Autonomous Road Vehicles
History and Current Developments

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Autonomous Road Vehicles

- ▶ **History: when the first automatic vehicle appeared?**
- ▶ **Automated Driving Levels (SAE J3016)**
- ▶ **Why we need autonomous driving vehicles? Benefits?**
- ▶ **Technical Challenges**

First Automated Vehicle – 1925/26
The Linrrican Wonder & Phantom Auto

The first driverless vehicles were presented in New York and Milwaukee in 1925 and1926. Despite the vehicles were controlled by radio signal sent by other following vehicles and so were not autonomous, they were a practical verification of the available technology at that time

1939 World's Fair
The **Futurama Exhibition**

Credits: https://www.youtube.com/watch?v=1cRoaPLvQx0

During the 1939 Word's Fair New Horizons, GM presented a its futuristic vision of the '60. Along with new telephones, lights, aircraft and much more, the first applications of autonomous vehicles were presented.

KEYNOTE: SAFETY (with high speeds)

1956 World's Fair
General Motors *Firebird II Vehicle*

Credits: https://www.youtube.com/watch?v=Rx6keHpeYak&t

*GM presented a new motorway concept (a distant 1976!) where cars were controlled by automated radio **autopilot** systems*

"Modern" Age – Mid '80s

With the technological advancements of computer vision, machine perception and computation power, in the beginning of the 80's the team of the Bundeswehr University Munich lead by Professor Ernst Dickmanns started the research in autonomous driving.

After years of preparatory developments, in 1986 the VaMoRs vehicle experimented on streets without traffic, traveling at speeds of 96 Km per hour, over more than 20 Km.

VaMoRs Vehicle 1986

Meanwhile, in the world … Before 2004
Some examples

Navlab
Carnegie Mellon
University

Argo Vehicle
Vislab – University of Parma

VaMP Vehicle
UniBWM
EUREKA Prometheus project

The DARPA Competitions 2004/2005 and 2007

Defense Advanced Research Projects Agency

Grand Challenge 2004/2005

Urban Challenge 2007

Junior Vehicle
Leader: Sebastian Thrun
University of Stanford

Boss Vehicle
Leader: Chris Urmson
University of Carnegie Mellon

Post DARPA, 2007 - nowadays

Google / Waymo (Alphabet)

