Automotive ADAS Systems

Overall Automotive ADAS System

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ADAS Overview

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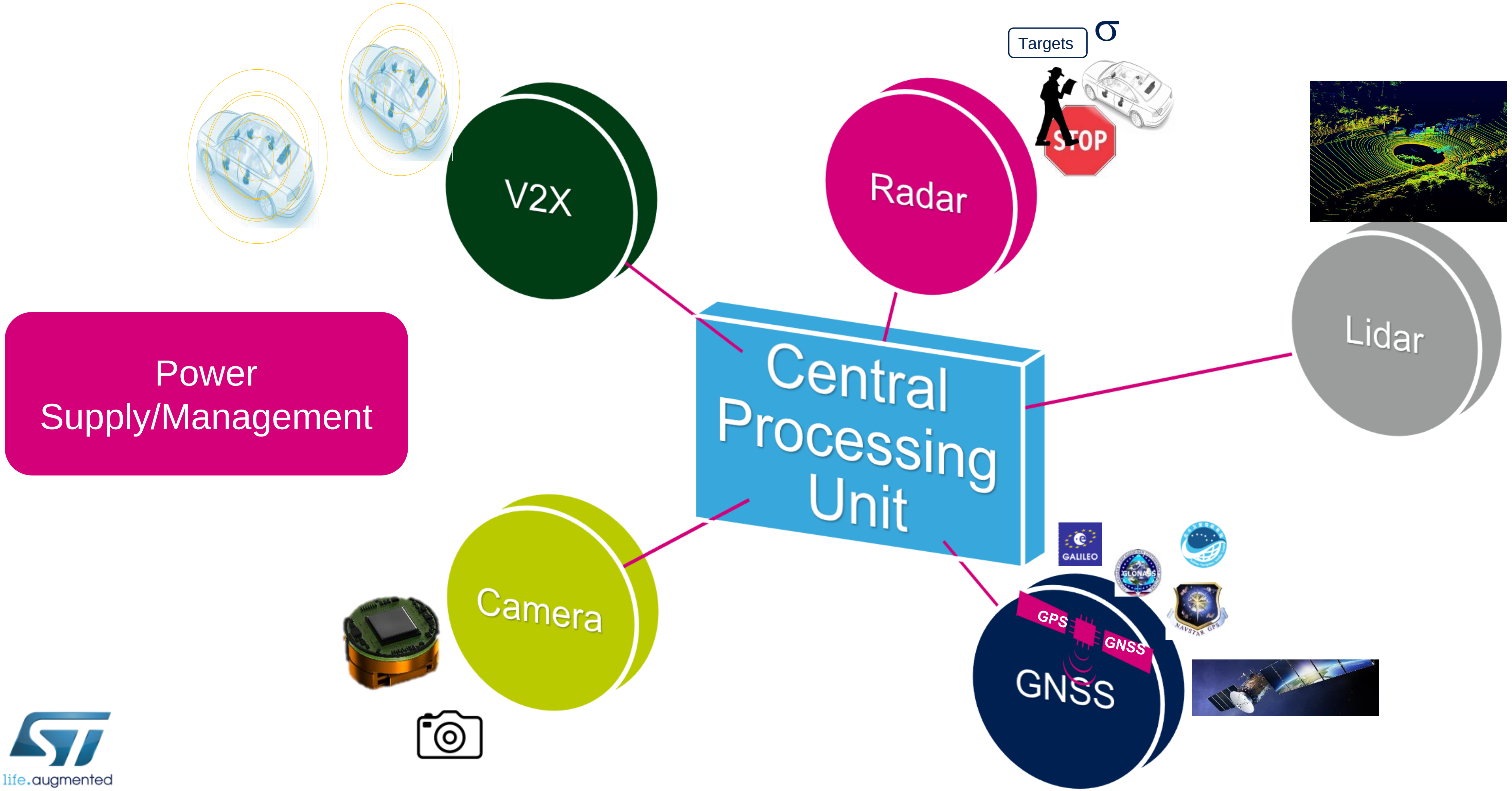
Overview of ADAS Technologies



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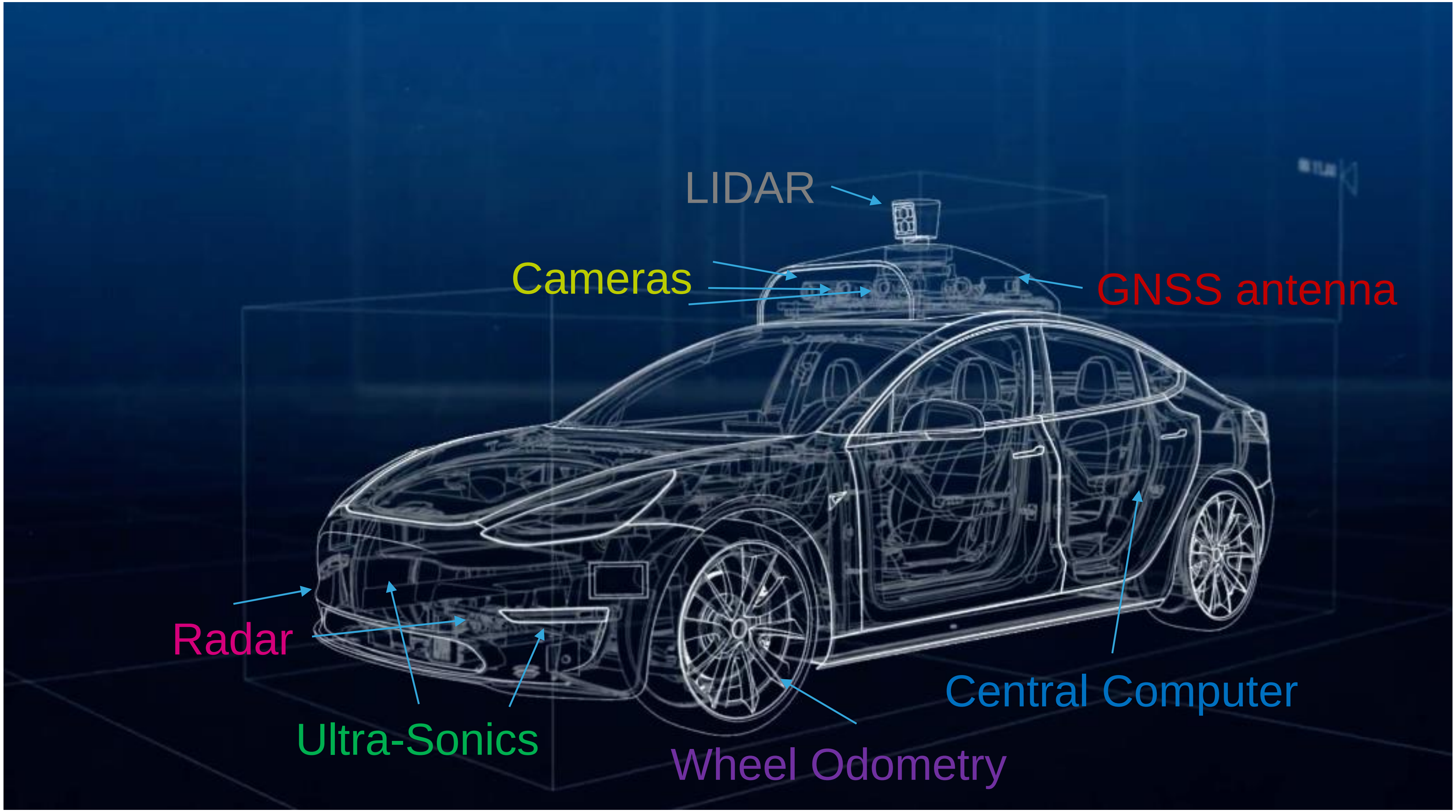
ADAS Sensors - Needed for Perception



