Connected and Automated Vehicles (C/AV) in Caltrans

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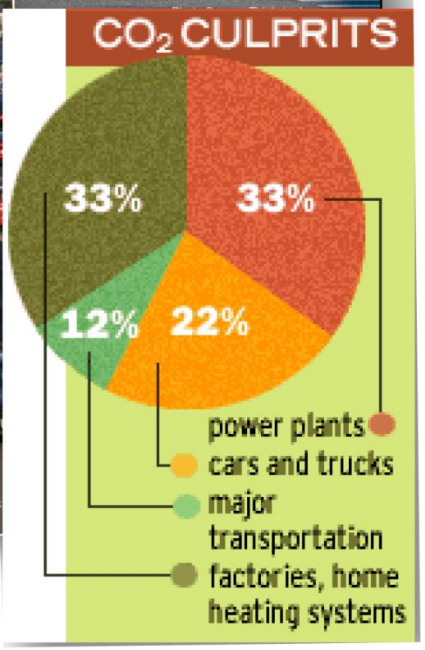
Today's Transportation Challenges

- Safety
  - 36,560 highway deaths nationally in 2018
    - 1,558 fatalities on State Highways in 2016
  - 6 million crashes per year on average
  - Leading cause of death "unintentional injuries" for ages 1-44
- Mobility
  - 8.8 billion hours of travel delay
  - $179 billion cost of urban congestion
- Environment
  - 3.3 billion gallons of wasted fuel



Data Sources: *Traffic Safety Facts: 2018 Data,* National Highway Traffic Safety Administration, October 2019; *2019 Annual Urban Mobility Report*, Texas Transportation Institute; National Vital Statistics Reports, Vol 68 No. 6, June 2019

5 Caltrans Priorities

Safety – CAVs hold the promise to reduce fatal and injury crashed on the SHS by up to 94%. Improved bike and ped safety. Tool to achieve Toward Zero Deaths and Vision Zero goals.

Modality – CAV technology can improve transit connectivity and reliability.

Innovation and Efficiency – CAV solutions provide an innovative approach to improve safety, mobility and air quality at a fraction of the cost of traditional infrastructure improvements.

Partnerships – CT is partnering internally and at the regional level, with academia as well as with private entities to leverage CAV technology to improve safety and mobility.

Background

- National Automated Highway System Consortium (NAHSC) 1997 Demo - Core Member, along with PATH
  - Highlight was the 1997 Demo on I-15 in San Diego
  - NAHSC ended its work in 1998
- Hosted a national workshop on Bus Automation in 2003 on I-15
- Truck Platooning
  - Caltrans and PATH tested on a closed track in 2003
  - Real-world testing by PATH in Nevada in 2009
  - Caltrans supporting recently awarded PATH/Volvo grant for truck platooning in an operational setting
- Bus Steering automation on narrow right-of-way - 2016
  - Lane County bus circulator system in Eugene, Oregon
  - AC Transit Bus at the San Mateo Bridge Toll Plaza

SAE Levels of Automation

Often referred to as Autonomous

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

Full Automation

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Connected and Automated Vehicles

