Making Use of Connected Functions in Advanced Driver Assistance and Automated Driving

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Toyota Motor Corporation

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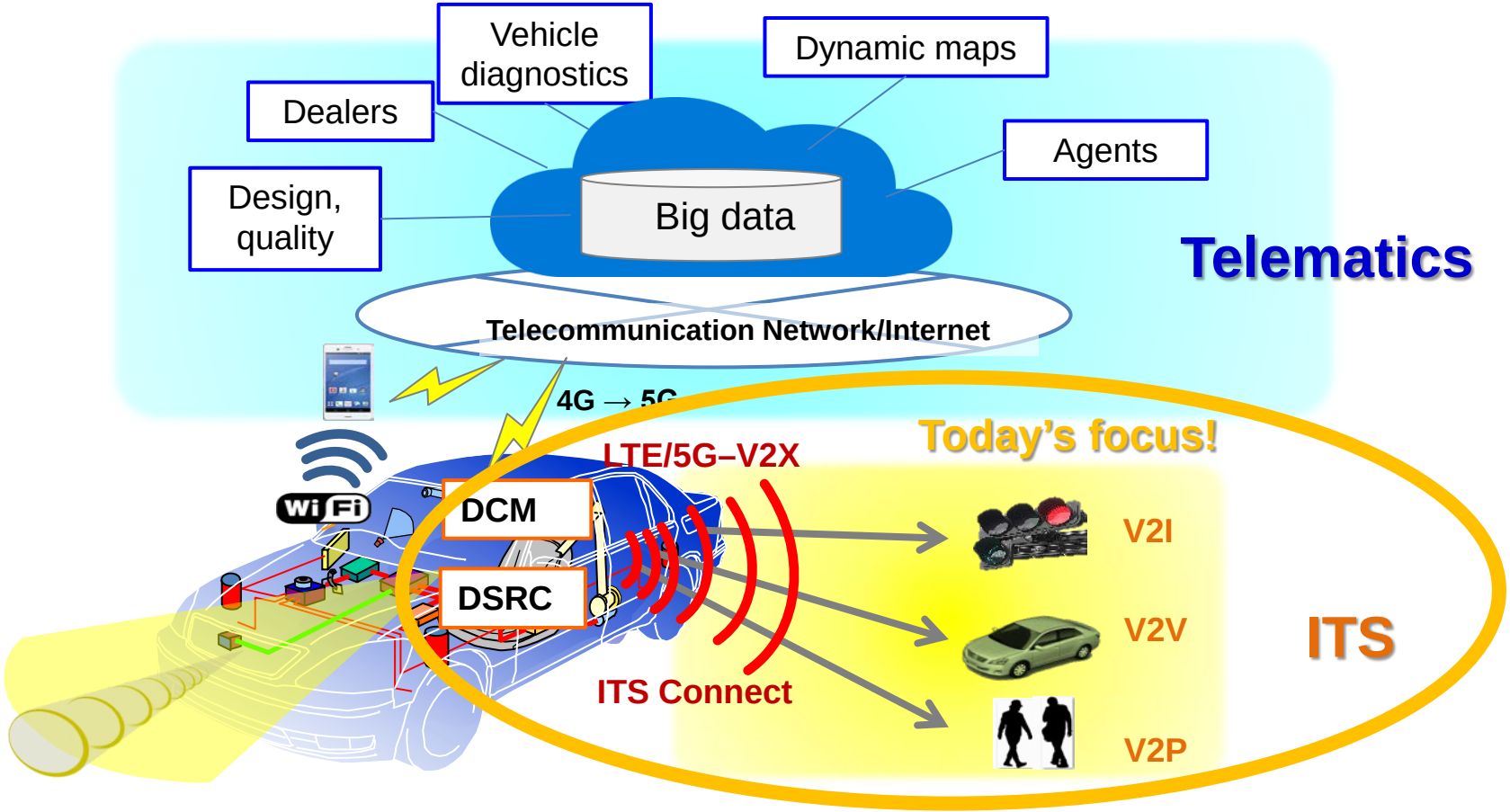
