V2X Applications

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March 16, 2023

UNECE Future Networked Car Forum

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Toyota InfoTech Labs

Toyota Motor North America

Base: Mountain View Research Park (US Headquarters)

Location: Mountain View, California

Established: April 2001

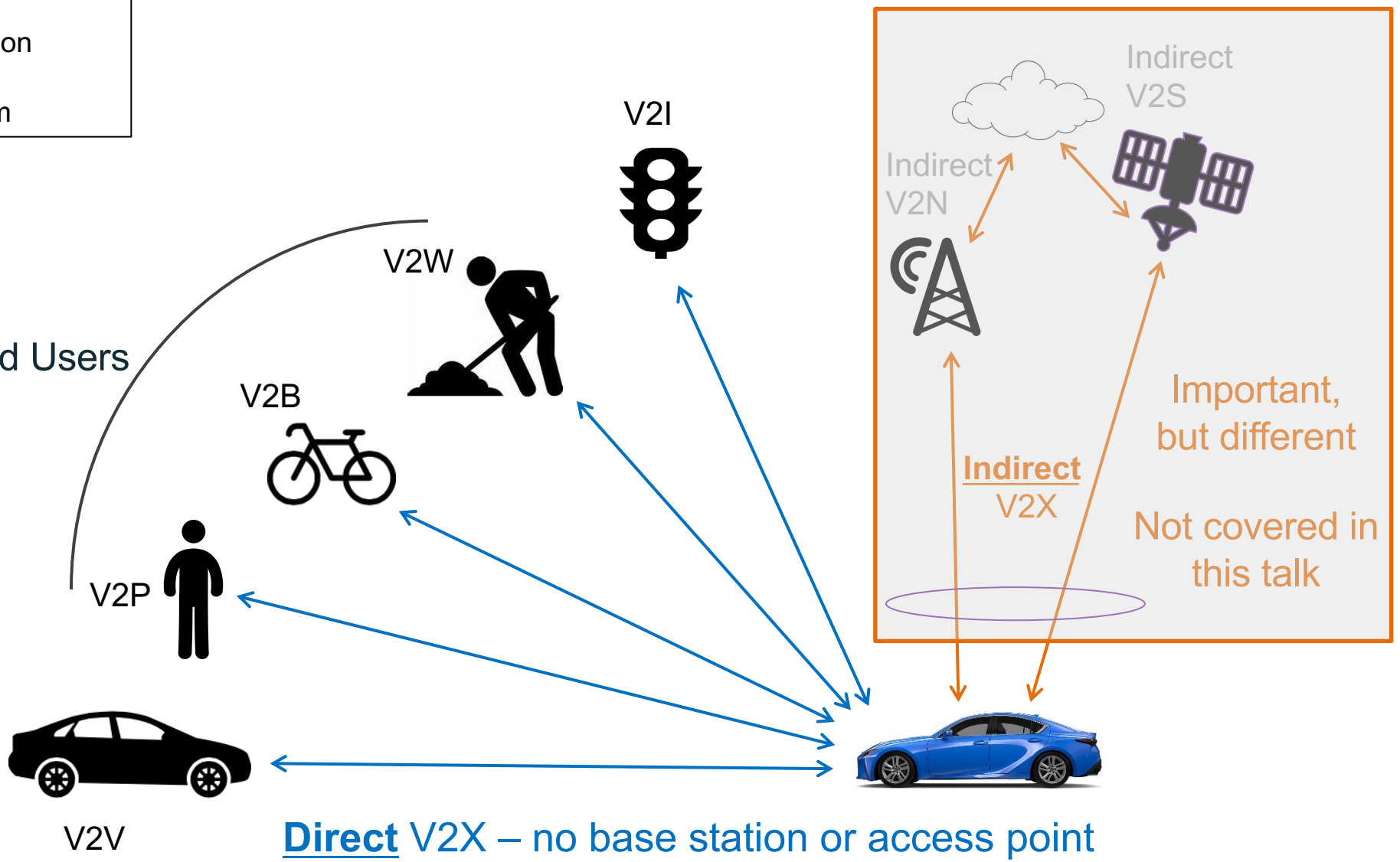
Formerly known as Toyota InfoTechnology Center

