10th Planning, Perception and Navigation for Intelligent Vehicles (PPNIV´18)

INTEGRATION OF COOPERATIVE SERVICES WITH AUTONOMOUS DRIVING

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Madrid, October, 1st

MADRID 2018 IROS

POLITÉCNICA "Ingeniamos el futuro"

INSIA

10TH PLANNING, PERCEPTION AND NAVIGATION FOR INTELLIGENT VEHICLES (PPNIV´18)

Integration of Cooperative Services (C-ITS) with Autonomous Driving

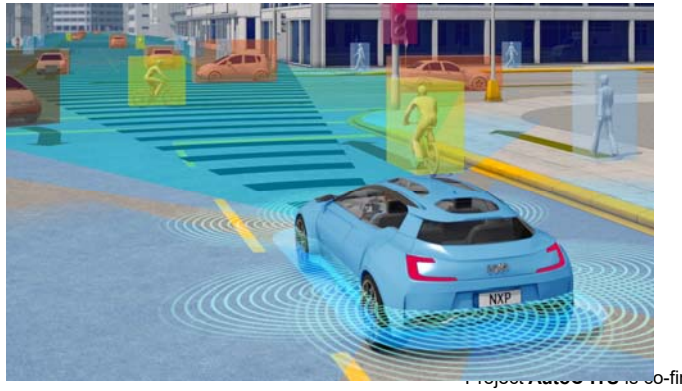
1. CONTEXT OF COOPERATIVE CONNECTED AND AUTOMATED MOBILITY

Connectivity vs Automation

Autonomous vehicles

An autonomous vehicle is a vehicle with the capacity of performing the dynamic driving task. This task includes all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation:

1. Lateral vehicle motion control via steering (operational);
2. Longitudinal vehicle motion control via acceleration and deceleration (operational);
3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical)
4. Object and event response execution (operational and tactical);
5. Maneuver planning (tactical); and
6. Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).



Connectivity vs Automation

Levels of Driving Automation

SAE J3016. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

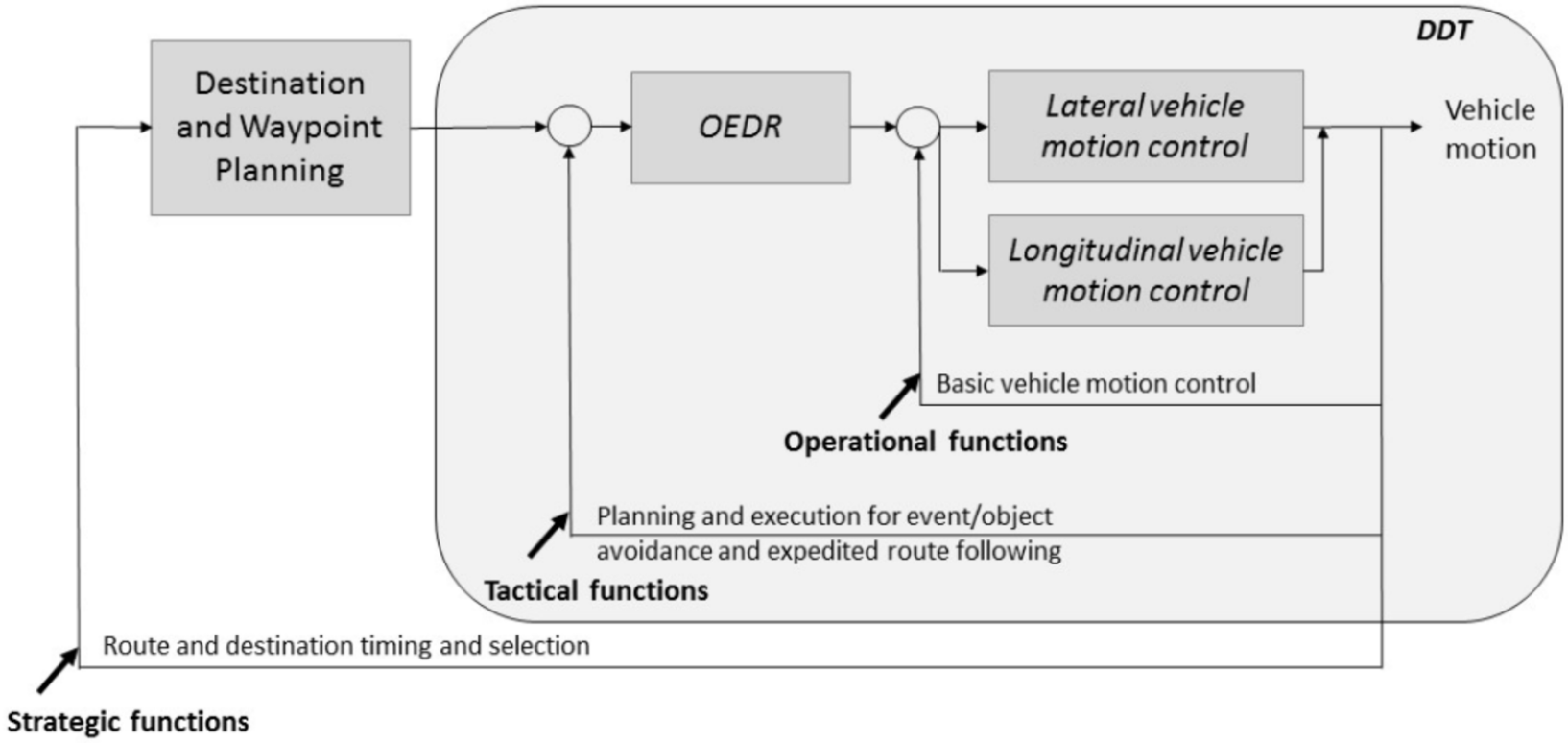
Full Automation

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Connectivity vs Automation

Architecture of an autonomous vehicle

Schematic view of driving task showing the dynamic driving task (DDT)



Connectivity vs Automation

Examples of autonomous vehicles

Volvo

Connectivity vs Automation

Examples of autonomous vehicles

Tesla

Connectivity vs Automation

Examples of autonomous vehicles

Google (Waymo)