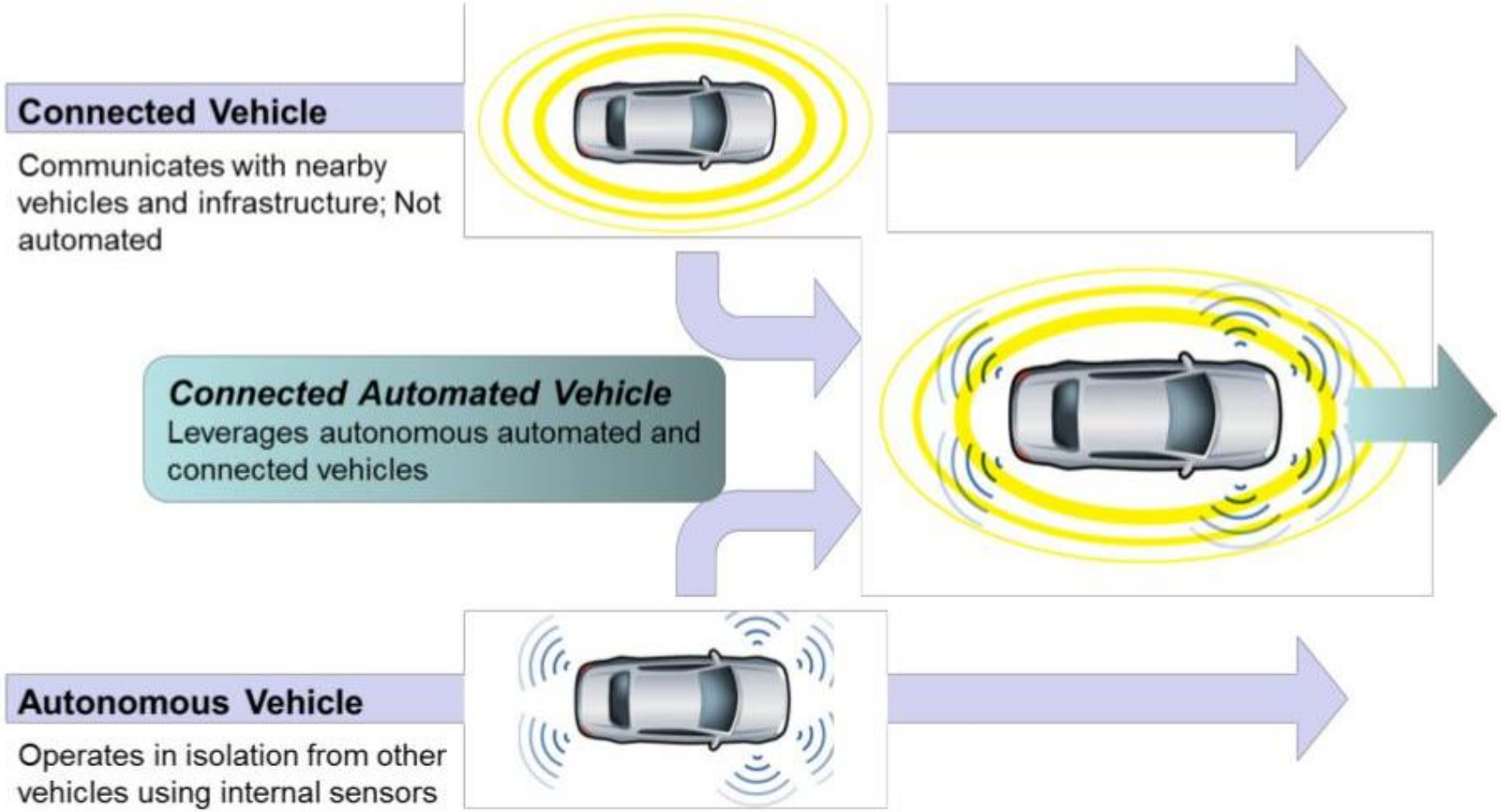


Image Source: Thinkstock/USDOT

U.S. Department of Transportation
ITS Joint Program Office

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Safety through Connectivity

- Vehicle to vehicle (V2V)
- Vehicle to Infrastructure (V2I)
  - Roadside equipment such as Traffic Signals
- Vehicle to Everything (V2X)
  - All variations in including Bikes and Peds – V2P
- Utilize line-of-site point-to-point communications technology
  - Low latency / high reliability
  - DSRC – Dedicated Short Range Communications
  - C-V2X – Cellular Vehicle to Everything
- Roadside Units (RSU)
  - Infrastructure based
- On Board Units (OBU)
  - Vehicle equipment
- Cloud or Cellular systems can support some mobility applications

C/AV Research Areas

Caltrans is actively engaged in the three areas: Technology Development, Applications and Standards

Technology Development

- Infrastructure Development
  - Model 2070 Traffic Controller Improvements
  - Upgrading Traffic Signal Control Program to work with C/AV Applications
  - Two Processor Model 2070 Controller
- Standard Design for Intersection Upgrades for C/AV compatibility
  - Mapping
  - High Accuracy GPS
  - Security Credential Management System
- Broadcast and Reception Capability
  - Signal Phase and Timing
  - MAP Message
  - High Accuracy GPS Message (RTCM)
  - Basic Safety Message

C/AV Research Areas (Continued)

