variable speed limits*)
- **Eco-Cooperative Adaptive Cruise Control** (*similar to adaptive cruise control*)
- **Eco-Ramp Metering** (*similar to ramp metering*)
- **Connected Eco-Driving** (*similar to eco-driving*)
- **Wireless Inductive/Resonance Charging**
- **Eco-Traveler Information Applications** (*similar to ATIS*)



ECO-INTEGRATED CORRIDOR MANAGEMENT

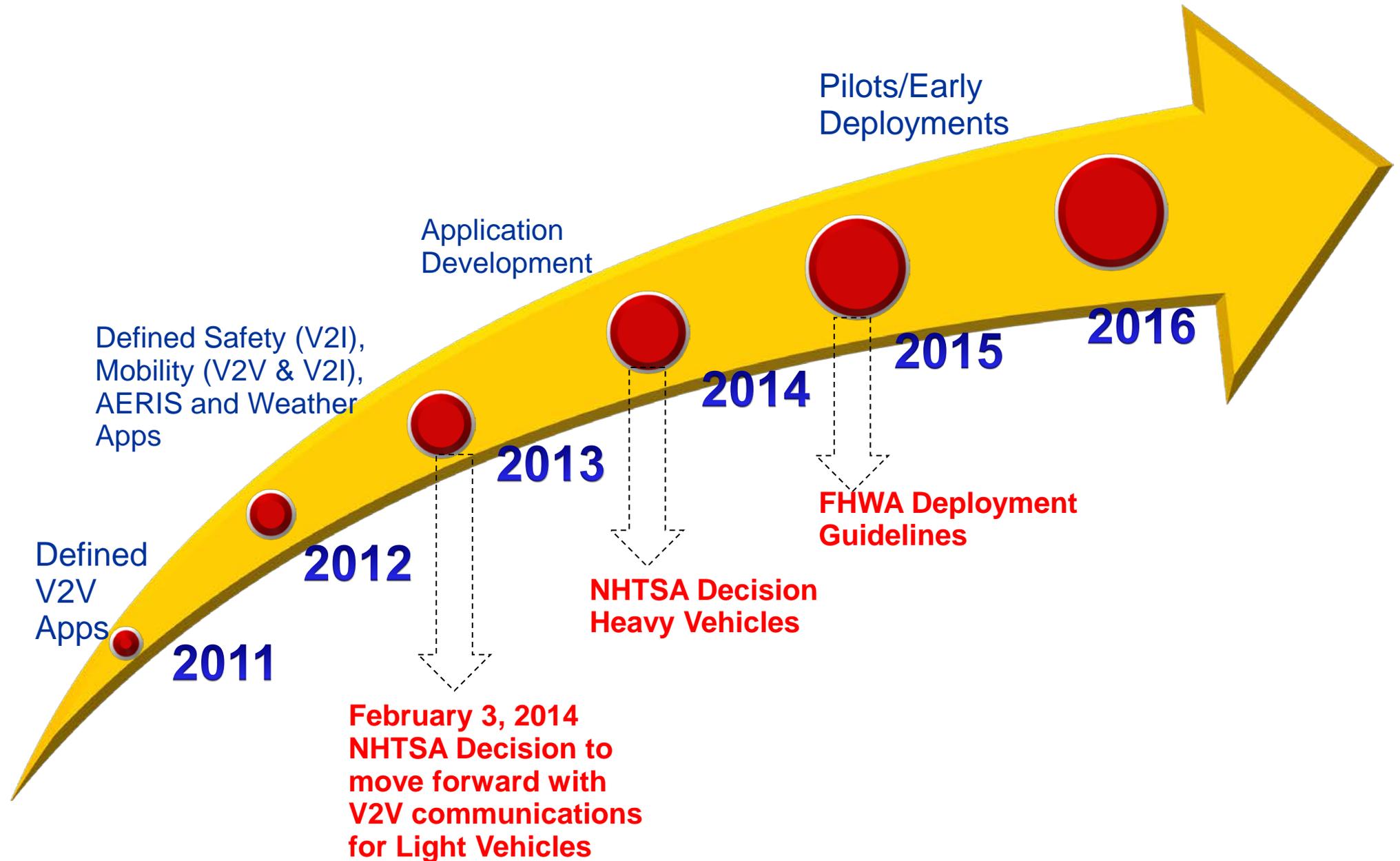
- **Eco-ICM Decision Support System** (*similar to ICM*)
- **Eco-Signal Operations Applications**
- **Eco-Lanes Applications**
- **Low Emissions Zones Applications**
- **Eco-Traveler Information Applications**
- **Incident Management Applications**



