AN OVERVIEW OF NVIDIA'S AUTONOMOUS VEHICLES PLATFORM

Pradeep Kumar Gupta | August 2017

Global Head – Solutions Architecture and Engineering-Autonomous Driving

NVIDIA

AGENDA

Autonomous Vehicles

Functional Safety

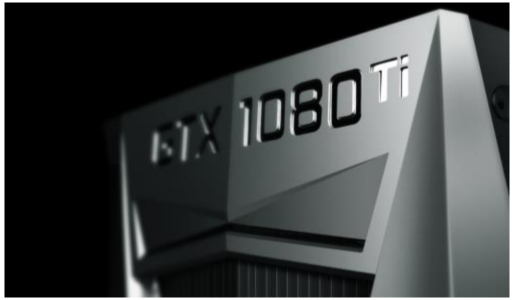
Levels of Automation

DRIVE PX Platform

Development Workflow

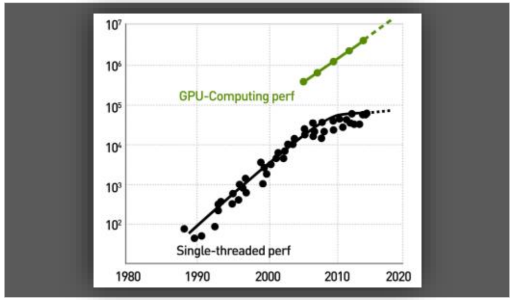
NVIDIA

Founded in 1993 — 11,000 Employees | Invented the GPU | Invented GPU-accelerated Computing



#1 PC Gaming

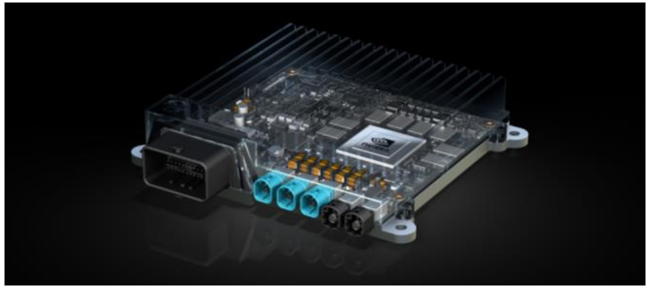
#1 Pro Graphics



#1 Accelerated Computing

#1 AI Computing

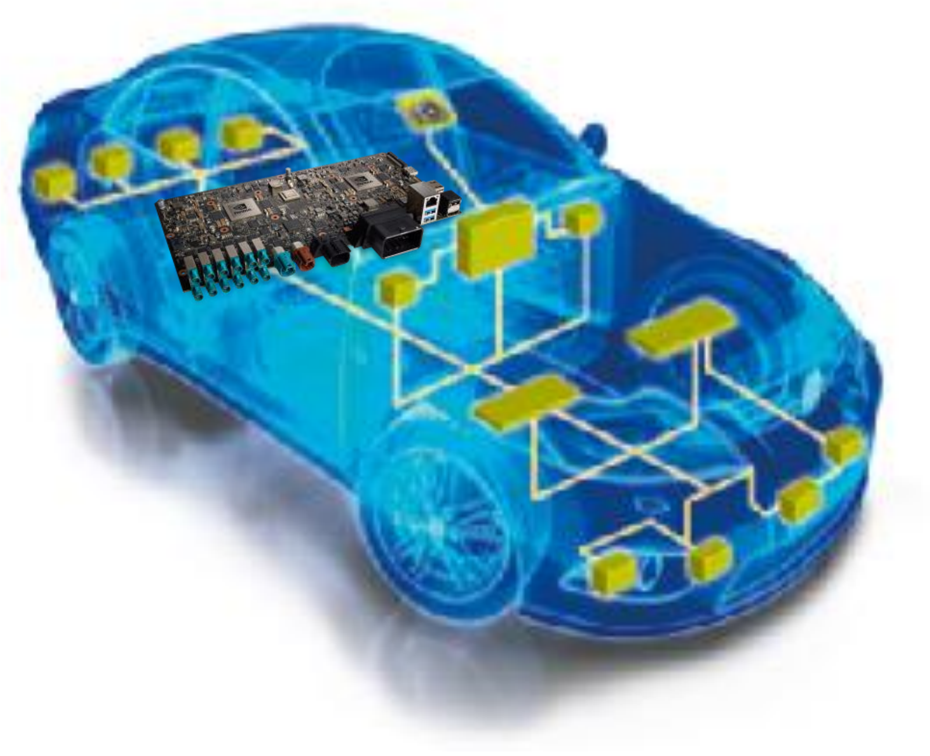
Fastest Supercomputers in Japan, U.S., Europe

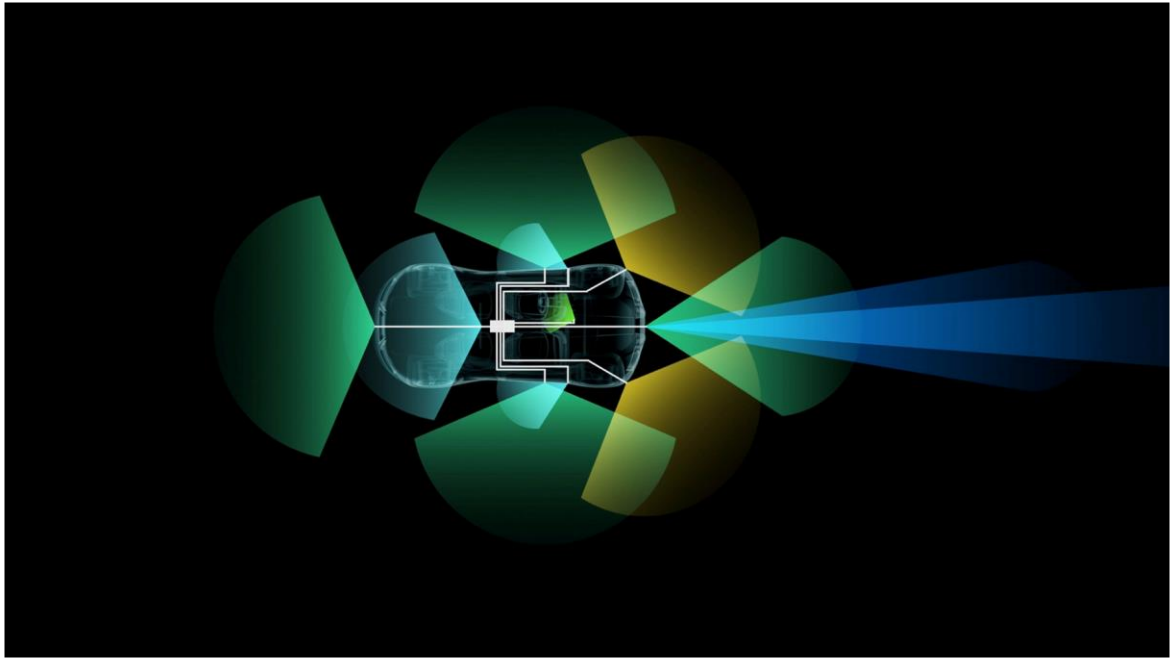


Pioneering AI Car Computer

Nintendo Switch

AUTONOMOUS VEHICLE





AI REVOLUTIONIZING TRANSPORTATION

280B Miles per year

800M parking spots for 250M cars in the U.S.