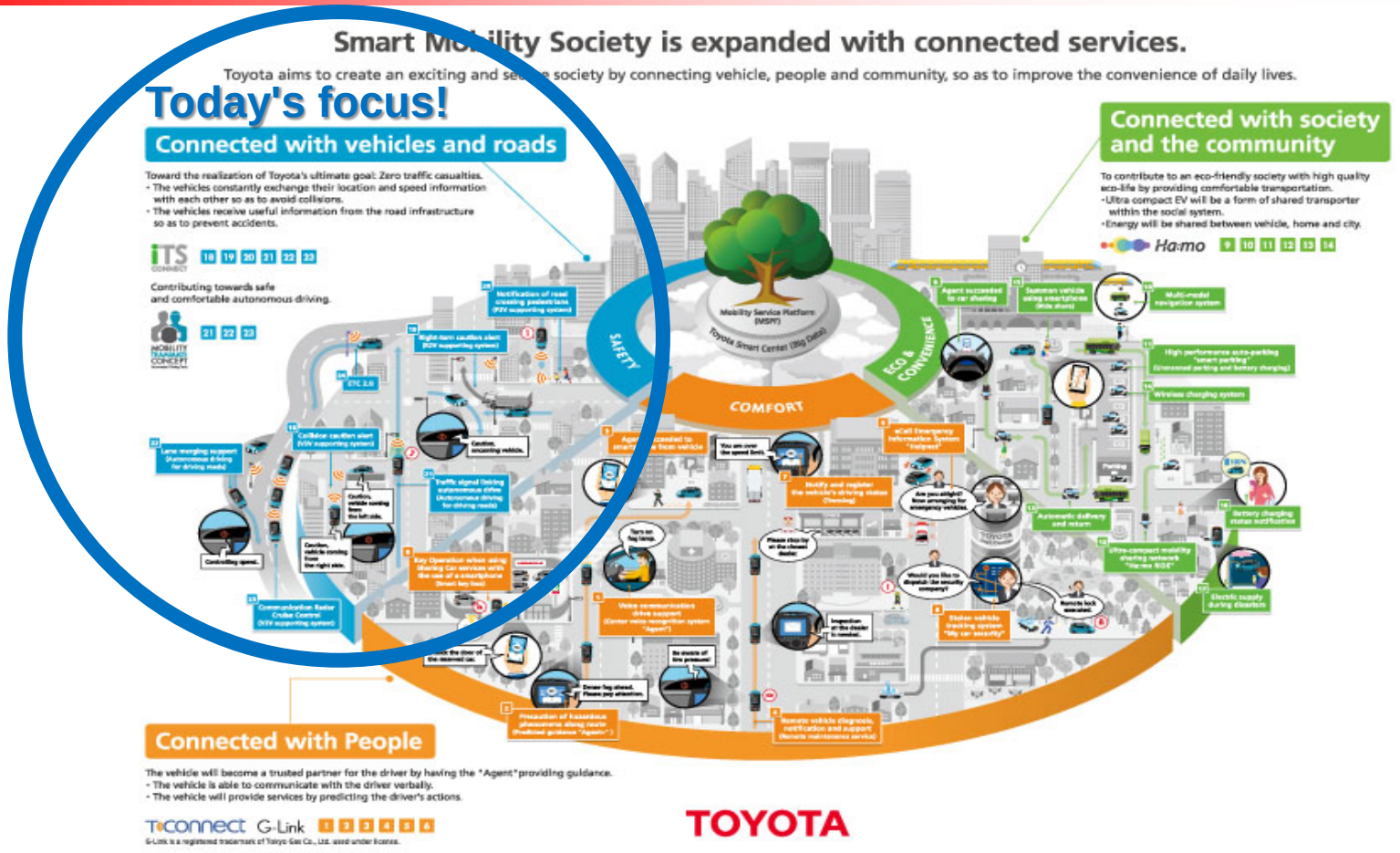
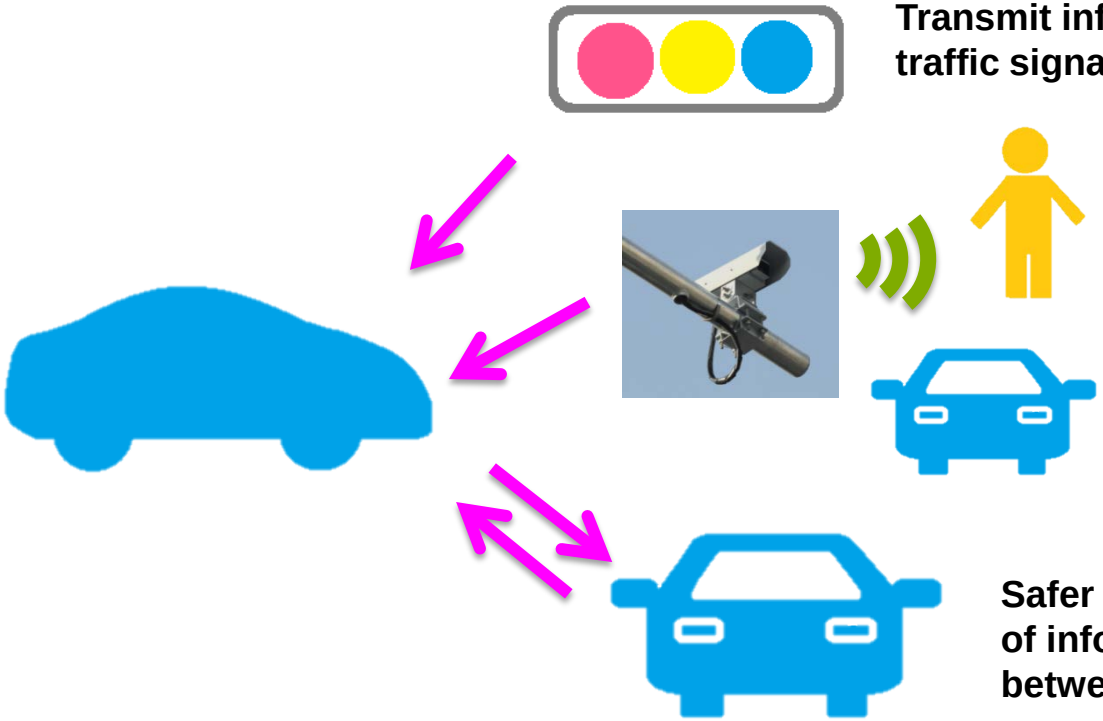
Connected Functions in Cars



Envisioned Future Services Centered on Connectivity



Connected with vehicles and roads



Transmit information such as when the traffic signal will change to vehicles.

