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http://www.lmt.ufla.br/

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BRAZIL, a country of continental proportions, is internationally recognized by its population passion for cars. However, decrease the number of road fatalities and injuries on the roadway system is the best motivation to Brazilian authorities regarding connected and automated vehicles. Some numbers should be mentioned: we have about thousand vehicle fatalities every year in Brazil and it is increasing[1]. We have 1,25 million of death around the world related to vehicle travels. The largest cause of death of children under age of 14 is vehicle accidents[2]. So, when we think about a new technology, a new pathway that will get us to a safer roadway vehicle and travel system we understand why National Traffic Departments all over the world, including the Brazilian one – DENATRAN – is willing to make that technology work.

At the state level, the challenge is huge: state transportation authorities – DETRAN – are involved in infrastructure and operation of the roadway system. Brazil has a network of 1,069,157.79 miles of national roads and highways, however, 30% of the entire road network has bad pavement condition and only 130,872,414 miles are currently paved. States DETRAN are also responsible for registering vehicles. The total motor vehicles fleet in the country is about 93 million units[3].

We understand that to realize the greatest benefits of connected and automated mobility, there are three arenas that public authorities should look at: regulatory framework, physical infrastructure and digital infrastructure. Brazil has to figure out all of these different functions that belong to different parts of Federal government and try to make them work together in a way that optimize the innovation as well as safety of high connected and automated vehicles.

These are the main focus on this project presented by the Federal University of Lavras (UFLA) that aims to develop a multiple facility arena to testing and certification of systems and applications to connect and autonomous vehicles.

1.1 The Brazilian auto market

Brazil is internationally recognized by the passion of their people for both cars and technology. In an article written by Muller (2012) for Forbes Magazine[4], what carmakers

[1] Ministry of Health, February 2015.
[2] For ages 5 to 34, crashes are the leading of death (see: http://www.americanbar.org/publications/youraba/2015/october-2015/are-we-there-yet–the-legal-aspects-of-driverless-cars.html).
[3] October 2016.
[4] Why The World's Automakers Love Brazil. Forbes Magazine.

see when they look at Brazil is South America's largest consumer market, a still-bustling economy and a lot of potential customers. In this sense, Brazil is the eighth largest producer of vehicles, behind China, the United States, Japan, Germany, South Korea, India and Mexico.

Despite the effects of the global crisis in automobile market, this sector still shows a positive growth trend both in relation to sale and production prospects. Regarding sales, projections are of 4 million units for 2017 and 4.2 million units for 2018; as for production, 3.7 million units by 2017 and 3.9 million units by 2018 (Roland Berger, 2015[5]). The agribusiness is also a very important sector of the Brazilian economy, which represents 23% of the gross domestic product, with more than approximately 320 billion dollars per year.

From the academic perspective, Brazil also stands out according to information extracted from the Web of Science database. Regarding to communicant and automated vehicles, the country ranks on the 17th place in publications worldwide and is the first in Latin America. Given such context, it becomes clear the great potential offered by the country for research and implementation of projects related to connected and autonomous vehicles.

1.2 The Complex Brazilian Traffic System

All produced vehicle in Brazil or imported must comply with the current legislation criteria. Regulation requires the approval and licensing for circulation from several federal and state organisms, as well as the homologation of sets and components according to established technical standards. In addition, it must be subject to vehicular inspections for approval and registration in local traffic agencies. Such procedures allow obtaining the Certificate of Adequacy to the Traffic Law (CAT), mandatory for its inclusion in the national vehicle registration.

Furthermore, the Ministry of Environment and the National Environment Council (CONAMA) maintain vehicular emission control programs, which include the homologation process for light and heavy road vehicles and agricultural machines. The tests to verify compliance with the legislation shall be performed by a certified technical agent in laboratories and test tracks approved by the National Institute of Metrology,

[5] https://www.rolandberger.com/en/solutions/Industries/Automotive.html

Quality, and Technology (INMETRO) or recognized by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA).