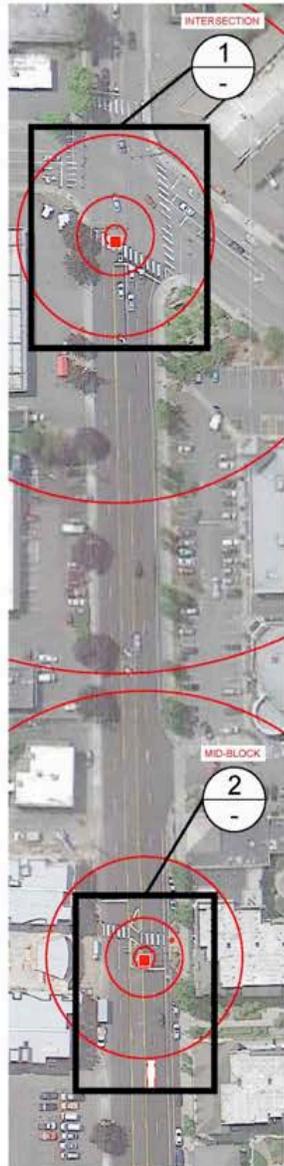
LOW EMISSIONS ZONES

- **Low Emissions Zone Management** (*similar to Low Emissions Zones*)
- **Connected Eco-Driving** (*similar to eco-driving strategies*)
- **Eco-Traveler Information Applications** (*similar to ATIS*)

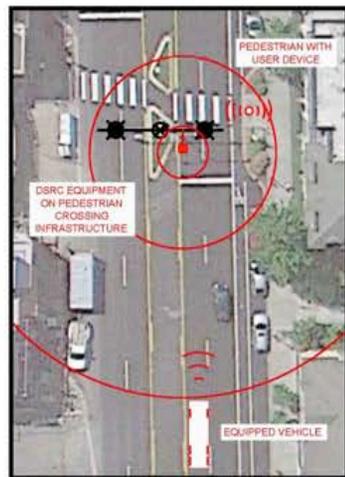
The Path To Deployment



Urban Intersection Footprint



1 INTERSECTION



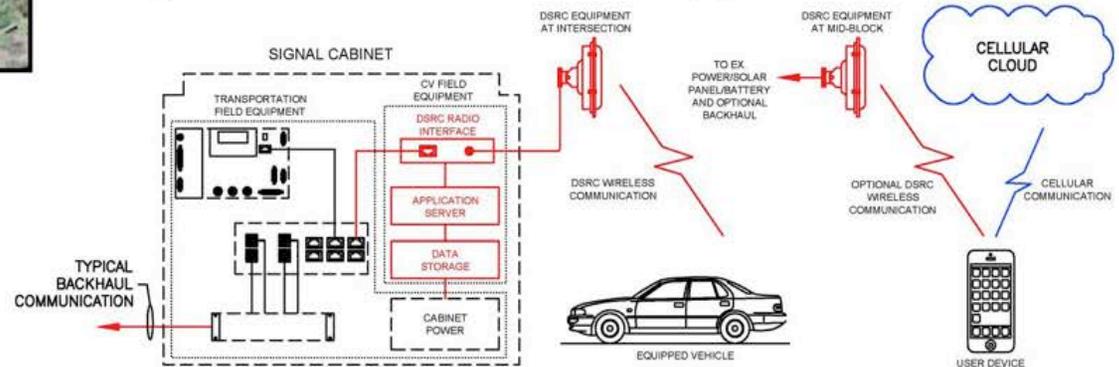
2 MID-BLOCK (OPTIONAL)



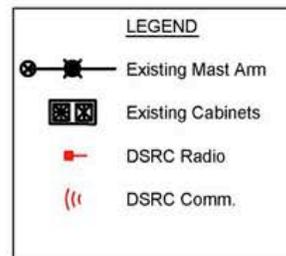
1 INTERSECTION INSTALLATION



2 OPTIONAL MID-BLOCK PEDESTRIAN CROSSING



3 COMMUNICATION AND POWER SCHEMATIC



TYPICAL SETTING FEATURES

Urban intersections are junctions of two or more roads in a city setting; they typically include curbing, designated lane markings, traffic signals, and pedestrian crossings.

CONCEPT EXAMPLE

DSRC antennas communicate with vehicles on all approaches of the intersection and at an optional mid-block location.

OTHER EXAMPLE APPLICATIONS

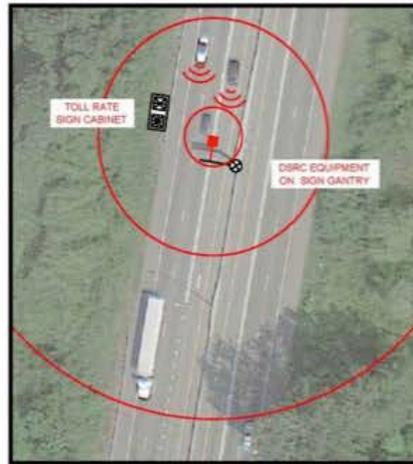
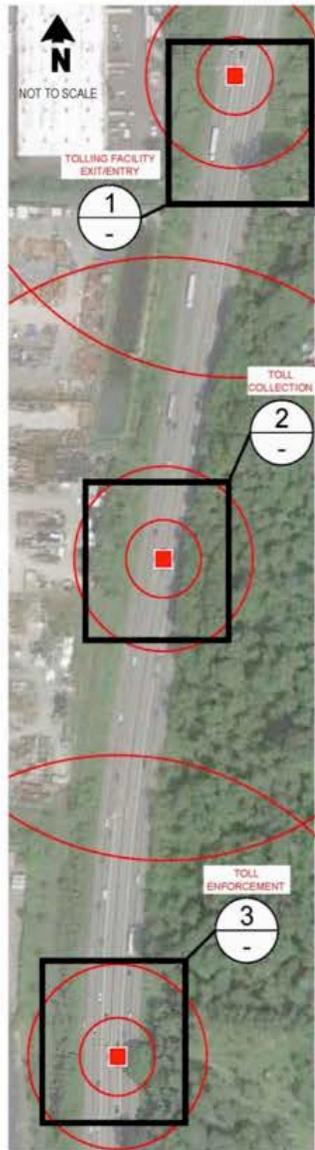
- Red Light Violation Warning and Stop Sign Violation
- Driver Gap Assist at Signalized Intersections and Stop Signs
- Multimodal Intelligent Traffic Signal Systems
- Advanced Arterial Management and Operations
- Advanced Signal Operations



