UNIMORE
UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

The Autonomous Driving Revolution

A view from HiPeRT Lab

Marko Bertogna
University of Modena, Italy
marko.bertogna@unimore.it
http://hipert.unimore.it/

HiPeRT Lab

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

- ✓ Research on High-Performance Real-Time Systems
- ✓ ~70+ people
  - 7 faculties
  - 16 post docs
  - 12 PhD students
  - 5 tech/admin
  - Many resident students…

HiPeRT Lab

http://hipert.unimore.it/

- ✓ Next-gen Embedded Computing Platforms
- ✓ Autonomous Systems
  - Cars, drones, LGV, water/underwater
- ✓ Real-Time Operating Ecosystems

HiPeRT Lab

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

✓ EU projects:

PRYSTINE
SECREDAS Digital Privacy Safety & Security
FRACTAL EDGE
IMECH
ENABLE-S3
CLASS
COMP4DRONES
5G CARMEN
NEWCONTROL
TACLe Timing Analysis on Code-Level
InSecTT
tetracom
HERCULES
5GMETA
P-SOCRATES
OPEN-NEXT

✓ Industrial collaborations:

NVIDIA
TII Technology Innovation Institute
Ferrari
ocme Moving Ideas
EVIDENCE EMBEDDING TECHNOLOGY
ROBOPAC
System Logistics
Tetra Pak
LYNX SOFTWARE TECHNOLOGIES
SACMI
EXPERT SYSTEM SEMANTIC INTELLIGENCE
XILINX
ARM
doxee Your Communication > Our Innovation
dallara
MASERATI
MARELLI
United Technologies
EGICON
3D[IVE] 3D INTEGRAL VOLUME EXPERIENCE
HUAWEI
BOSCH
bylogix

Autonomous Driving @HiPeRT

- ✓ Multiple EU projects on AD: HERCULES, PRYSTINE, SECREDAS, ENABLE-S3, CLASS, PRYSTINE, SECREDAS, 5G-CARMEN, 5G-META, NEWCONTROL, etc.
- ✓ Four cars with AD platforms and SW
  - Maserati Quattroporte MY18, MY20, Levante MY18, Ferrari
- ✓ LGV, AGV, autonomous delivery BOTs, etc.
- ✓ Multiple 1/10 scale cars equipped with AD stack
  - Organization of the F1tenth challenge
  - See it here and here in action
- ✓ Indy Autonomous Challenge!
  - https://www.indyautonomouschallenge.com/

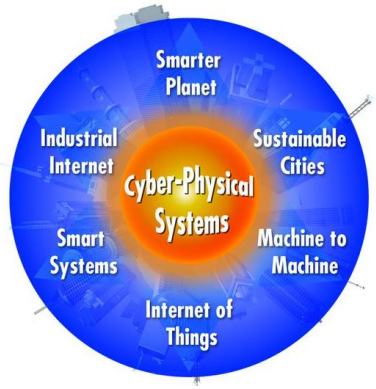
Please visit: f1tenth.org

Next-generation Embedded Applications

- ✓ Complex workload-intensive tasks
  - Perception, planning, ML/DNN
- ✓ Latency-critical control tasks
  - Cyber-physical interaction
  - Tight actuation loops

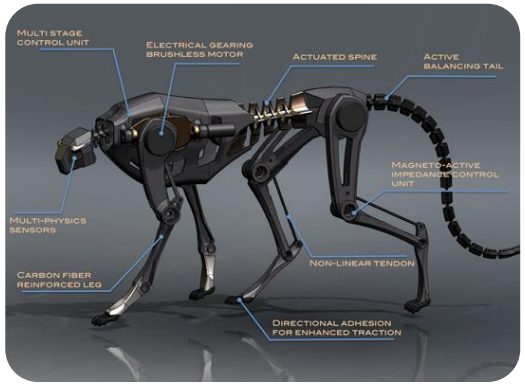
Industry 4.0

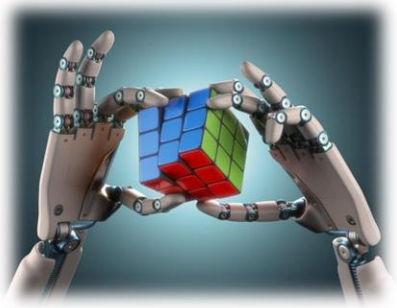
Artificial intelligence

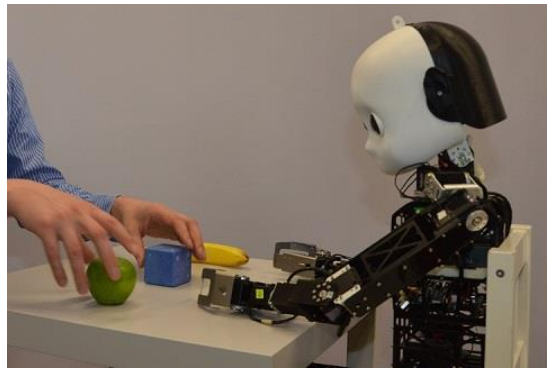


Cyber-physical systems

Autonomous driving







Robotics

Performance vs Predictability

- ✓ Performance-oriented world
  - Highly parallel data crunching applications
  - General purpose operating systems
  - Wide and dynamic library support
  - Optimized for the average case

Diverging needs

- ✓ Predictability-oriented world
  - Safety critical routines
  - Hard real time requirements
  - Functional safety standards (ISO 26262, DO178c)
  - Qualification/certification (ASIL, DAL)
  - Strict programming practices (MISRA C, AUTOSAR)
  - Optimized for the worst-case

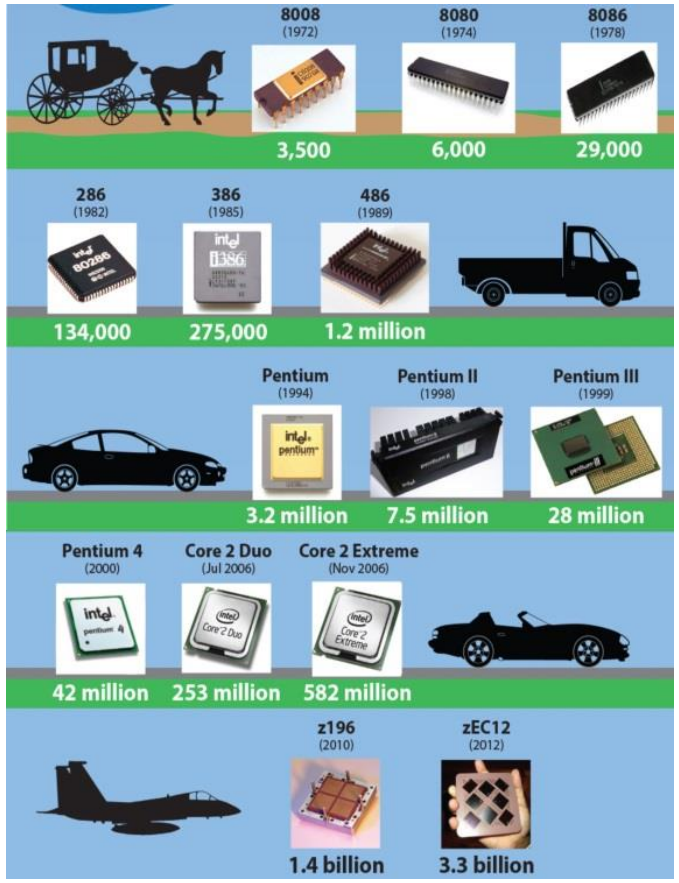
MOTIVATION

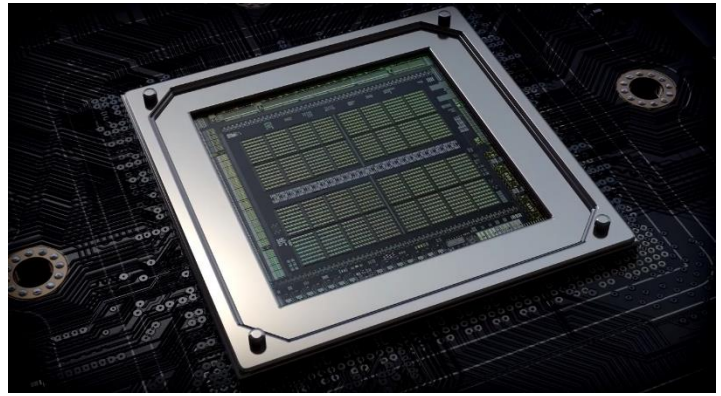
Moore's law

Number of transistors-per-chip doubles every ~2 years

1 T/cm^2 (50's)

1000 T/cm^2 (70's)



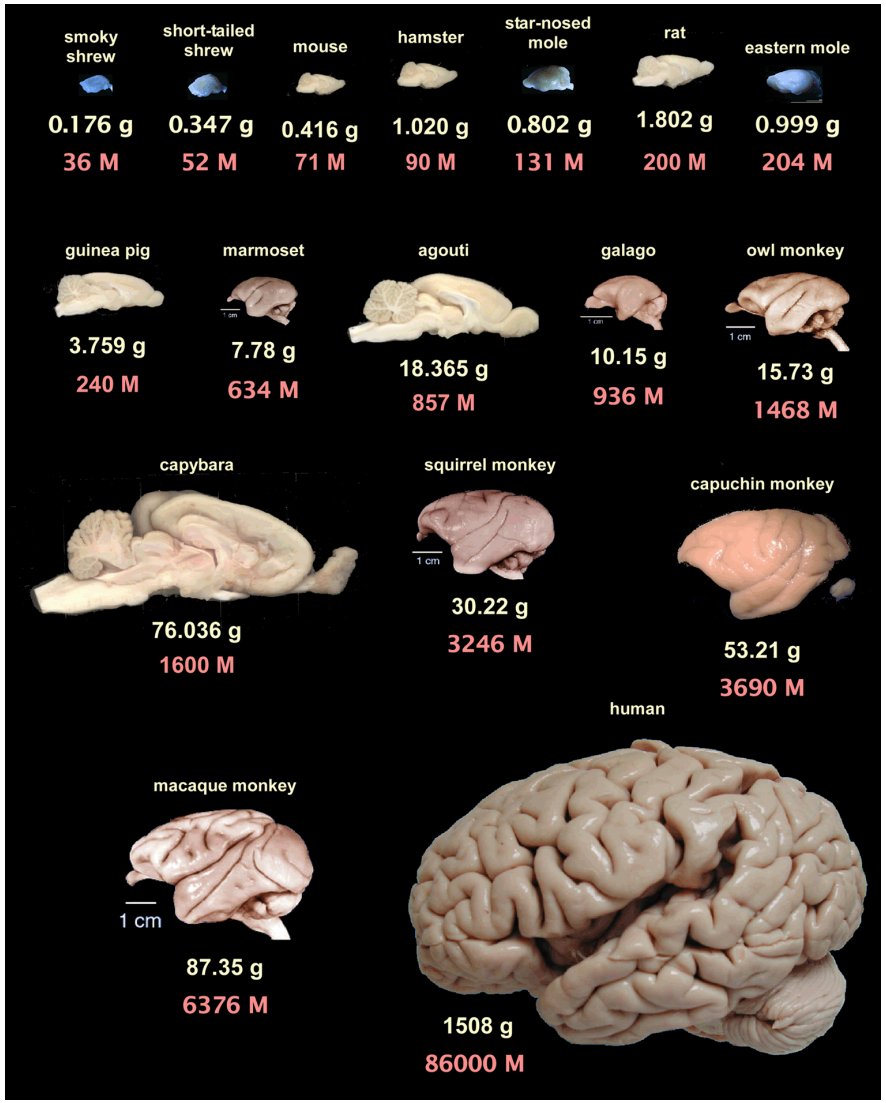


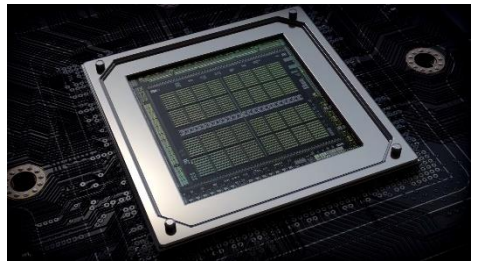
50+ billion T in 8 cm^2

(2020: Nvidia Ampere GPU)

