연세대학교 YONSEI UNIVERSITY

Challenge and Opportunity for Autonomous Vehicles beyond Level 5.0

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STL SEAMLESS TRANS-X LAB

Trans-everything(Trans-X)

- Autonomous and intelligent mobility for Transportation
- AI(Artificial Intelligence) for Digital Transformation
- Metaverse, VR for Transition

Outline

- Outlook of the Automotive Industry and Market
- Roadmap of Autonomous Vehicle (AV)
- Challenges and Opportunity of AV
- Tesla vs. Google Waymo and the others
- AV developed by Yonsei STL
- Concluding remarks

Outlook of the Automotive Industry & Market (Y2017)

- **Global Vehicle Manufacturing : ~ 90M /Year (약 9천만대/년)**
- **Global Vehicle Market : ~ 2000B US $ (약 2400조원/년)**
- The world's largest producing Country : China (~ 25M/Y)
- **No. of Vehicles Produced in Korea : ~ 4.5M/Y**
- **No. of Korean Brand Vehicles : ~ 7.8M/Y**
- **No. of Vehicles sold in Korea : ~ 1.7M/Y**
- **No. of Vehicles Registered in Korea : ~ 22M**

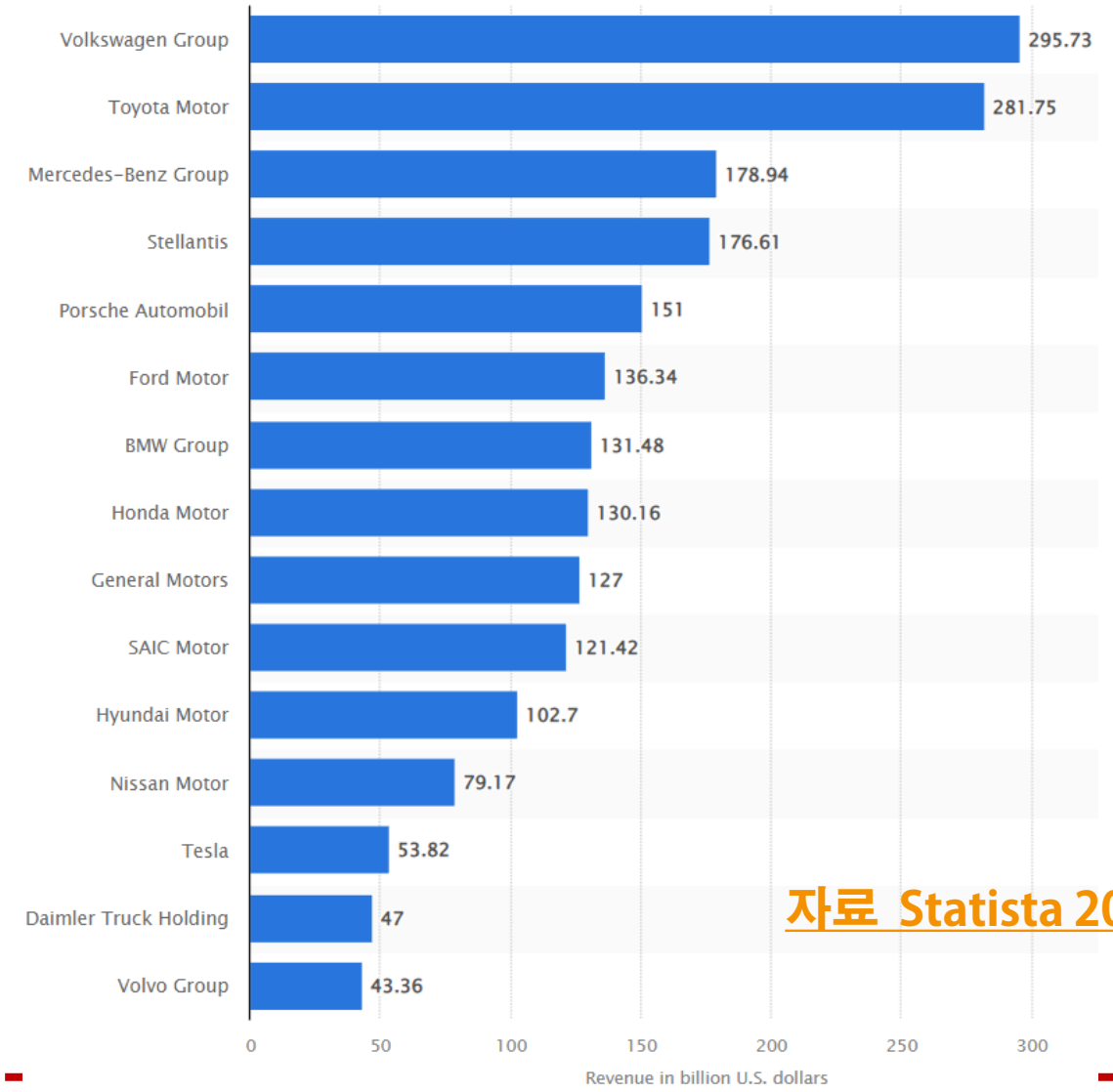
- **Number of Components composing a Vehicle ~ 30K/Vehicle**
- **Portion of Electronic Components > 45%**

Outlook of the Automotive Industry & Market

Top 15 largest manufacturers by production volume (2017)

Rank	Group	Vehicles
1	Toyota	10,466,051
2	Volkswagen Group	10,382,334
3	Hyundai	7,218,391
4	General Motors	6,856,880
5	Ford	6,386,818
6	Nissan	5,769,277
7	Honda	5,236,842
8	Fiat Chrysler	4,600,847
9	Renault	4,153,589
10	PSA Group(Stellantis)	3,649,742
11	Suzuki	3,302,336
12	SAIC Motor(중국)	2,866,913
13	Mercedes Benz	2,549,142
14	BMW	2,505,741
15	Geely (중국)	1,950,382

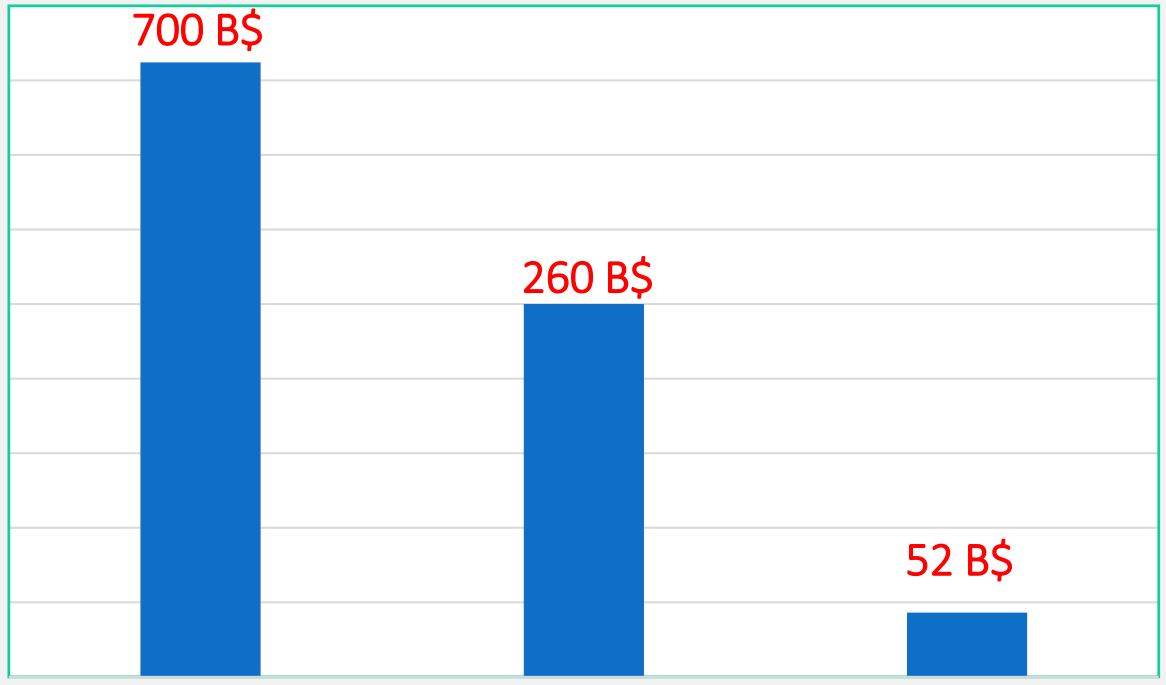
Revenue of leading automakers in 2021(US $)



