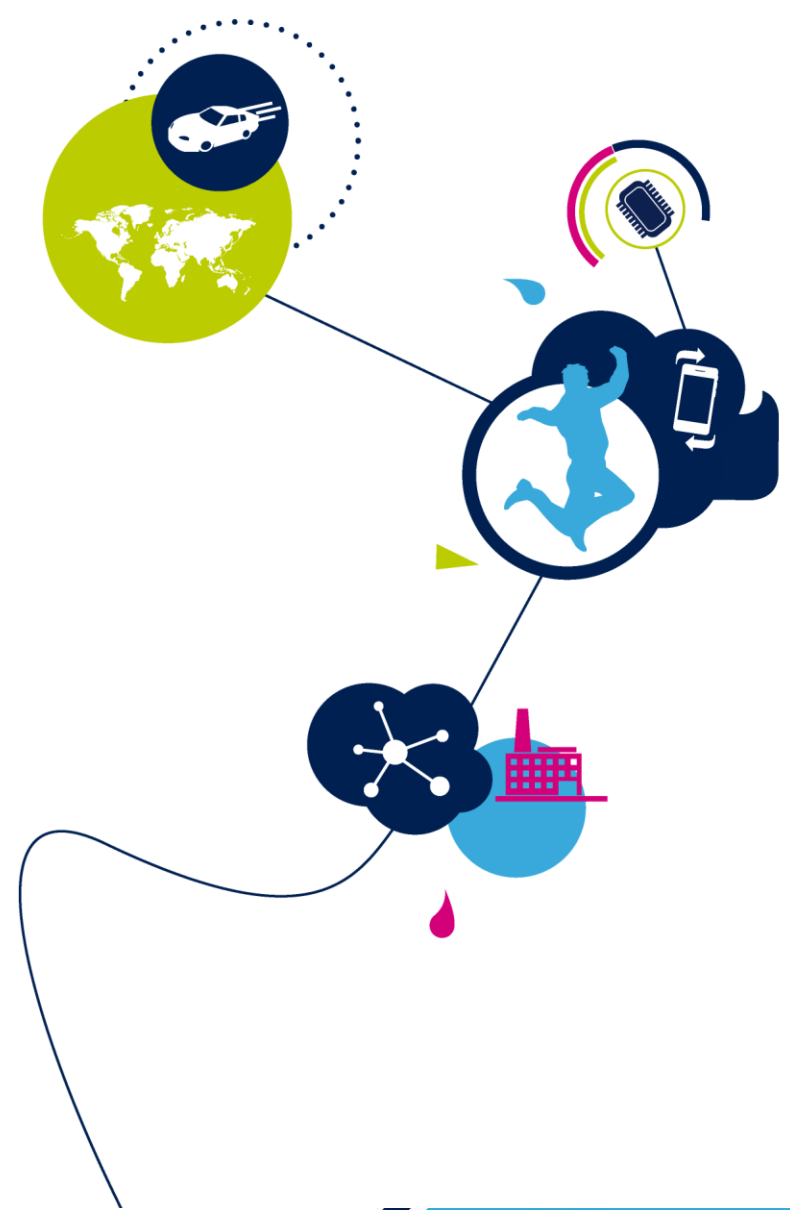


Automotive ADAS Systems

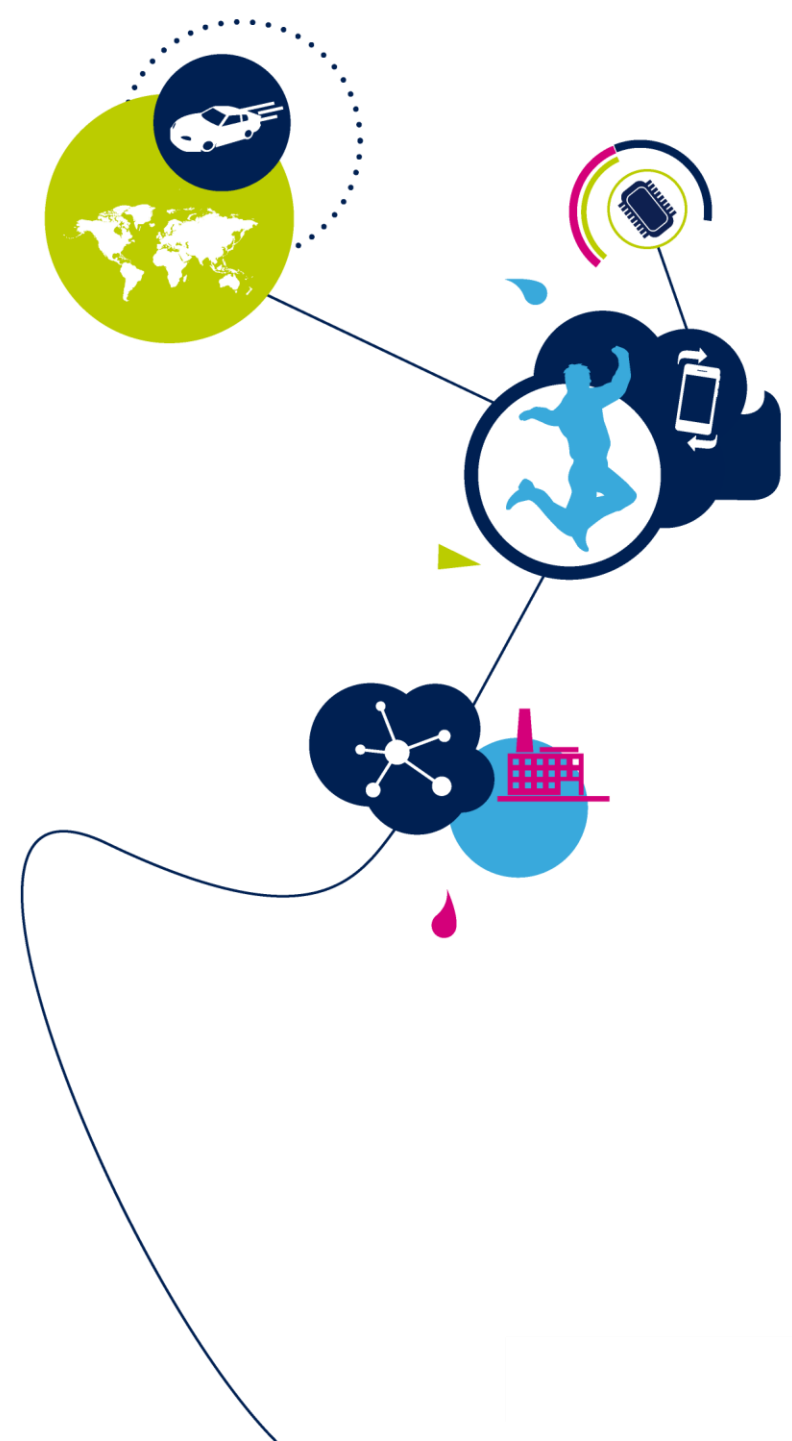
Overall Automotive ADAS System



- ADAS overview
- ADAS Vehicle Architectures
- ADAS Technologies/Sensors
 - Vision(Cameras) System
 - LiDAR System
 - Radar System
 - GNSS/IMU System
 - V2X System
- Sensor Fusion Example