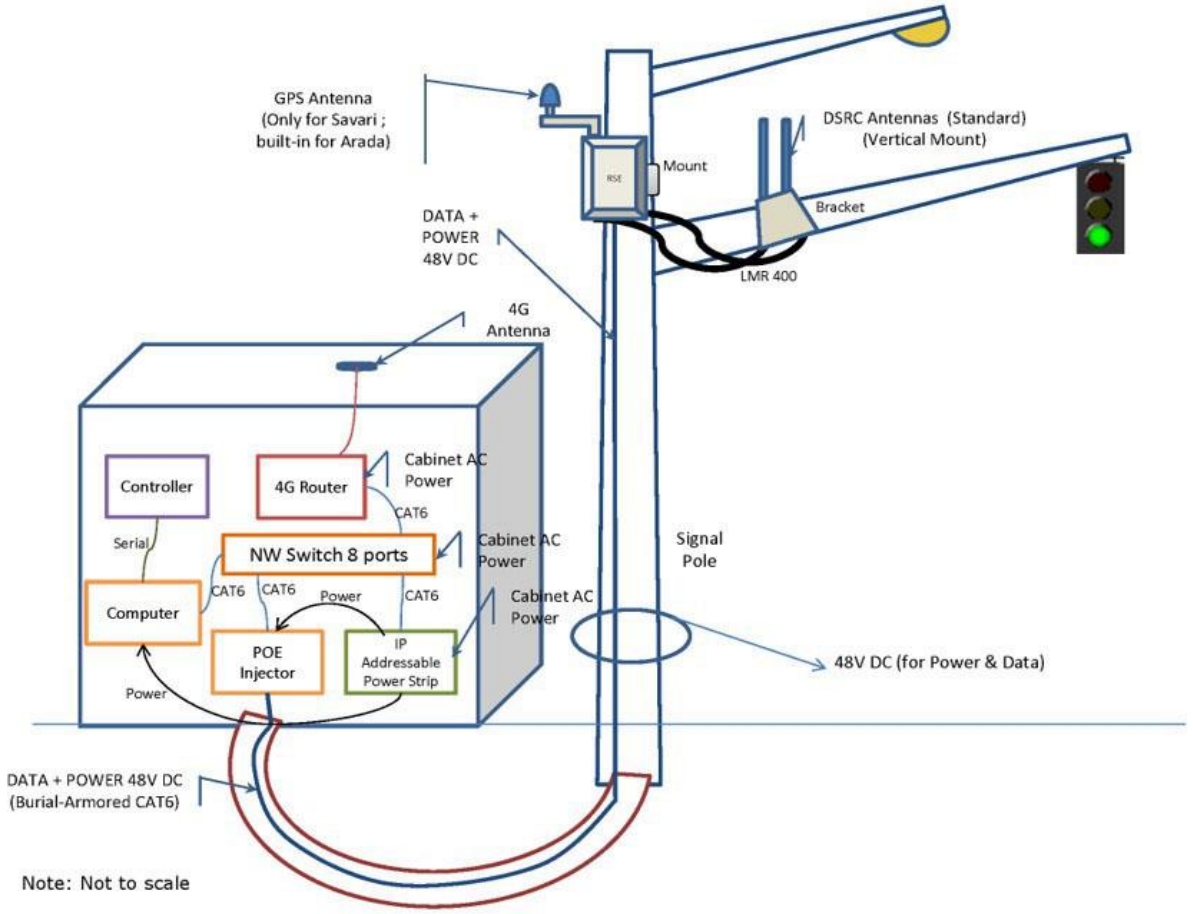
Application Development

- Eco Approach and Departure
- Transit Signal Priority
- Red Light Violation Warning
- Mid Block Pedestrian Detection
- Bike Signal Priority
- Lane Closure Warning
- Pedestrian Mobility

Standards & Regulation Development

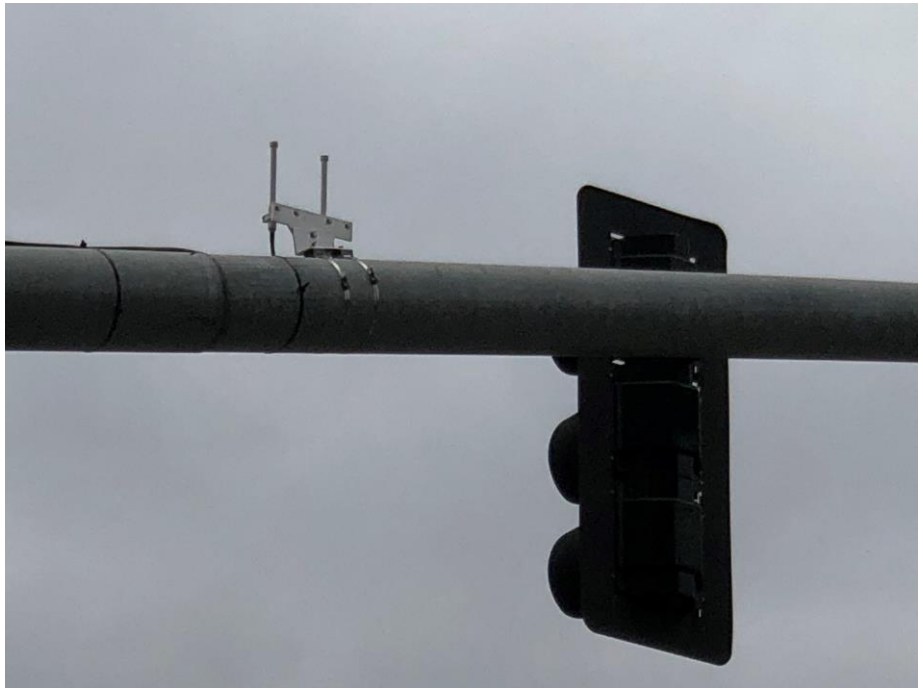
- Involvement in various TRB, NCHRP and USDOT sponsored projects

Example Layout Schematic (Roadside)

