Connected Vehicles and Signalized Intersections

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(Content provided by Gary Duncan, Chief Technology Officer)

Today's Transportation Problems

Safety
33,561 highway deaths in 2012
5,615,000 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
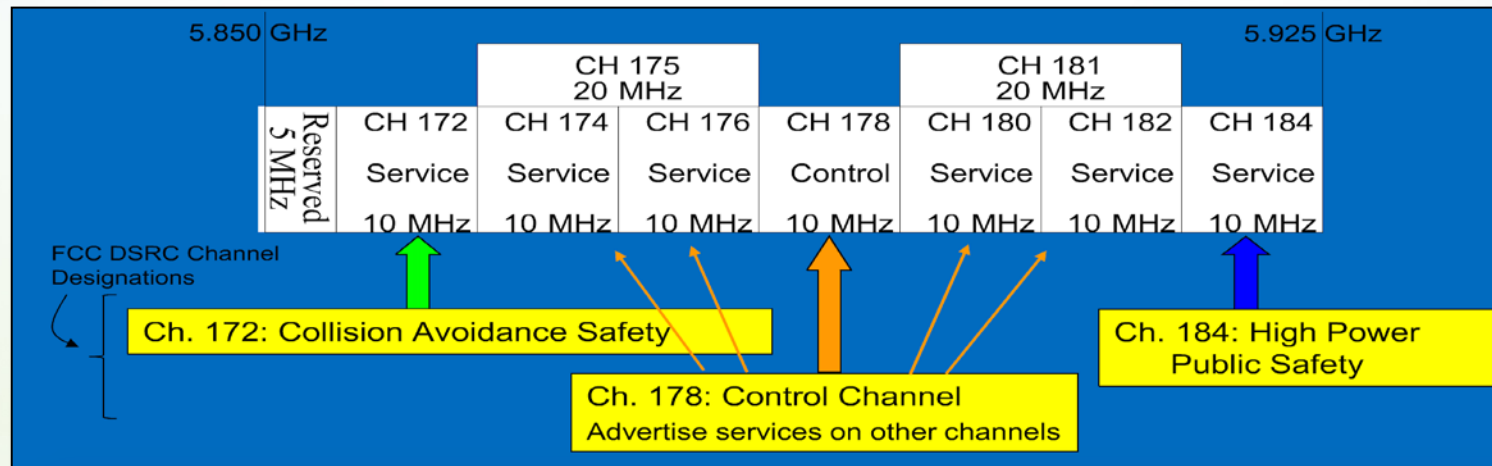56 billion lbs. of additional CO_2

Connected Vehicles

- The vehicle awareness of Connected Vehicles opens the door to a myriad of radical improvements in Safety, Mobility and the Environment.

- Many expect the impact on transportation to be bigger than anything since the signalized intersection or even the invention of the automobile.

- In safety alone, Connected Vehicles have the potential of addressing approximately 80% of the vehicle crash scenarios involving unimpaired drivers!

Safety
LIMIT 35
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Leading cause of death for ages 4, 11-27

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Key Technology Enabler – 5.9GHz DSRC
(Dedicated Short Range Communications)

- ## What is it?
  - Special WiFi radio (802.11p) adapted for low latency
    - Latency < 0.2 milliseconds – well suited for Safety Applications
    - Range: max ~1,000 meters; min 300 meters
  - NA Frequency 5.9GHz – EU/Asia 5.8GHz
    - Dedicated frequency set aside by FCC – local agency license
    - 75 MHz of dedicated Spectrum
  - Relatively inexpensive in production quantities

5.850 GHz   5.925 GHz

	Reserved 5 MHz	CH 172	CH 175 20 MHz		CH 178	CH 181 20 MHz		CH 184
			CH 174	CH 176		CH 180	CH 182	
		Service	Service	Service	Control	Service	Service	Service
		10 MHz	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz	10 MHz