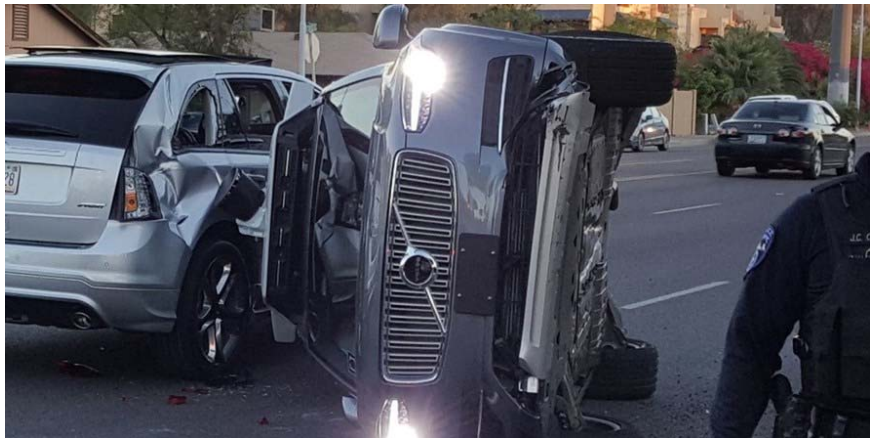
Connectivity vs Automation

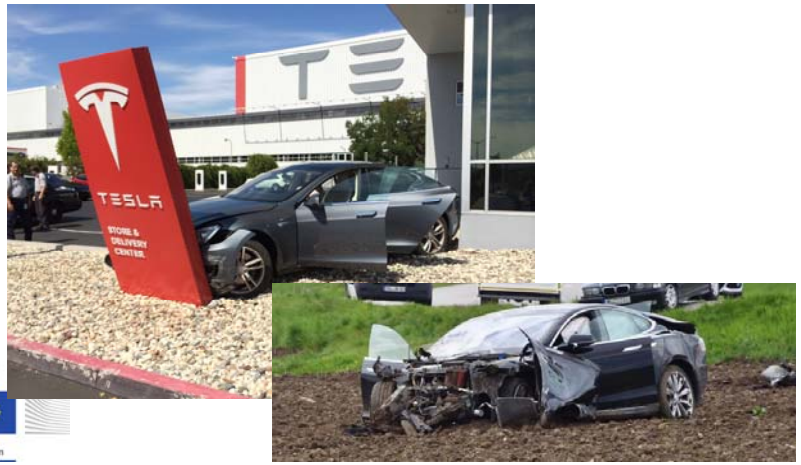
Examples of autonomous vehicles

Uber

Connectivity vs Automation

Examples of autonomous vehicles





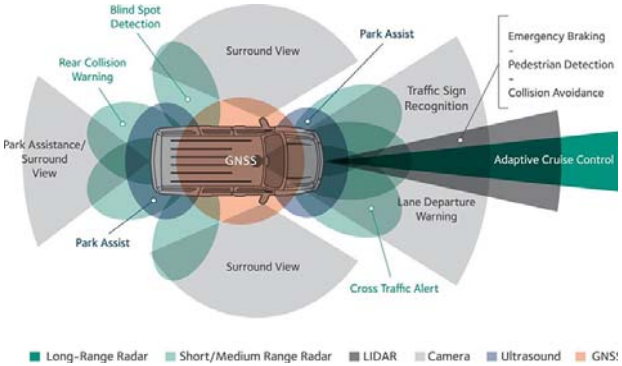
Connectivity vs Automation

Conclusions of the current state of play in autonomous vehicles field

1. There are certain circumstances in which an isolated autonomous vehicle is incapable of responding, limiting itself to the information provided by its own sensors and its driving systems, independently of the:
   - Accuracy of its perception.
   - Intelligence of its auto-pilot.

2. There are certain circumstances that could be solved by the perception and the intelligent pilots but, due the random casuistic, the effort to success in the 100% of the situations is extremely high.

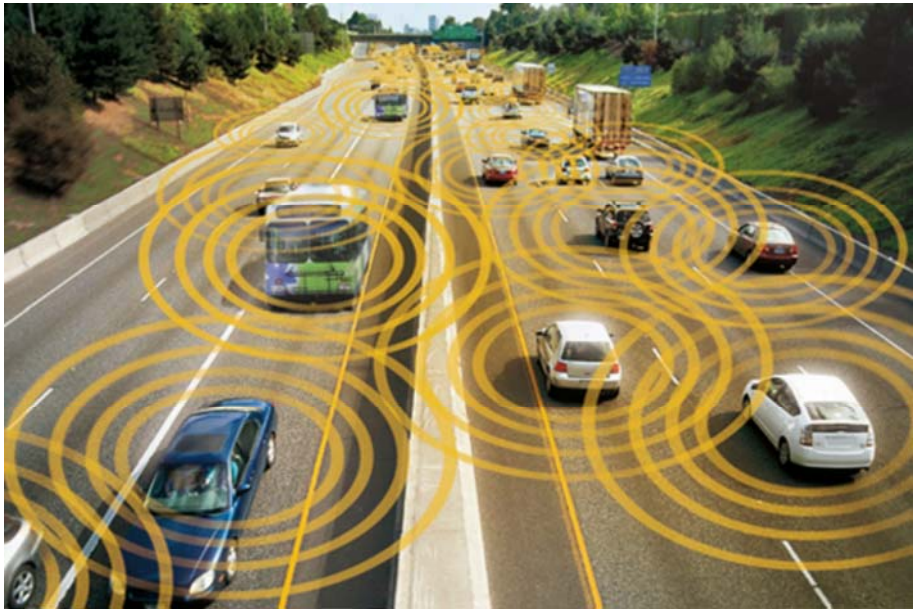
3. There are certain circumstances of medium complexity that increases the workload of the autonomous driving systems and the number of sensors



Connectivity vs Automation

Connected Vehicle

- Connected vehicles are vehicles that use any of a number of different communication technologies to communicate with the driver, other cars on the, roadside infrastructure and the “Cloud”.
- This technology can be used to not only improve vehicle safety, but also to improve vehicle efficiency and commute times.



Connectivity vs Automation

V2X Communications

- Wireless communications have been identified as key technologies for increasing road safety and transportation efficiency.

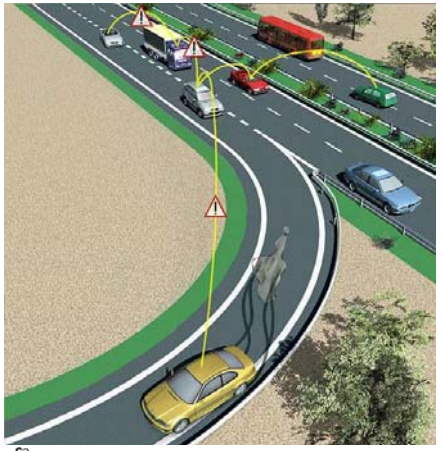
Connectivity vs Automation

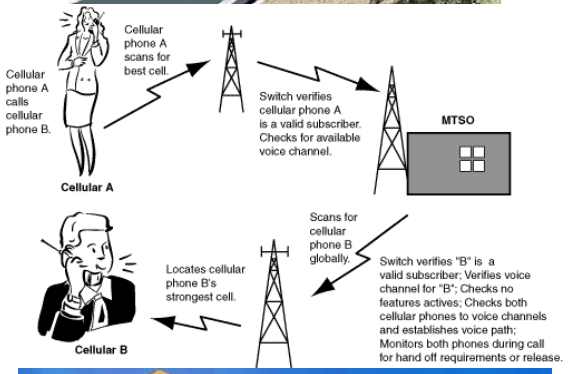
V2X Technology and standardization

Hybrid

- **Short range Communications, based on IEEE 802.11p /ETSI ITS-G5.**
  - Low latencies.
  - Multihop.
  - Geo-Broadcast.
  - No service provider. 5.9 GHz band.
  - Bandwidth: 27 Mbps.
- **Cellular Telephony**
  - Latencies in function of the network load.
  - Network cell schema.
  - Service provider: 3/4 G.
  - Bandwidth: max. 1 Gbps

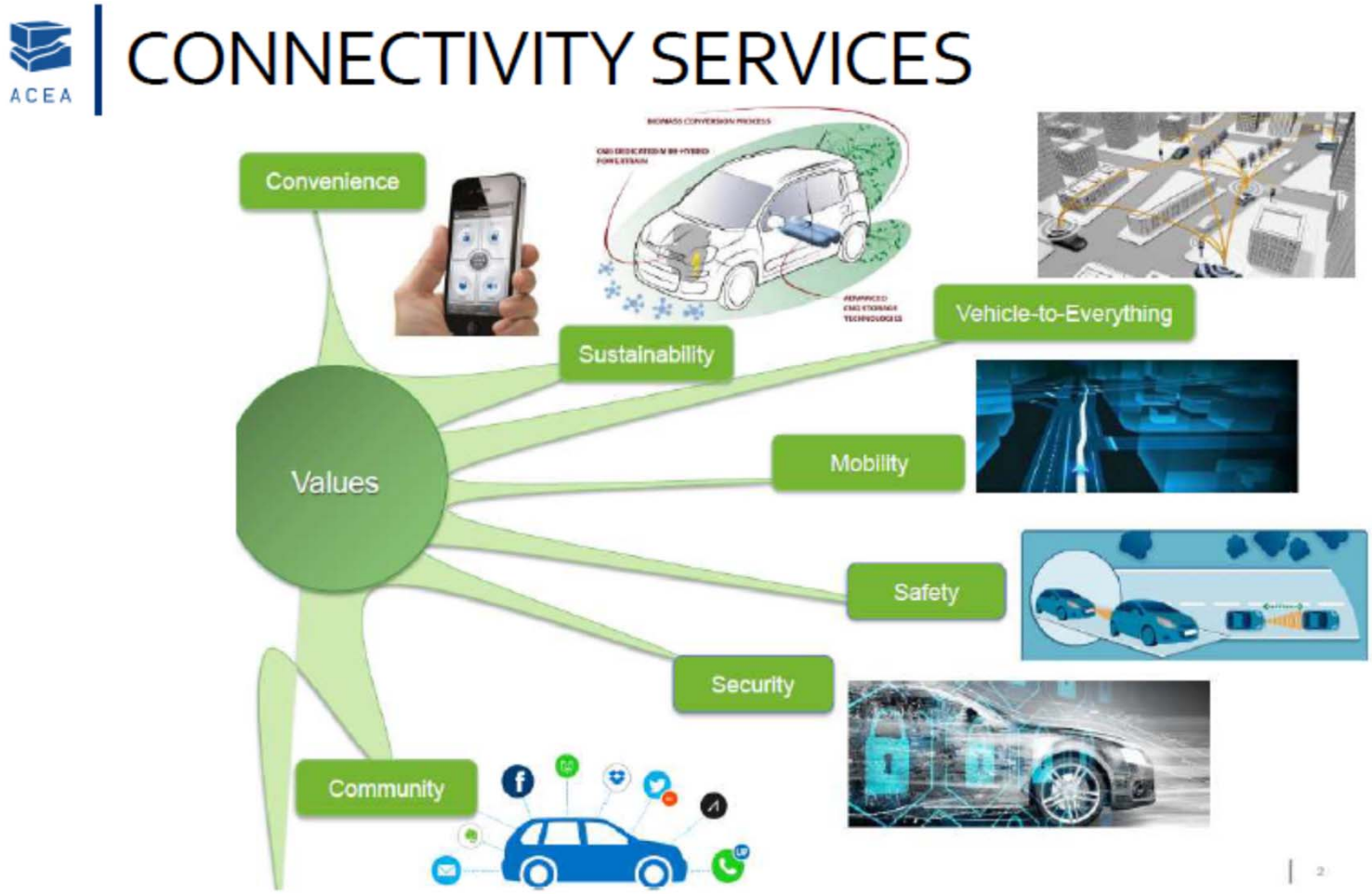
- **5G**
  - Low Latencies.
  - Multihop (Cellular-V2X).
  - Broadcast (Cellular-V2X).
  - Network cell schema; local cell services enabled.
  - Service provider: 5 G.
  - Bandwidth: ∞ Gbps





