Welcome

to the C-V2X Workshop and **Demonstration** for North American Transportation Planning and Road Operator Communities

Washington DC, 26 April, 2018

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C-V2X Workshop and Demonstration for North American Transportation Planning and Road Operator Communities

Jim Misener, Qualcomm

26 April, 2018

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Workshop and Demonstration Goals

- Objective: Extend the Partnership
  - Develop solid next steps
  - Establish C-V2X as a viable and deployable Vehicle-to-Everything technology
- Goals
  - Provide foundational information
    - Technology
    - Deployment models
  - Initiate discussion: user needs and technology matching
  - Determine how to continue the dialog toward partnership

Deployment of C-V2X and its evolution to 5G requires a partnership of the vehicle industry, the telecommunication industries and the government. Partnership with road owner-operators is essential.

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Agenda

09:15am – 09:45am	**Introductory Remarks: Welcome and Goals of Workshop** - Jim Misener, Qualcomm - Christoph Voigt, Chairman 5GAA
09:45am – 10:30am	**The C-V2X Proposition** - Jovan Zagajac, Ford
10:30am – 11:30am	**Roundtable: Transportation Needs & C-V2X Solutions** Moderator: Chris Armstrong, Panasonic - Lev Pinelis, Transurban - Amy Ford, Colorado Department of Transportation - Virginia Lingham, Virginia Department of Transportation - Jim Misener, Qualcomm
11:30am – 12:45pm	Luncheon Keynote Speakers - Roger Lanctot, Strategy Analytics - Mike Mollenhauer, Virginia Tech Transportation Institute
12:50pm – 01:10pm	Product Life Cycle Management - Frank Perry, Savari
01:10pm – 02:00pm	Economics of C-V2X: Alternative Models of Deployment - Matt Arcaro, AT&T
02:00pm – 02:20pm	Wrap Up and Next Steps
02:30pm – 06:30pm	Bus Shuttle in Groups to RFK Festival Ground Lot 7

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5G Automotive Association, **pioneering digital transformation** in the **automotive industry**

Christoph Voigt, Chairman 5GAA

Learn more at
WWW.5GAA.ORG

5GAA brings together automotive, technology and telecommunications companies to work closely together to develop end-to-end solutions for future mobility and transportation services

AUTOMOTIVE INDUSTRY

Vehicle Platform, Hardware and Software Solutions

TELECOMMUNICATIONS

Connectivity and Networking Systems, Devices and Technologies

End to end solutions for intelligent transportation, mobility systems and smart cities

5GAA: A Global Cross Industry Association

September 2016

- “Audi, BMW Group, Daimler AG are teaming with Ericsson, Huawei, Intel, Nokia, and Qualcomm to create the 5G Automotive Association (5GAA), which will help develop, test, and promote 5G standards”
- “Scope of the alliance is focused on bringing connectivity solutions to market addressing technical, business, and regulatory challenges”

Q1 2018

- 5GAA unites 80+ members working together to:
  - Deliver innovation for road safety, connectivity and sustainability
  - Accelerate cooperative, connected, automated mobility
  - Develop 360º solutions for SMART mobility services
  - Pave the way towards 5G mobility

Looking 18 months back…

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Set up 5GAA - Our Organizational Structure

BOARD

EXECUTIVE COMMITTEE

GENERAL ASSEMBLY

WG1	WG2	WG3	WG4	WG5
Use Cases and Technical Requirements	System Architecture and Solution Development	Evaluation, Testbeds and Pilots	Standards and Spectrum	Business Models and Go-To-Market Strategies

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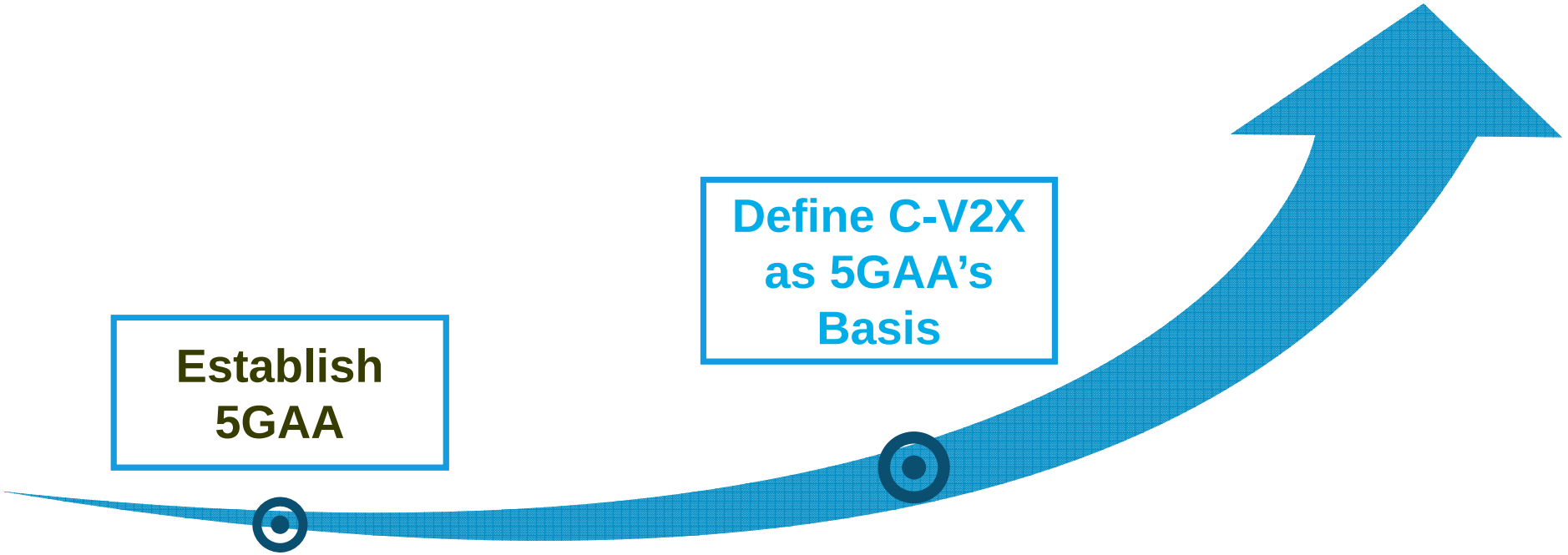
Liaisons with regulators and organizations

- MoU with European Automotive Telecom Alliance (EATA) – **Feb 2017**
- MoU with Next Generation Mobile Networks (NGMN) – **Feb 2017**
- MoU with Alliance Global TD-LTE Initiative (GTI) – **Feb 2017**
- Market Representation Partner (MRP) in 3GPP – **April 2017**
- Round Table with Chinese Government during Mobile World Congress Shanghai – **June 2017**
- MoU with China IMT 2020 – **November 2017**
- Round Table with European Road Operators Munich – **January2018**
- MoU with Telematics Industry Application Alliance (TIAA) – **March 2018**

Looking 18 months back…



What is V2X (Vehicle to Everything)?

Comprehensive vehicle and traffic safety

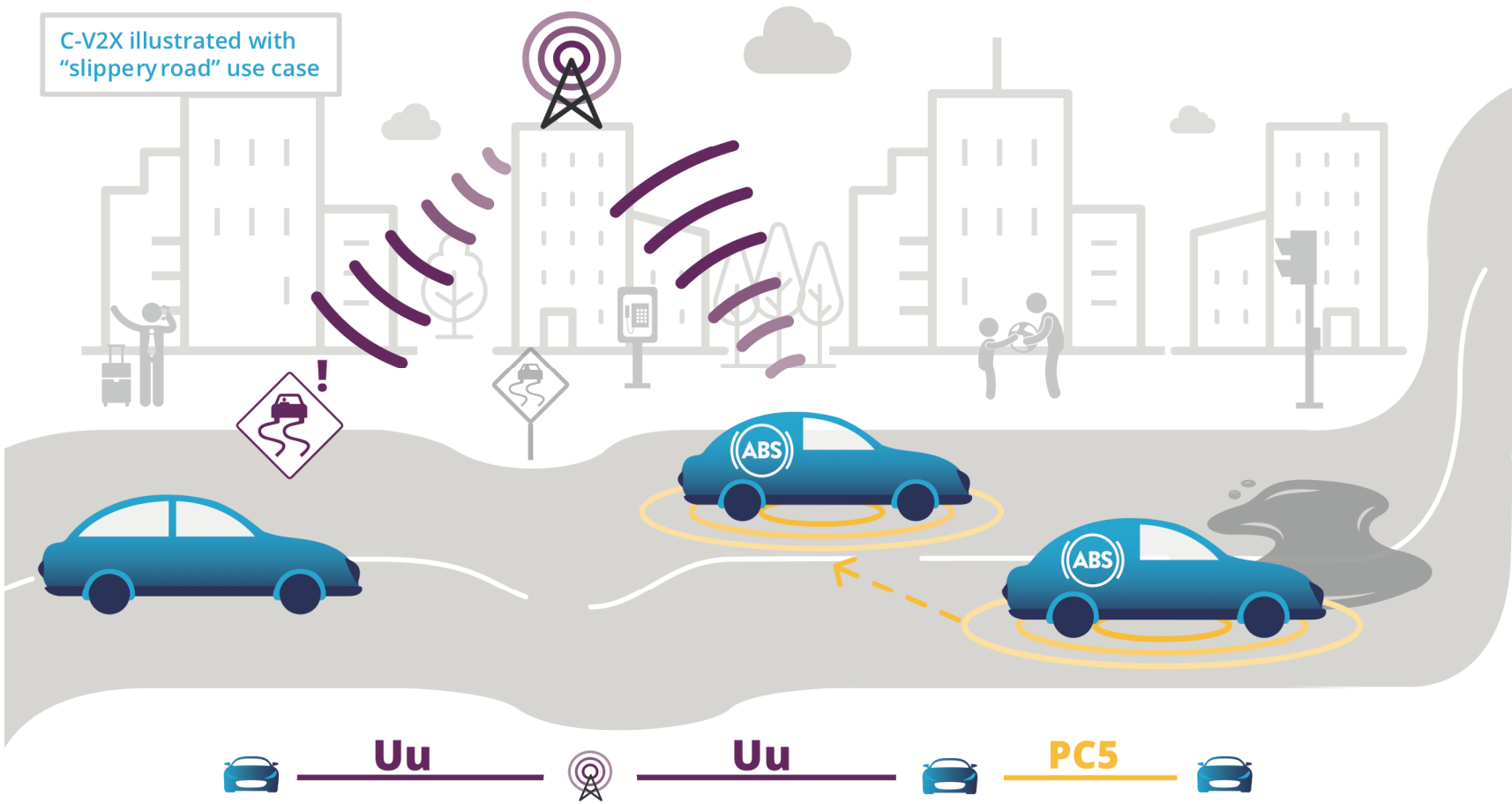
Accelerates autonomous driving

Allows vehicles to communicate with each other **V2V** and the wider transport ecosystem **V2N, V2P, V2I**

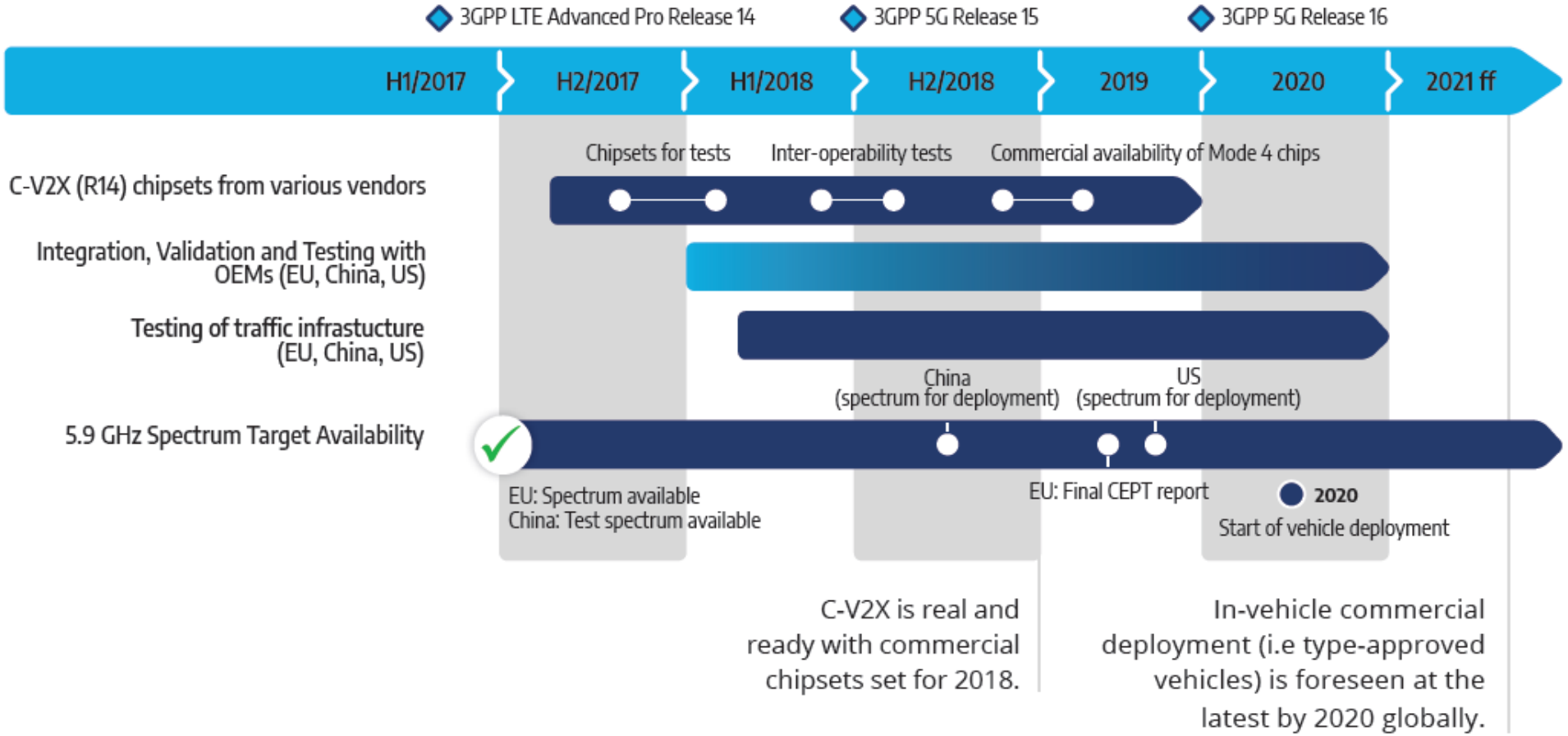
Why Cellular V2X (C-V2X)?

C-V2X is a unified technology platform including both:

- Short range direct communications (LTE-V2X PC5)
- Long range cellular network communications (LTE-V2X Uu)



Timeline for deployment of C-V2X (V2V/V2I)



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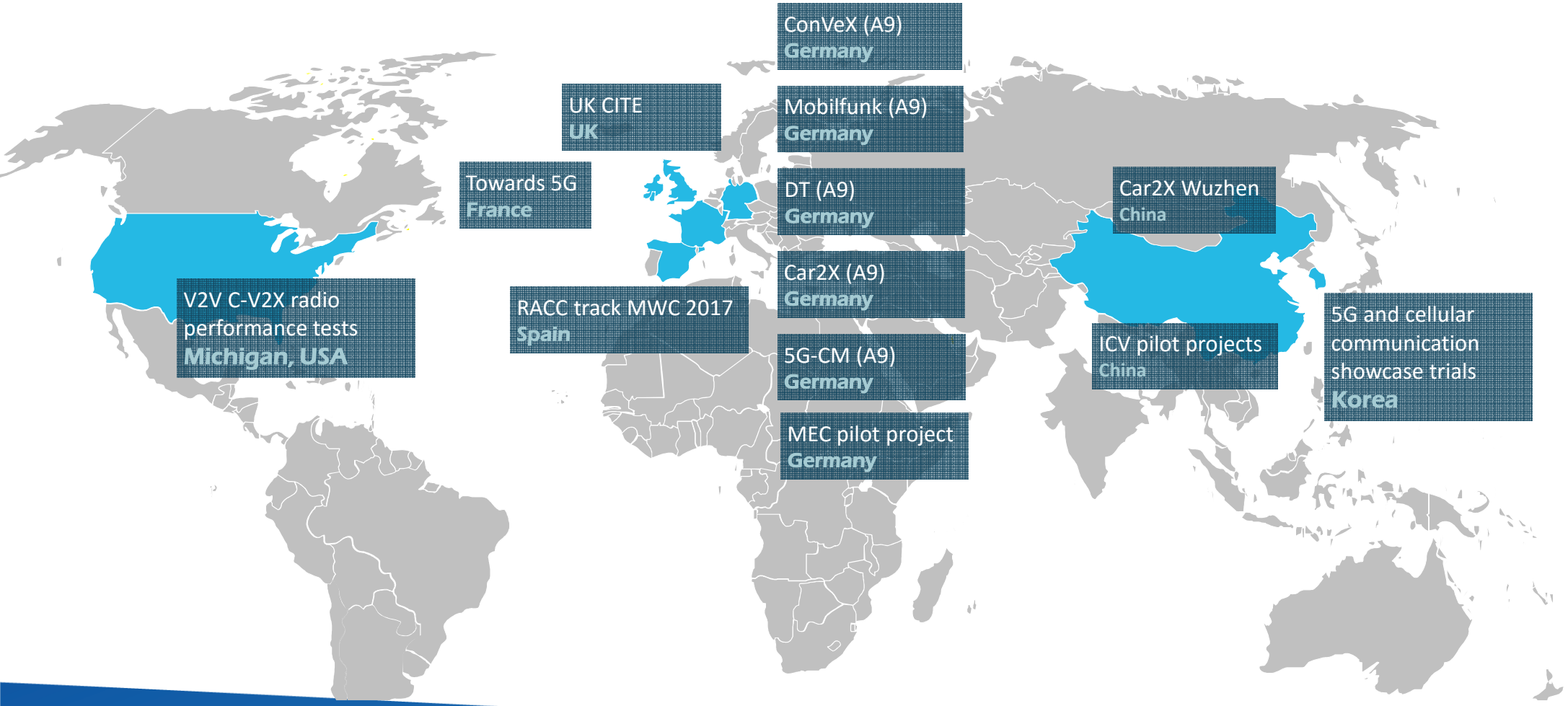
Worldwide C-V2X Trials



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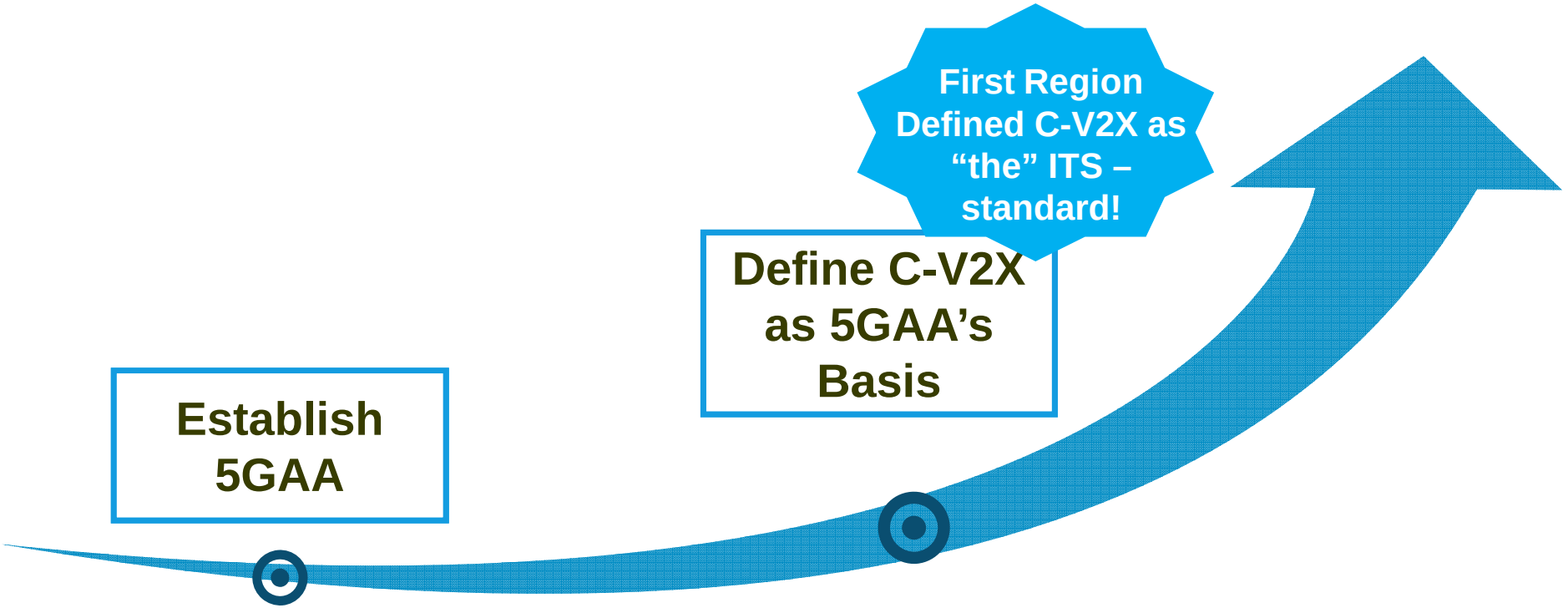
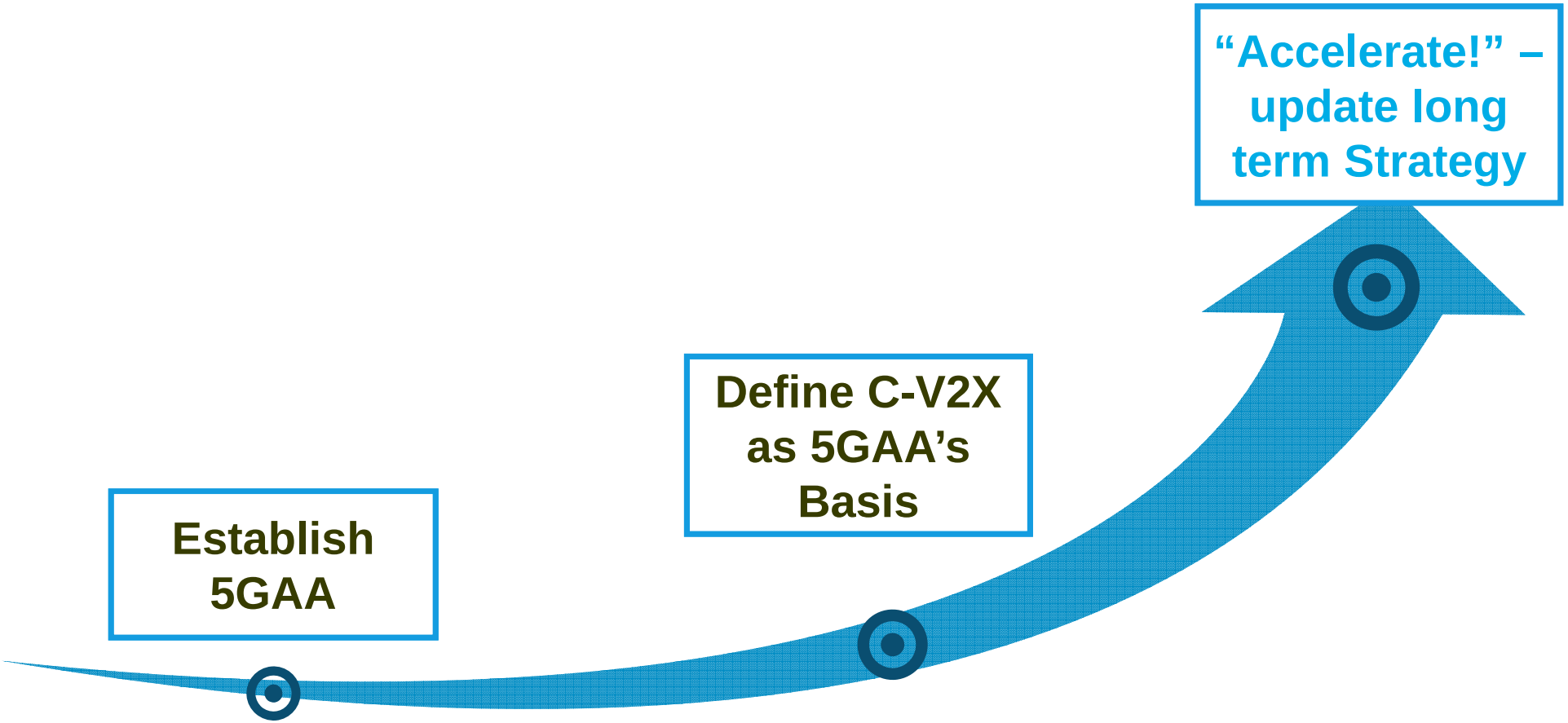
Looking 18 Months Back…