FCC DSRC Channel Designations

Ch. 172: Collision Avoidance Safety

Ch. 178: Control Channel
Advertise services on other channels

Ch. 184: High Power Public Safety

DSRC Products

- Onboard Unit (OBU)
  - Vehicle radio and supporting equipment
    - Vendors: Denso, Delphi, Siemens, Savari Networks, Choda Wireless, Arada Systems, Kapsch
  - Aftermarket devices
    - Plug into vehicle's OBD port
  - Collectively, "Onboard Equipment" (OBE)
- Roadside Unit (RSU)
  - Infrastructure equipment
    - Vendors: Savari Networks, Choda Wireless, Arada Systems, Siemens, Denso, Kapsch
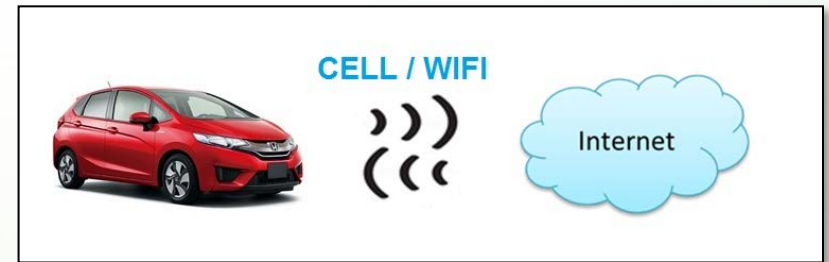 - Collectively, "Roadside Equipment" (RSE)

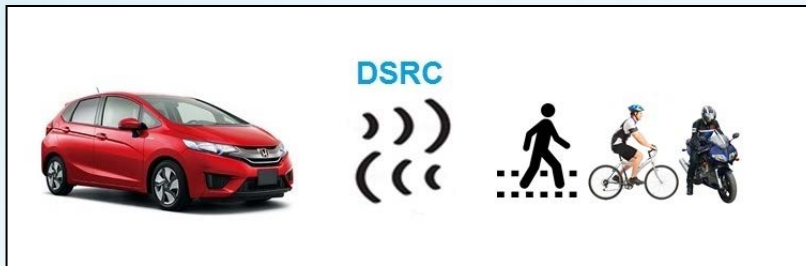# Forms of "Connected Vehicle"

- V2V – Vehicle to Vehicle

- V2I – Vehicle to Infrastructure

Forms of "Connected Vehicle"

- V2X – Vehicle to Vulnerable Road Users

Basic CV Messages
From SAE J2735 Standard

- Broadcast by Vehicle
  - **BSM** (Basic Safety Message)
    - Vehicle position, speed, heading, acceleration, brake status, size, steering, …
    - Every 100 milliseconds

- Broadcast by Infrastructure
  - **SPaT** (Signal Phase and Timing)
    - Every 100 milliseconds
  - **GID/MAP** (Intersection Map)

- Specific Communication
  - **SRM** (Service Request Message)
    - i.e. Priority Request
  - **SSM** (Service Status Message)

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Connected Vehicle Applications

CV Applications Research

V2I Safety

Red Light Violation Warning
Curve Speed Warning
Stop Sign Gap Assist
Spot Weather Impact Warning
Reduced Speed/Work Zone Warning
Pedestrian in Signalized Crosswalk
Warning (Transit)

V2V Safety

Emergency Electronic Brake Lights
(EEBL)
Forward Collision Warning (FCW)
Intersection Movement Assist (IMA)
Left Turn Assist (LTA)
Blind Spot/Lane Change Warning
(BSW/LCW)
Do Not Pass Warning (DNPW)
Vehicle Turning Right in Front of Bus
Warning (Transit)

Agency Data

Probe-based Pavement Maintenance
Probe-enabled Traffic Monitoring
Vehicle Classification-based Traffic
Studies
CV-enabled Turning Movement &
Intersection Analysis
CV-enabled Origin-Destination Studies
Work Zone Traveler Information

Environment

Eco-Approach and Departure at
Signalized Intersections
Eco-Traffic Signal Timing
Eco-Traffic Signal Priority
Connected Eco-Driving
Wireless Inductive/Resonance
Charging
Eco-Lanes Management
Eco-Speed Harmonization
Eco-Cooperative Adaptive Cruise
Control
Eco-Traveler Information
Eco-Ramp Metering
Low Emissions Zone Management
AFV Charging / Fueling
Information
Eco-Smart Parking
Dynamic Eco-Routing (light
vehicle, transit, freight)
Eco-ICM Decision Support System

Road Weather

Motorist Advisories and Warnings
(MAW)
Enhanced MDSS
Vehicle Data Translator (VDT)
Weather Response Traffic
Information (WxTINFO)

Mobility

Advanced Traveler Information System
Intelligent Traffic Signal System
(I-SIG)
Signal Priority (transit, freight)
Mobile Accessible Pedestrian Signal
System (PED-SIG)
Emergency Vehicle Preemption (PREEMPT)
Dynamic Speed Harmonization (SPD-
HARM)
Queue Warning (Q-WARN)
Cooperative Adaptive Cruise Control
(CACC)
Incident Scene Pre-Arrival Staging
Guidance for Emergency Responders
(RESP-STG)
Incident Scene Work Zone Alerts for Drivers
and Workers (INC-ZONE)
Emergency Communications and
Evacuation (EVAC)
Connection Protection (T-CONNECT)
Dynamic Transit Operations (T-DISP)
Dynamic Ridesharing (D-RIDE)
Freight-Specific Dynamic Travel Planning
and Performance
Drayage Optimization

Smart Roadside

Wireless Inspection
Smart Truck Parking

Intersection Related CV Apps

- Intelligent Traffic Signal Systems
- Transit signal priority
- Emergency Vehicle Preemption/Priority
- Pedestrian Mobility
- Freight Signal Priority

Pedestrian Warning System
Warns the driver for potential pedestrian accident through vehicle to people communication

These applications require vehicles and roadside to be equipped with DSRC and application software.