Roadside sensors can detect oncoming vehicles hidden from sight or crossing pedestrians that drivers often fail to notice, and alert the vehicle.

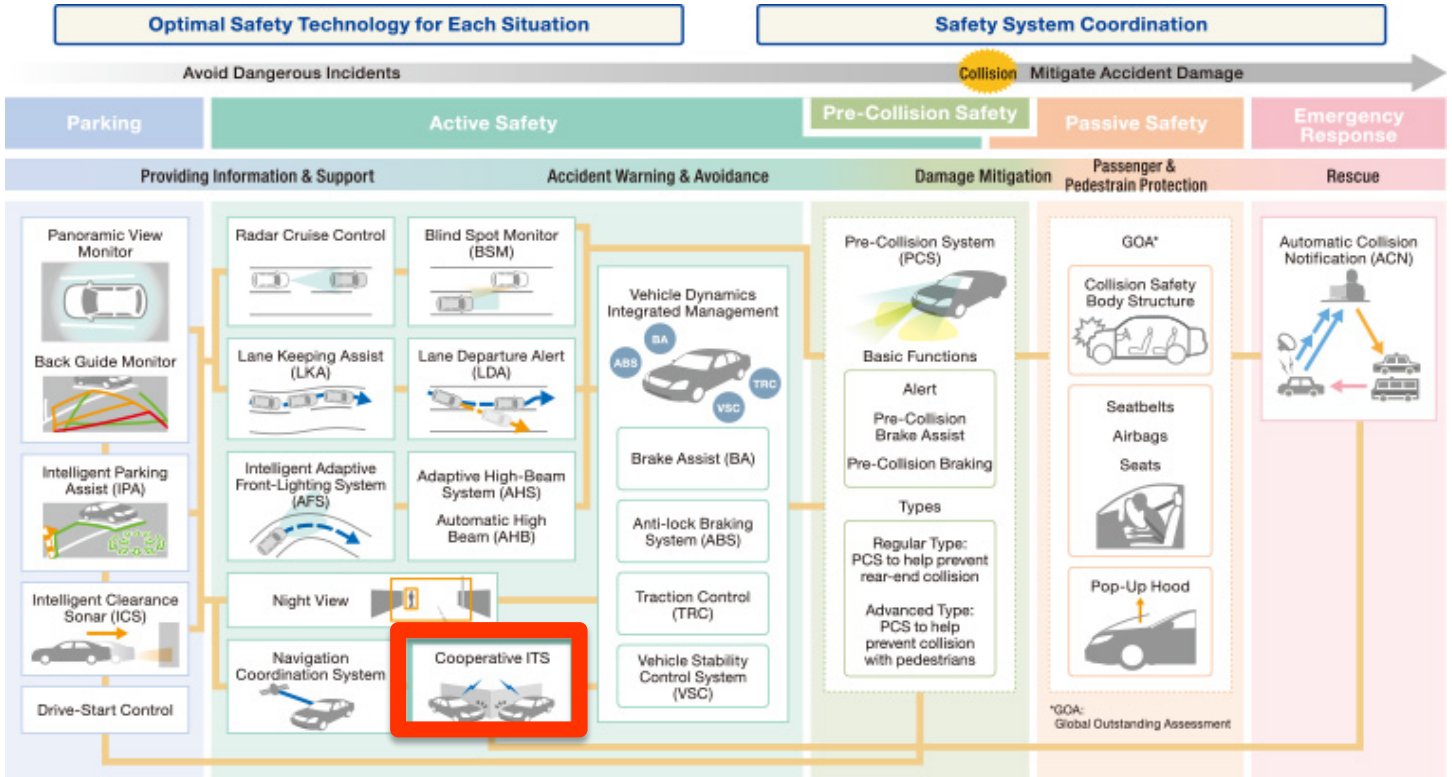
Safer driving based on the mutual exchange of information such as location and speed between vehicles.

Toward the realization of Toyota's ultimate goal

Zero traffic casualties

Integrated Safety Management Concept

Optimal support for all driving situations
Integration of individual safety systems

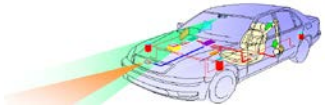


Autonomous and Cooperative Systems

Various safety systems

Autonomous systems

Pre-collision safety system



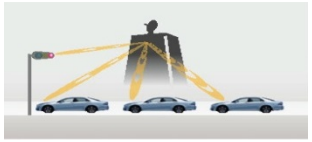
Radar cruise control

On-board cameras, radar or other sensors are used to detect objects (other vehicles, pedestrians) around the vehicle within the visibility range.

* These systems cannot fully cover areas outside the visibility range.