Connectivity vs Automation

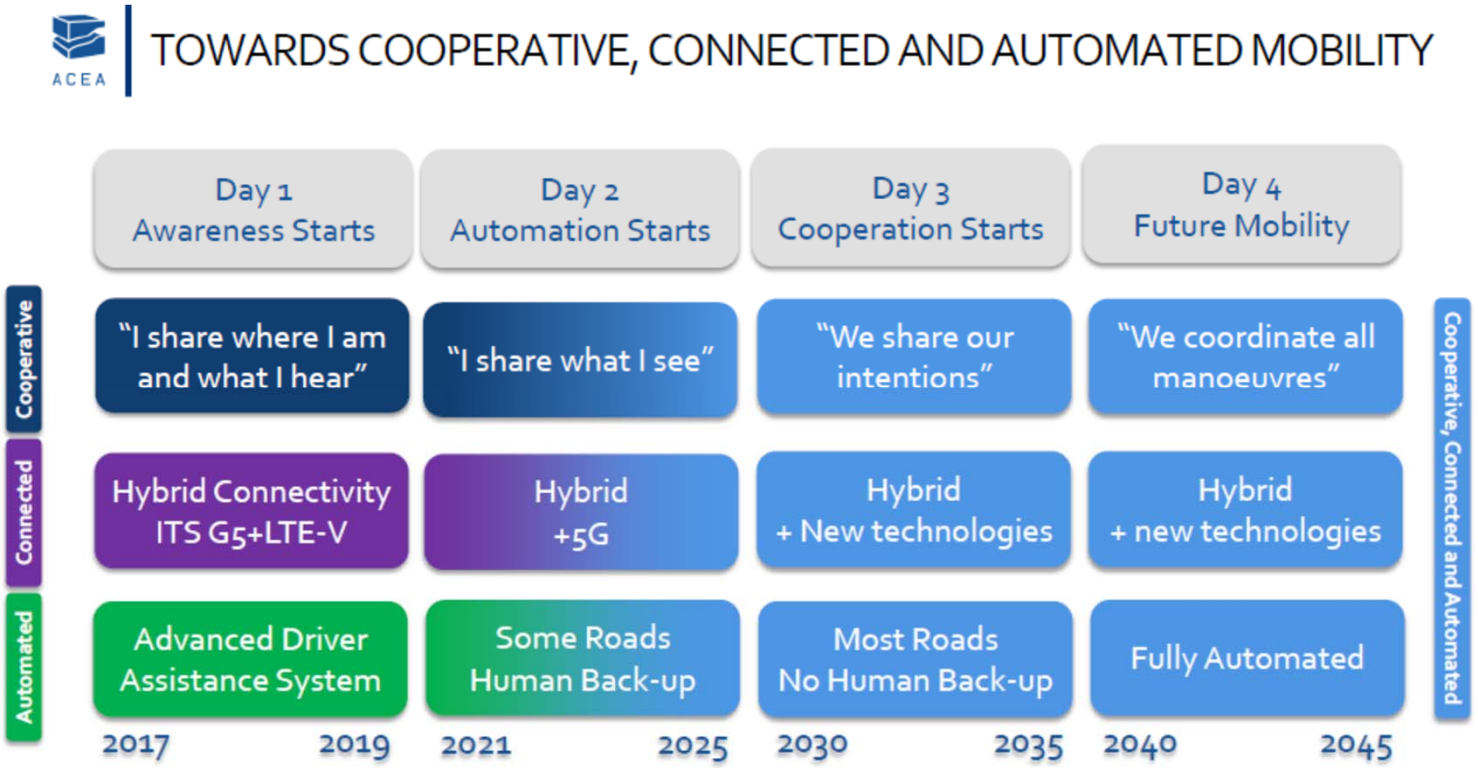
V2X Services



Connectivity vs Automation

V2X Services → Cooperative Systems (C-ITS)

- **European C-ITS Platform**
- Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles, with traffic signals and roadside infrastructure as well as with other road users.



Connectivity vs Automation

V2X Services → C-ITS Day-1, 1.5

These services were chosen on their importance from policy perspectives or potential to answer major societal needs, such as increasing road safety. A further split was introduced based on technical readiness in the short-term (Day 1 vs Day 1.5).

#	Day 1 Services		
1	Emergency electronic brake light	V2V	Safety
2	Emergency vehicle approaching	V2V	Safety
3	Slow or stationary vehicle(s)	V2V	Safety
4	Traffic jam ahead warning	V2V	Safety
5	Hazardous location notification	V2I	Motorway
6	Road works warning	V2I	Motorway
7	Weather conditions	V2I	Motorway
8	In-vehicle signage	V2I	Motorway
9	In-vehicle speed limits	V2I	Motorway
10	Probe vehicle data	V2I	Motorway
11	Shockwave damping	V2I	Motorway
12	GLOSA / Time To Green (TTG)	V2I	Urban
13	Signal violation/Intersection safety	V2I	Urban
14	Traffic signal priority request by designated vehicles	V2I	Urban

#	Day 1.5 Services		
1	Off street parking information	V2I	Parking
2	On street parking information and management	V2I	Parking
3	Park & Ride information	V2I	Parking
4	Information on AFV fuelling & charging stations	V2I	Smart Routing
5	Traffic information and smart routing	V2I	Smart Routing
6	Zone access control for urban areas	V2I	Smart Routing
7	Loading zone management	V2I	Freight
8	Vulnerable road user protection (pedestrians and cyclists)	V2X	VRU
9	Cooperative collision risk warning	V2V	Collision
10	Motorcycle approaching indication	V2V	Collision
11	Wrong way driving	V2I	Wrong Way