자료 Statista 2022

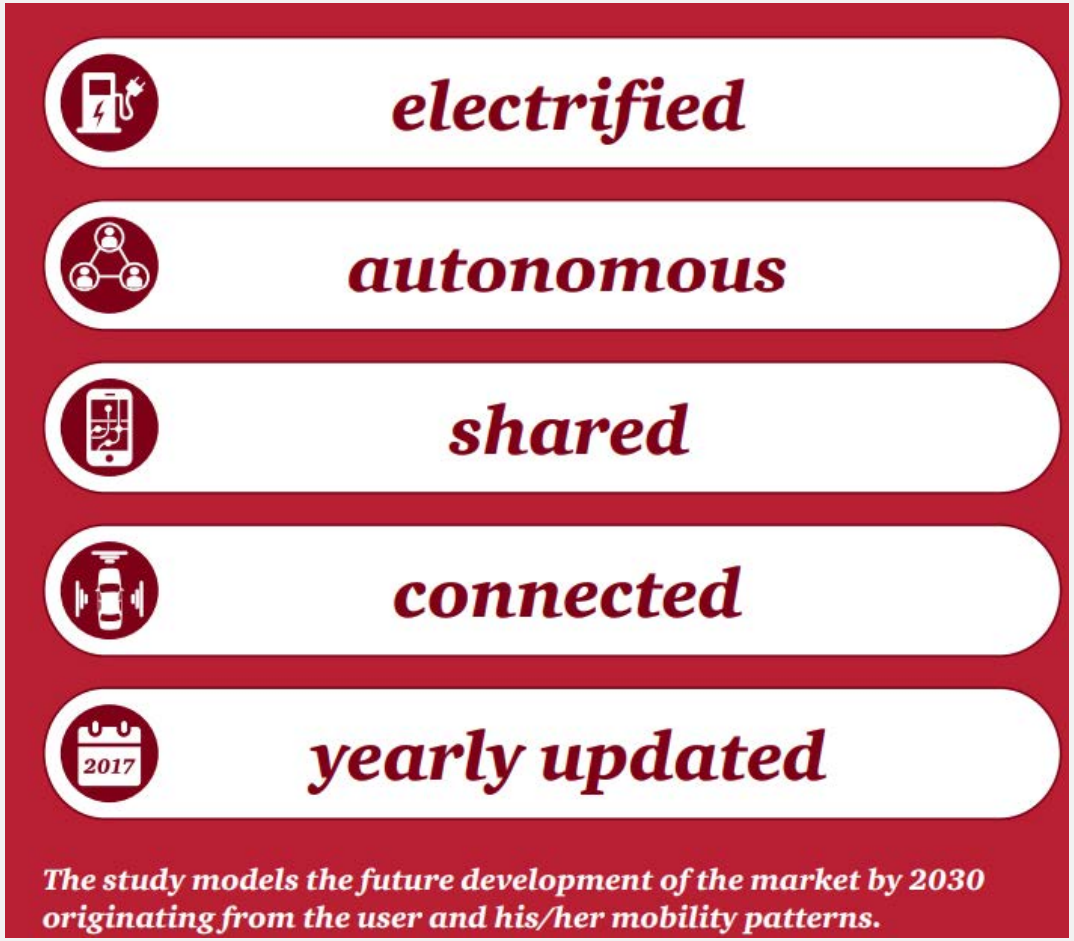
Outlook of the Automotive Industry & Market

Total stock Value (B$) (21st May 2022)



Tesla	Toyoda	GM	Volkswagen Group
생산 : 1M 매출 : 60 조원	생산 : 10M 매출 : > 300조원	생산 : 6.8M 매출 : 150조원	생산 : 10M 매출 : > 300조원

5 Mega Trends : (Digital) Transformation of Automotive Industry

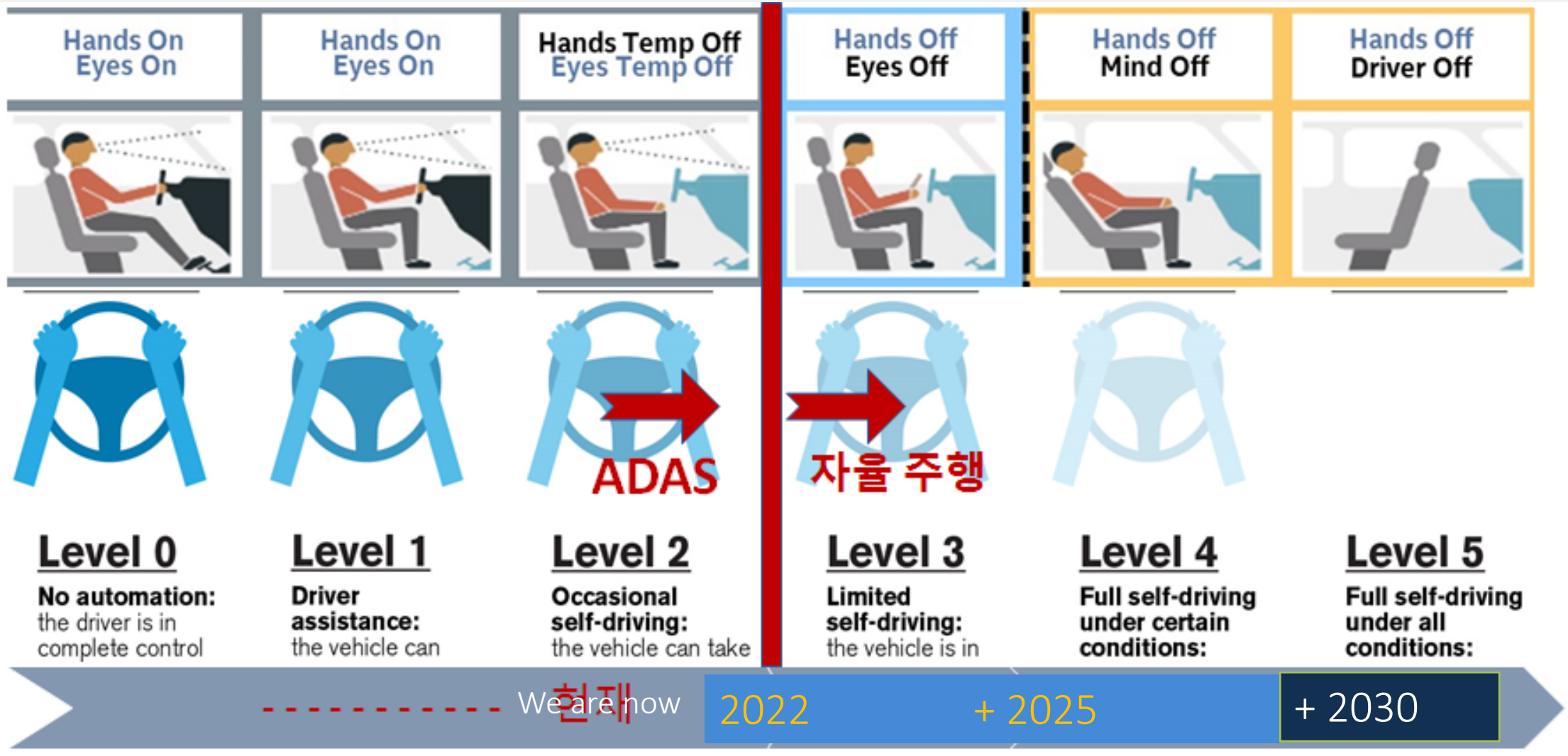


Energy	X Electric Vehicles
A I	Self driving Intelligent Vehicles
Ownership	MaaS (Mobility as a Service)
Networked	5G-C V2X, IoV (Internet of Vehicles)
SW	OTA (Over The Air update)