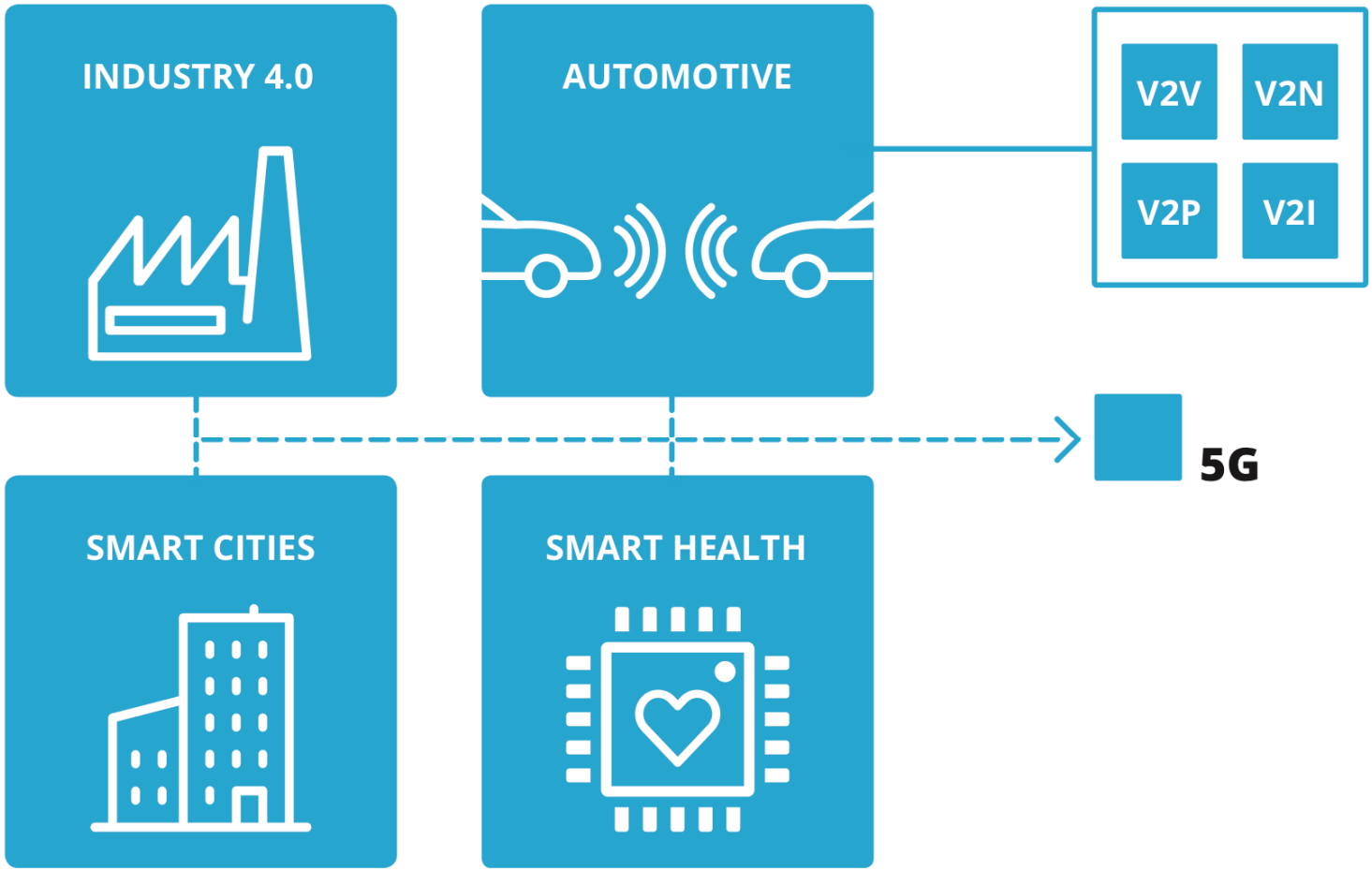


And now? – Accelerate!



5G for Major Industry Verticals

C-V2X and its evolution to 5G V2X will foster synergies between the automotive industry and other verticals which are moving to 5G



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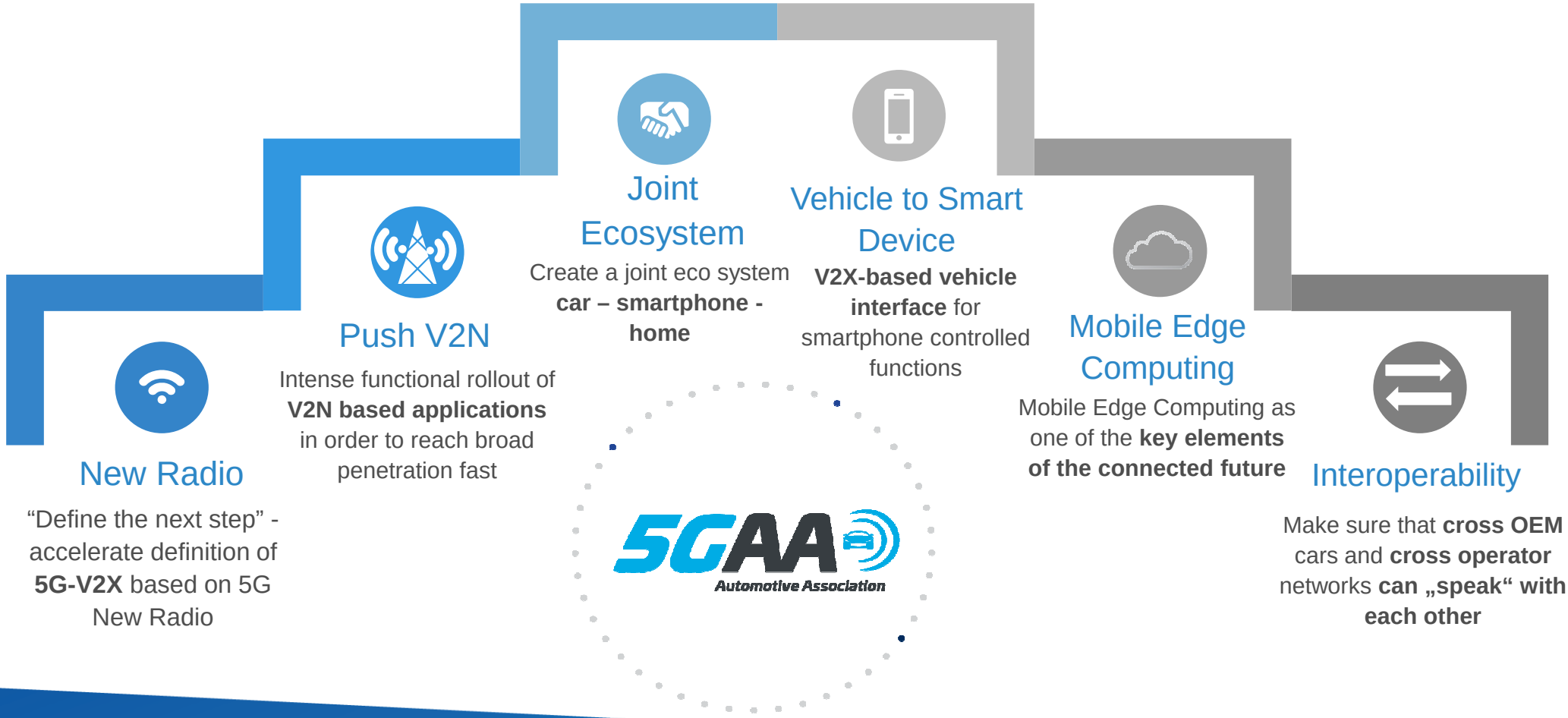
Our updated Strategy



New Radio

"Define the next step" - accelerate definition of **5G-V2X** based on 5G New Radio

Push V2N

Intense functional rollout of **V2N based applications** in order to reach broad penetration fast

Joint Ecosystem

Create a joint eco system **car – smartphone - home**

Vehicle to Smart Device

V2X-based vehicle interface for smartphone controlled functions

Mobile Edge Computing

Mobile Edge Computing as one of the **key elements of the connected future**

Interoperability

Make sure that **cross OEM** cars and **cross operator** networks **can „speak" with each other**

5GAA Automotive Association

For more information please contact:

secretariat@5gaa.org

or visit:

www.5GAA.org

The C-V2X Proposition

Jovan Zagajac
Ford Motor Company
Washington DC
April 26, 2018

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My job @ Ford

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Important cellular radio technology enhancements were codified in Release 14 of 3GPP (2017)

Before	Now
Devices using cellular technology required infrastructure support.	Cellular V2X devices can communicate directly without any network support.
Low latency communication was not possible with cellular solutions.	Cellular V2X technology supports low-latency needs for V2V.
Cellular solutions required use of (costly) licensed spectrum.	Cellular V2X technology can operate in the ITS 5.9Ghz band.
Cellular solutions lacked mechanisms to address privacy issues.	Cellular V2X operates w/out SIM cards and enables anonymity on par to DSRC
DSRC was the only technology available to support V2V.	Cellular technology is a viable alternative to meet and exceed V2V requirements.

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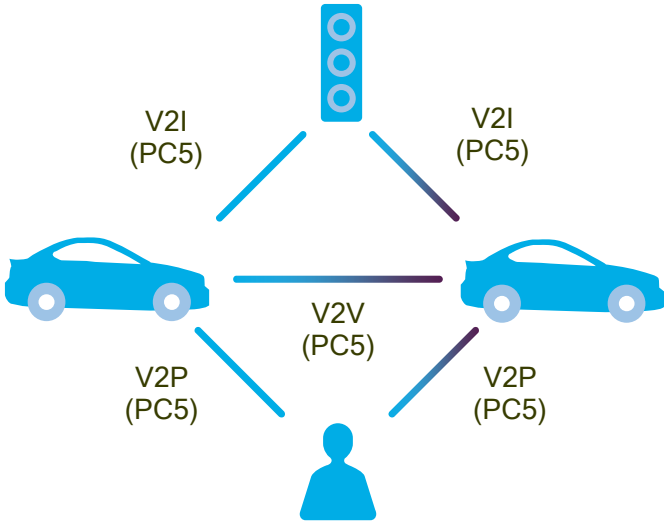
C-V2X has two complementary communication modes

Direct

V2V, **V2I**, and **V2P** operating in ITS bands (e.g. ITS 5.9 GHz) independent of cellular network

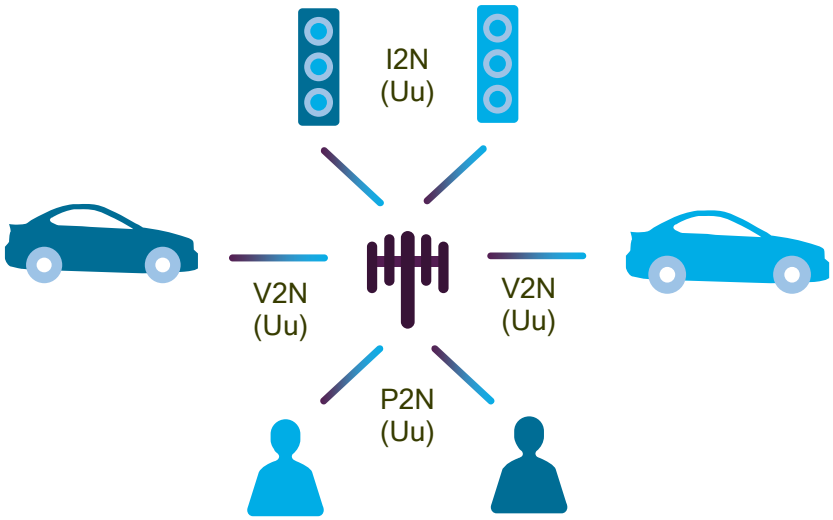


Short range (<1 kilometer), location, speed …

Implemented over "PC5 interface"

Network

V2N operates in traditional mobile broadband licensed spectrum



Long range (>1 kilometers). e.g. accident ahead

Implemented over "Uu interface"

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Why is this important?

A. **Performance**: C-V2X delivers superior performance and reliability by leveraging the latest advances in radio technology

B. **Implementation Efficiency**: C-V2X can be implemented by utilizing the cellular technology platforms that automakers are already deploying
   - Analysts expect that 90% of new US vehicles will have cellular modems by 2025
   - In the US, by 2019 100% of new Ford vehicles will have cellular modems
   - Integration with existing in-vehicle cellular platforms and services will results in fewer things-gone-wrong at a lower expected cost

C. **Readiness**: Commercial C-V2X products are available for deployment as early as 2019
   - supported by a broad ecosystem reflected in the diversity of 5GAA membership

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Why is this important?

D. **Reuse**: C-V2X leverages a very significant portion of the V2X work already done
   - Benefits from existing V2X transport layers and application protocols: safety Apps developed for DSRC will work unchanged with CV2X radios
   - Learnings from past V2X research are reusable

E. **Global Footprint**: C-V2X will be deployed consistently and predictably across the world in the same way that other cellular technologies such as LTE have been

F. **Evolution**: C-V2X is the first step towards 5G that will leverage future improvements in cellular radio technology while remaining backward compatible

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C-V2X is the first step towards 5G that can leverage future improvements in cellular radio technology.

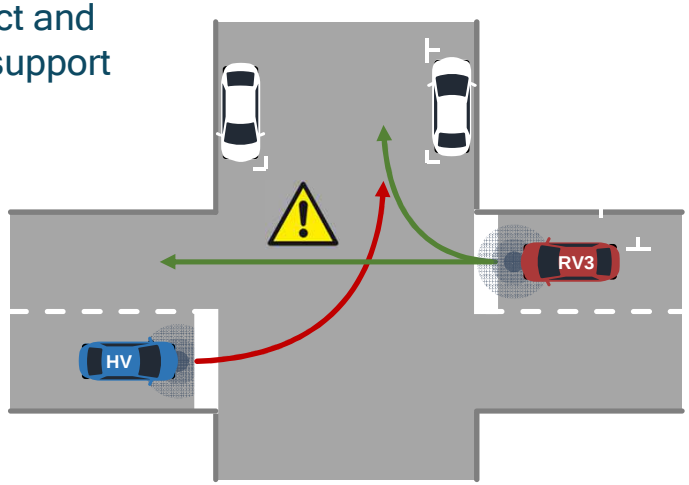
1H17 | 2H17 | 1H18 | 2H18 | 2H20

Rel14 — Rel15 — Rel16

Basic and enhanced safety

C-V2X R14/R15 with enhanced range and reliability

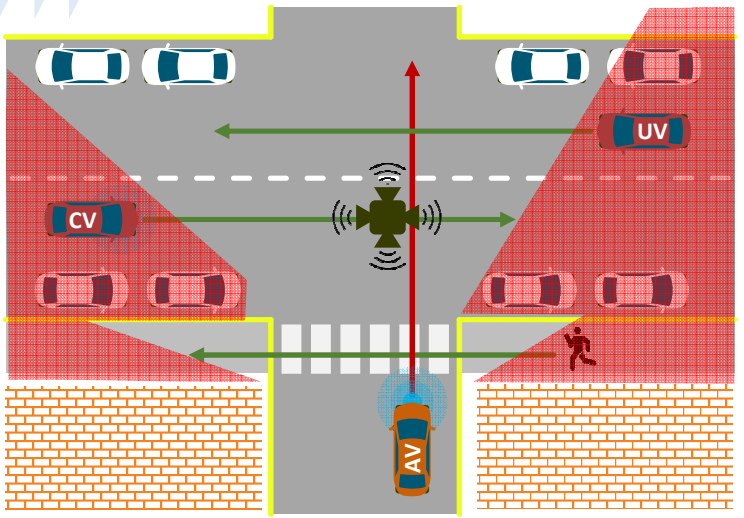
- Basic safety messaging
- Dual (direct and network) support



Autonomous driving / Automation

5G NR based C-V2X R16

- Backward compatible
- HD sensor and intent sharing



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Key Cellular-V2X Technical Characteristics

A. **Low-latency**: C-V2X is designed for reliable, predictable, low-latency direct communications
B. **Network independence:** "Direct" C-V2X is designed to operate without network assistance (does not require SIM cards to function) *but can use the deployed mobile networks to enhance functionality*
C. **High-speed use cases**: C-V2X is designed for high-speed vehicular use cases. By design and following extensive analyses R14 C-V2X works up to 500 km/h relative Doppler in 5.9 GHz band
D. **ITS spectrum** : C-V2X is designed to operate in the ITS spectrum
E. **Security**: Benefits from established security protocols defined by the automotive standards communities, including SAE, IEEE and ETSI.

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Extensive testing to validate CV2X radio performance initiated in 2017 will be completed by this summer in Ann Arbor, San Diego, Aberdeen and Shanghai.

Range	**Lab** Cabled Tx and Rx Tests
	Field LOS Range Tests
	Field NLOS Range Tests
Interference	**Lab** Cabled Tx and Rx Test with Simulated External Interference
	Lab Cabled Near-Far Test
	Field Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3
	Field Co-existing of C-V2X with Adjacent DSRC Carrier (CH172 and CH174)
Congestion	**Lab** Cabled Congestion Control
	Field Congestion Control Field Test: Multi-Lane Line-of-Sight Highway

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Testing

- Ford in partnership with Qualcomm (in US) and Datang (in China) has been testing C-V2X devices since 2H17. Work will be completed in 2H18.
- Test procedures have been documented and are now being harmonized in 5GAA to ensure global uniformity.
- Initial results are consistent and very encouraging. They support our beliefs in the benefits of the technology.