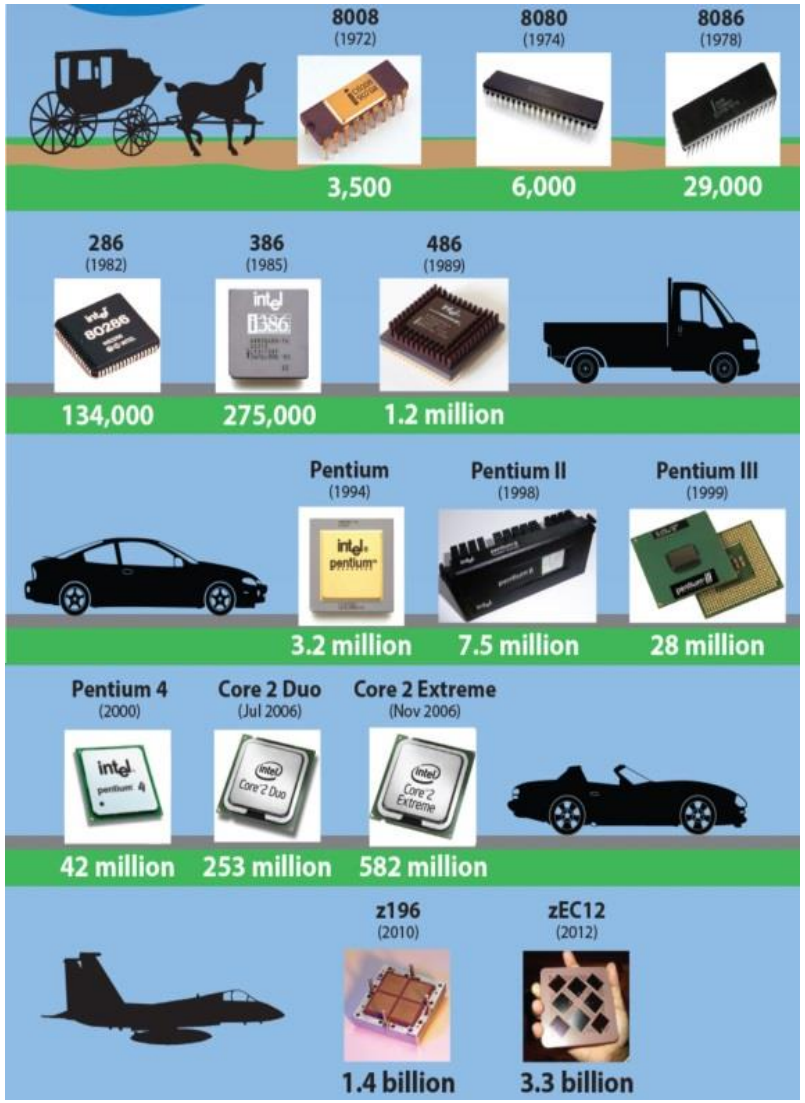
MOORE'S LAW

If transistors were neurons…





50+ billion T in 8 cm^2
(2020: Nvidia Ampere GPU)

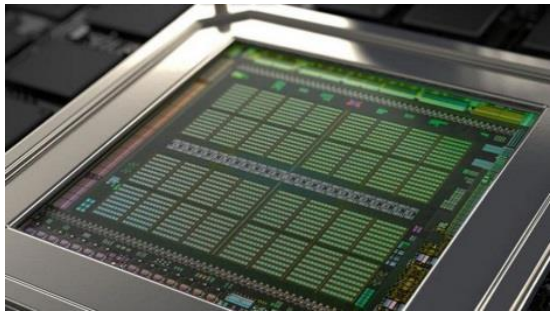


A NEW COMPUTING PARADIGM

Heterogeneous many-core architectures

CPU
MULTIPLE CORES

GPU
THOUSANDS OF CORES

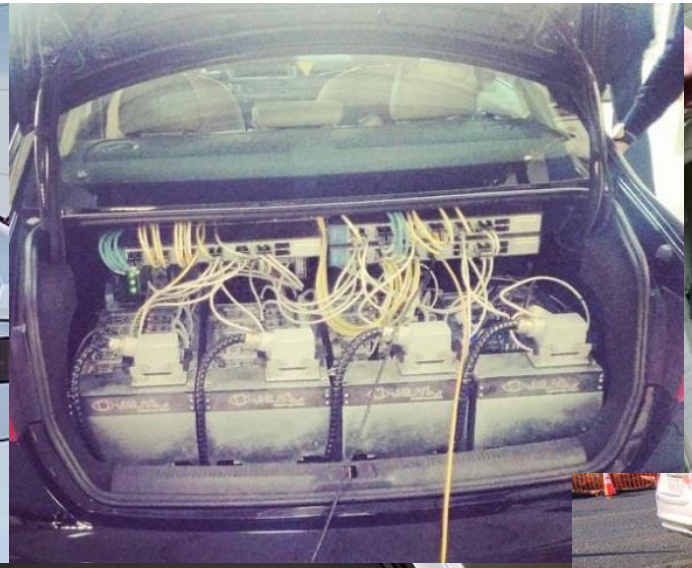


E.g.: Nvidia Xavier
30 TOPS at 30W

ASCI White (2001): 100+ tons, 3 MW (+3 for cooling)

CURRENT SOLUTION

AD Prototypes

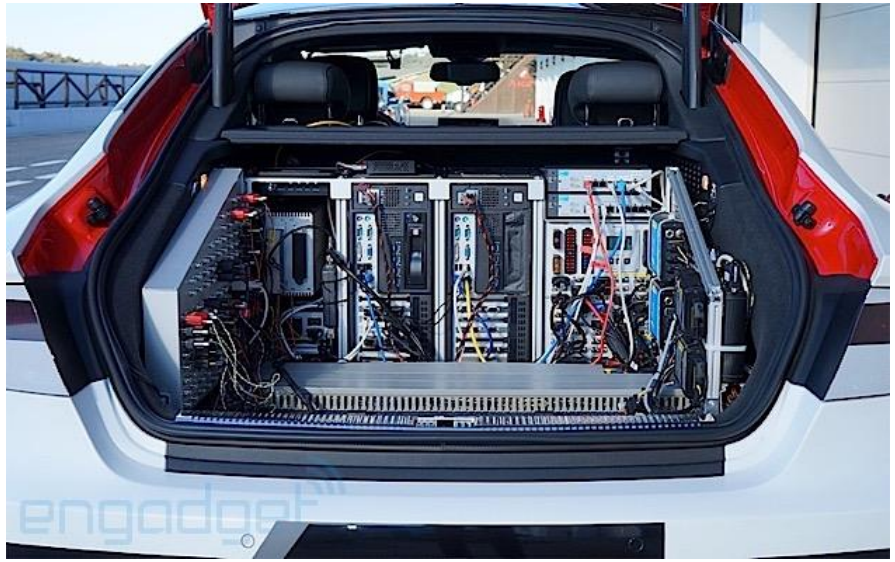


The HERCULES Project:

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

High-Performance Real-time Architectures for Low-Power Embedded Systems

- ✓ Next-gen platforms for next-gen robotic applications
- ✓ Autonomous driving, drones and UAV
- ✓ Predictable performance