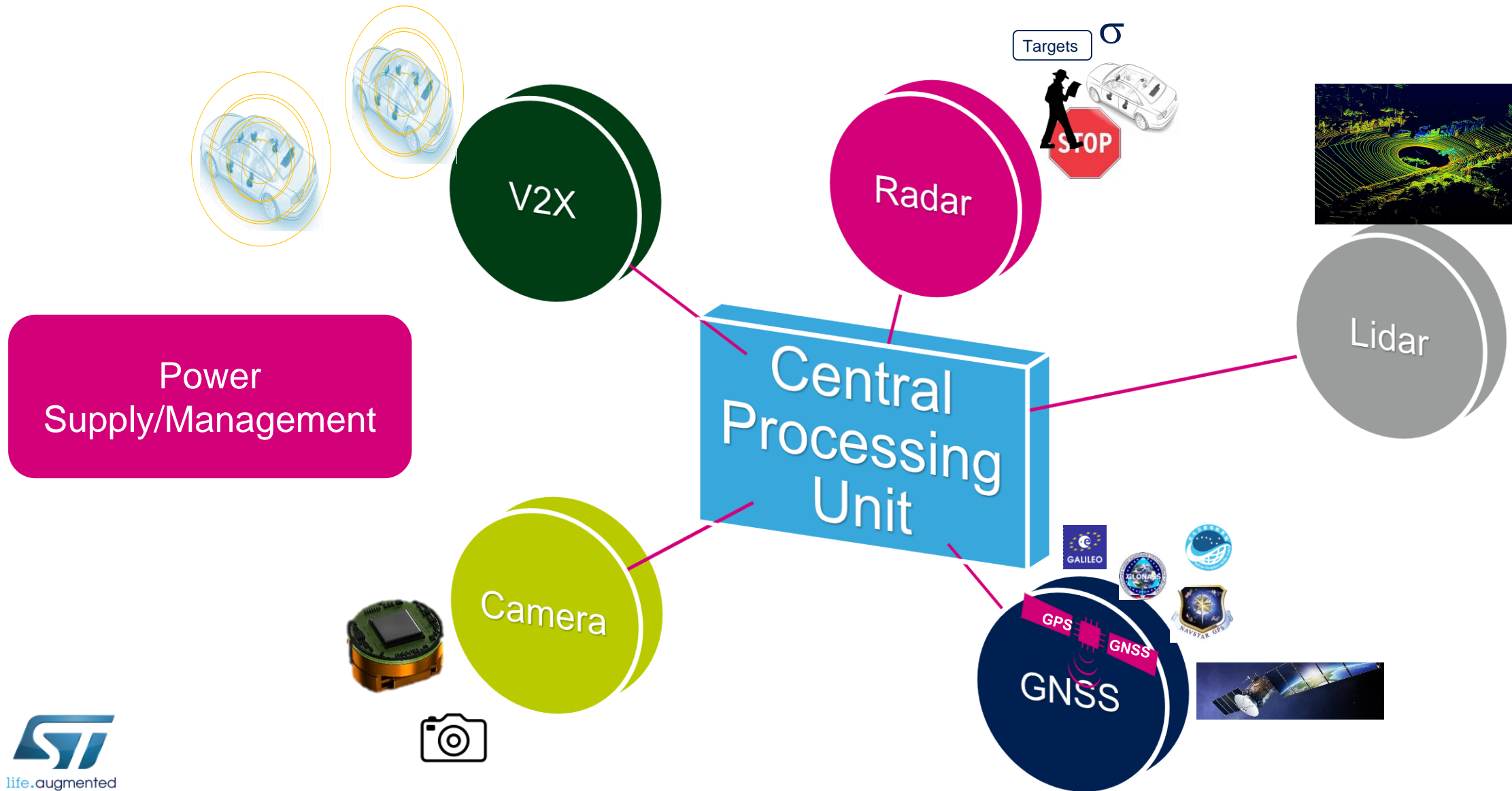
Automotive ADAS Systems

ADAS Overview



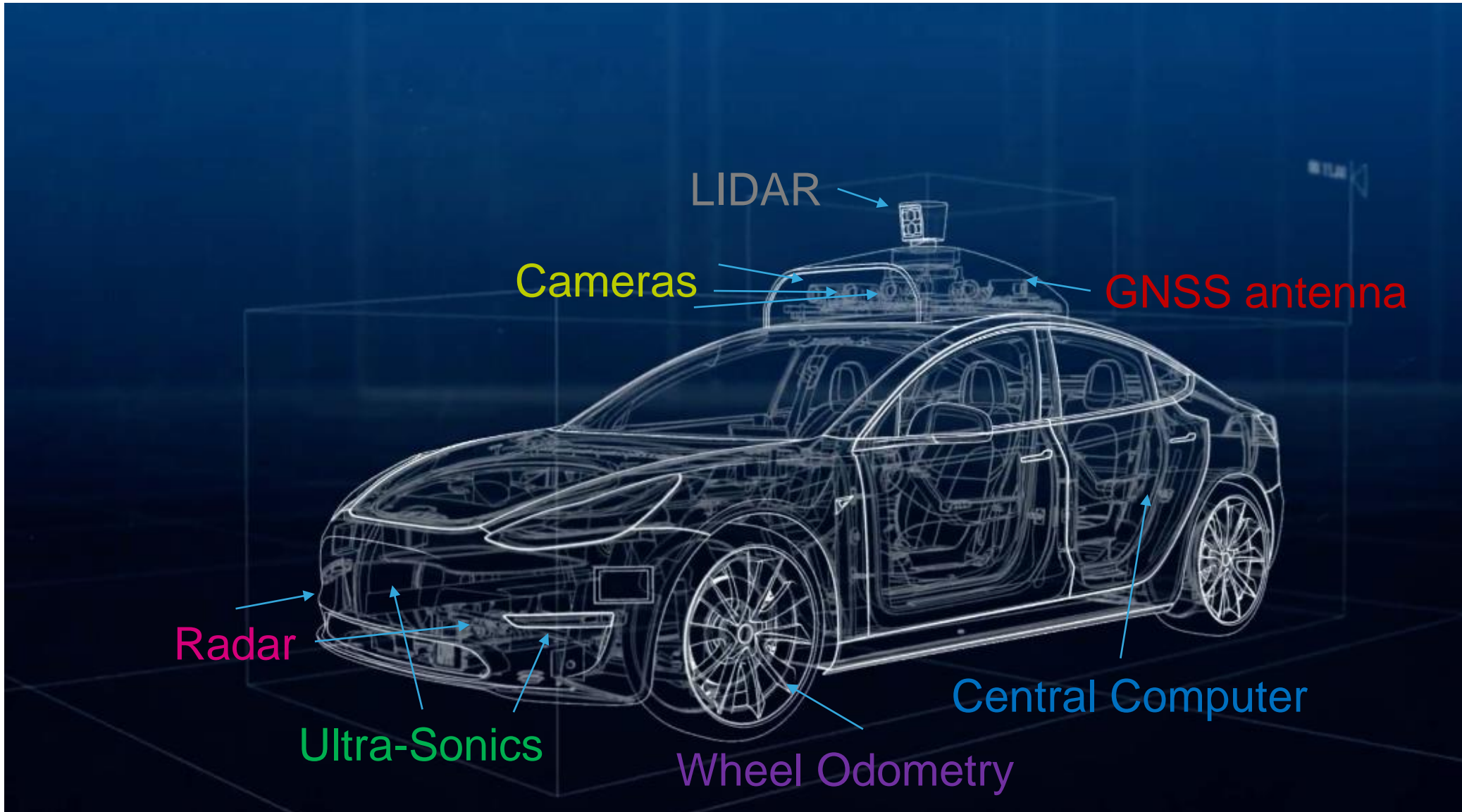
Overview of ADAS Technologies

4



ADAS Sensors - Needed for Perception

5



The 5 Levels of Vehicle Automation

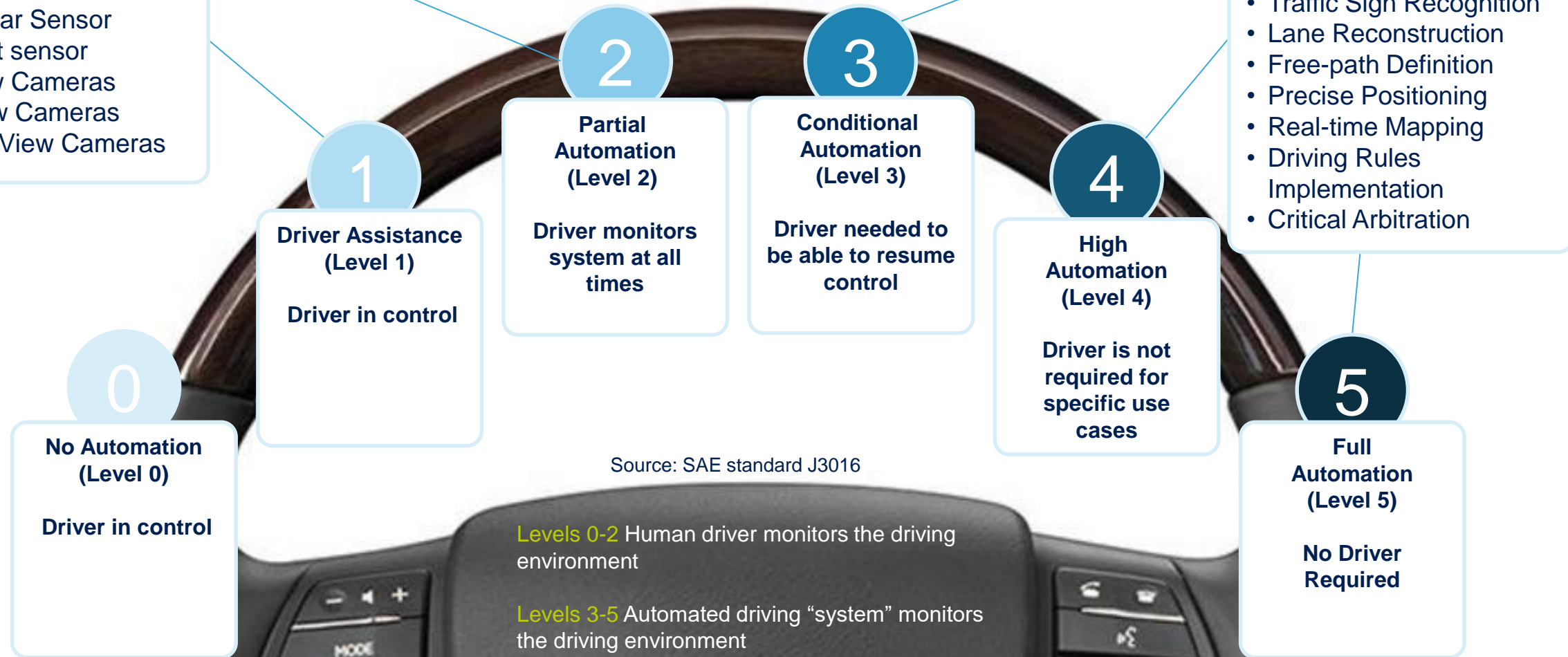
6

Adding Senses

- Accelerometers and Gyro
- Steering Wheel Angle
- Ultrasonic sensors
- Front Radar Sensor
- Blind Spot sensor
- Rear View Cameras
- Front View Cameras
- Surround View Cameras

Learning to Drive

- Systems Networking
- Sensor Fusion
- Distance Measurement
- Traffic Sign Recognition
- Lane Reconstruction
- Free-path Definition
- Precise Positioning
- Real-time Mapping
- Driving Rules Implementation
- Critical Arbitration



Sensor Fusion is Key to Autonomous

7

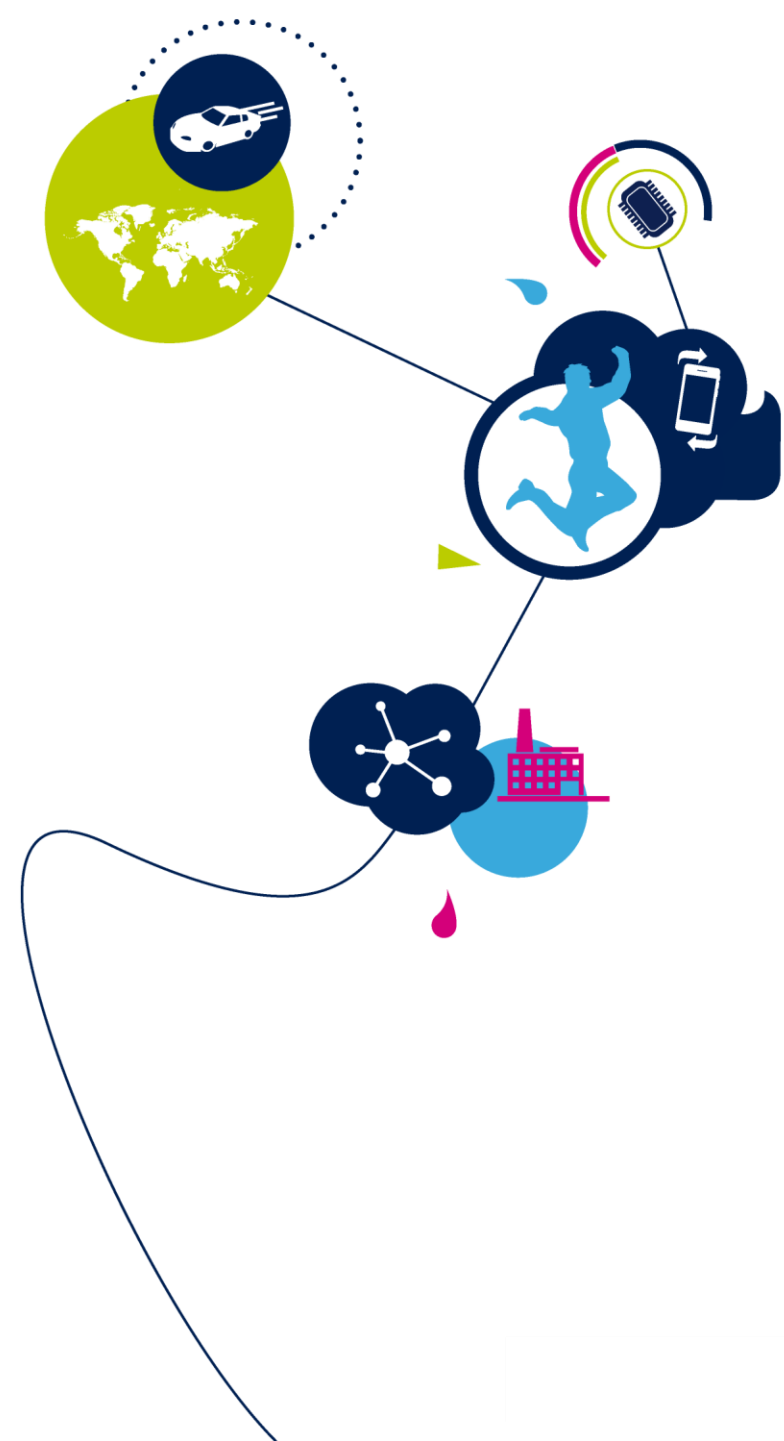
No sensor type works well for all tasks and in all conditions, so sensor fusion will be necessary to provide redundancy for autonomous functions

■ Most likely used fusion solution in future ● Good ● Fair ● Poor

	Camera	Radar	LiDAR	Ultrasonic	LiDAR+Radar+Camera
Object detection	●	●	●	●	●
Object classification	●	●	●	●	●
Distance estimation	●	●	●	●	●
Object edge precision	●	●	●	●	●
Lane tracking	●	●	●	●	●
Range of visibility	●	●	●	●	●
Functionality in bad weather	●	●	●	●	●
Functionality in poor lighting	●	●	●	●	●