Ref1 : pwc-five-trends-transforming-the-automotive-industry.compressed.pdf
https://eu-smartcities.eu/sites/default/files/2018-03/

C-V2X(Celluar Vehicle to Everything)

Roadmap of Autonomous Vehicle (AV)
Levels of automation (SAE J3016)



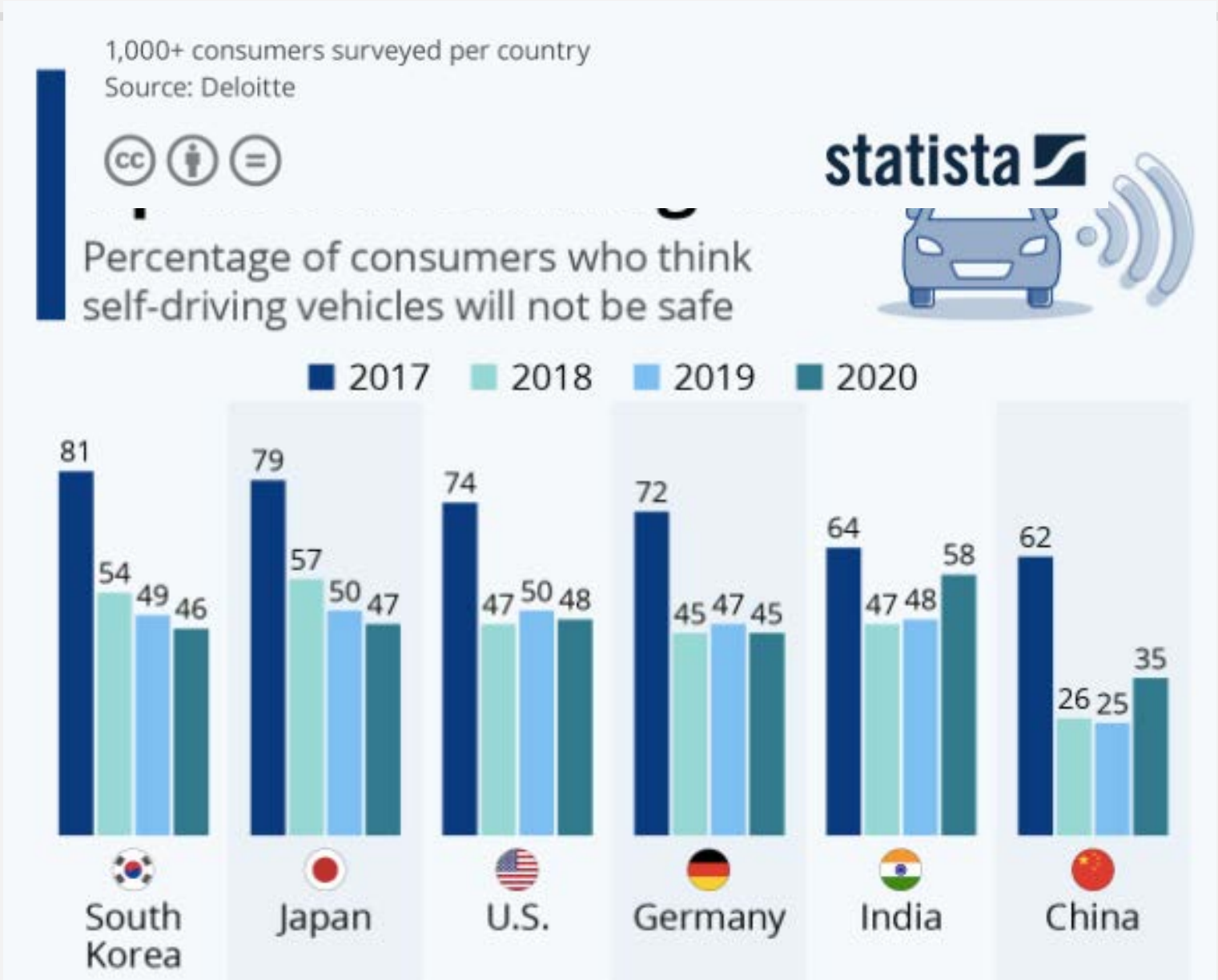
ADAS : (Advanced Driver Assistance Systems), AV: Autonomous Vehicle

Challenges for Autonomous Vehicle System

❖ Challenging Issues

- Technology - Performance, Safety, Cyber-Security
- Social Acceptance - Comfort, Congestions, Driving Behavior
- Business Model – Vehicle Ownership, Mobility as a Service (MaaS)

Social Acceptance
Impact on Life style, new business, and economy



Opportunity for AV

- Intelligent vehicle industry
- Connected Cars
- Impact on Life style, new business, and economy

Impact on Life style, new business, and economy
Benefits of Autonomous Vehicles

93% of all accidents are caused by human error.[1]

Improved Safety

Sensors and cameras using Intel technology make "things" smarter so you get where you want to go more safely.

Increased Productivity

Imagine safely collaborating with coworkers, friends and family inside your car—the ultimate connection hub.

5.5 billion hours of potential productivity is lost in traffic.[2]

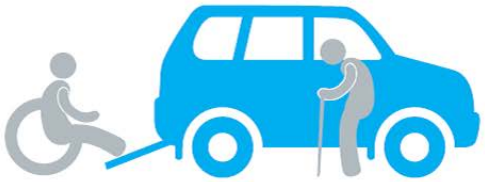
56% less fuel emissions for driverless cars.[3]

Environmentally Friendly

If one out of five cars were driverless, fuel consumption would decline by **724,000,000 gallons.**[4]