Domino’s: 1M Pizzas delivered per Day

COLLISIONS

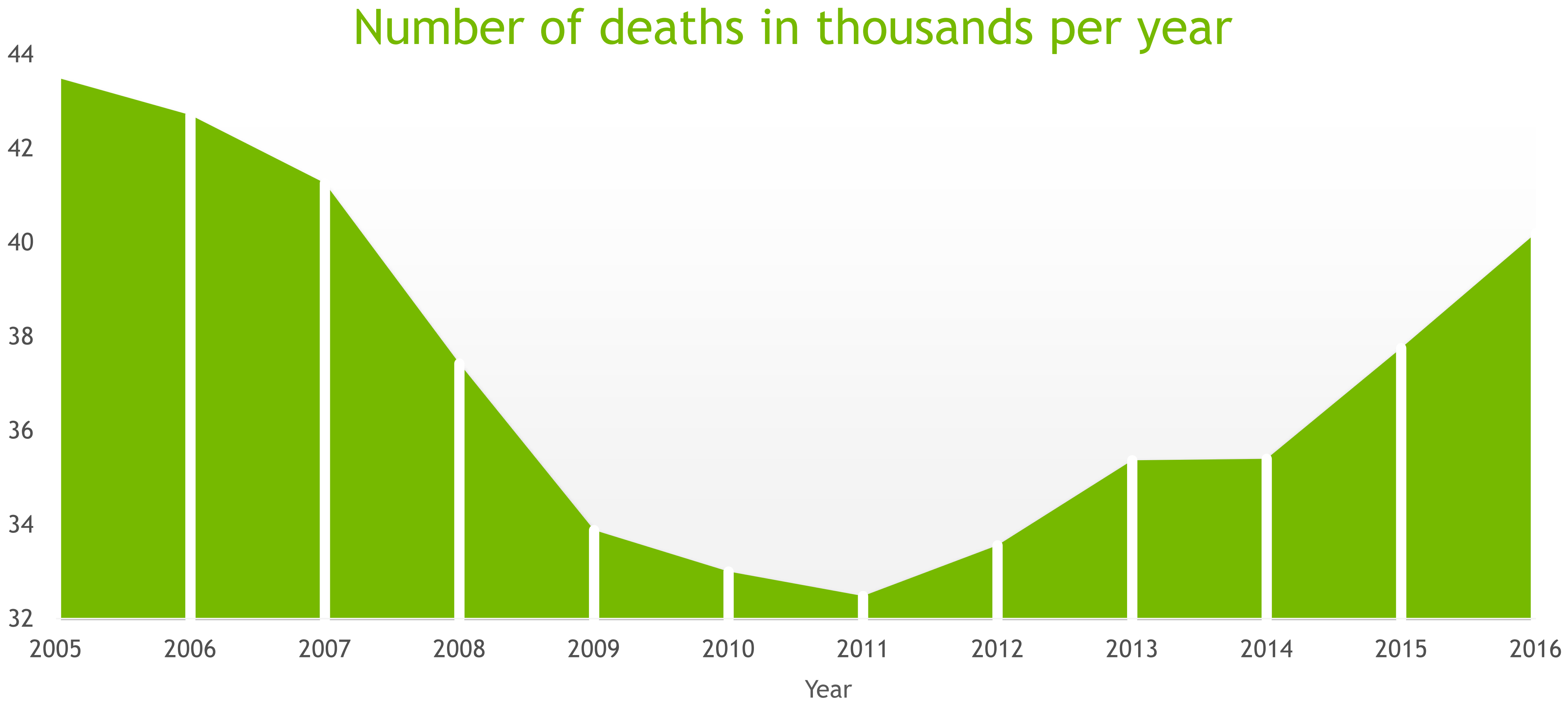
CRITICAL REASON ATTRIBUTED TO	ESTIMATED	
	NUMBER	PERCENTAGE* ±95% CONF. LIMITS
Drivers	2,046,000	94% ±2.2%
Vehicles	44,000	2% ±0.7%
Environment	52,000	2% ±1.3%
Unknown Critical Reasons	47,000	2% ±1.4%
Total	2,189,000	100%

** Percentages are based on unrounded estimated frequencies (Data Source: NMVCCS 2005-2007)*

CRITICAL REASON	ESTIMATED (Based on 94% of the NMVCCS Crashes)	
	NUMBER	PERCENTAGE* ±95% CONF. LIMITS
Recognition Error	845,000	41% ±2.2%
Decision Error	684,000	33% ±3.7%
Performance Error	210,000	11% ±2.7%
Non-Performance Error (sleep, etc.)	145,000	7% ±1.0%
Other	162,000	8% ±1.9%
Total	2,046,000	100%

** Percentages are based on unrounded estimated frequencies (Data Source: NMVCCS 2005-2007)*

MOTOR VEHICLE FATALITY ESTIMATES



Source: National Safety Council: http://www.nsc.org/NewsDocuments/2017/12-month-estimates.pdf

 NVIDIA.

FUNCTIONAL SAFETY

"Part of overall safety relating to the equipment under control and the control system that depends on the correct functioning of the electrical, electronic, and programmable electronic safety-related systems and other risk reduction measures"
–IEC 61508-4:2010; 3.1.12

"Absence of unreasonable risk due to hazards caused by malfunctioning behavior of electrical/electronic systems"
–ISO 26262-1:2011; 1.51

FUNCTIONAL SAFETY

ISO 26262

Automotive Safety Integrity Level
(ASIL)

FUNCTIONAL SAFETY

ASIL Standard

ASILs identified by Standard - ASIL A, ASIL B, ASIL C, ASIL D.

ASIL D dictates the highest integrity requirements on the product and ASIL A the lowest.

ASIL's are 3D with 3 variables: severity, probability of exposure, and controllability.

ISO 26262-3, section 7 "Hazard analysis and risk assessment" provides tables that break these three variables down into classes.

Probability of exposure has five classes: "Incredible" to "High probability" (E0-E4).

Severity has four classes: "No injuries" to "Life-threatening injuries (survival uncertain), fatal injuries" (S0-S3).

FUNCTIONAL SAFETY

ASIL Standard

Controllability, which means controllability by the driver, not by the vehicle electronic systems, has four classes: “Controllable in general” to “Difficult to control or uncontrollable.”

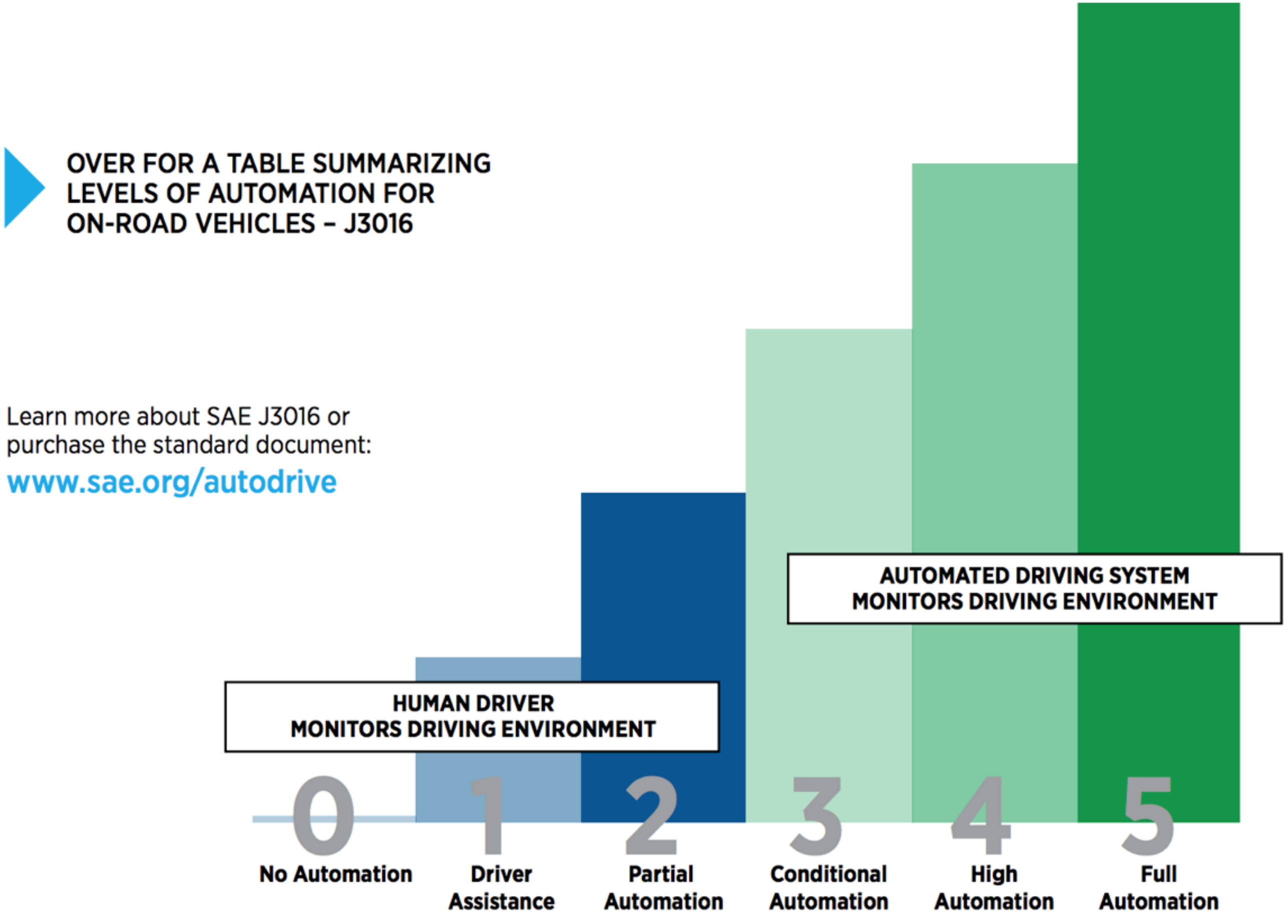
http://www.electronicdesign.com/embedded/understanding-iso-26262-asils

http://www.eetimes.com/document.asp?doc_id=1331459&page_number=4

Why ASIL D now?