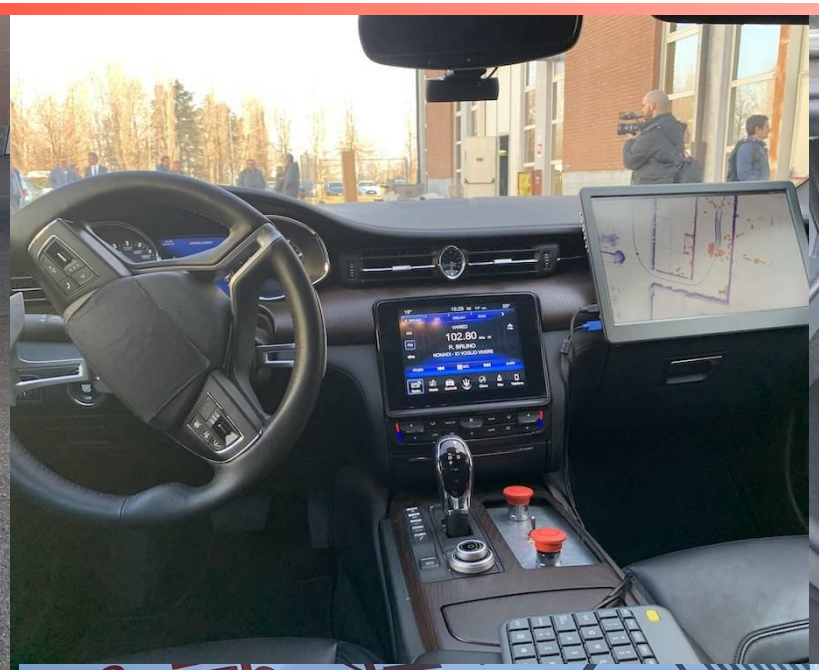
HERCULES

EU funded H2020
2016 – 2019
hercules2020.eu

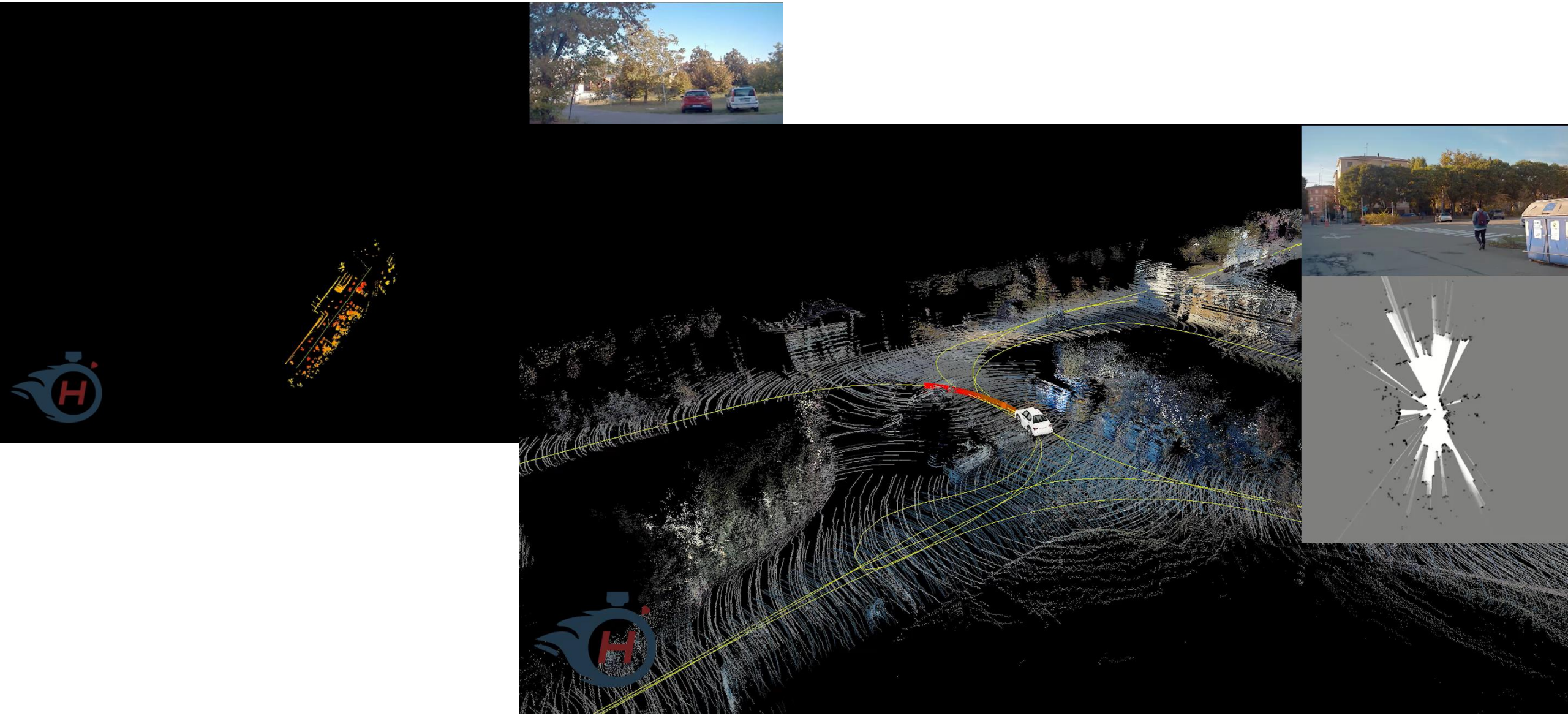
UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
ETH zürich
AIRBUS GROUP
CZECH TECHNICAL UNIVERSITY IN PRAGUE
MAGNETI MARELLI
pitom think over movement
EVIDENCE EMBEDDING TECHNOLOGY

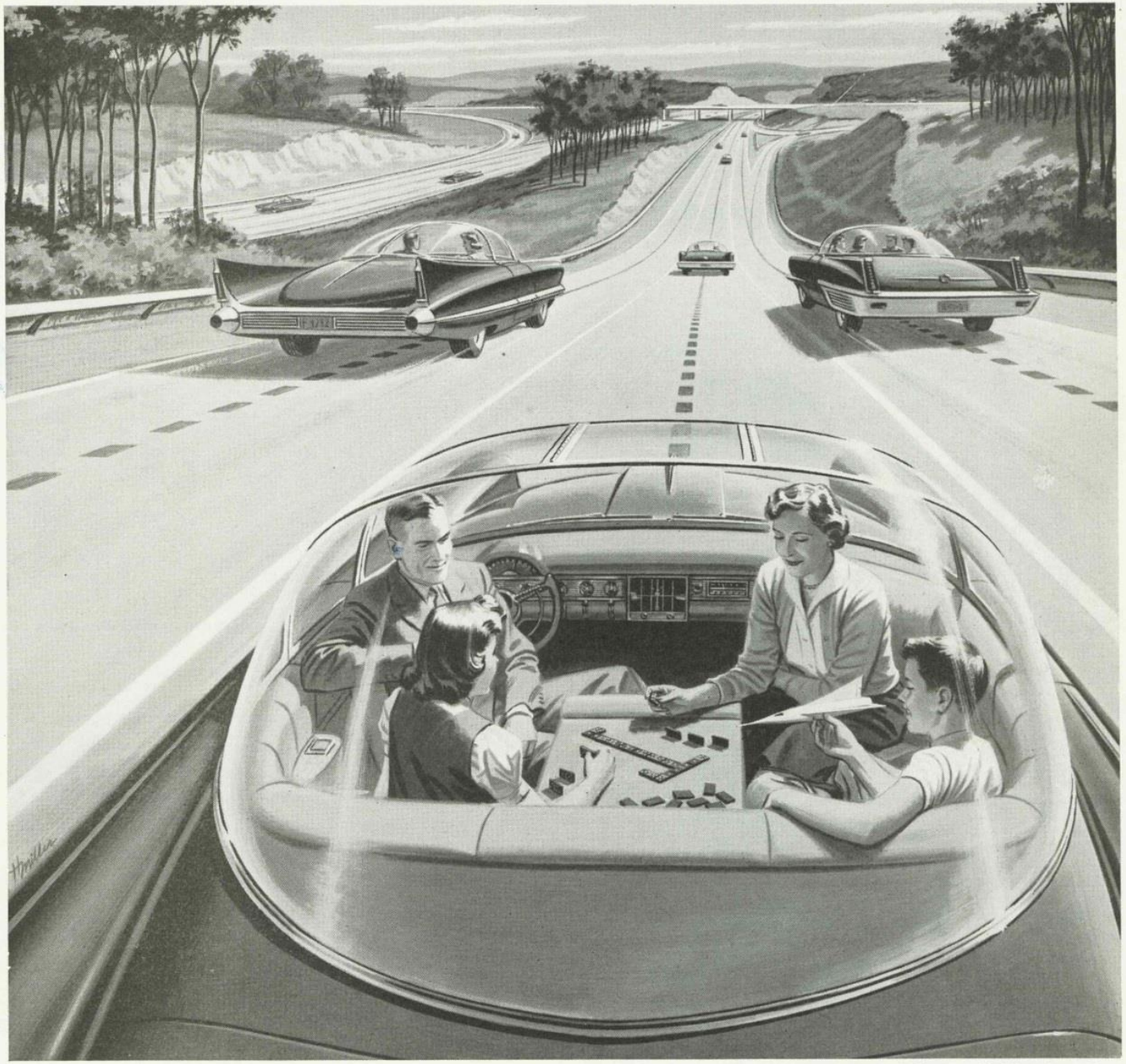
HiPeRT Autonomous Car

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA



Precise Localization and Mapping



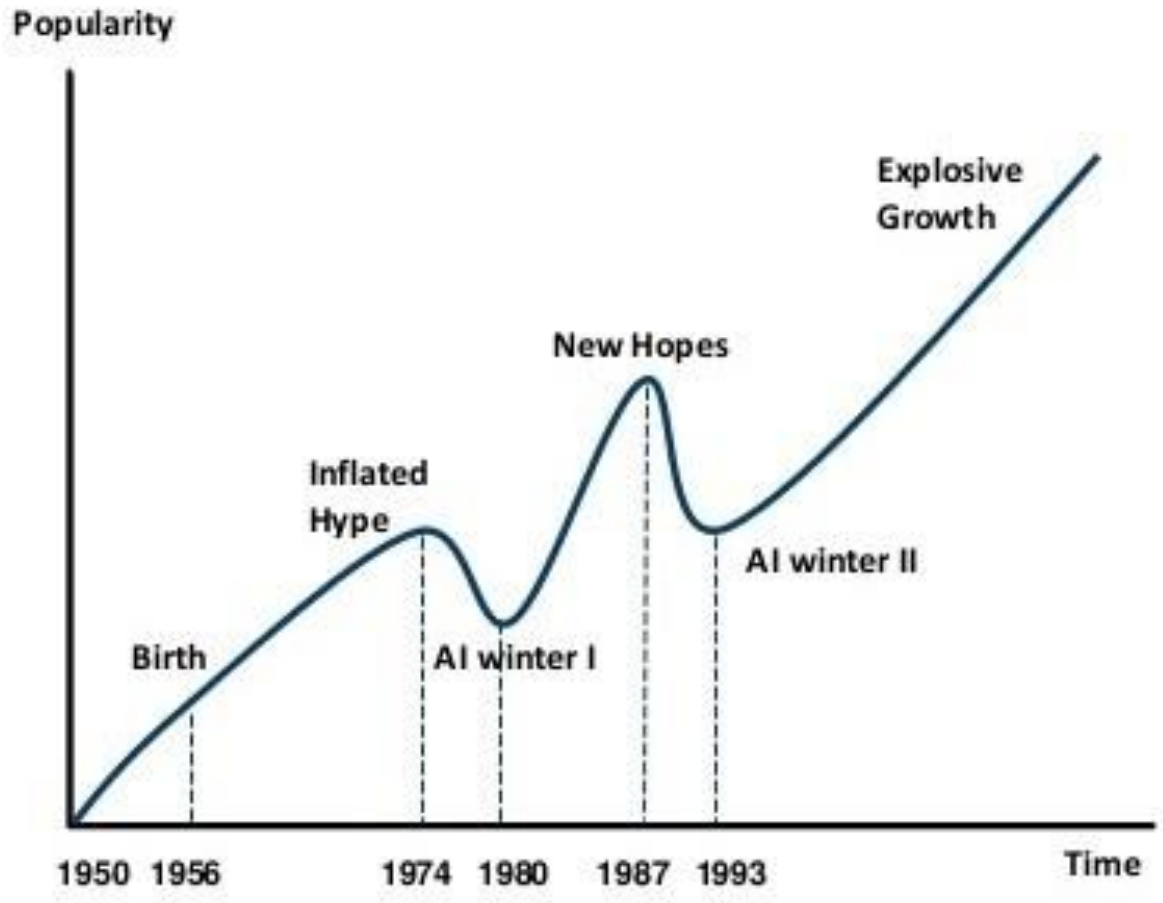


ELECTRICITY MAY BE THE DRIVER. One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road. Travel will be more enjoyable. Highways will be made safe—by electricity! No traffic jams . . . no collisions . . . no driver fatigue.

Driverless Car of the Future, advertisement for "America's Electric Light and Power Companies," Saturday Evening Post, 1950s.