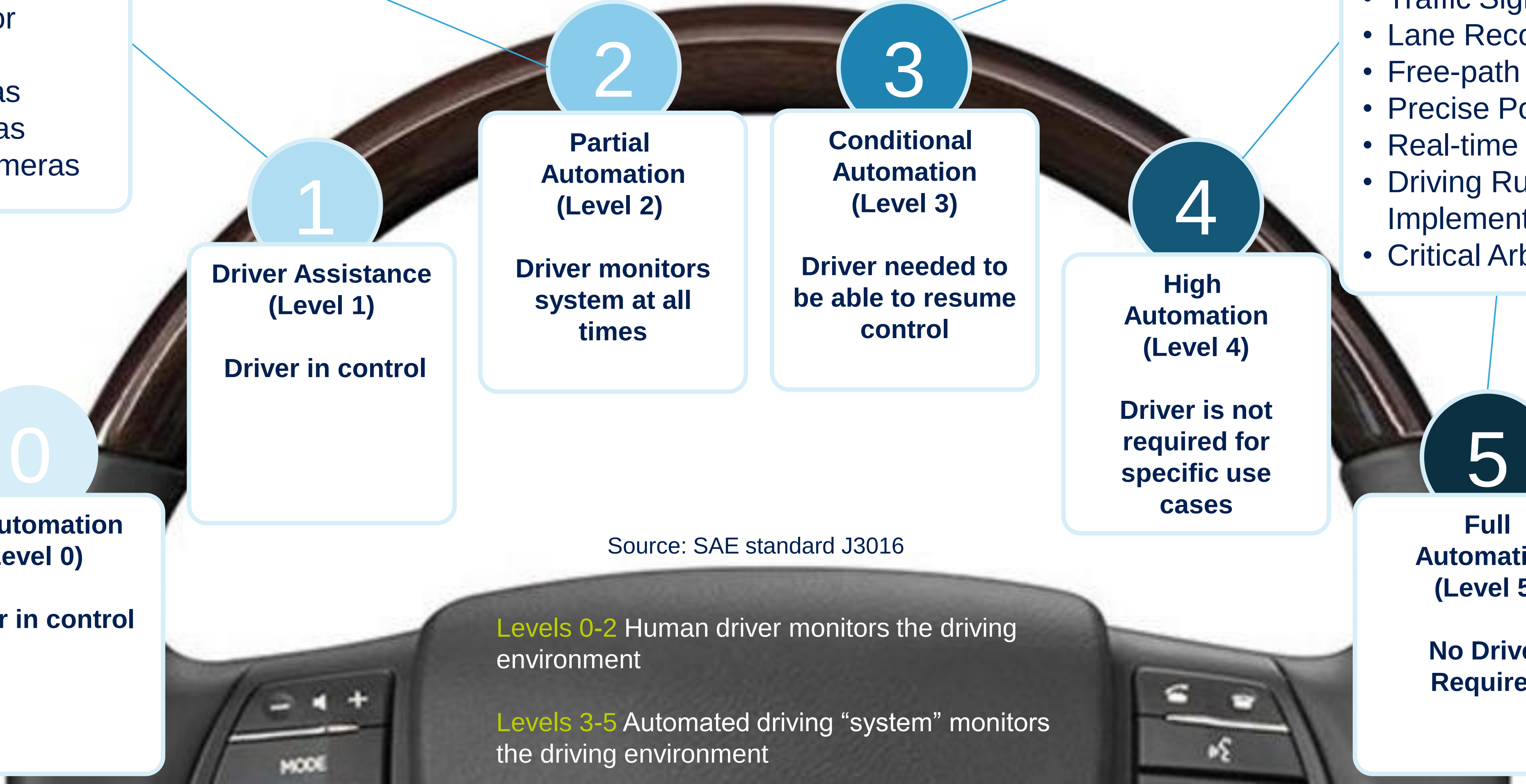
The 5 Levels of Vehicle Automation

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



0

No Automation (Level 0)

Driver in control

1

Driver Assistance (Level 1)

Driver in control

2

Partial Automation (Level 2)

Driver monitors system at all times

3

Conditional Automation (Level 3)

Driver needed to be able to resume control

4

High Automation (Level 4)

Driver is not required for specific use cases

5

Full Automation (Level 5)

No Driver Required

Source: SAE standard J3016

Levels 0-2 Human driver monitors the driving environment

Levels 3-5 Automated driving "system" monitors the driving environment

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Sensor Fusion is Key to Autonomous

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	Fair	Good	Good	Good	Good
Object classification	Good	Poor	Fair	Poor	Good
Distance estimation	Fair	Good	Good	Good	Good
Object edge precision	Good	Poor	Good	Good	Good
Lane tracking	Good	Poor	Poor	Poor	Good
Range of visibility	Fair	Good	Fair	Poor	Good
Functionality in bad weather	Poor	Good	Fair	Good	Good
Functionality in poor lighting	Fair	Good	Good	Good	Good

Source: Woodside Capital Partners (WCP), “Beyond the Headlights: ADAS and Autonomous Sensing”, September 2016

Automotive ADAS Systems

ADAS Vehicle Architectures

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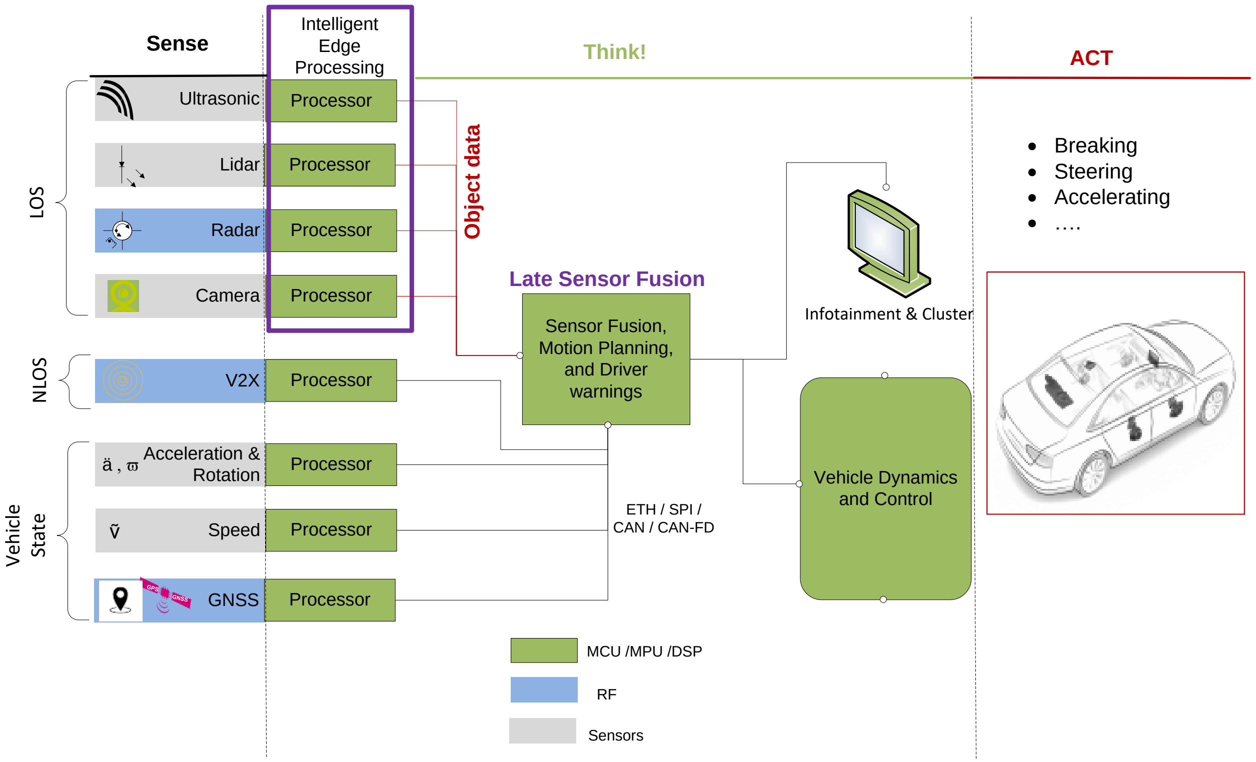
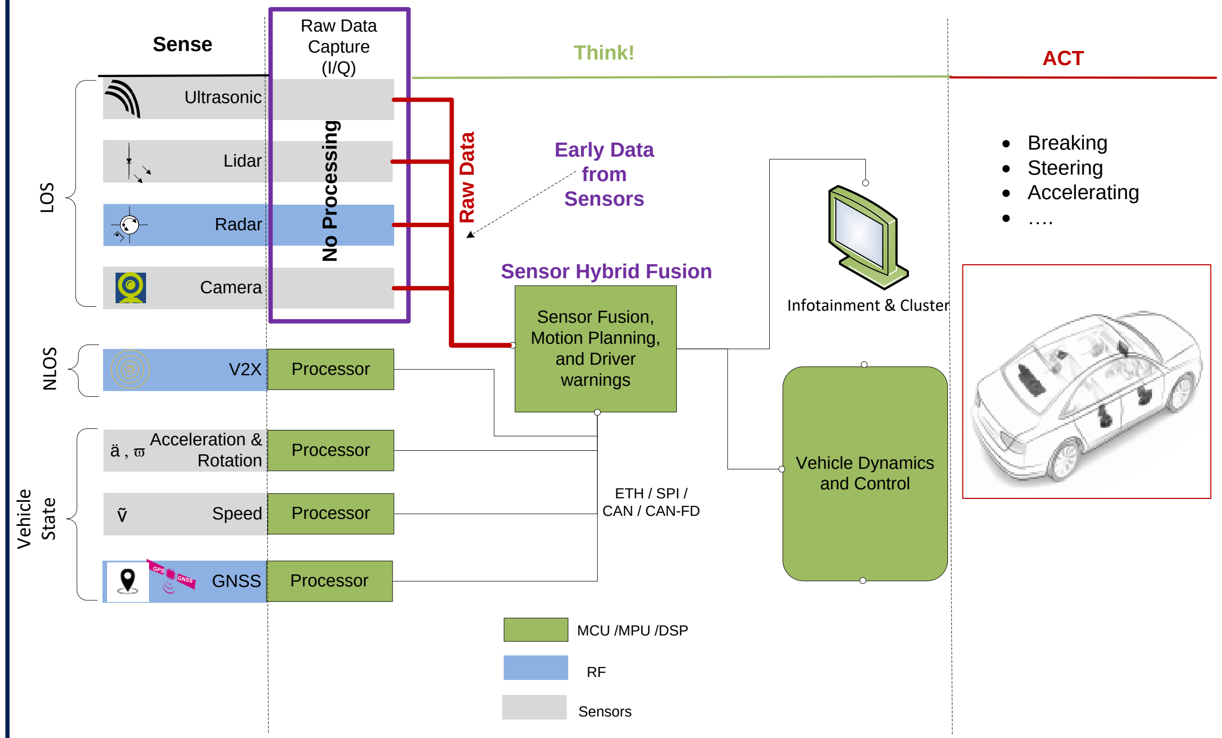
Distributed vs Centralized Processing