Greater Freedom

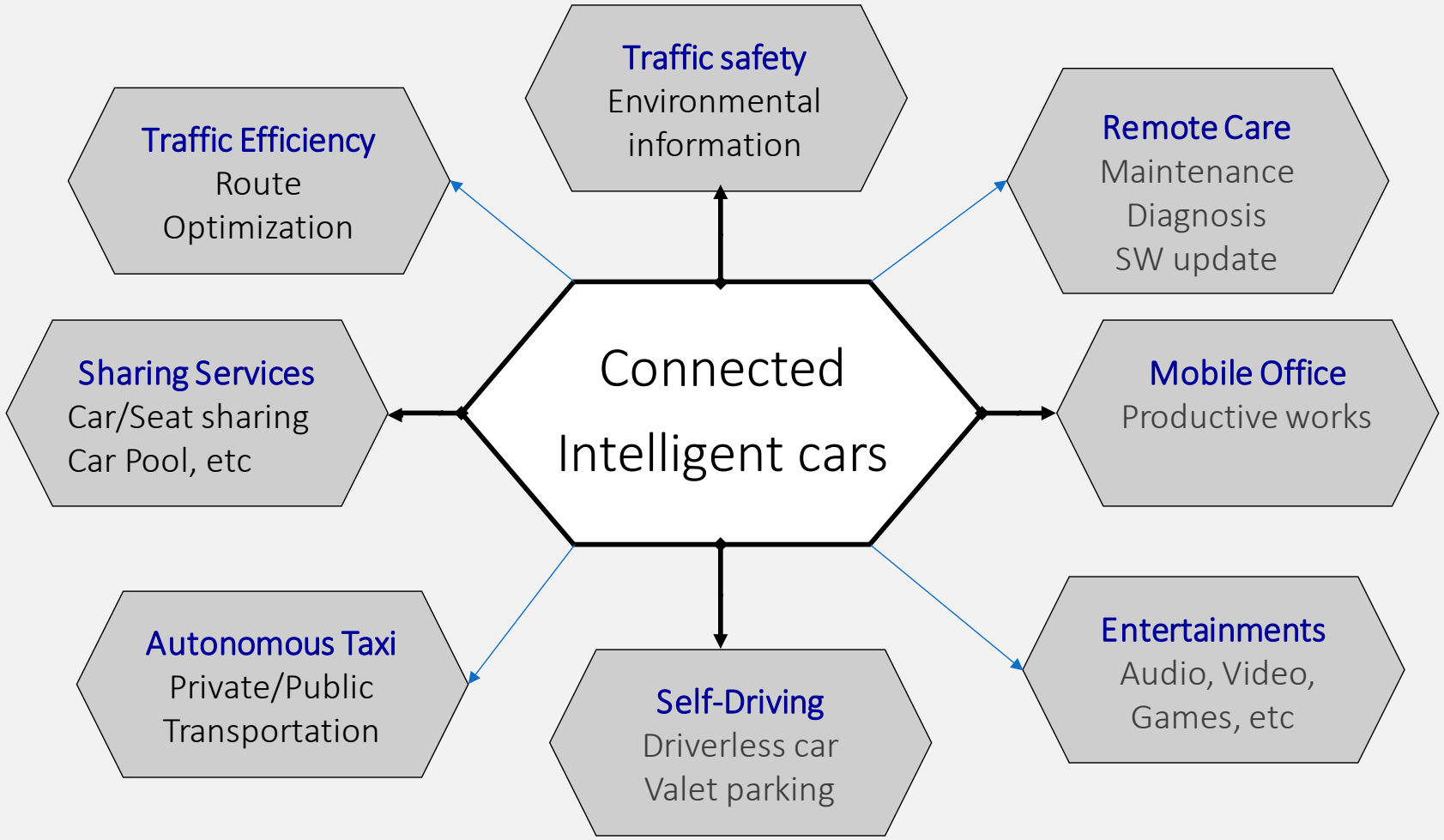
Intel technologies can help the elderly and disabled be more mobile and independent with self-driving cars.



There will be **~3x more** 80+ years old in just a few decades.[5]

Traffic fatality(교통 사고 사망자) : 104/1M (Korea) , In USA 30,000 Deaths/Y

Opportunity for AV : Service and applications of connected cars



S. Kim, Blockchain for a Trust Network Among Intelligent Vehicles, Advance in Computers, Elsevier 2018

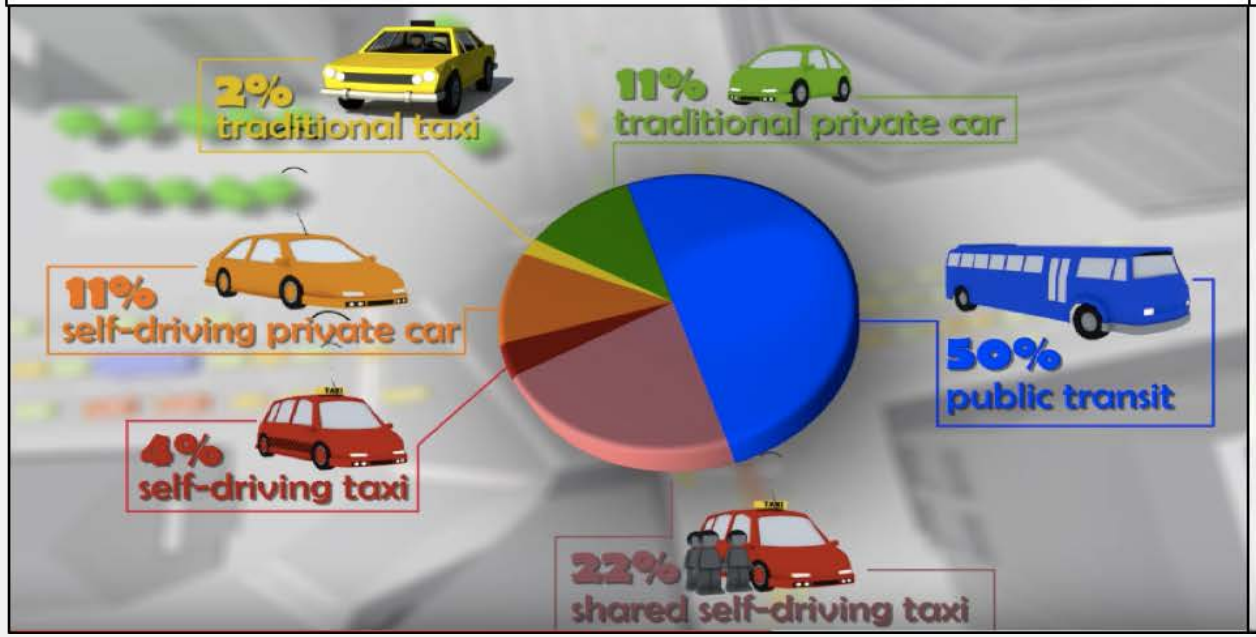
Impact on Life style, new business, and economy

The project Boston 2030 : Modelling Boston City Traffic with Autonomous Vehicles

- The World Economic Forum in collaboration with the Boston Consultancy Group and the city of Boston, intend to pilot autonomous vehicles in the city.
- The **project Boston 2030** will look into 1) AV technology, 2) Business models for reliable and safer transportation, 3) Infrastructure to support AVs.

The Private Car Evolution

Resulting modal shift	Impact Summary



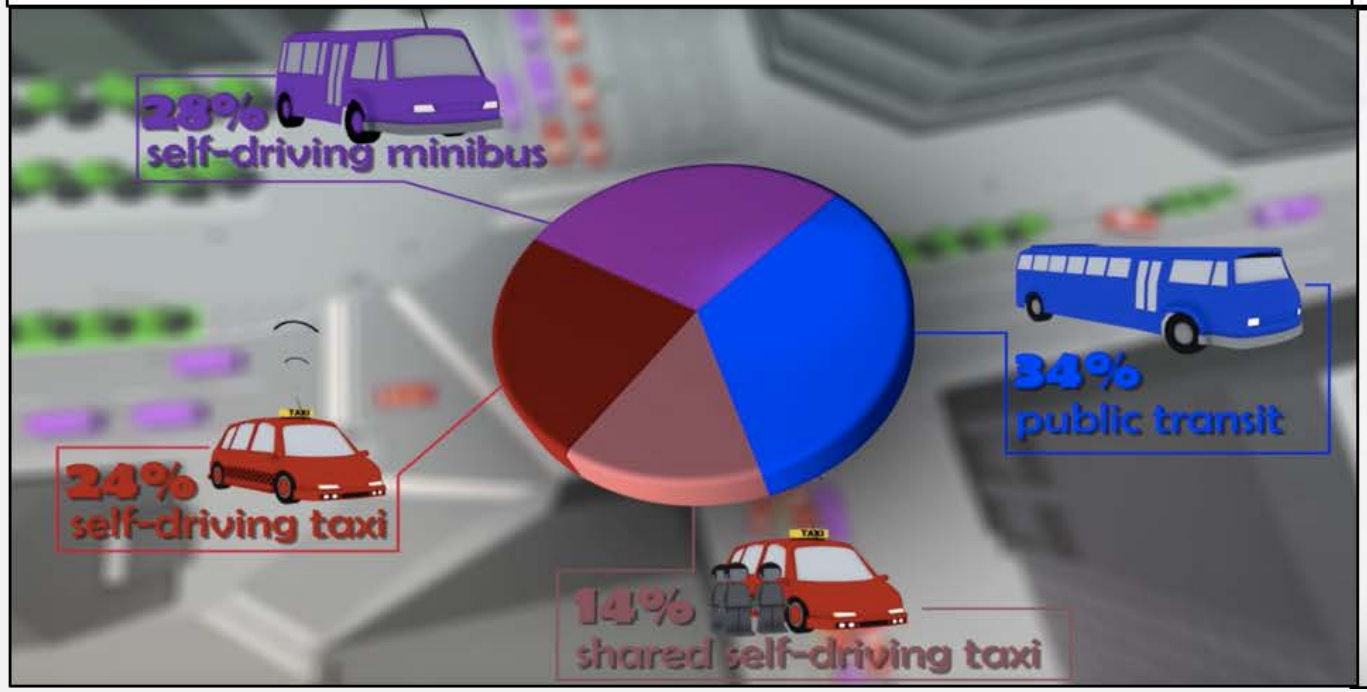
Impact Summary	
Number of vehicles	-11%
Vehicle distance traveled	+13%
Average travel speed	+15%
Average travel time	-11%
Emissions	-42%
Parking space needed	-16%

Impact on Life style, new business, and economy

The project Boston 2030 : Modelling Boston City Traffic with Autonomous Vehicles

- The scenario of "**The robo-transport revolution**", the personal car is completely replaced by self-driving taxis (with and without ride-sharing) and mini buses.