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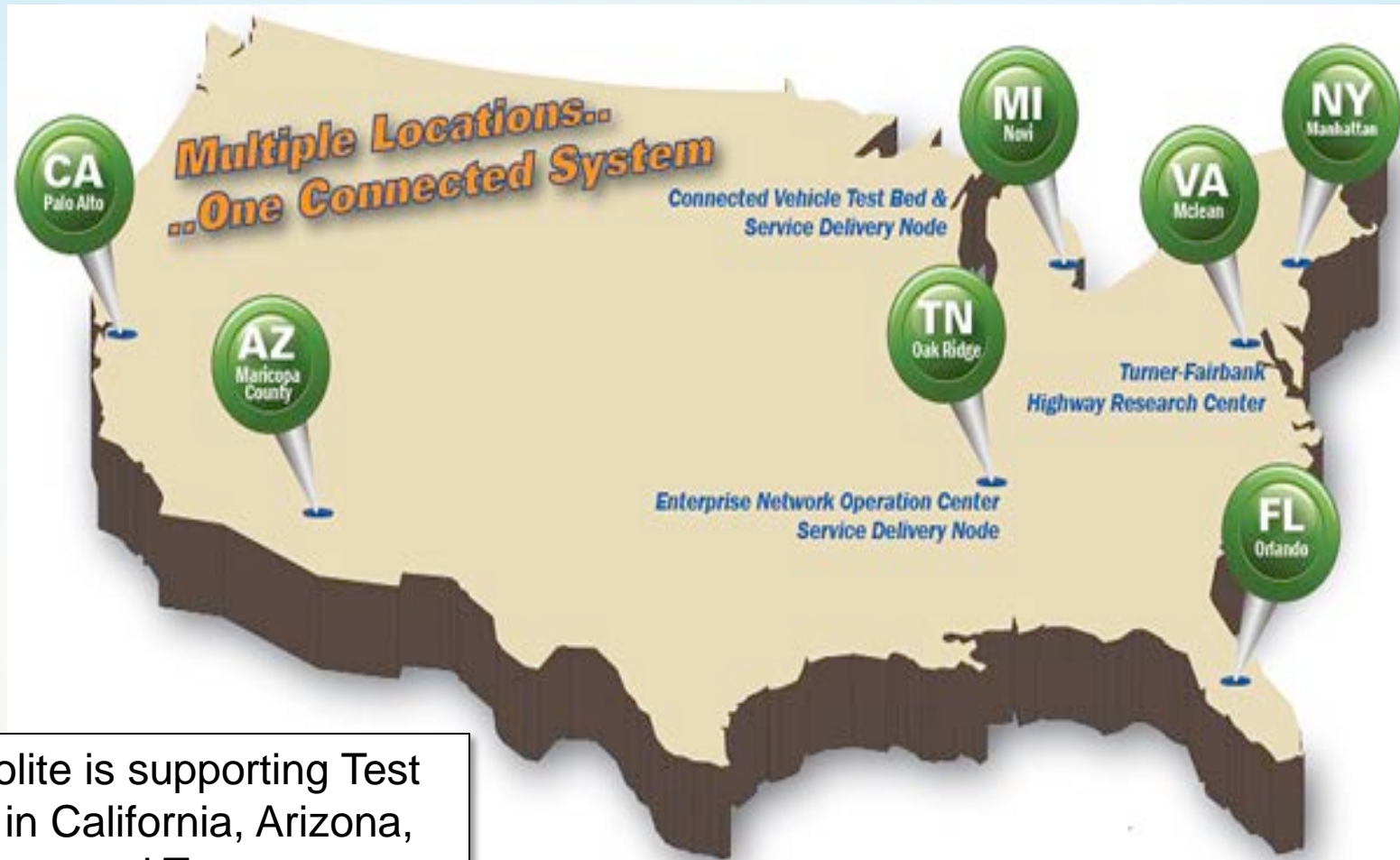
Example CV Application