Distributed Processing with Object Level Fusion



Centralized Processing with Raw Data Fusion

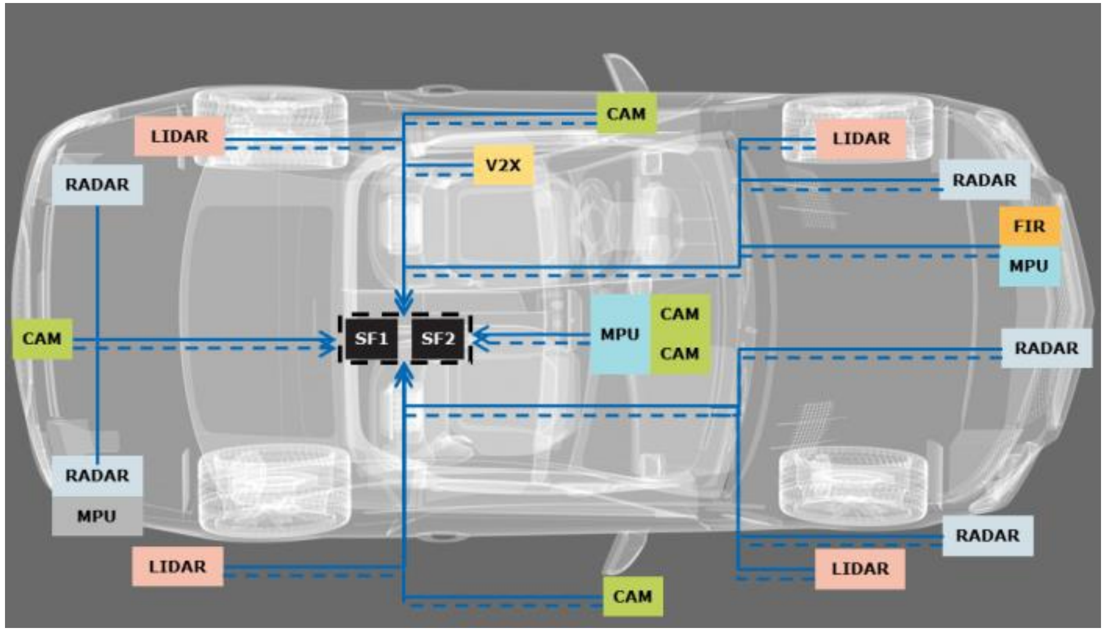


LOS: Line-of-Sight
NLOS: Non-Line-of-Sight

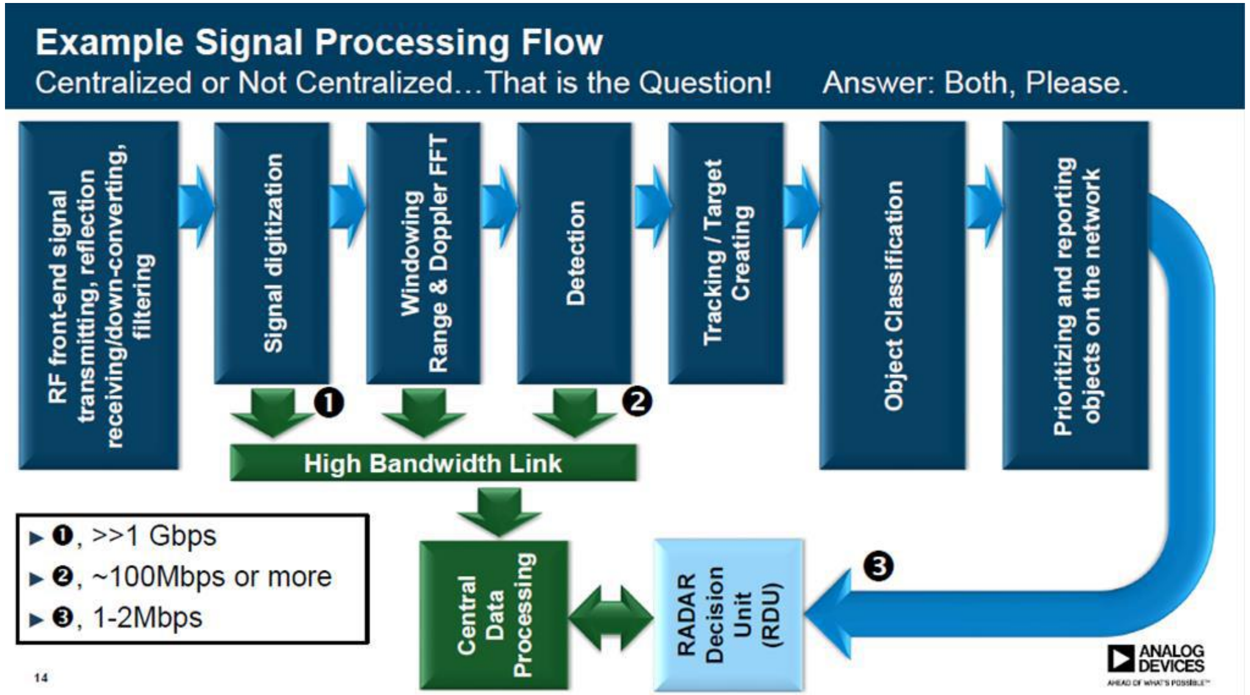
- Distributed Interfaces
  - ETH, SPI, I2C, CAN, CAN-FD
    - RADAR, Ultrasonic, V2X, IMU, Wheel Odomerty, GNSS
  - MIPI(CSI-2), GMSL(Maxim), FPD-Link(TI), PCIe, HDBaseT(Valens)
    - Video Cameras?
    - Lidar?

- 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



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



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.

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Vision (Cameras) System

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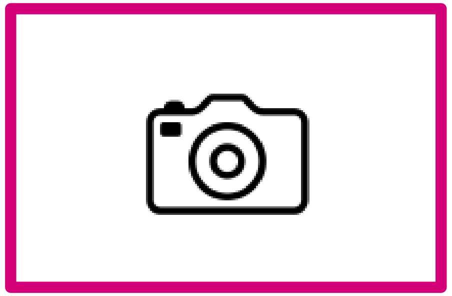
Camera

- Essential for correctly perceiving environment
- Richest source of raw data about the scene - only sensor that can reflect the true complexity of the scene.

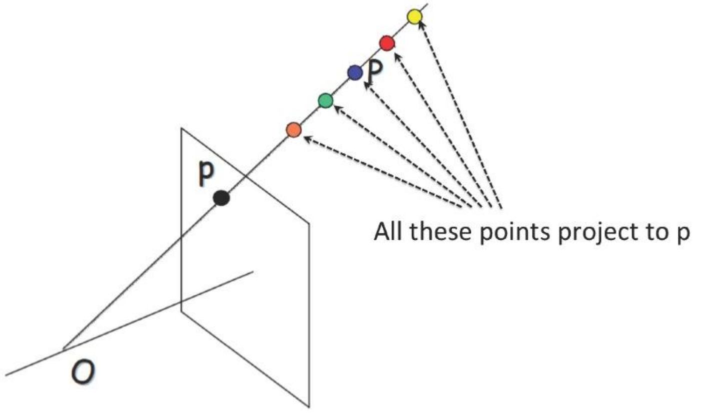


- The lowest cost sensor as of today
- Comparison metrics:
  - Resolution
  - Field of view (FOV)
  - Dynamic range
- Trade-off between resolution and FOV?

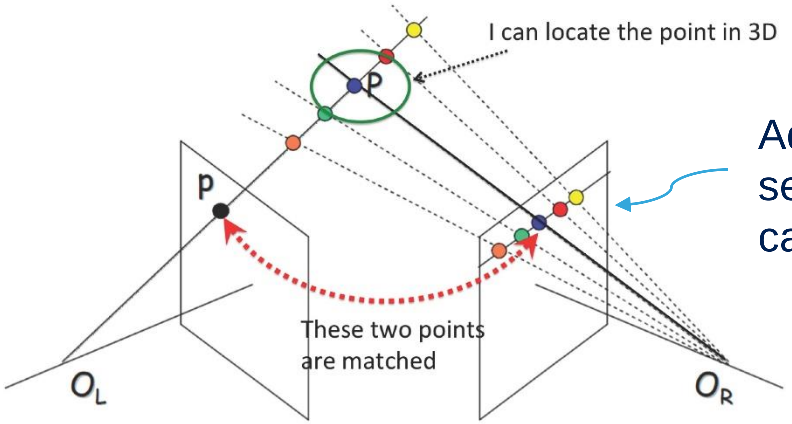
Camera-Stereo

- Enables depth estimation from image data

All points on projective line to P map to p

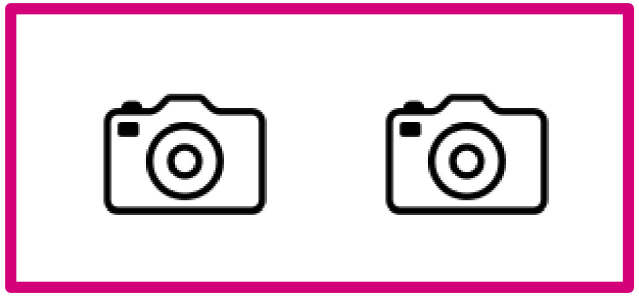


One camera



Add a second camera

Find a point in 3D by triangulation!