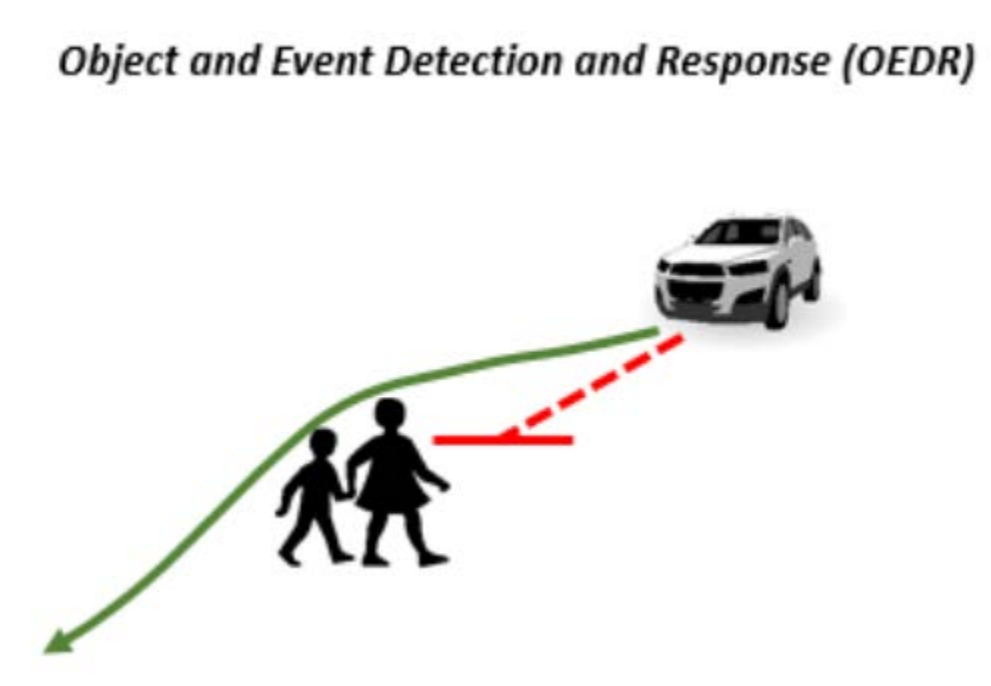
The Robo Transport Revolution

Resulting modal shift	Impact summary
	Number of vehicles **-28%** Vehicle distance traveled **+6%** Average travel speed **+30%** Average travel time **-30%** Emissions **-66%** Parking space needed **-48%**

https://www.drivesweden.net/en/modelling-boston-city-traffic-autonomous-vehicles

Autonomous Driving Process and Dynamic Driving Task

Autonomous Vehicle : DDT



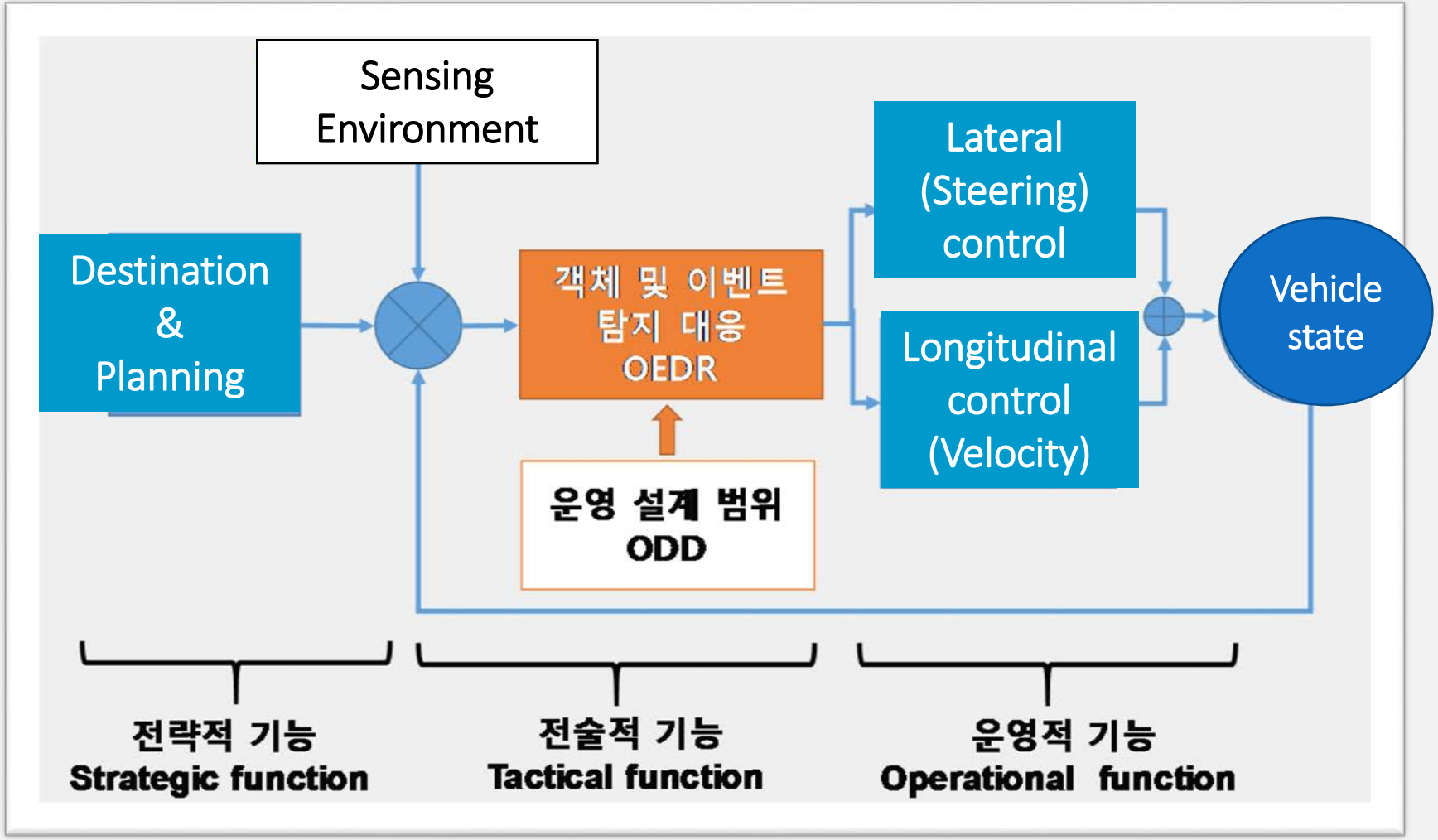
DDT fallback

Operational Domain Design (ODD)