AI Winter(s)…

AI HAS A LONG HISTORY OF BEING "THE NEXT BIG THING"…



Timeline of AI Development

- **1950s-1960s**: First AI boom - the age of reasoning, prototype AI developed
- **1970s**: AI winter I
- **1980s-1990s**: Second AI boom: the age of Knowledge representation (appearance of expert systems capable of reproducing human decision-making)
- **1990s**: AI winter II
- **1997**: Deep Blue beats Gary Kasparov
- **2006**: University of Toronto develops Deep Learning
- **2011**: IBM's Watson won Jeopardy
- **2016**: Go software based on Deep Learning beats world's champions

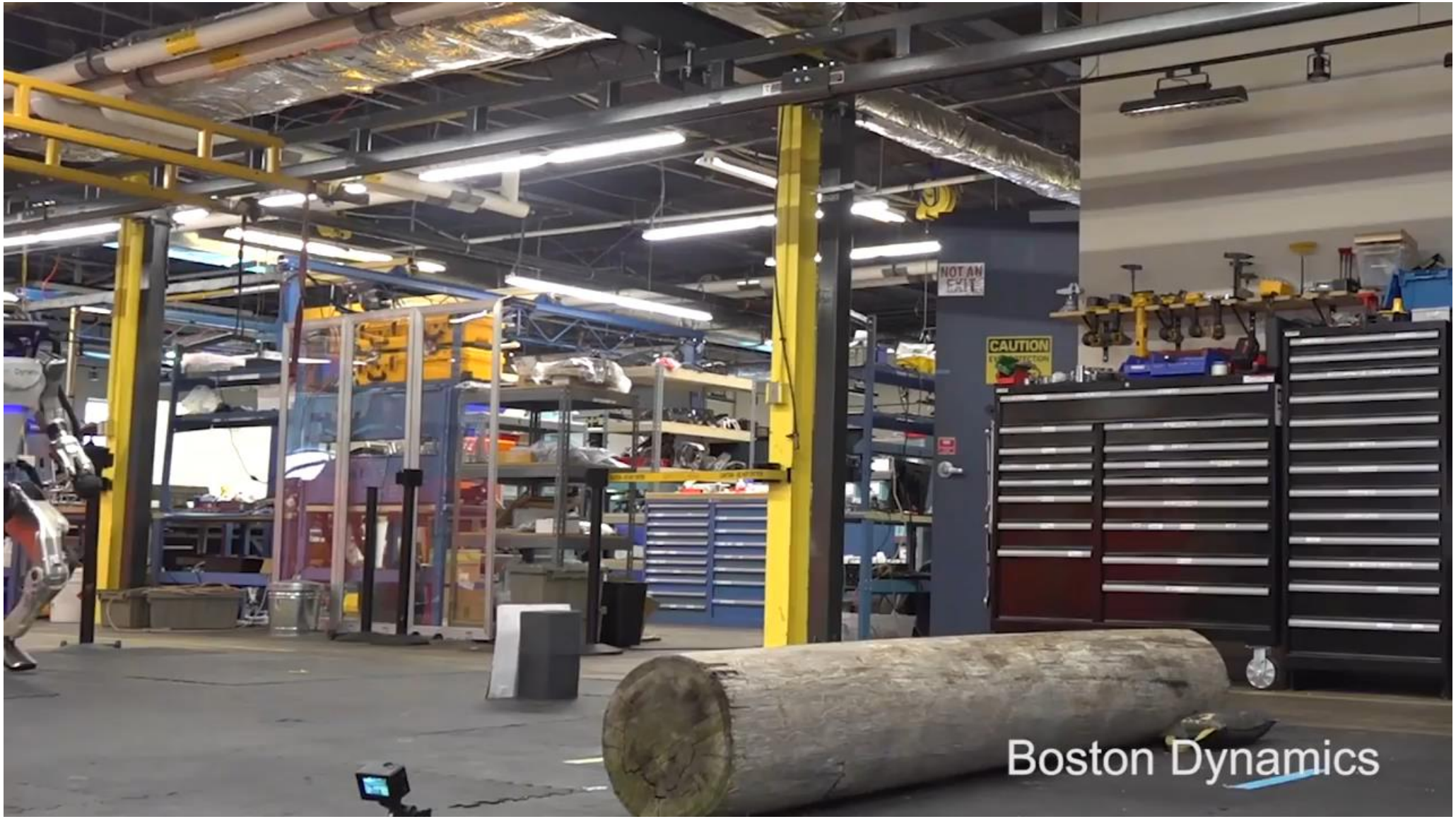
AI's Epic Wins

- ✓ 1997: IBM's Deep Blue defeats Garry Kasparov in a 6 rounds game
- ✓ 2016: Google's Alpha GO beats Lee Sedol, the best Go player in the world

Moravec’s paradox

- ✓ Moravec, Brooks, Minski ‘80s:
  - High-level reasoning requires very little computation, but low-level sensorimotor skills require enormous computational resources