Approx. 50 research staff

V2X is Vehicle-to-Everything direct communication

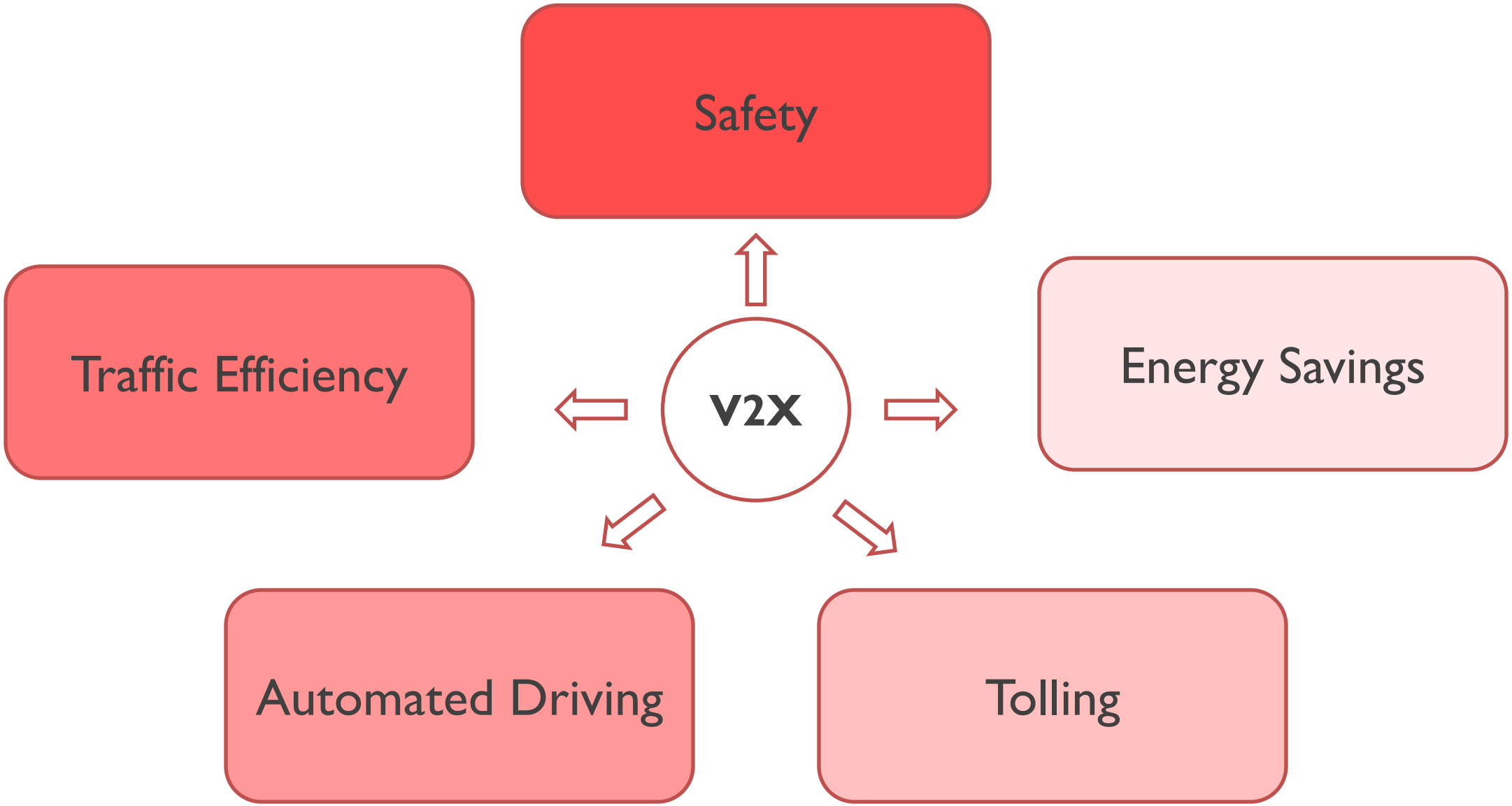
V2X Characteristics:
- Ad hoc communication
- Low latency
- Free public spectrum

Collectively:
Vulnerable Road Users
(VRUs)



Direct V2X – no base station or access point

V2X enhances or supports …



V2V Safety Concept

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Envisioning Mobility

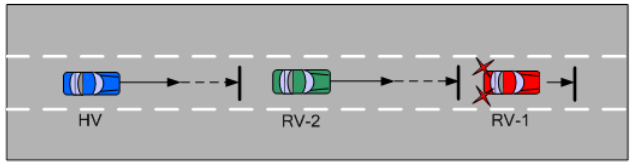
Basic Safety Message (SAE J2735)