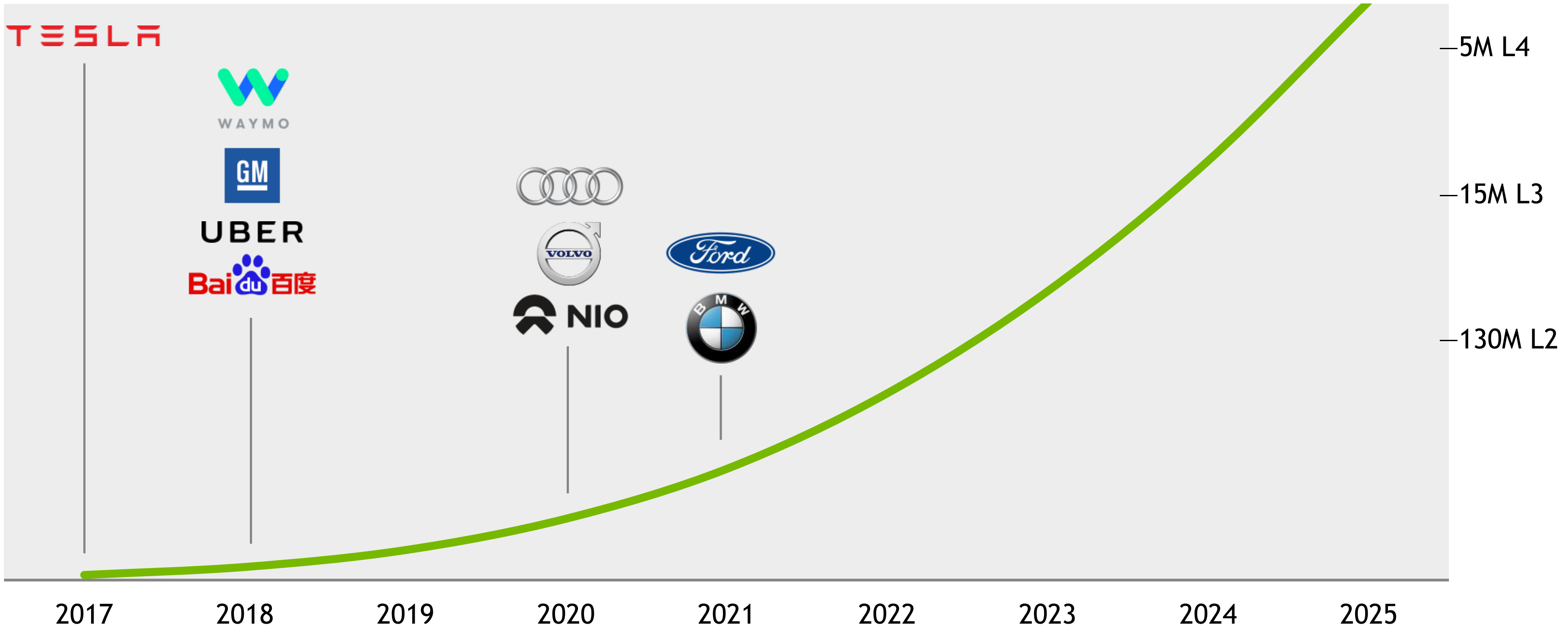
If your car meets the ISO 26262 specification for ASIL D, it means that the machine [car] is “making a decision for you” when it comes across a safety-critical path, explained Raucher. At ASIL B, the car would warn a driver of imminent danger, but at ASIL D, the car — faced with a hazard — brakes and stops or pulls into a safe space.”