- Univ. of Arizona under the direction of Dr. Larry Head is developing a set of intersection applications called **Multi-Modal Intelligent Traffic Signal System (MMITSS)**
  - Family of applications, leading off with Priority Control
  - Handles multiple, simultaneous priority requests
  - Live test deployments in AZ and at ITSA World Congress
  - Pooled fund research with equipment support from Econolite and Savari

Real-World Testing to Support Deployment

Multiple Locations...
...One Connected System

CA Palo Alto

AZ Maricopa County

MI Novi

NY Manhattan

VA Mclean

TN Oak Ridge

FL Orlando

Connected Vehicle Test Bed & Service Delivery Node

Turner-Fairbank Highway Research Center

Enterprise Network Operation Center Service Delivery Node

Econolite is supporting Test Beds in California, Arizona, Michigan and Texas

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University of Michigan Mobility Transformation Center (MTC) and Mcity

Mcity CV/AV Test Facility

https://youtu.be/R_bPMICmJ18

Funded CV Pilot Deployments

- CV Safety Pilot – Ann Arbor, MI, 2013
  - 3,000 DSRC equipped vehicles; 6 DSRC intersections
- 1st wave of Pilot Deployments
  - Just announced 3 projects
    - New York City
    - Tampa, FL
    - Wyoming
  - More could be added if funds become available
- 2nd wave of Pilot Deployments
  - Planned for 2017

NEW YORK CITY DOT

City of TAMPA

WYOMING DEPARTMENT of TRANSPORTATION

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V2I Deployment Coalition

ITS AMERICA   ite   AASHTO

- Provide leadership for the Connected Vehicle Deployment Program

- Establish CV deployment strategies

- Lead and provide support on continued technical research to support CV deployment

- Support CV standards development

- Provide input and refinement to the CV Deployment Guidelines

- First meeting – June 2015 in Pittsburg
    - 150+ attendees – cross section of public, private, academic & OEM's

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V2I Deployment Coalition Structure

Connected Vehicle Executive Leadership Team

V2IDC Executive Committee (consists of V2IDC Technical Work Group Chairs and USDOT Reps)

V2IDC

TWG 1: Deployment Initiatives

TWG 2: Deployment Research

TWG 3: Infrastructure Operator, OEM, and Supplier Partnerships

TWG 4: Deployment Guidance

TWG 5: Deployment Standards

USDOT ITS JPO FHWA FTA NHTSA Etc.
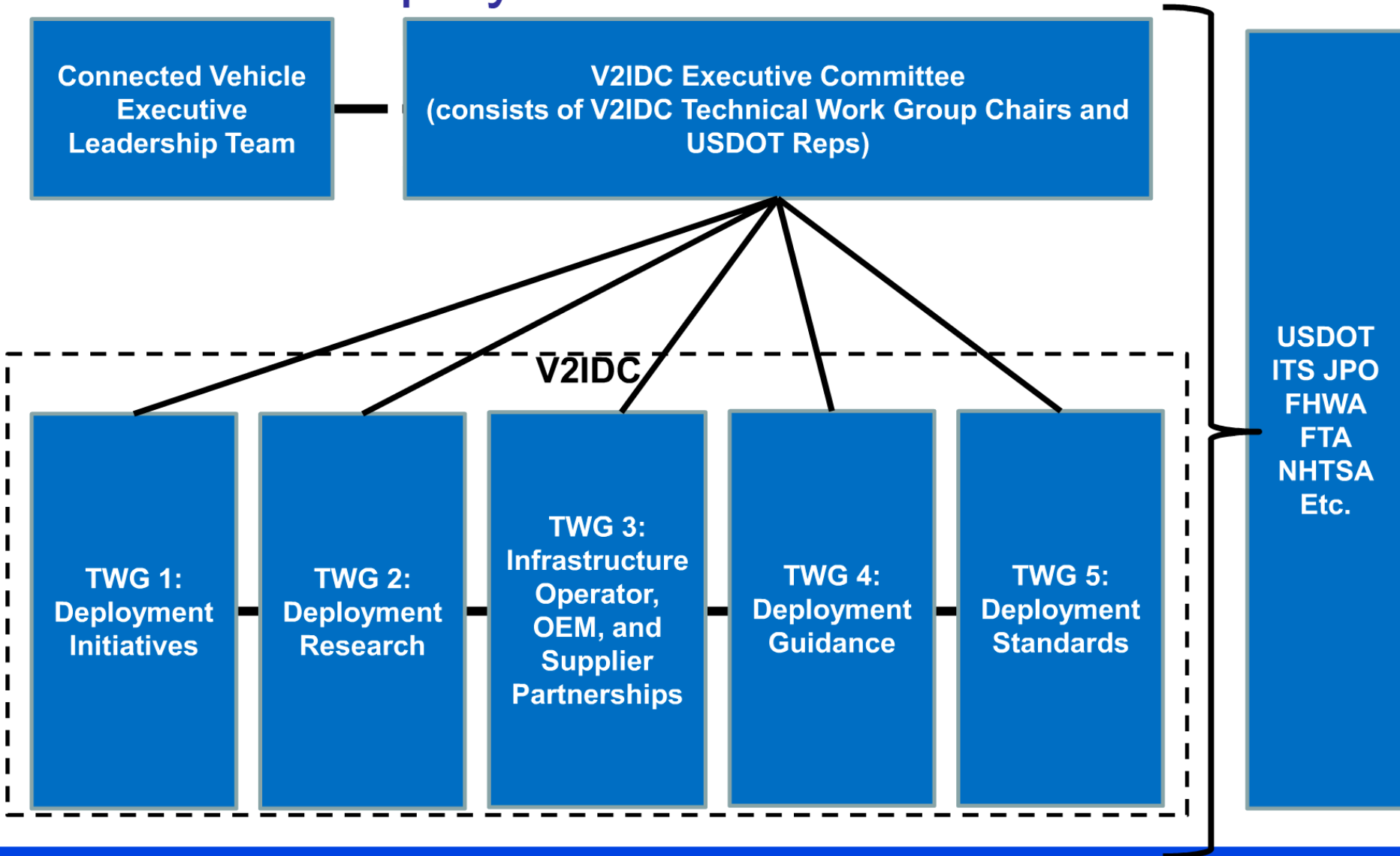
CV Intersection Block Diagram