In order to receive INMETRO certification, a component, mechanical assembly, or vehicle must be built or modified (if imported) to meet the specifications and standards of the Brazilian Association of Technical Standards (ABNT)[6]. Once approved, products receive a conformity seal for automotive components according to the Brazilian System of Conformity Assessment (SBAC). After January 2017, their commercialization will have to meet new requirements established in a specific ordinance issued by INMETRO. Vehicles whose constructive characteristics are in accordance with the CAT should give full conditions to the driver/operator to respect the Brazilian Traffic Code.

With the maximum coordination of the Ministry of Cities, the National Traffic System is a set of organs and entities that act in the traffic with normative, advisory, and executive competencies. It covers different Ministries and Secretariats, in the Federal, State/District, and Municipal spheres, forming an integrated network[7].

The national traffic system includes the National Traffic Council (CONTRAN), the Union's highest normative and advisory body; the National Department of Transportation (DENATRAN[8]), acting as the executive institution; and State DETRAN, responsible for vehicle registration.

It is expected that DENATRAN, through the National Department of Transportation Infrastructure[9] (DNIT), will create partnerships to invest in V2I applications and digital infrastructure that will be selected on assessment of various criteria as public benefits, agency benefits, and industry need and application readiness.

On local level, the city of Lavras, in the State of Minas Gerais, already counts with a territorial unit of the Department of Transportation, which is acting openly regarding to projects related to traffic intelligence and intelligent infrastructure and vehicles.

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[6] Standards elaborated by international institutions, such as ISO, SAE, IEEE, NHTSA, etc., are evaluated, reviewed, and adjusted for the specific conditions of the Brazilian market.

[7] Each of its members has specific duties, for the purpose of carrying out planning activities, administration, regulation, research and education, the operation of the road system, supervision, and application of penalties.

[8] DENATRAN has an educational purpose, being responsible for educational campaigns and preparation of training guides for drivers and standards manuals for road signs.

[9] Among its various functions, DNIT is responsible for implementing transportation policies for the country, promoting research and experimental studies in road engineering, establishing standards, norms and technical specifications for safety programs, traffic signs, maintenance or conservation, restoration or replacement of Roads, design and execution of road works. In an intelligent infrastructure program, this agency would be responsible for feeding the system, providing information and data to support vehicle-to-infrastructure communication (V2I).

1.3 Terrestrial Mobility Laboratory

Connected and automated vehicles are a reality, with an increasing acceptance from Brazilian consumers due to several usage benefits, including the major concerning to decrease road fatalities[10]. However, before being available to the grand public, intelligent vehicles must undergo strenuous tests to prove their safety and efficiency.

At this point, UFLA, through the Terrestrial Mobility Laboratory (LMT)[11], is working very heavily and closely to the National Institute of Metrology, Standardization and Industrial Quality (INMETRO)[12] on the purpose to create a test bed in the campus.

The envisaged circuit focus not only in private vehicles to urban areas but also off-road and agricultural ones. This facility is designed to match Brazilian reality in geometric design, with uphill and considerable slopes, besides the irregularities and most common imperfections in pavement, including markings and roadway signs.

We wish to understand better the safe deployment of advanced technologies and the long-term societal and ethical impacts that these technological advancements may impose. Create an openly share best practices (performance metrics and results of objective tests) for safe conduct of testing and operations, and to contribute to the insertion of autonomous vehicles in Brazil. Thus, to share best practices around the safe testing, demonstration and deployment of AV technology.

2 The intelligent systems test track at LMT/UFLA

After a careful analysis, an area of approximately 21,500 m^2 was chosen in UFLA to receive the test track. **Erreur ! Source du renvoi introuvable.** presents two points of view of the region chosen for the test track with their approximated dimensions. Note the significant height variation of the terrain, which will result in considerable uphill and downhill on the course.

The scaled sketch proposed for the track was designed as shown in Figure , with some important details about its structure. Briefly, it is divided into three major areas: Urban area; Agricultural area; and Off-road area. All these areas together is a unique complex for the test of AVs in Brazil.

[10] In Brazil, there are more than 430,000 accidents by year, with 619,000 non-fatal victims and 38,000 deaths[10], where the huge majority (about 90%) are caused by human errors.
[11] http://www.lmt.ufla.br/
[12] In Brazil, certification bodies must be accredited by INMETRO.

Figure 1 - Chosen area for the test track of the LMT.