LEVELS OF AUTOMATION



Source: *SAE International – Levels of Driving Automation*

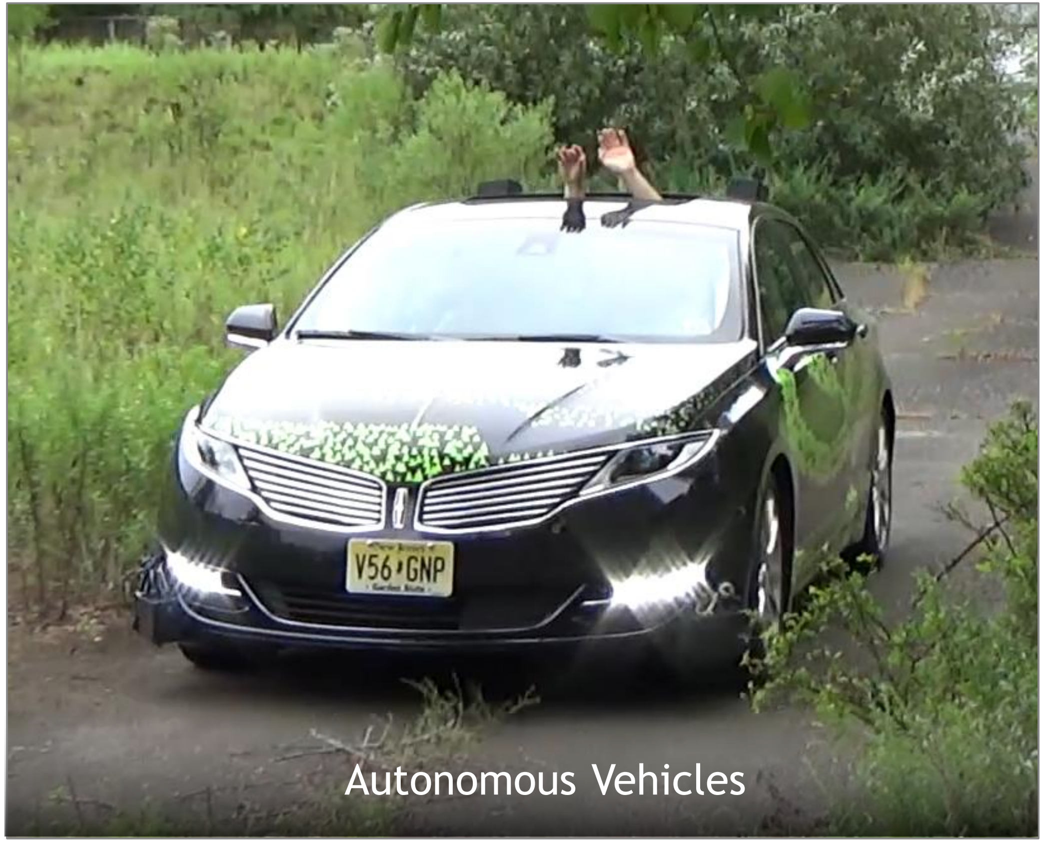
150M AUTONOMOUS VEHICLES BY 2025



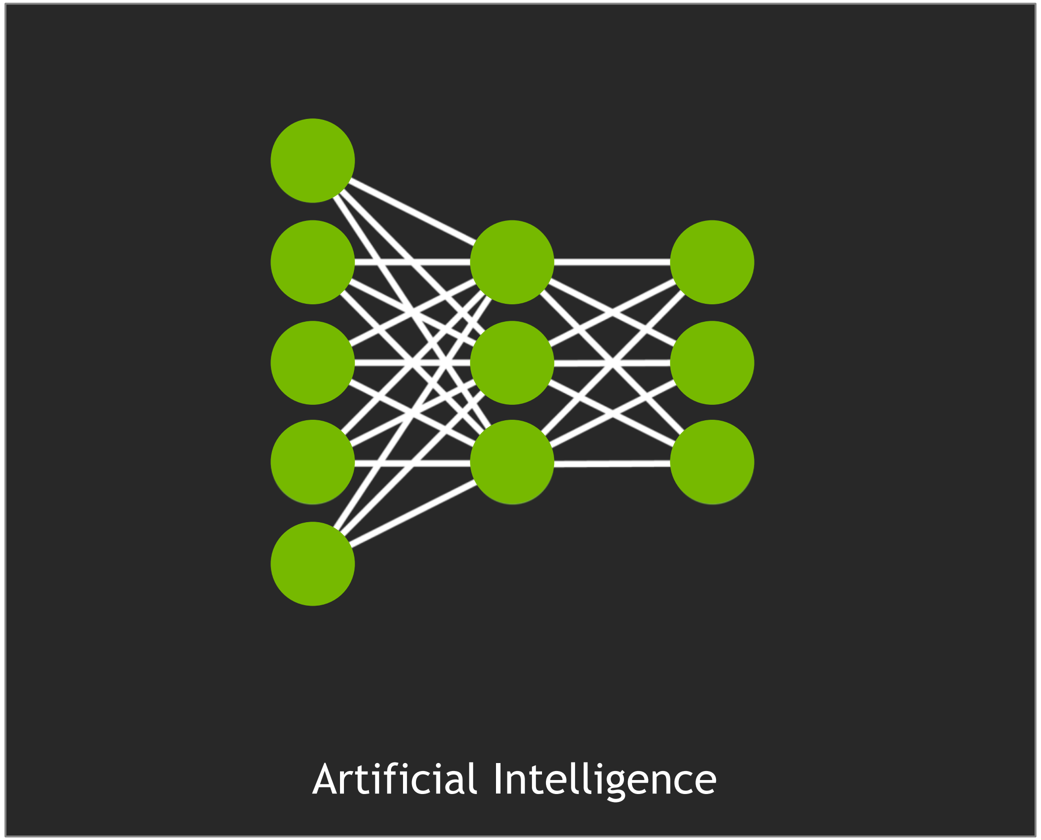
Source: ABI

NVIDIA AND DEEP LEARNING

At the Center of AV Revolution



Autonomous Vehicles


Artificial Intelligence

DEEP LEARNING AUTOMOTIVE PARTNERS

Audi

Ford

TOYOTA

VOLVO

AdasWorks

Bai du 百度

CRUISE

drive.ai

Elektrobit

FICOSA

fka

ibeo

infineon

NAGOYA UNIVERSITY

Preferred Networks

QNX

QUANERGY

SoundHound

UNIVERSITAT DE BARCELONA

WEpods

ZMP

AUTONOMOUS VEHICLES

Key summary points

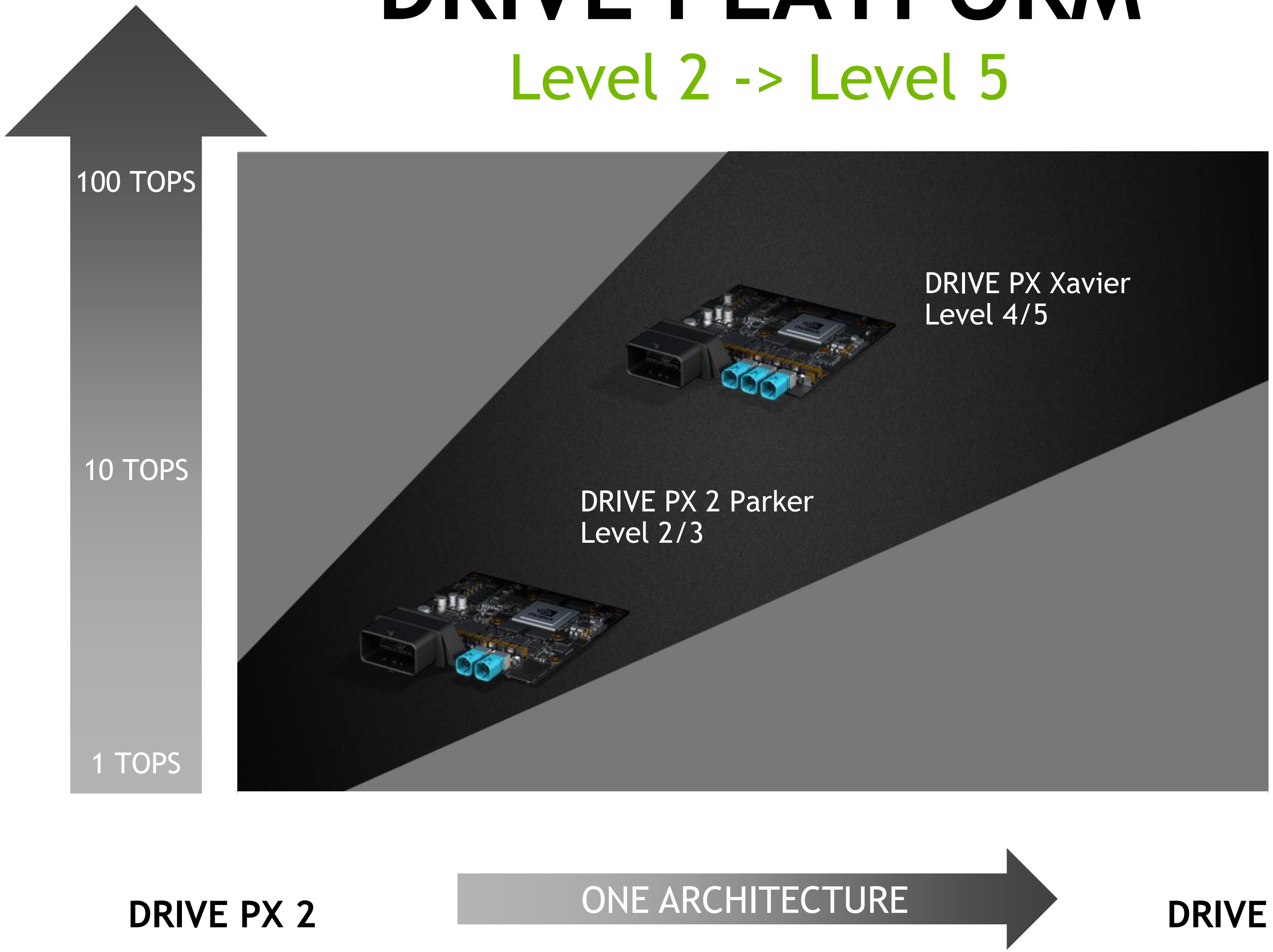
It is quite clear that putting Autonomous Vehicles on the road is possible only with Artificial Intelligence. AV = AI.

The key challenge with Autonomous Vehicles is that we need an AI super computer in the car.

And, we brought the DRIVE Computer to address the challenge of Autonomous Vehicles

DRIVE PLATFORM

Level 2 -> Level 5

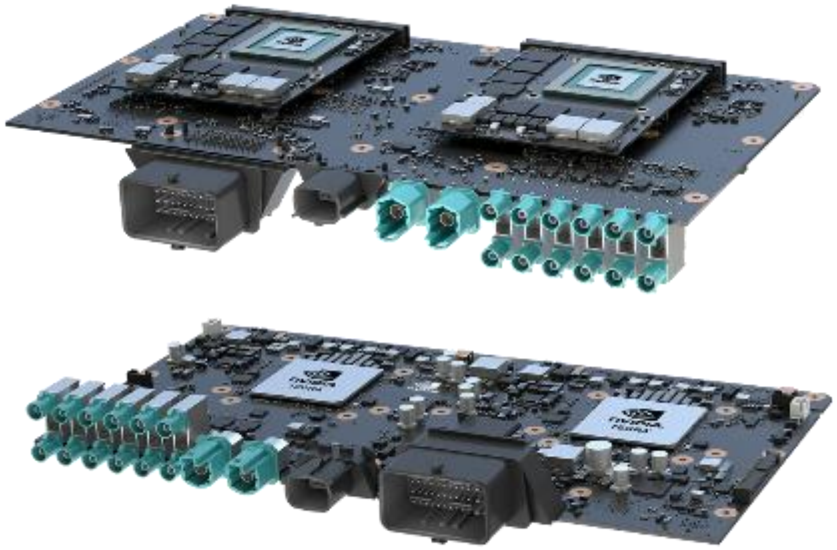


DRIVE PX 2

2 PARKER + 2 PASCAL GPU | 20 TOPS DL | 120 SPECINT | 80W

DRIVE PX (Xavier)

30 TOPS DL | 160 SPECINT | 30W



DRIVE PX 2 COMPUTE COMPLEXES

2 Complete AI Systems

Pascal Discrete GPU
- 1,280 CUDA Cores
- 4 GB GDDR5 RAM

Parker SOC Complex
- 256 CUDA Cores
- 4 Cortex A57 Cores
- 2 NVIDIA Denver2 Cores
- 8 GB LPDDR4 RAM
- 64 GB Flash

Safety Microprocessor

AURIX Safety Microprocessor

IS IT THAT SIMPLE?