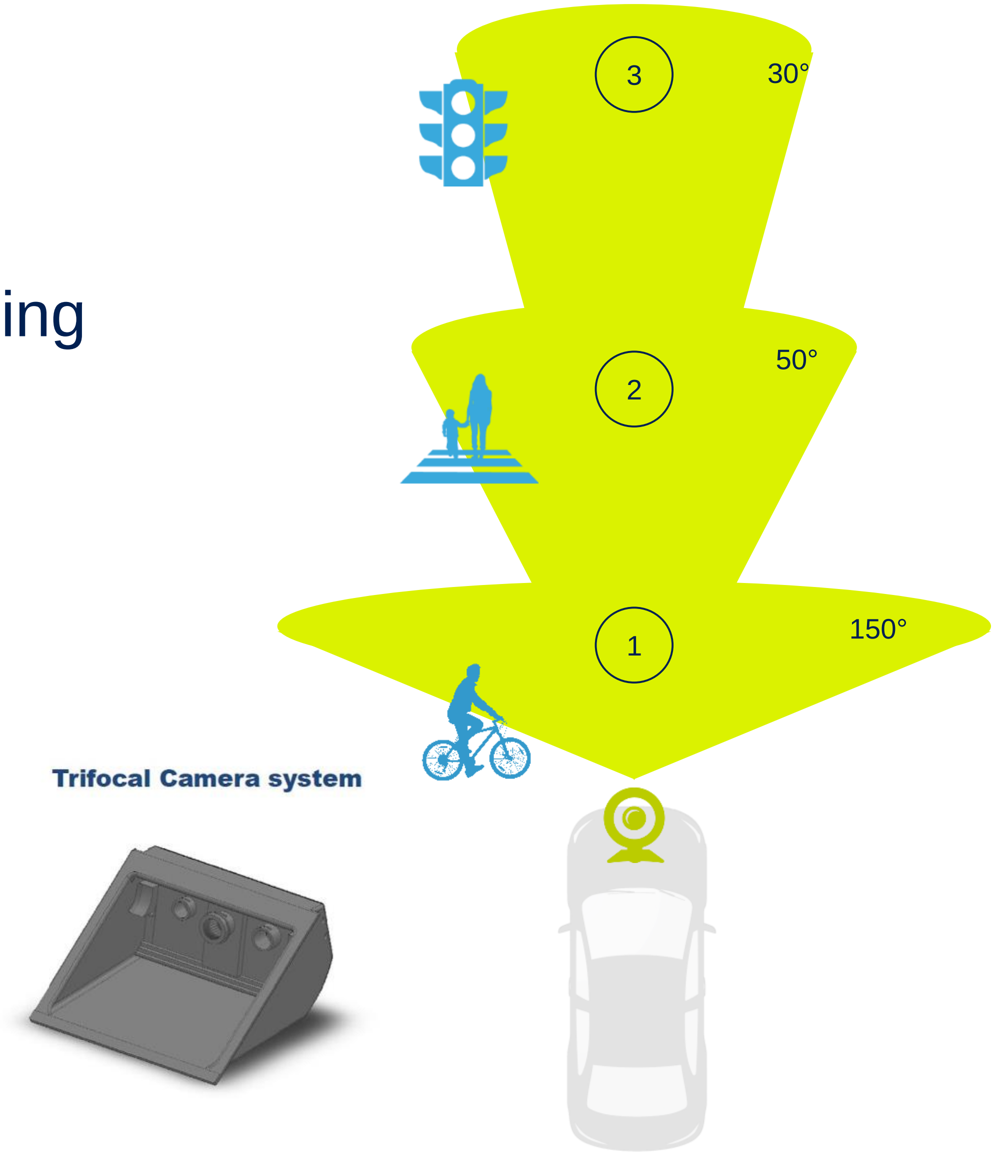


Left and right images

Source: Sanja Fidler, CSC420: Intro to Image Understanding

The Next Phase for Vision Technology

- 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



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Machine Vision: ST & Mobileye

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

MOBILEYE®

Partnership

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

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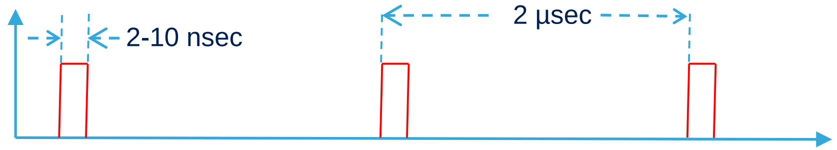
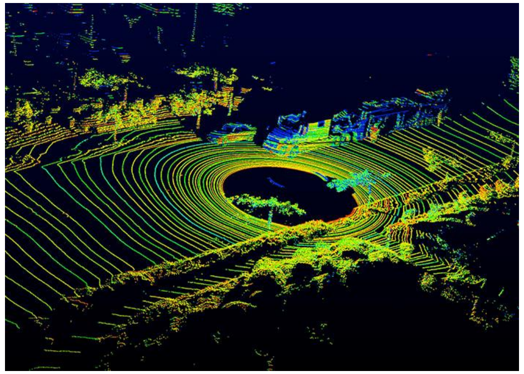
LiDAR Technology Overview

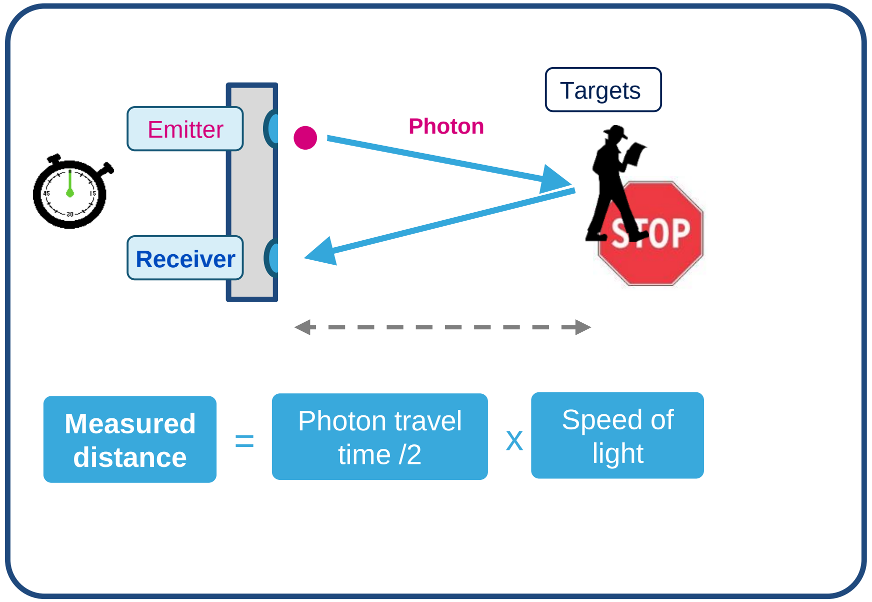
- LiDAR (light detecting and ranging, or "light radar") sensors send one or more laser beams at a high frequency and use the Time-of-Flight principle to measure distances. LiDAR capture a high-resolution point cloud of the environment.

- 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".





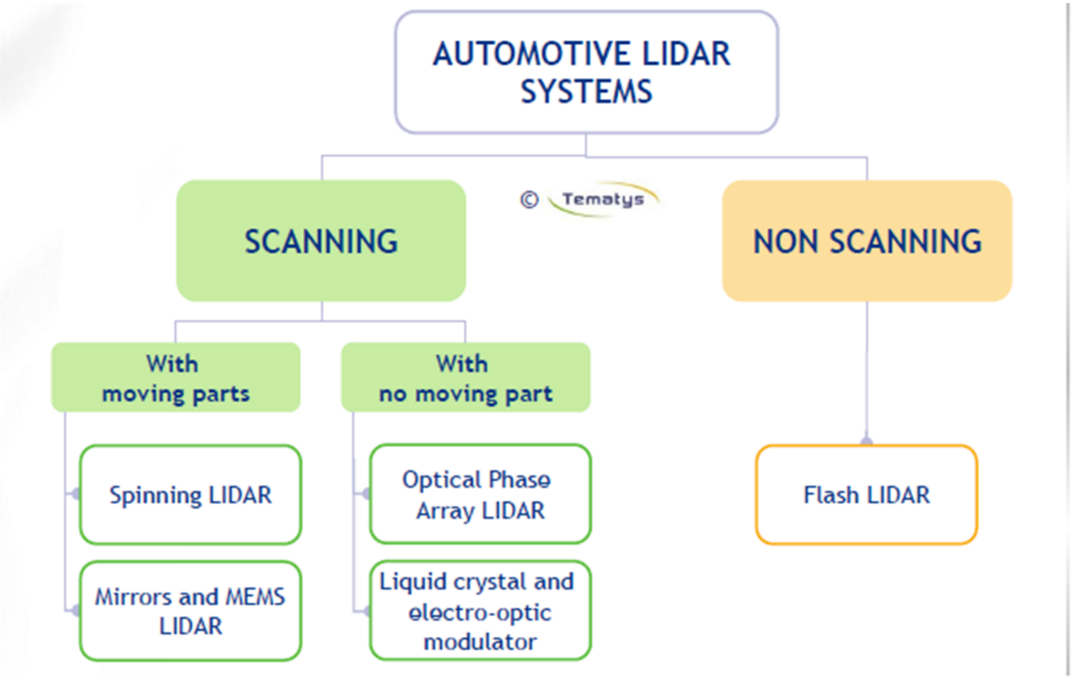


LiDAR Techniques

- 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!