Automotive ADAS Systems

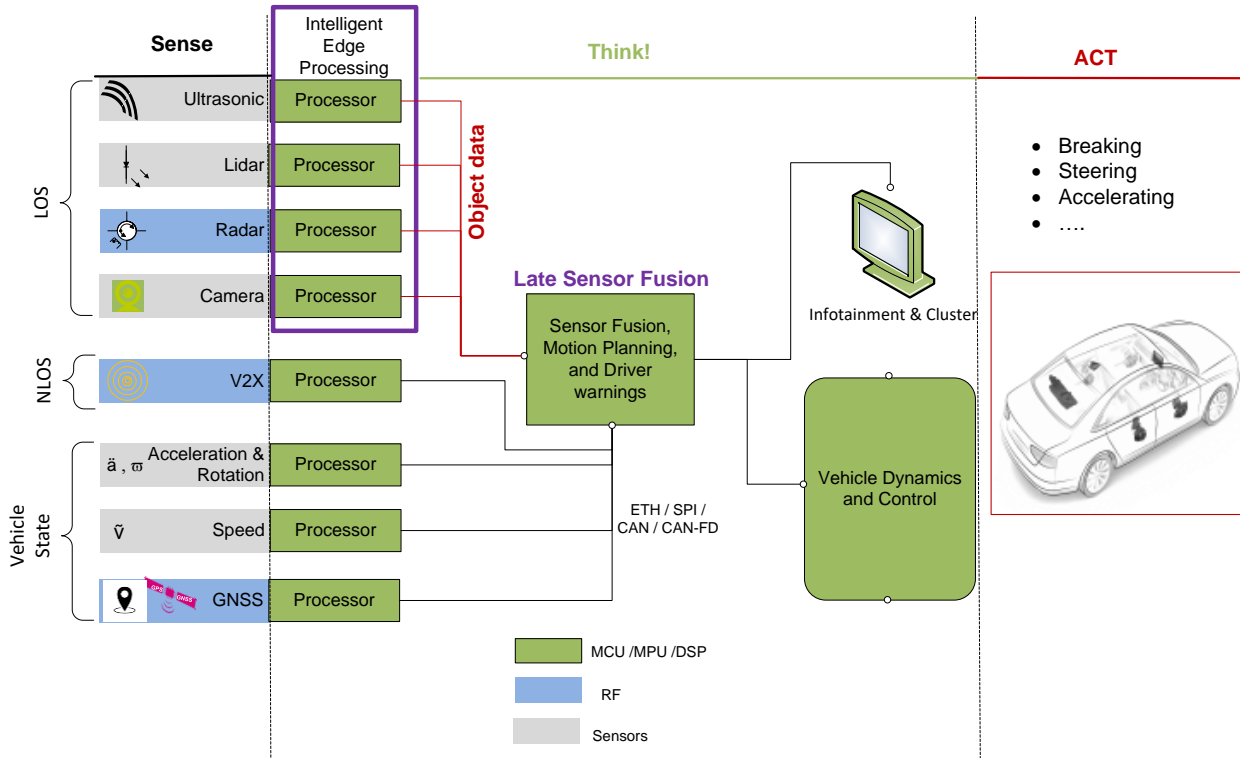
ADAS Vehicle Architectures



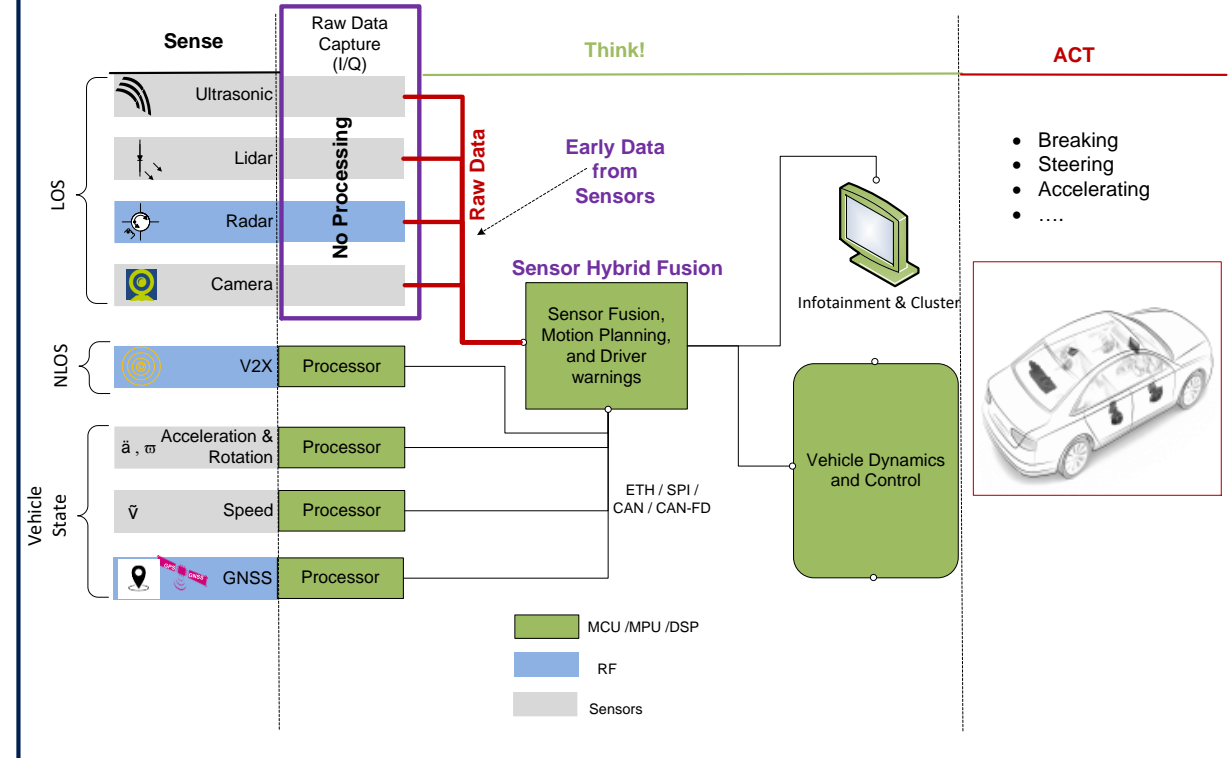
Distributed vs Centralized Processing

9

Distributed Processing with Object Level Fusion



Centralized Processing with Raw Data Fusion



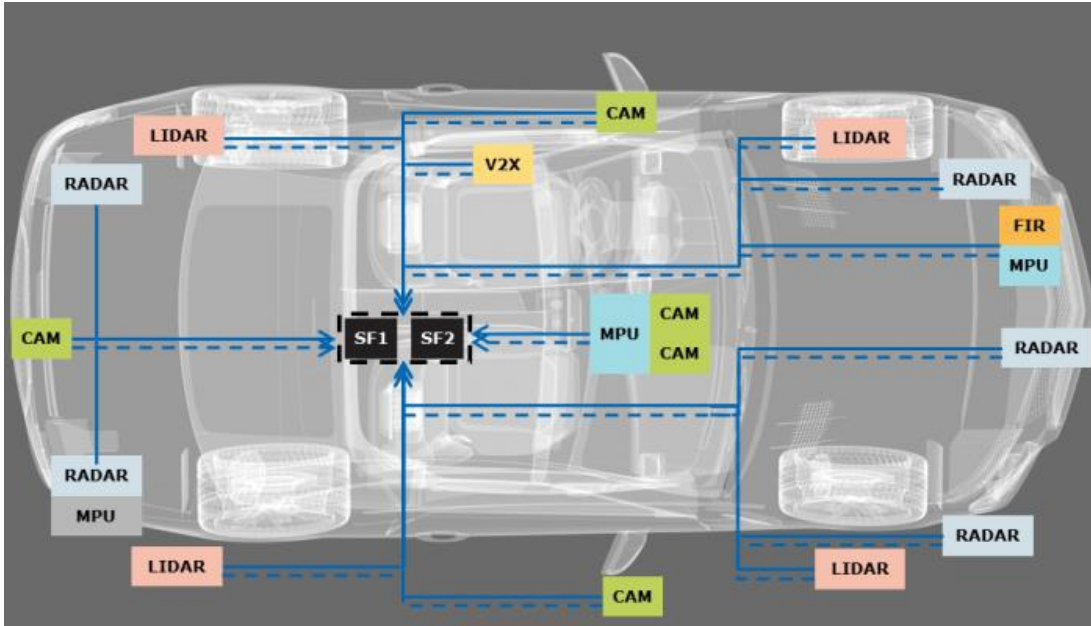
LOS: Line-of-Sight
NLOS: Non-Line-of-Sight

- Distributed Interfaces
 - ETH, SPI, I2C, CAN, CAN-FD
 - RADAR, Ultrasonic, V2X, IMU, Wheel Odomerty, GNSS
 - MIPI(CSI-2), GMSL(Maxim), FPD-Link(TI), PCIe, HDBaseT(Valens)
 - Video Cameras?
 - Lidar?

- Centralized Interfaces
 - ETH, SPI, I2C, CAN, CAN-FD
 - V2X, IMU, Wheel Odomerty, GNSS
 - MIPI(CSI-2), GMSL(Maxim), FPD-Link(TI), PCIe, HDBaseT(Valens)
 - Radar, Ultrasonic
 - Cameras
 - Lidar?

Distributed vs Centralized Processing

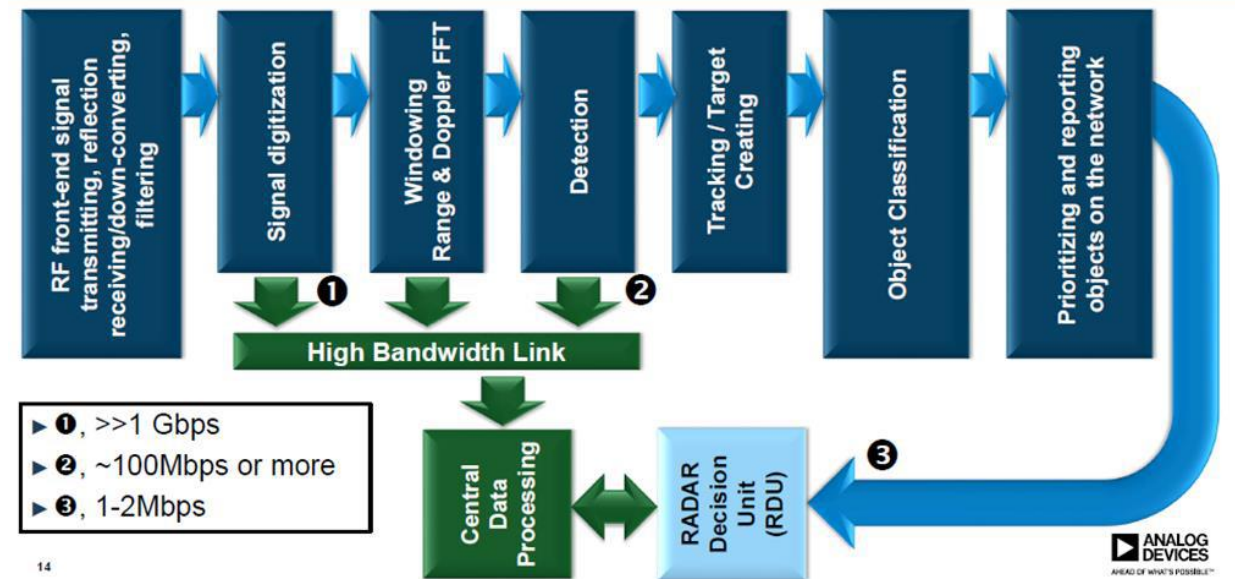
10



Source: 2018 IHS Markit – “Autonomous Driving-The Changes to come”

Example Signal Processing Flow

Centralized or Not Centralized... That is the Question! Answer: Both, Please.



Source: ADI

- What are the Data rates requirements for each sensor?
 - Centralized (i.e. SERDES?) vs Distributed (i.e. ETH?)
- Example: 4-5 Corner Radars are utilized in high end/premium vehicles.

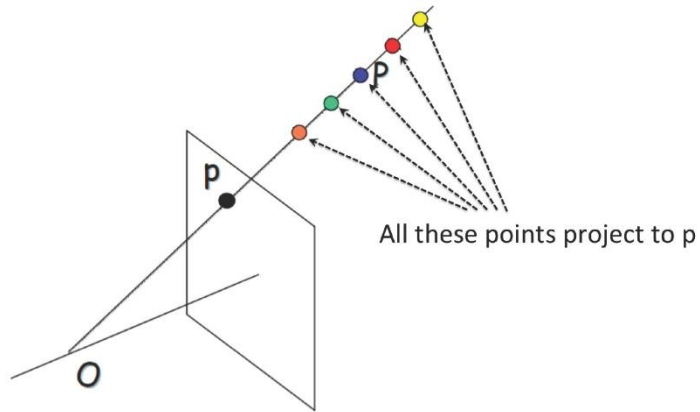


- Essential for correctly perceiving environment
- Richest source of raw data about the scene - only sensor that can reflect the true complexity of the scene.
- The lowest cost sensor as of today
- Comparison metrics:
 - Resolution
 - Field of view (FOV)
 - Dynamic range
- Trade-off between resolution and FOV?

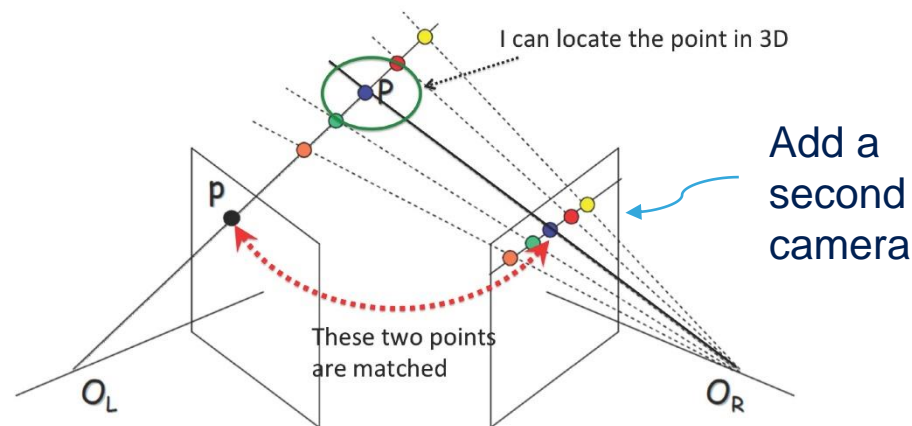


- Enables depth estimation from image data

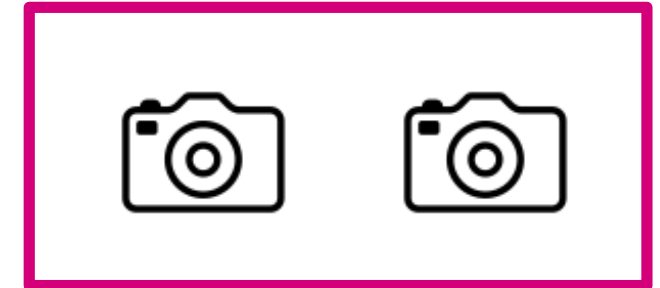
All points on projective line to P map to p



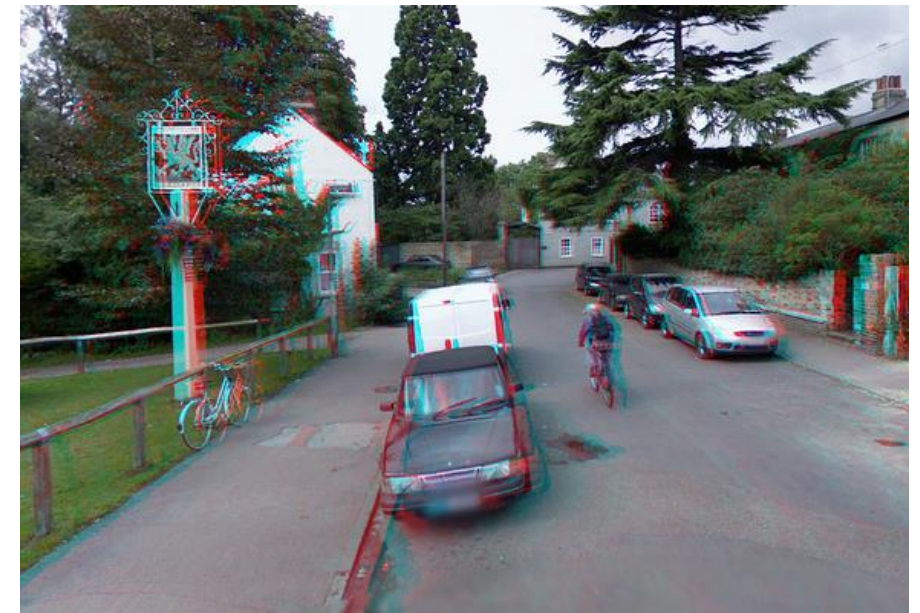
One camera



Find a point in 3D by triangulation!