- Location
- Speed
- Acceleration
- Heading
- Brake Status
- Path History
- Event Flags
- Vehicle size
- Other vehicle data

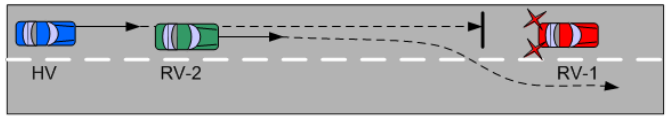
- Concept: each vehicle sends Basic Safety Messages frequently in all directions.
- Receiving vehicles assess collision threats
- Threat: Warn driver or take control of car

Note: Other global regions have BSM-equivalents, e.g. ETSI CAM

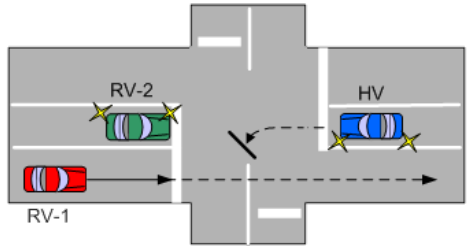
Example V2V collision avoidance applications



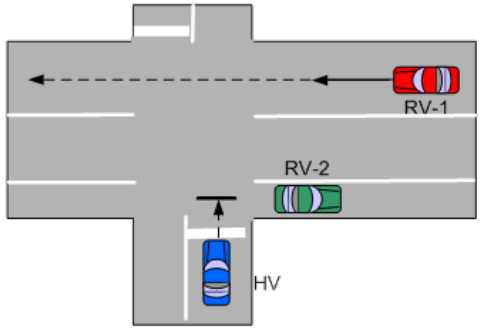
Emergency Electronic Brake Lights (EEBL)



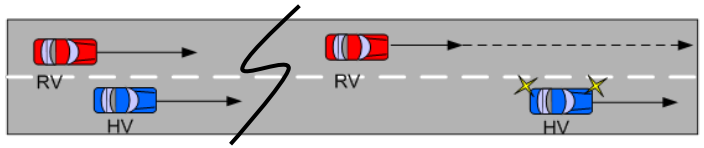
Forward Collision Warning (FCW)



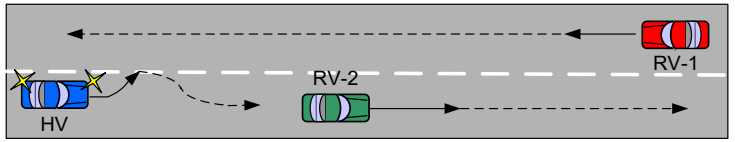
Left Turn Assist (LTA)



Intersection Movement Assist (IMA)



Blind Spot / Lane Change Warning (BSW / LCW)



Do Not Pass Warning (DNPW)

- All apps enabled by exchange of V2V BSMs
- Receiver applications are not standardized
- Innovative uses of BSM encouraged

NHTSA estimates V2X can address ~80% of non-impaired-driver crashes

These two intersection apps alone can save > 1000 lives per year

HV = Host Vehicle (driver gets a warning)
RV = Remote Vehicle (its BSM triggers warning)

Note: Channel Congestion Control is needed for high vehicle density scenarios. See ETSI TS 102 687 and SAE J2945/1

I2V and P2V also support safety

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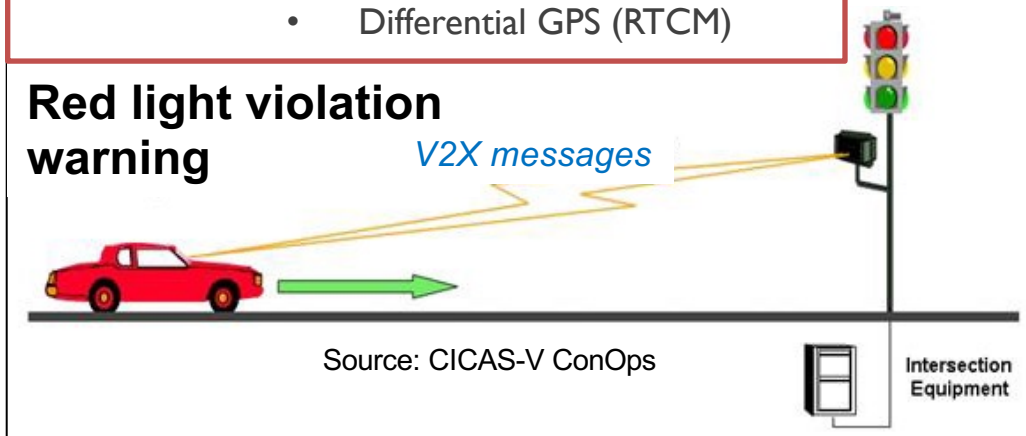
I2V Messages
- Signal Phase and Timing (SPaT)
- Geographic Map
- Differential GPS (RTCM)