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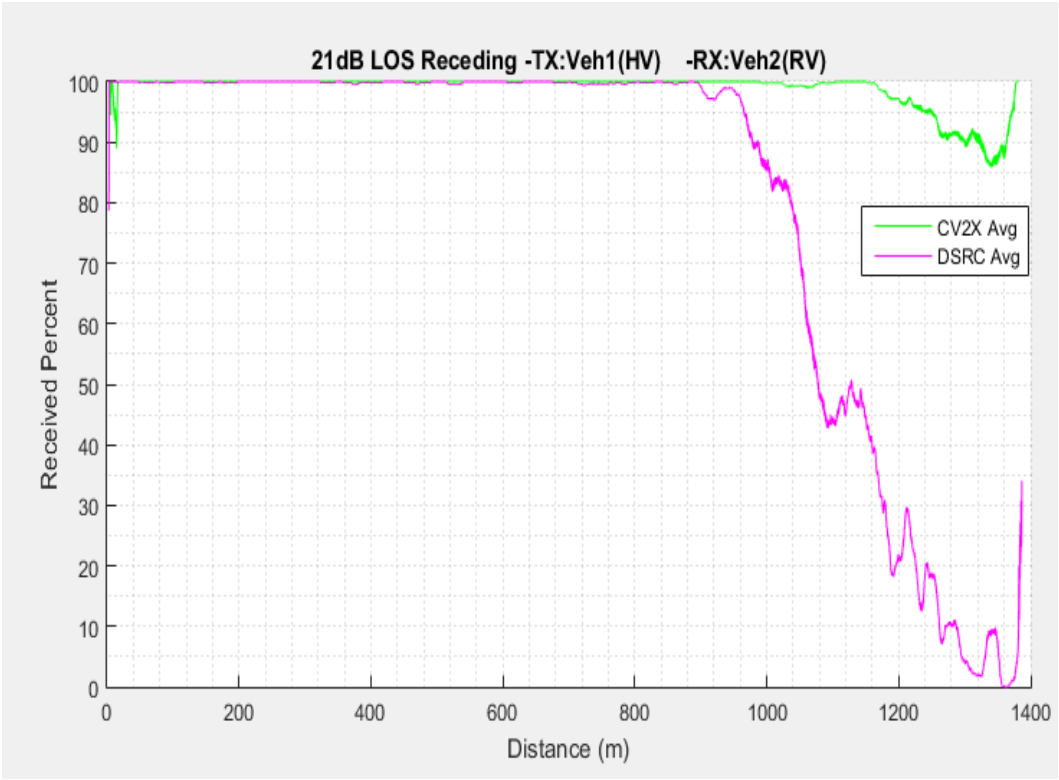
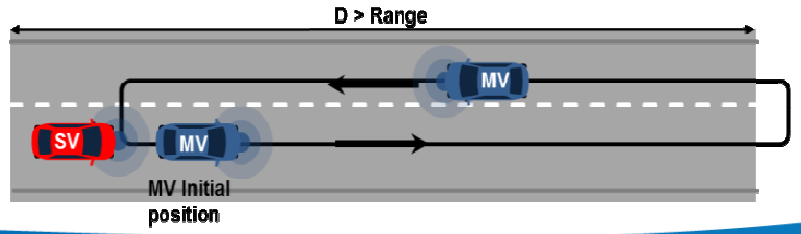
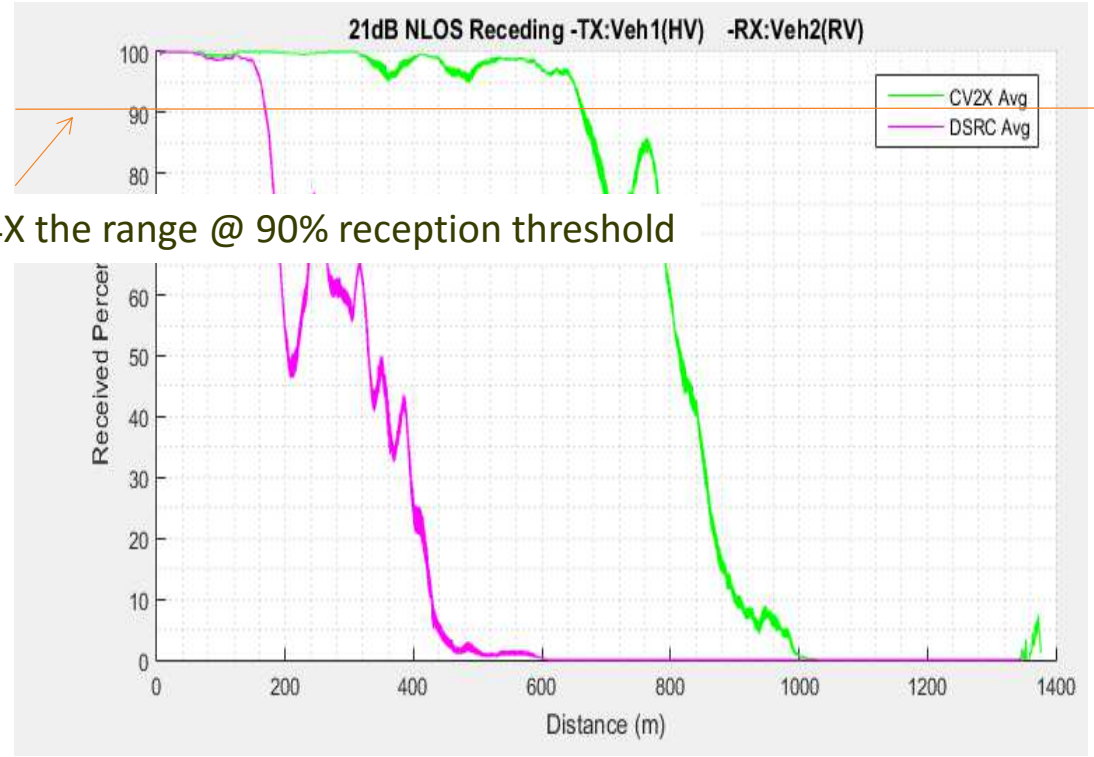
Line-of-Sight (LOS) Range / Reliability Road Test in Fowlerville, Michigan

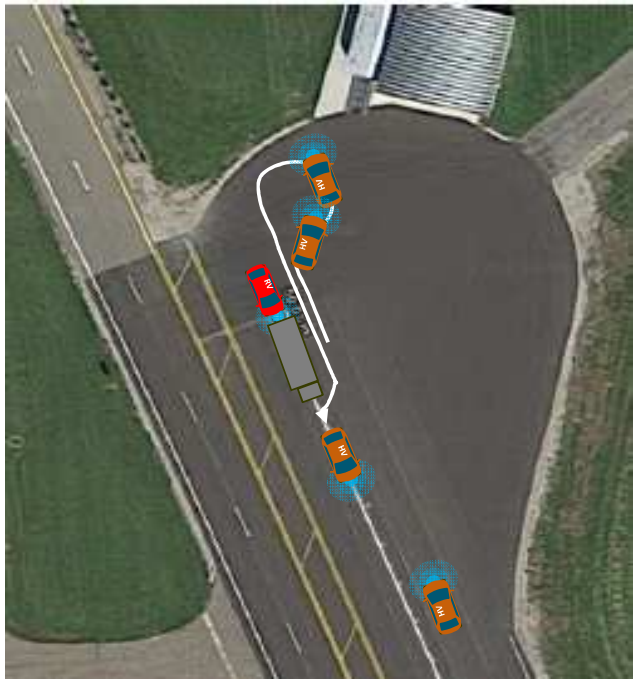


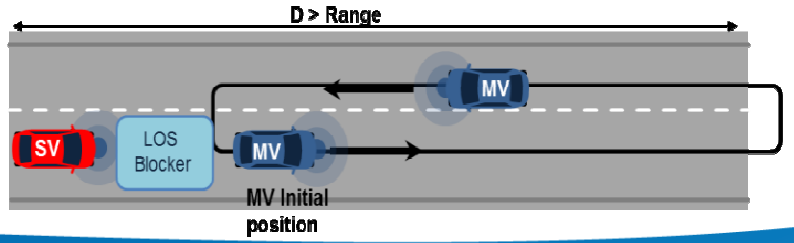


Obstructed Non-Line-of-Sight (NLOS) Range/Reliability Road Test in Fowlerville, Michigan

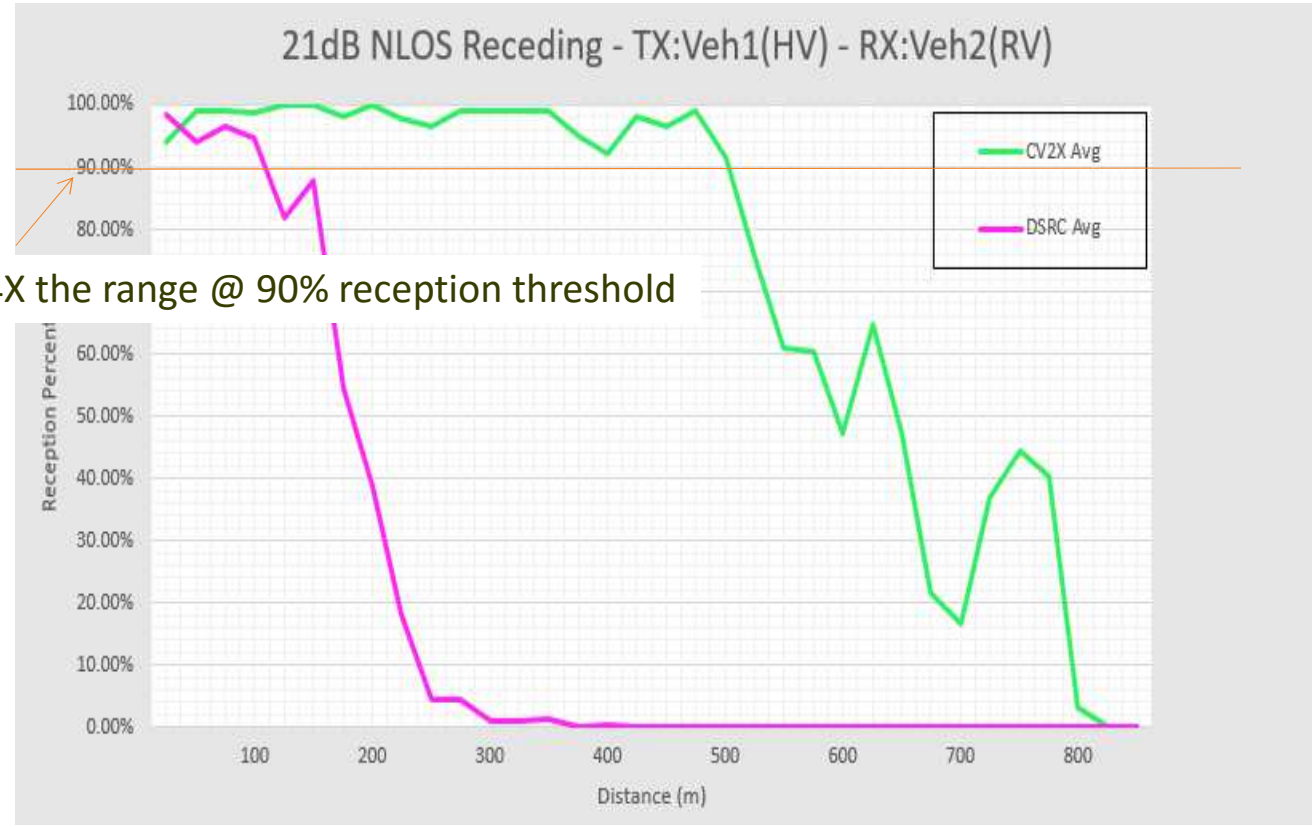


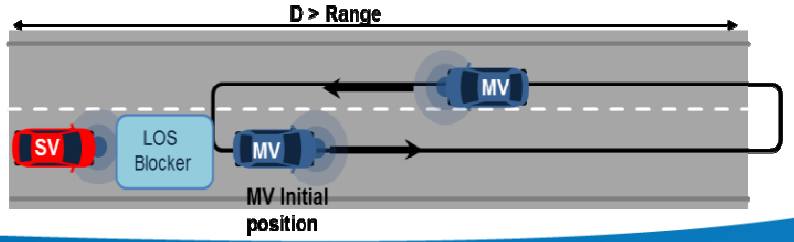
4X the range @ 90% reception threshold



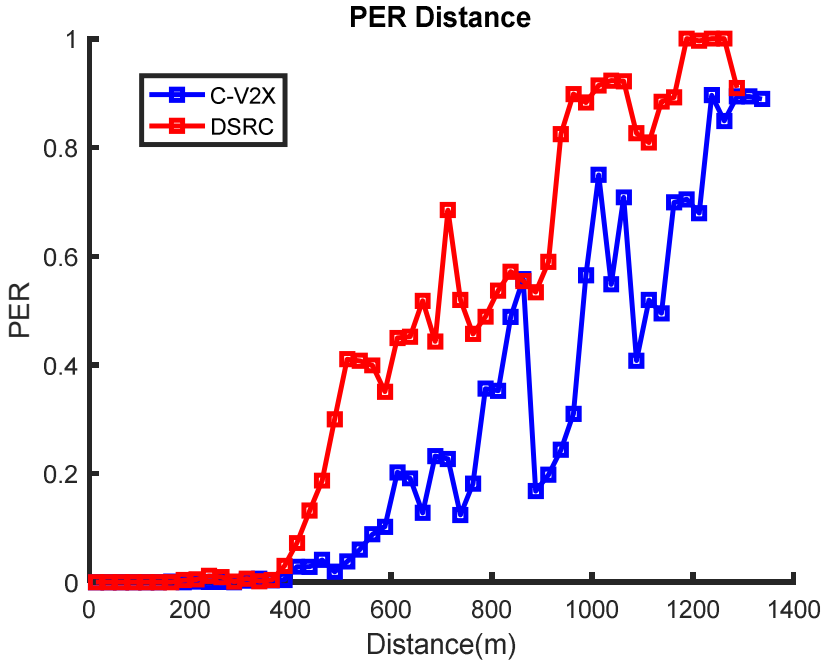


Obstructed Non-Line-of-Sight (NLOS) Range/Reliability Road Test in Miramar, San Diego





Highway Testing Near Beijing



- Vehicles driven at 80 km/h, 100 km/h and 120 km/h
- Both cars slowly separating until no packet received, then closing gap, three times
- Distance maintained at 200m, 400m, 600m etc. for 5 min

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Thank You!

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Roundtable Discussion: Transportation Needs & C-V2X Solutions

April 26, 2018, 10:30am-11:30am

Moderator: Chris Armstrong (Panasonic)

Participants: Amy Ford (CDOT)
Virginia Lingham (VDOT)
Lev Pinelis (Transurban)
Jim Misener (Qualcomm)

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Roger C. Lanctot

Director, Automotive Connected Mobility

Roger Lanctot has 25+ years of experience as a journalist, analyst and consultant advising electronics companies, car companies, wireless carriers, Tier 1s and developers on product and market development and strategy.

He is currently Director, Automotive Connected Mobility, in the Global Automotive Practice at Strategy Analytics. He is a graduate of Dartmouth College and a frequent blogger and keynote speaker. Roger is a member of the TU-Automotive Hall of Fame and was selected as 2017 Tech Cars Best Analyst or Connected Car Celebrity.

5GAA C-V2X Workshop and Demonstration for North American Transportation Planning and Road Operator Communities

A 5G Perspective on Connecting Cars

STRATEGY ANALYTICS

Roger C. Lanctot
Director, Connected Mobility

Why 5g matters

- Lower latency communications
- Device to device connections
- Greater reliability
- Network slicing
- Layered, ubiquitous connectivity
- True IoT – network of everything

- New vehicle architecture(s)
- New business models
- New development strategy
- New organizational structure
- New priorities – privacy, security, autonomy
- Changing vehicle ownership and usage

Auto industry to wireless industry:

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Telematics Market Status

- **Gen 1.0**
  - Launched: 1996
  - Objective: Monetize to consumers directly
  - Findings: “Free-Trials” too short
  - Result: Huge number of de-activated subscriptions

6 months FREE! + Only $10 per month! = Market FAILURE



Source: Infotainment & Telematics Service

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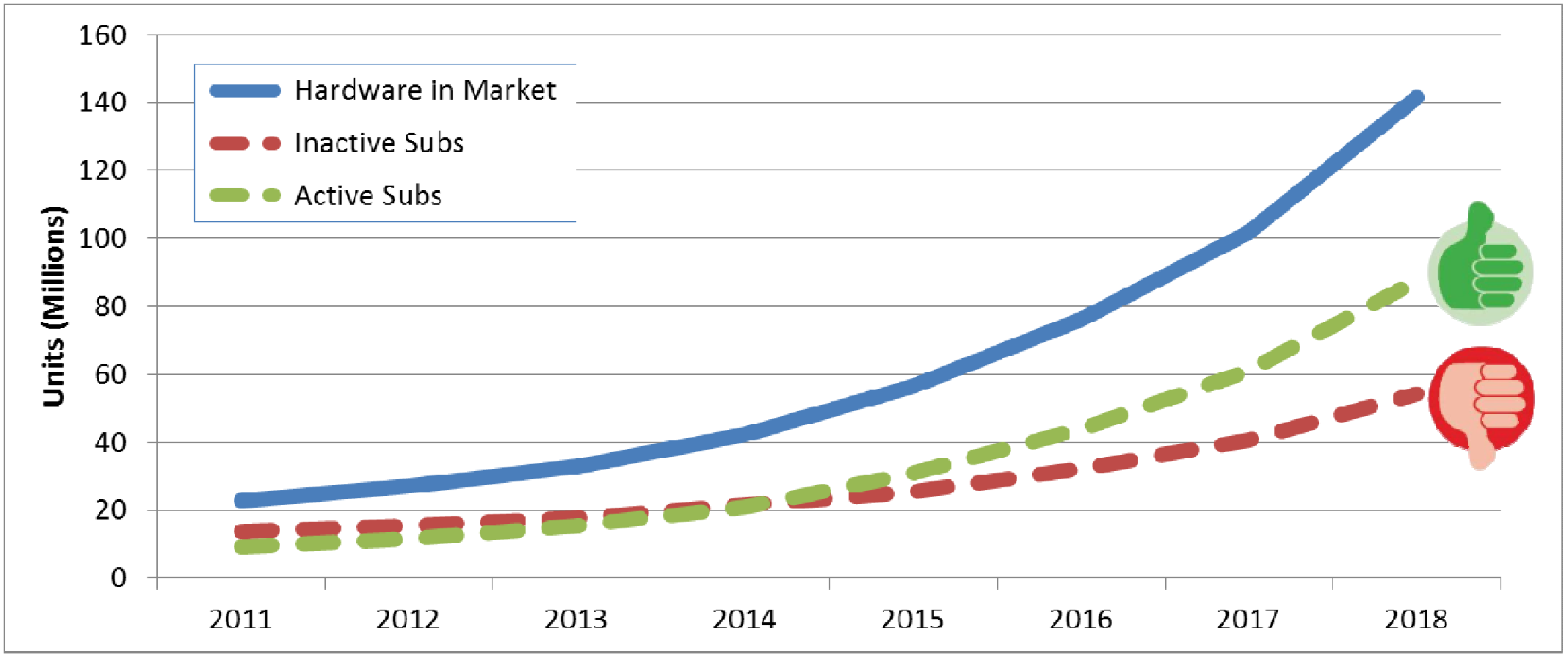
Telematics Gen 1.0
IN-Active Subscriptions (Cumulative)



Source: Strategy Analytics Infotainment & Telematics Service

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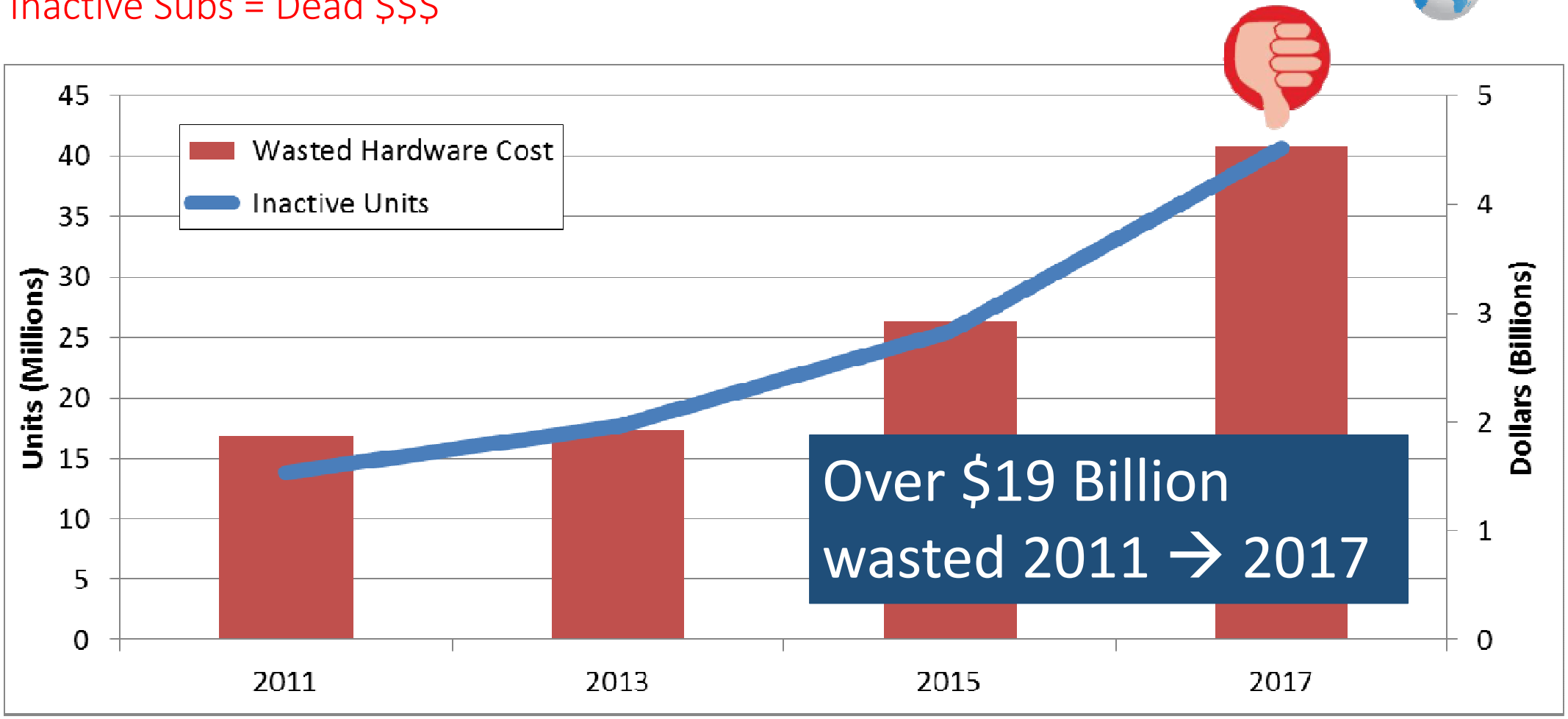
Telematics Gen 1.0
Inactive Subs = Dead $$$