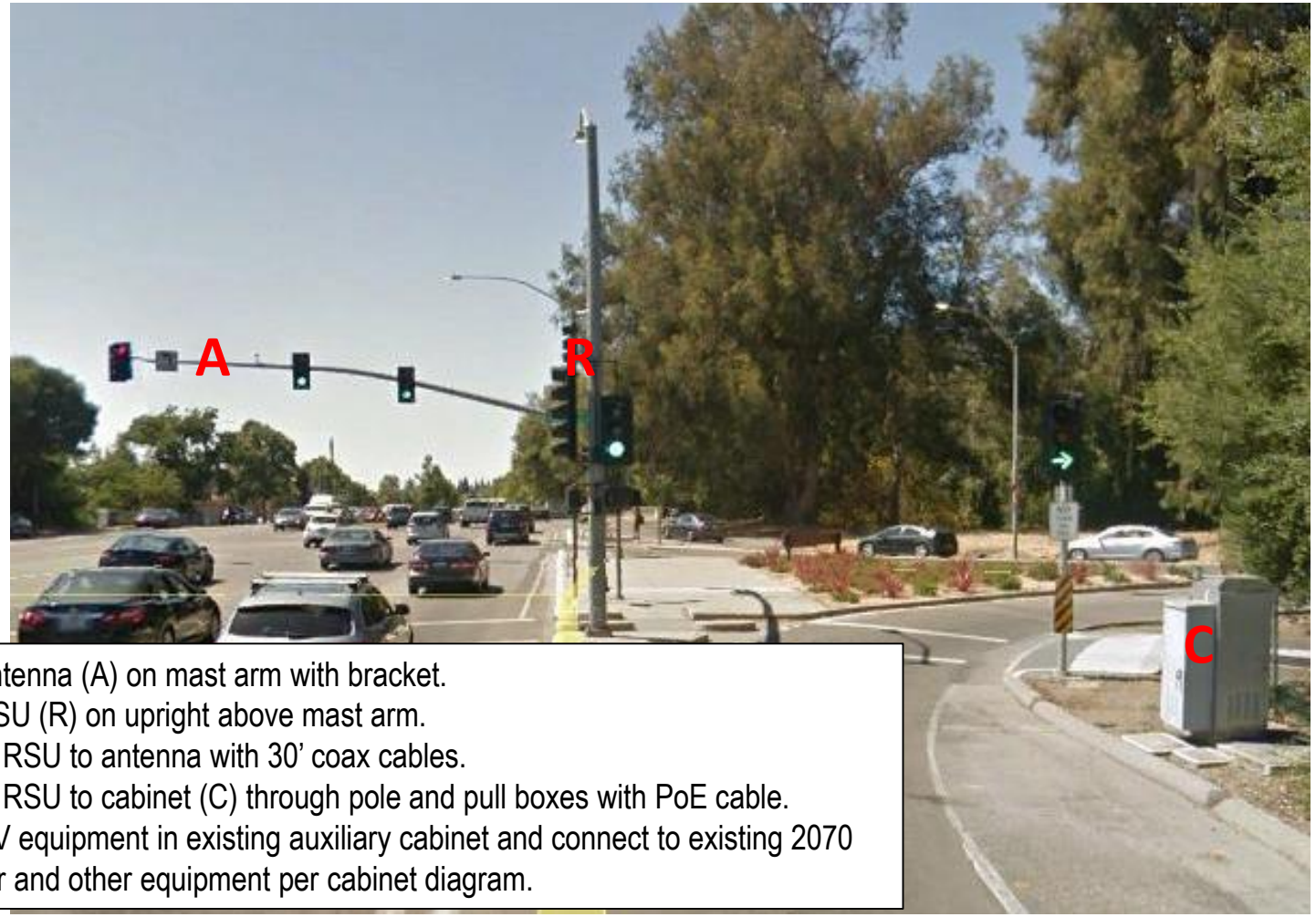


Actual Installation (RSU and Antenna)