Cooperative systems

Roadside-to-vehicle communication



Vehicle-to-vehicle communication

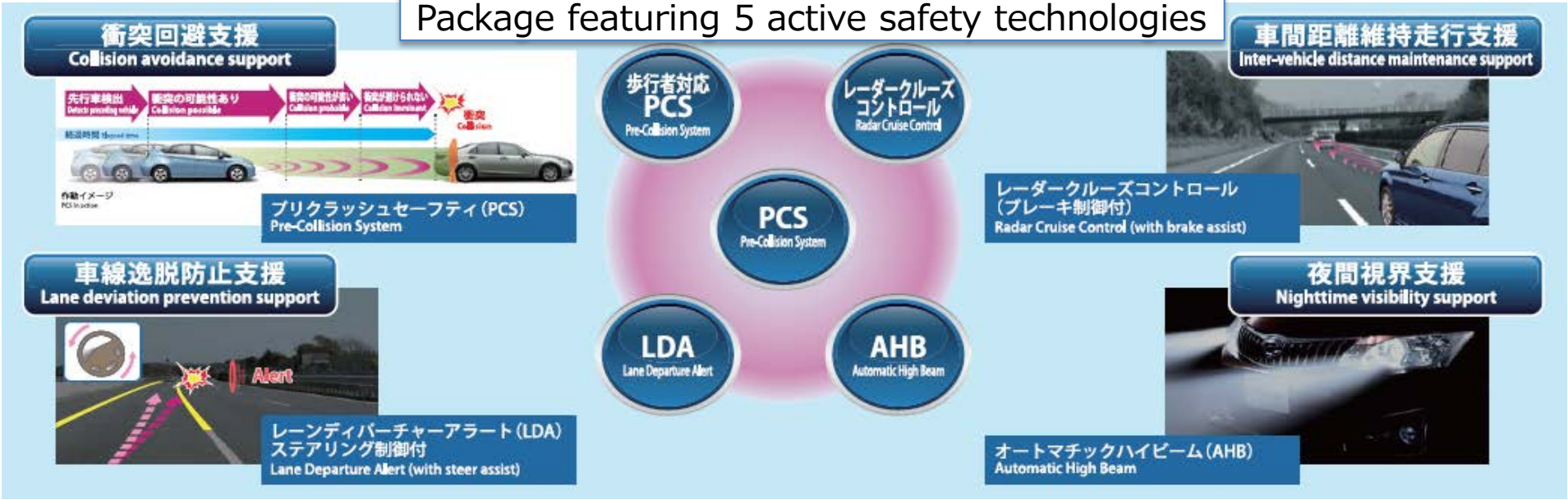
Communication with infrastructure or other vehicles enables detection of objects outside the visibility range and the acquisition of traffic signal information.

Coordinating autonomous and cooperative systems leads to enhanced safety systems.

Autonomous System: Toyota Safety Sense

- Two types of “eyes” (sensors) are used to ensure high recognition accuracy and reliability.
- Packaging of highly effective accident avoidance safety technologies.

Package featuring 5 active safety technologies



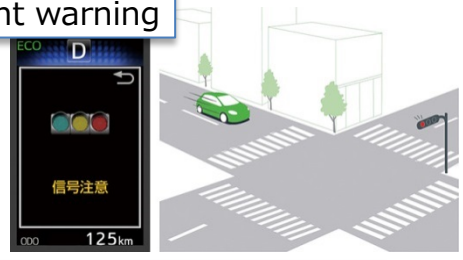
To be installed in almost all models by the end of 2017, starting with Japan, the U.S. and Europe.

Cooperative System: ITS Connect

Roadside-to-vehicle communication systems

Right turn collision caution

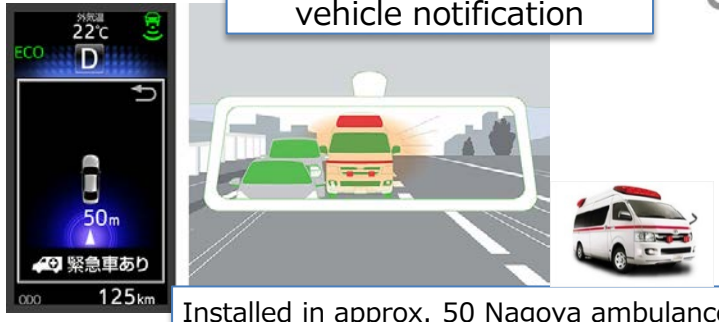
Red light warning



Signal change starting support

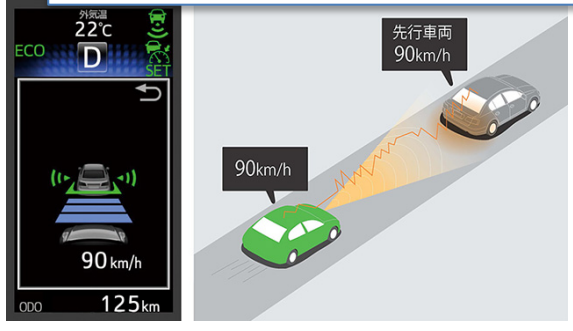
Vehicle-to-vehicle communication systems

Approaching emergency vehicle notification



Installed in approx. 50 Nagoya ambulances (2014, 2015)

Cooperative adaptive radar cruise control



Cooperative System: ITS Connect

ITS Connect has been equipped in 4 following models
to be equipped in many models in future

LEXUS

RX

TOYOTA

CROWN

Prius

Prius PHV

ITS Connect unit sales 70,000 (as of April 2017)

Right Turn Collision Caution

Cooperative Adaptive Cruise Control

Evolution of Automated Driving Technologies

Autonomous

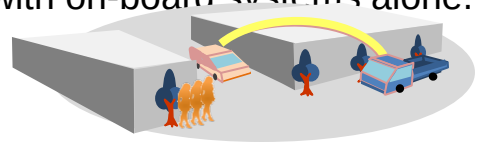
Improvement of decision-making technology
to enhance safety and support automated driving.