Red light violation warning

V2X messages



Source: CICAS-V ConOps

Safe driving support **Traffic Queue Warning**

Brings one's attention to unseen traffic congestion such as ahead of curvy roads in accident-prone areas

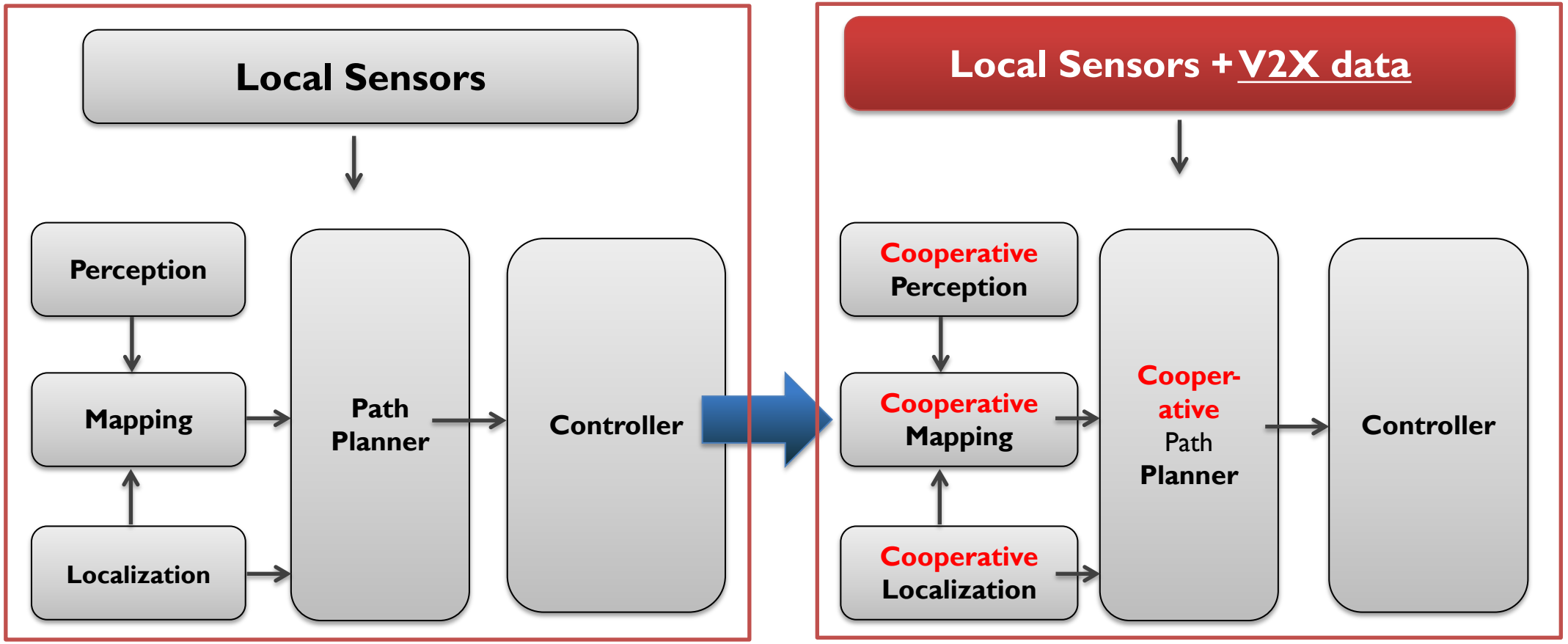
Source: VICS (Japan)

Road-Side Unit equipped with sensors (e.g. camera)

Smartphone

Cooperative Automated Driving (CAD)