LiDAR Summary

- 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

Automotive ADAS Systems

Radar Systems

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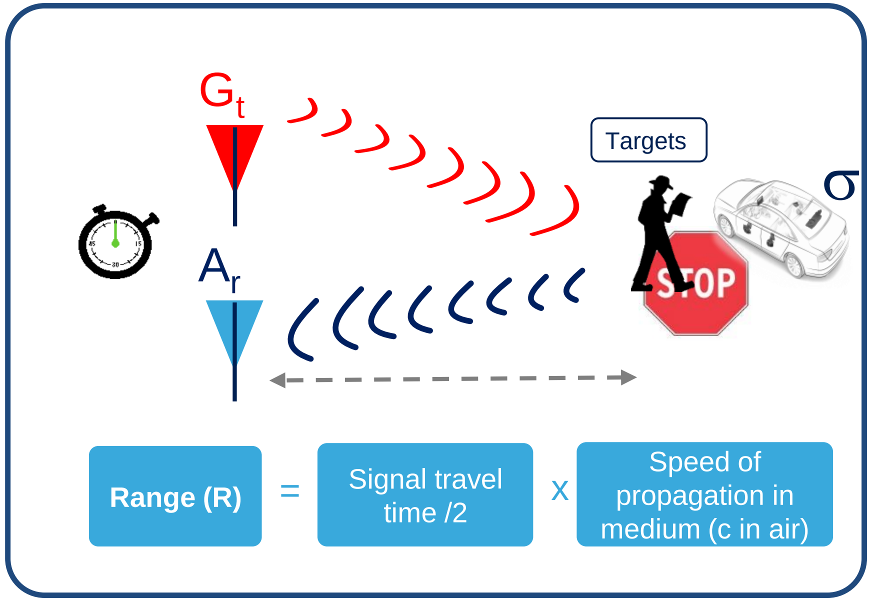
RADAR Technology Overview

- RADAR (**RA**dio **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.



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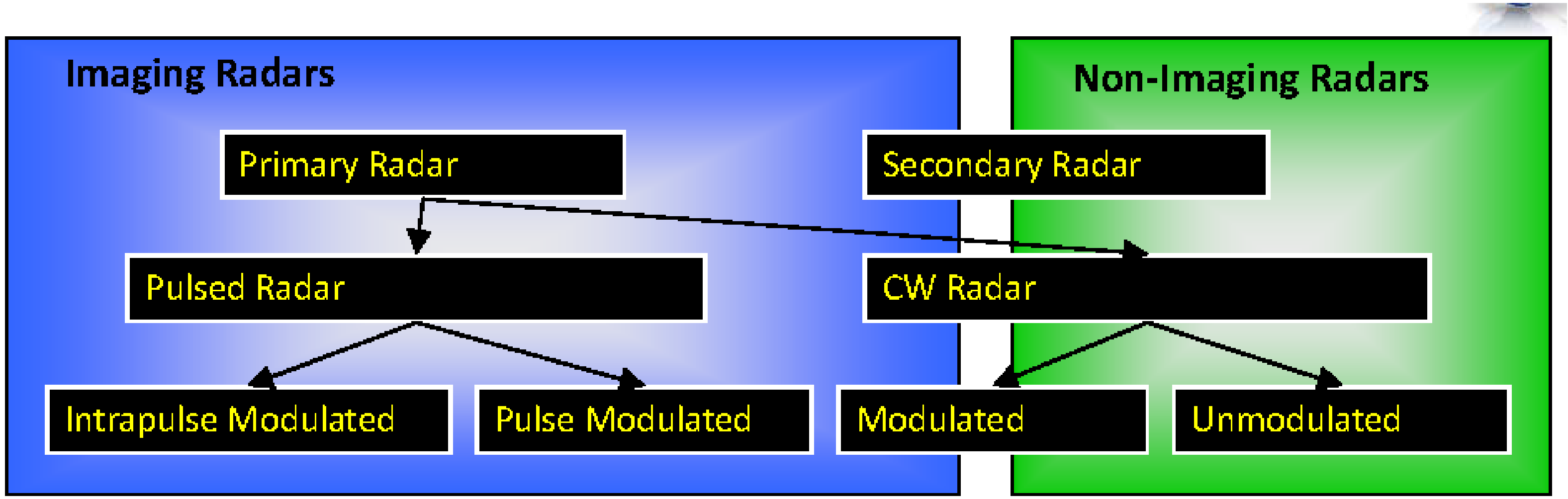
RADAR Techniques



- 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

Source: Strategy Analytics Lunch & Learn the Market Session European Microwave Week 2013

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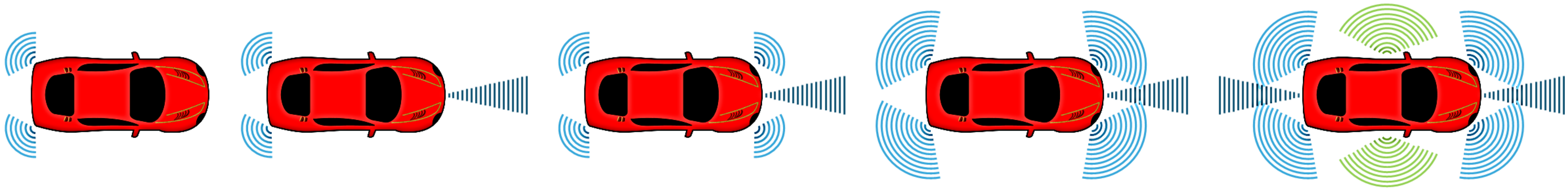
Source: Rodhe & Schwarz - Automotive radar technology, market and test requirements, White paper – Oct 2018 (Salvo S. presentation)

Automotive Radar Vs. Automation Levels

< 2014 Level 1 Driver Assistance	2016 Level 2 Partial Automation	2018 Level 3 Conditional Automation	2019 / 2020 Level 4 High Automation	> 2028 Level 5 Full Automation



Object detection	**Object detection**	**High resolution target separation**	**3D detection**	**360° object recognition**
2x SRR	**2x SRR 1x LRR**	**4x SRR 1x LRR**	**4x SRR-MRR 1x LRR**	**2x USRR 4x SRR-MRR 2x LRR**
Applications	**Applications**	**Applications**	**Applications**	**Applications**
BSD, LCA	**BSD, RCW, LCA ACC, AEB**	**BSD, RCW, LCA FCW, RCTA ACC, AEB**	**BSD, LCA, RCTA AEB pedestrian ACC, AEB**	**AVP, PA BSD, LCA, RCTA AEB pedestrian ACC, AEB**

USRR - Ultra Short Range Radar
SRR - Short Range Radar
MRR - Medium Range Radar
LRR - Long Range Radar

BSD - Blind Sport Detection
LCA - Lane Change Assist
RCW - Rear Collision Warning

ACC - Adaptive Cruise Control
AEB - Automatic Emergency Breaking
FCW - Forward Collision Warning

RCTA - Rear Cross Traffic Alert
AVP - Automated Valet Parking
PA - Parking Assist

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Automotive ADAS Systems

GNSS/IMU System

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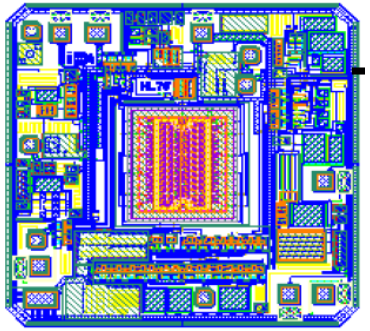
GNSS/IMU Positioning

- 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)