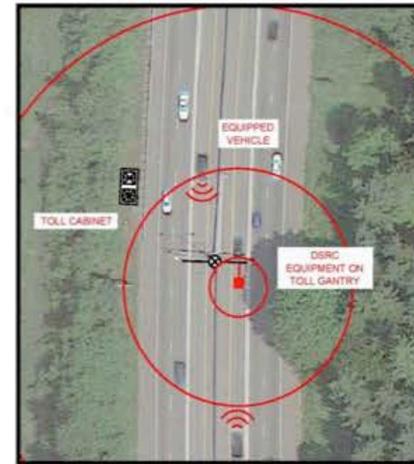
Urban Intersection Deployment Concept

NATIONAL CONNECTED VEHICLE FIELD INFRASTRUCTURE FOOTPRINT ANALYSIS

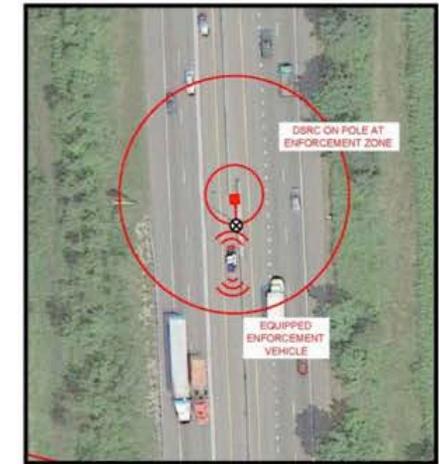




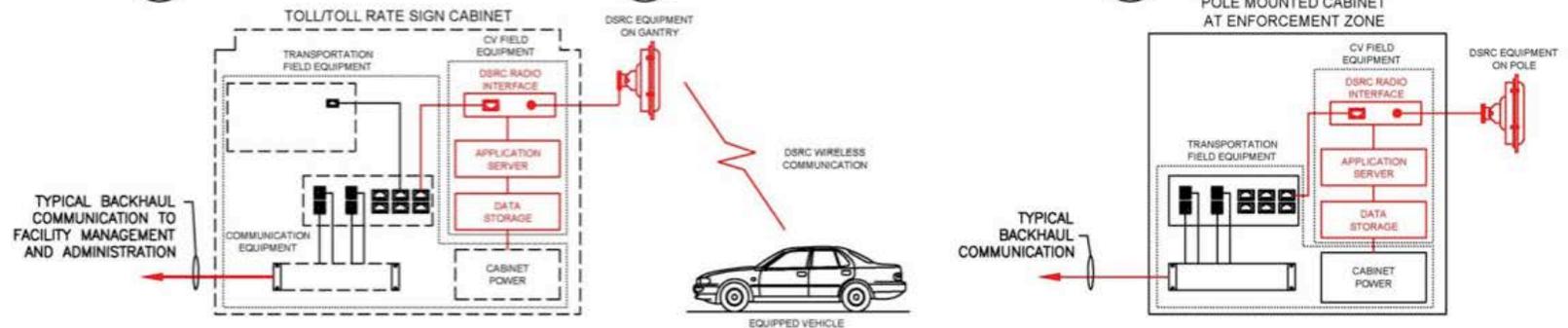
1 TOLL FACILITY ENTRY/EXIT



2 TOLL FACILITY



3 TOLL ENFORCEMENT



4 COMMUNICATION AND POWER SCHEMATIC

LEGEND	
	Existing Mast Arm
	Existing Pole
	Existing Cabinets
	DSRC Radio
	DSRC Comm.

TYPICAL SETTING FEATURES

Deployment at toll facility entry and exit points on limited access roadways.

CONCEPT EXAMPLE

Application for communication with the toll facilities to share information on user fees and collect payments from user accounts.

OTHER EXAMPLE APPLICATIONS

- Approach lane use management
- Automated toll/user fee collection and administration
- Congestion pricing
- High-occupancy toll lanes

Fee Payment Deployment Concept

NATIONAL CONNECTED VEHICLE FIELD INFRASTRUCTURE FOOTPRINT ANALYSIS

M:\12\12131.00 - Connected Vehicle General Concept for Deployment\Engineering\CAD\Sheets\Concept 9 - User Fees.dwg<Concept 8>Karl Typolt 8/16/2013 4:48 PM

NOT FOR CONSTRUCTION

Focus: Provide drivers with information regarding upcoming fee payment facility, account balance, alternate non-tolled parallel routes, and fees associated with using system