Control systems

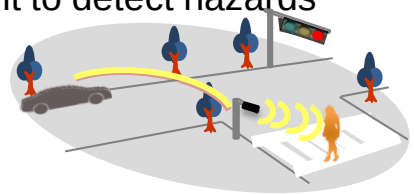
Detection, accident prevention and mitigation

Cooperative
(using communication)

Wireless communication is particularly well-suited
to situations in which it is difficult to detect hazards
with on-board systems alone.



Vehicle-to-Vehicle communication



Vehicle-to-Infrastructure communication

Intelligence

Automated driving

Concept Underlying Automated Driving at Toyota

MOBILITY TEAMMATE CONCEPT
Automated Driving Tech.

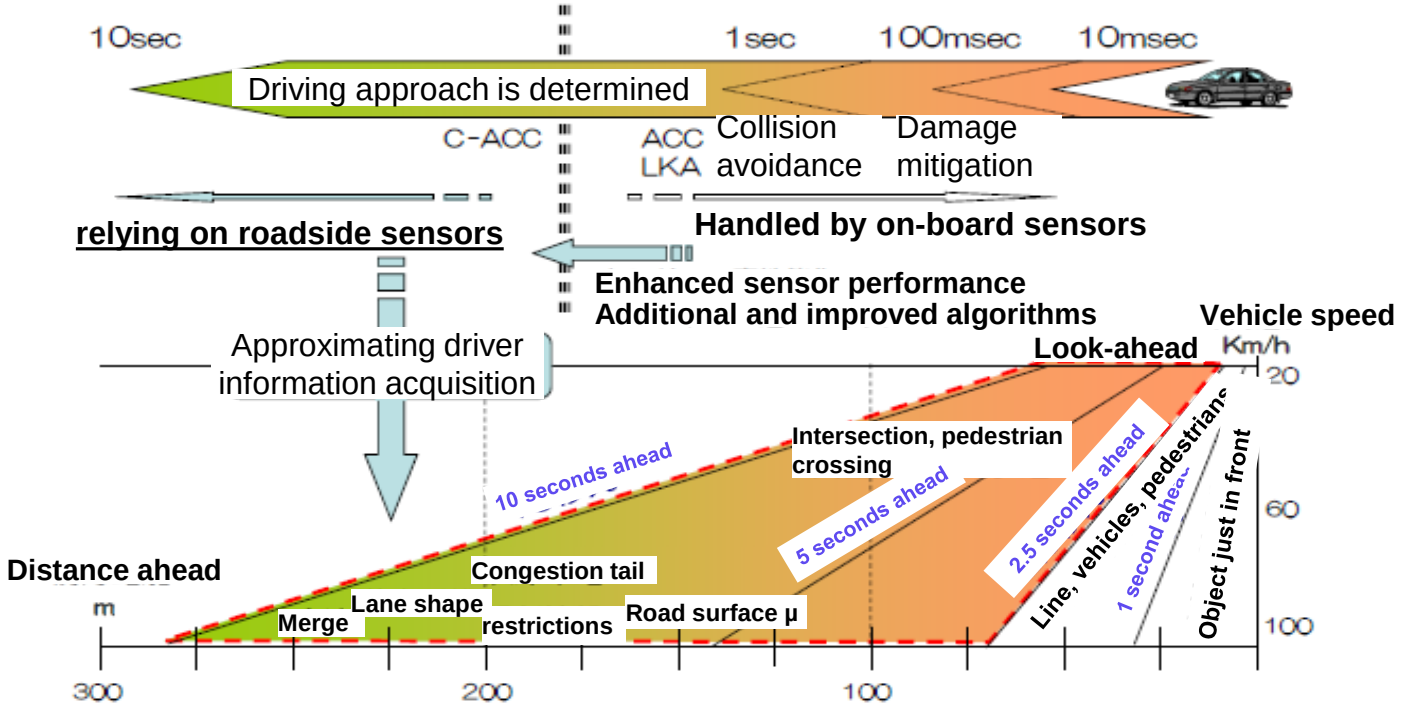
Building a relationship where people and cars become partners who understand each other, share the same purpose and, at various times, watch out for or help one another.

(a) Provide freedom of travel to all people.
(b) Do not build cars that make driving boring when the driver chooses to drive.
(c) Ensure that driving can be safely left up to the car when the driver is unwilling or unable to drive.
(d) In the context of the *Mobility Teammate Concept*, establish an automated driving system involving cooperation between people and cars.

The three technological pillars that realize the *Mobility Teammate Concept*.