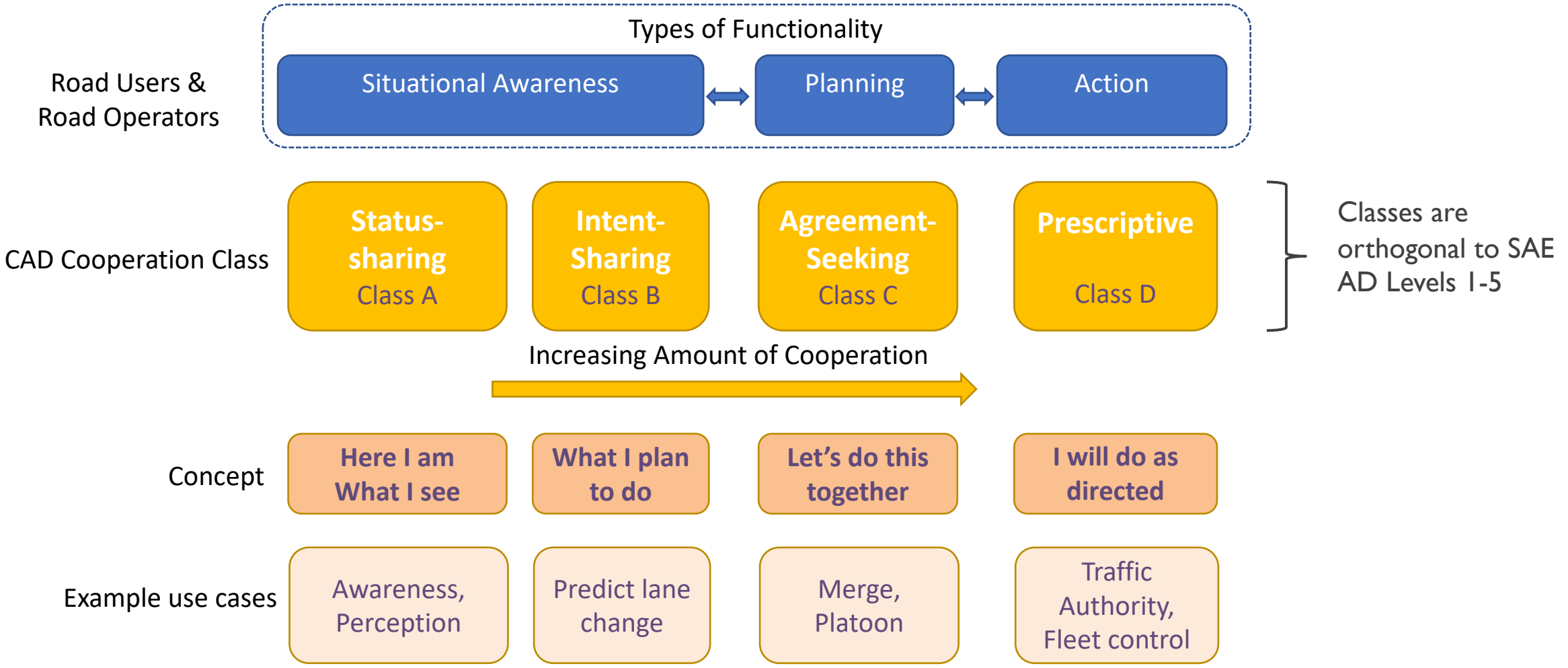
CAD uses V2X data to improve localization, mapping, perception, and path planning



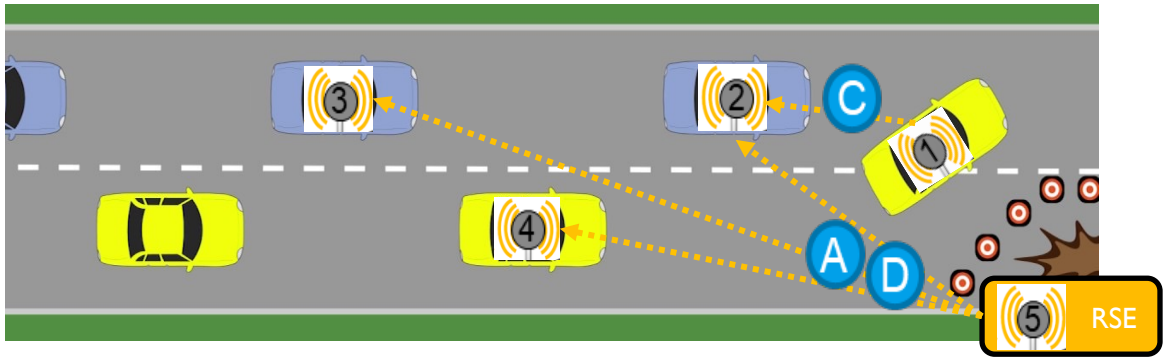
Standard Automated Driving Functions

Cooperative Automated Driving Functions

SAE Taxonomy and Terms for CAD (J3216)