NVIDIA DRIVE - SOFTWARE

Localization

Path Planning

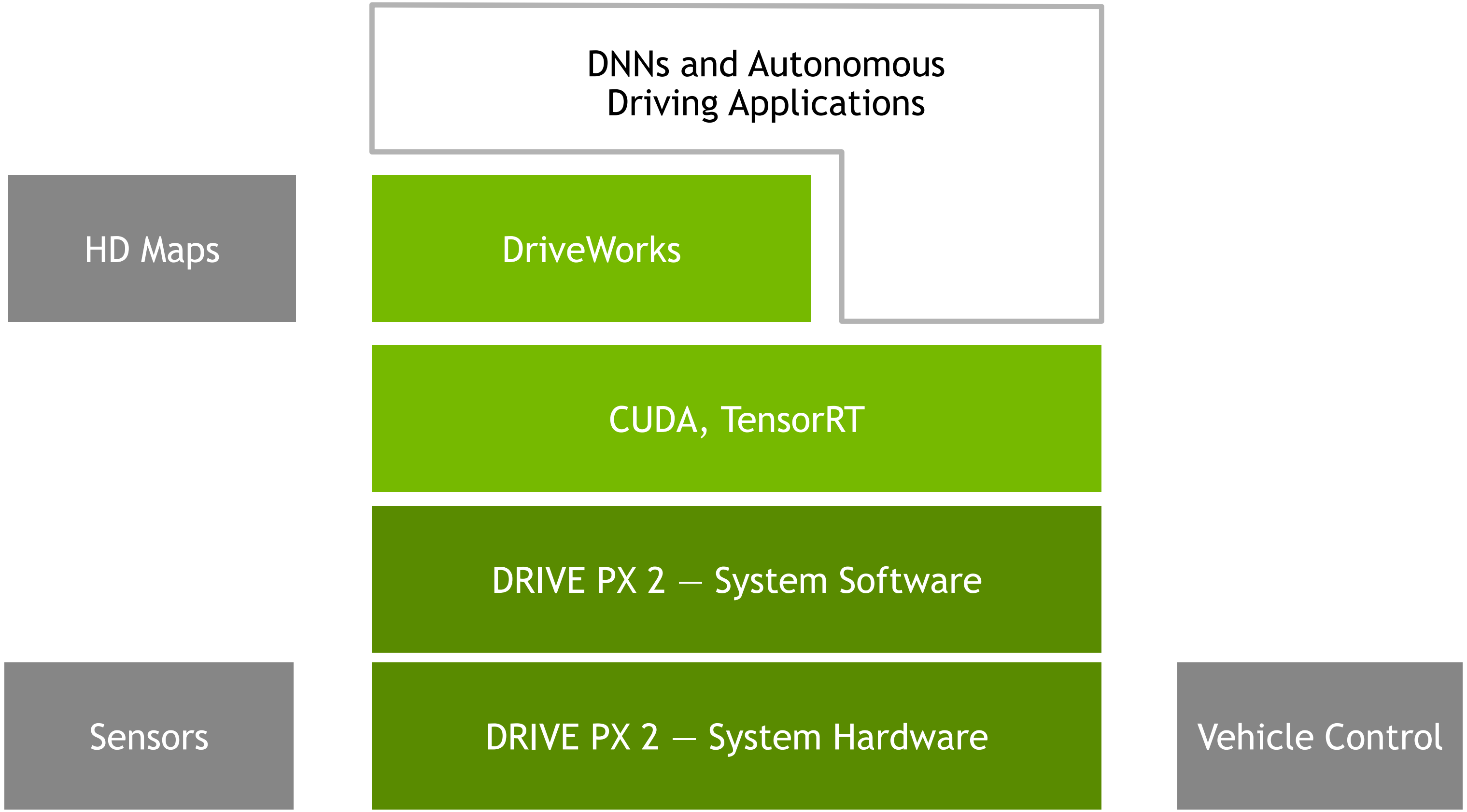
Perception AI

Computer Vision Libraries

CUDA, cuDNN, TensorRT

OS

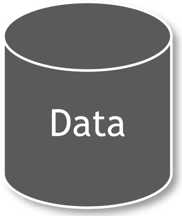
DRIVE PLATFORM



DRIVEWORKS

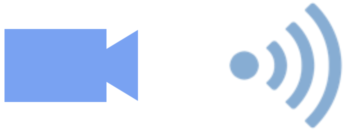
USE CASES

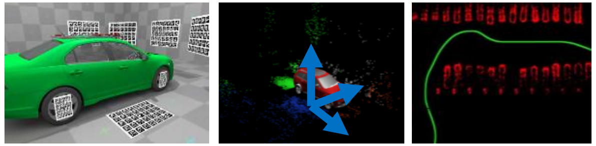
Autonomous Driving

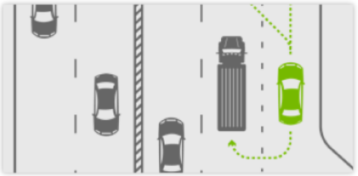


Data Acquisition

APIs
(> 450 AND GROWING)







DESIGN PHILOSOPHY

Modular

Scalable

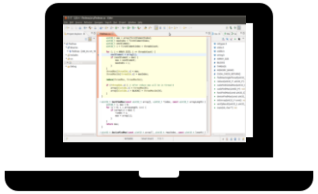
Optimized for GPU

Rapid prototyping
& production

GETTING STARTED...

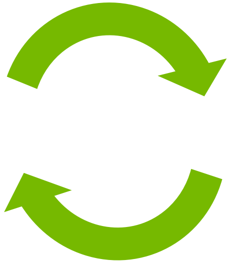
Workflow

DEVELOP



Linux PC

Cross-Compile

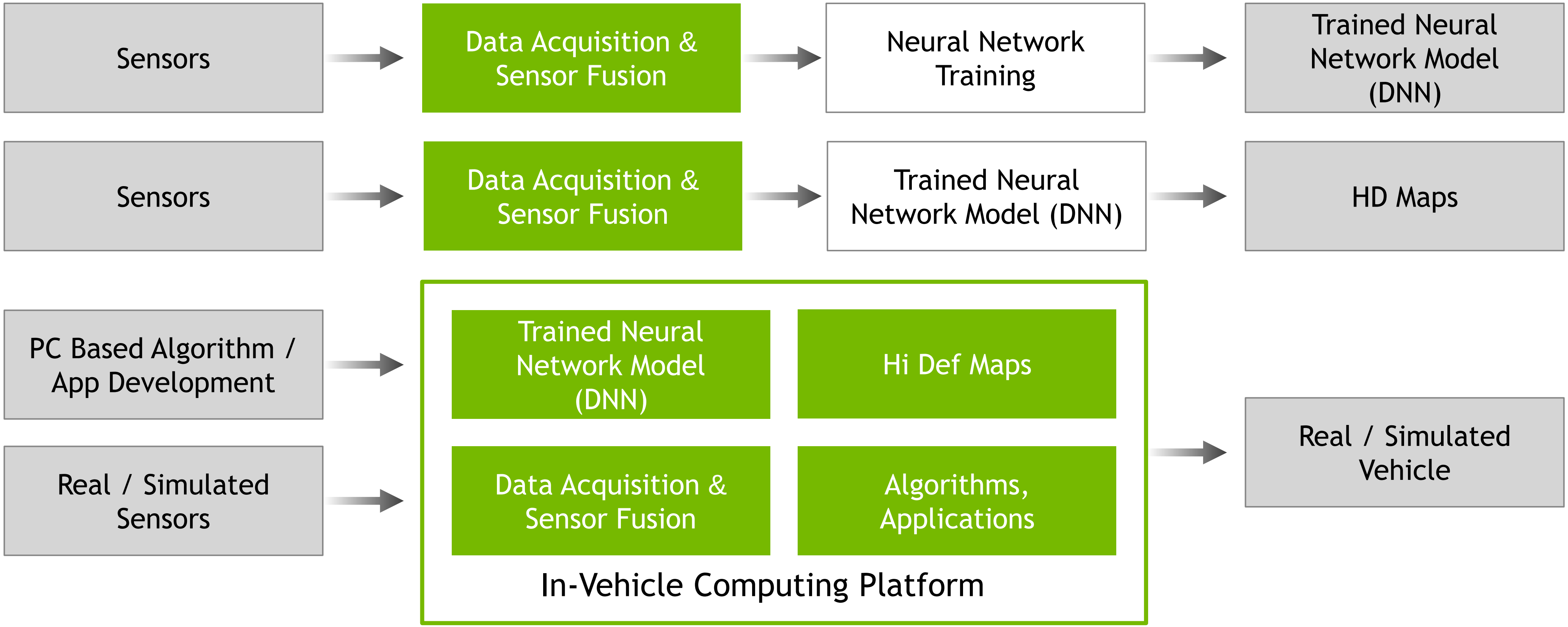


Feedback & Iterate

BENCHMARK/DEPLOY

DRIVE PX 2

DIFFERENT WORKFLOWS



DEVELOPMENT FLOW

Self Driving Vehicle Development

DATA ACQUISITION
Sensor integration
Sensor calibration
Image capture
Storage

→

DATA CURATION, LABELING
Manage data lifecycle

DNN TRAINING
Train NN with data

MAP CREATION
Create HD map

→

APPLICATION DEVELOPMENT
Compute libraries
NN Inferencing
System level applications