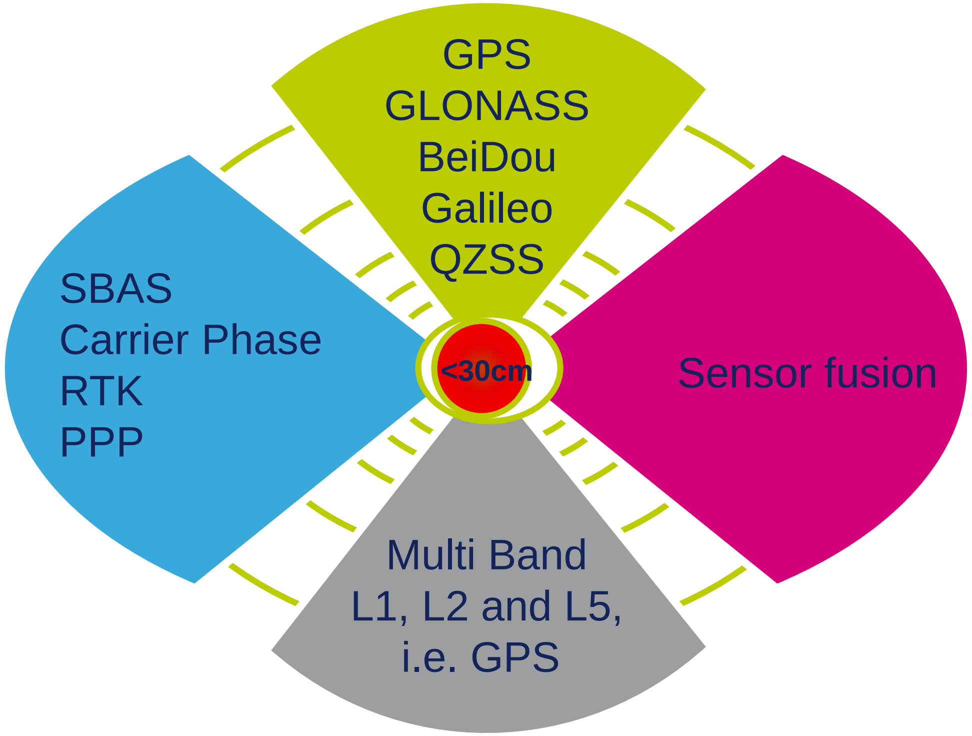
GNSS/IMU Positioning

More Precision Enables More Safety Features

Precise Positioning: Towards Autonomous Driving

Precise Positioning to enable < 30cm precision

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

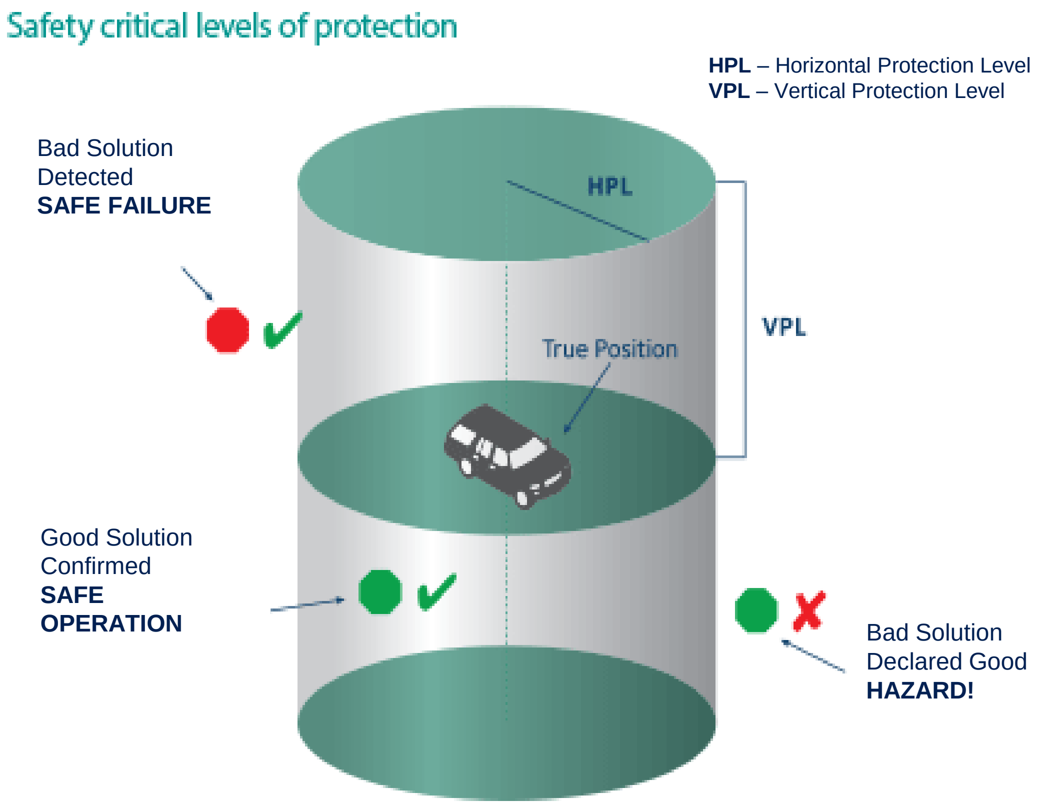


Precise GNSS is a Critical ADAS Sensor

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.)



Courtesy of Hexagon PI

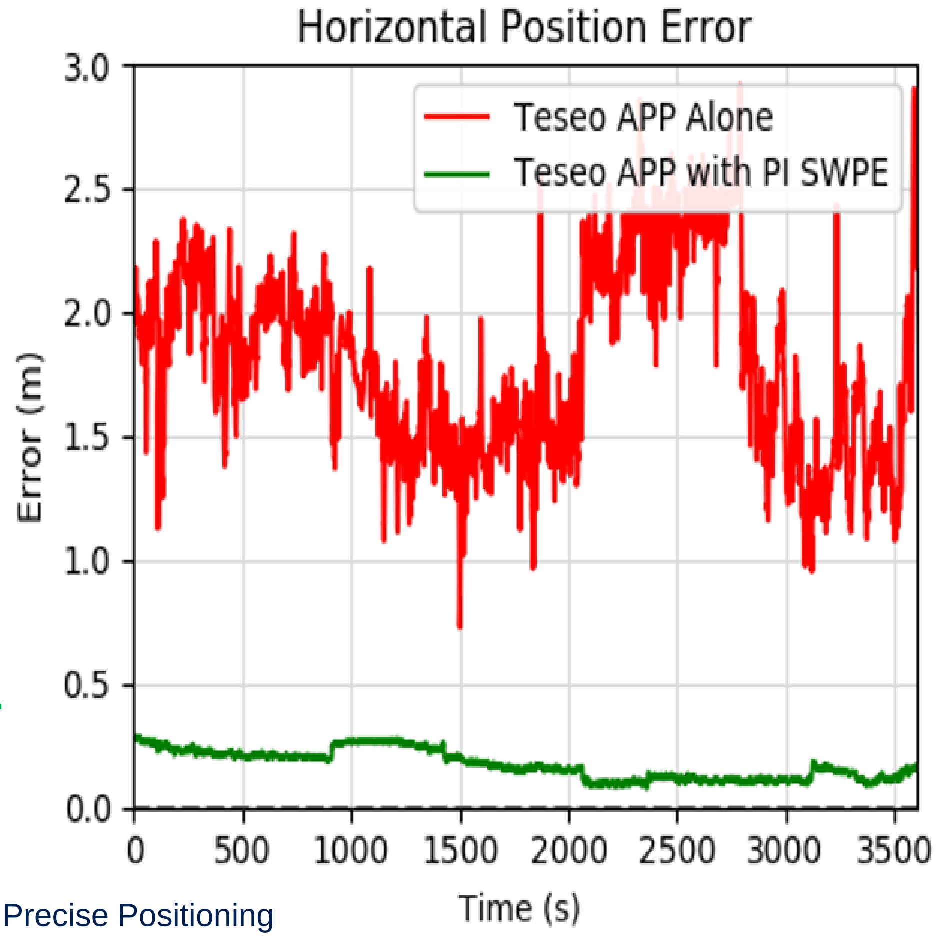
ST's GNSS Receiver Family for ADAS and AD