DSRC Radio (RSU)

DSRC
802.11p
IEEE 1609
SAE J2735

SAE J2735
(or alternative)

Traffic Cabinet

Connected
Vehicle
Applications
Processor

NTCIP 1202
[& 1211]

Controller

DSRC Radio (OBU) Equipped

Connected
Vehicle
Backhaul

Traffic
Management
System
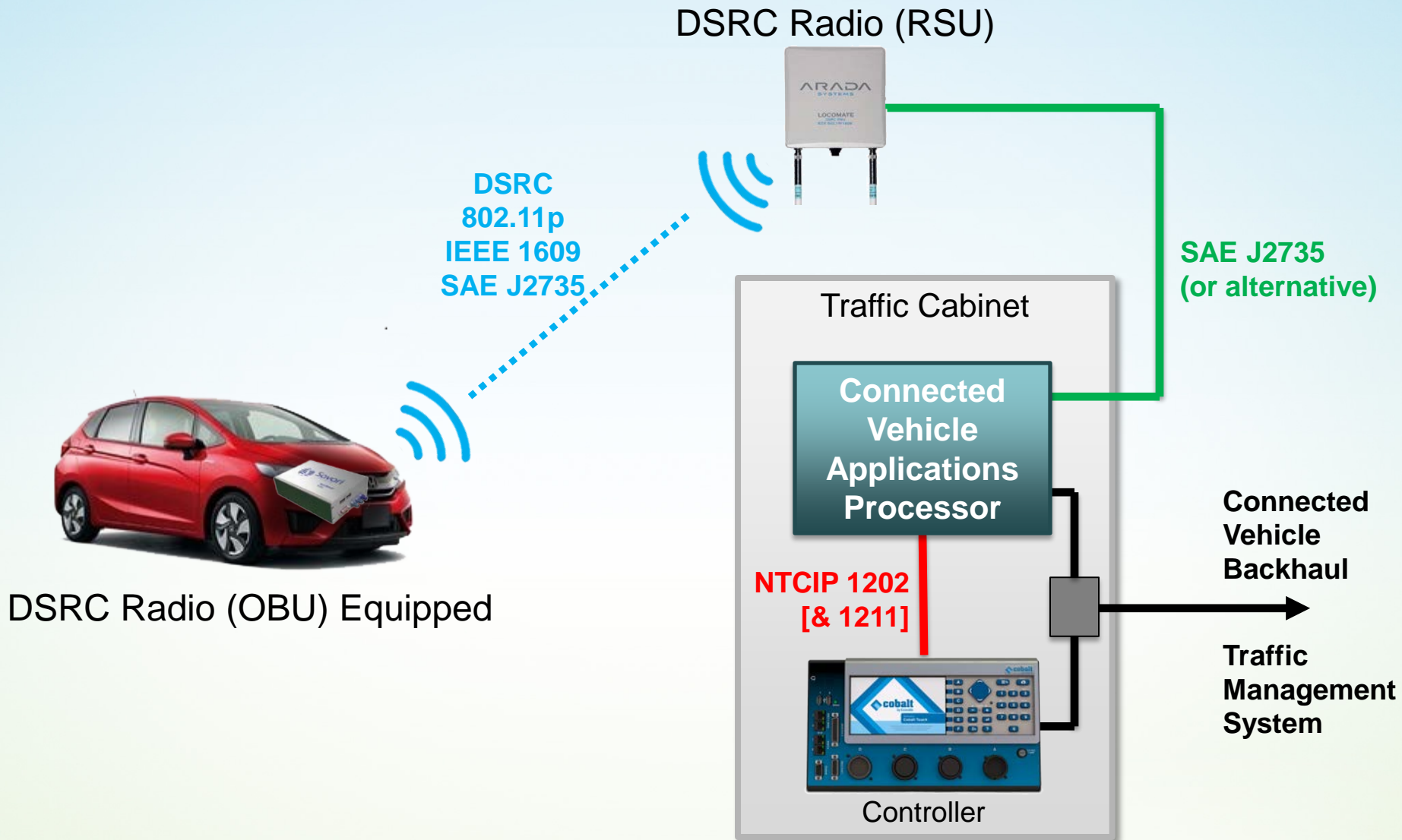
Specification Considerations