PC → DRIVE PX

→

SIMULATE, DRIVE, TEST
HIL/SIL simulation
Vehicle integration
Test

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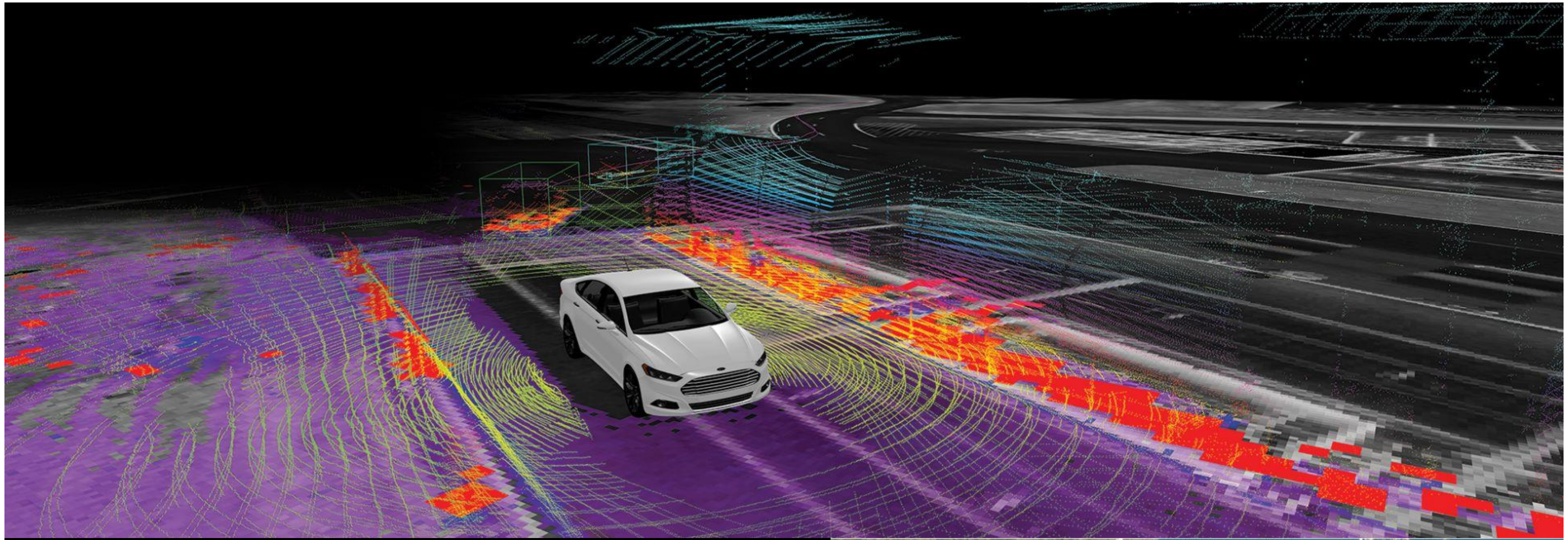
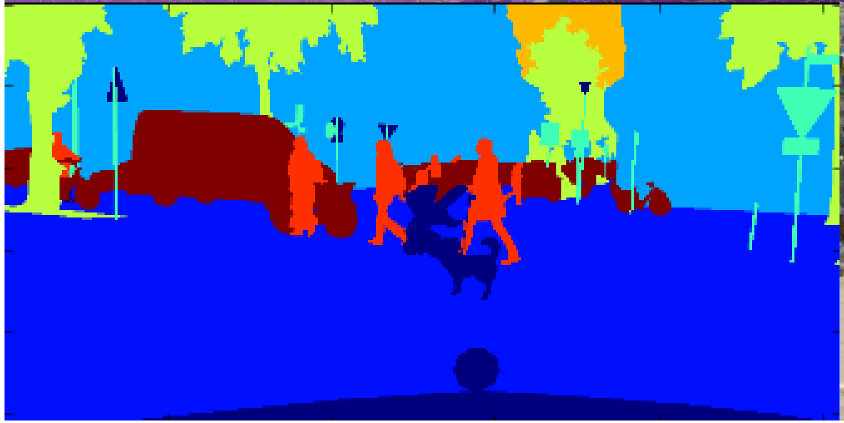
HOW MUCH DATA?





TARGETED DATA COLLECTION

Use Cases

Learning to drive

Lane keeping, emergency braking, intersections

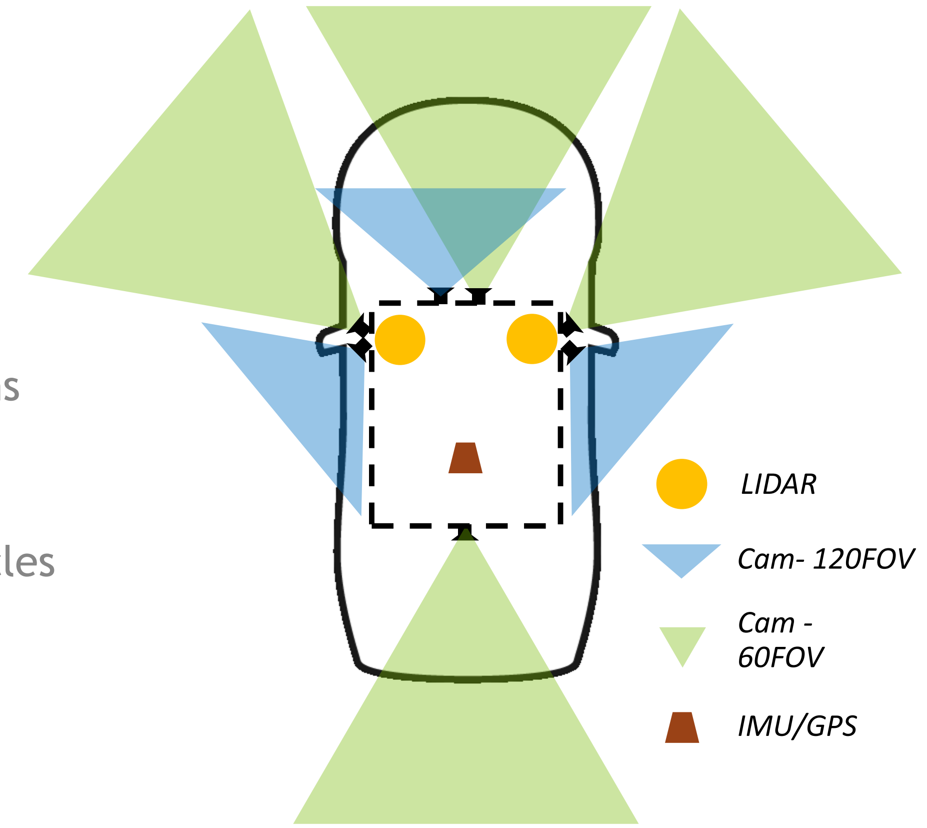
Perceiving your surroundings

Detect lane boundaries, drivable paths, cars, pedestrians

Summarizing your world-view to support others

Provide my understanding of this location to other vehicles

Updating the “base map”



INTERFACES

70 Gigabits per second of I/O

Sensor fusion interfaces:

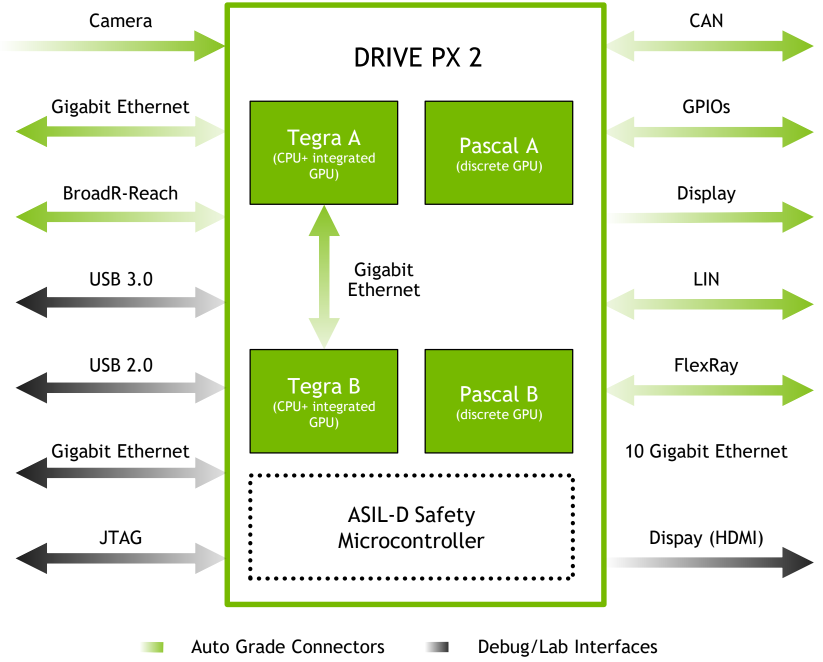
GMSL camera, CAN, GbE, BroadR-Reach, FlexRay, LIN, GPIO