New humanoid robots



Enabling technologies

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

ROBOTICS BOOSTS EVERY INDUSTRY

Delivery

Consumer

Healthcare

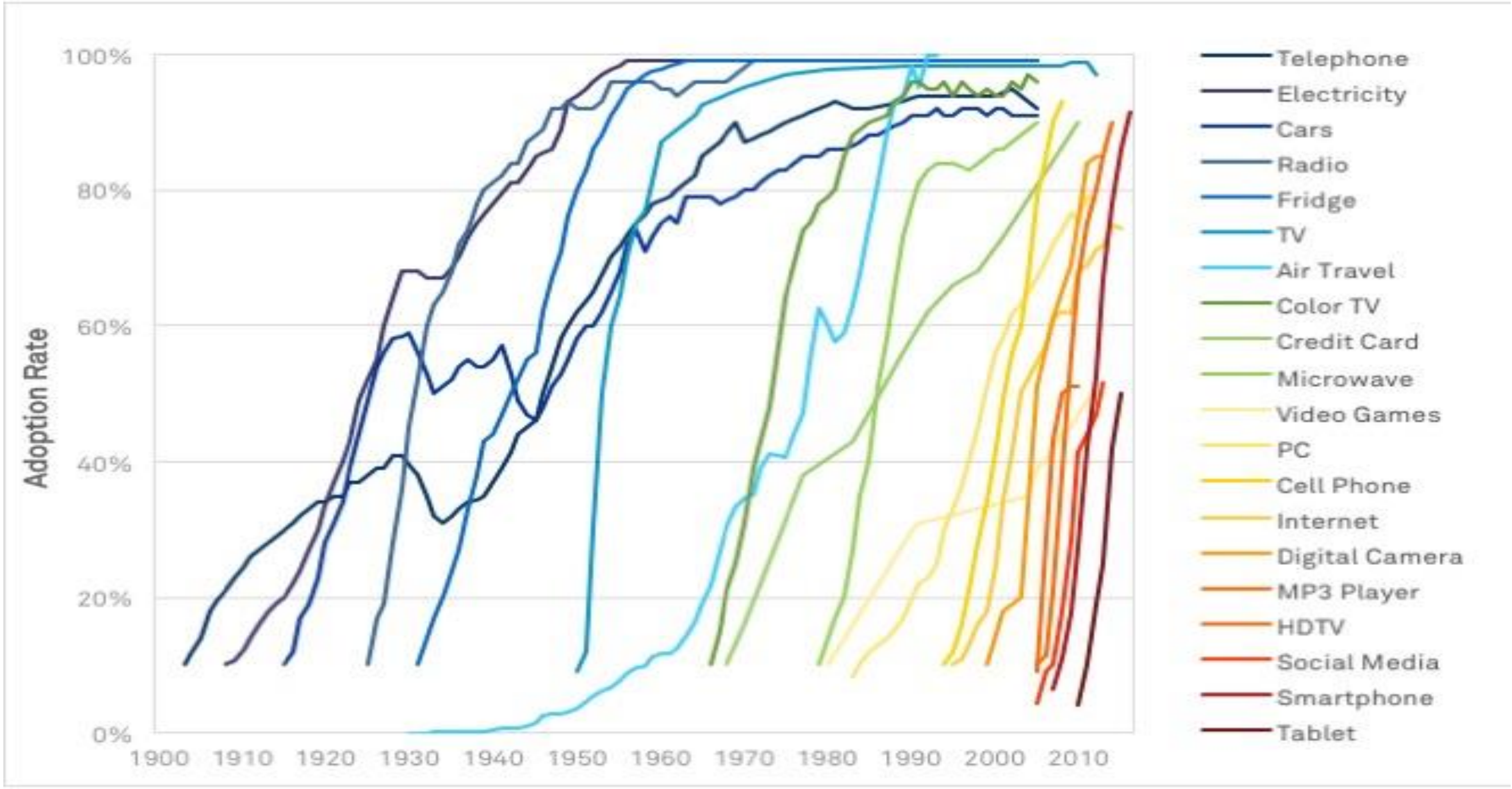
Agriculture

Retail

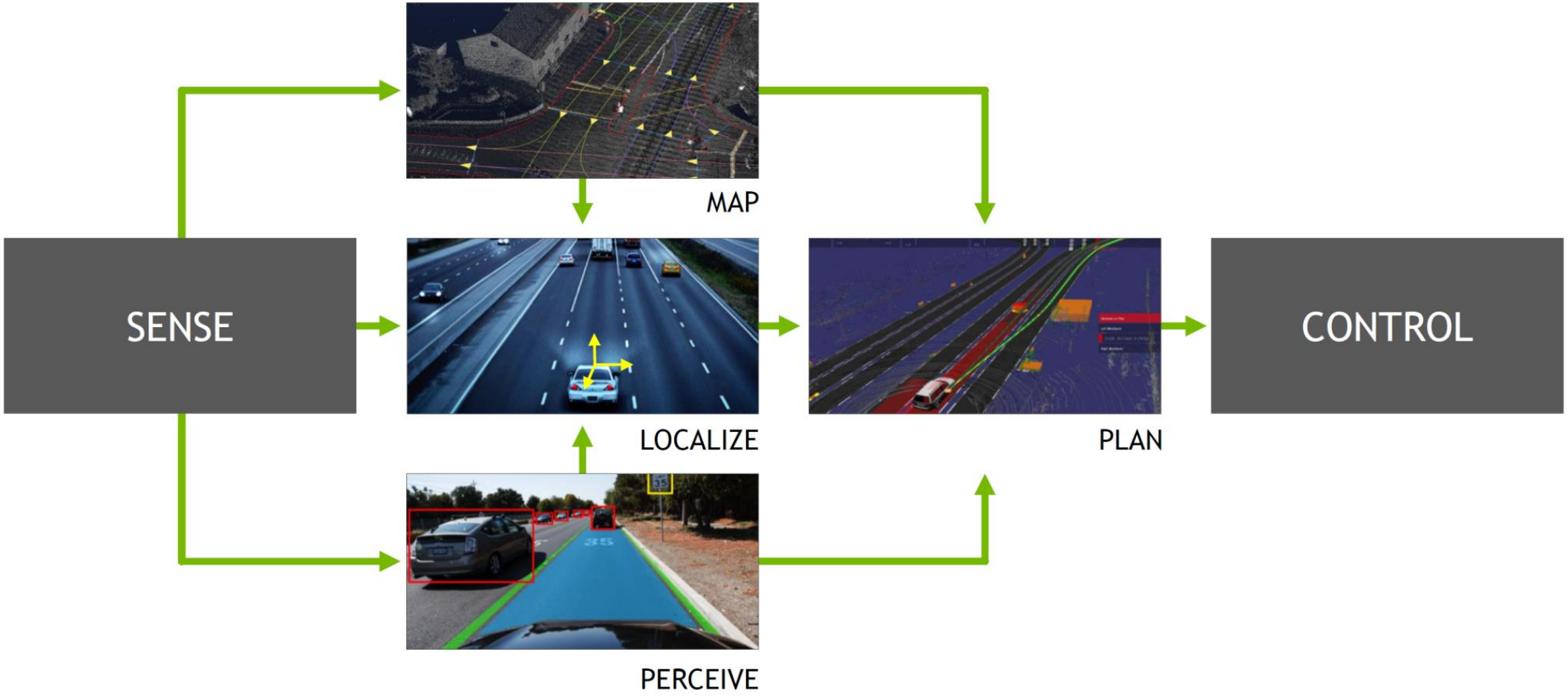
Logistics

Manufacturing

The rising speed of tech adoption

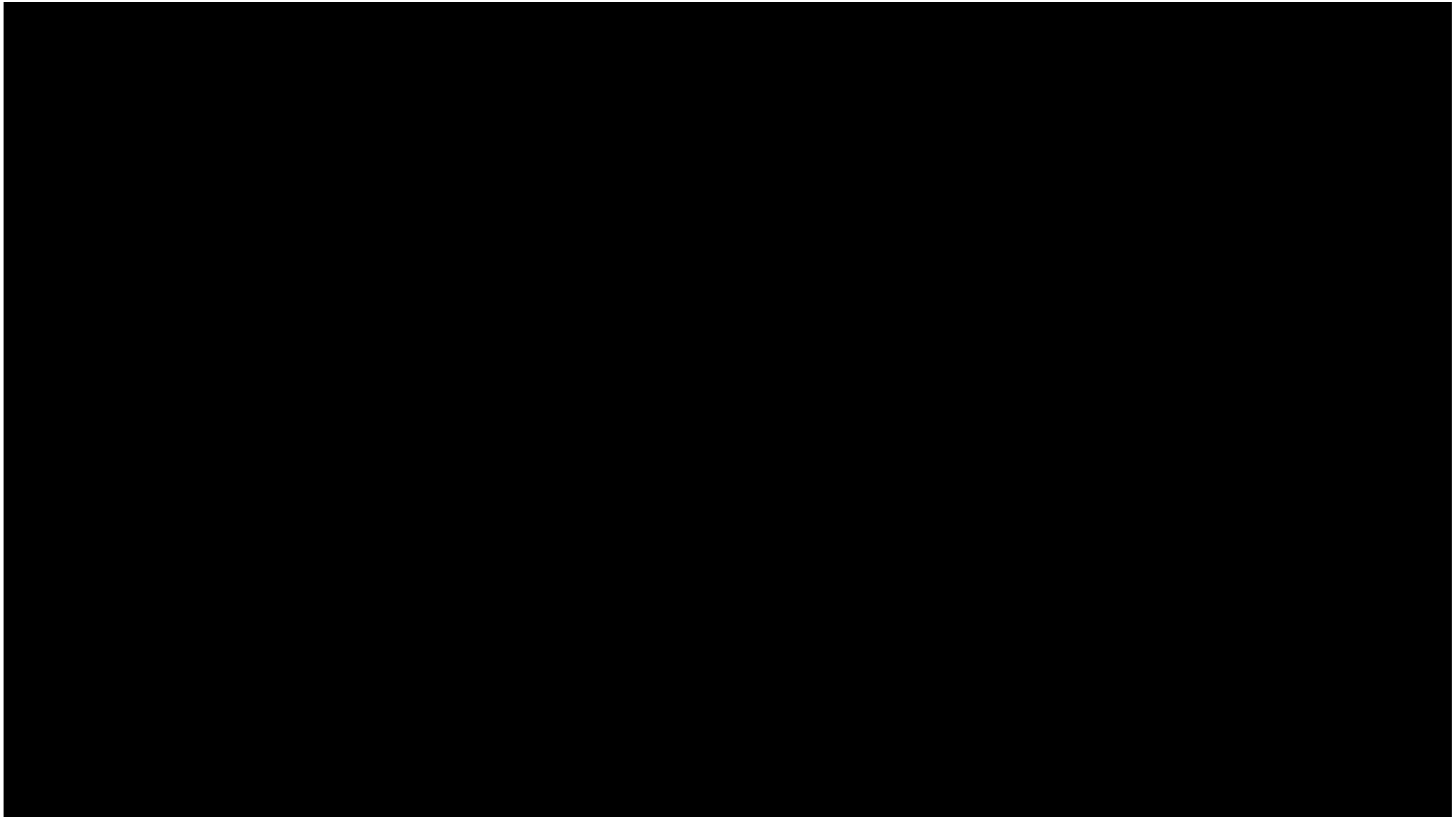


The basic scheme of Robotics



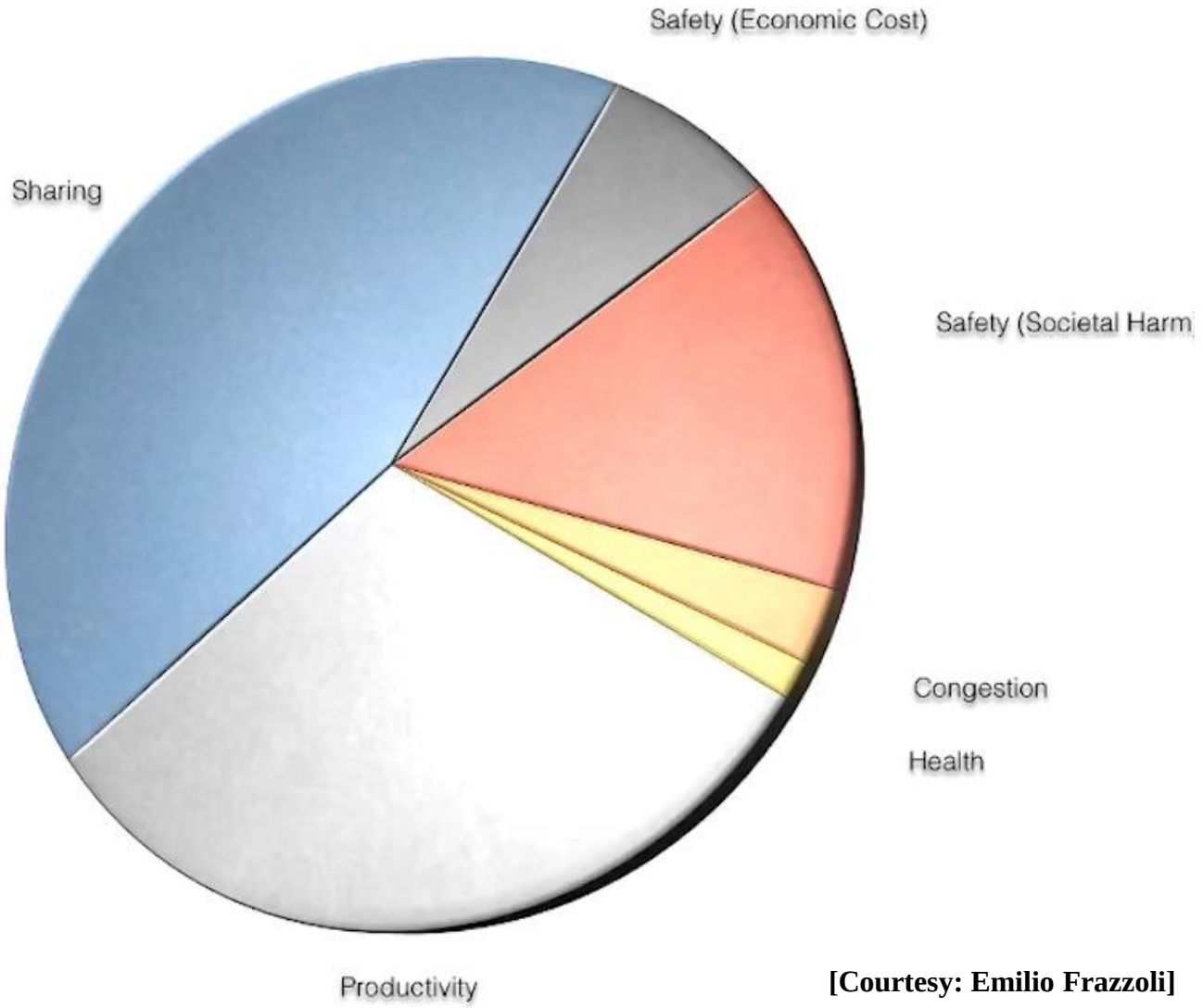
Path planning in the future

- ✓ V2V and V2X connectivity
- ✓ Real-time traffic information
- ✓ Cars "declare" their plans e.g., in a crossroad



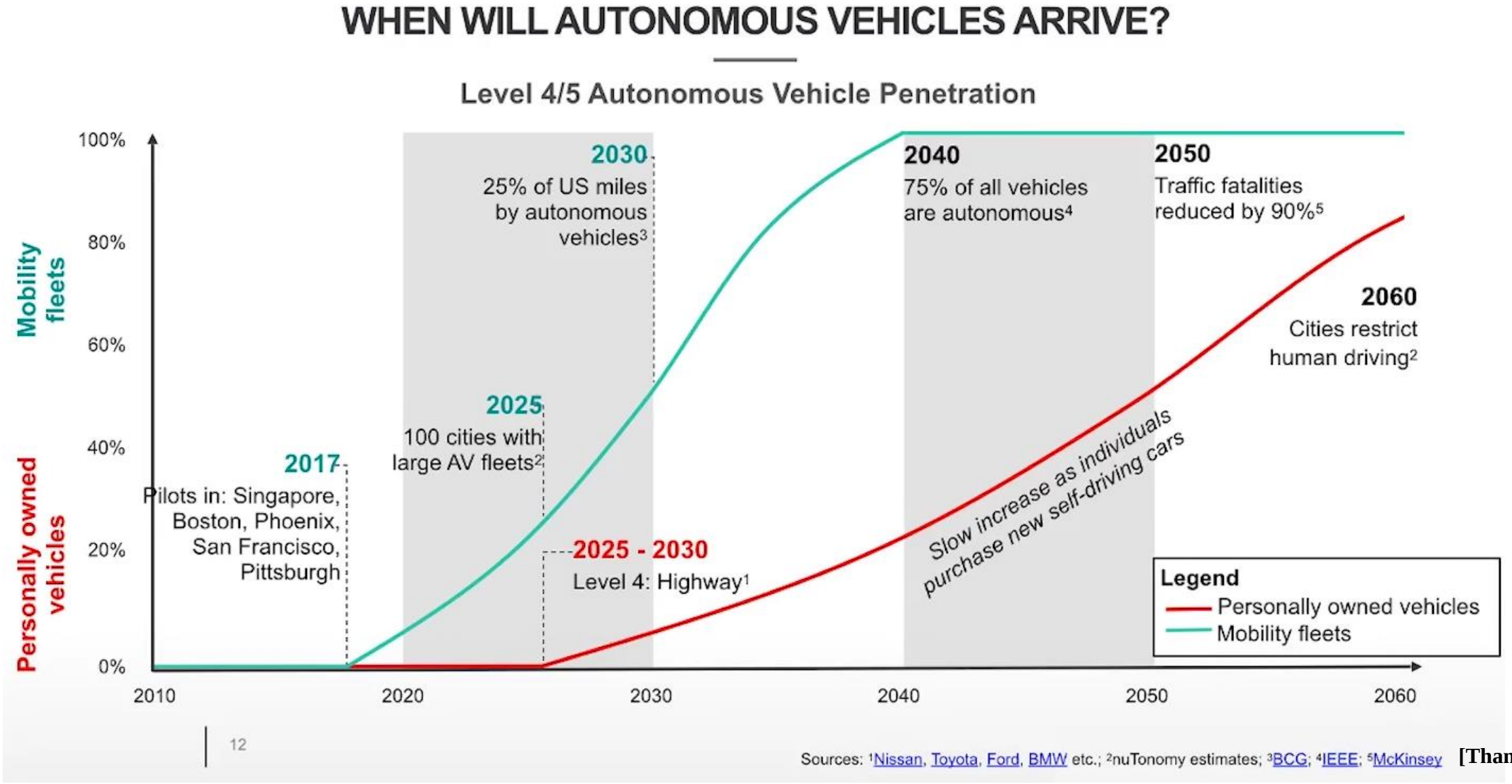
A financial perspective on US mobility

- Safety:
  - "Cost of a statistical life": $9.1M
  - 2014 NHTSA report:
    - Economic cost of road accidents: ~ $277B/year.
    - Societal harm of road accidents: ~ $594B/year
- Cost of congestion:
  - Texas Transportation Institute, 2012: ~ $100B/year
- Health costs of congestion:
  - Harvard School of Public Health, 2010: ~ $50B/year
- Increased productivity/leisure:
  - Estimate $1.2T/year
- Car sharing:
  - Assuming a "sharing factor" of 4, estimate $1.8T/year of benefits to individuals.
  - Other studies [Burns et al., '13, Fagnant, Kockelman '14] suggest higher sharing factors, up to ~10.