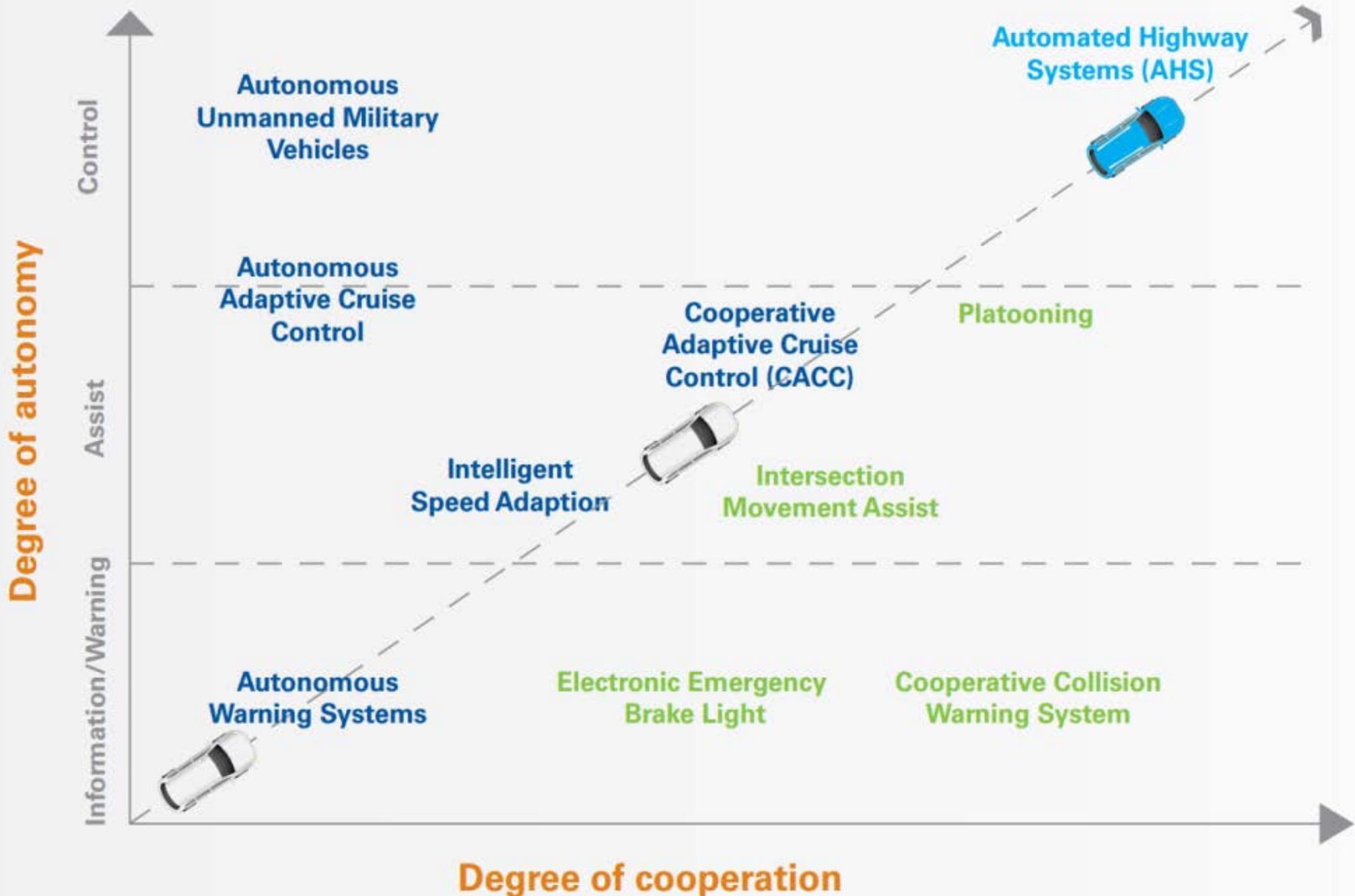
Description

- With appropriate transactional safeguards, could provide access to a **payment transaction system**
- DSRC antenna mounting locations in close proximity to roadside toll equipment where communication source and power is available
- DSRC can use **one radio that can cover an entire road.**
- **Backhaul communications** network owned and maintained by operator
- **High bandwidth** provides capacity for sharing among CV applications
- Could universally process user fees for out-of-state vehicles