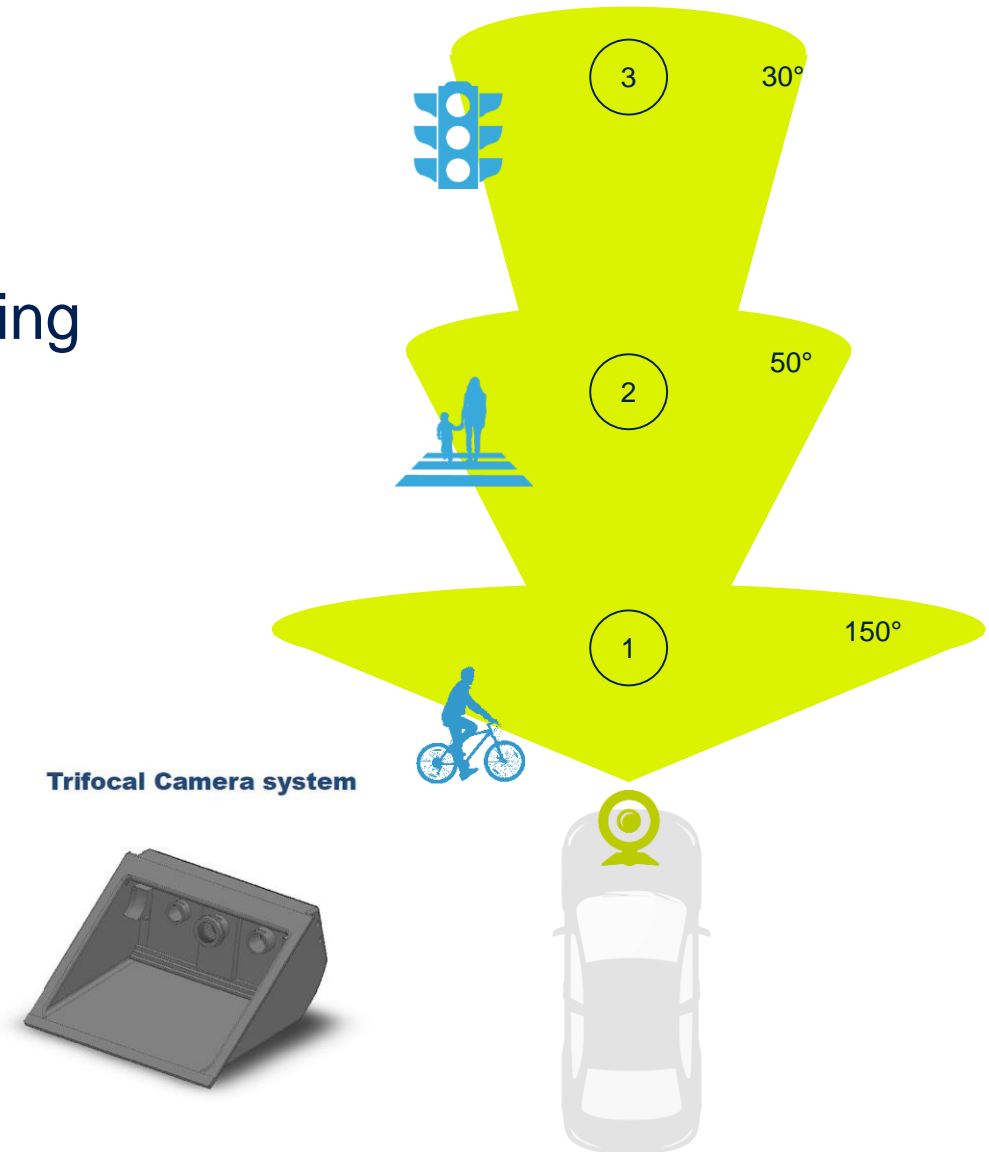
Left and right images



The Next Phase for Vision Technology

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- From sensing to comprehensive perception
- Machine learning used already for object sensing
- Autonomous driving needs
 - Path planning based on holistic cues
 - Dynamic following of the drivable area
- Deep learning is now being applied



Machine Vision: ST & Mobileye

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EyeQ3™ 3rd Generation vision processor

- Detection of driving lanes
- Recognition of traffic signs
- Detection of pedestrians and cyclists
- Seeing obstacles how the human eye sees them
- Adapting cruise speed
- Emergency braking when car ahead slows suddenly



EyeQ4™ 4th Generation enables

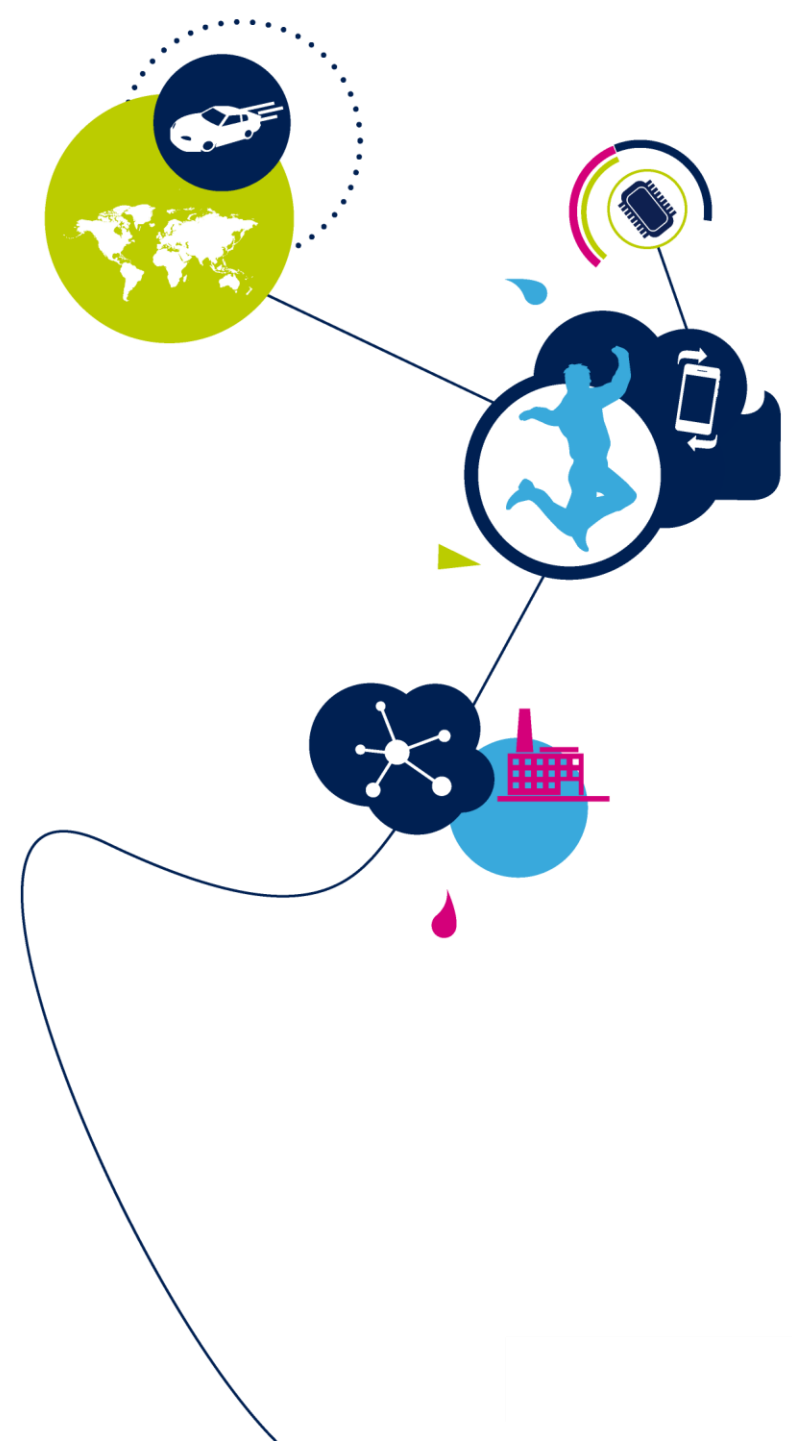
- Detection of more objects, more precisely
- More features required for automated driving
Free-space Estimation, Road Profile Reconstruction
- Monitoring of environmental elements (fog, ice, rain) and their safety impact
- Detailed understanding of the road conditions allowing automatic suspension and steering adjustment
- Highly automated vehicles

EyeQ5™

The Road to Full Autonomous Driving: Mobileye and ST to Develop EyeQ®5 SoC targeting Sensor Fusion Central Computer for Autonomous Vehicles

Automotive ADAS Systems

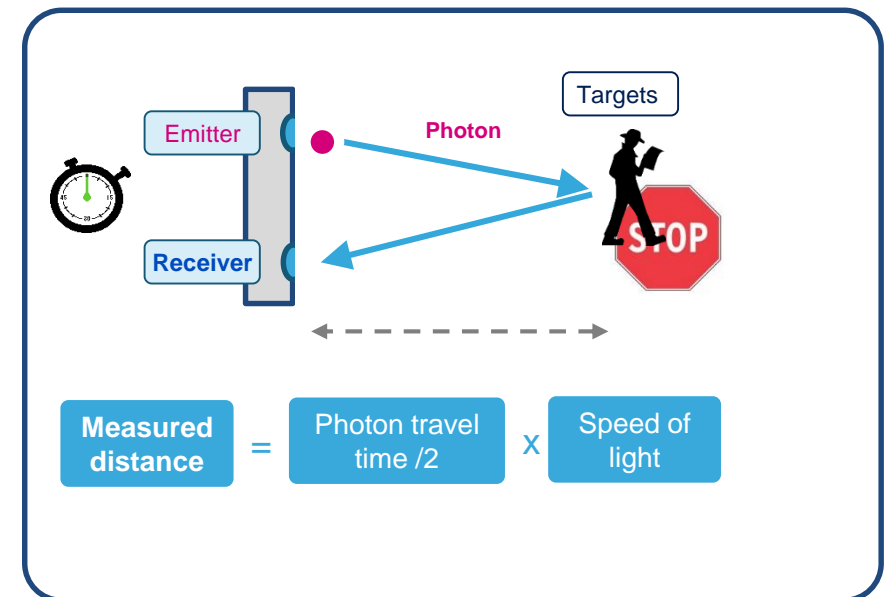
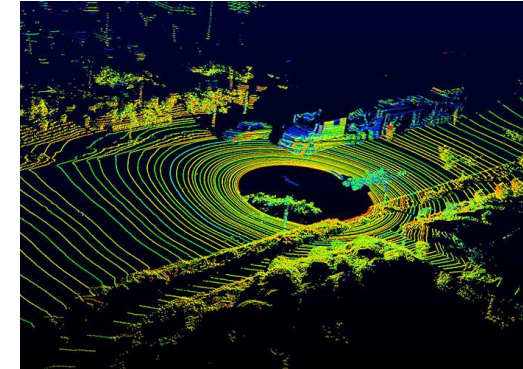
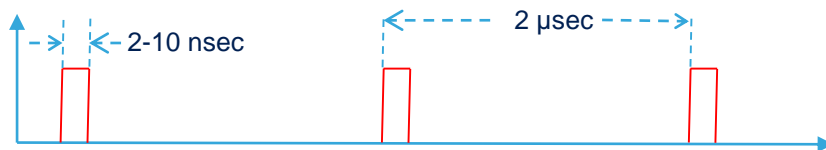
LiDAR System



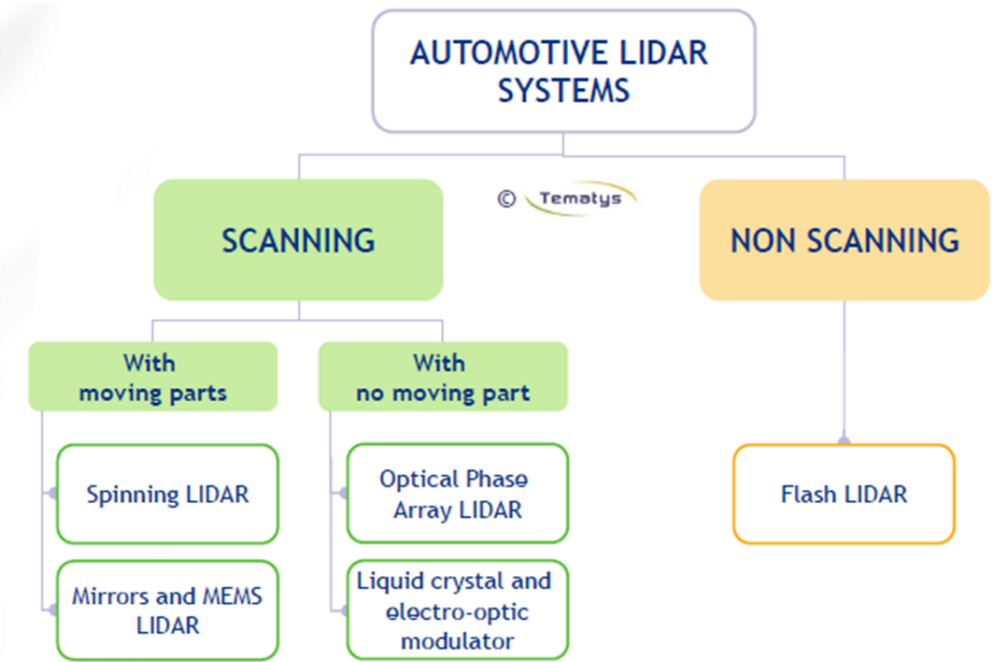
LiDAR Technology Overview

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- LiDAR (light detecting and ranging, or “light radar”) sensors send one or more laser beams at a high frequency and use the Time-of-Flight principle to measure distances. LiDAR capture a high-resolution point cloud of the environment.
- Can be used for object detection, as well as mapping an environment
 - Detailed 3D scene geometry from LIDAR point cloud
- LiDAR uses the same principal as ToF sensor, but at much longer distances, minimum 75M for “near field” and 150-200M for “far field”.



- There are multiple techniques currently under evaluation for LiDAR including rotating assembly, rotating mirrors, Flash (single Tx source, array Rx), scanning MEMS micro-mirrors, optical phased array.
- From a transmitter/receiver (Tx/Rx) perspective the following technologies need to be developed or industrialized for automotive.
 - MEMS Scanning Micro-mirror technologies
 - SPAD (Single Photon Avalanche Detectors) - Rx
 - 3D SPAD - Rx
 - Smart GaN (Gallium nitride)
- Comparison metrics:
 - Number of beams: 8, 16, 32, and 64 being common sizes
 - Points per second: *The faster, the more detailed the 3D point cloud can be*
 - Rotation rate: *higher rate, the faster the 3D point clouds are updated*
 - Detection Range: *dictated by the power output of the light source*
 - Field of view: *angular extent visible to the LIDAR sensor*



Source: J. Cochard et.al., "LiDAR Technologies for the Automotive Industry", Tematsys, June 2018

Upcoming: Solid state LIDAR!