Connectivity vs Automation

Convergence between automation and connectivity

Connected

Communicates with other vehicles, nearby infrastructure and ITS backends

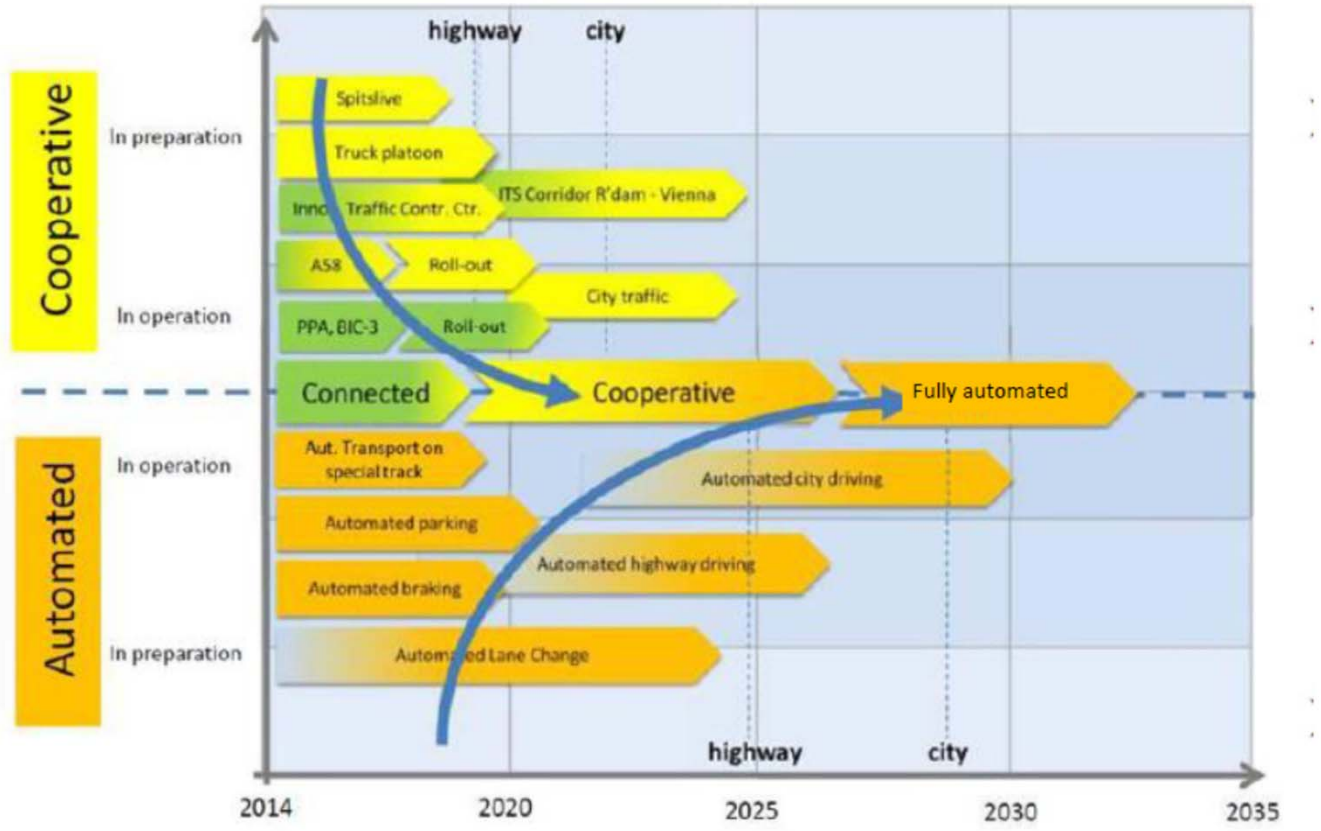
Connected and Autonomous Driving

Operates in isolation from other vehicles using internal sensors

Autonomous vehicles

Connectivity vs Automation

Convergence between automation and connectivity



Connectivity vs Automation

Steps towards Connected and Autonomous Driving

- It is not trivial.
- V2X communications are in continuous evolution.
- Standardization is a key element.
- The evolution of the V2X communications is in parallel with the evolution of autonomous vehicles, but with a shorter time for deployment.
- Direct link with the development and deployment of new generation communications technologies: 5G
- The first step is to take advantage of deployments and technologies made in the field of connected vehicles (C-ITS) to support V2X communications to autonomous vehicles.
- The real implementation of autonomous vehicles without connectivity is almost impossible in real deployments.
- V2X communications technologies are in development, although there are still many elements to solve.
- Cooperative systems can serve as catalysts for the deployment of autonomous and connected driving.
- Unification with the scope of the IOT → Cooperative, Connected and Autonomous Mobility (CCAM).

Connectivity vs Automation

Declaration of Amsterdam

- Declaration of Amsterdam
- 14 April 2016
- Signed by the transport ministers of all 28 EU member states

https://english.eu2016.nl/binaries/eu2016-en/documents/publications/2016/04/14/declaration-of-amsterdam/2016-04-08-declaration-of-amsterdam-final-format-3.pdf

Connectivity vs Automation

Declaration of Amsterdam

Highlights (objectives)

- to work towards a coherent European framework for the deployment of interoperable connected and automated driving, which should be available, if possible, by 2019;
- to bring together developments of connected and automated driving in order to reach their full potential to improve road safety, human health, traffic flows, and to reduce the environmental impact of road transport;
- to adopt a “learning by experience” approach, including, where possible, crossborder cooperation, sharing and expanding knowledge on connected and automated driving and to develop practical guidelines to ensure interoperability of systems and services;
- to support further innovation in connected and automated vehicle technologies to strengthen the global market position of European industry; and
- to ensure data protection and privacy.

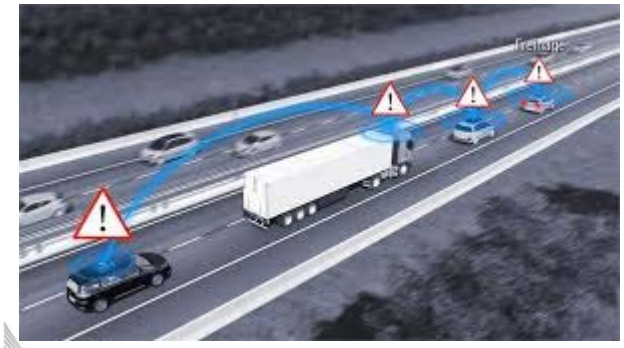
Connectivity vs Automation

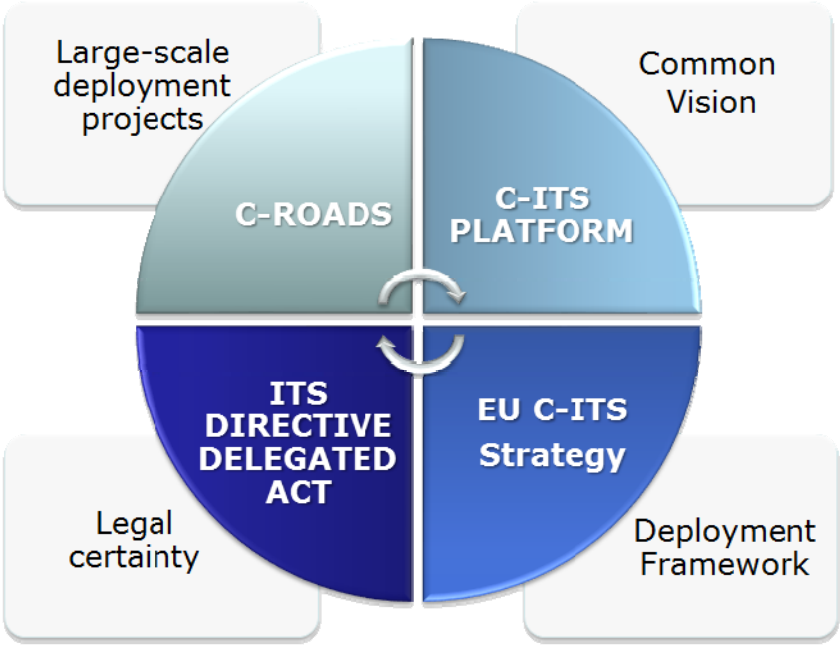
V2X European projects

The C-Roads Platform is a joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonization and interoperability.

C-ROADS → National Mirrors → C-ROADS SPAIN

AUTO C-ITS





2. EUROPEAN PROJECT AUTOCITS IN THE CONTEXT OF COOPERATIVE CONNECTED AND AUTOMATED MOBILITY

AUTOCITS - In a nutshell

*"AUTOCITS aims to **contribute to the deployment of C-ITS in Europe** and to boost the role of C-ITS as catalyst for the implementation of autonomous driving"*

C-ITS: Intelligent Transport Systems (ITS) where ITS stations (vehicles, roadside equipment, traffic control centers and personal devices) communicate and share information

CAD – Connected & Autonomous Driving take advantage of a variety of techniques to detect their surroundings and advanced control systems to interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage