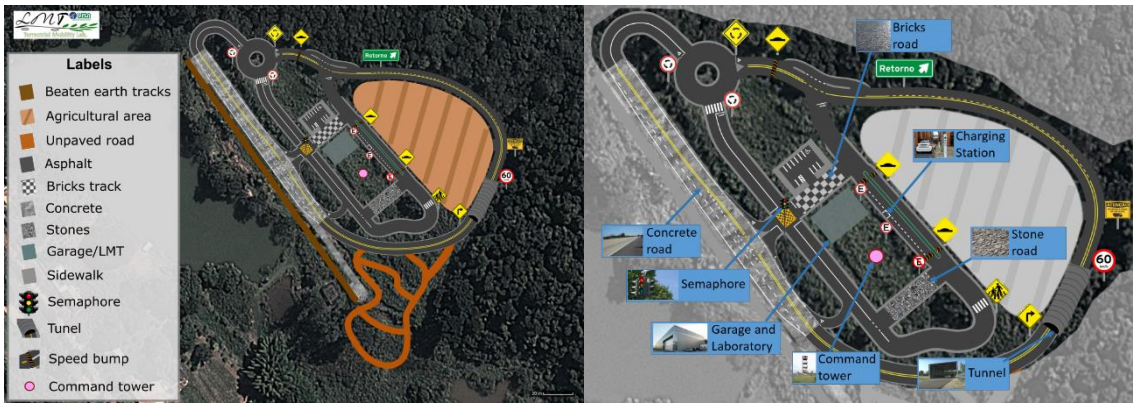

Figure 2 - The scaled sketch for the proposed test track at UFLA (on the left), and urban area of the proposed test track with some struturing elements on evidence (on the right).

2.1 The urban area

The urban area of our proposed test track has the advantage of being inserted in the Brazilian reality, where the relief is a considerable factor. The scaled sketch for this area is shown in Figure 2 (on the right). Structurally, this track will have:

- Roads of asphalt, bricks, stones, and concrete, with visible lane mark or not;
- Sidewalks with some elevation in relation to the street level;
- Curves with distinct radius, in up and downhill;
- Roundabout and tunnel;
- Different types of traffic signals and control devices;
- Urban lighting: fixed and prepared for the insertion of new light-based wireless communication models and also data transmission through electrical networks;
- Lane markings, pedestrian cross, speed limiters, exclusive bicycle lanes and level crossings;
- Fixed and movable constructions.

These elements allow the simulation of several real situations to the AVs, like the priority management in a roundabout for example. Some of the items will be discussed in more detail in the next sections.

2.1.1 Asphalt, bricks, stones and concrete roads

The environment perception is an arduous task for any AV. However, not all public roads are made of asphalt, which requires distinct and robust algorithms for each type of surface found. As a way of representing these possible differences, the proposed circuit has streets with four types of pavements: asphalt, bricks, stones, and concrete. It is also possible to observe the different lane markings on the ground on these tracks, with single or double lanes, traffic control signs (‘stop’ and ‘give way’), overtaking, etc. To enhance the realism, other structural elements will be added as speed reducers (or speed bump) and parking areas that require specific actions for the vehicle. In addition, the streets distribution allows tests at higher speeds (greater than 80 km/h).

2.1.2 Tunnel

A widely used sensor in AV navigation is the GPS, which suffers from many interferences. Therefore, replicating such situations in the test track may aid in the design and test of more robust localization systems. This is the intention of installing an artificial tunnel on the test track. As shown in Figure , it will allow the simulation of GPS signal losses, communication, and abrupt lighting changes. Moreover, a metallic grille to block electromagnetic signals and avoid wireless communications. This kind of signal block is important to simulate interference situations in the vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication.

Figure 3 - Example of an artificial tunnel made by metal (on the left), and a metallic grille to block electromagnetic signals (on the right).

2.1.3 Traffic light and dynamic traffic signs

One of the most important assumptions for AVs is to respect the traffic rules and signs. Traffic lights and signs will be present on the test track as a reliable representation of the urban reality. Focusing on a concept of smart city, the track will allow structural modifications to perform tests in vehicle to infrastructure communication (V2I) and issues on energy efficiency. This includes Smart Traffic Lights, with self-adjustment of the transition time between red and green lights, and Dynamic Traffic Signs, which constantly update their visual information like the speed limit for example. Both including the V2I communication.