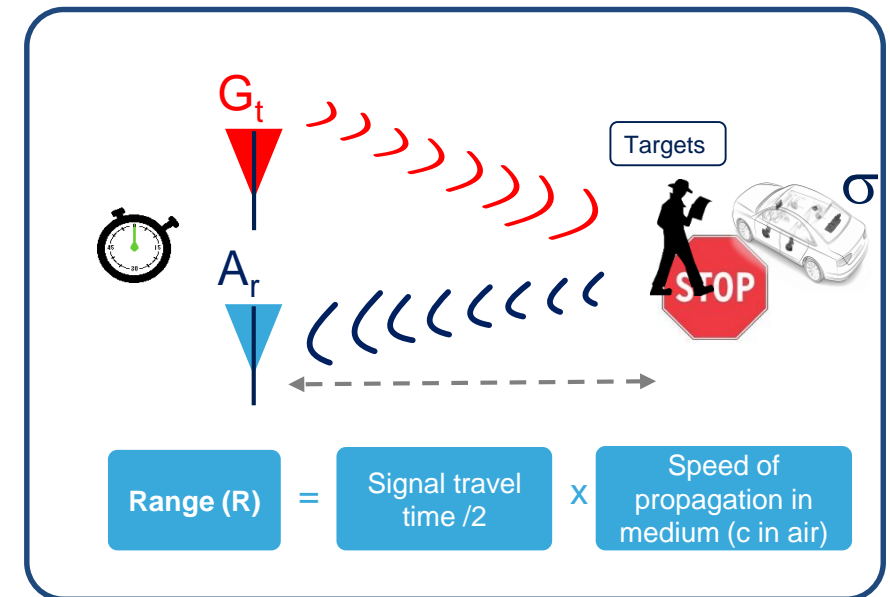
- Autonomous vehicles have been around for quite some time but only now the technologies are available for practical implementations
- No single sensor solution exists to cover all aspects – range, accuracy, environmental conditions, color discrimination, latency etc.
 - Multi-sensor fusion and integration will be a must
 - Each technology attempts to solve the overall problem while having multiple limitations
- Many LiDAR solutions (technologies) are available or being proposed with no clear winners
- Market is still in very early stage of development and experimentation
- When and which technology or system will be widely adopted and mass production starts is still unknown

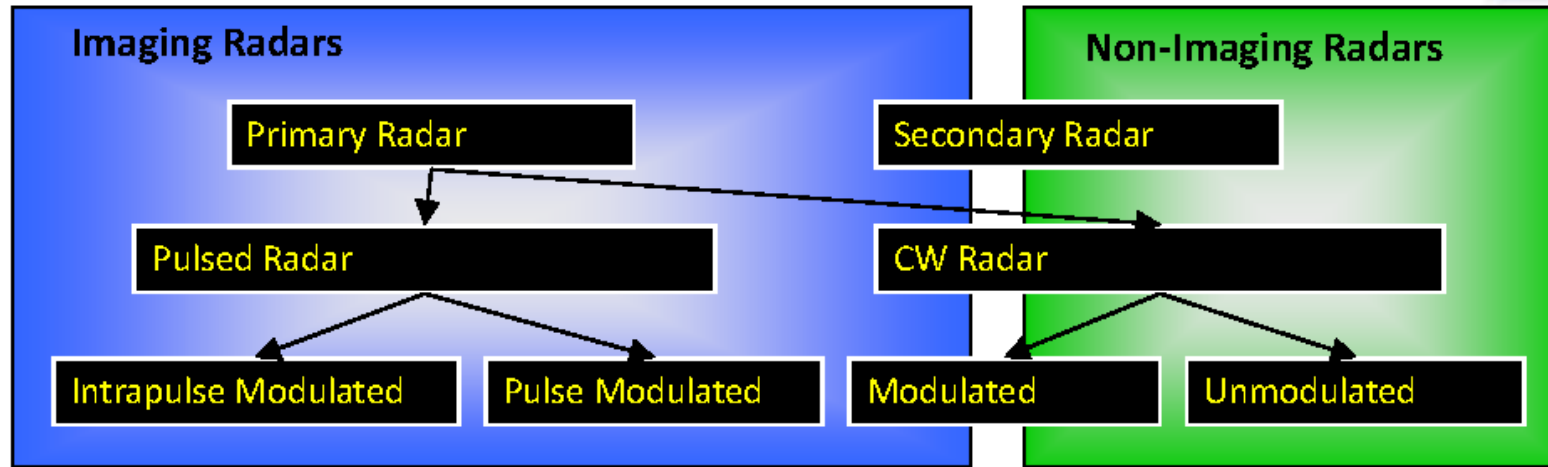
[illegible]

RADAR Technology Overview

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- RADAR (**R**Adio **D**etection and **R**anging) is one necessary sensor for ADAS (Advanced Driver Assistance System) systems for the detection and location of objects in the presence of interference; i.e., noise, clutter, and jamming.
- Robust Object Detection and Relative Speed Estimation
- Transmit a radio signal toward a target, Receive the reflected signal energy from target
- The radio signal can the form of “Pulsed” or “Continuous Wave”
- Works in poor visibility like fog and precipitation!
- Automotive radars utilize Linear FM signal, Frequency Modulated Continuous Wave (FMCW)
 - FM results in a shift between the TX and RX signals that allows for the determination of time delay, Range and velocity.





- Definitions:

- **Imaging Radar:** Forms a picture of the object or area
- **Non-Imaging Radar:** Measures scattering properties of the object or area
- **Primary Radar:** Transmits signals that are reflected and received
- **Secondary Radar:** Transponder that responds to interrogation with additional info
- **Pulsed Radar:** High power signals are only present for a short duration and repeated at specific intervals
- **CW Radar:** Signal is present continuously

2013 Defence & Security Forum, EuMW

- Comparison metrics:

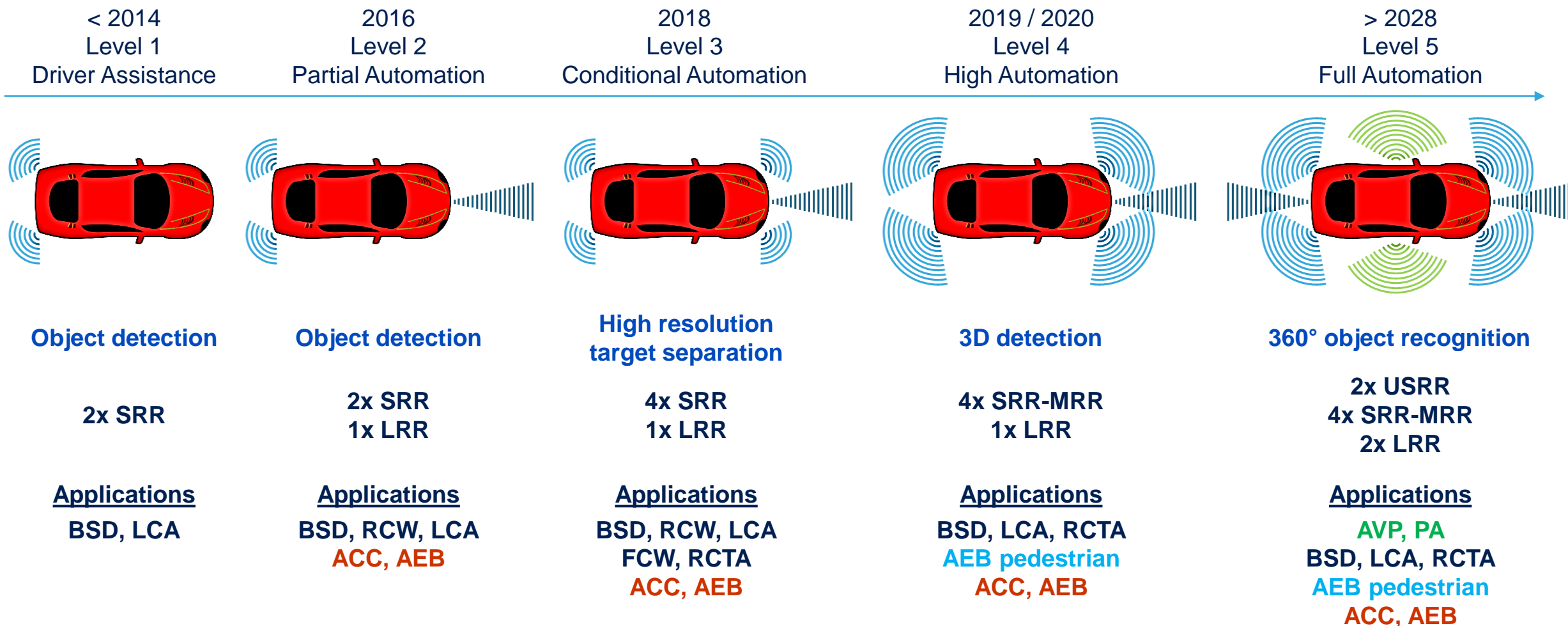
- Range
- Field of view
- Position and speed accuracy

- Configurations:

- Wide-FOV: Short Range
- Narrow-FOV: Long Range

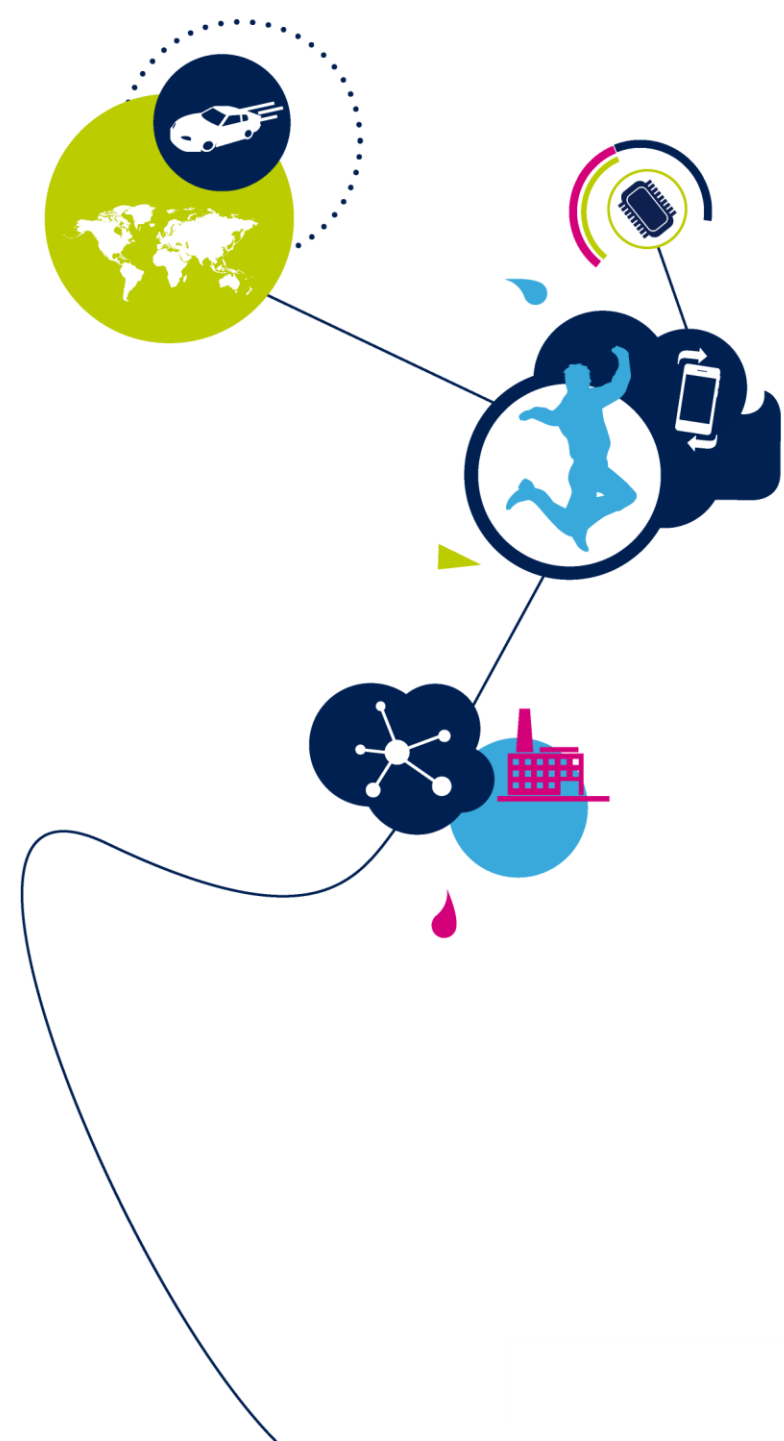
Automotive Radar Vs. Automation Levels

23

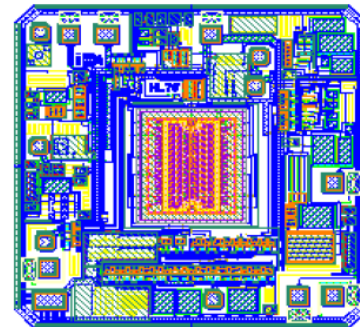


Automotive ADAS Systems

GNSS/IMU System



- Global Navigation Satellite Systems and Inertial Measurement Units
- Direct measure of vehicle states
 - Positioning, velocity, and time (GNSS)
 - Varying accuracies: Real-time Kinematic (RTK-short base line), Precise Point Positioning (PPP), Differential Global Positioning System (DGPS), Satellite-based augmentation system (SBAS-Ionospheric delay correction)
 - Angular rotation rate (IMU)
 - Acceleration (IMU)
 - Heading (IMU, GPS)