Regulatory Framework

European Transport Network – Atlantic Corridor

AUTOCITS: Partners & Figures

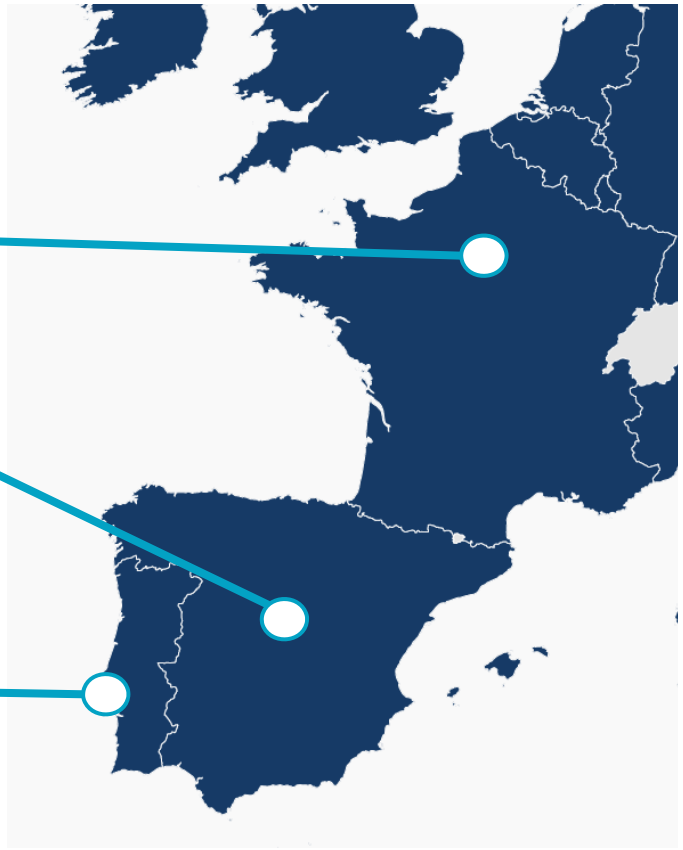
Programme: Connected Europe Facility
Starting date: 01-11-2016
Ending Date: 31-03-2019
Duration: 29 months

Call: CEF- 2015
Budget : 2,606,550 €
Coordinator: INDRA
Funding: 50%

Paris Pilot

Madrid Pilot

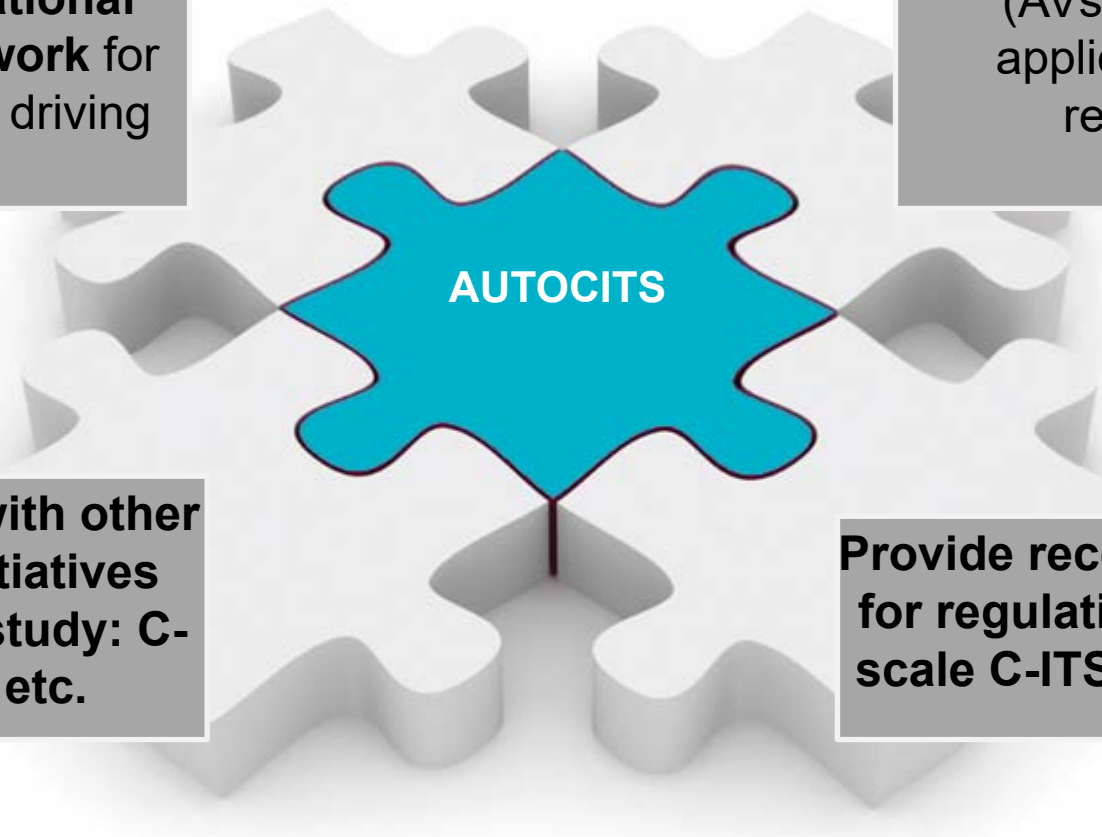
Lisbon Pilot



AUTOCITS - Objetives

Study on the current National, European and International legal framework for autonomous driving

Pilot C-ITS services for autonomous vehicles (AVs) under the applicable traffic regulation



Cooperate with other current initiatives during the study: C-Roads, etc.

Provide recommendations for regulations and large scale C-ITS deployments

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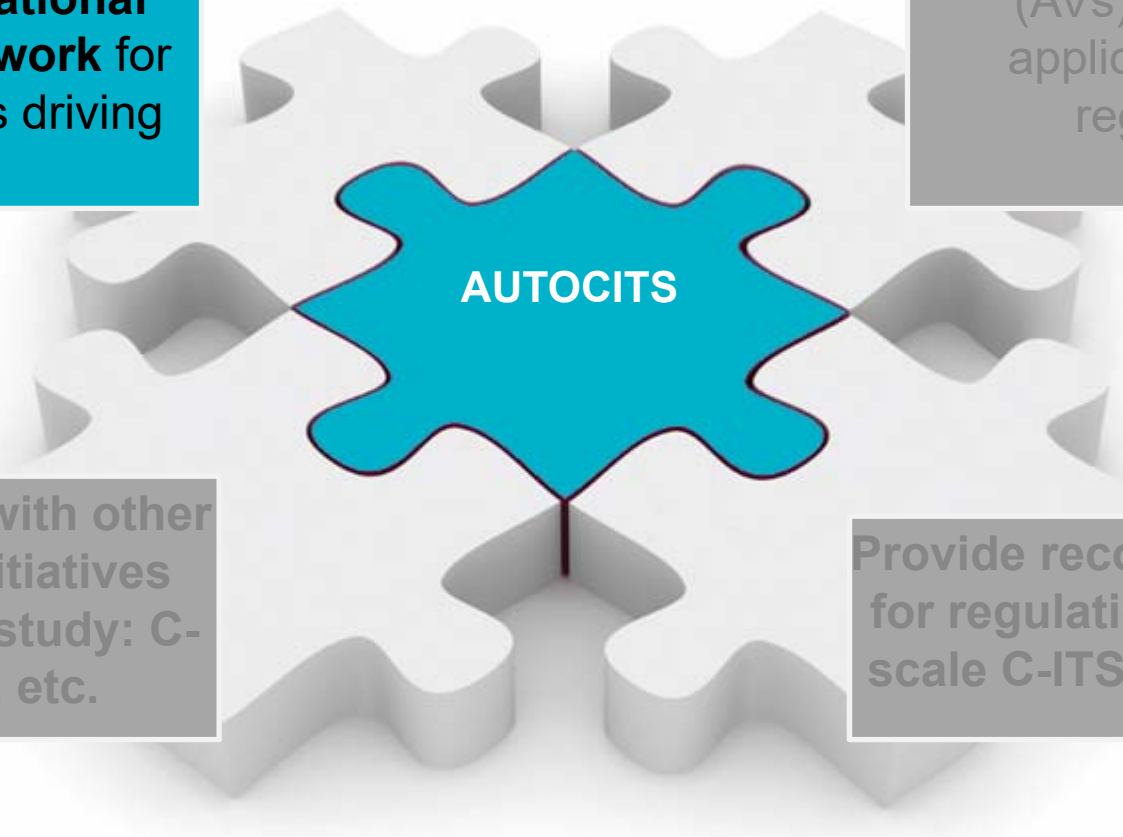

Cooperate with other current initiatives during the study: C-Roads, etc.

Provide recommendations for regulations and large scale C-ITS deployments

Regulation study in AUTOCITS (Study)

Study of the national and European regulatory frameworks for the deployment of the Autonomous Driving

United States of America, Japan, Singapore, South Korea , China, Australia, etc.