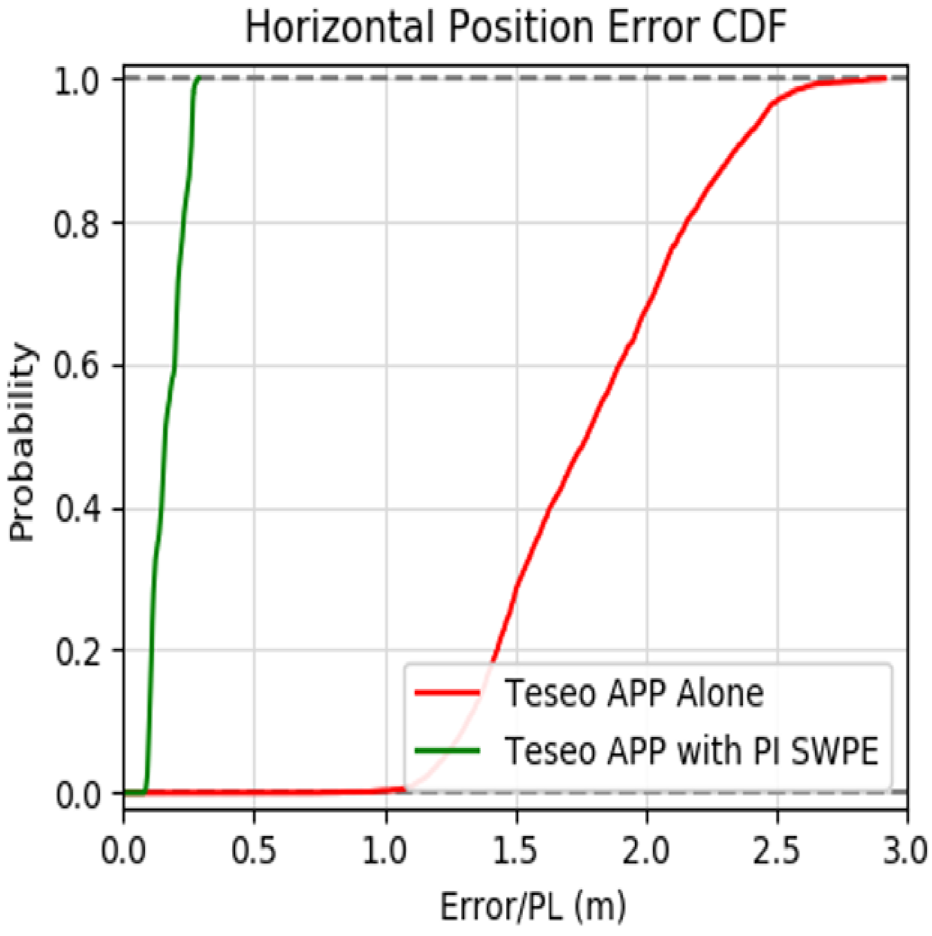
Precise GNSS is a Critical ADAS Sensor

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

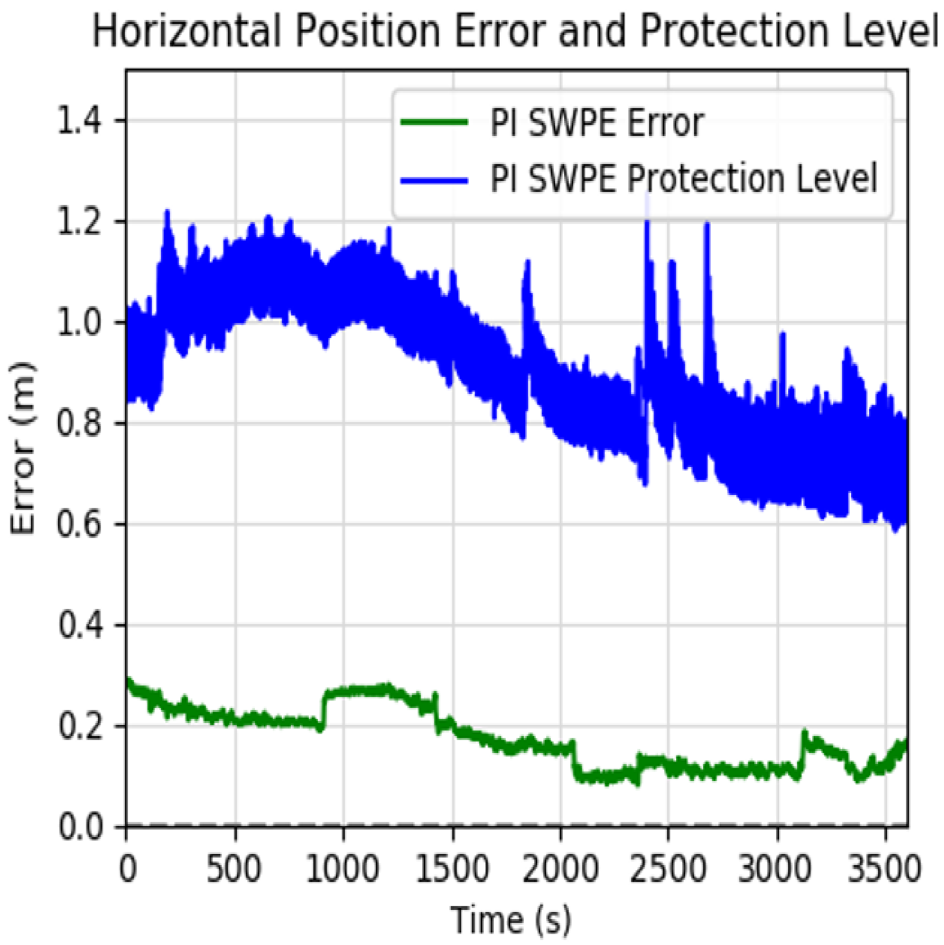


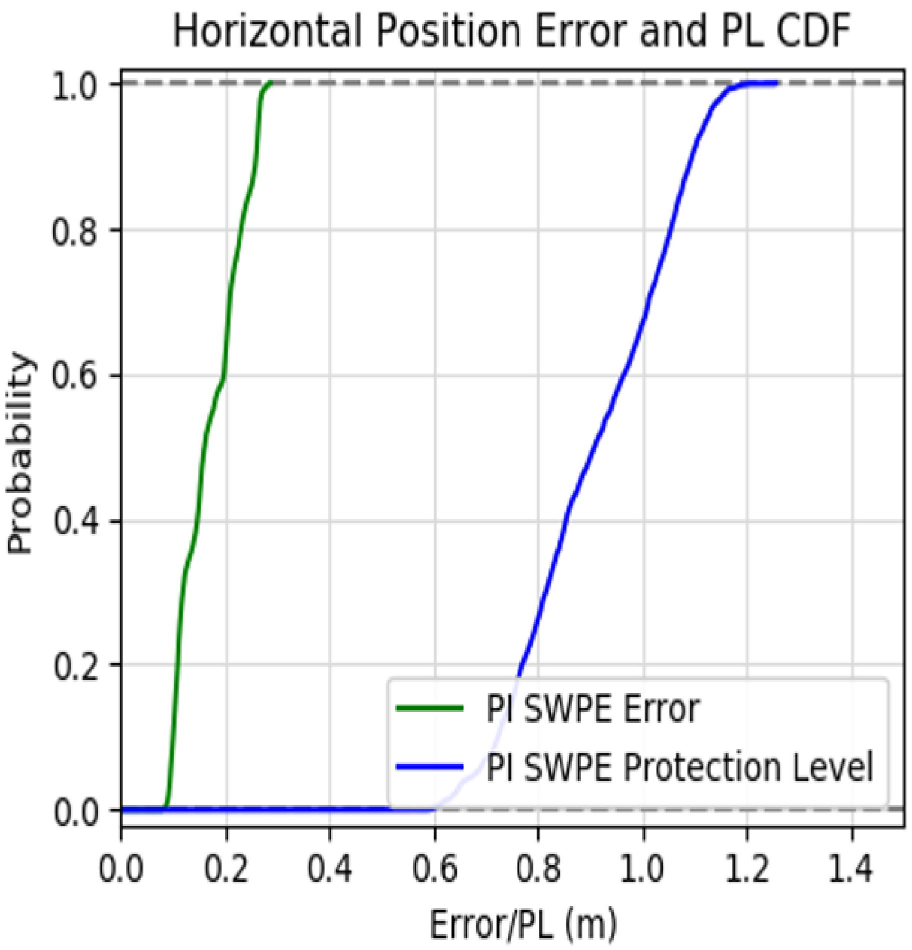


APP: ASIL Precise Positioning
SWPE: Software Positioning Engine

Precise GNSS is a Critical ADAS Sensor

GNSS Integrity – Protection Levels





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Automotive ADAS Systems

V2X System

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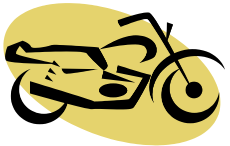
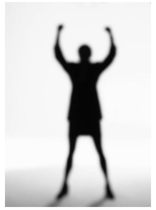
Vehicle-to-Everything (V2X)

V2X

V2V	V2I	V2M	V2D	V2P
Vehicle-to-Vehicle	Vehicle-to-Infrastructure	Vehicle-to-Motorcycle	Vehicle-to-Device/object	Vehicle-to-Pedestrian
				

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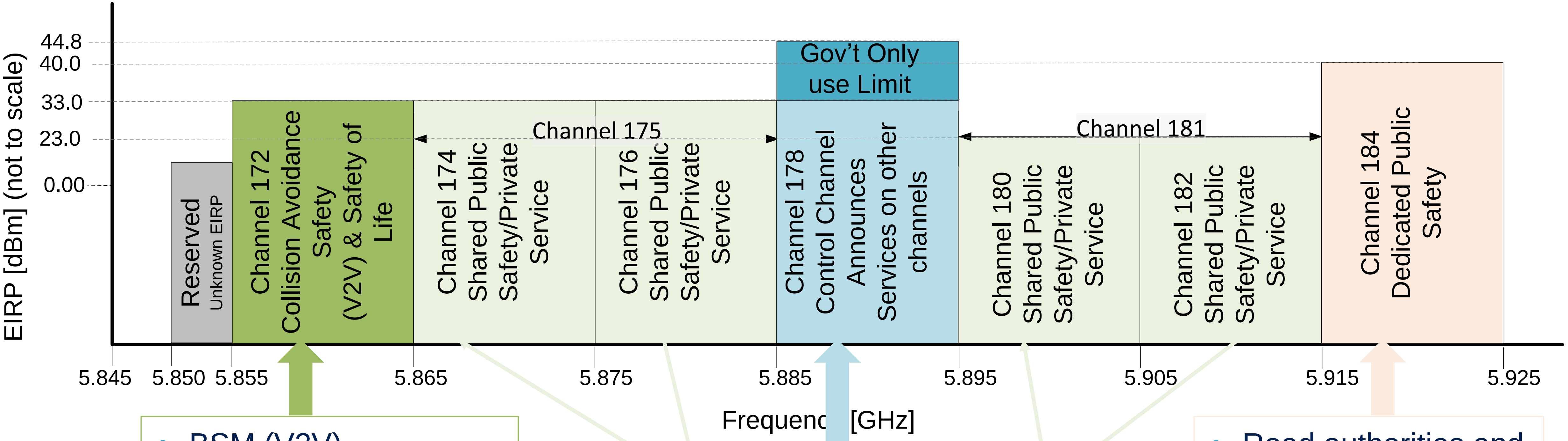
FCC Spectrum Allocation for DSRC of ITS



- BSM (V2V)
- MAP Message (V2I)
- SPAT (V2I)
- TX Power +20dBm

- Control Channel, Advertises and indicates how to access services on other "Service channels"

- Road authorities and public agencies primarily responsible for usage

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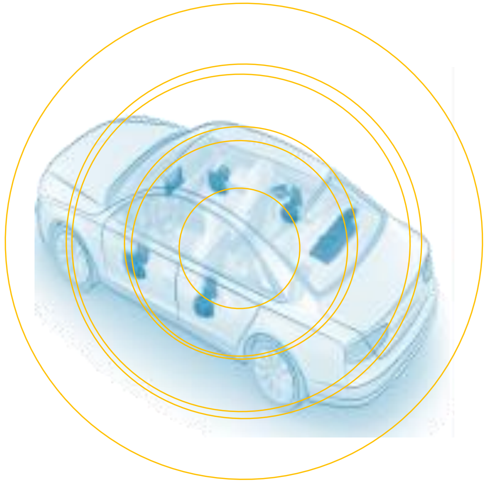
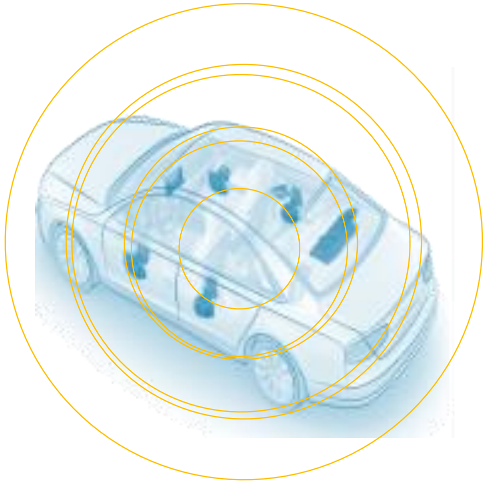
EIRP: Effective Isotropic Radiated Power
ITS: Intelligent Transportation Systems