GNSS/IMU Positioning

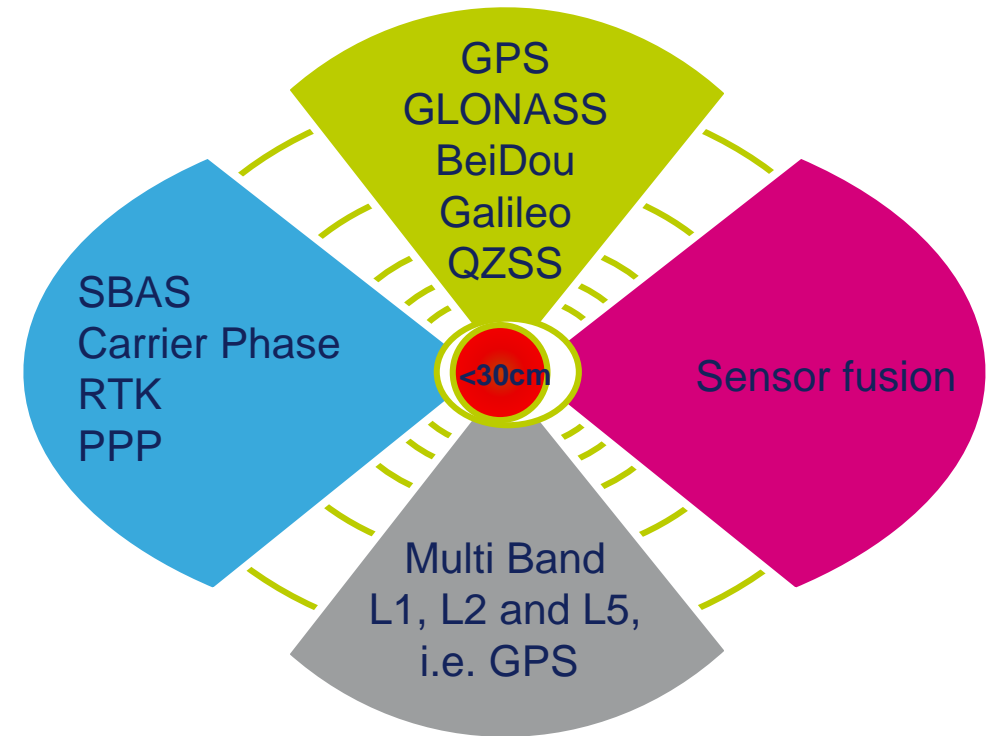
26

More Precision Enables More Safety Features

Precise Positioning: Towards Autonomous Driving

Precise Positioning to enable $< 30\text{cm}$ precision

- Lane detection
- Positioning data for V2X sharing
- Collision avoidance
- Autonomous parking
- Autonomous driving
- eCall accident location



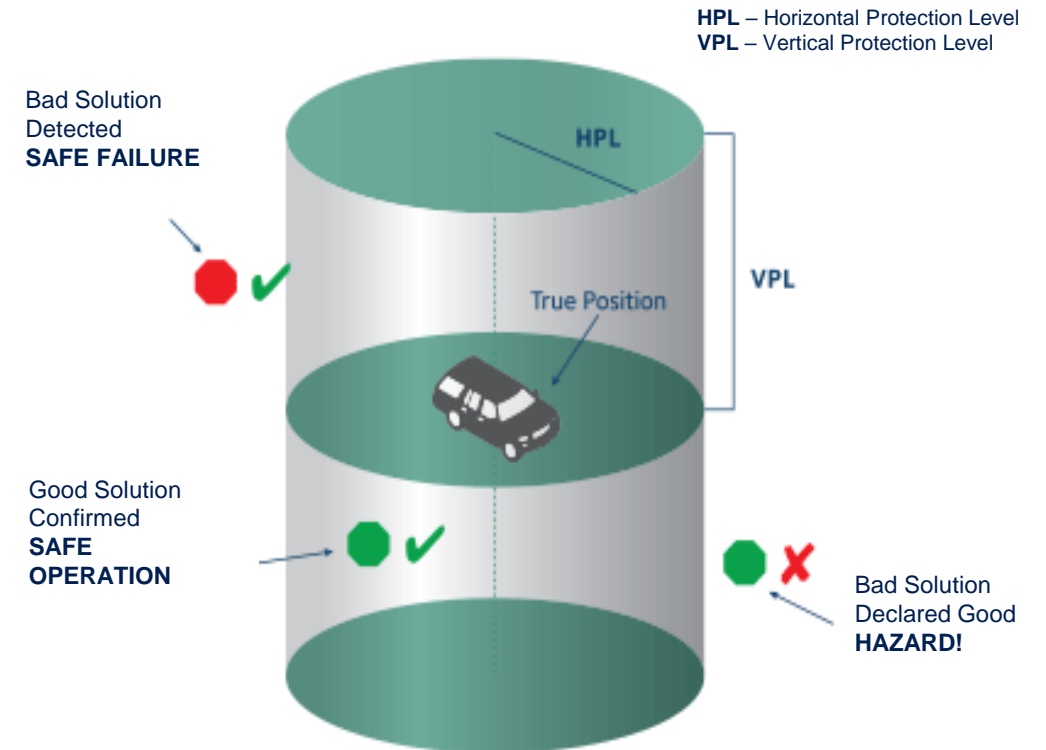
Precise GNSS is a Critical ADAS Sensor

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Higher integrity requirements across safety-critical applications

- Semi- and Autonomous driving safety-related applications requirements **increase**
 - Higher safety levels
 - Added redundancy
 - More Robustness & integrity
 - Security
- **Teseo APP** (ASIL Precise Positioning) GNSS receiver, **new sensor** based on **ISO26262** concept with unique **Absolute and Safe** positioning information complementing **relative** positioning other sensor inputs(i.e. LIDAR, RADAR, etc.)

Safety critical levels of protection



Courtesy of Hexagon PI

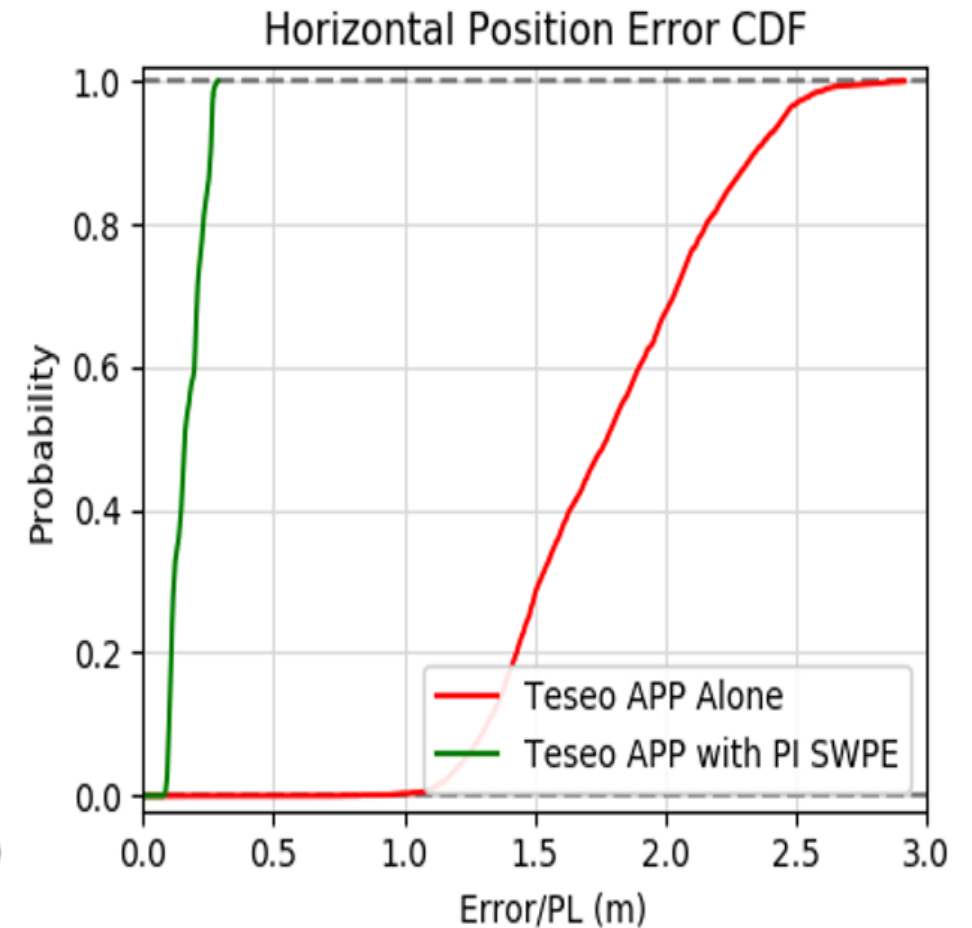
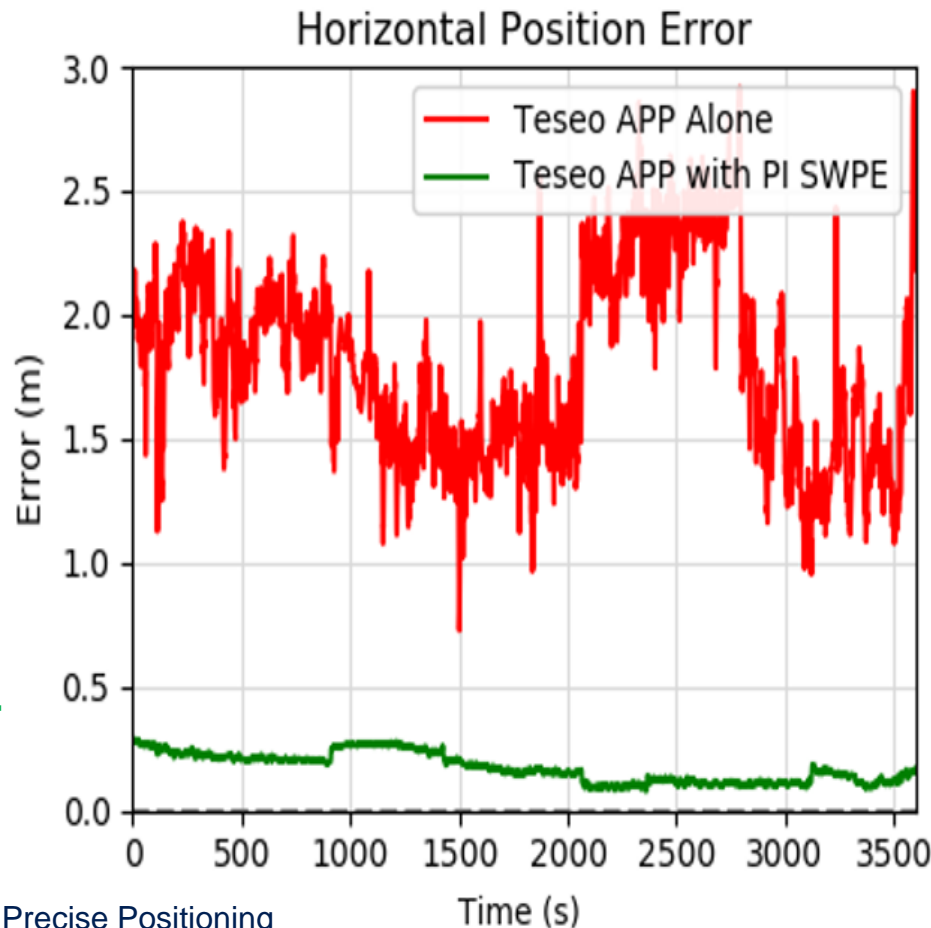
Precise GNSS is a Critical ADAS Sensor

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GNSS Accuracy in Automotive Environment (using PPP – Precise Point Positioning)

Single Frequency
(i.e. L1) multi-
constellation/code-
phase(1msec
modulation signal)

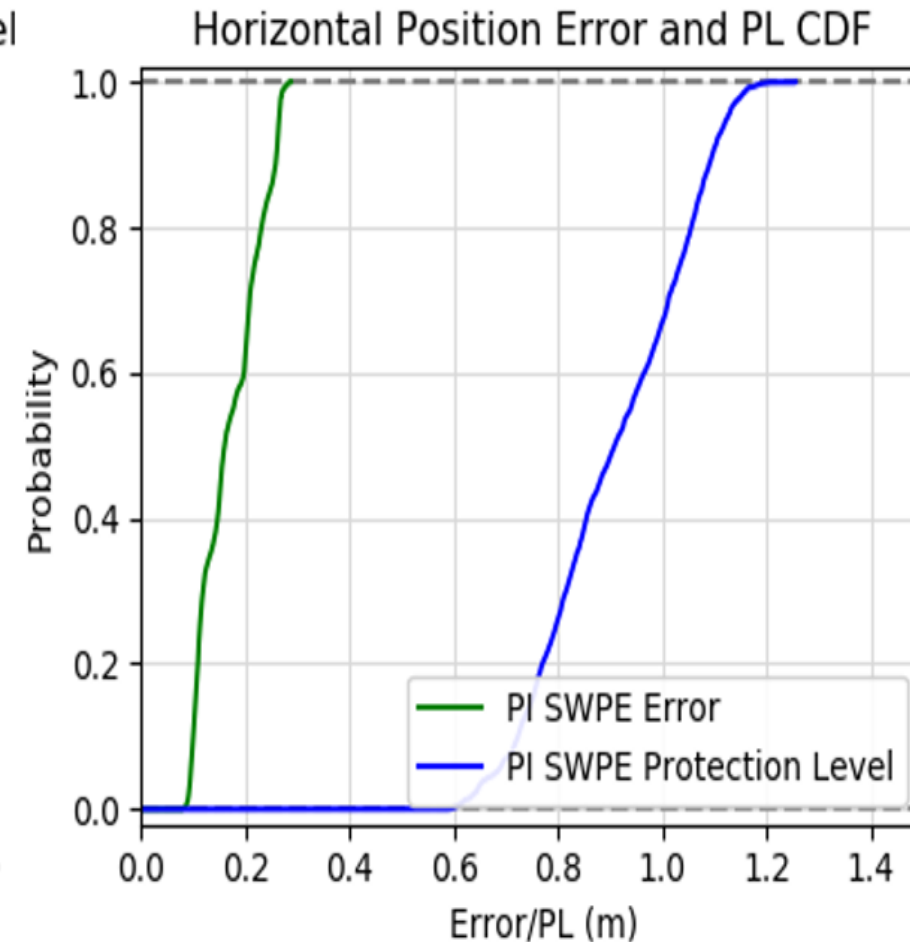
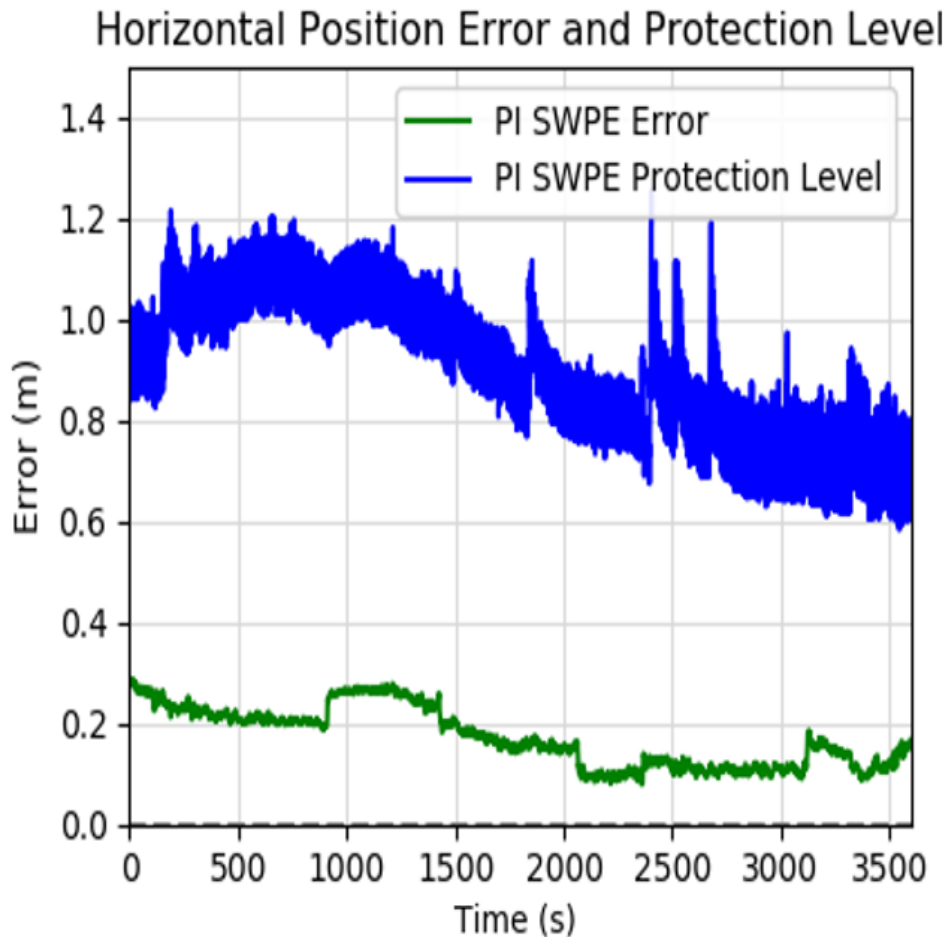
Multi Frequency (i.e.
L1, L2) multi-
constellation/carrier-
phase