- Modern Signal Controller
  - Require NTCIP 1202 v3.05 (support for J2735 messages)
  - Consider ATC standard controller with comm module slot
- Processor to run Connected Vehicle Applications
  - Standalone black box or…
  - Integrated into controller—either fully integrated or plugin
    - If sharing controller processor, sufficient processing power and memory must be specified
  - May be possible to run some applications in RSU

Specification Considerations

- One or more DSRC radios (RSU)
  - Geometry could require more than one for good coverage
  - In-cabinet equipment to support the RSU (i.e. surge prot.)
  - POE will require 48VDC source
- Network backhaul with sufficient bandwidth
  - For security management, data, and path to Internet for cellular/wifi apps
  - May be able to use existing network or high speed cellular
- Design/Planning, installation, setup, training, maintenance, on-going software license fees

Potential CV Intersection Costs

- AASHTO DSRC RSE Cost Estimates (per site)
  - Site deployment costs - $17-18K
  - Backhaul costs - $4-40K (depending on existing network)
  - Ongoing O&M costs - $2-3K per year
- No specific funding has been set aside by the FHWA for DSRC deployment other than Pilot Deployments
  - Deployment can be funded using typical intersection funding program
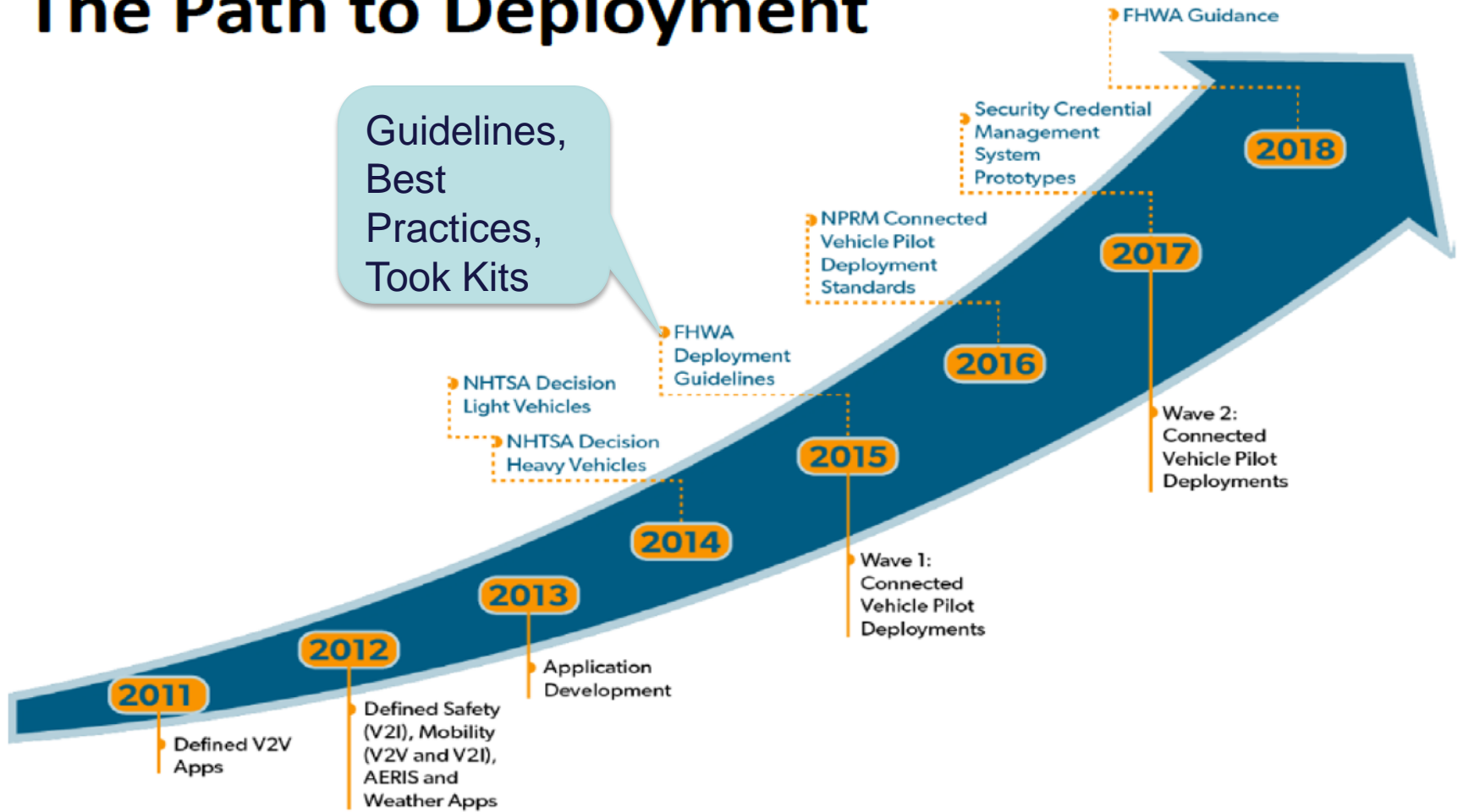
Connected Vehicles Timeline