STRATEGY ANALYTICS



Source: Strategy Analytics Infotainment & Telematics Service

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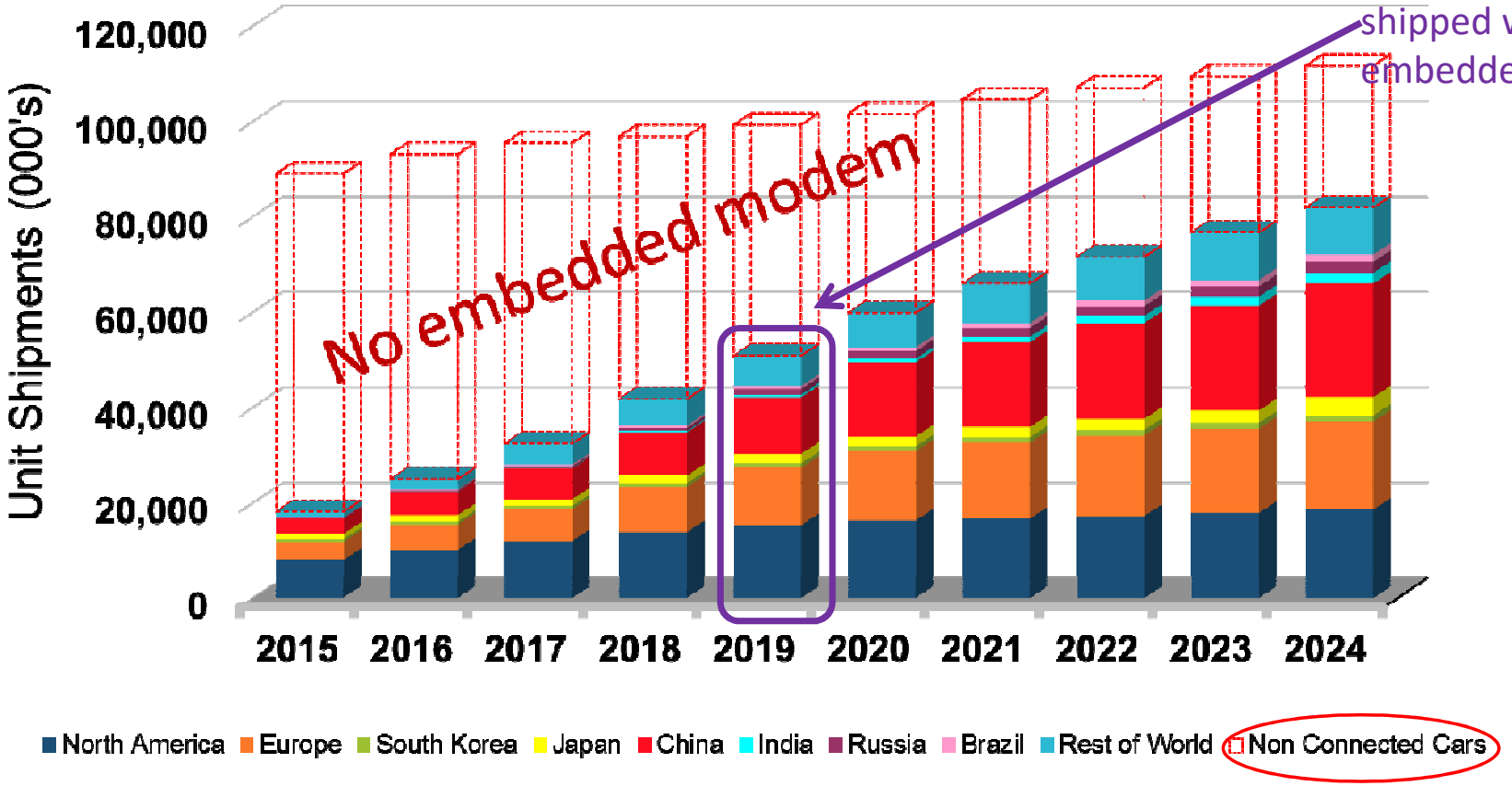
Automotive Embedded Modems
Global annual Shipments

STRATEGY ANALYTICS

51% of vehicles shipped will have embedded modems



Telematics 1.0

Source: Infotainment & Telematics Service

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Let's make sure we agree

- Lower latency communications
- Device to device connections
- Greater reliability
- Network slicing
- Layered, ubiquitous connectivity
- True IoT – network of everything

- Equivalent to DSRC
- Mode 4 – no network necessary
- Trust but verify
- Application focused
- Not your father's wireless network
- Connects to infrastructure, other cars, mobile devices

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Core 5g-enabled applications

- Autonomous driving
- Remote control
- Platooning
- Collision avoidance
- Inter-vehicle communications (V2V)
- Vehicle to infrastructure communications (V2I)
- Vehicle to pedestrian communications (V2P)
- Over-the-air updates

Regulators are requiring autonomous vehicles be equipped with remote control – it is likely that only 5G can delivery the necessary low latency for this application.

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New value propositions

- Ubiquitous connectivity
- Inter-vehicle communication
- Data collection, aggregation, interpretation, sharing
- Monetization of data – data brokering
- Artificial intelligence
- Machine learning
- Neural networks
- Augmented/virtual reality
- Contextualized marketing
- OTA updates

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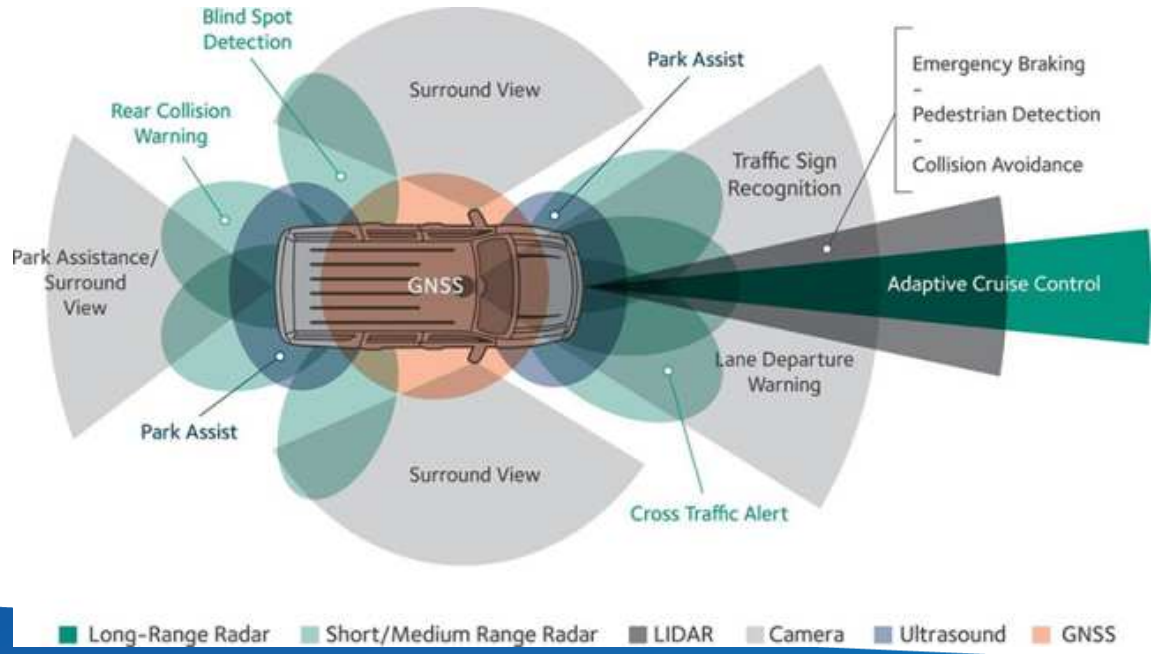
Cellular becomes mission critical

STRATEGY ANALYTICS

Example is Safety - There is increasing reliance on:

- LIDAR, RADAR
- Cameras
- Contextual awareness with the objective of collision avoidance



…most of these systems have COMPLEX software…

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Cellular - no longer a cost center

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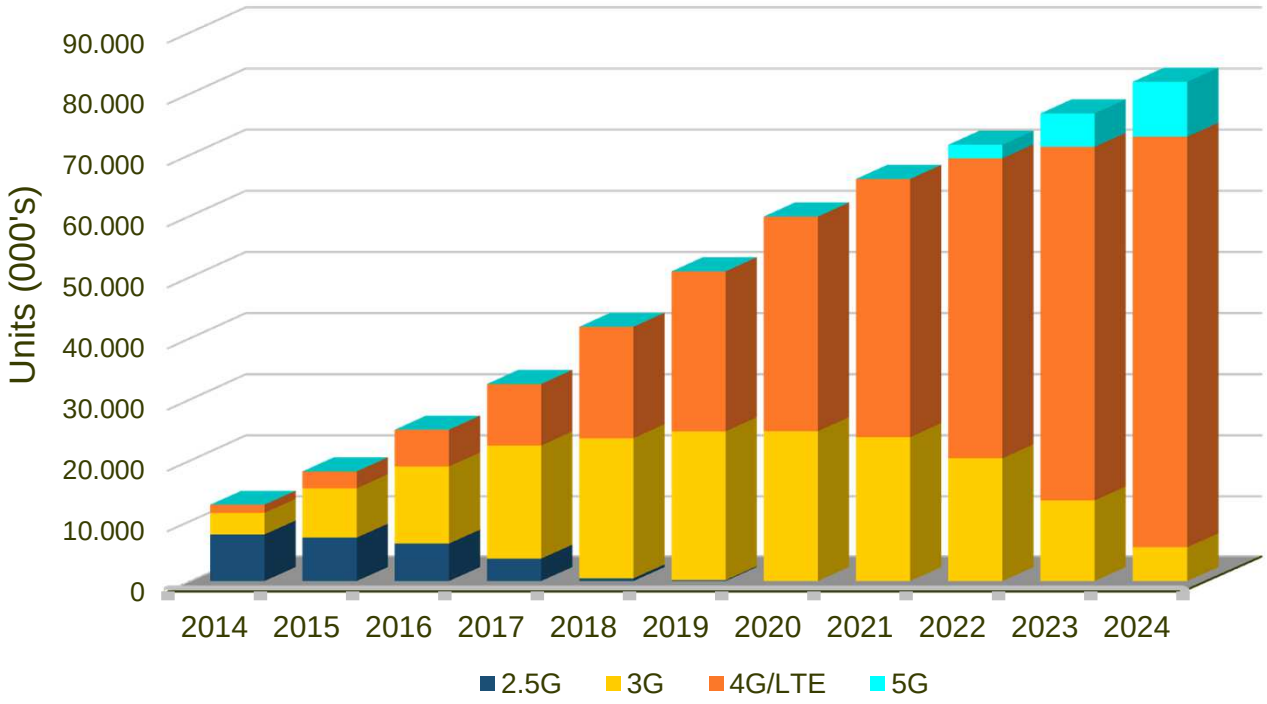
OEM embedded Telematics
Cellular Modem Shipments - Global

Telematics Forecast 2016 vs. 2024 (25 Mil. units → 82 Mil. units)



- 2.5G Network: 6.3 Mil units in 2016 to 0K units from 2020
- 3G Network: 12.7 Mil in 2016 units to 5.6 Mil units in 2024
- 4G/LTE Network: 6 Million units in 2016 to 67 Mil units in 2024
- 5G Network: 9 Million units in 2024

Source: Infotainment & Telematics Service

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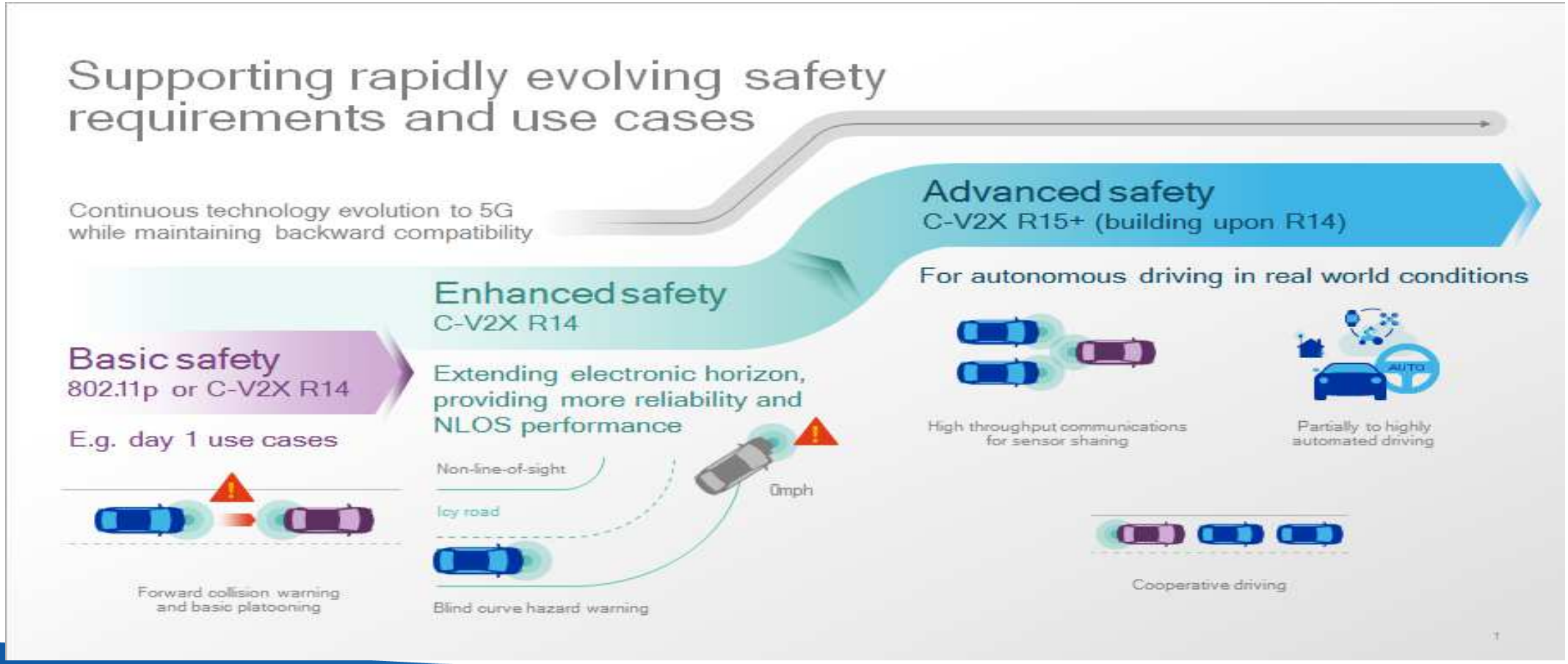
Cellular-based V2V arrives with C-V2X



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Every car creates its own maps?

MWC: “Qualcomm Drive Data Platform powers TomTom’s plans to crowdsource high-definition mapping data for autonomous driving”

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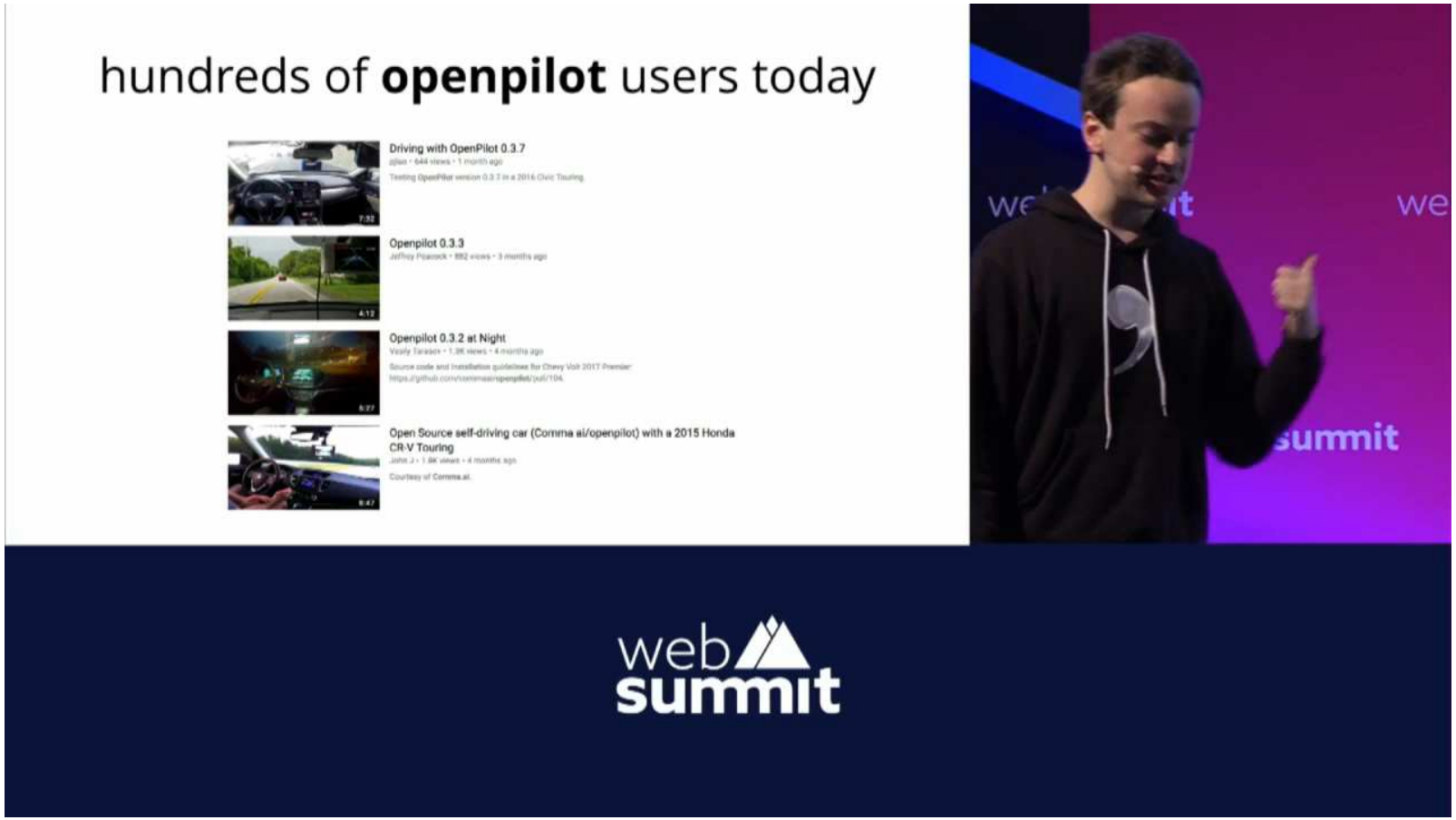
Some would have you think it is easy



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V2V/V2X

- Market development HIGHLY dependent upon mandates – C-V2X offers an organic path to market adoption
- 802.11-based approaches seen as having huge business model challenges by Strategy Analytics. Who will pay for new, automotive-specific infrastructure?
- LTE/5G approaches including C-V2X can overcome these issues
  - Latency-critical applications should rely on on-board sensors
  - Yes, network coverage is not universal – but it is a lot wider than a dedicated automotive network could hope to be in any reasonable timeframe
  - 5G peer-to-peer capabilities will allow V2V even without network coverage

- Smartphones and apps
  - Speed to market; Consumer familiarity
  - Ubiquitous usage/device ownership
  - Global Mobile Alert, Haas Alert, Ridar Systems

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V2I: the missing piece

- To escape geo-fencing – automated driving will need vehicle to infrastructure communications
- Cellular is best positioned to enable V2I at low cost and within a short time horizon
- Cellular infrastructure can be reused as RSU, particularly for C-V2X

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Global eco-system

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Global eco-system

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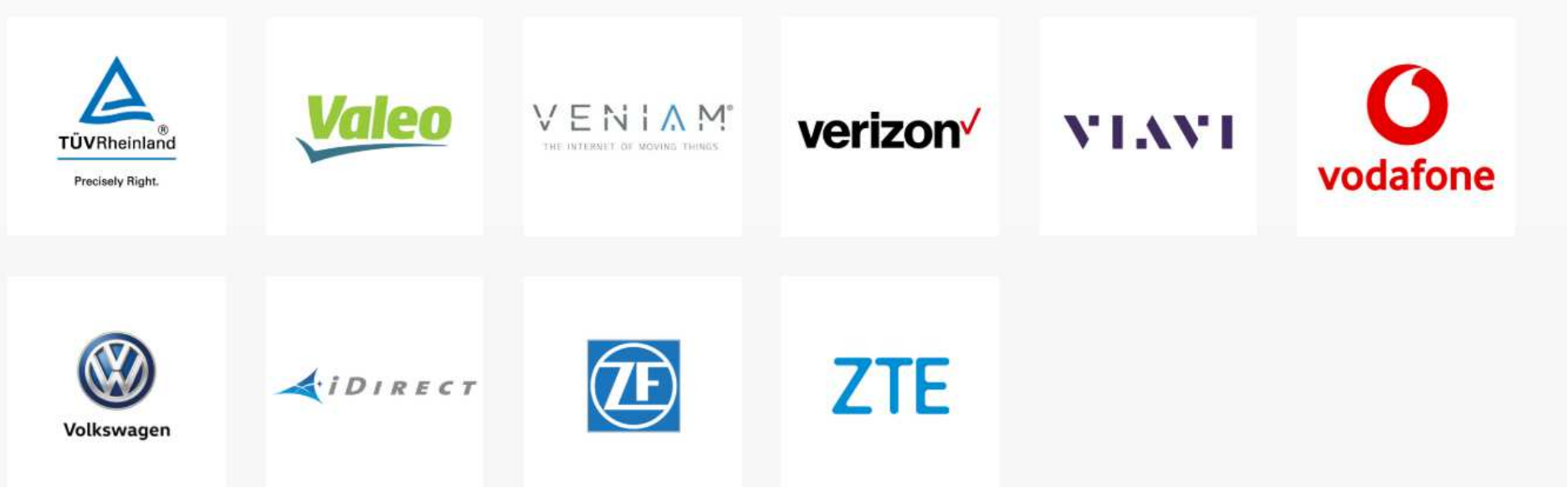
Global eco-system



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conclusions

- Ubiquitous connectivity is transforming how vehicles are used and owned
- Monetization of data will pay for connectivity
- Autonomous vehicles are already here – Cellular V2I is the essential application to open up autonomy in urban areas
- Privacy, security concerns must be overcome to enable this new connectivity environment
- Data sharing and inter-vehicle communications are in the process of being resolved today
- 5G collaboration between automotive and wireless industries is a game changer for solving these challenges

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A thinking car

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The car as browser

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Automotive Infotainment & Telematics

THANK YOU

STRATEGY ANALYTICS

O 617 614-0714
M 571 446-8192

rlanctot@strategyanalytics.com
@rogermud

Mike Mollenhauer

Director of the Center for Technology

Dr. Michael Mollenhauer is the Implementation at the Virginia Tech Transportation Institute.

He leads a team of researchers and software engineers that help customers conduct early stage deployment and evaluation of connected and automated vehicle systems.

More recently, Mike is leading VTTI’s efforts to partner with the Virginia DOT to develop the Virginia Connected Corridor through the deployment of V2I infrastructure, a cloud computing environment, and a variety of mobile connected vehicle applications.