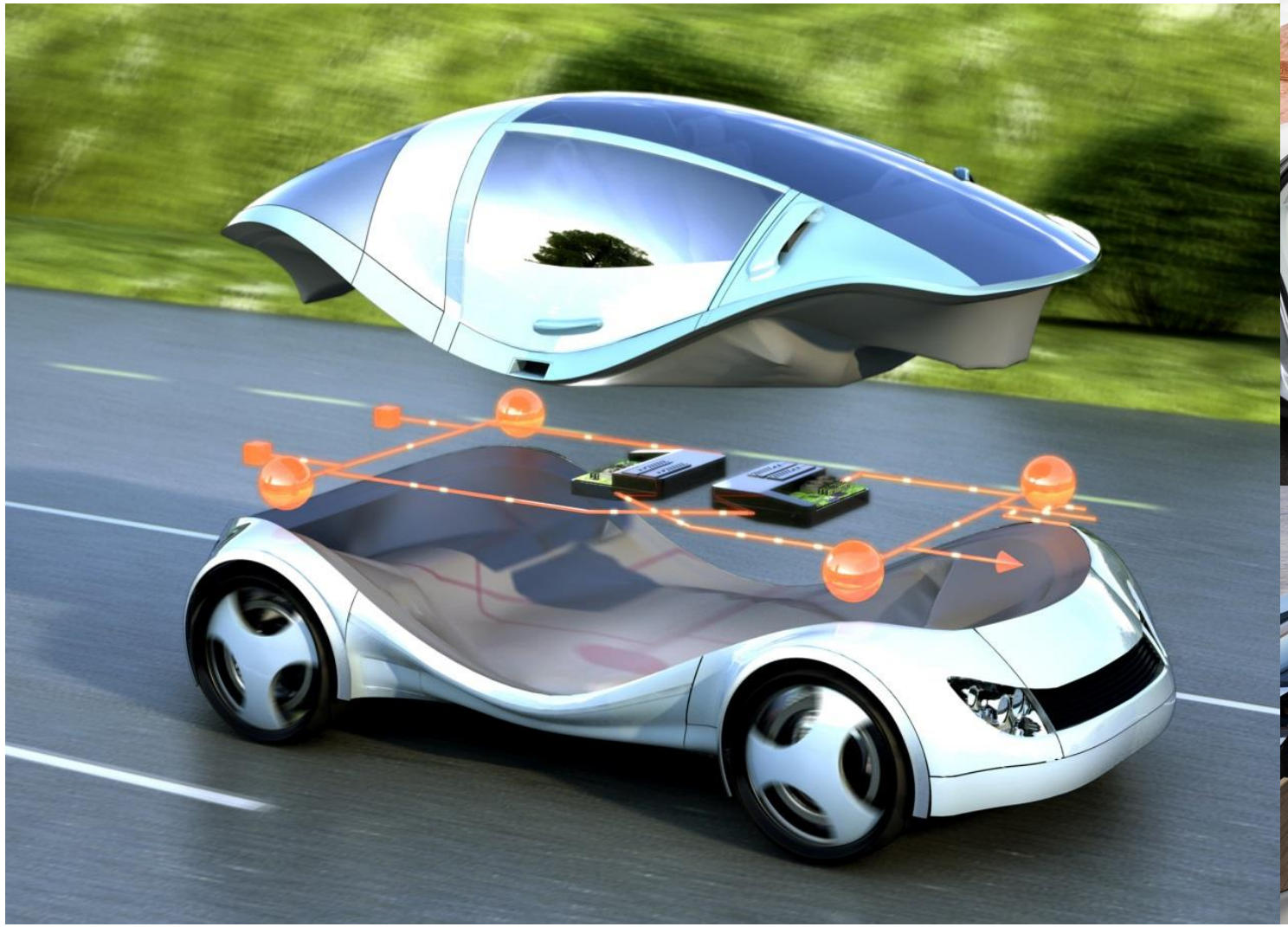


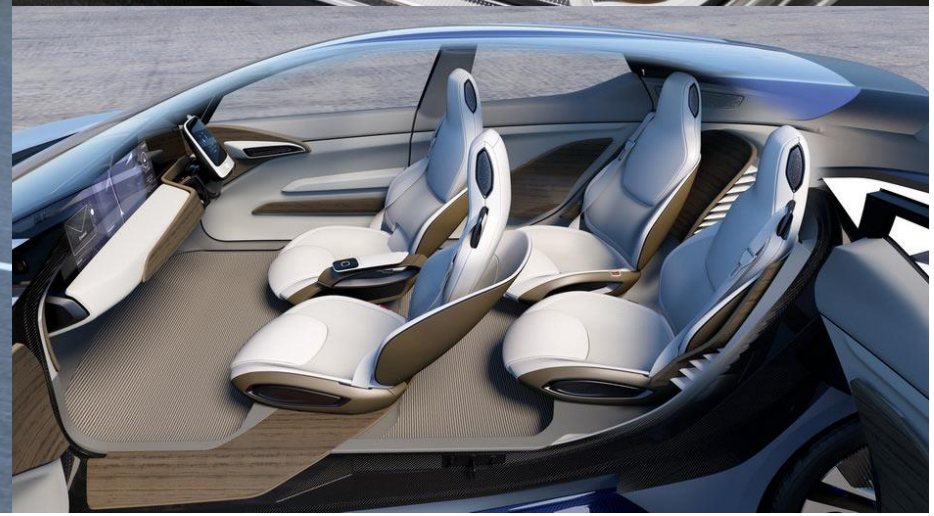
[Courtesy: Emilio Frazzoli]

When?



[Thanks Emilio Frazzoli]



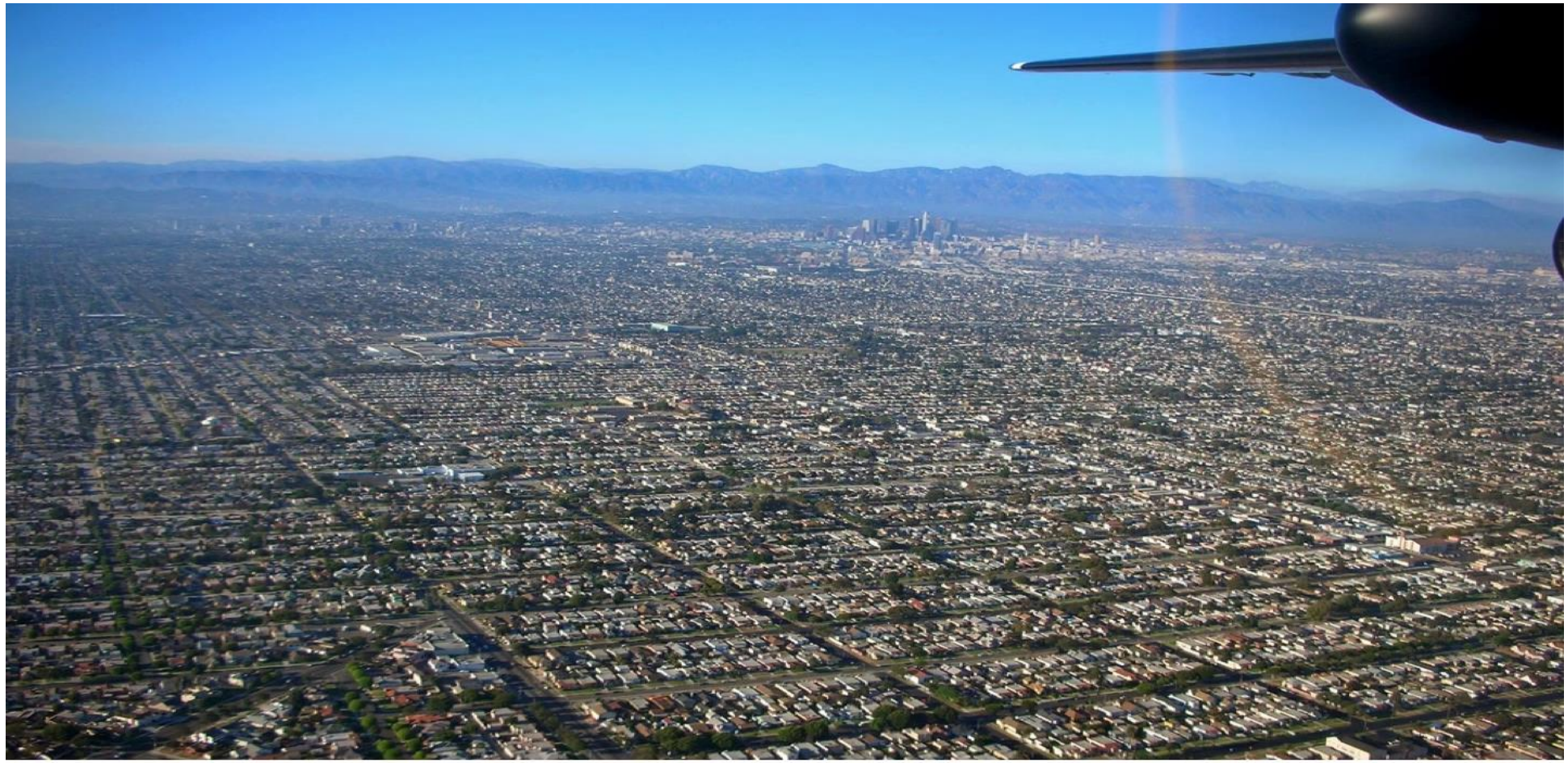


The car of the future will be the most powerful computer you will ever own

Fitting cities with cars

- Fitting pre-automobile cities with highways in mid 20th century:
  The Boston Central Artery under construction.