Making propositions and recommendations for regulation and legal framework

Some of the **aspects under study** are:

Alignment with Vienna Convention
Normative on driving
Testing Legislation
Vehicle certification (individual vehicles, mass production)
Laws to be modified
Changes on SAE 3-5 already initiated/foreseen

AUTOCITS - Objetives

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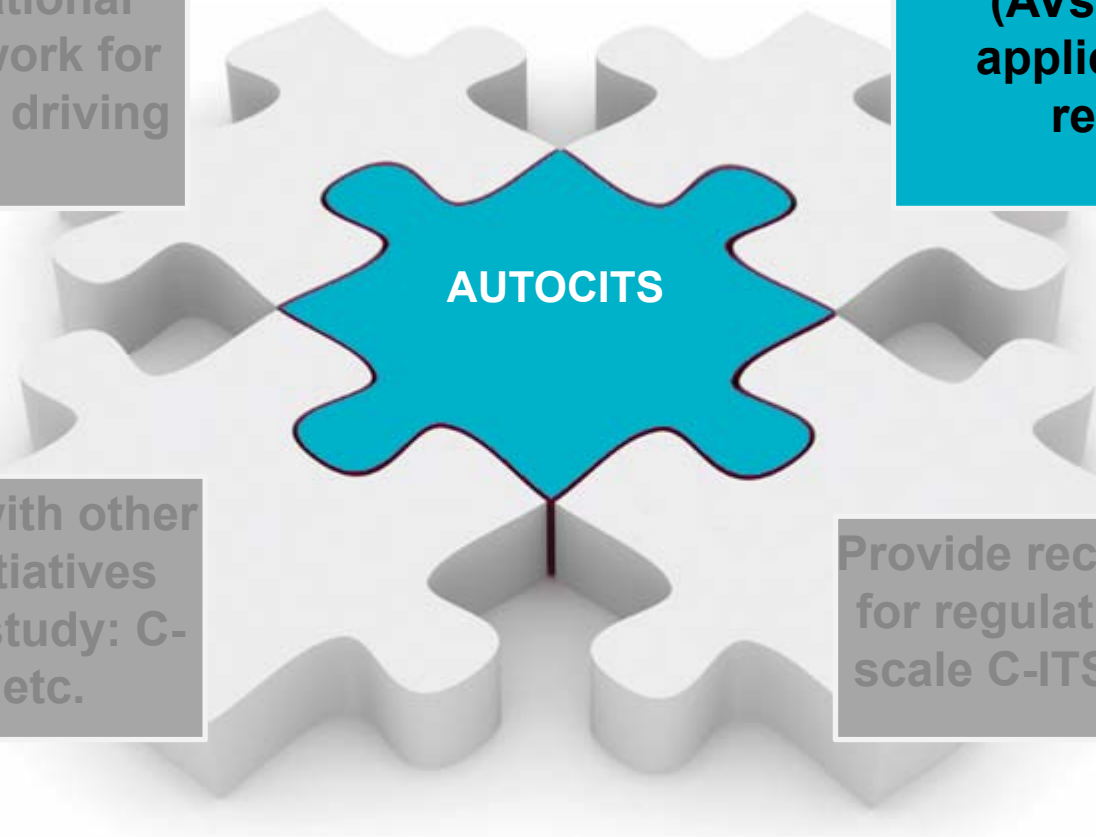

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Provide recommendations for regulations and large scale C-ITS deployments

AUTOCITS Pilots

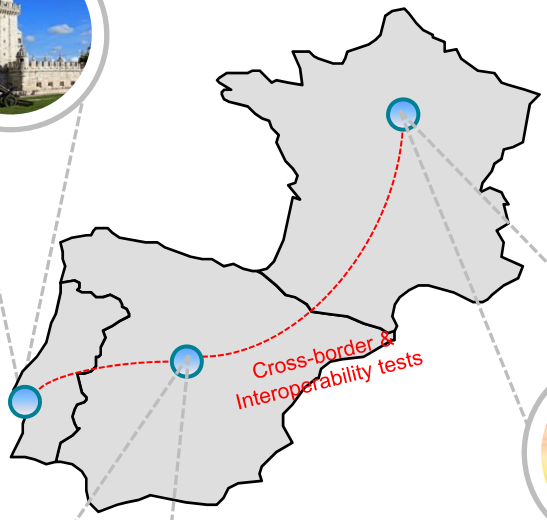
3 Pilots in the Atlantic Corridor

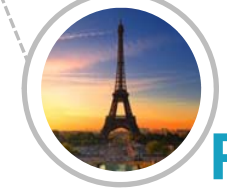
Location:
A9 – CREL Circular Regional Externa de Lisboa

Day 1 C-ITS Services:
- Slow or stationary vehicle & traffic ahead warning
- Weather conditions
- Other hazardous notifications

Test vehicles
1 autonomous vehicle
1 instrumented vehicle
1 autonomous shuttles

Lisbon





Paris

Location:
The highway A13

Day 1 C-ITS Service:
- Slow or stationary vehicle & traffic ahead warning
- Weather conditions
- Other Hazardous notifications

Test vehicles
4 connected vehicles
1 autonomous vehicle

Madrid

Location:
The HOV Lane located between the M30 and M40

Day 1 C-ITS Services:
- Slow or stationary vehicle & traffic ahead warning
- Road works warning
- Weather conditions

Test vehicles
4 instrumented and connected vehicles
2 autonomous vehicles

Pilot Overview - Spain

Road: A6 Autovía del Noroeste, stretch between M30 and M40, Reversible high occupancy lane
Length: 10 kms, **15 RSUs** have been installed

Traffic conditions

- More than 20.000 vehicles/day
- Close to traffic: controlled tests
- Open to traffic: private vehicles and public collective transport (bus)

Vehicles involved

- **Autonomous vehicles:** 2 vehicles
- **Connected vehicles:** 4 vehicles

C-ITS Day 1 services

- **Service 1:** Road Works information service
- **Service 2:** Weather information service
- **Service 3:** Traffic ahead service

Communication Channel

- **ITS G5**

Pilot Overview - Portugal

Roads

1) A9-CREL Between (Cirular Regional Enterior de Lisboa) and a national

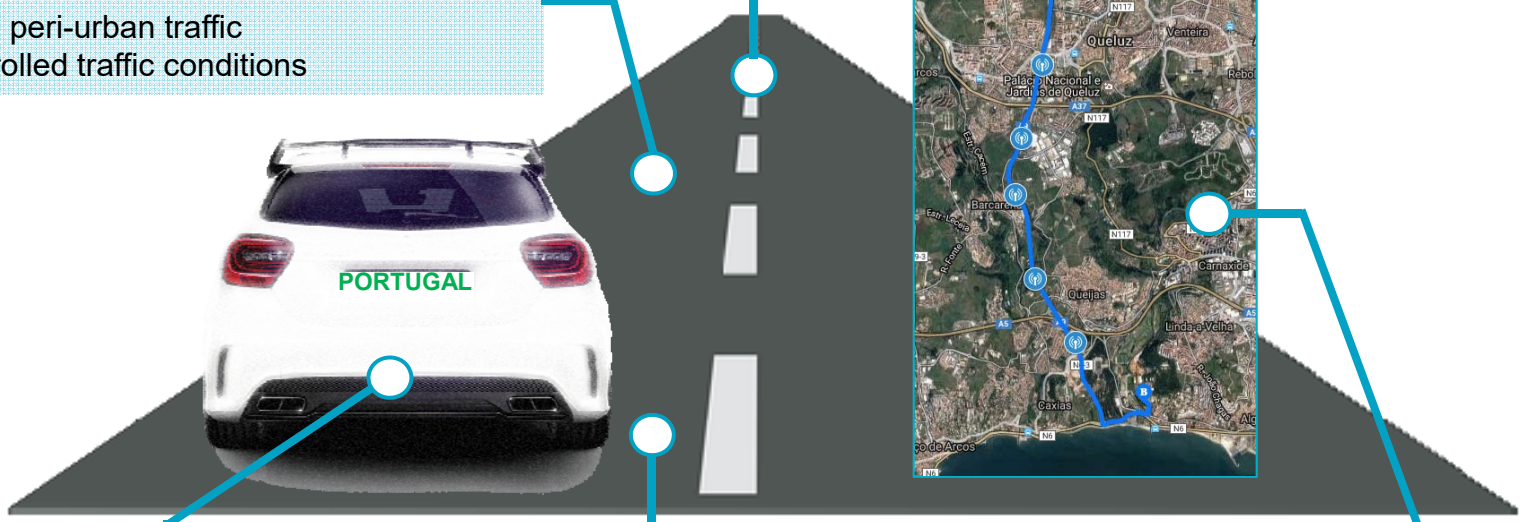
Length: 7 kms , **5 RSUs** have been installed

2) road connecting A9 and Faculty of Human Kinetics

Length: 1kms

Traffic condition

1) Open peri-urban traffic
2) Controlled traffic conditions



Vehicles involved

- **Autonomous vehicles**: 1 vehicles
- **Autonomous shuttle:** 1 vehicle
- **Connected vehicles:** 1 vehicles