Connected Vehicle Implementation Activity in Northern Virginia

Virginia Tech
TRANSPORTATION INSTITUTE

Overview Presentation
4/26/2018

Dr. Michael A. Mollenhauer
Director
Center for Technology Implementation
Virginia Tech Transportation Institute

5GAA Automotive Association

VTTI's Role

- Participate in VDOT's planning for CAVs and their impacts on roadway operations
- Provide technical leadership and evaluation services to understand the impact of CAVs
- Facilitate and manage early stage deployment of connected vehicle systems
- Create solutions that bridge gaps in commercially available solutions when necessary

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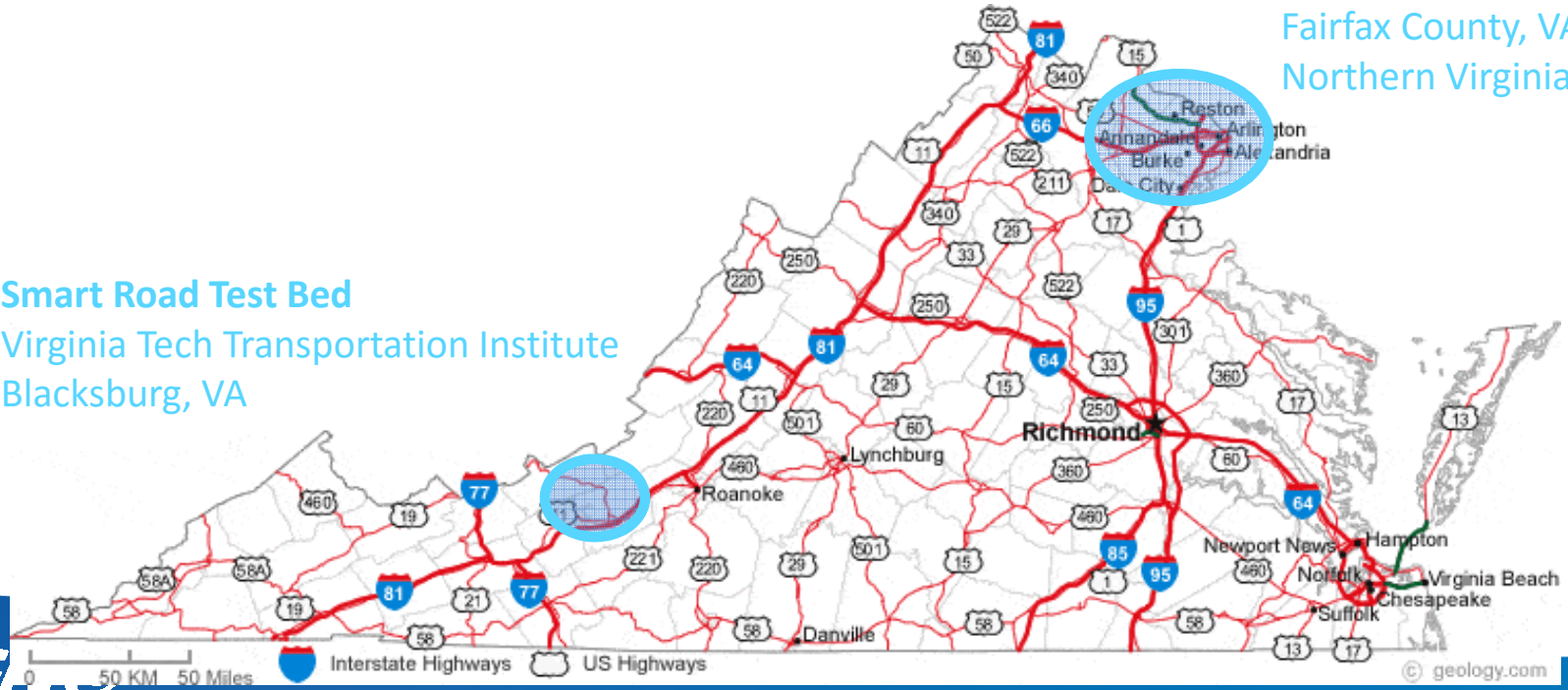
Virginia Connected Corridors

Mission: Provide an open environment where connected vehicle concepts can be developed, tested, deployed, and evaluated in real world operating environments.

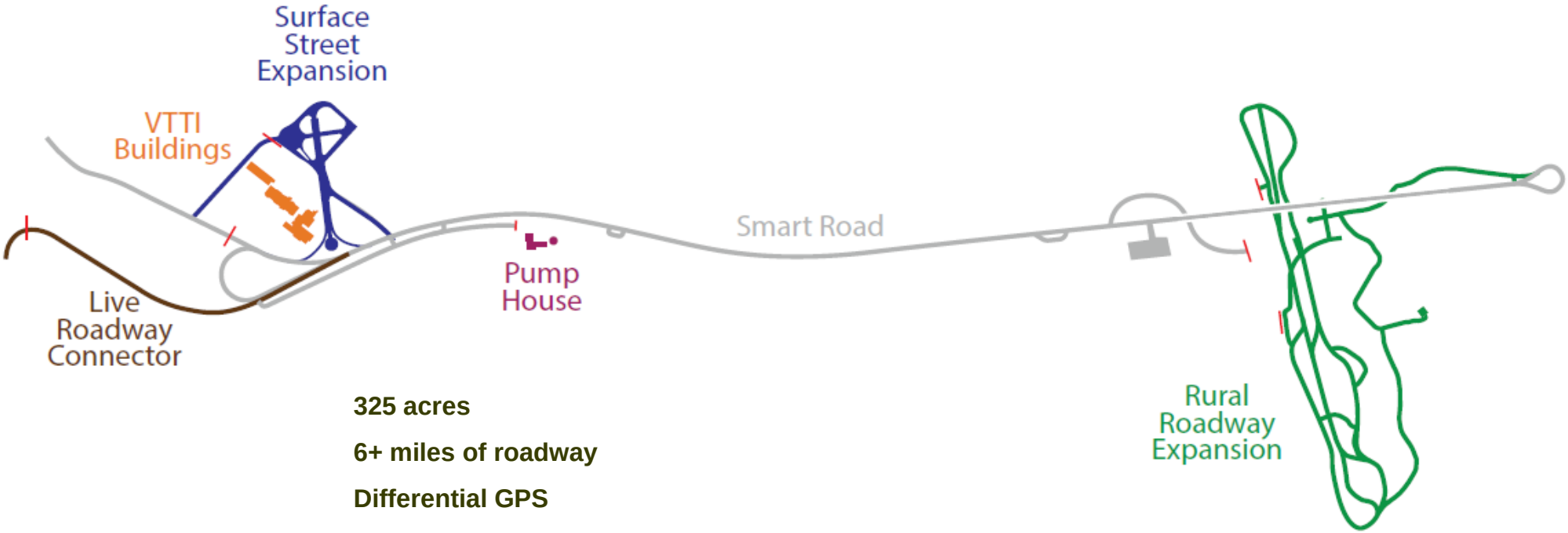
Northern Virginia Test Bed
Fairfax County, VA
Northern Virginia

Smart Road Test Bed
Virginia Tech Transportation Institute
Blacksburg, VA



Virginia Department of Transportation

Virginia Smart Road



325 acres

6+ miles of roadway

Differential GPS

Cellular coverage with varying levels of service

Continuous DSRC coverage

Contiguous driving in a mix of environments

- Freeway, rural, and reconfigurable urban roadway sections
- 22,000+ hours of groundbreaking research
- Weather, lighting, diverse pavement, intersection

STRATEGYANALYTICS

VDOT
Virginia Department of Transportation

VirginiaTech
Transportation Institute

photo by Michael Kiernan

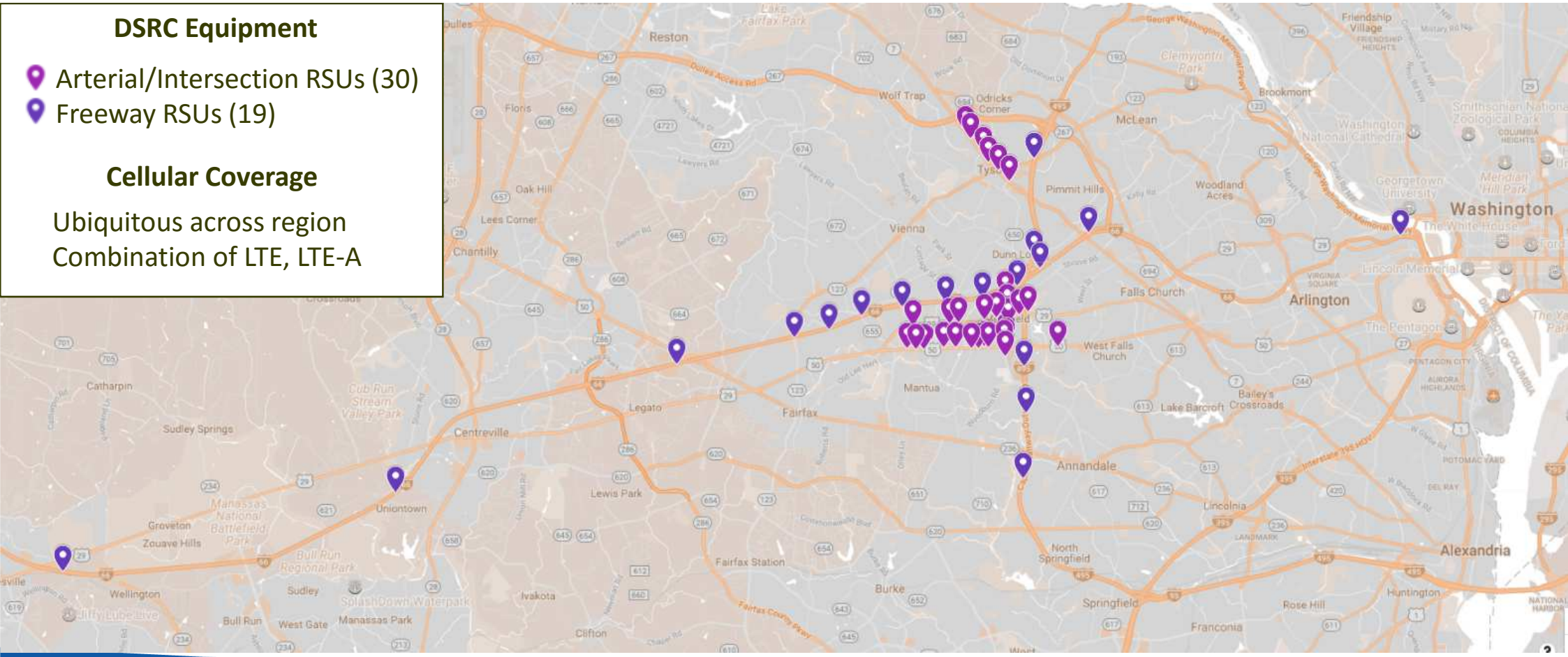
Northern Virginia Test Bed

DSRC Equipment

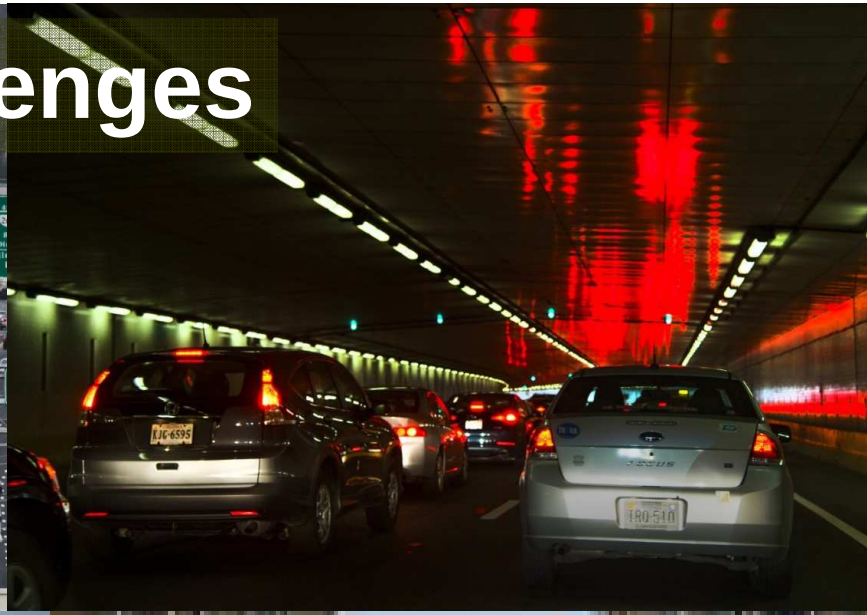
- Arterial/Intersection RSUs (30)
- Freeway RSUs (19)

Cellular Coverage

Ubiquitous across region
Combination of LTE, LTE-A



Northern VA Challenges



The VCC is Communications Agnostic

- Current Communications Capabilities
  - Dedicated Short Range Communications (DSRC)
  - 3G/4G Cellular
- Anticipated Future Capabilities
  - C-V2X
  - 5G Cellular
- VTTI characterizes the performance of the communications capabilities available on the test bed environments
- VCC deployments seek to assess the impacts of communication technology characteristics on the individual CAV applications

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Prototype and Proof of Concept

Real World Challenges

VCC Cloud

- Application Processing
- Data Hub Management
- External Data Interfaces
- Cellular and DSRC

Design & Test

Smart Road

- 2.5 mile Test Track Facility
- Intersection, Ramps, Bridge
- Controlled Weather and Lighting

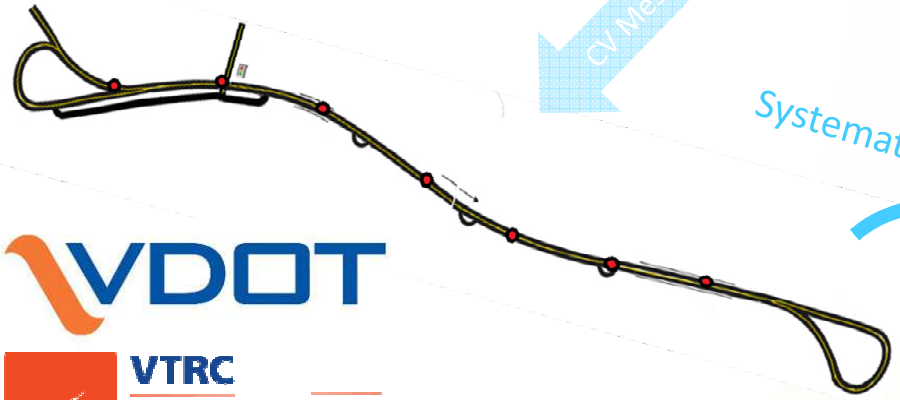
CV Message Traffic

CV Message Traffic

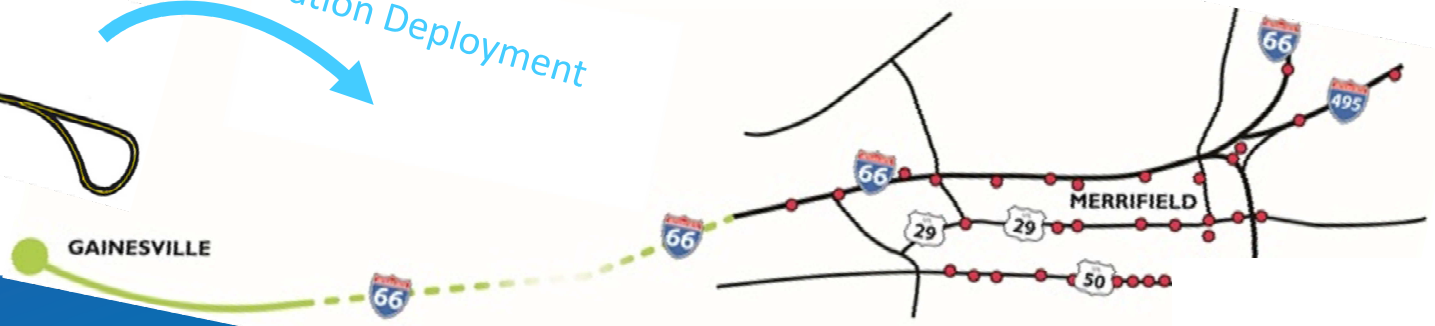
Deploy & Evaluate

Northern VA Test Bed

- Heavily Congested Arterials and Freeways
- Interface to VDOT Northern Region TOC
- ATM, VDMS, HOVs, Toll Lanes, Ramp Meters



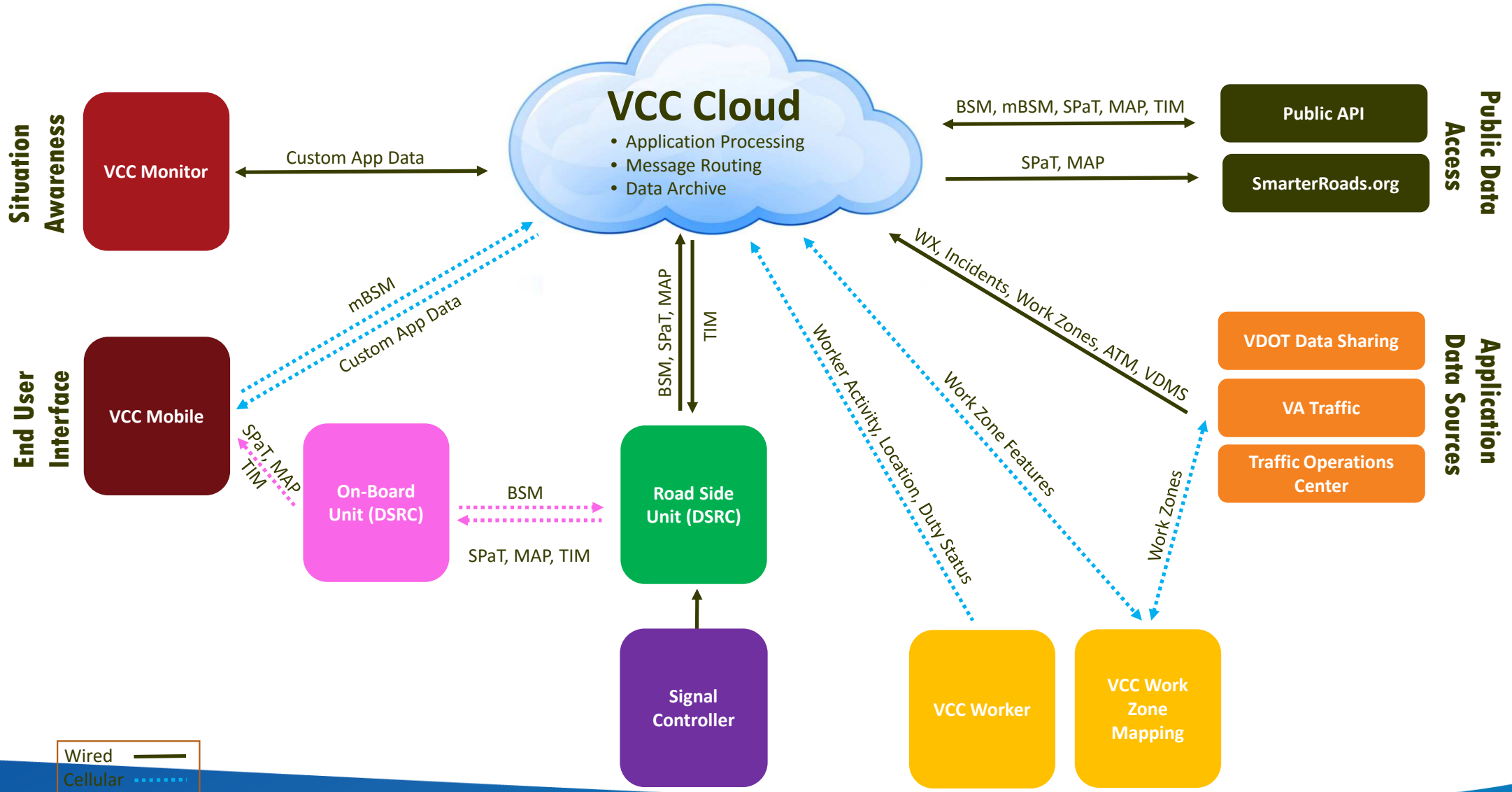
Systematic Application Deployment



VDOT

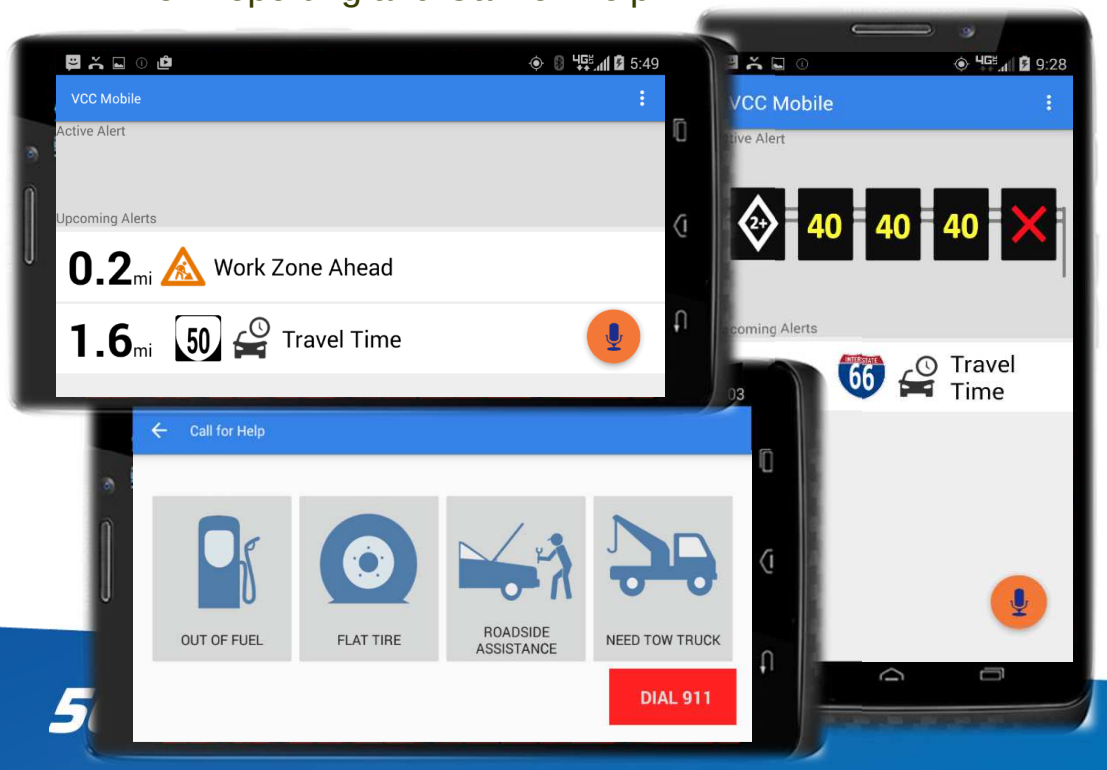
VTRC
Virginia Transportation Research Council