Connected Vehicle Penetration

- NHTSA is expected to issue a NPRM in late 2015 (under new accelerated schedule) that will mandate the use of DSRC. Mandate will probably require DSRC by the 2020 model year vehicles.
  - Focused mainly on V2V

- At ITS World Congress in 2014 Cadillac committed to install DSRC radios in certain 2017 models

The Path to Deployment

Guidelines, Best Practices, Took Kits

- **2011** — Defined V2V Apps
- **2012** — Defined Safety (V2I), Mobility (V2V and V2I), AERIS and Weather Apps
- **2013** — Application Development
- **2014** — NHTSA Decision Light Vehicles; NHTSA Decision Heavy Vehicles
- **2015** — FHWA Deployment Guidelines; Wave 1: Connected Vehicle Pilot Deployments
- **2016** — NPRM Connected Vehicle Pilot Deployment Standards
- **2017** — Security Credential Management System Prototypes; Wave 2: Connected Vehicle Pilot Deployments
- **2018** — FHWA Guidance

Source: *USDOT*

Goal: Deploy Stable, Interoperable, Reliable Systems

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DSRC OBE Market Penetration Projection

Assumes year 1 = 1% and reaches 75% in 2030

Source: VDOT Case Study
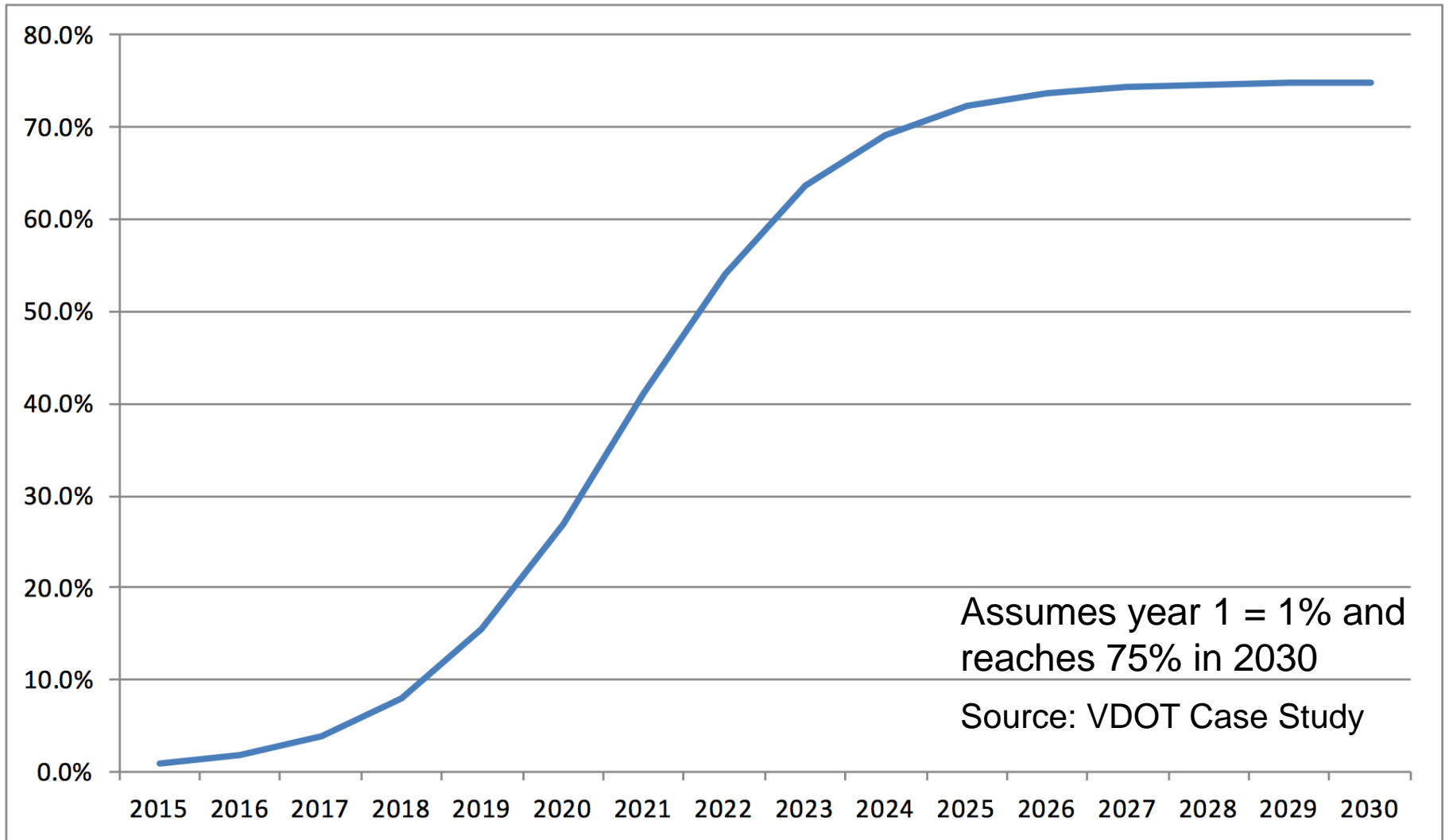
Infrastructure Rollout Projection

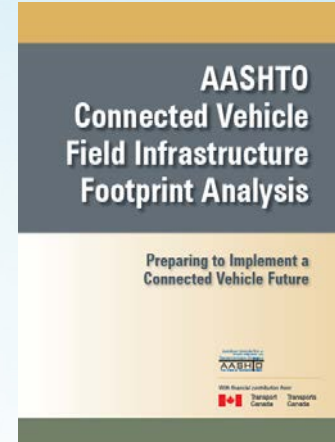|	2014	2015	2016	2017	2018	2019	2020	2025	2030	2035	2040