Source: **Federal Communications Commission FCC 03-324**

DSRC

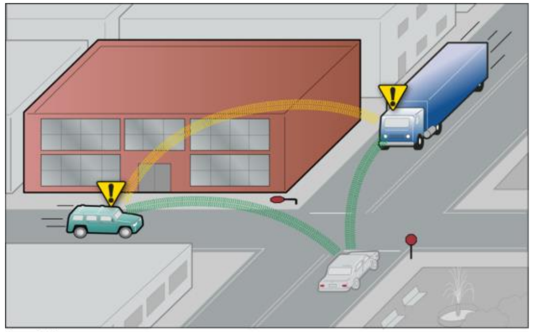


- Wireless Access in Vehicular Environments (WAVE)
  - Amendment to IEEE 802.11-2012 to support WAVE/DSRC
  - no authentication, no access point/no association
  - 5.8 – 5.9 GHz OFDM



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

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 (360º coverage)
- DSRC units share the same channel

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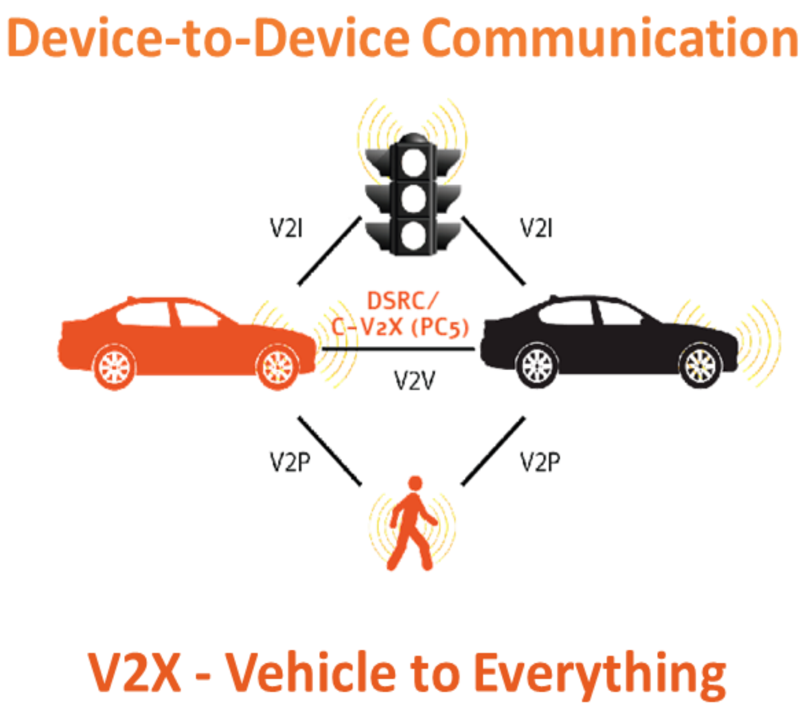
C-V2X Basics

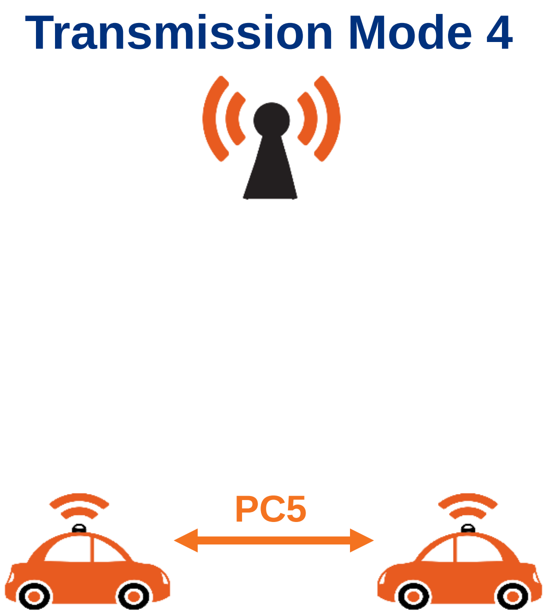
- C-V2X is a V2X radio layer:
  - C-V2X is Device-to-Device (D2D) communication service added to the LTE Public Safety ProSe (Proximity Services) Services
  - C-V2X makes use of the D2D interface – PC5 (aka Side Link) for direct Vehicle-to-Everything communication
  - C-V2X takes the place of DSRC radio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



ITS Layers Remain Unchanged!

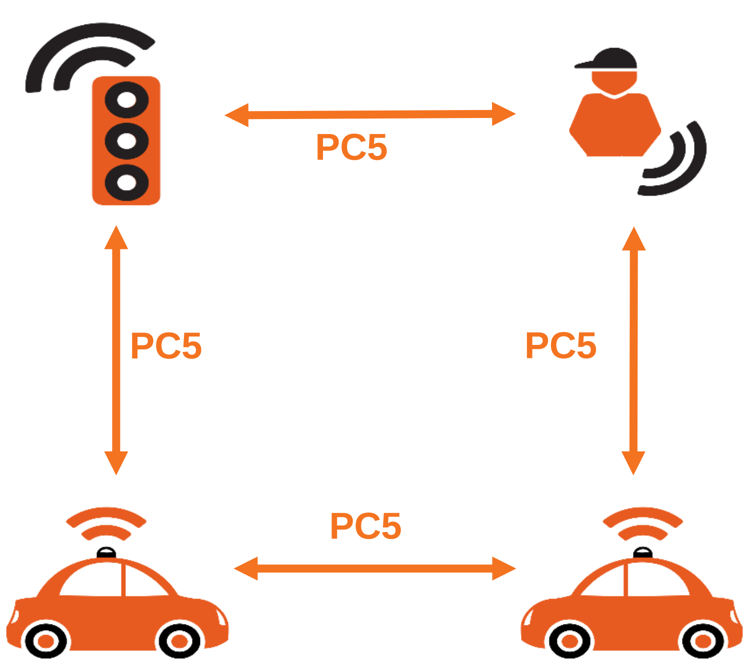
C-V2X Basics

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



C-V2X Basics

- 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



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C-V2X Air Interface

- 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

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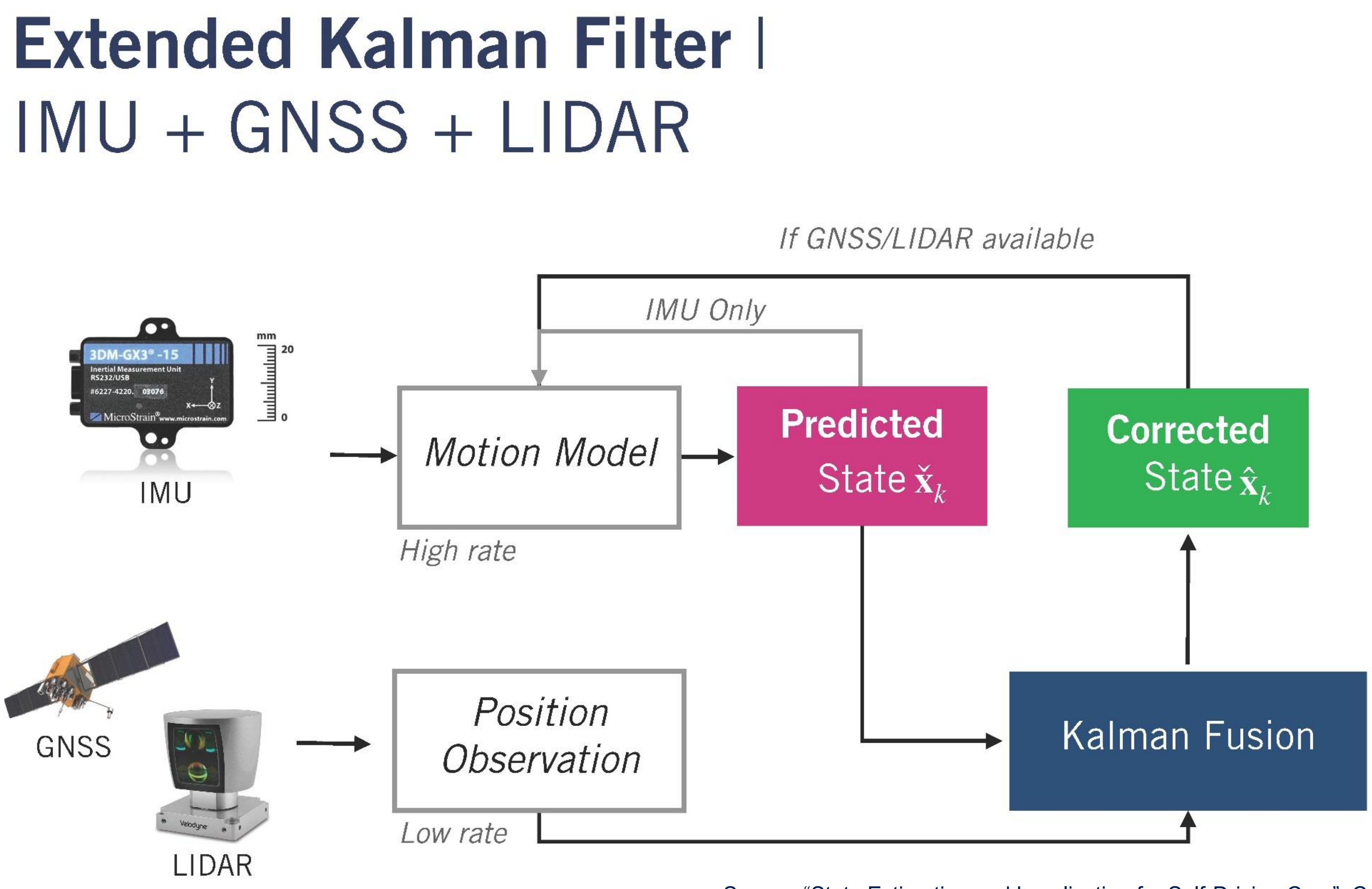
Multi-sensor Fusion for State Estimation



Source: "State Estimation and Localization for Self-Driving Cars", Coursera by University of Toronto

Thank You!

Q&A