El Camino Real & Park Avenue Intersection



Example Intersection Design



A = Antenna

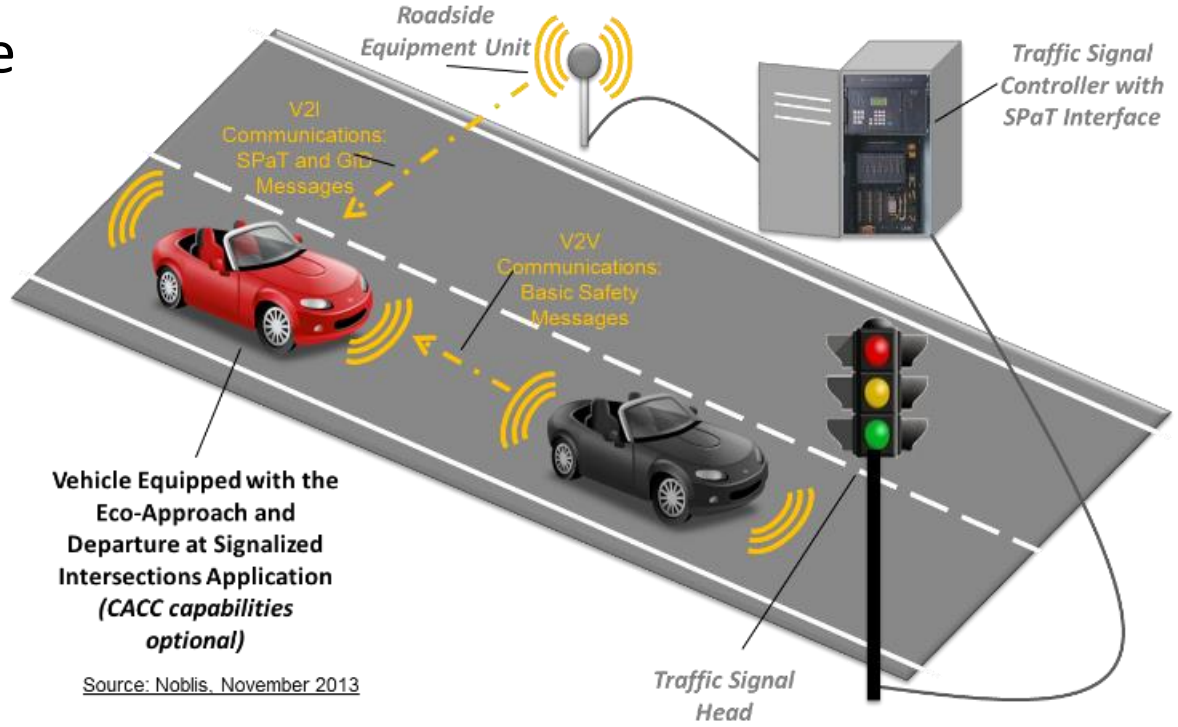
R = RSU

C = Cabinet

1. Install antenna (A) on mast arm with bracket.
2. Install RSU (R) on upright above mast arm.
3. Connect RSU to antenna with 30’ coax cables.
4. Connect RSU to cabinet (C) through pole and pull boxes with PoE cable.
5. Install CV equipment in existing auxiliary cabinet and connect to existing 2070 controller and other equipment per cabinet diagram.

Eco-Approach and Departure

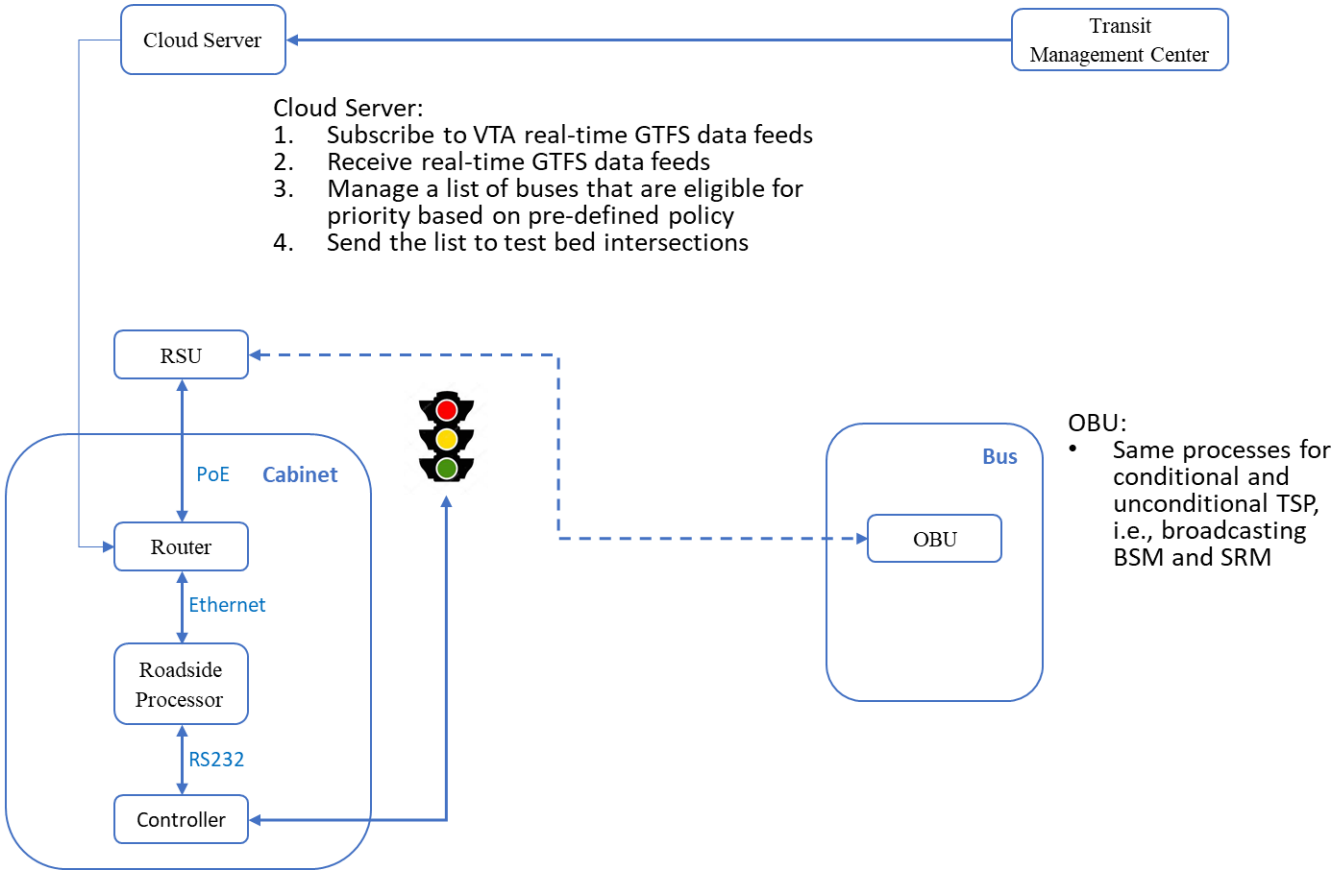
- ***Basic Concept***
  - EAD Application utilizes traffic signal phase and timing (SPaT) data to provide driver recommendations that encourage “green” approaches to signalized intersections
- ***Highlights***
  - Ability to handle actuated signals
  - Utilizes RTCM correction message (DSRC) for lane-level position accuracy
  - Detects downstream vehicles/queues using radar (critical for real-world mixed traffic environment)
  - Currently, MAP data is hardcoded (enabling DSRC MAP messages)