Guaranty Safety

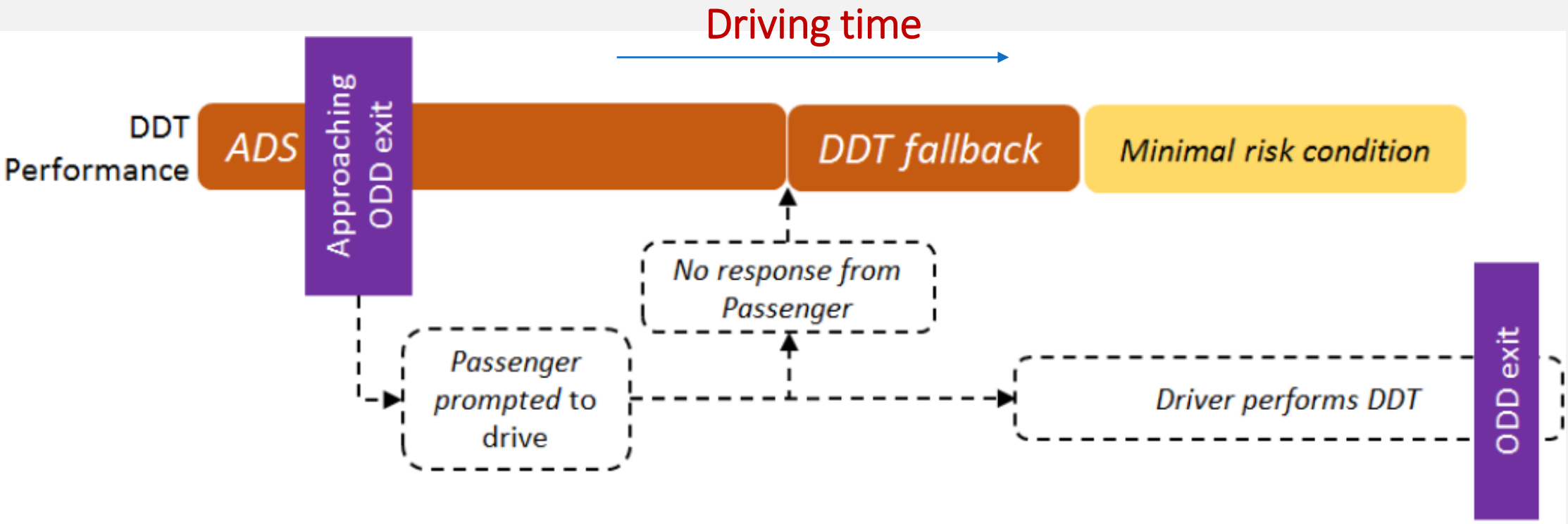
Limitation of Driving environment

Dynamic Driving Task (DDT) and Self-Driving Process



ODD(Operational Design Domain)
OEDR(Object and Event Detection and Response)

Autonomous Driving Process and Dynamic Driving Task



Note: dotted lines represent optional condition

DDT = Dynamic Driving Task

ADS = Automated Driving System

Minimal Risk Condition: the vehicle will park itself safely until the passenger or remote supervisor takes control as a driver; or the circumstances change so that the ODD again applies

SAE 2016

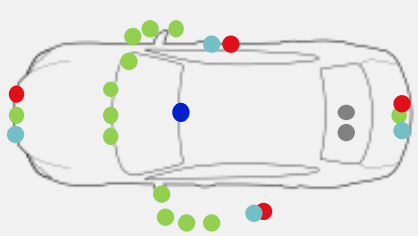
ODD(Operational Design Domain)
OEDR(Object and Event Detection and Response)

Challenges for L5.0 AV (on going research at STL)

Human like driving, but Overcoming Human's Capability

- Driving comfort : Comfortable driving experience based on Occupant Preference Metric
- Dynamic Localization using Vision and HD map matching
- 3D Object detection and tracking
- Recognition and Understanding irregular situations and environment

Autonomous Vehicles developed by STL



1st AV (2011)

DGPS, LiDAR, Camera,

Labview, PC

Tracking pre-planed Path

2nd AV (2017)

LiDAR, Camera, Rader

NVidia GPGPU PX2

End-to-End steering

(Learning based)

3rd AV (2019)

Camera, LiDAR/Rader

Linux PC + Neural Processing Unit

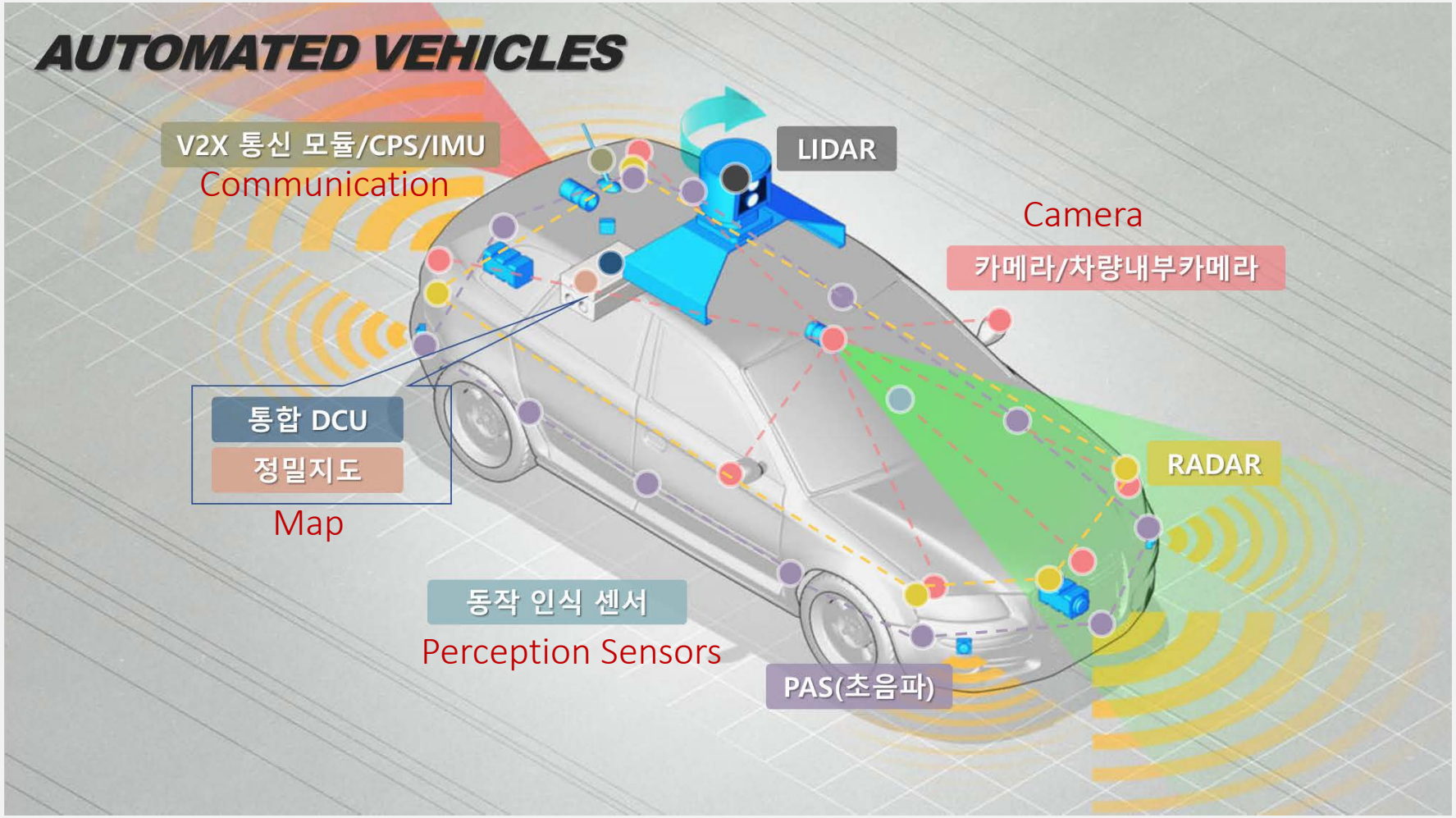
Learning based Control

Tesla vs. Google Waymo and the others

- Typical Configuration of sensors and equipment
- **Waymo** : Lidia + Camera based sensing
- **Tesla : Cameras Only**