C-ITS Day 1 services

- **Service 1:** Notification of slow or stationary vehicles
- **Service 2:** Weather information service
- **Service 3:** Other hazardous notifications

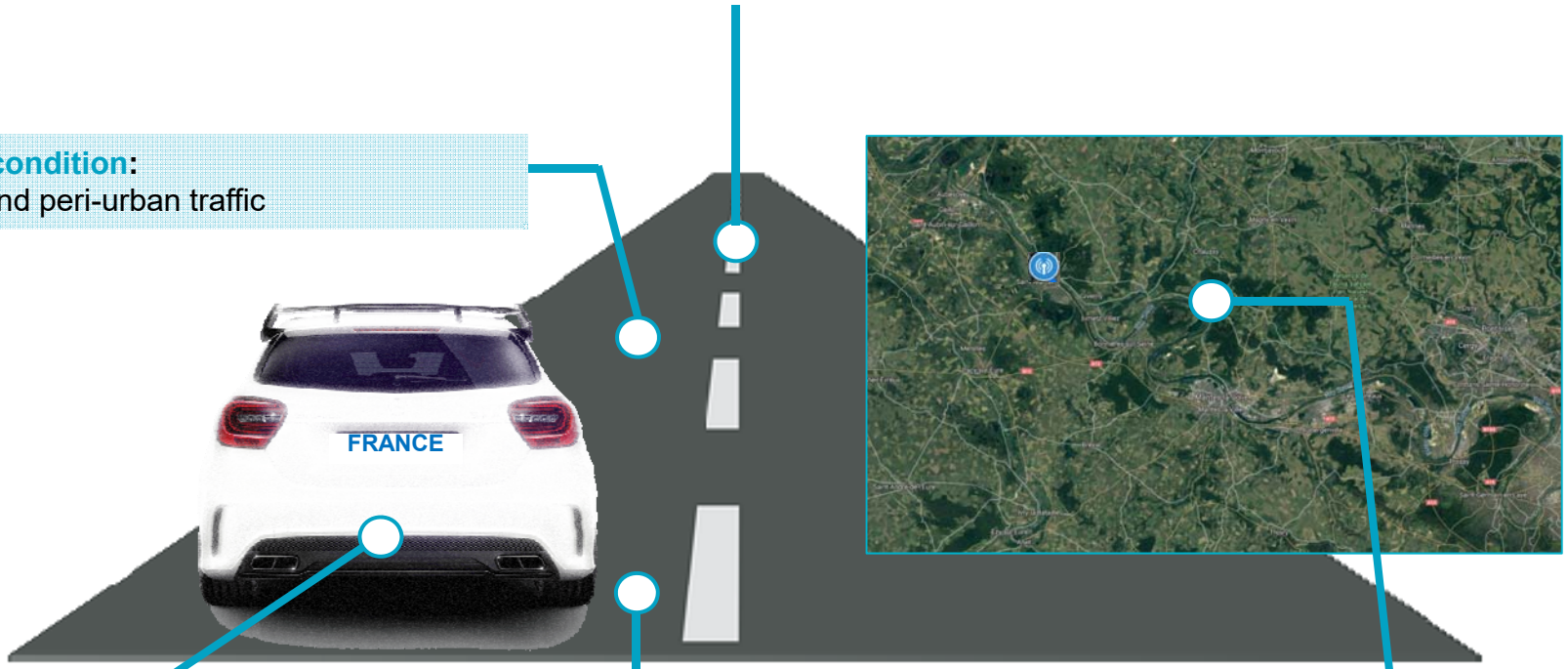
Communication Channel

- **ITS G5**

Pilot Overview - France

Road: Peri-Urban A13 Highway entrance to Paris
Number of RSUs: 1 **RSU** has been installed

Traffic condition:
Urban and peri-urban traffic



Vehicles involved
- **Autonomous vehicles:** C1 Evie
- **Connected vehicles:** 4 C3 vehicles

C-ITS Day 1 services
- **Service 1:** hazardous location notification
- **Service 2:** contextual speed adapting
- **Service 3:** traffic scheduling assist

Communication Channel
- **ITS G5**

Interoperability and Cross-border tests

Initial interoperability lab tests: (MADRID, February '18)

Test Infrastructure:
- INSIA Lab Equipment
- V2X Equipment from 5 manufacturers involved in all pilots

Test Objective: Validating compatibility on:
- Frequency channel
- Physical level compatibility
- Sending/Reception of CAM/DEMN messages

Test Results:
- Total compatibility at physical level.
- Frequency channel stablished in 5.900 GHz.
- Stable geo-networking version 0.1.
- Success in interoperability. Sending & reception of CAM/DENM messages.
- The ITS station of the 5 manufacturers are interoperable at the AUTOCITS premises.

Initial cross-border tests: (LISBON, July '18):

Test infrastructure:
- Two connected vehicles
- V2X equipment from 3 manufacturers

Test Objectives:
- Ensure interoperability of one C-ITS Service (Traffic ahead warning)

Test Results:
- Timestamp origin of times is the same for all teams and are synchronized
- All fields of DEMN messages should be filled to be detected as DEMN
- MAC identification should be unique for each RSU
- Number of hops should be defined in order to forward of messages

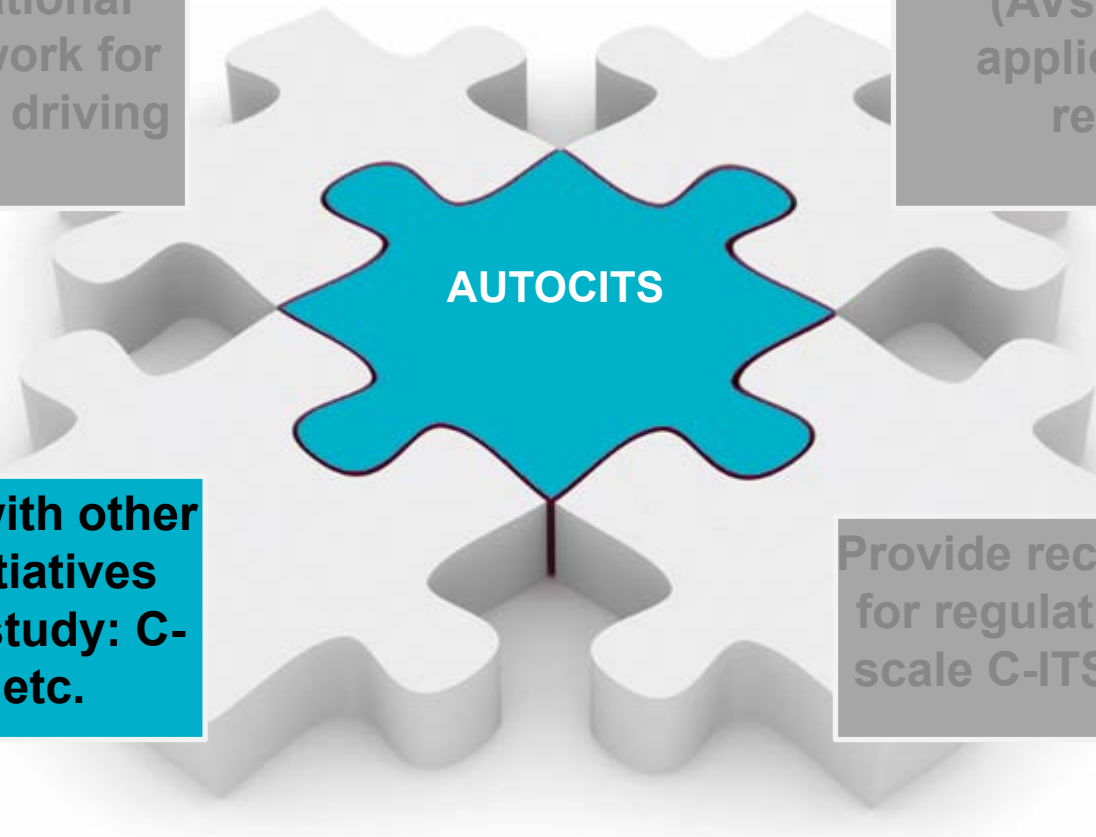
Initial Conclusions:
- **Synchronization** of the time zone is needed
- The equipment must all work in the **same frequency**
- Same **versions of geonetworking** protocols must be implemented

Next Cross border tests
- **Lisbon** – 15th / 19th Of October 2018
- Additional C-ITS services
- Autonomous Vehicles

AUTOCITS - Objetives

Study on the current National, European and International legal framework for autonomous driving

Pilot C-ITS services for autonomous vehicles (AVs) under the applicable traffic regulation



Cooperate with other current initiatives during the study: C-Roads, etc.