Virginia Tech Transportation Institute


Situation Awareness
VCC Monitor
Custom App Data
VCC Cloud
• Application Processing
• Message Routing
• Data Archive
BSM, mBSM, SPaT, MAP, TIM
SPaT, MAP
Public API
SmarterRoads.org
Public Data Access
End User Interface
VCC Mobile
mBSM
Custom App Data
BSM, SPaT, MAP
TIM
WX, Incidents, Work Zones, ATM, VDMS
Worker Activity, Location, Duty Status
Work Zone Features
Work Zones
VDOT Data Sharing
VA Traffic
Traffic Operations Center
Application Data Sources
SPaT, MAP
TIM
On-Board Unit (DSRC)
BSM
SPaT, MAP, TIM
Road Side Unit (DSRC)
Signal Controller
VCC Worker
VCC Work Zone Mapping
Wired
Cellular
DSRC
Signal Timing Data
Work Zone Data

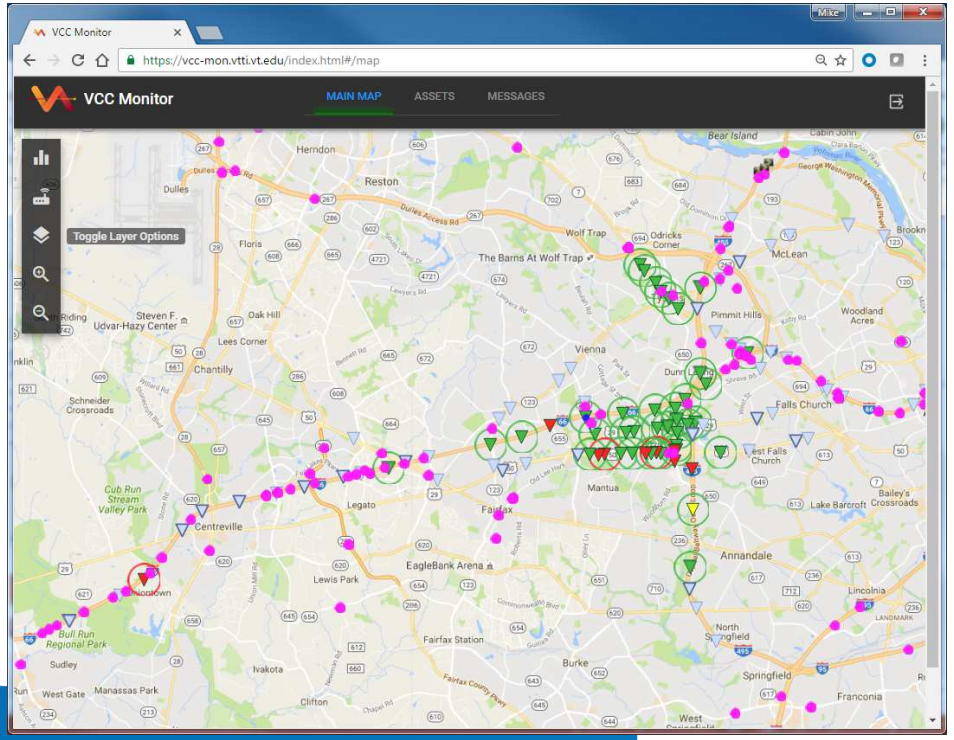
VCC Mobile

- Cellular or DSRC/OBE
- Dynamic Driver Messaging
- Work Zone Alerts
- Weather Advisories
- Traffic Incidents
- ATM/HOV Status and Alerts
- Pot Hole Detection and Road Surface Temp Monitoring
- Driver Reporting and Call for Help



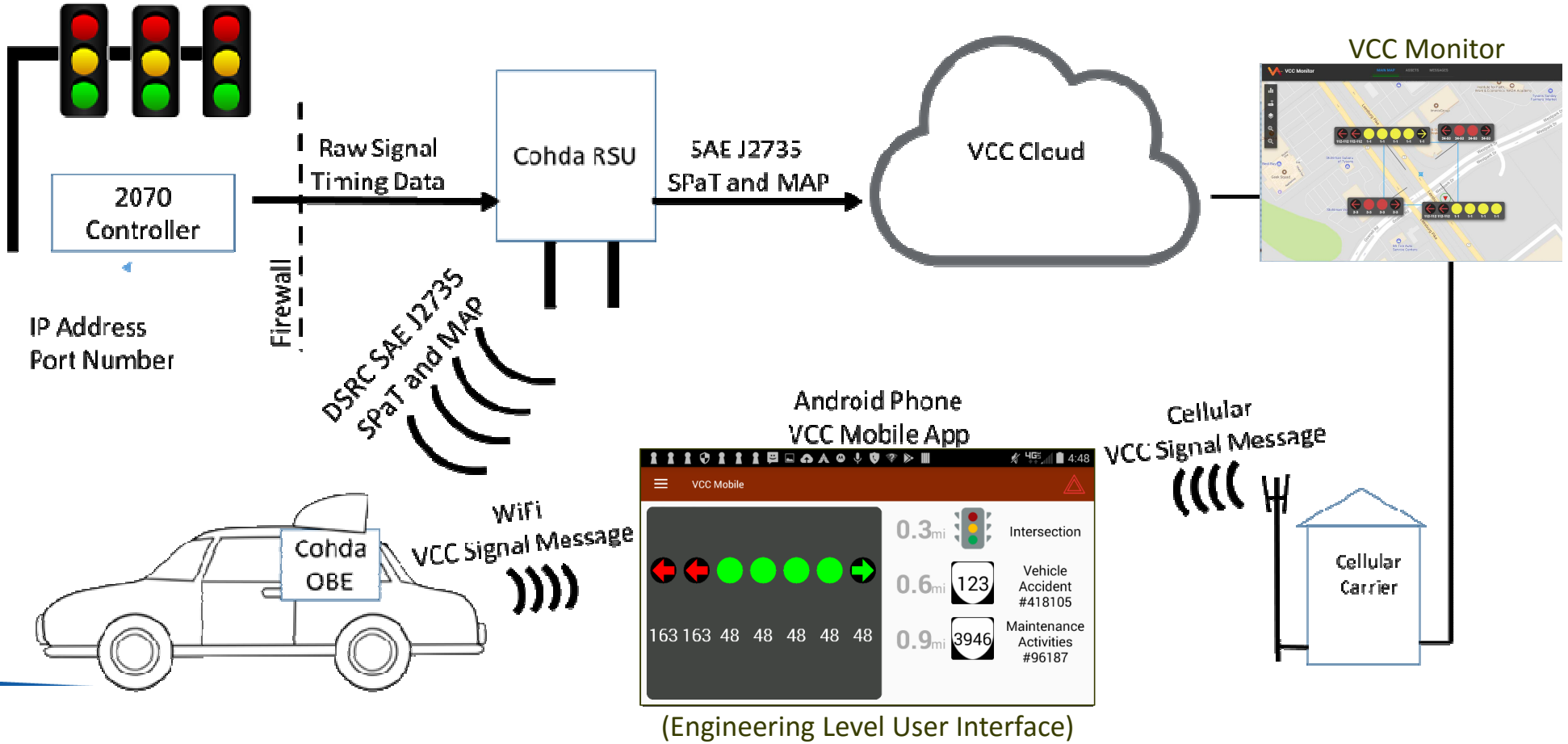
VCC Monitor

- Realtime Situation Awareness Tool
- RSU Status and Performance Monitoring
- Message Flow Monitoring (BSM, BMM, PDM, TIM, etc.)
- SPaT Status Display
- Control Message Management
- Traveler Information Message Management
- Driver Report Location



SPaT Implementation

Each of 4 arterial corridors (US50, US29, Rt 7, Rt 650) has at least 6 and as many as 11 consecutive intersections



(Engineering Level User Interface)

Focus: Work Zone Safety

- VDOT is interested in how CAVs will affect work zone safety
  - Can CV messaging be used to improve safety?
  - What are the data requirements future CAVs and how can it be managed?
- VTTI is working to develop an end-to-end solution for evaluating concepts to improve safety
  - Multiple projects pieced together to work towards a solution to evaluate in the field
  - Work with existing VDOT systems to extend capability
  - Build systems to address gaps in technology and data
  - Test and evaluate novel solutions

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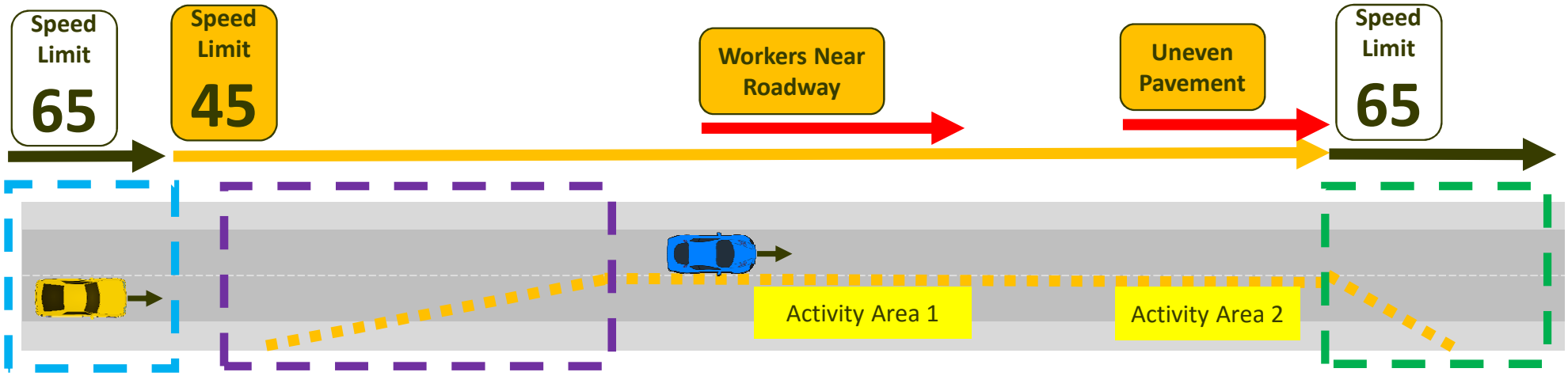
Desired CAV Data Elements



Approach
- Lat / Lon Geo Position
- General Description
- Operational Restrictions

Transition
- Lat / Lon Geo Position
- Beginning of Taper
- End of Taper
- Required Actions
- Merge Direction
- Lanes Offsets / Alternate Paths
- Speed Reduction
- Maneuver Restrictions

Activity Area(s)
- Lat / Lon Geo Position
- Description
- Potential Hazards
- Barrier Type
- Active / Inactive

Termination
- Lat / Lon Geo Position
- Beginning of Taper
- End of Taper
- Resume Speed Limit

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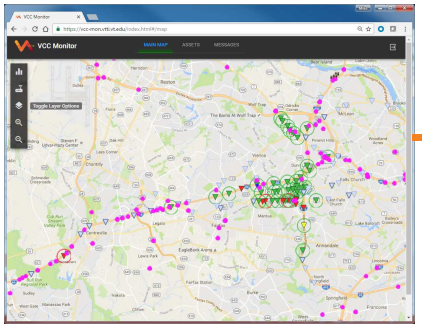
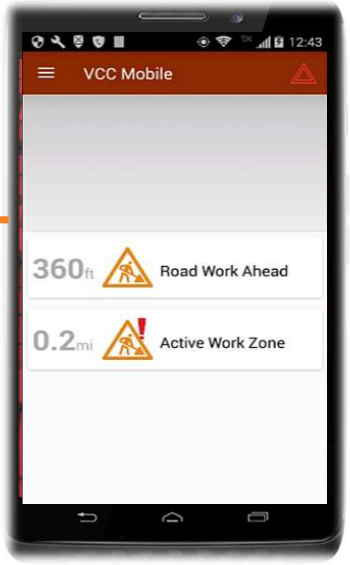
VCC Work Zone Components

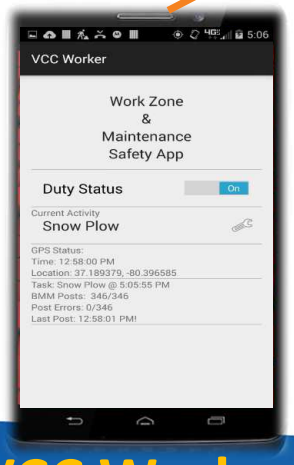


VCC Monitor
Situation Awareness

VCC Cloud
Data and Processing Hub

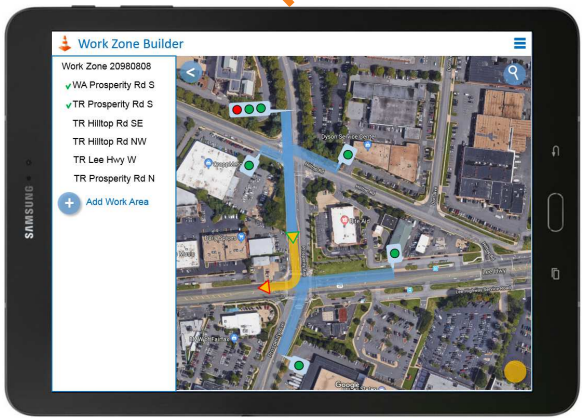


VCC Mobile
Driver Interface



VCC Worker
Dynamic Worker Location and Activity

VCC Vest



Work Zone Builder
Detailed Work Zone Definition

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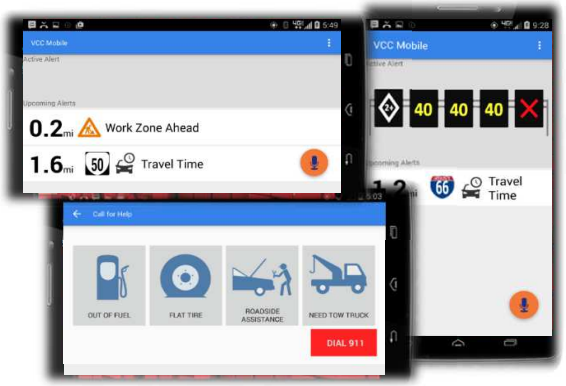
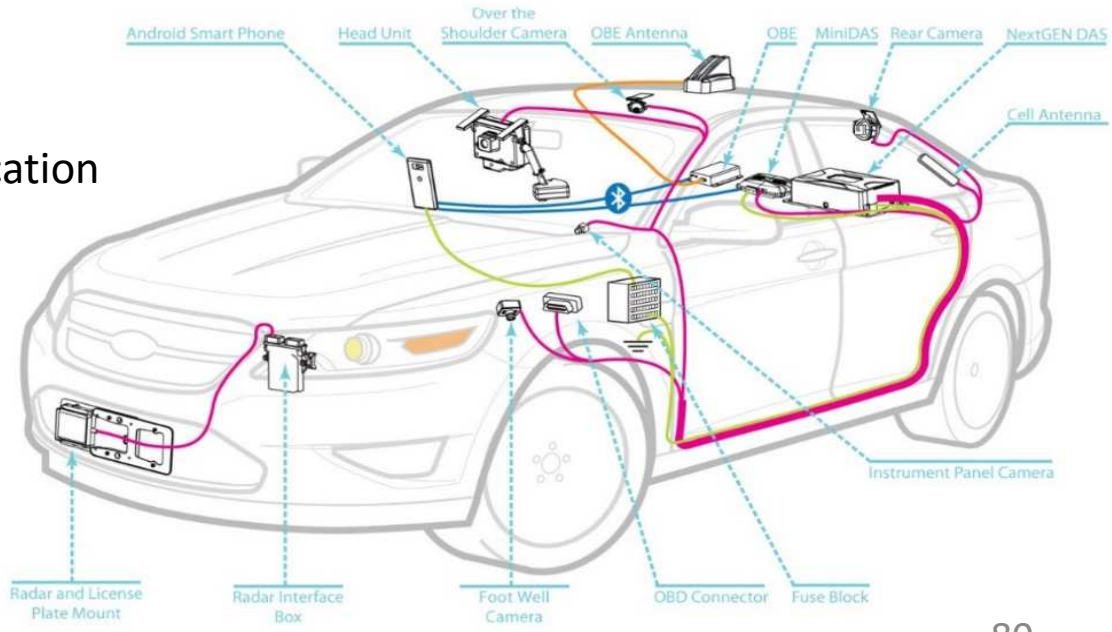
VCC L2 “Elite” NDS

Purpose: Build naturalistic dataset to assess behavior with early production L2 vehicles and responses to a mobile CV application

Details:

- 50 personally owned production L2 and ADAS equipped vehicles
- 12 months of data collection
- Use of connected vehicle application on the VCC CV environment
- Evaluating drivers interactions with technologies
- Early look at production level 2 automated vehicles





Equipped Vehicles

- 11 – Tesla Model S
- 1 – Tesla X
- 2 – Acura RDX
- 1 – Acura MDX
- 2 – Acura TLX
- 3 – Jeep Grand Cherokee
- 4 – Hyundai Genesis
- 3 – Hyundai Sonata
- 1 – Ford Flex
- 4 – Ford Fusion
- 1 – VW Passat
- 5 – Honda Accord
- 1 – Honda Civic
- 1 – Cadillac SRX
- 1 – Mercedes CLS550
- 1 – Nissan 300ZX
- 3 –Toyota Highlander
- 1 – Toyota RAV4
- 1 – Volvo S90
- 1 – Volvo XC 90
- 2 –Chrysler Pacifica Limited
- 1 – Chevrolet Suburban

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Questions?

Mike Mollenhauer

mmollen@vt.edu

(970)227-3373

V2X Product Life Cycle Management

Washington DC

26 April, 2018

Frank Perry

Program Manger

Savari

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Current Deployments

- Estimates indicate there are between 2,000 and 3,000 RSUs and between 8,000 and 10,000 OBUs in operation around the country

- Estimates indicate another 1,000 RSUs and 12,000 OBUs will be deployed within the next 18 months

V2X is still in the early stages of Deployment

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Technology Evolution

- Past Examples:
  - SAE J2735-2009-to-J2735-2016 **Firmware upgrade**
  - RSU Spec v3.0-to-4.0 **-Hardware upgrade**

- We need to continually be thinking about ways to future proof deployments as technology evolves.

- Road Operators need convenient, low cost, methods to **upgrade existing deployments**.

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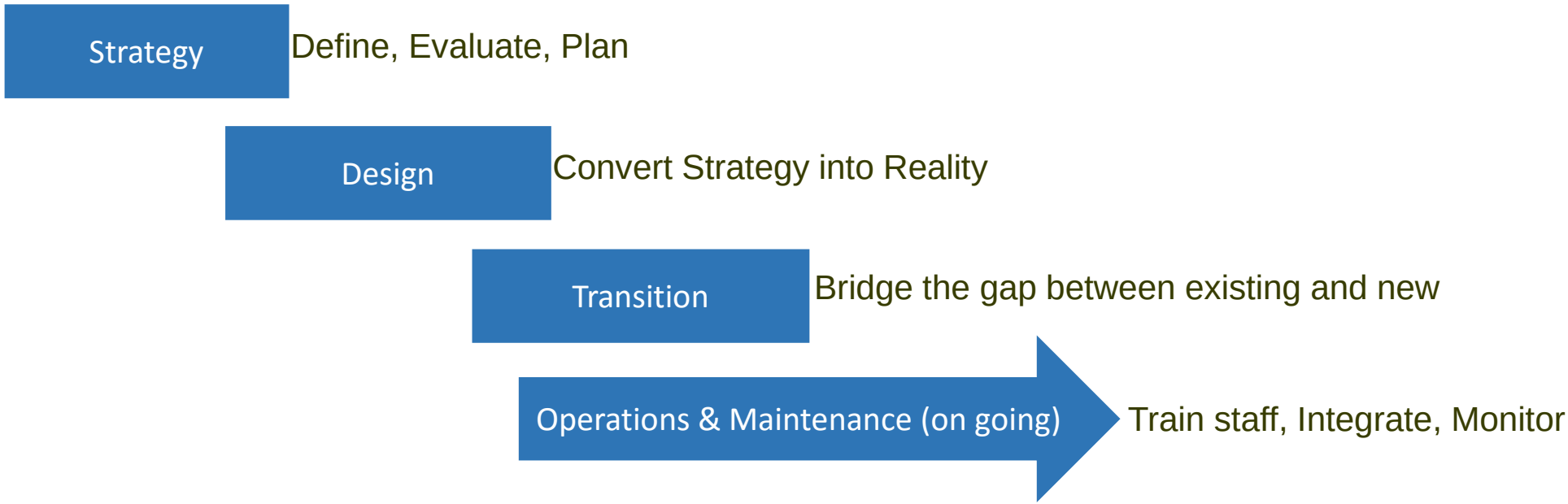
Product Life Cycle Stages



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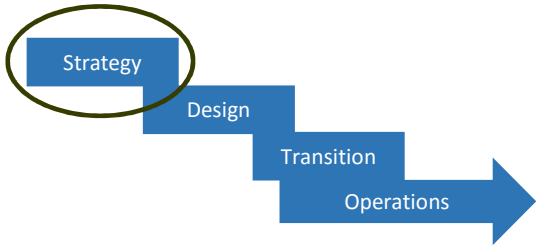
Strategy



- Technology Transitions need to be carefully planned and executed by the hardware manufacturer, software developer, and the hardware owner

- Transitioning to a new technology involves either:
  a. Replace
  b. Upgrade

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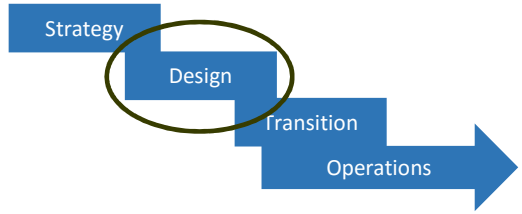
Design