The Sprawl



Los Angeles

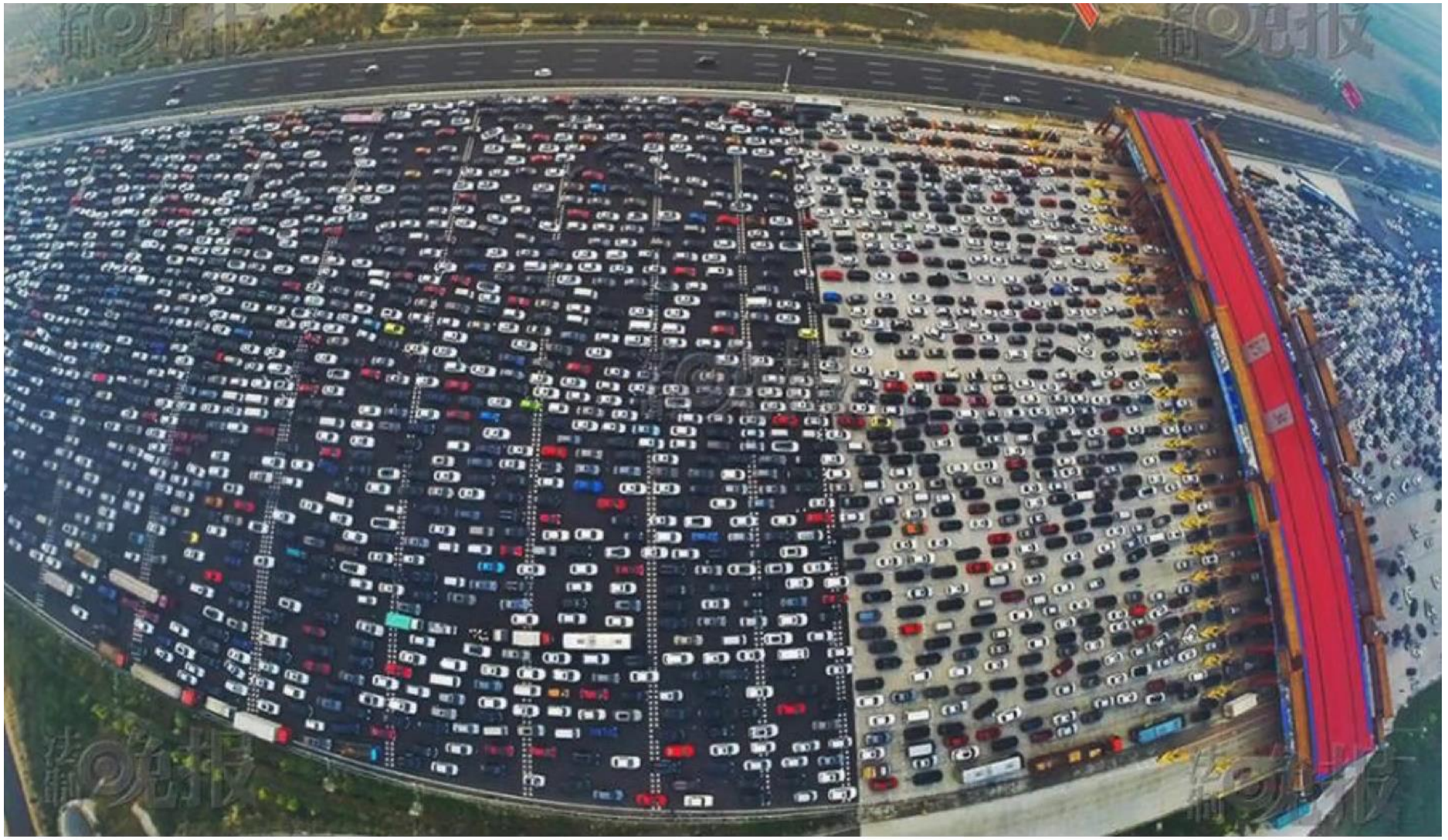
Sprawl: The mark that the affordable car left.

The Sprawl

Mexico City

Sprawl: The mark that the affordable car left.

The Sprawl



- Congestion: The 100-mile traffic in China that lasted 3 days

Car (size/weight) growth

The average weight of a passanger car is
25x the average weight of its passangers.

- Rapid increase in vehicle speed and vehicle weight in the late 20th century.

Car (size/weight) growth

The size of an average car is
10x the average size of its passengers sitting!

- Rapid increase in vehicle speed and vehicle weight in the late 20th century.

Parking lots and cities

In the United States, the automobile consumes close to 50% of the land area in cities.

In LA, this figure approaches two thirds!

Where would you like to live?

HiPeRT Lab
High-Performance Real-Time Lab

UNIVERSITAS STUDIORUM MUTINENSIS ET REGIENSIS
1175

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Thank you!

Marko Bertogna
marko.bertogna@unimore.it

http://hipert.unimore.it

MASA

Modena automotive smart area

The World is a Small City

MASERATI

UNIVERSITAS STUDIORUM MUTINENSIS ET REGIENSIS 1175

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Comune di Modena

Endorsed by

Ministero delle Infrastrutture e dei Trasporti

RegioneEmilia-Romagna

FONDAZIONE Cassa di Risparmio di Modena

Partners

AD CONSULTING

DANISI ENGINEERING

Addfor

ALTRAN

AVL

AXIS COMMUNICATIONS

eNERGICA

GENERALI

Automobile Club Modena

here

Hewlett Packard Enterprise

LIFETOUCH

MSC Software

nebbiolotechnologies
fog computing pioneers

AUTODROMO di MODENA
Centro Guida Sicura

NEXT2U
MACHINE SENSING EMOTIONS

OCTO

OMOOVE

RE:Lab

WIND

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE

DEMOCENTER

EU project CLASS:

Edge **Cl**oud Computation: **A** Highly Distributed **S**oftware Architecture for Big Data Analytic**S**

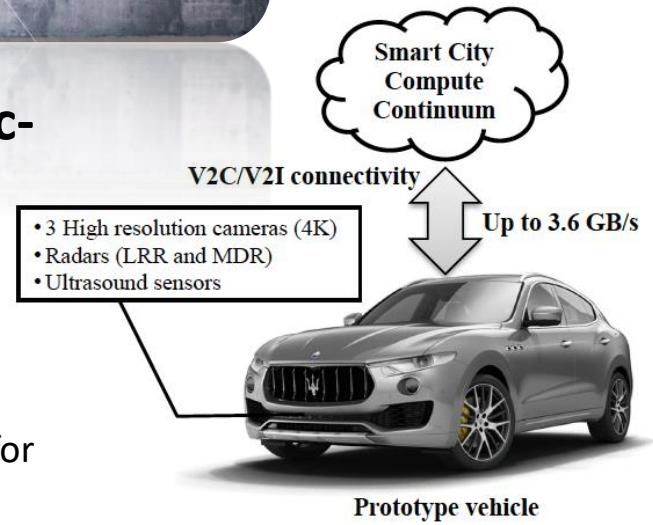
Funded by H2020-RIA ICT-16-2017 GA n°780622

Duration: 36 month (2018-2020)
Budget: 3.900.803
European Funding: 100%

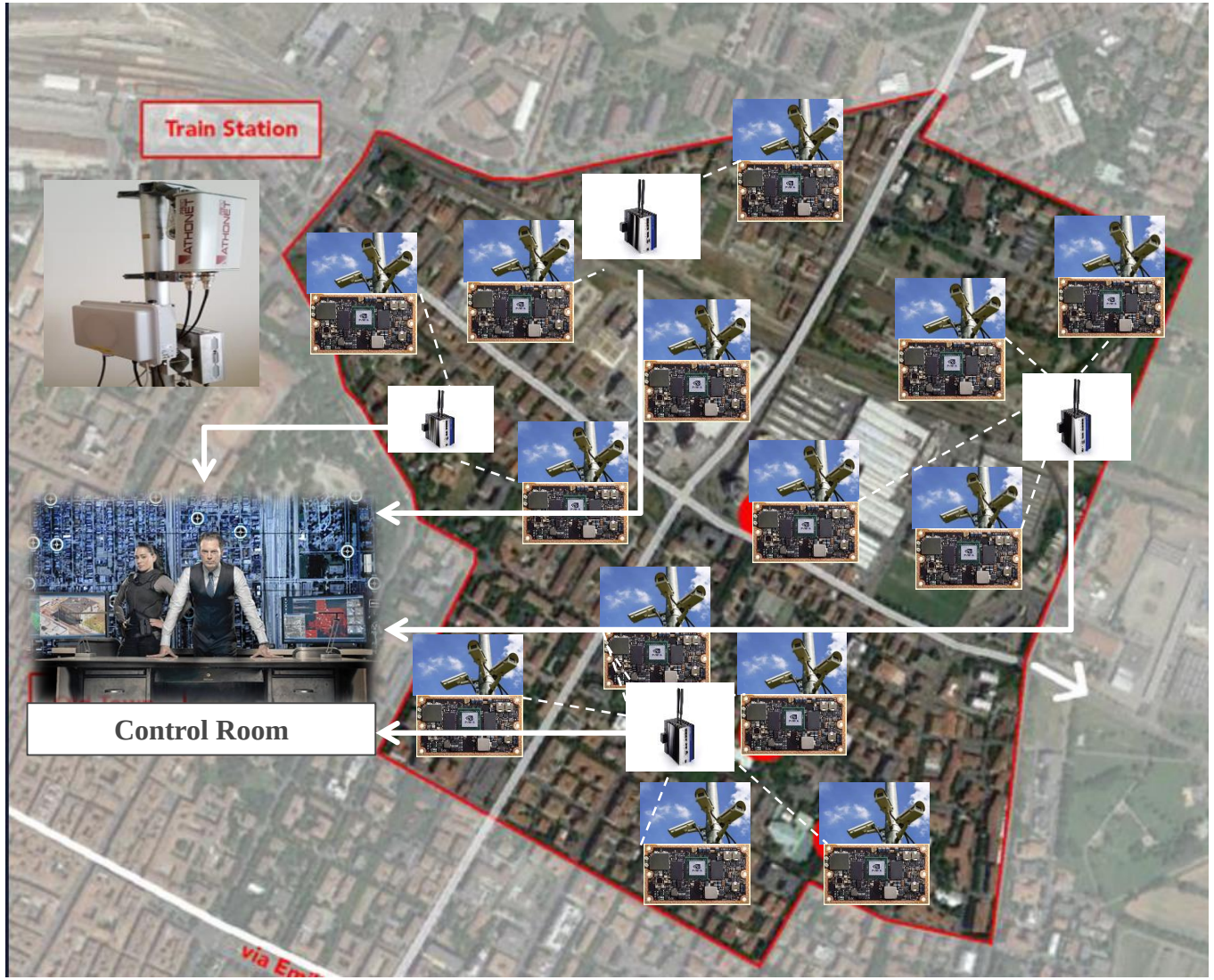
Fog computing infrastructure for Urban Autonomous driving: a public-private partnership within Modena Automotive Smart Area (MASA)

- **Accurate awareness of road users and obstacles in real-time**
- **Distributed traffic monitoring and enforcement in metropolitan areas**
- **Enabling technology for advanced AD applications in urban settings**

  V2I obstacle detection, Coordinated intersection crossing, Dynamic traffic signalling, Green routes for public vehicles, Smart parking: free lot detection and valet parking



Modena Automotive Smart Area (MASA)



- Hundreds of smart cameras installed

- Cameras are locally connected to a high-performance embedded board (a.k.a. Fog node)
- Each Fog node elaborates video streams detecting road users in real-time
- Elaborated information is sent in V2I to vehicles for enhanced perception to L3/L4 autonomous driving
- Fog nodes are connected to servers receiving data at block level (a.k.a. cluster nodes)

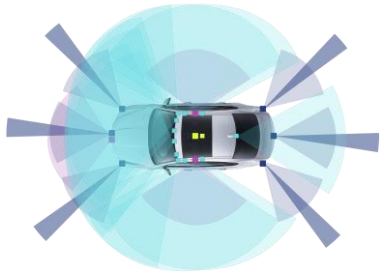
- Cluster nodes are fiber connected to main control center


Urban Area
Palamadiba
Coop Canaletto
Parco XXII Aprile
Piazza Darsena
Via Nonantolana
Via Nonantolana
Via Nonantolana
Trattoria Via Ferrari
Google