Tesla

Daimler / Mercedes Benz

GM – Cruise Automation

Google   Uber   Tesla   Nvidia   Ford   Volvo   Nissan

A Standard for Automated Driving Levels
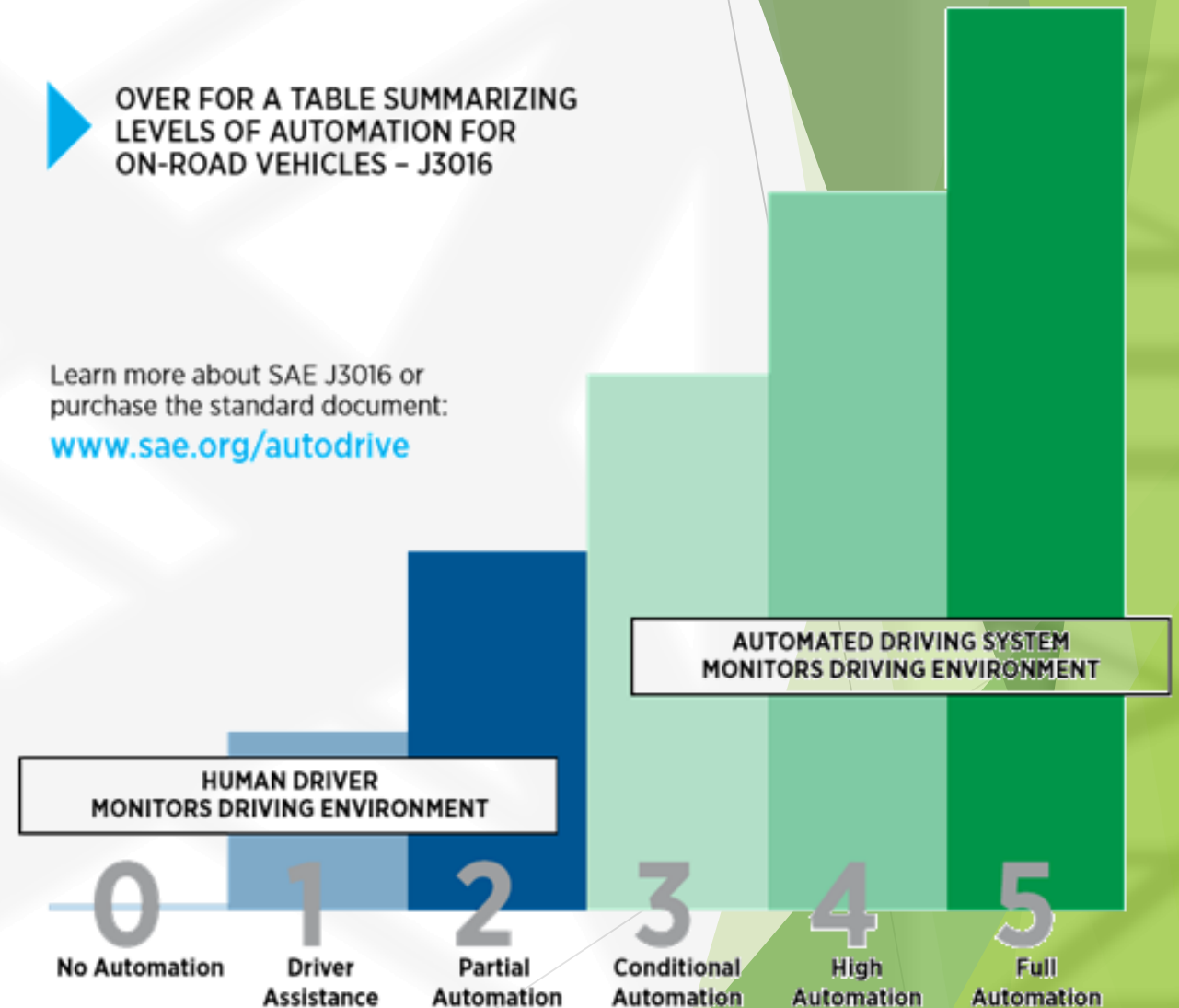
SAE Levels 0 to 5 Defined

The full SAE Levels, which are now the standard in the US and internationally where SAE regulations are observed, are as follows:

" · At **SAE Level 0**, the human driver does everything;

· At **SAE Level 1**, an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task;

· At **SAE Level 2**, an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task;

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· At **SAE Level 3**, an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the human driver must be ready to take back control when the automated system requests;

· At **SAE Level 4**, an automated system can conduct the driving task and monitor the driving environment, and the human need not take back control, but the automated system can operate only in certain environments and under certain conditions; and

· At **SAE Level 5**, the automated system can perform all driving tasks, under all conditions that a human driver could perform them.

— NHTSA, USDOT

OVER FOR A TABLE SUMMARIZING LEVELS OF AUTOMATION FOR ON-ROAD VEHICLES – J3016

Learn more about SAE J3016 or purchase the standard document:
www.sae.org/autodrive

AUTOMATED DRIVING SYSTEM MONITORS DRIVING ENVIRONMENT

HUMAN DRIVER MONITORS DRIVING ENVIRONMENT

0	1	2	3	4	5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation

SAE J3016 Keyword Definition

▶ **Dynamic driving task**
includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task

▶ **Driving mode**
is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)

▶ **Request to intervene**
is notification by the automated driving system to a human driver that s/he should promptly begin or resume performance of the dynamic driving task

A Standard for Automated Driving Levels

SAE Levels 0 to 2 Examples

Adaptive Cruise Control: The driver can leave the gas pedal alone and the vehicle will travel at a constant speed, and it will sense a vehicle in front and slow down to maintain a set gap.

Lane-Keeping Assist: Controls the vehicle steering to help prevent the driver from unintentionally wandering out of their lane on the highway.