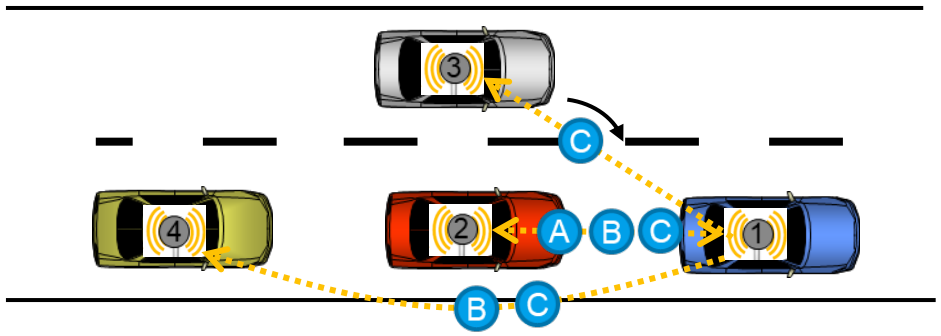


Use cases involve multiple classes: 2 Examples



Cooperative traffic management with temporary lane closure and dynamic speed limit

- A Work Zone Awareness
- C Cooperative Merge
- D Reduced speed limit



Cooperative vehicle following features

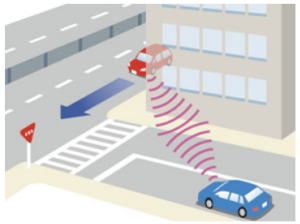
- A Location, Velocity, Close following
- B Intend to reduce speed
- C Mid-platoon join agreed

Japan “ITS Connect”

- Direct V2X in Japan is called “ITS Connect”
- https://www.itsconnect-pc.org/en/
- Deployment began in 2015
- > 250,000 equipped vehicles

Applications of ITS Connect

Driving Assistance Service via Use of V2V Communication

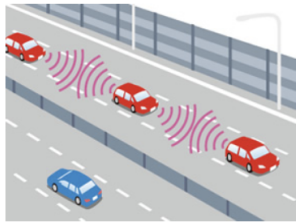


Collision Avoidance Assistance

Avoidance of collisions during left turns, right turns, entering/passing an intersection

Assistance in Confirmation of Nearby Vehicles

Assists in confirming vehicles in the vicinity using information from other cars



C-ACC (Cooperative Adaptive Cruise Control)

Adjustment of the distance between vehicles using information provided by the preceding vehicle

Information Support on Status of Nearby Vehicles

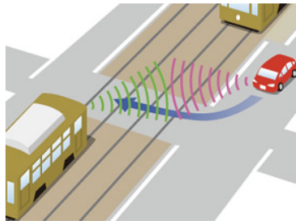
Information on the status of other vehicles and matters etc. reported by the vehicle will be sent to you

Under consideration

Information Support on Status of Passengers

Information regarding the passengers in other vehicles and passengers getting in and out of a vehicle will be sent to you

Under consideration

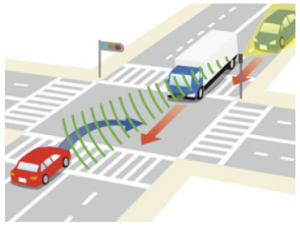


Information Support Regarding Incoming Trams

Provision of the information on the railways of trams, etc.

Under consideration

Driving Assistance Service via Use of V2I Communication



Collision Avoidance Assistance during Right Turns

Assistance in Avoiding the Overlooking of Pedestrian Crossings

Warning of overlooking a red light

Summary: V2X Applications

TOYOTA INFOTECH Envisioning Mobility

- Direct V2X supports Safety, Efficiency, Driving Automation and other applications
- Direct V2X has low latency, uses free public spectrum
- Collision avoidance applications can address ~80% of crashes
- Cooperative Automated Driving: many new advanced applications
- SAE has defined 4 classes of Cooperation in J3216
  - A given use case will often employ more than one of these classes