Hardware and sensors

Configuration of sensors and other equipment of typical AVs



(Google) Waymo : vehicle sensors

Radar System

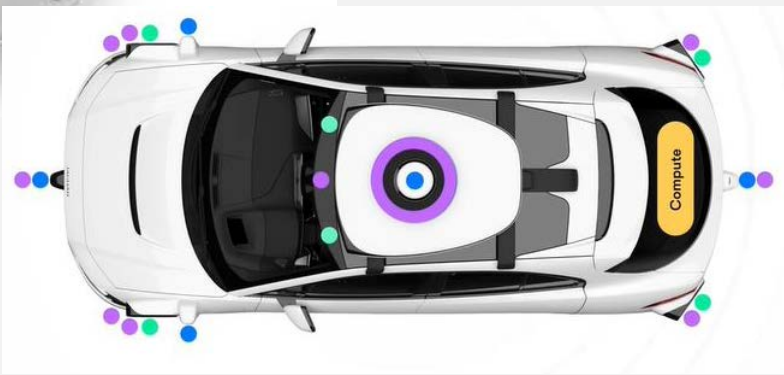
Vision (Camera) System

Lidar 360 System

Inertial Measurement Unit (관성 센서)

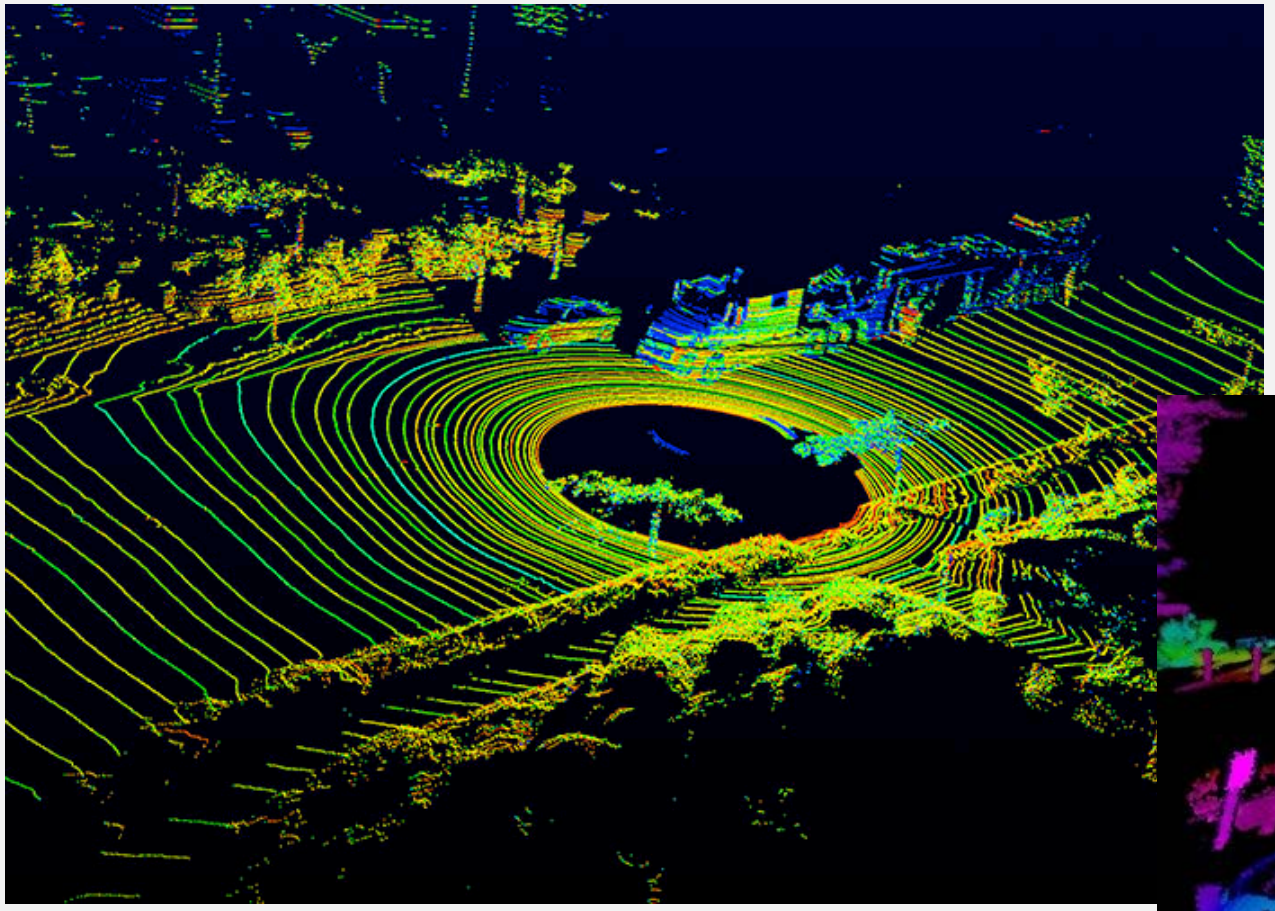
Supplemental Sensors (GPS etc...)