Automatic Emergency Braking: The vehicle detects an imminent crash and applies the brakes to prevent, or limit the severity, of the collision.

Current Tesla Motors Autopilot is at Level 2

Enhance Autopilot Preannounced in Jan 17

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

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SAE Level 3 – Conditional Automation

In specific driving modes, the automated driving system performs all the aspects of the dynamic driving task, with the expectation that the human driver will respond appropriately to a request to intervene

No commercial application yet (jan 2017)

However,

"The first example of a Level 3 vehicle that we can expect to see on the roads is one that can drive itself from on-ramp to off-ramp on a freeway. Astro Teller of Google stated that the Google Self-Driving Car Project achieved highway driving capability in late-2012, but they chose not to commercialize it"

SAE Level 4 – High Automation

In specific driving modes, the automated driving system performs all the aspects of the dynamic driving task, <u>even if a human driver does not respond appropriately to a request to intervene</u>

Some commercial applications are available, constrained in some way such as geo-fenced areas, private areas, specific weather or maximum speeds

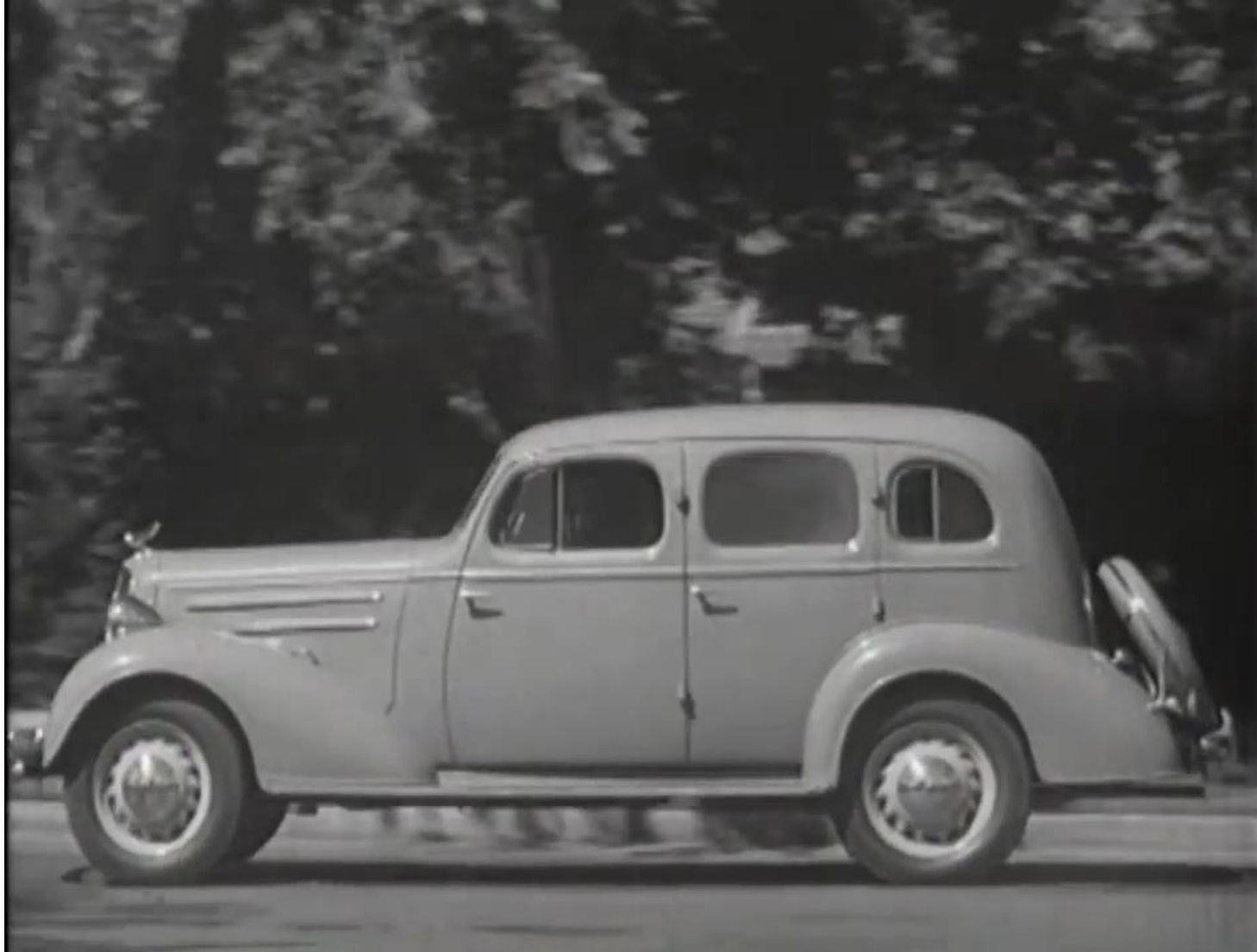Demo at 22nd ITS World Congress 2015

SAE Level 5 – Full Automation