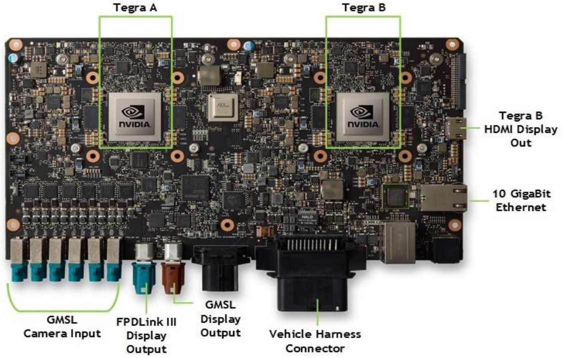
Displays interfaces

HDMI, FPDlink III and GMSL

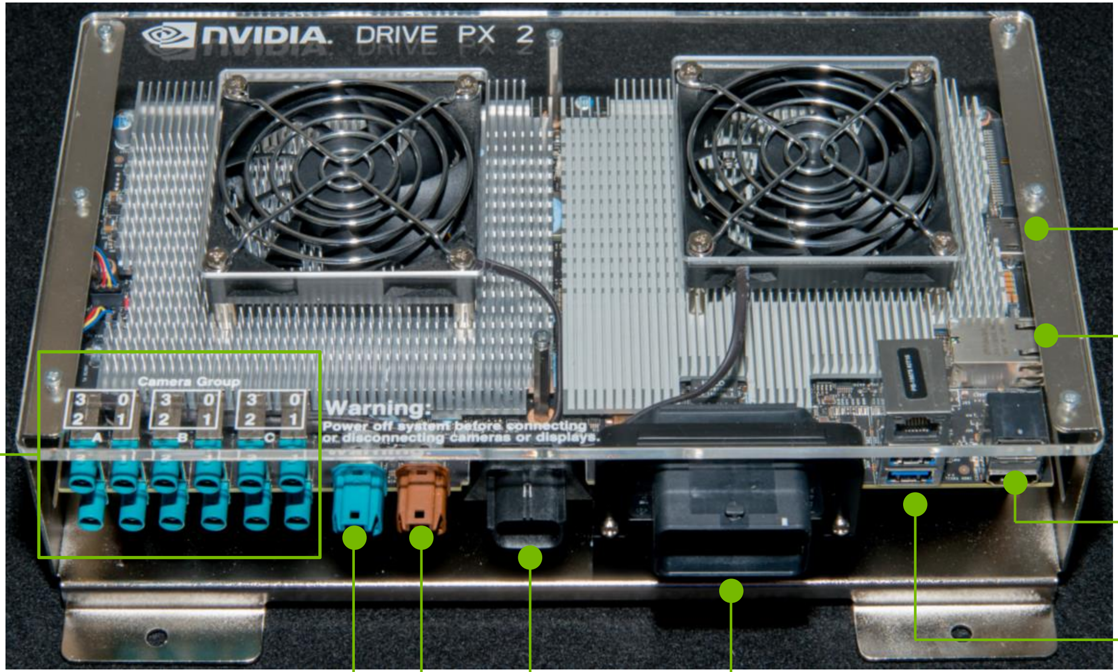
Storage interfaces

10GbE, USB3





DRIVE PX 2 HARDWARE CONNECTIVITY



12 Cameras

- GMSL
- Power over Coax

FPDLink Video Out

GMSL Video Out

BroadR-Reach Ethernet + 8 GPIO

Vehicle Harness

- 6 CAN
- 4 LIN
- 2 FlexRay
- GbE
- AURIX Debug

HDMI Parker B

10 GbE

HDMI Parker A
USB Debug

GbE
USB 3.0 Parker A
USB 3.0 Parker B

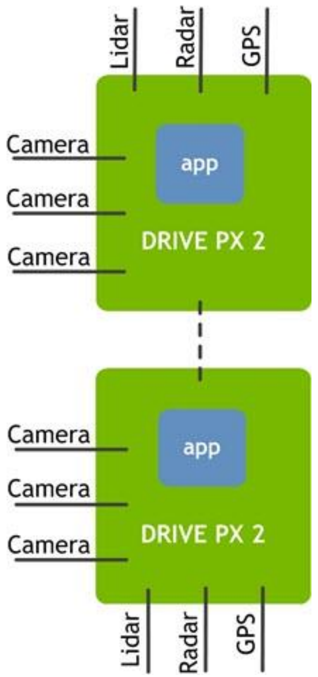
DISTRIBUTED RECORDING

DriveWorks Tools

Multiple sensors; multiple DRIVE PX devices log synchronized data

Each DRIVE PX unit collecting data with a timestamp recording time (ms)

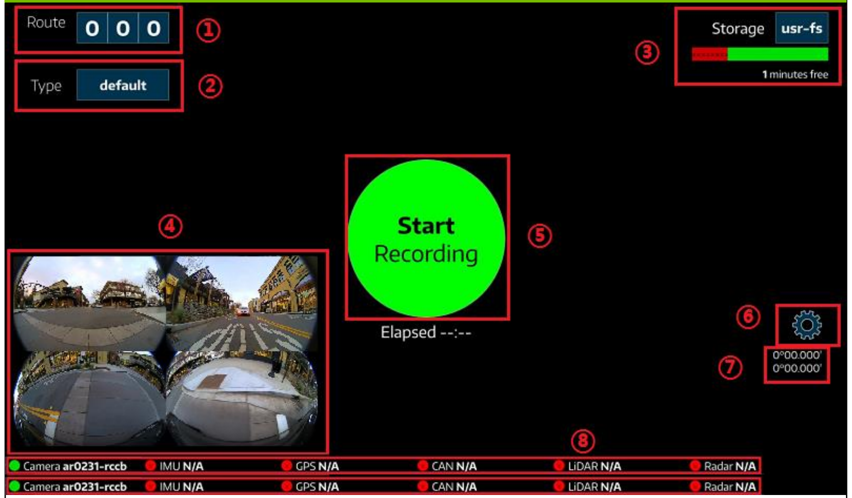
Data between units sync'd based on timestamps



RECORDING TOOL

DriveWorks Tools

Calibration & Sensor Registration

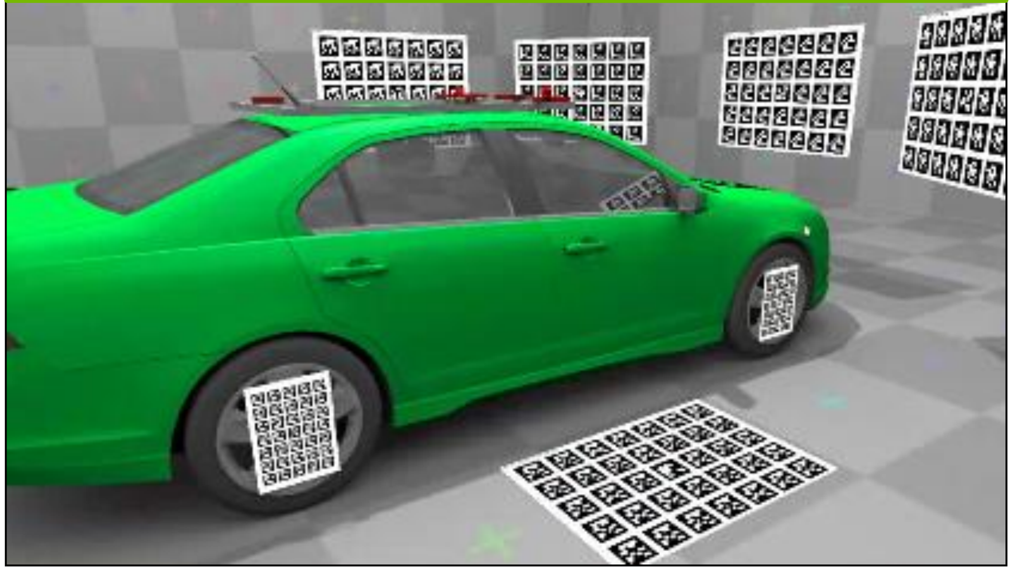


1. Route setting
2. Configuration switching
3. Storage info
4. Camera preview
5. Start Recording control button
6. Settings button
7. GPS info
8. Sensor Status