Standards

Design
- ConOps
- Use Cases
- Requirements

Implementation
- Hardware
- Software

Proof-of-Concept
- Prove Design
- Prove Implementation

C-V2X

"Design for Deployment"
- Replace
- Upgrade

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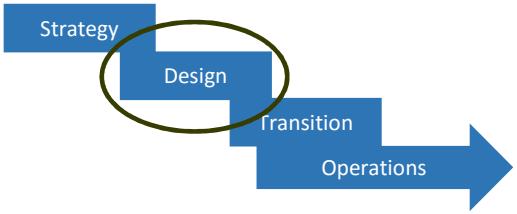
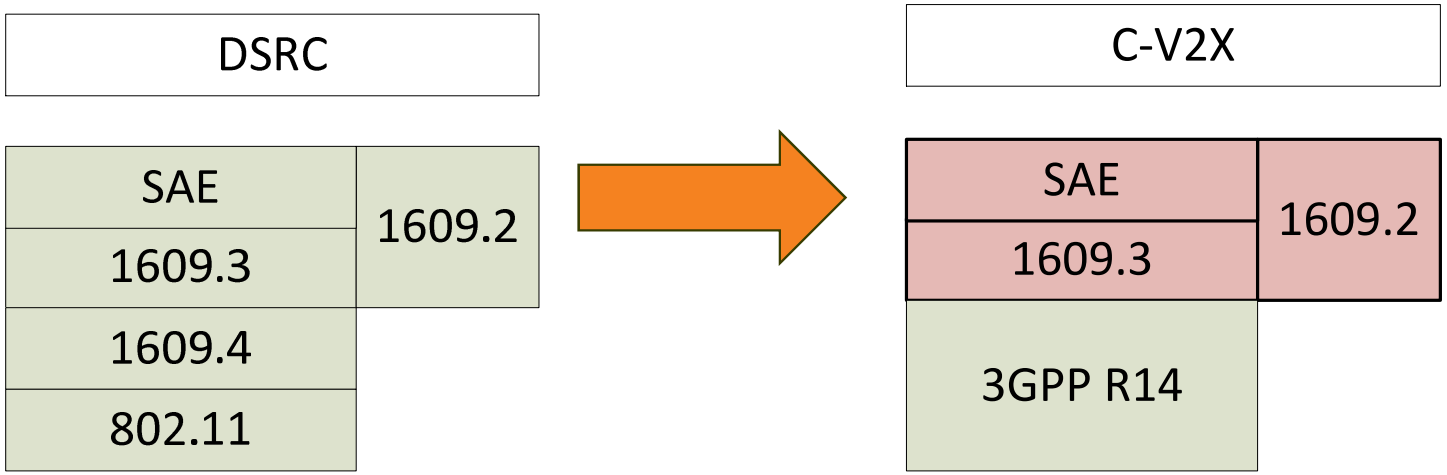
Design (PoC)



- Several 5GAA members partnered to develop C-V2X Proof-of Concept devices

- We ported our communication stack to the C-V2X reference platform, which included
  - SAE
  - IEEE 1609.2
  - IEEE 1609.3



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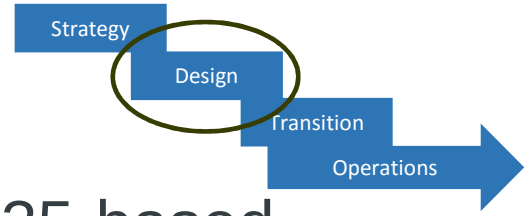
Design (Demonstration)



- The C-V2X Solution supports the following SAE J2735-based messages
  - Basic Safety Message (BSM)
  - Signal Phase and Timing (SPaT)
  - Map (MAP)

- Demonstrating the following applications:
  - Forward Collision Warning (FCW)
  - Electronic Emergency Brake light (EEBL)
  - Left Turn Assist (LTA)
  - Intersection Movement Assist (IMA)
  - SPaT Visualization (Status with Time Remaining)

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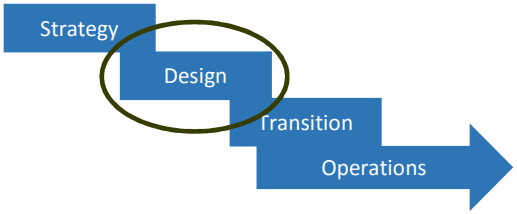
Design



Independent Evaluation

- Standards Compliance confirmation
- Interoperability

Deployment

- Replace
- Upgrade

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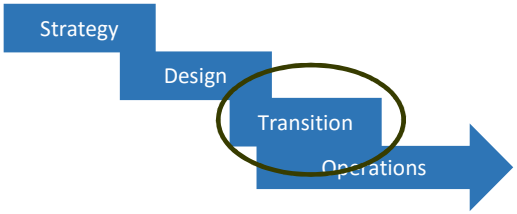
Transition



- Replace
  - Deploy new hardware
    - Reuse of Antenna's, power, etc.
    - Other external interfaces (Backhaul, Signal Controller, CAN, etc.) remain the same

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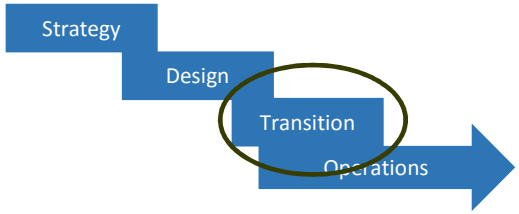
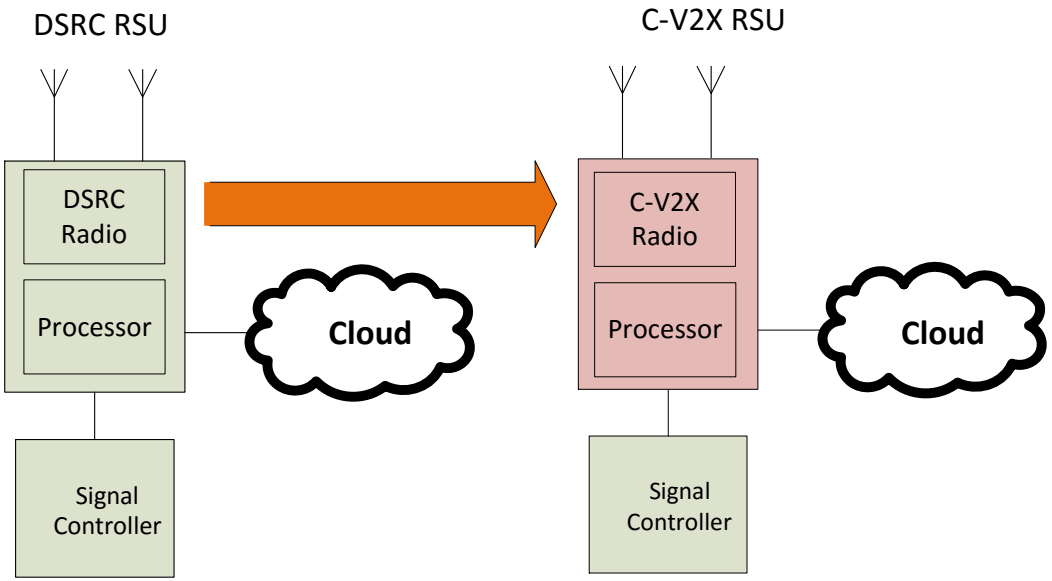
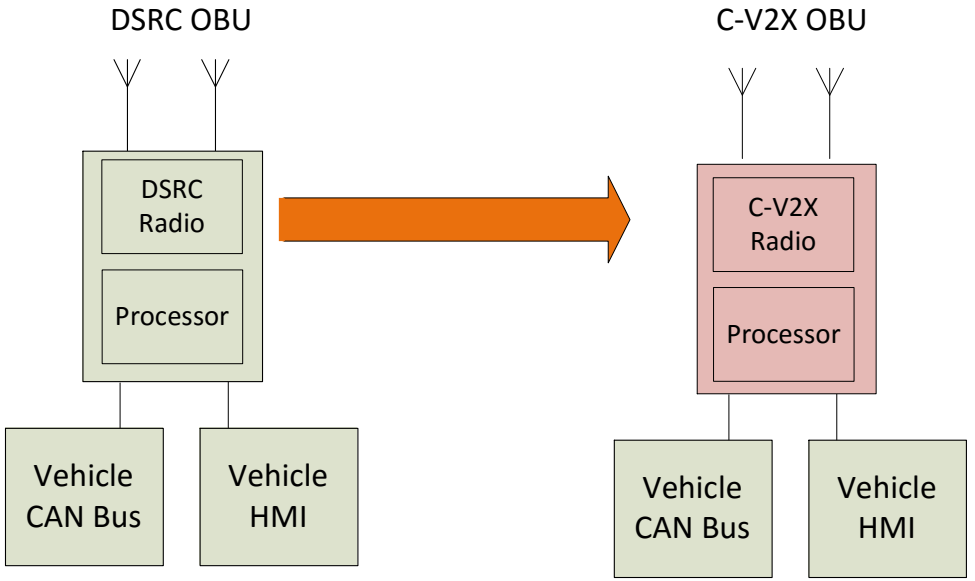
Transition-Replace



RSU



OBU



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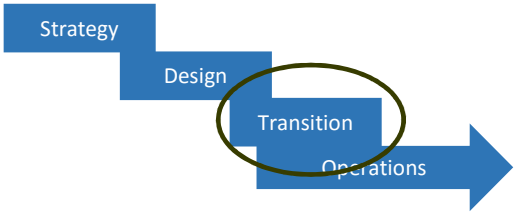
Transition



- Upgrade-Retrofit
  - Owner removes hardware
  - Owner return hardware to manufacturer
  - Manufacturer adds new technology
  - Manufacturer returns hardware to owner
  - Owner re-installs

Costly and Time Consuming

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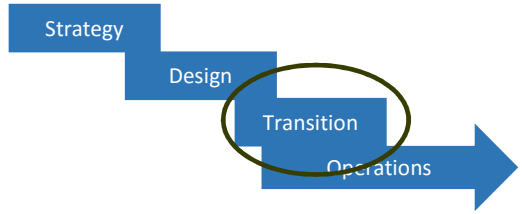
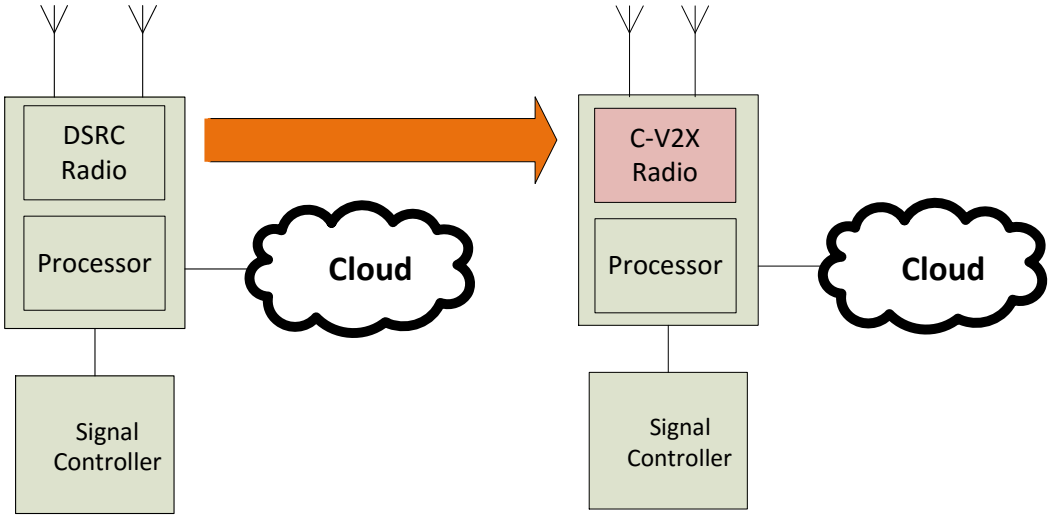
Transition: retrofit



RSU

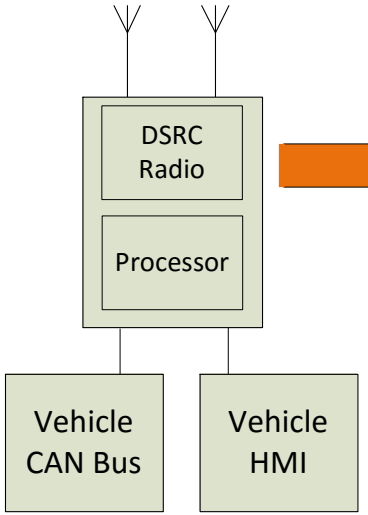
DSRC RSU



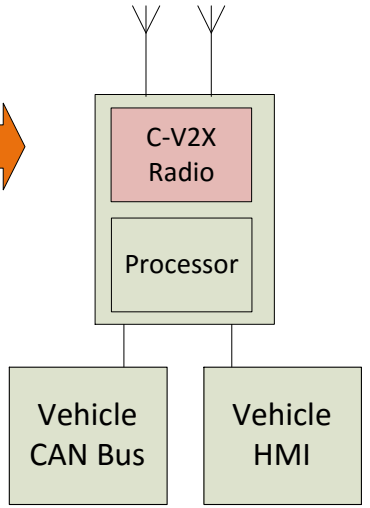
C-V2X RSU

OBU

DSRC OBU



C-V2X OBU



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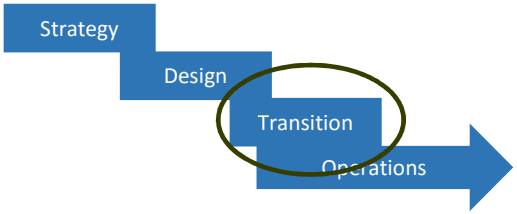
Transition



- Upgrade-Add on
  - Install additional hardware
    - Reuse Antenna’s
    - Other external interfaces (Backhaul, Signal Controller, CAN, etc.) remain the same
  - Firmware upgrade

More cost effective but requires additional effort/development by manufacturer

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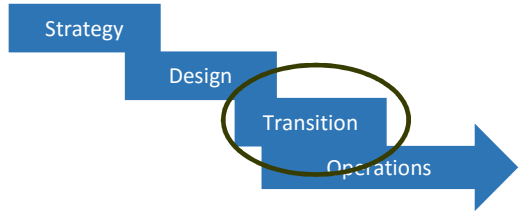
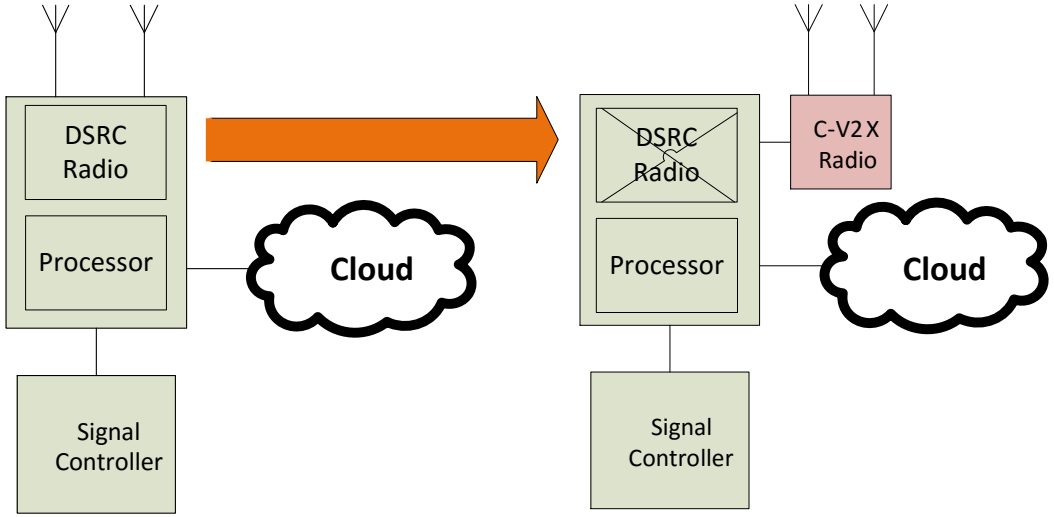
Transition: add-on



RSU

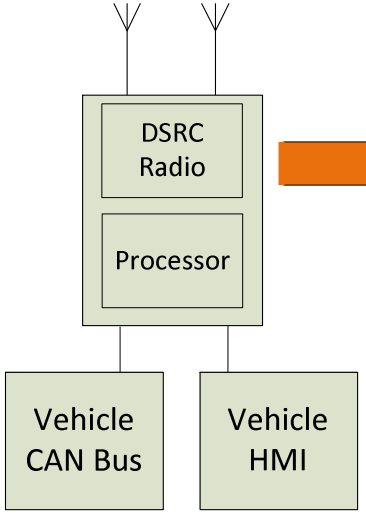
DSRC RSU



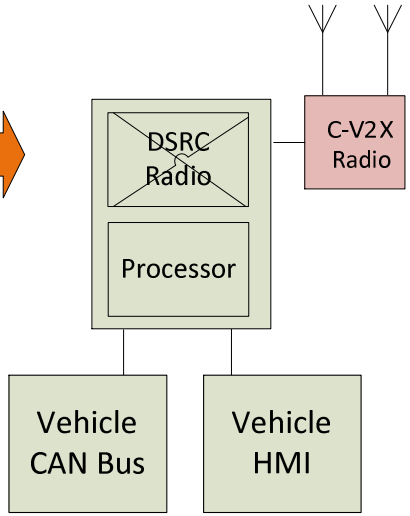
C-V2X RSU

OBU

DSRC OBU



C-V2X OBU



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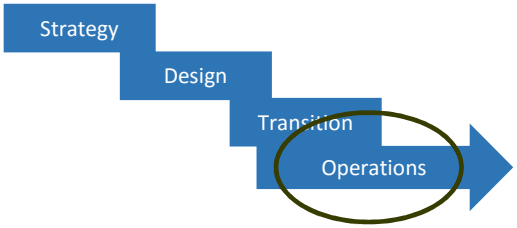
Operations



Operations & Maintenance	Training should be minimal for existing deployments
Back Office	Integration should be minimal for existing deployments

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Summary

- Technology transition must be carefully planned and executed
- C-V2X is quickly maturing
- Adding incremental hardware can be more cost effective than “rip and replace”
- Impact to O&M should be minimal

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Questions

Frank Perry
fperry@savari.net

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Economics of C-V2X: The Mobile Network Operator and Support for Alternative Deployment Models

Matt Arcaro
AT&T Product Marketing Manager

Washington DC

26 April, 2018

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FCC Auction 903 Admonishment Statement:

I have been asked to remind everyone at the outset of our session that the ‘quiet period’ for FCC Auction 903 (also known as the CAF II Auction) is now in effect. During the quiet period, auction applicants are required to avoid discussions of bids, bidding strategy, and post-auction market structure related to CAF II with other auction participants. Our agenda will avoid these topics. While we encourage participation through questions, please avoid asking questions or raising issues about these topics.

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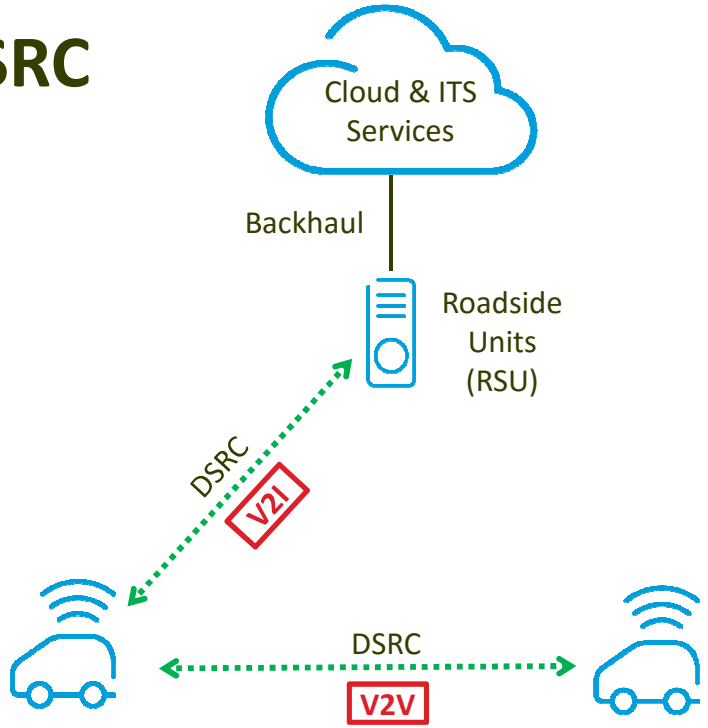
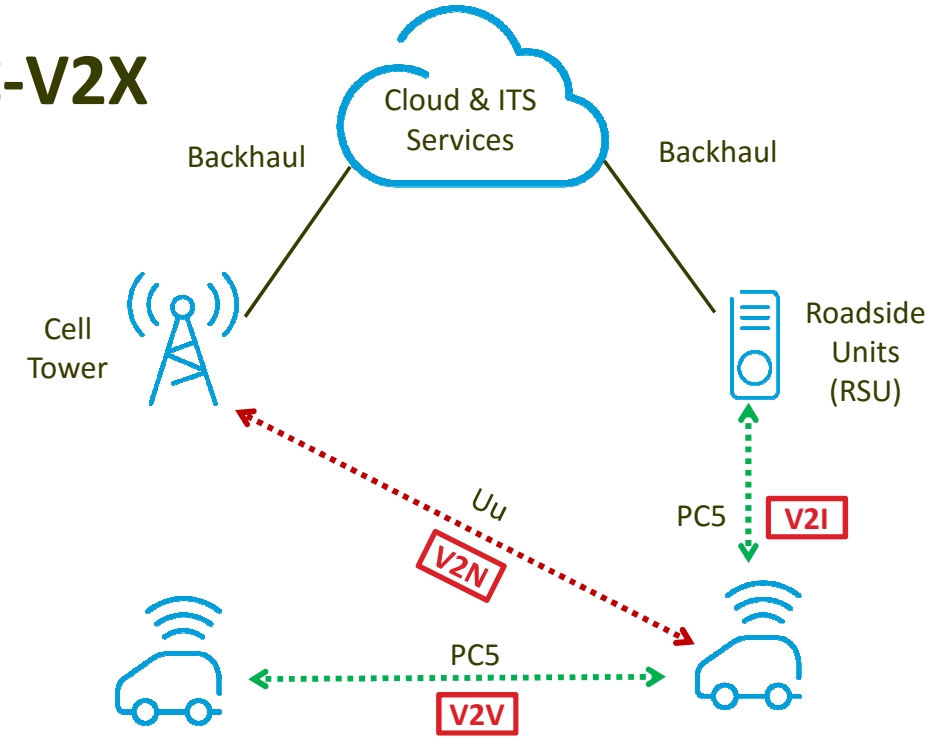
DSRC and C-V2X: Delivering V2V and V2I Communications Without a Cellular Subscription

DSRC



- Direct short-range communications for V2I and V2V
- No standards based integration to connect via V2N

C-V2X



- Direct short-range communications for V2I and V2V
- Standards driven integration to connect via V2N

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V2N: Augmenting and Complementing V2V and V2I