(a) Driving intelligence (Recognition, decision, operation)	**(b) Connected intelligence (Look-ahead technology)**	(c) Interactive intelligence (Optimal HMI for automated driving)

Connected Intelligence / Role of Cooperative Systems



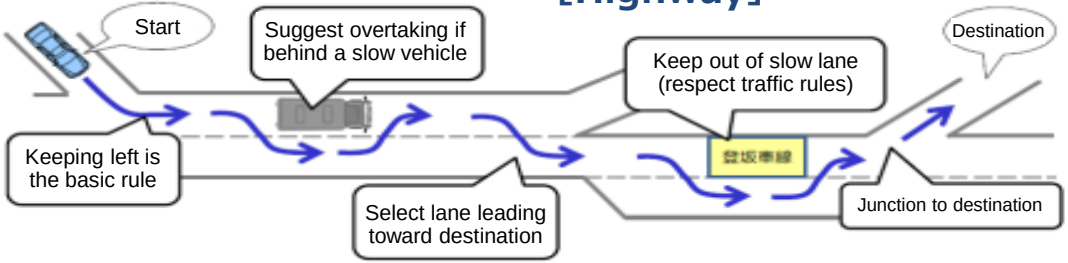
Source: Strategic Innovation Promotion Program (SIP) documents

The strength of cooperative systems is a high-level look-ahead prediction ability.

Contributing to Automated Driving

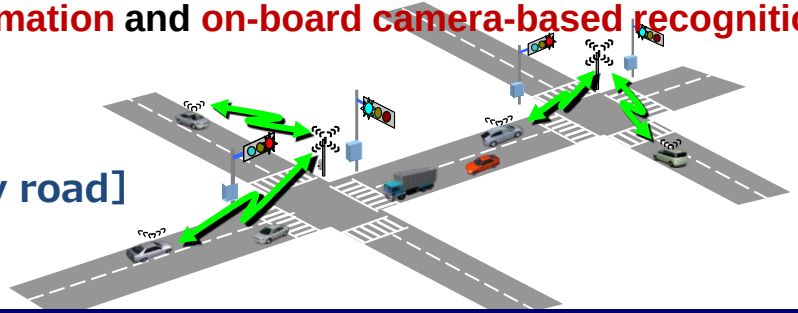
- **Realize smooth automated driving by having the road provide information on conditions ahead that cannot be detected by autonomous sensors.**

[Highway]



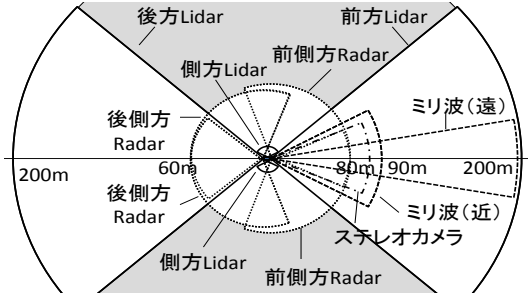
- **Realize smooth passing of intersection and automatic control by using the redundancy provided by both look-ahead traffic signal information and on-board camera-based recognition.**

[Ordinary road]



Advances in recognition technology due to autonomous systems (examples)