CAMERA CALIBRATION & SENSOR REPLAY

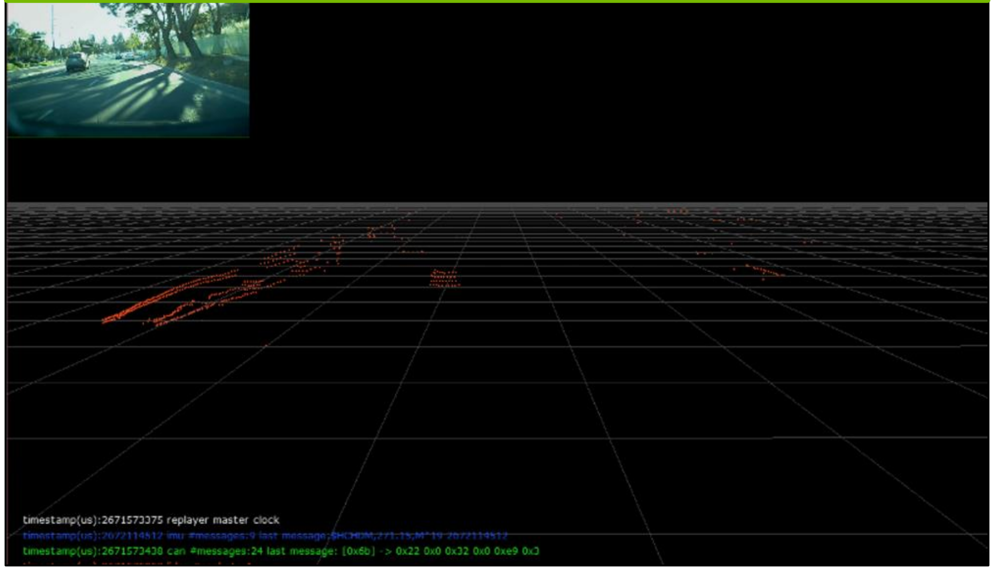
DriveWorks Tools

CALIBRATION & SENSOR REGISTRATION



Calibrate N cameras	Cameras can be pinhole or fisheye	No restriction on field of views	No manual measurements involved

DATA REPLAY TOOL



Replays the sensor data captured	Displays the data for each sensor type	Provides a simple UI for quick sanity checks

DEVELOPMENT FLOW

Self Driving Vehicle Development

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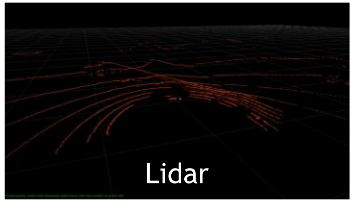
DRIVEWORKS MODULES

Sensing



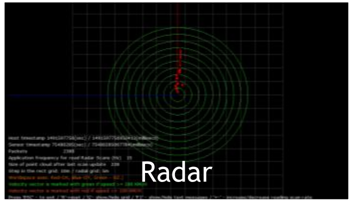
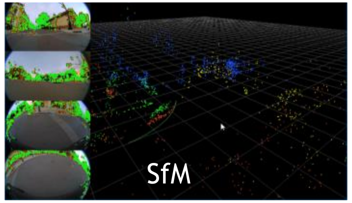
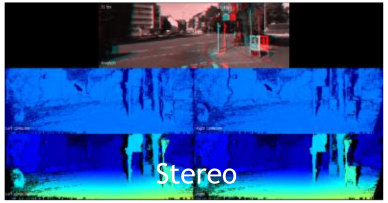


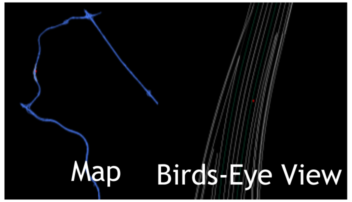
Image Processing

Computer Vision





Maps



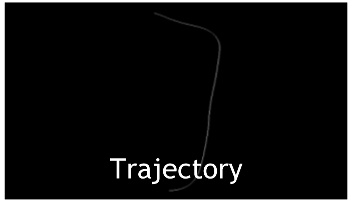
Detection

Renderer

Image Pipeline

Vehicle IO*

Egomotion



AI CO-PILOT

Adding Value When Humans Choose to Drive

Autonomous driving modes are OFF

Vehicle continues to be aware of its surroundings

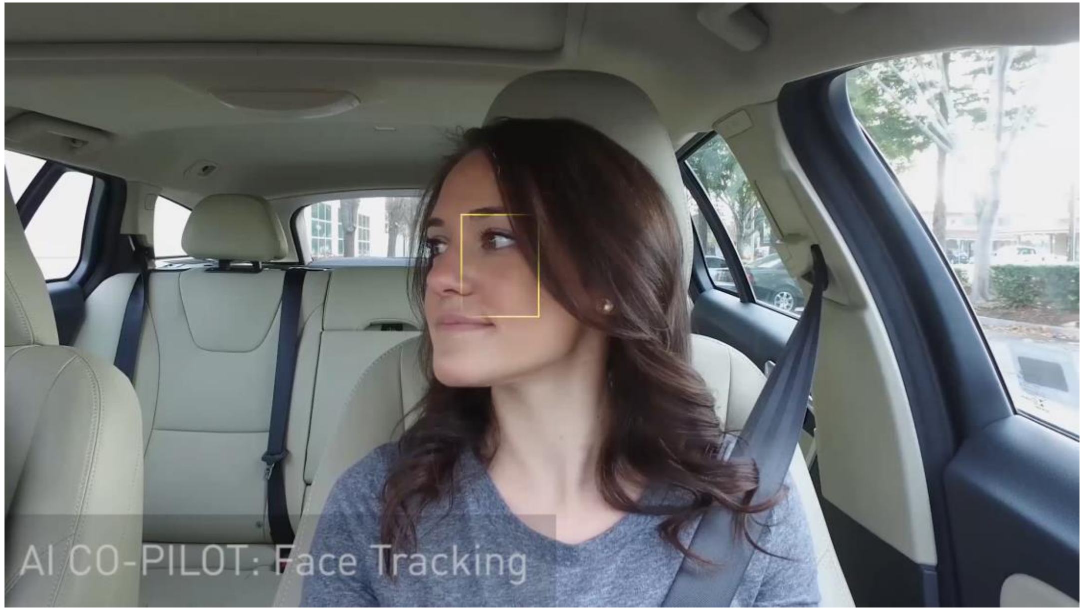
Driver facing camera

Driver notification via:

- Audio (sounds and language)
- Visual (LEDs, icons, text, HUD)
- Vibration (steering wheel, seat, seatbelt)

AI CO-PILOT

Convenience



Driver Recognition

Route Memory

Driver Habit Customizations

AI CO-PILOT

Communication

Lip Reading
Natural Language Understanding
Conversational Interaction

AI CO-PILOT

Safety

Meaningful Alerts Filter
Tracks Where Driver is Looking
Notifies on Unseen Situations

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PX2: ON WHEELS

HARDWARE

DRIVE PX 2 nicely mounted in the trunk of a car, pre-wired for cameras, and other sensors

Sensors — Your choice or NVIDIA's configuration

SOFTWARE

All of what comes with DRIVE PX2

DRIVE PX + SENSORS CONFIGURED TO GO

With Ford Fusion + DRIVE PX + cameras, LIDAR, radar, navigation sensors and storage options

Photo courtesy of AutonomouStuff

DRIVE PLATFORM

For Production

HARDWARE

ZF Pro AI — built on DRIVE PX 2 Auto Cruise

Bosch — building on DRIVE PX using Xavier

Xavier: 30 DL TOPS + ASIL-C for Level 4

SOFTWARE

QNX — Common arch across Linux and QNX

Common APIs across CUDA, TensorRT, cuDNN, NvMedia + Support for POSIX APIs

NVIDIA AI CARS

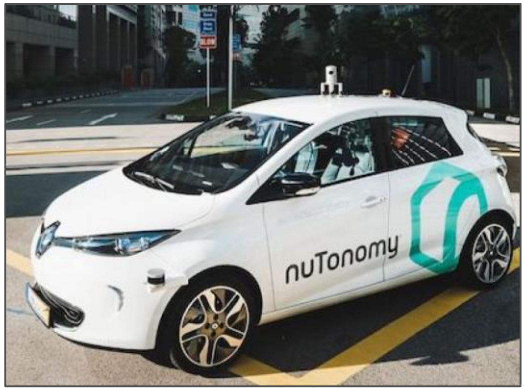
Audi

Tesla

Mercedes-Benz

Baidu

Volvo



nuTonomy

WEpods

RoboRace


NVIDIA
NVIDIA
NE
Date & time
3:56
Tuesday
1/3/2017
PILOTNET
NVIDIA DRIVE PX 2
LILLIPUT

SUMMARY

What are autonomous vehicles

Introduced the concept of functional safety

Discussed the levels of automation

AV & Co-Pilot

DRIVE PX

Development workflow

QUESTIONS?