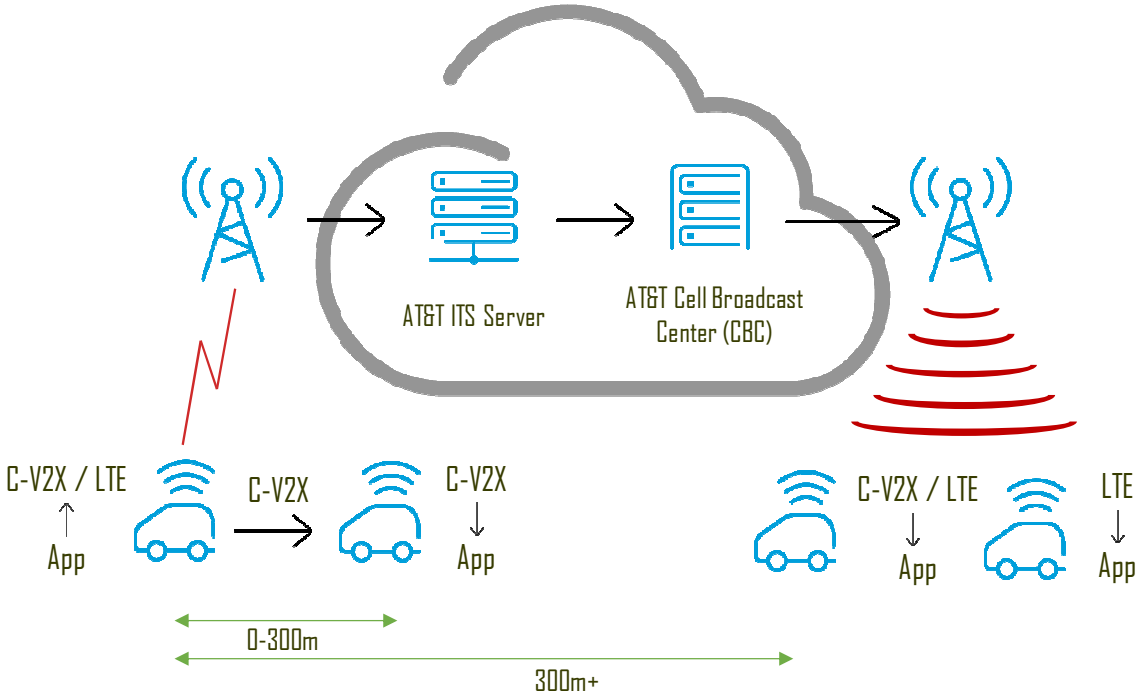
The Number of V2N Connected Vehicles Continues to Grow

AT&T Added +6 Million Connected Vehicles in 2017 and Now Connect 17.8M Vehicles*

- **Extending Range**
- **Expanding the Audience**
- **Selective Geo-targeting**

*Figures Taken From 4Q17 Public Earnings Disclousures

Example: Event Notifications



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V2N Increasing the Effectiveness of Roadside Units (RSUs)

V2N Augmenting RSUs

- Redundancy for Missing/Inoperable RSUs
- Supporting Security Credential Management System (SCMS)
  - Enrollment / Certificate Top Off
  - Certificate Revocations Lists (CRLs)
  - Misbehavior Reporting
- Event Notifications

V2N Complementing RSUs

- Supporting Cross-Jurisdictional & Nationwide Coverage
- Privacy/Security Services
- Broadcasting Traffic/Transportation Management Info
- Over-the Air (OTA) Updates

5GAA Automotive Association

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As a Mobile Operator, We Understand Networks…

- Planning, Building, Maintaining and Upgrading Networks are Costly and Complex
- AT&T Has Invested More Capital Than Any US Public Company:*
  - *"AT&T invested more than $200 billion in capital in our U.S. networks over the past 10 years."*
  - *2018: "Capital expenditures approaching $25 billion; $23 billion net of expected FirstNet reimbursements and inclusive of $1 billion incremental tax reform investment."*

*Numbers and Figures Referenced Taken From the 2017 AT&T Annual Report and 4Q2017 Earnings Disclosure

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V2N and V2I Also Align With Mobile Operator's Goals to "Densify" Mobile Networks for 5G

Traditional Cell Sites

- Expand Coverage
- Increase Capacity
- Support Diverse Mobility Use Cases

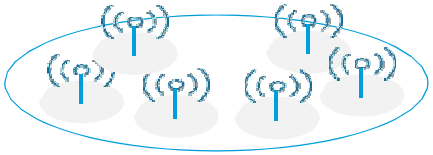
Broad (Km)

~150K

Estimated US Macro Towers Deployed 2007-2017*

Small Cells

- Increase Capacity
- Support Hyper Local Deployment
- High Bandwidth Via Point-to-Point Connections (including mmWave)



Dense (000s of m)

+770K

Estimated US Small Cells to be Deployed 2018-2026*

*Numbers and Figures Taken from CTIA Conducted Research

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Illustration: Leveraging Common Infrastructure to Implement Small Cells

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FirstNet – A Privately Built Network for Critical Communications

AT&T was selected in 2017 to build and manage FirstNet, a nationwide public safety broadband network, services, and solutions platform dedicated to First Responders and those that support them. All 50 US States, 5 Territories, and Washington D.C. have opted in to FirstNet.

Relevance of FirstNet to Road Operators?

- Example of a Public-Private Partnership (PPP) for Critical Communications
- FirstNet will Expand Coverage to Where First Responders Need It
- Certain Road Operator Users May be Eligible to Participate as “Extended Primary” Users

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Ensuring Support for Cellular Infrastructure in Funding Models

- Transportation funding mechanisms may be applied to support communications infrastructure and deployment
- By involving mobile network operators in conversations around ITS deployments, opportunities may exist to better optimize funding and impact
- Mobile network operators and Road Operators will need to work together to develop successful business models, including discussing PPPs

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Thank You

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C-V2X Workshop and Demonstration for North American Transportation Planning and Road Operator Communities

Jim Misener, Qualcomm

26 April, 2018

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Realizing the Workshop Objectives

- Objective: Extend the Partnership
  - Establish C-V2X as a viable and deployable Vehicle-to-Everything technology
  - Develop solid next steps
- Discussion of Next Steps…
  - How can road owner/operators prepare for C-V2X and 5G?
    - Are there solid steps in not precluding C-V2X, e.g., technology-neutral RSU procurements?
  - How do we establish a dialog?
    - The “5GAA community” would like to be part of the US connected and automated vehicle community
      - Can we join you? Can you join us?
  - Next meetings and opportunities for deeper engagement?

Automotive + Telecommunications + Road Owner/Operators → Deployment

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Six C-V2X Demonstrations

26 April 2018

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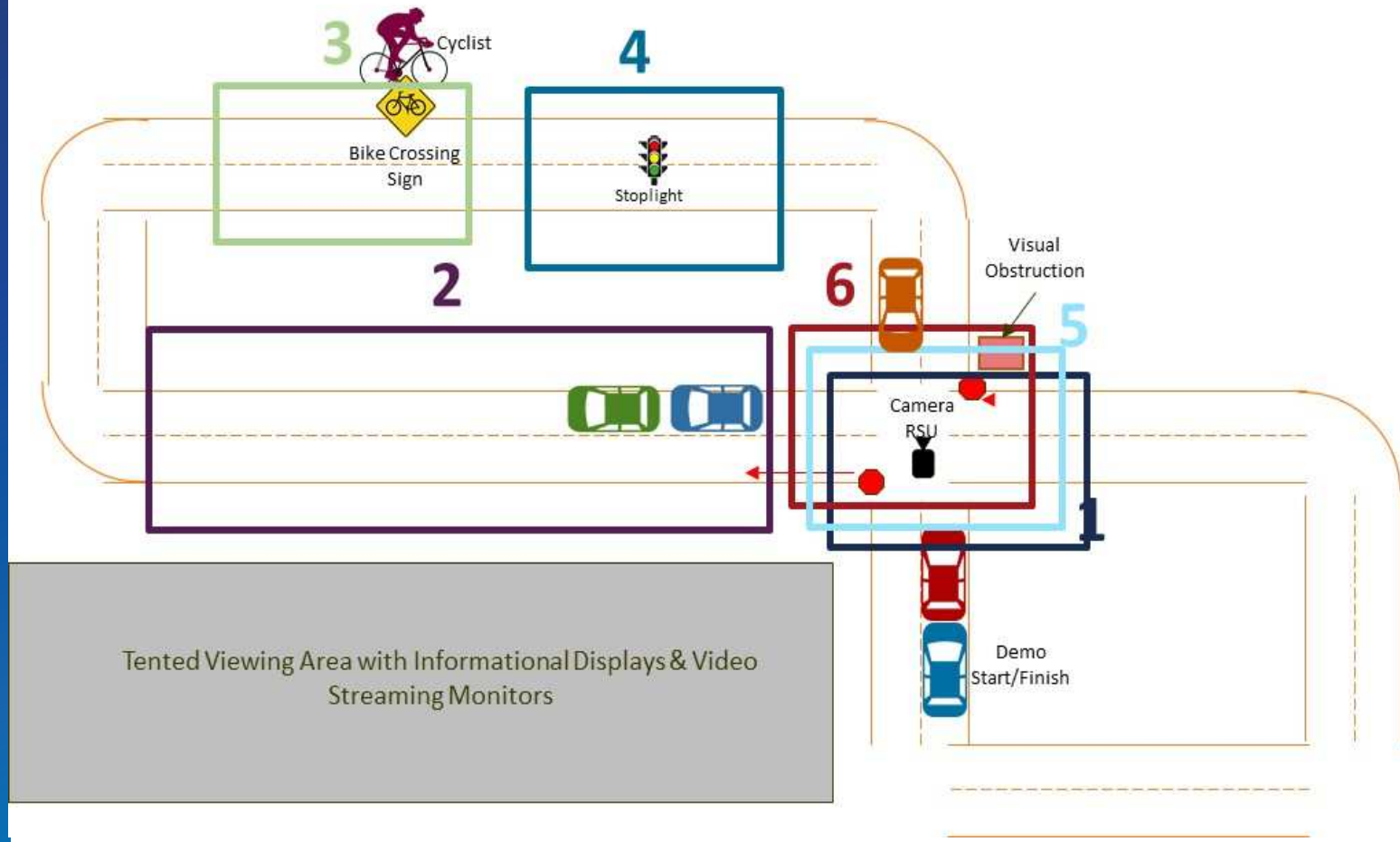
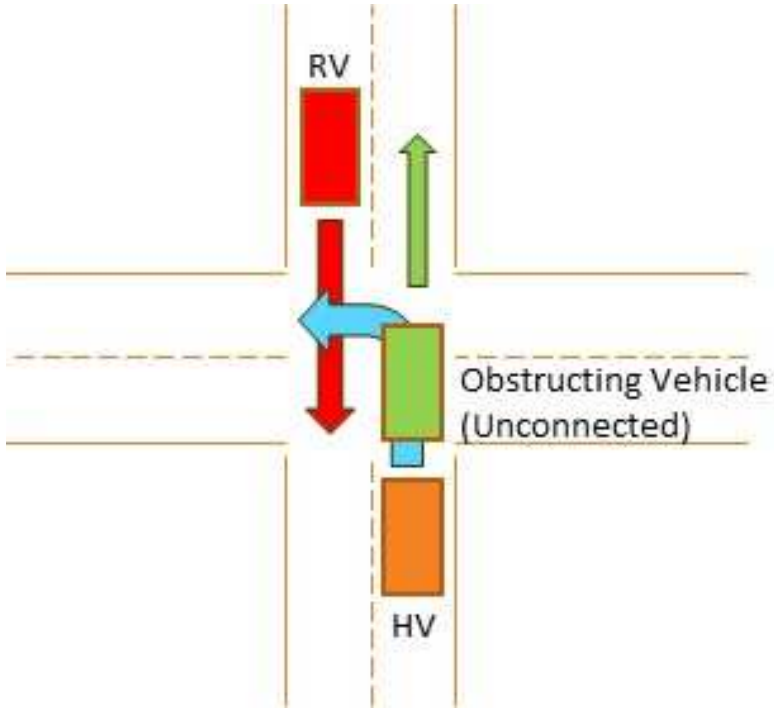
Demonstration Use Cases

1. Left turn assist
2. Emergency electronic brake light
3. Cyclist road crossing alert
4. Traffic signal timing
5. Intersection movement assist
6. Video streaming RSU



Left Turn Assist

Scenario: HV turning left at intersection with view obstructed by another vehicle, RV goes straight through intersection, triggering left turn assist alert in HV



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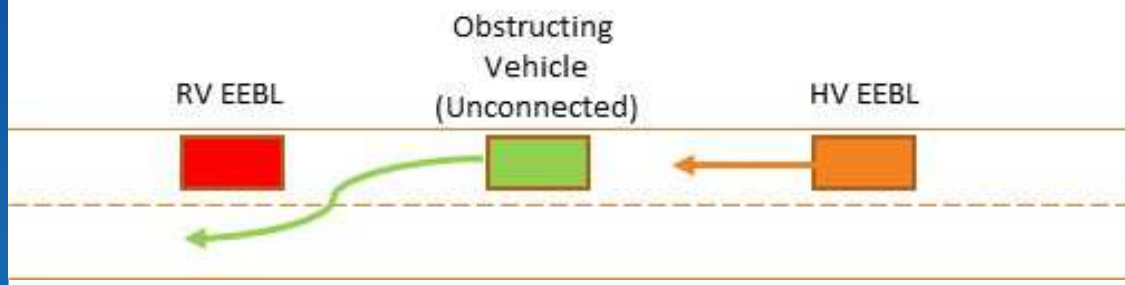
Emergency Electronic Brake Light (EEBL)

Scenario: HV turning left at intersection with view obstructed by another vehicle, RV goes straight through intersection, triggering left turn assist alert in HV



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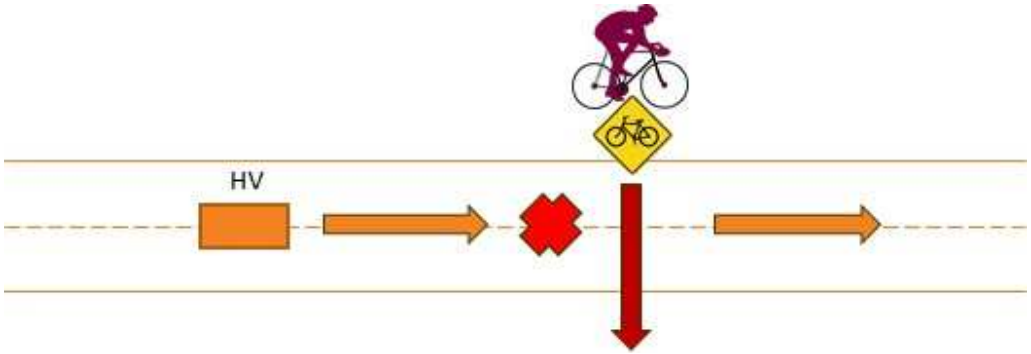
Cyclist Crossing

Scenario: HV gets notification from C-V2X board on a cyclist crossing sign warning of a cyclist crossing the road ahead. Vehicle stops to allow the cyclist to pass before proceeding.



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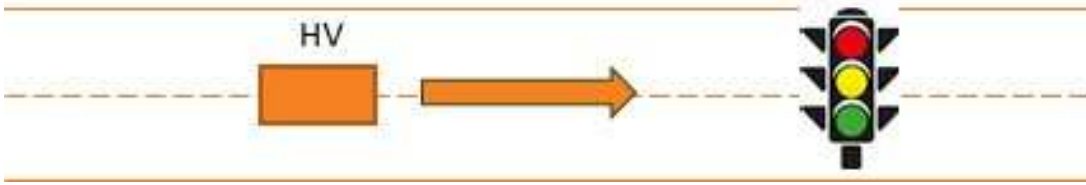
Signal Phase and Timing (SPaT)

Scenario: HV on straightaway, encounters stoplight, sees SPaT timing on HMI



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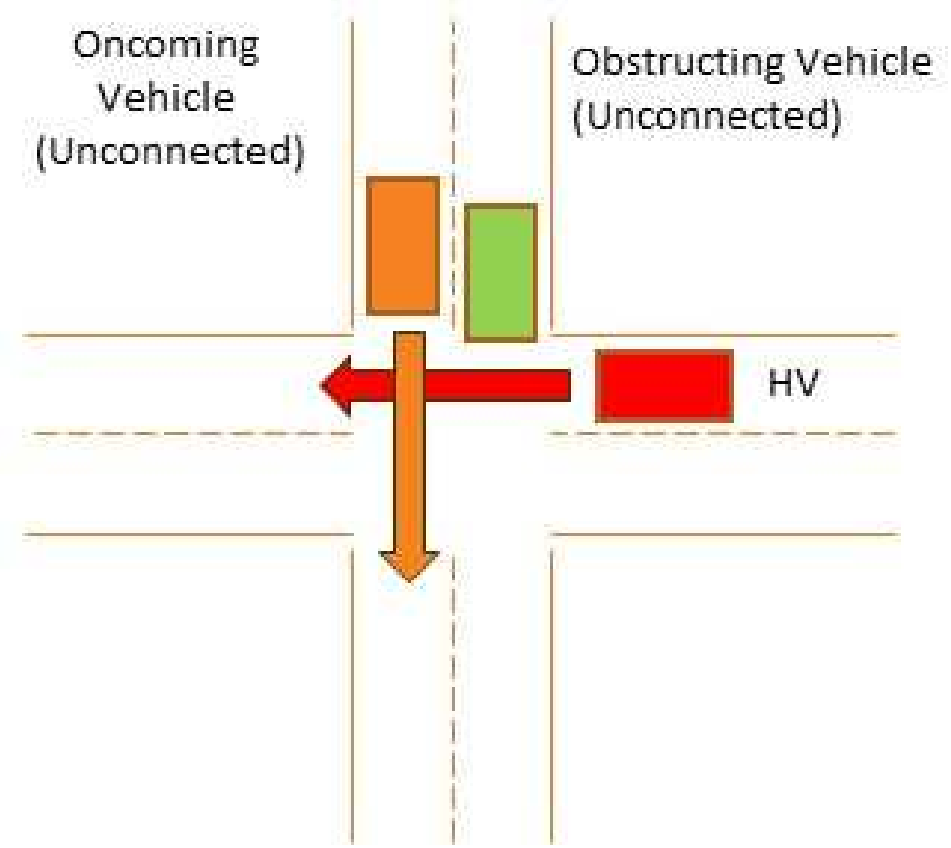
Intersection Movement Assist

Scenario: HV going straight through intersection, RV crosses directly in front, triggering intersection movement assist alert



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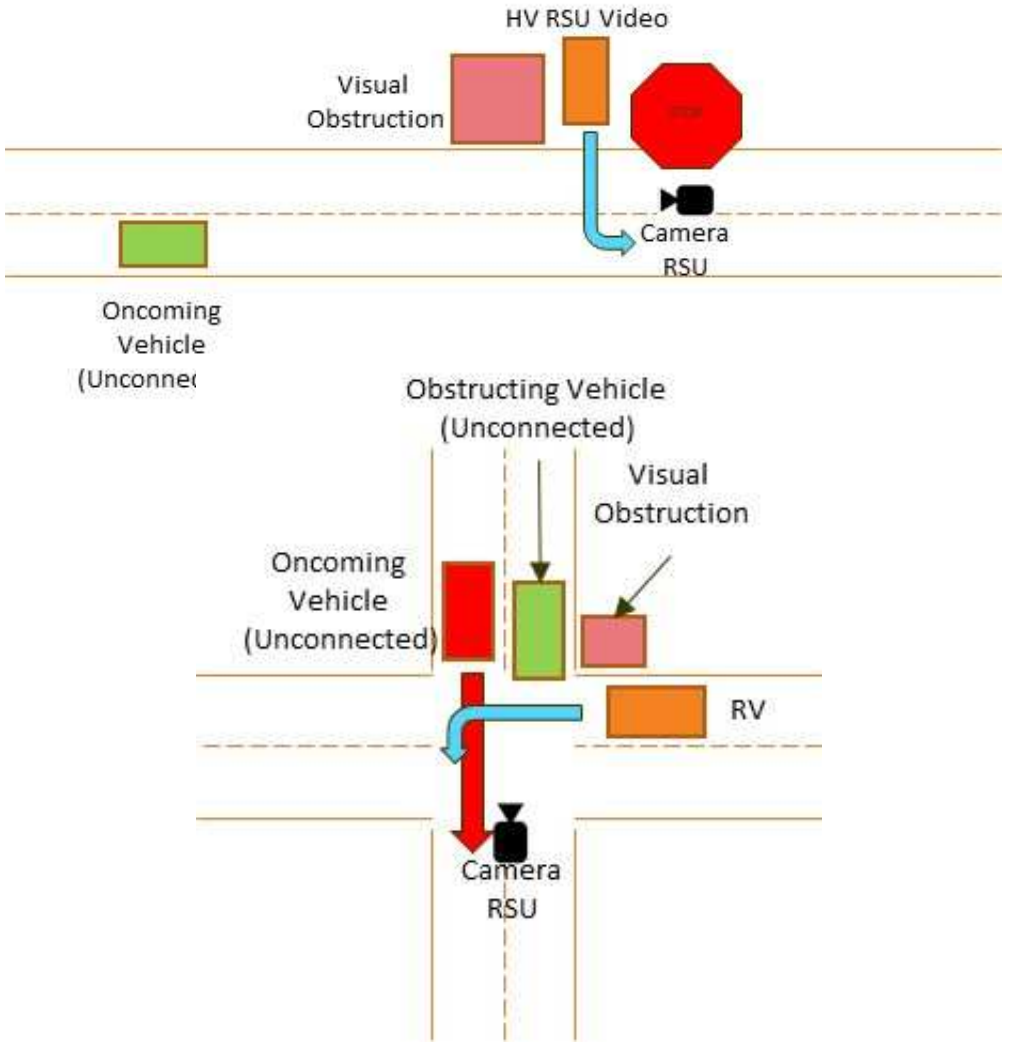
RSU Video Layout

Scenario: HV making blind left turn, streams video from camera RSU to see oncoming unconnected vehicle

Scenario: HV making blind left turn, streams video from camera RSU to see oncoming unconnected vehicle. HV allows vehicle to pass before proceeding.



Thank You
for joining the 5GAA C-V2X workshop!

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