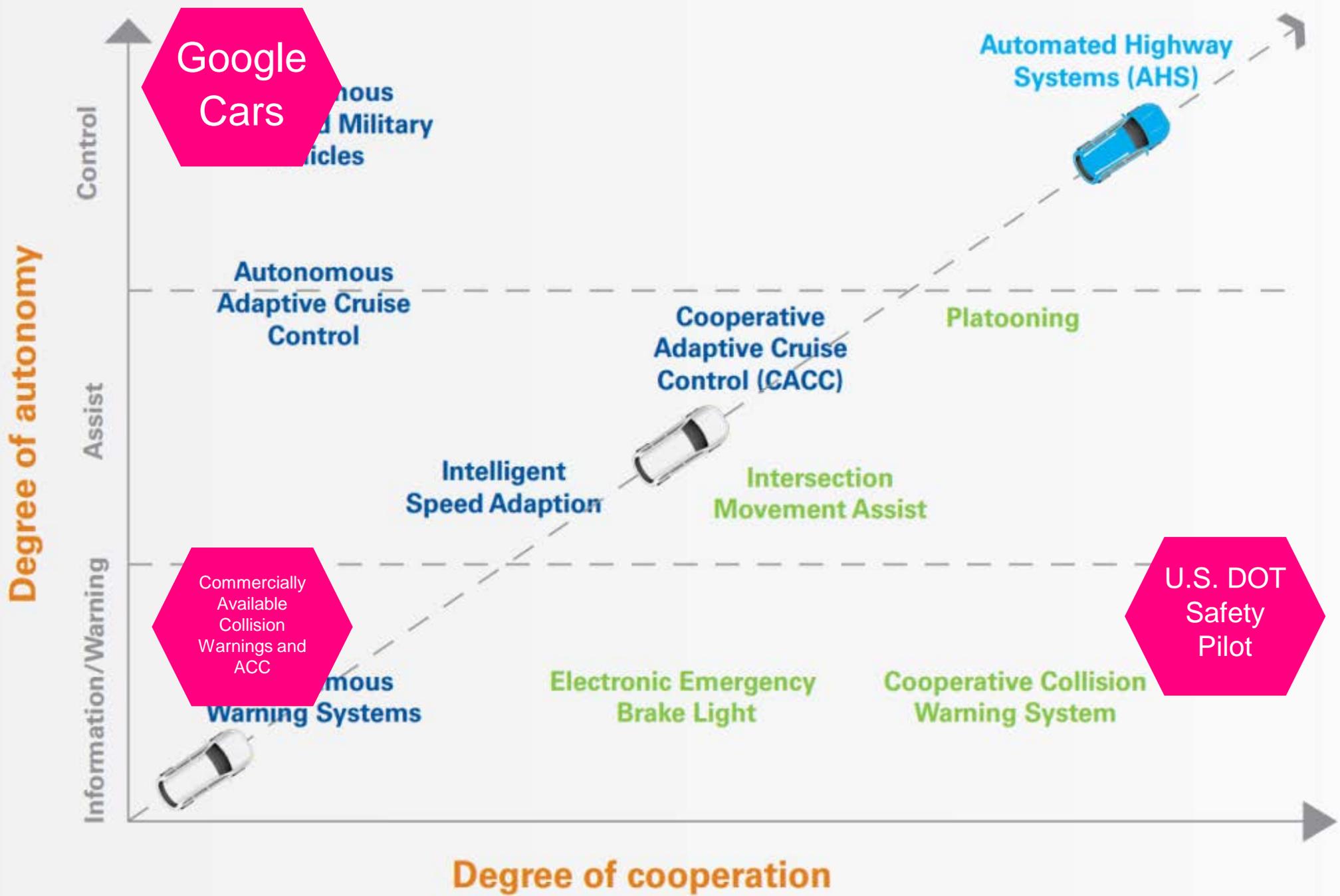
Common Applications

- Approach lane use management
- Automated toll collection and administration
- Congestion pricing and high-occupancy toll lanes