Lidar (Laser) System



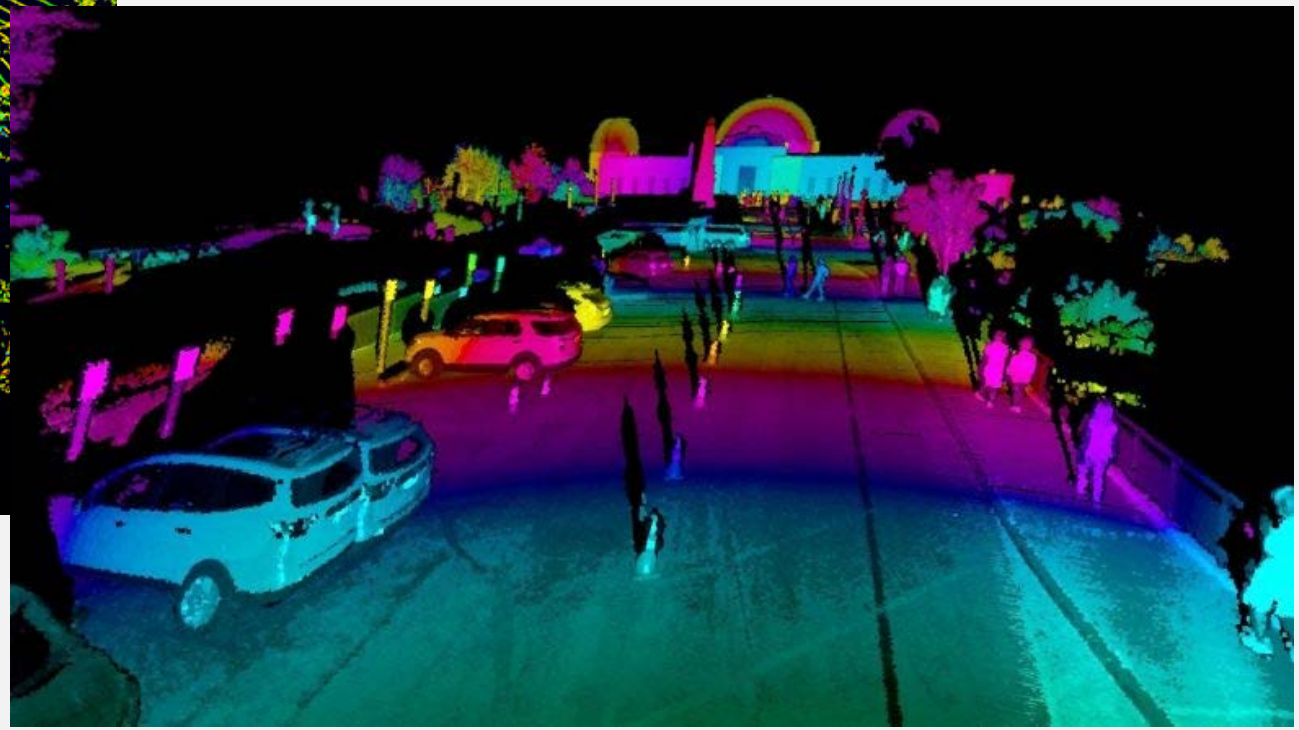
Ref: Waymo safety report, Feb. 2021

(Google) Waymo : Lidar Map

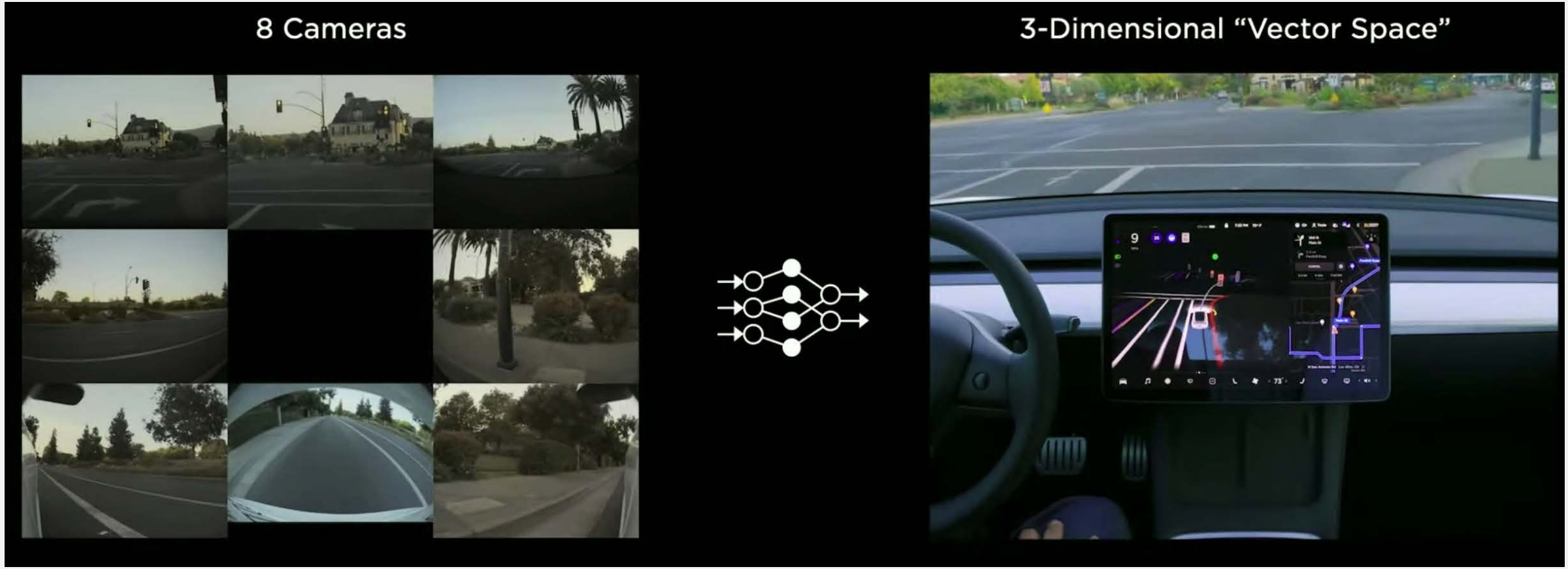


Lidar Point Cloud

Waymo's 3D Lidar

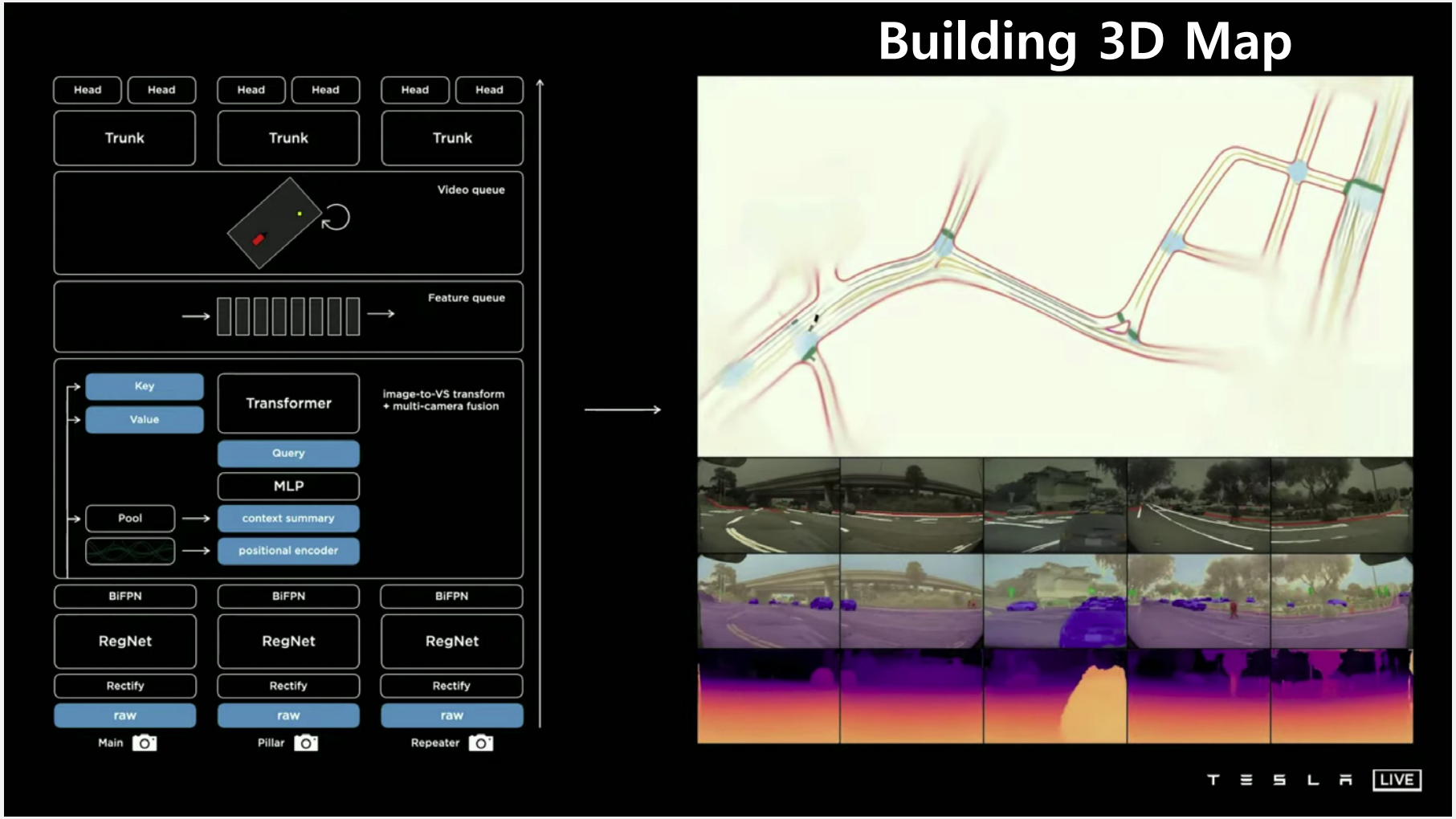


Tesla: Vision Based approach (Camera only)



Ref: Tesla AI day 2021

Tesla: Vision Based approach (Camera only)



Reconstruction

Segmentation

Ref: Tesla AI day 2021

Concluding remarks

- ❑ Outlook the current Status, Challenges and Opportunity of AV
- ❑ Vehicle Industry facing a destructive revolution
  - Automotive Industry is the last industry of digital destructive transformation
- ❑ AV will change the life style as well as ICT Industry
  - Autonomous Vehicle providing next ICT platform
- ❑ Artificial Intelligence is the key enabling technology