Source: Noblis, November 2013

Transit Signal Priority

- Implemented DSRC-based and Cloud-based (4G/LTE) TSP
- Conditional TSP for VTA route 522 and 22



Cloud Server:
1. Subscribe to VTA real-time GTFS data feeds
2. Receive real-time GTFS data feeds
3. Manage a list of buses that are eligible for priority based on pre-defined policy
4. Send the list to test bed intersections

Roadside Processor:
1. Processing BSM and SRM
2. Check whether the requesting vehicle is on the eligibility list
3. Request priority to the controller only the vehicle is on the list

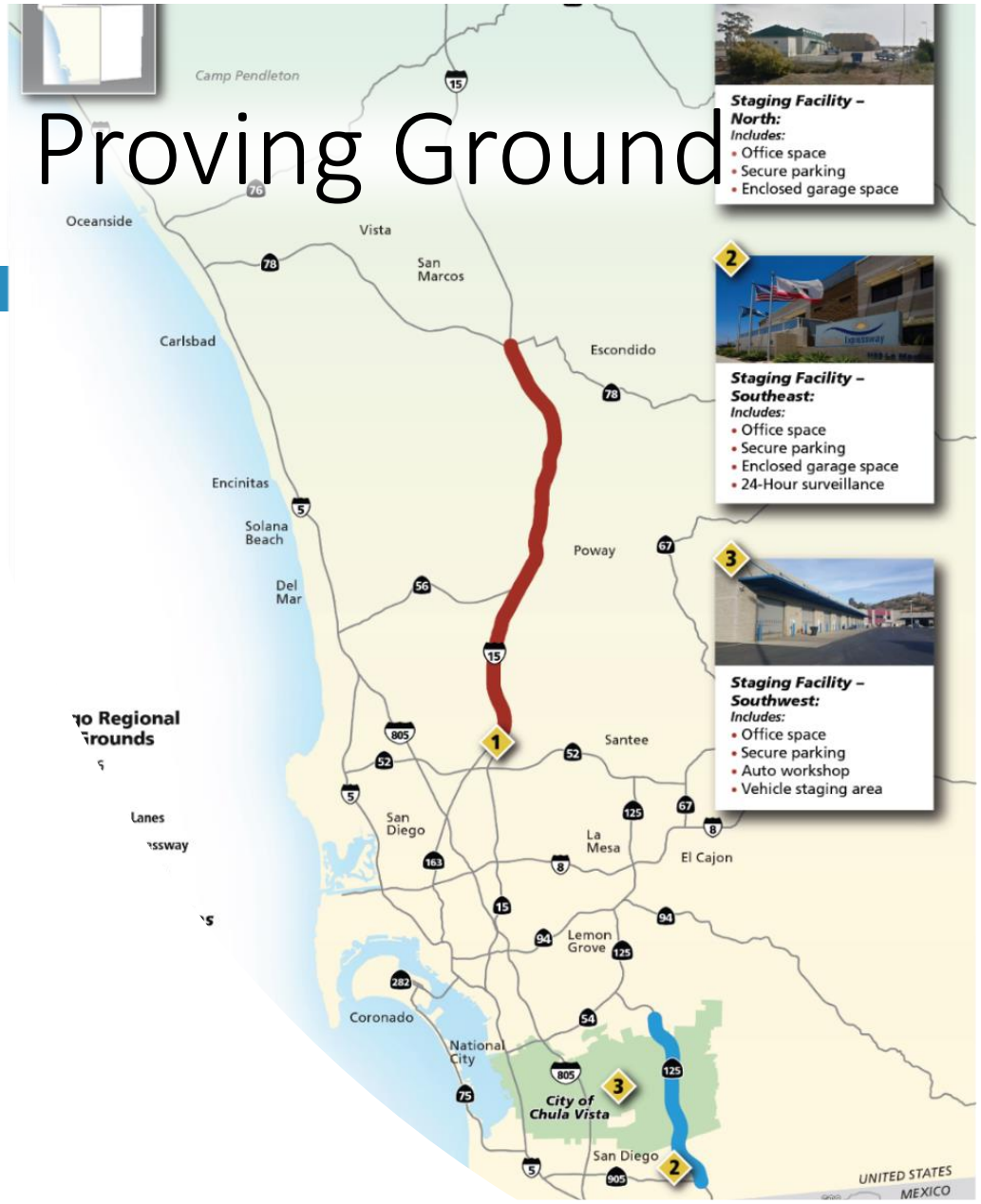
OBU:
- Same processes for conditional and unconditional TSP, i.e., broadcasting BSM and SRM