Sensors with wider angles and faster response times



Versatile situation awareness through next-generation cameras

Traffic signals

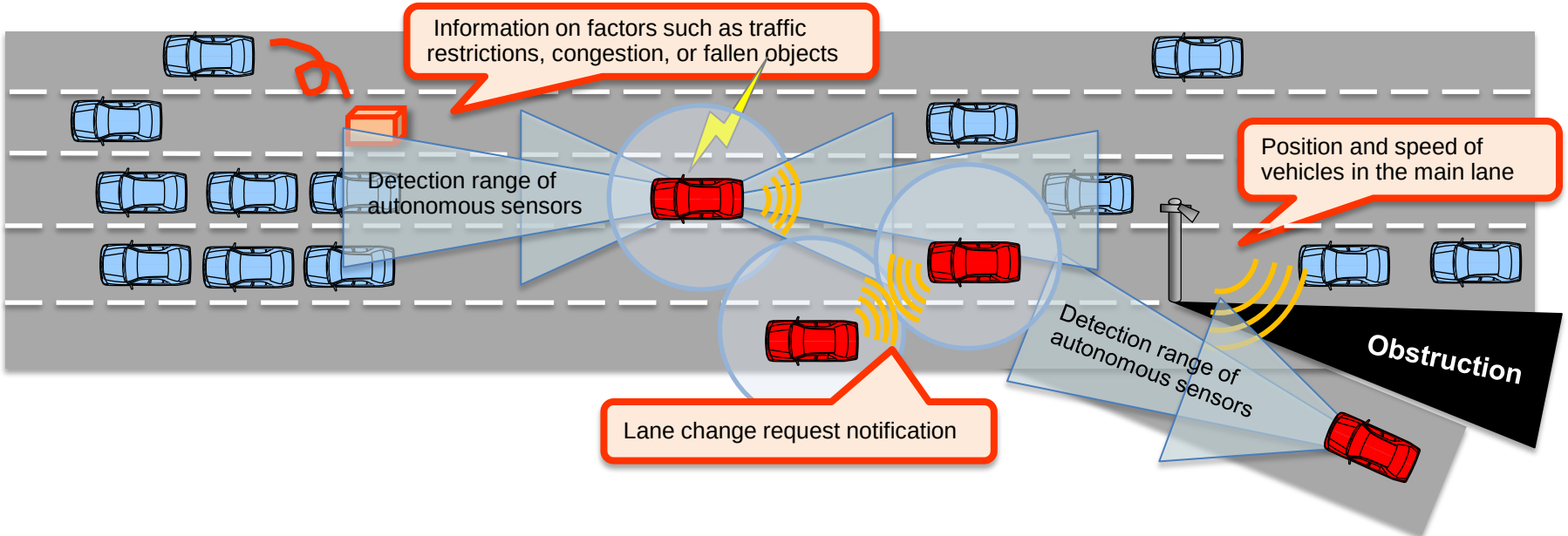
Lamps

Restrictions

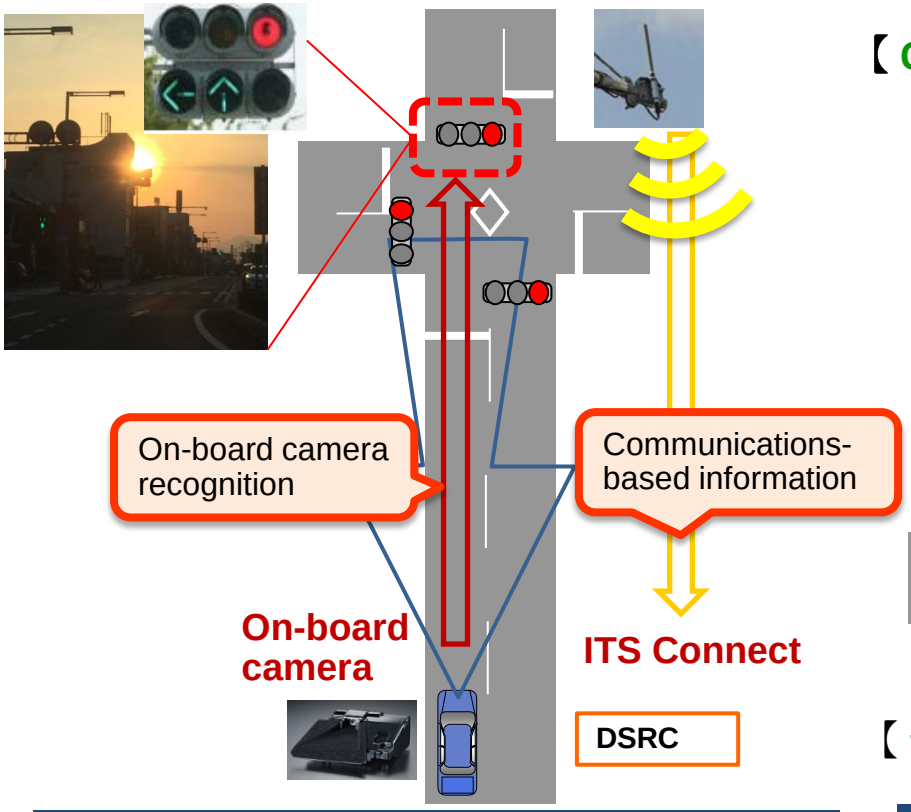
The use of look-ahead information contributes to safe and smooth automated driving.

Merging and Lane Changes

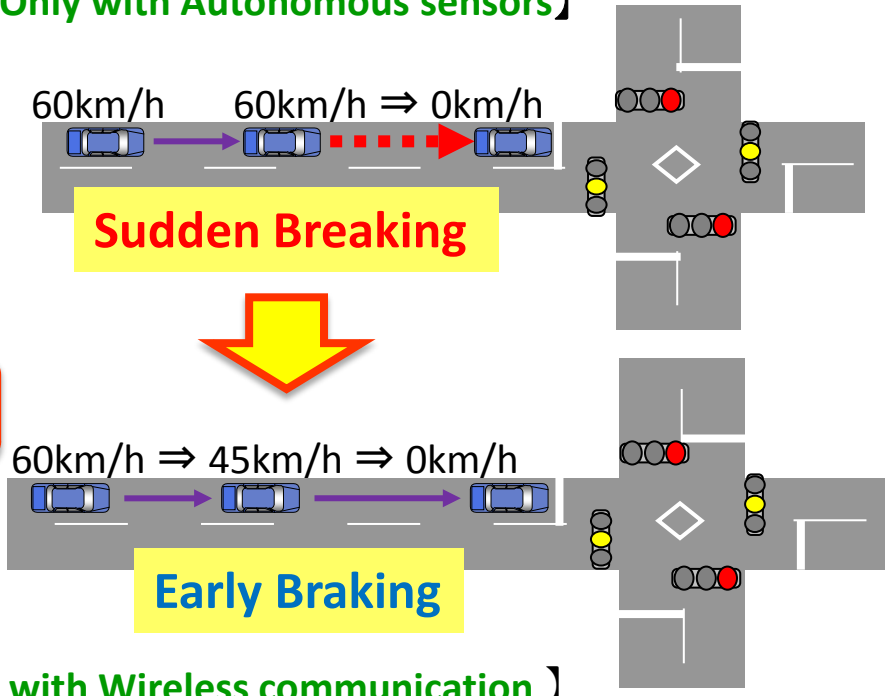
- **Safe and smooth merging control**
  - **Vehicle speed control based on prior measurement and prediction of the motion of vehicles in the main lane**
  - **In the future, Steering control using information such as lane change requests**
- **Modify the automated driving plan using look-ahead information on factors such as traffic restrictions, congestion, or fallen objects.**