Precise GNSS is a Critical ADAS Sensor

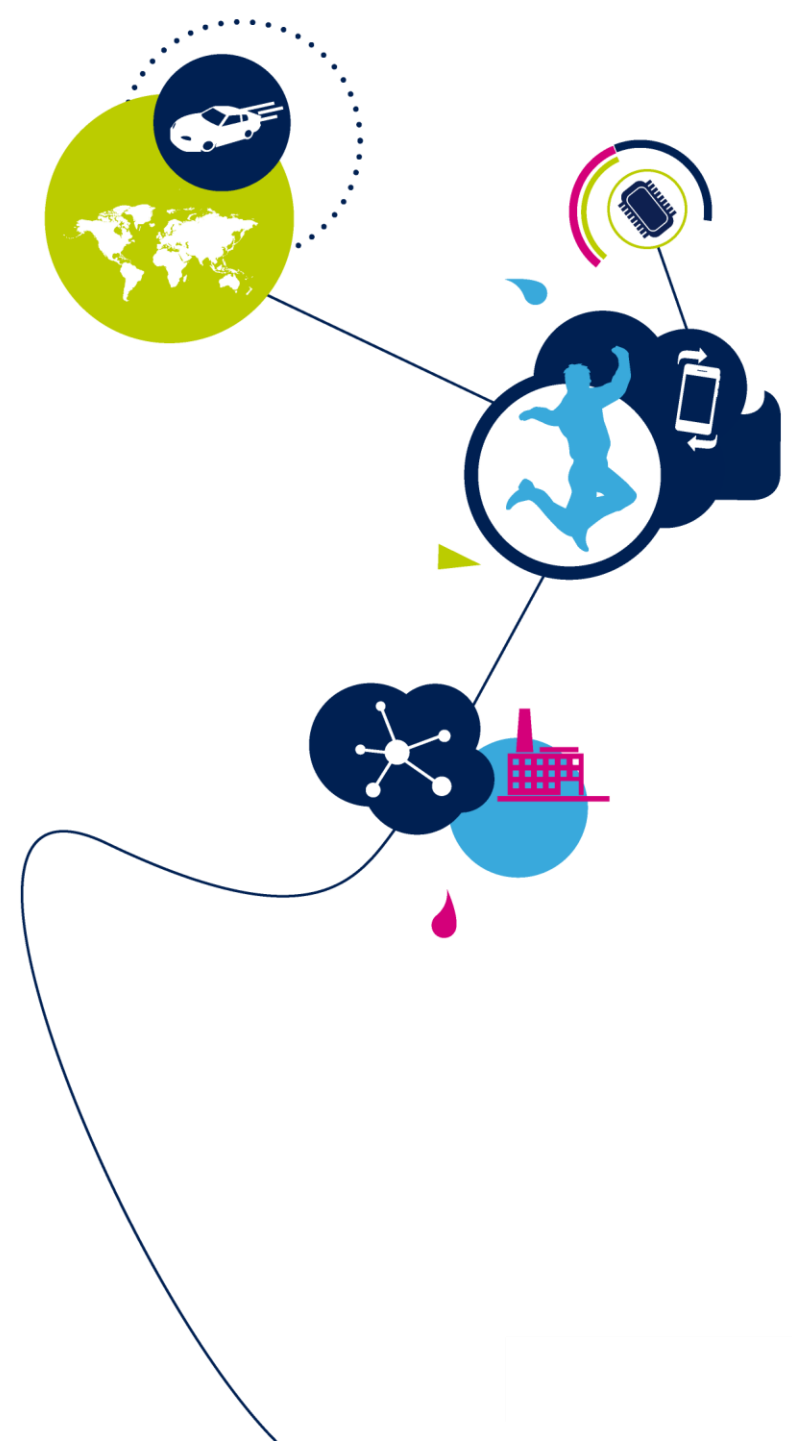
29

GNSS Integrity – Protection Levels



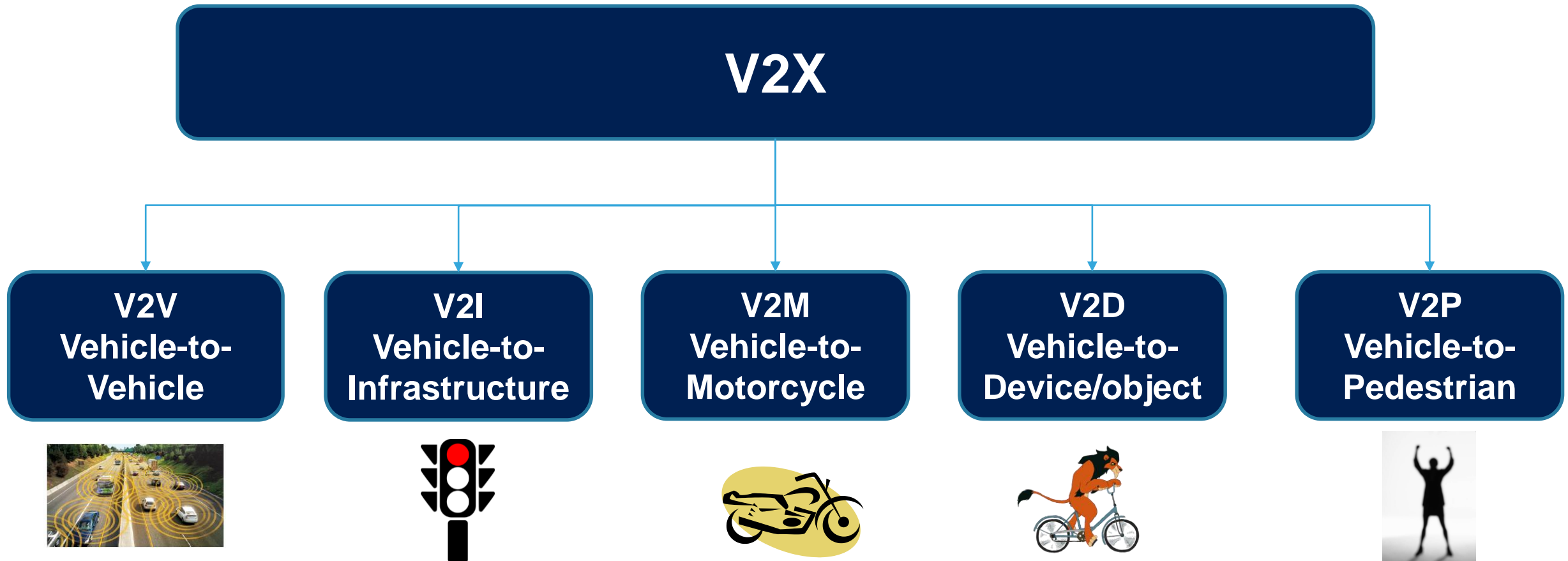
Automotive ADAS Systems

V2X System



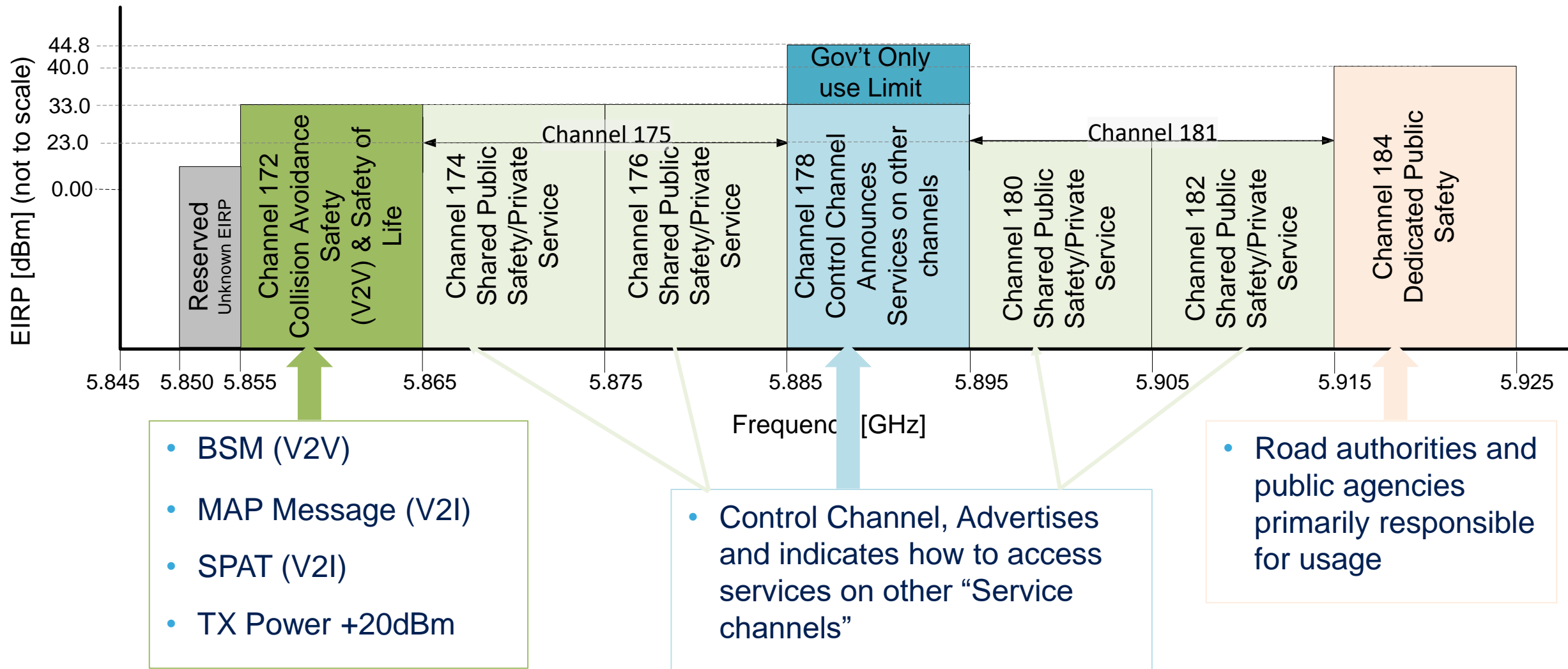
Vehicle-to-Everything (V2X)

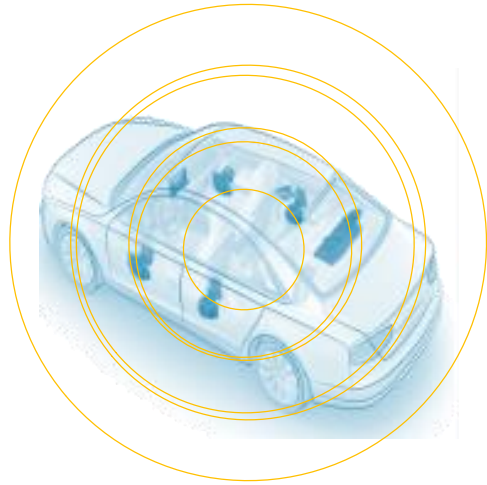
31



FCC Spectrum Allocation for DSRC of ITS

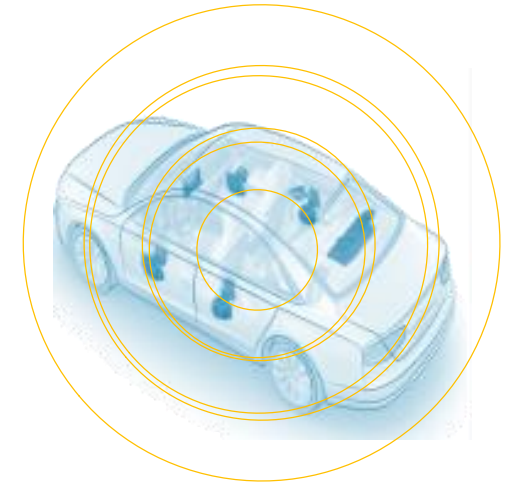
32



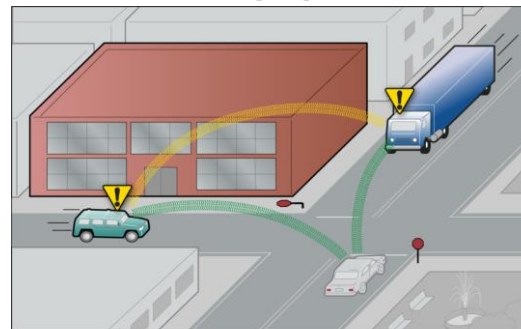


• Wireless Access in Vehicular Environments (WAVE)