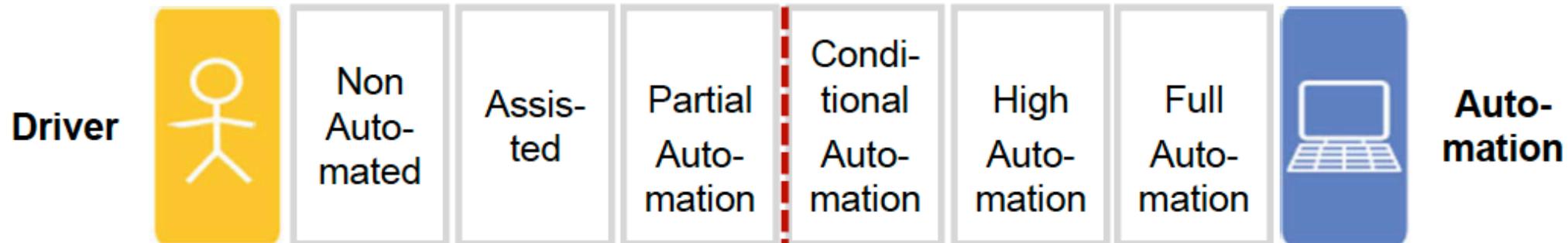
Autonomy vs. Cooperation



Autonomy vs. Cooperation



Taxonomy & Definitions



LDW, BSD, Warnings

LKA, ACC

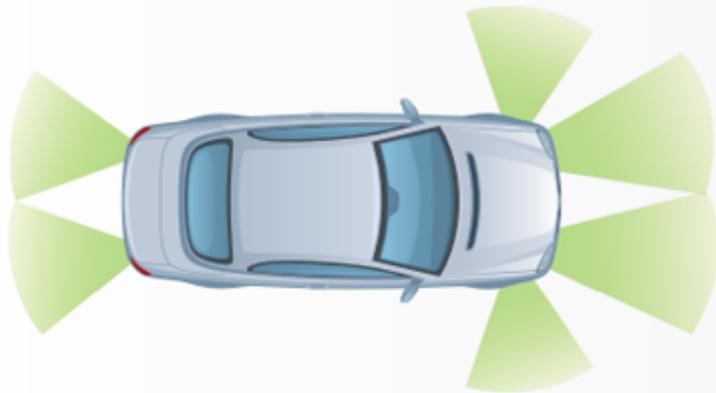
Traffic Jam Assist

Traffic Jam Pilot

Full Highway Pilot

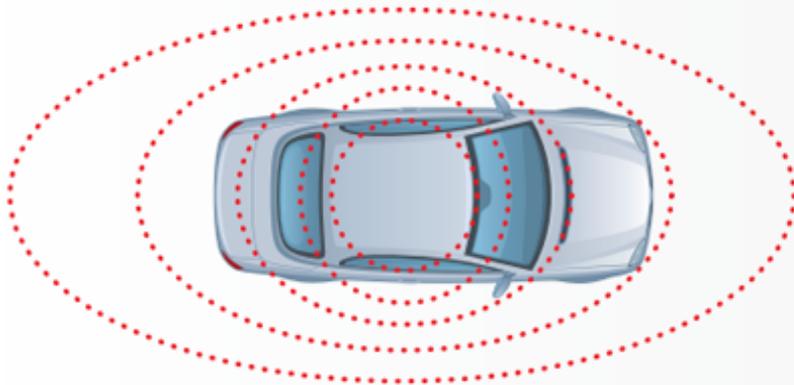
Taxi Function

Driver in the loop	yes (must!)		no	
Reaction time	~ 1 s		~ 10 s	~ 10 min
Secondary tasks	none		texting	sleeping
Minimal Risk Cond.	none		some	always (must!)



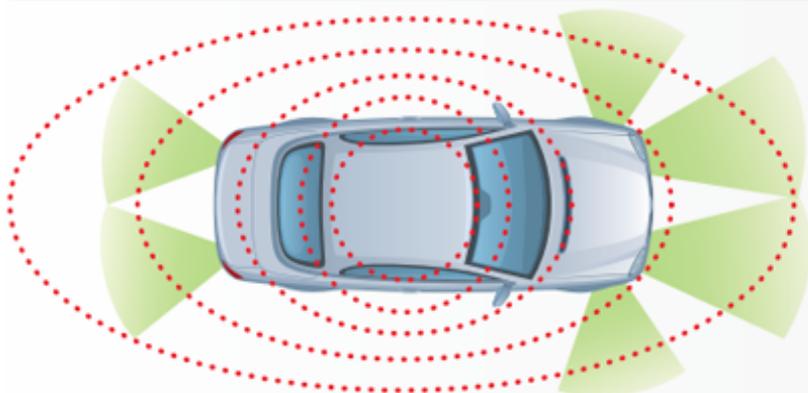
Sensor-Based Solution Only

- Cannot sufficiently mimic human senses
- Not cost-effective for mass market adoption
- Lack of adequate 360° mapping of environment in urban grids



Connected Vehicle Solution Only

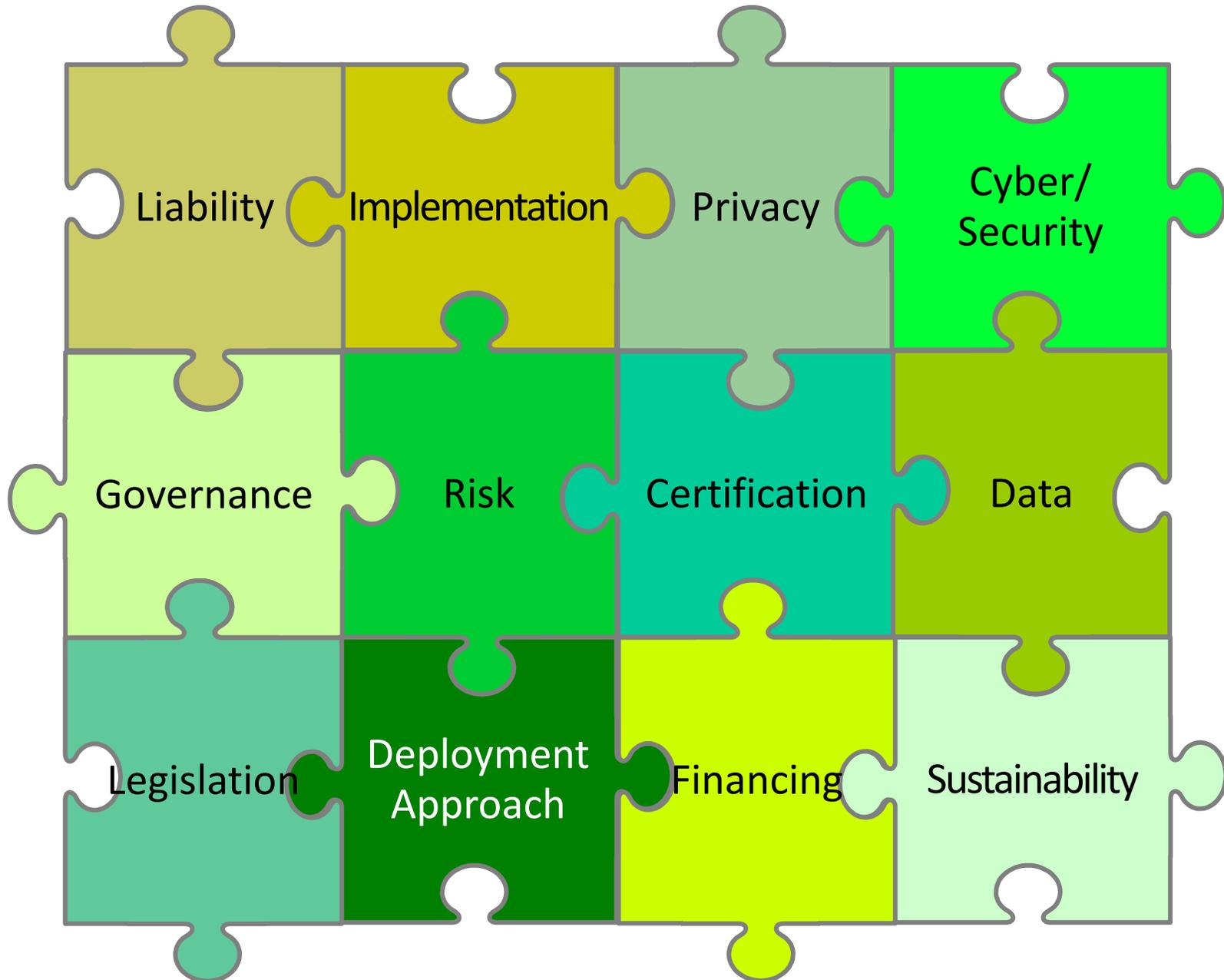
- DSRC does not currently work with pedestrians, bicyclists, etc.
- DSRC-based V2I might require significant infrastructure investment
- V2V requires high market penetration to deliver value reliably