California Connected Vehicle Test Bed

- Located on El Camino Real (SR 82) - 2011
  - 7 miles with A total of 31 intersections,
  - Existing in green (16) Funded in blue (15)
    - To be completed by December 2020
  - AADT of about 50K vehicles
  - California Connected Vehicle Testbed
- Compliant with national CV standards
  - SAE J2735-201603 messages
  - V4.1 RSUs (support SCMS)
  - 4G/LTE backhaul (potential with Fiber)
  - Broadcast SPaT, MAP & RTCM corrections
  - Security Credential Management System implementation work in progress
- Test Bed Functions
  - Standardize the Roadside Equipment (RSE) Design
  - Attract the CAV application developers for application development
  - Test and develop various Caltrans focus applications
  - Developed Applications
    - Eco Approach and Departure
    - Transit Signal Priority

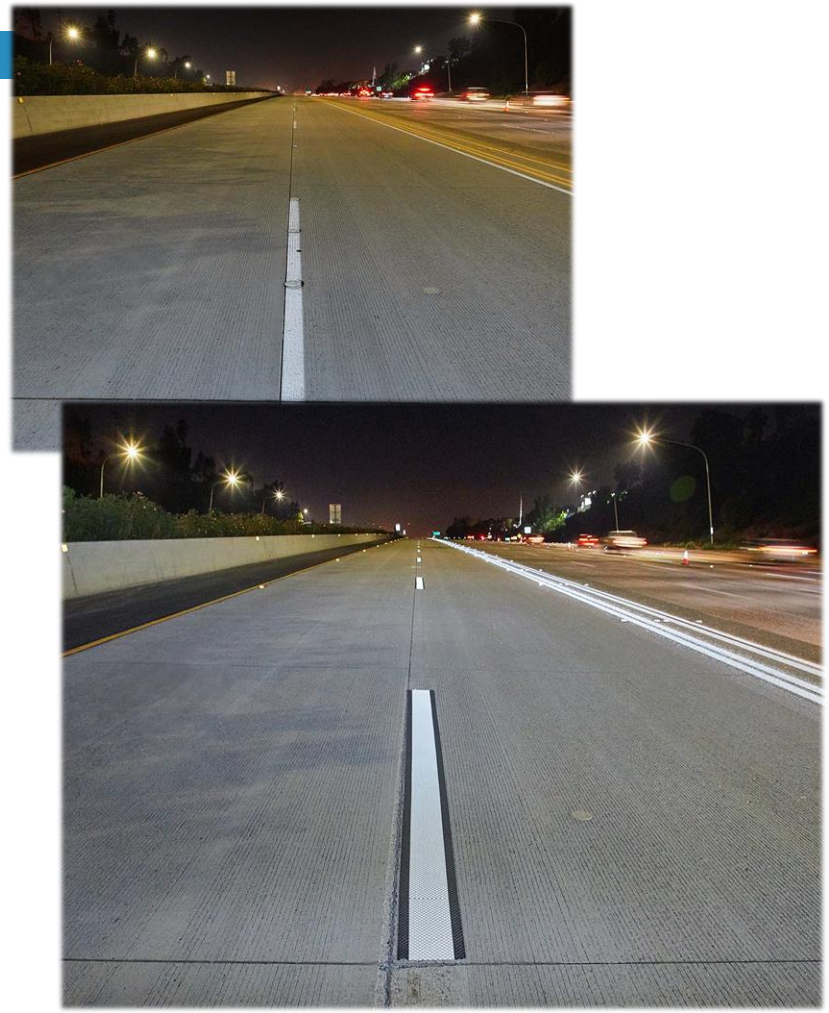
San Diego AV Regional Proving Ground

- Initially a USDOT designation in 2017
- Partnership with District 11, SanDAG, City of Chula Vista
- Consists of three locations
  - I-15
  - SR 125
  - City of Chula Vista
- District 11 Traffic Operations is the lead agency
  - Technology trials by Traffic Operations
  - Active testing and familiarization with On-Board Units (OBU), Road-Side Units (RSU)
  - Partnering with Qualcomm to pilot C-V2X technology