- Amendment to IEEE 802.11-2012 to support WAVE/DSRC
- no authentication, no access point/no association
- 5.8 – 5.9 GHz OFDM



NLOS



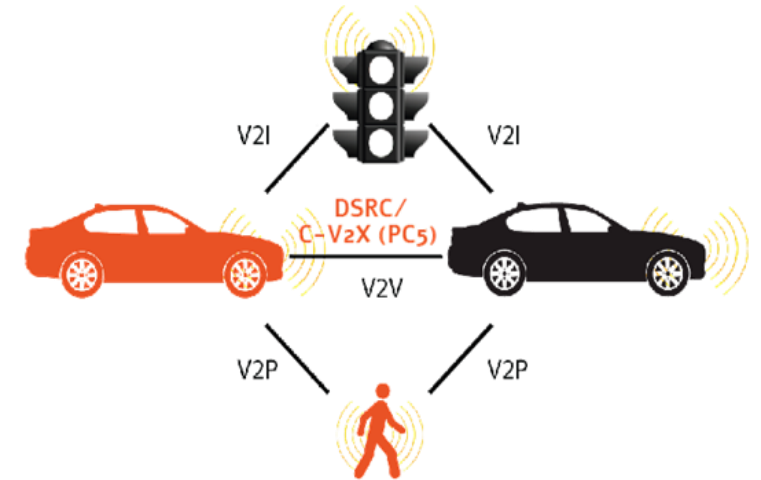
Source: GAO.

- Broadcasts BSMs 10 times per second
- Transmit power are about 100mW (20dBm @Antenna Port - Per IEEE802.11-D.2.2 Transmit power level) with a nominal range of 300m (360° coverage)
- DSRC units share the same channel

- Fast Network Acquisition & low latency (<50msec)
- Priority for Safety Applications
- Interoperability
- Security and Privacy (ensured through a root certification system)

- C-V2X is a V2X radio layer:
 - C-V2X is Device-to-Device (D2D) communication service added to the LTE Public Safety ProSe (Proximity Services) Services
 - C-V2X makes use of the D2D interface – PC5 (aka Side Link) for direct Vehicle-to-Everything communication
 - C-V2X takes the place of DSRC radio layer in relevant regions
 - V2V, V2I and V2P

Device-to-Device Communication



V2X - Vehicle to Everything

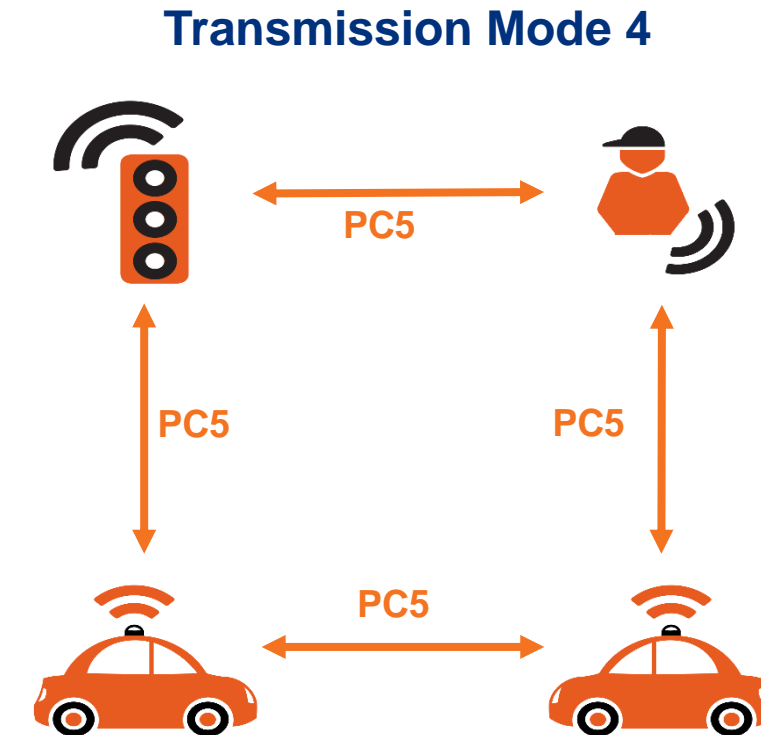
ITS Layers Remain Unchanged!

- C-V2X Transmission Mode 4:
 - **Mode 4** – Stand alone, distributed
 - Uses GNSS for location and time for synchronization

Transmission Mode 4



- Transmission Mode 4:
 - Out of Coverage operation: The transmitting vehicle is not connected to the network
 - No SIM card or inter-operator collaboration is required
 - Each vehicle performs its own scheduling and allocation
 - No dependency on inter-vehicle components (eNB, Allocation Server etc...)
 - Mandatory for SAE, ETSI



- C-V2X is based on LTE (4G) uplink transmission - SC-FDMA (Single Carrier Frequency Division Multiple Access) signal:
 - A single carrier multiple access technique which has similar structure and performance to OFDMA
 - Utilizes single carrier modulation and orthogonal frequency multiplexing using DFT-spreading in the transmitter and frequency domain equalization in the receiver
 - A salient advantage of SC-FDMA over OFDM/OFDMA is low Peak-to-Average Power Ratio (PAPR). Enables efficient transmitter and improved link budget

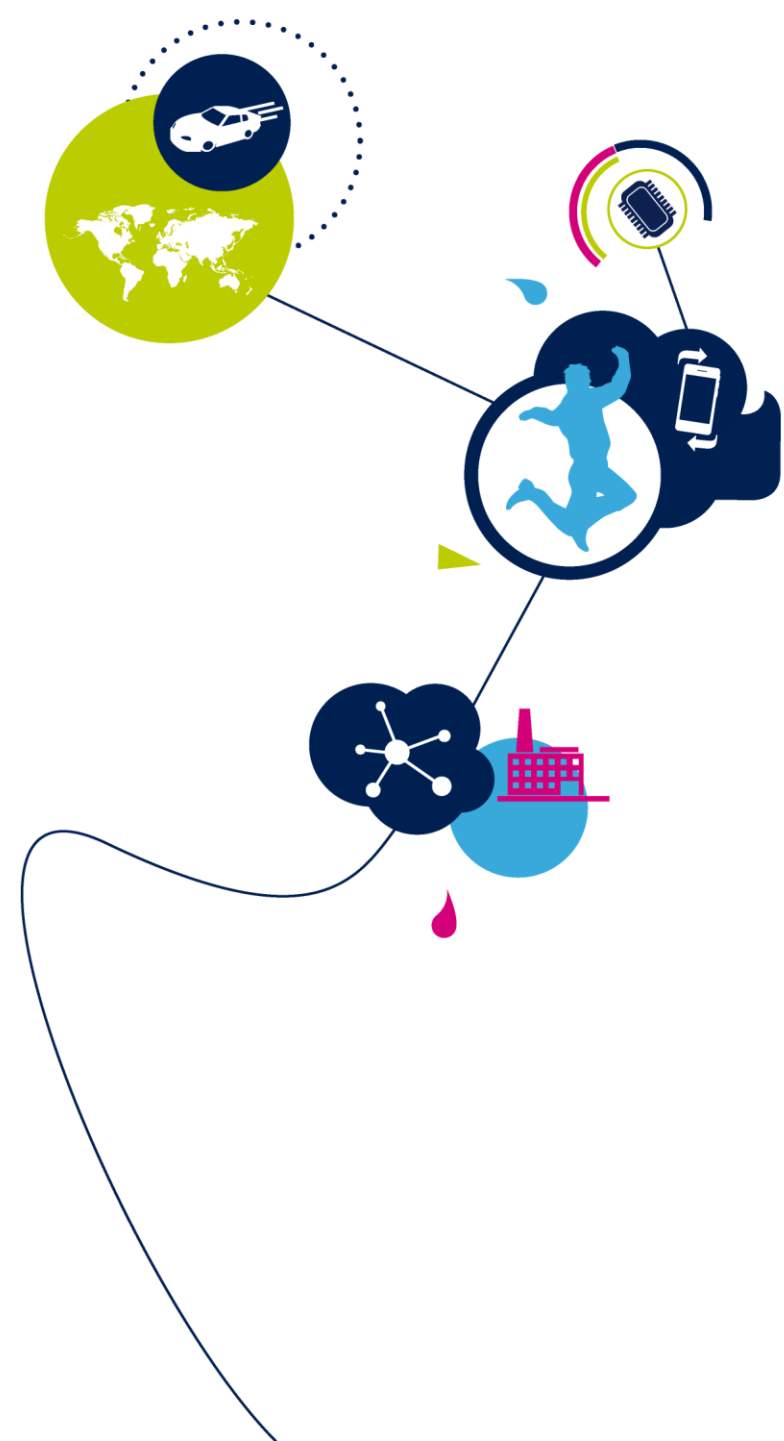
Both Technologies will do the JOB!

But:

- Industry is waiting for regulatory certainty, Government Mandate is preferred!
- C-V2X has to reach automotive production maturity
- Implementation and deployment will depend on OEM system architecture
- The market will demand standalone V2X module for OEMs and aftermarket because V2X is a safety critical sensor.

Automotive ADAS Systems

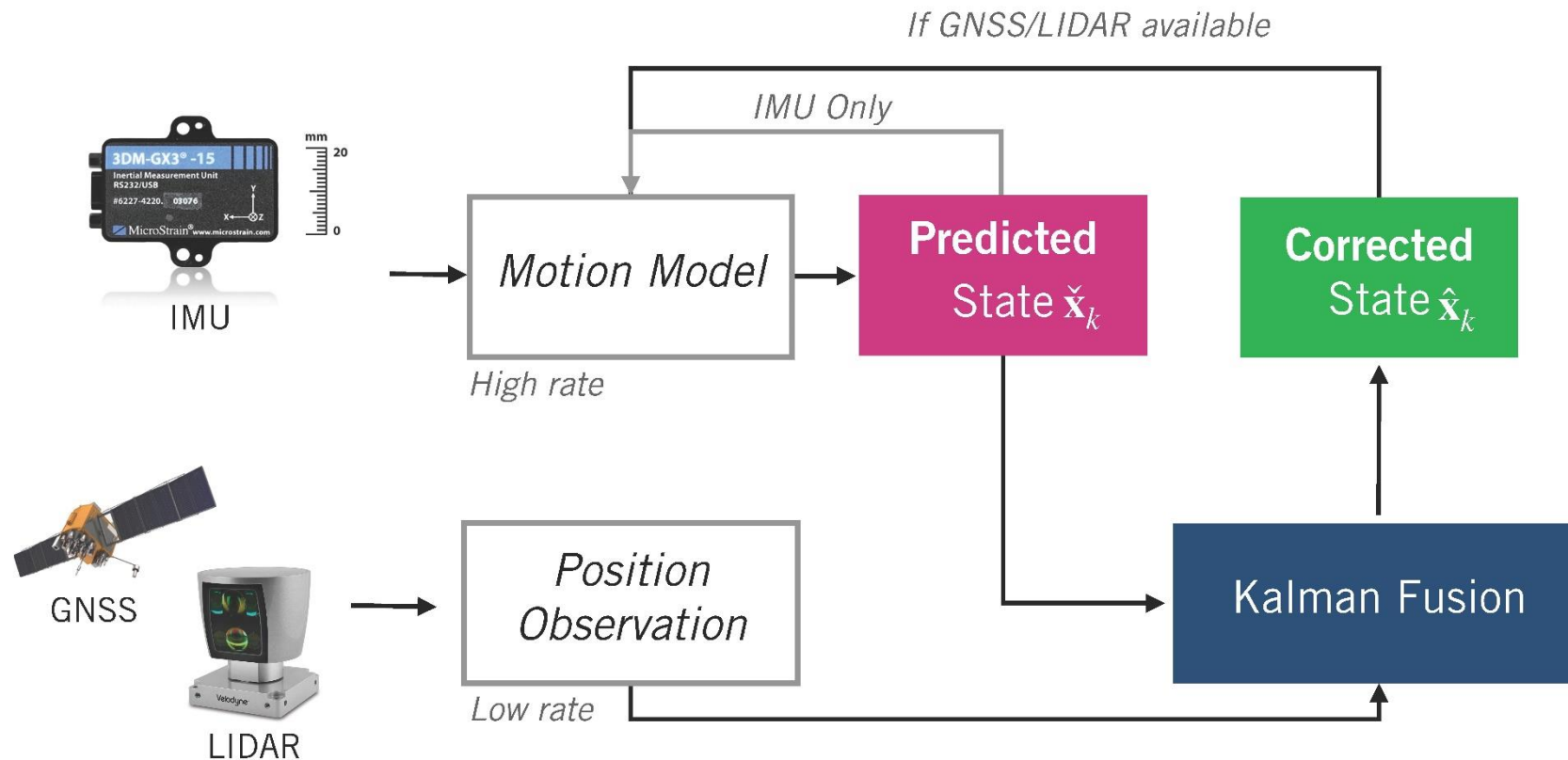
Sensor Fusion Example



Multi-sensor Fusion for State Estimation

40

Extended Kalman Filter | IMU + GNSS + LIDAR





Thank You!

Q&A