Converged Solution

- Convergence will facilitate adequate mimicking of human senses
- Convergence will reduce need for an expensive mix of sensors and reduce the need for blanket V2I investment
- Convergence will provide the necessary level of functional redundancy to ensure that the technology will work 100 percent of the time

Policy Issues



Potential Implications



Crash Elimination



Reduced Need for New Infrastructure



Travel Time Dependability



Productivity Improvements



Data Challenges



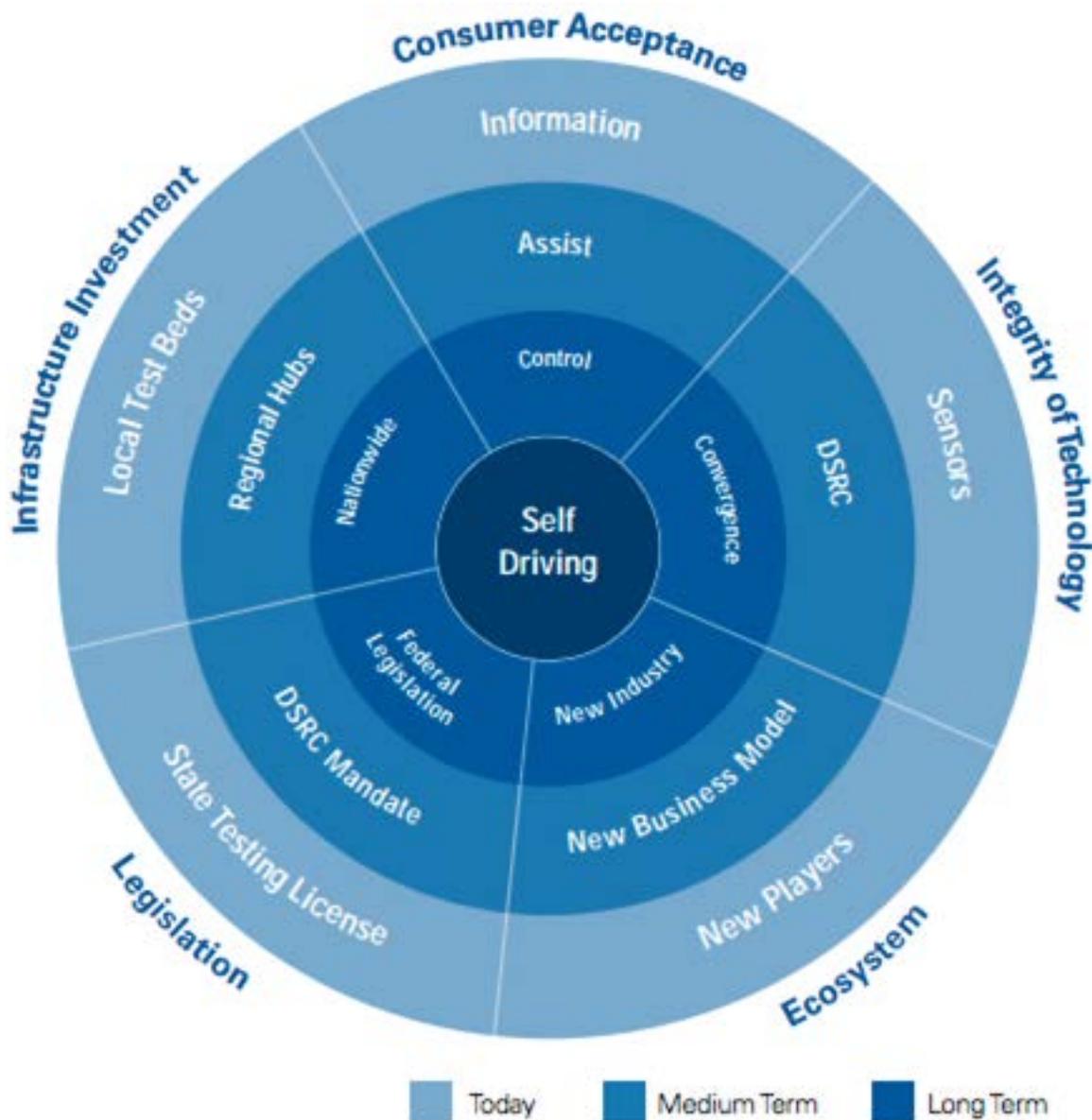
New Models for Vehicle



Improved Energy Efficiency

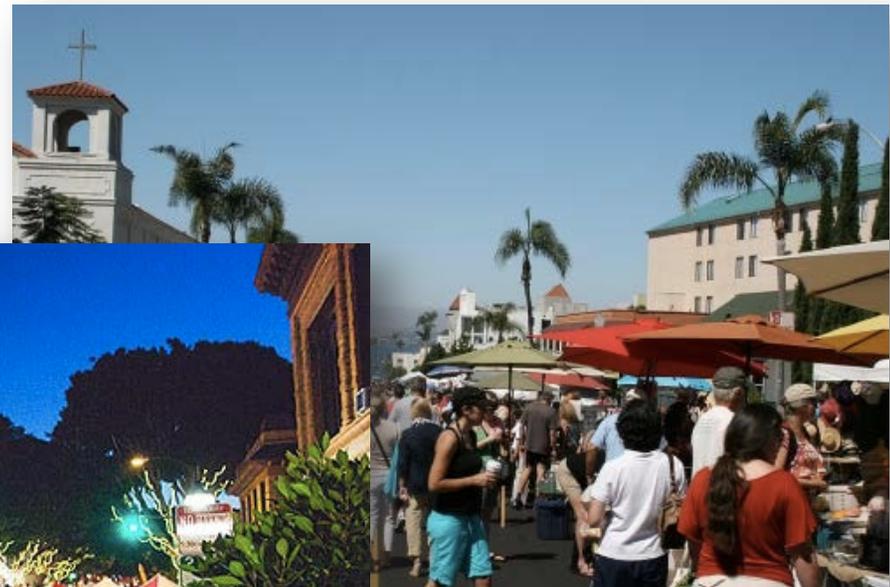
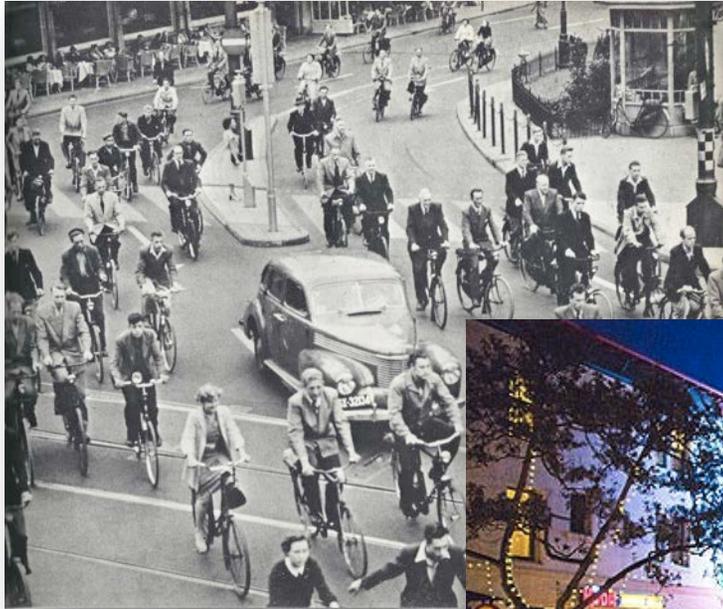


New Business Models & Services



Don't Forget

- Design places where people want to be
- Streets are for people