Provide recommendations for regulations and large scale C-ITS deployments

Contribution to/from the C-ROADS Platform

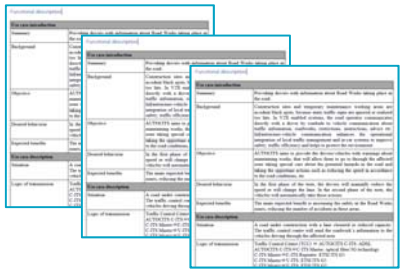
WG2 Technical Aspects/ WG3 Evaluation methodology

TF2 Service Harmonisation
TF3 Infrastructure Communication
TF4 Hybrid Communication
TF5 Cross border Validation

EXPECTED CONTRIBUTION TO THE PLATFORM

AUTOCITS C-ITS specifications for
Harmonised C-ITS specifications

Road Weather warning
Roadworks warning
Traffic ahead warning



- Implementation of services
- Provision of Communication model used
- Results of cross-border validation tests
- Results from pilots assessment and evaluation

EXPECTED CONTRIBUTION FROM PLATFORM

- Harmonised C-ITS specifications
- Evaluation and assessment plan
- Use of service standardisation
- Adpotions of Infrastructure Communication model
- Application of Hybrid Communications vision
- Cross border Validation tests
- Strategy for assessment and evaluation

Contribution to/from the C-ROADS Spain

AUTOCITS - Objetives

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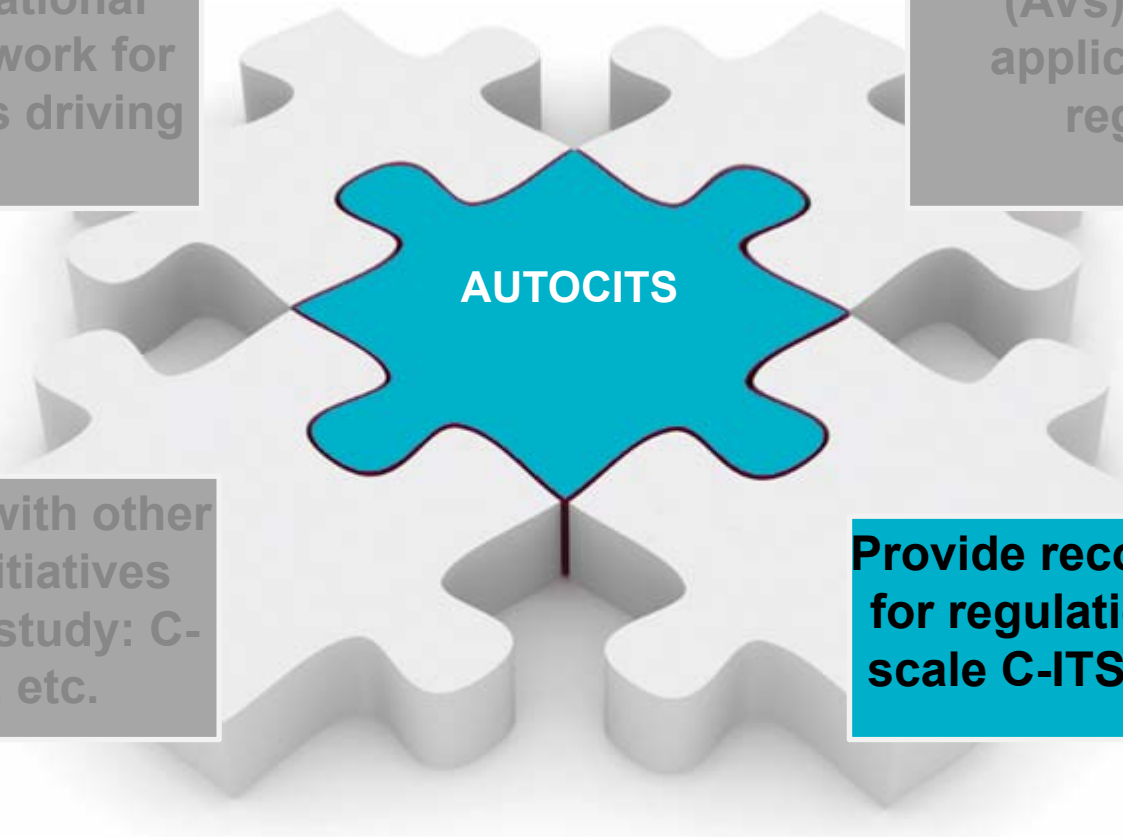

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Workshops

1st AUTOCITS WORKSHOP
MADRID, Nov 23rd 2017

2nd AUTOCITS WORKSHOP
PARIS, May 10th 2017

3rd AUTOCITS WORKSHOP
Lisbon, October 10th 2017

1st INTERNATIONAL WORKSHOP
Cologne, 5th July 2017

4th AUTOCITS WORKSHOP
Madrid February 2018

2nd INTERNATIONAL WORKSHOP
Vienna, 17th April 2018

5th AUTOCITS WORKSHOP
PARIS, Dec 11th 2018

6th AUTOCITS WORKSHOP
Lisbon, February 2019

FINAL AUTOCITS WORKSHOP
Madrid, March 2018

Pilot Deployment

Connected Vehicles

Autonomous Driving Pilot Deployment

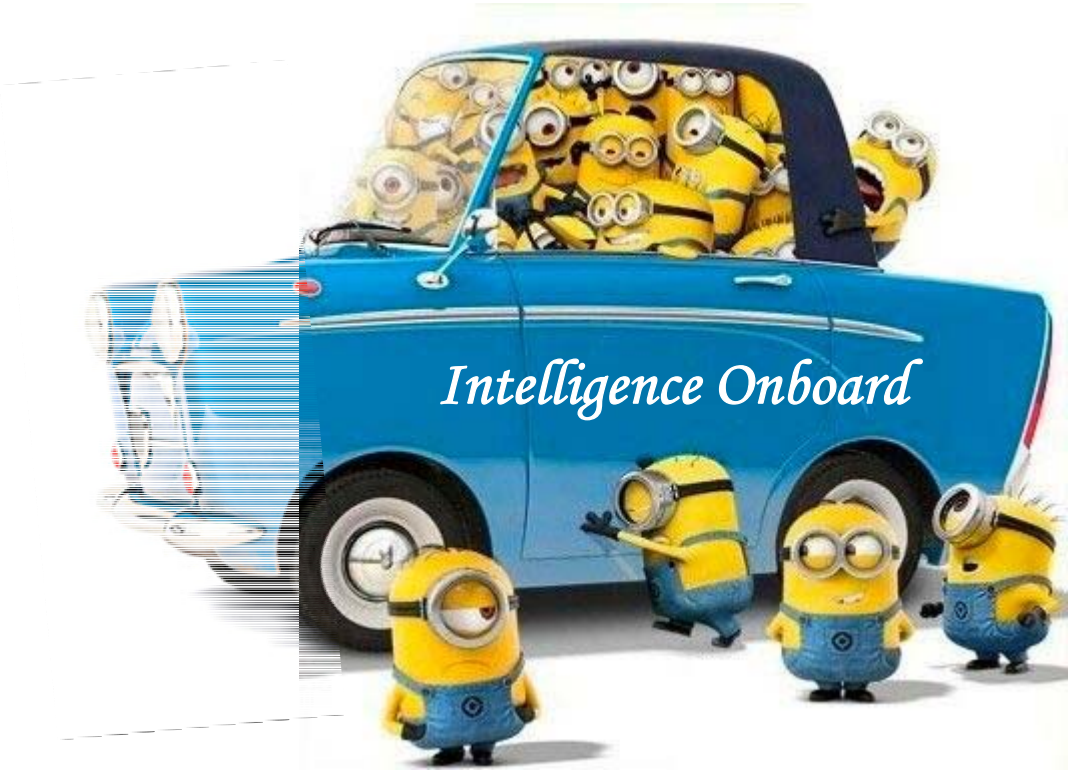
Autonomous Vehicles

AUTO
C-ITS

Regulation Study for Interoperability in the Adoption the Autonomous Driving in European Urban Nodes

Project **AutoC-ITS** is co-financed by the European Union's Connecting Europe Facility (CEF)

Co-financed by the European Union
Connecting Europe Facility



Thanks for your attention