Safety	Plan	Pilot		Evaluate		Deploy		**~ 61K Intersections** Expand		**~ 250K Intersections**	
	NHTSA Light V2V Decision				1st DSRC on signals	DSRC for Other Local Safety Apps		DSRC on 20% of signals		DSRC on up to 80% of signals	
Mobility	Plan	Pilot		Evaluate		Deploy		Expand			
							1st CV-enabled ATM		Traveler Info on 90+% of Roadways		System-wide Active Traffic Mgmt
Freight Mobility			Plan	Pilot	Evaluate		Deploy		Expand		
		NHTSA Heavy V2V Decision									
Border Crossings			Plan		Pilot		Evaluate	Deploy		Expand	
Agency Operations	Plan	Pilot	Evaluate	Deploy		Expand					
	MN/NV/MI Integrated Mobile Observations										

Source: AASHTO CV Footprint Analysis

Connected Vehicles Resources

Deployment Guidance

- AASHTO CV Infrastructure Footprint Analysis
  - Provides information on deployment requirements, costs, example plans, etc.
- FHWA V2I Deployment Guidance & Products
  - Guidelines to help owner/operators deploy V2I
  - Due to be published late in 2015
- V2I Deployment Coalition
  - Joint effort by AASHTO, ITE, ITSA
  - Work output for Deployment Guidance, Initiatives, Research, Standards and Partnerships

AASHTO Connected Vehicle Field Infrastructure Footprint Analysis

Preparing to Implement a Connected Vehicle Future

Questions?