In ALL driving modes, the automated driving system performs all the aspects of the dynamic driving task, <u>under all roadway and environmental conditions that can be managed by a human driver.</u>

No supervision at all, so "no driver needed"

"Some believe that vehicles with this level of capability may never exist. Some say that they will take a very long time. When Thinking Highways interviewed a panel of vehicle automation specialists in September 2014, both Steven Shladover and Alain Dunoyer thought that vehicles that would drive themselves to your day and take you places would be 50+ years away"

https://www.driverless.id/news/definitive-guide-levels-automation-for-driverless-cars-0176009/
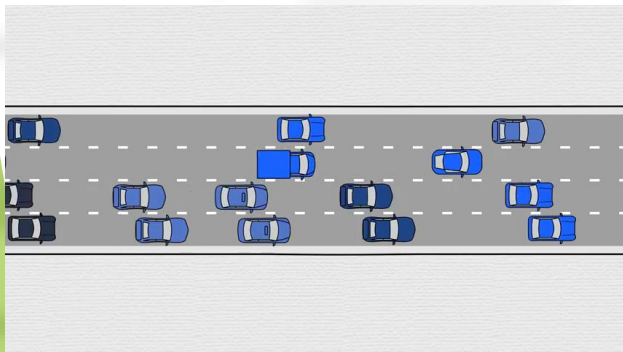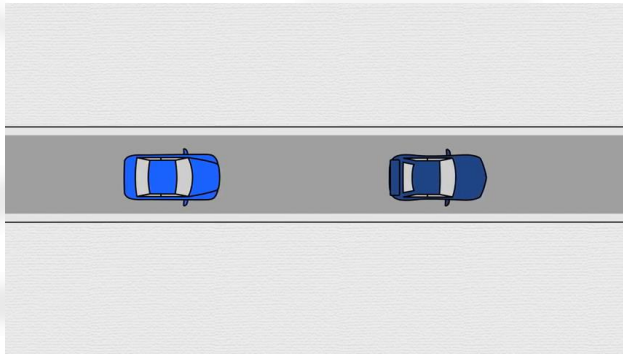
Why we need autonomous vehicles?

Why we need autonomous vehicles?

- ▶ Safety issues
- ▶ Traffic management
- ▶ Emission, reduce required energy

How far are autonomous vehicles?

▶ Safety challenges: how many Km should be driven before?

▶ Which *"Mean Time Between Failures"* (MTBF) is desired?
Currently in US:

                Fatal-MTBF is 3 million vehicle hours
                Injury-MTBF is 65000 vehicle hours
How many hours or KM are needed for autonomous vehicles?

▶ Software verification procedures

▶ Cyber Security Issues

▶ New Crashes typologies caused by automation

▶ Ethical Scenarios
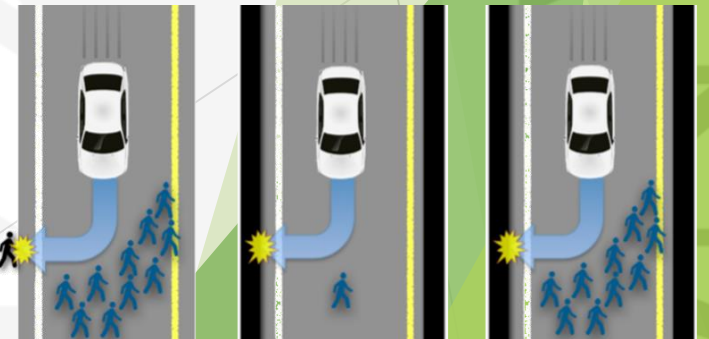
Some numbers ...