Control Coordinated with Traffic Signals



【 Only with Autonomous sensors】



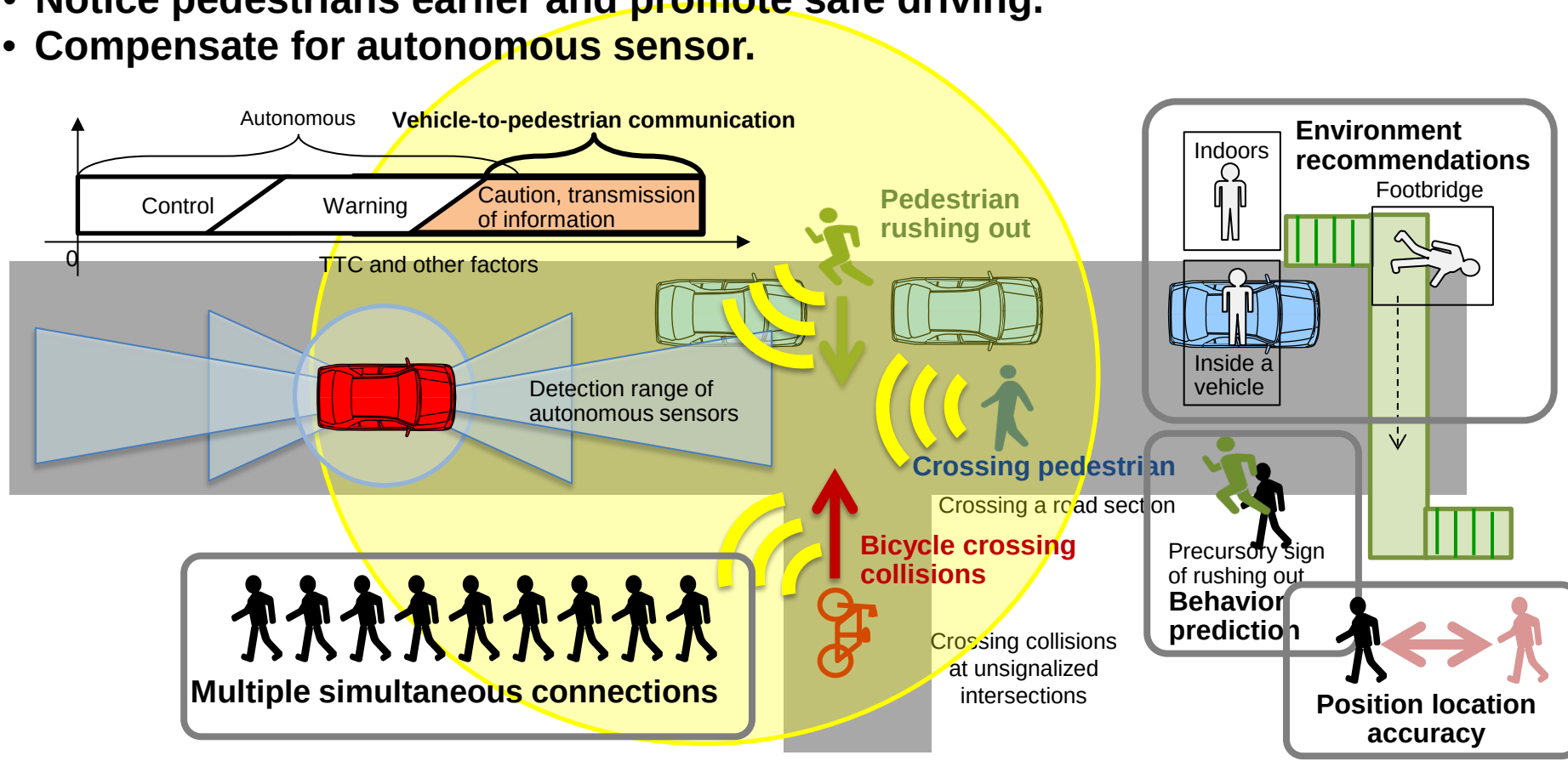
【 with Wireless communication 】

Reliable control provided by redundant recognition systems

Safe and smooth decision on stopping at or going through intersections

Pedestrian Detection (V2P)

- **Notice pedestrians earlier and promote safe driving.**
- **Compensate for autonomous sensor.**



Issues in Cellular V2X

- **Clarification of the positioning of DSRC (760 MHz/5.9 GHz) and LTE/5G–V2X.**
  - **Use cases beyond DSRC**
  - **Performance of LTE/5G-V2X**

- **Coexistence of DSRC (760 MHz/5.9 GHz) and LTE/5G–V2X.**
  - **Backward compatibility**

- **Business model for LTE/5G–V2X (operators, communication costs).**

- **Guaranteeing dedicated frequencies and bands, ensuring reliability in cases such as failure detection.**

Thank you for your attention

Rewarded with a smile

by exceeding your expectations

TOYOTA