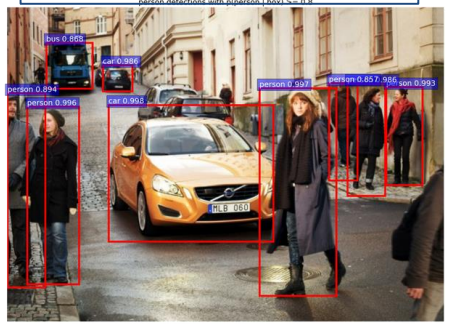
Real-time Urban Awareness

Infrastructure sensors

In-vehicle sensors



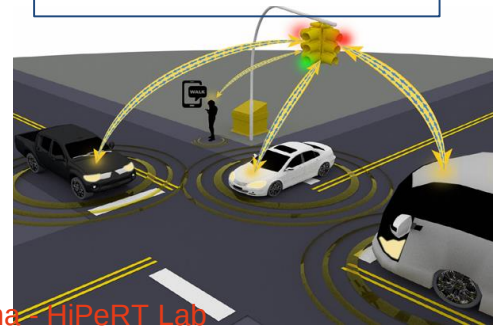
Real-time detection



Low-latency V2X communication

Autonomous vehicles

Traffic enforcement



Public authorities

Data analytics

MATSim on MASA

- ✓ 900 Agents, represented as “independent traffic flows”
- ✓ Each agent has its own routine and behavior
- ✓ One way streets, traffic lights, yields, parking spaces as in the MASA
- ✓ Contingencies:
  - Accidents
  - Misbehaving drivers
  - Emergency vehicles

MASA Real-Time Smart Cameras

MIND city

RGBW LED FOR CITIZEN INFO

AIR SENSORS
co2, pollution,
temperature, humidity

CARRIER
3 wifi network cards
rj45, Dali, 4g

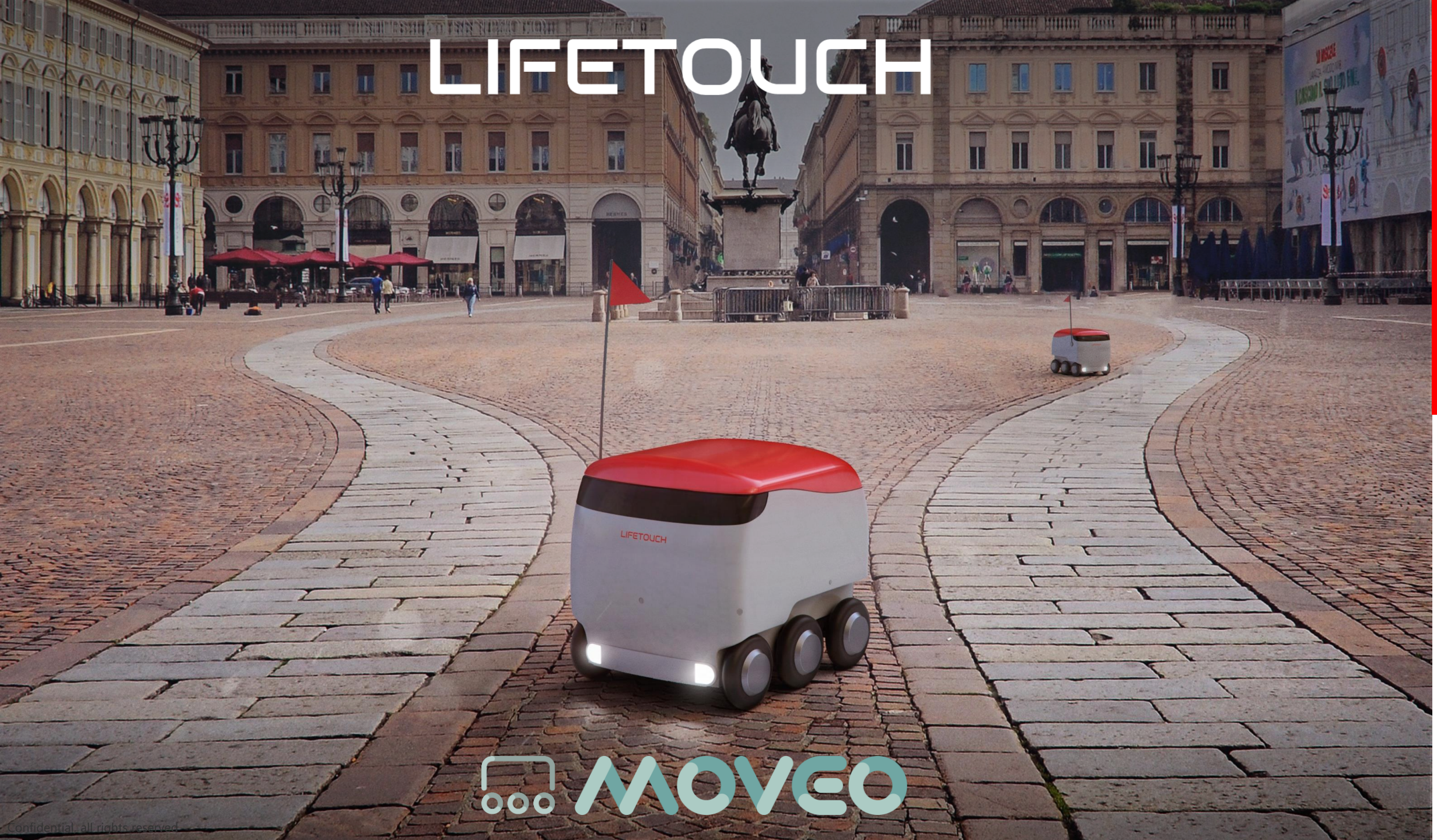
NVIDIA TX2 SOM

2 HD CAMERA 140° FOV

Example from yesterday's feed

Not only cars..

LIFETOUCH



MOVEO

LIFETOUCH
MOVEO

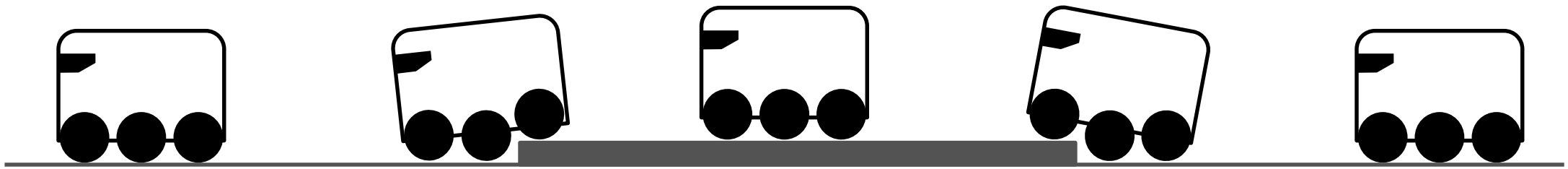
LIFETOUCH MOVEO: Characteristics

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

LIFETOUCH

Control Unit:	**NVIDIA Jetson Xavier**
Chassis:	**6 motor wheels** (independent)
	able to climb over curbs
Speed:	up to **6 km/h** in pedestrian areas
	up to **20 km/h** in bike lane
Range:	> 20 km
Load:	Max Volume **50x50x45 cm**
	Max load **50 kg**
Autonomous driving:	localization and mapping, object detection, obstacle avoidance, human overtaking in case of issues
Connectivity:	**Smart city data, destination/route request, Smart buildings systems**

MOVEO

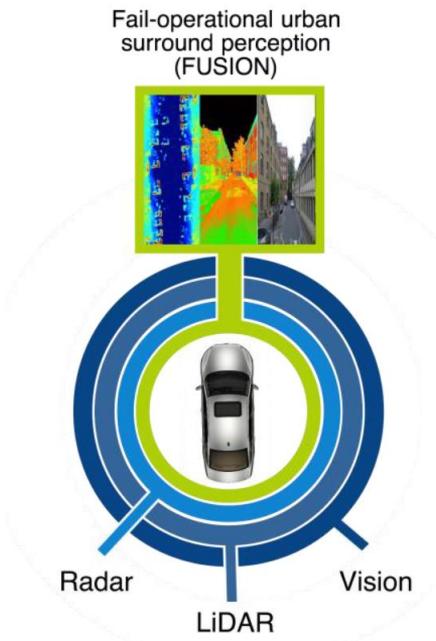


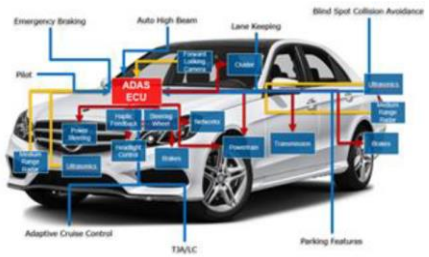
PRYSTINE

Programmable Systems for Intelligence in Automobiles

"Fail-operational Urban Surround perceptION (FUSION) based on robust sensor fusion and control functions to enable safe automated driving in urban and rural environments."

- ✓ Dependable embedded control by co-integration of signal processing and AI approaches for FUSION
- ✓ Electrical/electronic (E/E) architecture for automated vehicles
- ✓ ECSEL Joint undertake (60 international partners)





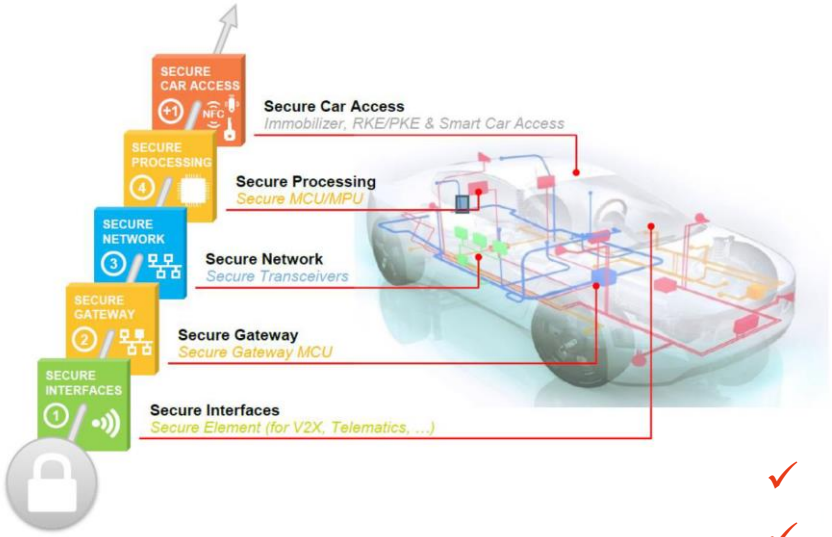
HiPeRT role:

- Develop next-gen HW/SW model architecture to integrate control theory and signal processing with AI models into AD embedded intelligent agents;
- Develop fail-operational robust sensor-fusion and decision-making models (embedded intelligent agents);
- Set up a demonstrator of a passenger vehicle integrating FUSION stack
- Develop a “co-driver” model to study feasibility of shared control between the driver and the AI agent;
- Leader of WP5 for system integration to build a working prototype of the FUSION stack for each SC

SECREDAS

Cyber Security for Cross Domain Reliable Dependable Automated Systems

"Multi-domain architecting methodologies, reference architectures & components for autonomous systems, combining high security and privacy protection while preserving functional-safety and operational performance"



- ✓ Cross-domain **cybersecurity** and **safety** technologies for automated systems
- ✓ Next generation **secured sensing and processing components** to comply with Safety, Security and Privacy challenges
- ✓ ECSEL Joint undertake (70+ partners from 15 countries)

HiPeRT role:

- ✓ Secured and privacy-protecting external communication technologies (V2X, 5G)
- ✓ Secured in-vehicle network technology, connected to a central gateway/VCU