- Transportation is not an end in itself

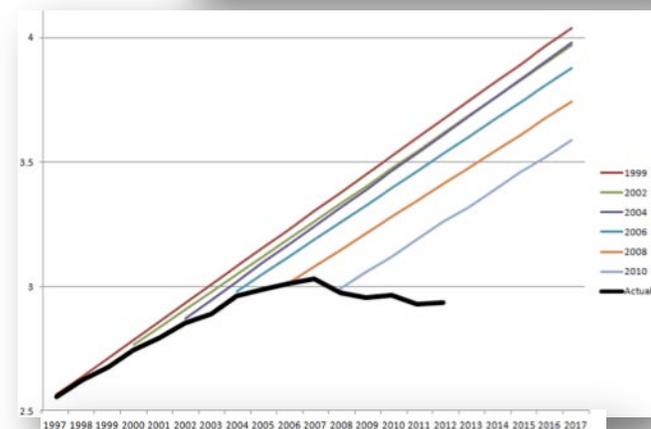


Don't Forget

- Automated Vehicles Will Be Connected
- Safety, Accessibility, CO₂
- Demographics and Forecasts
- Data and Evaluation
- Fleets, Multimodal and Off-Road Vehicles
- Design Communities We Want
- Silos: Integrate Licensing, Planning, Design, Operations (Data is Key)
- Collaboration and Innovative Partnerships: Public, Private, Academic



Demographic	Population	Percentage of Total
Digital Natives (0–14 years)	49 million	16%
Gen Now (15–34 years)	84 million	28%
Gen X (35–44 years)	43 million	14%
Baby Boomers (45–65 years)	80 million	26%
Older Adults (66+ years)	47 million	16%



Thank You for Your Attention

CAL POLY
— SAN LUIS OBISPO

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