▶ **The California DMV just published the**
<u>Autonomous Vehicle Disengagement Reports for 2016</u>

	Miles	Diseng	Miles/D	Road type
BMW	638	1	638.0	Likely Highway
Bosch	983	1442	0.7	Interstates/Freeways
GM/Cruise	9 776	181	54.0	**Urban**
Delphi	3 125	178	17.6	Highway/Urban/Suburban
Ford	590	3	196.7	Highway
Google/Waymo	635 868	124	5128.0	**Mostly suburban**
Mercedes	673	336	2.0	**Urban**
Nissan	4 099	28	146.4	Highway/Urban/Suburban
Tesla	550	182	3.0	Highway/Suburban/Unknown

References:

- Road Vehicle Automation History, Opportunities and Challenges, Steven E. Shladover, V-Charge Summer School, ETH Zurich July 7, 2014

- Videos in the slides:

Self driving car in 1935
https://www.youtube.com/watch?v=tKAIZJbHSmA

Nissan Imagine a 2020 Future
https://www.youtube.com/watch?v=mre6SHyfYnQ

https://www.youtube.com/watch?v=VG68SKoG7vE
Autopilot Full Self Driving Demonstration Nov
18 2016 Realtime Speed

2005 Driverless Car Competition
https://www.youtube.com/watch?v=7a6GrKqOxeU

Darpa Urban Challenge
https://www.youtube.com/watch?v=7R7d-bYSyUE

https://www.youtube.com/watch?v=7a6GrKqOxeU

The Driverless Future, Brought to You by GM?
https://www.youtube.com/watch?v=KEk4sXUsjj8

A Ride in the Google Self Driving Car
https://www.youtube.com/watch?v=TsaES--OTzM

Tesla Autopilot 2.0 Full Self Driving Hardware
https://www.youtube.com/watch?v=hLaEV72elj0

1960s Citroën DS driverless car test
https://www.youtube.com/watch?v=MwdjM2Yx3gU

The Driverless Future, Brought to You by GM
https://www.youtube.com/watch?v=KEk4sXUsjj8

https://www.youtube.com/watch?v=eUp6vo0XXSc
The First Self Driving Car is 500 Years Old

https://www.youtube.com/watch?v=1cRoaPLvQx0
Futurama 1939 New York World's Fair "To New
Horizons" 1940 General Motors 23min

https://www.youtube.com/watch?v=I39sxwYKlEE
Ernst Dickmanns' VaMoRs Mercedes Van, 1986

GM Motorama Exhibit 1956
https://www.youtube.com/watch?v=Rx6keHpeYak

Celebration of MilleMiglia in Automatico
https://www.youtube.com/watch?v=S-lpHvQ3jYY

California PATH's mission
https://www.youtube.com/watch?v=VaQmhxmKd2I

NavLab 1 (1986)
https://www.youtube.com/watch?v=ntIczNQKfjQ

The S 500 INTELLIGENT DRIVE in California
https://www.youtube.com/watch?v=DlgGTi4Gs50

Cruise Automation - Episode One: Election Day
https://www.youtube.com/watch?v=1Tp6Ubf6mE4

NAVYA ARMA Fleet on the open road in Bordeaux (FR)
: Street views
https://www.youtube.com/watch?v=RwX7HTFHB8w

Platooning - how it works
https://www.youtube.com/watch?v=X7vziDnNXEY

The Simple Solution to Traffic
https://www.youtube.com/watch?v=iHzzSao6ypE

8 car platooning on I-15 San Diego in year 1997
https://www.youtube.com/watch?v=ycz-e6w4dMo

California PATH's mission
https://www.youtube.com/watch?v=VaQmhxmKd2I

Thanks!

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