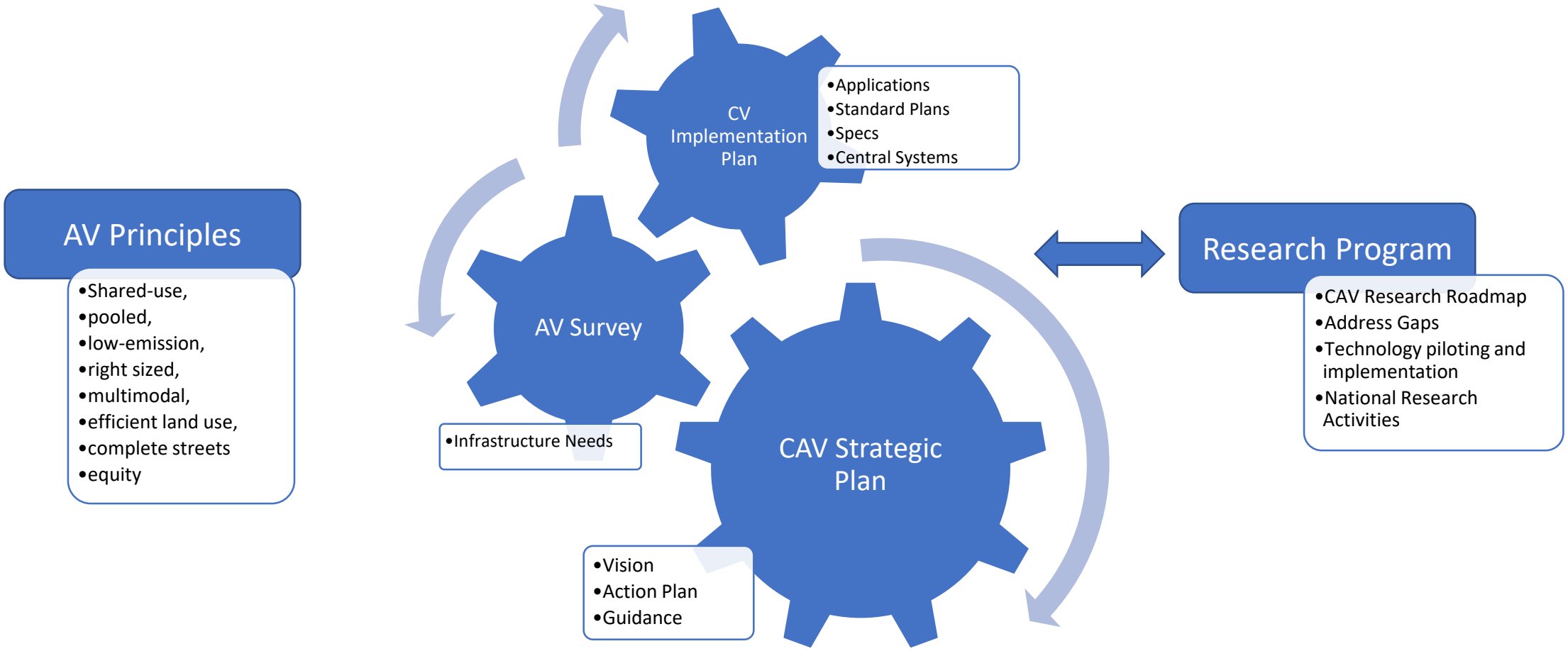


Infrastructure Improvements

- Improve infrastructure interface for both human and machine drivers
- Remove/eliminate use of “Bots Dots”
- Improved Striping detail that is now standard
  - Improved contrast
  - Better performance in wet conditions
- Better retroreflective signing
- AV Industry Survey
  - Need for better partnership with OEMs, Tier 1 providers



CT CAV Road Map



Statewide Policy Efforts

- AV Principles
  - Development led by the Governor's Office of Planning and Research in 2018
  - Caltrans participated in the development which consisted of multiple state agencies and departments
  - Key Principles
    - Shared-use, pooled, low-emission, right sized, multimodal, efficient land use, complete streets and equity

CT CAV Initiatives

- CT Strategic Plan
  - Establish a clear vision for adopting CAV technology and policies
  - Expected completion Dec 2020
- AV Industry Survey
  - Review of AV industry and how infrastructure can be better aligned
  - Expected completion Sep 2020
- CT CAV Implementation Plan
  - Development of Applications, Standards, Staffing Criteria, Skills and Organizational Needs
  - Expected completion March 2021

AV regulations

- Current DMV regulations
  - 2014 – AV Testing allowed on all roadways – passenger vehicles < 10,000 GVW
  - 2018 – Regulations for driverless AVs (without safety driver) < 10,000 GVW
- AV permits
  - Over 60 active permits issued for testing permitted with safety driver
  - 2 permits issued for full autonomous mode, no driver – Waymo, Nuro
    - 1 pending
- Requires disengagement reports
  - 2.8 mil miles driven - 9,338 disengagements in 2019 -
  - Data may prove useful for understanding AV capabilities and the interface to the infrastructure
- Partnering with sister departments
  - CHP – Responsible for enforcement – accident reporting
  - Office of Traffic Safety – Driver education – public awareness campaigns

Regulation Challenges

- In 2016 NHTSA proposed regulation to include DSRC radios in all new vehicles
  - Regulation was not pursued
- Two competing standards - DSRC vs C-V2X
  - DSRC was established by FCC for transportation related applications only
  - C-V2X is a industry driven standard – Qualcomm and Ford
- FCC Notice of Proposed Rulemaking (NPRM)
  - Reducing dedicated spectrum to 30 MHZ (less than half)
  - 20 MHz dedicated to C-V2X
  - 10 MHz may be dedicated to the established DSRC standard
- Closely monitoring FCC activities to finalize the spectrum allocation
  - Resolution may not be for several months
- Major impact on OEM's decisions on equipping vehicles
- Will affect policy decisions impacting new programmed projects and further research

Moving Forward

- In this rapidly changing environment, Caltrans will continue to work with our state and local partners to develop a comprehensive Connected and Automated Vehicle plan to improve safety, mobility, air quality and equity for our customers.

Thank You!