2.1.4 Garage and laboratory facilities

A space with approximately 580m^2 (920m^2 of constructed area) was allocated on two floors, contemplating (see Figure):

- Three covered garages, with one for large vehicles;
- An auditorium for 32 people;
- Two laboratories for workstations with computers, mechanics and electrical/electronic equipment;
- A convenience area with pantry and bathrooms;
- Offices for visiting.

The built area will also assist in the landscape part of the urban area, as it will represent a real building.

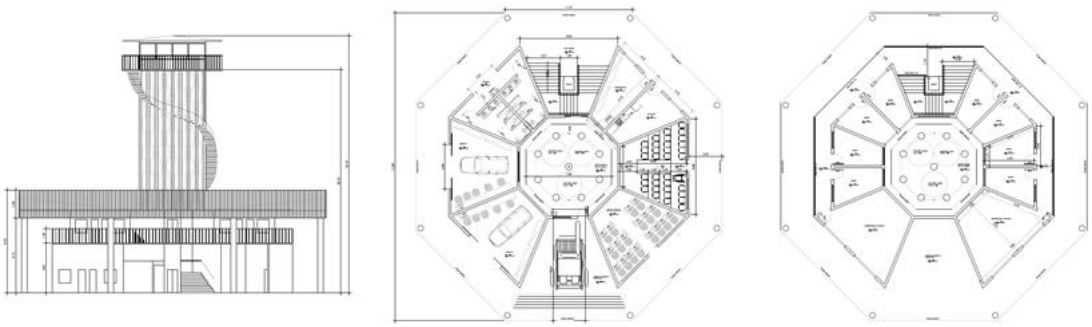

Figure 4 - Sketch with the frontal and up views of the installations of the garage and LMT laboratory facilities for the test track.

2.1.5 Space for civil cybernetics defense tests

The connectivity between vehicles (V2V) and between vehicles and infrastructure (V2I) will also increase the need for security practices to prevent cyber-attacks. Cyber security is a strategic area for Brazil, considering the major events that have been held in recent years, such as the Football World Cup and the Olympics. It is no wonder that the Brazilian Army created a Center for Cyber Defense (CDCiber) linked to the Defense Ministry.

2.2 The agricultural area

The test track has a farming area for different applications, as highlighted in Figure . With an approximated dimension of 110x60 m, the agricultural area is completely surrounded by a paved road. Its dimensions were designed to receive robotics projects in precision agriculture, which use automated tractors capable of sowing, harvesting, spraying, etc., in an automated way. To do so, the area allows the maneuvering of tractors (with an 180 ° change of orientation), different plantation configurations, perennial crops in level arrangements (similar to coffee plantations present in the state of Minas Gerais, Brazil), and many other tasks. Large vehicles may also be tested in this same environment.

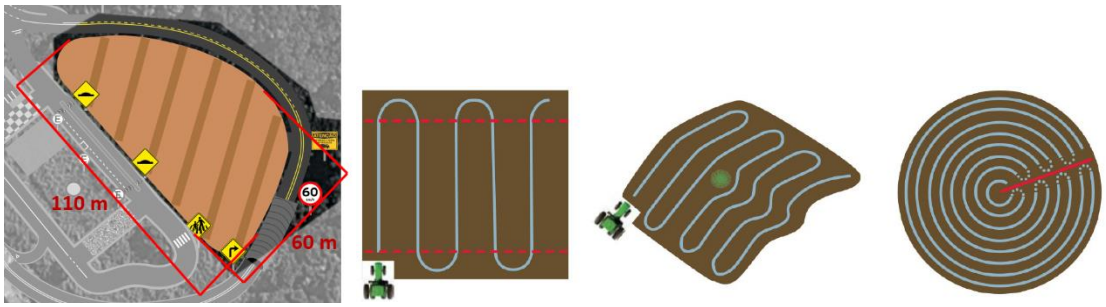

Figure 5 - Agricultural area with its dimensions on evidence (on the left), and examples of plantations formats with a dedicated area for maneuvers (on the right).

2.3 The off-road area

A diversity of pavements, structured or not, can enrich the perception system of AVs and make them more robust to the different environments of the Brazilian reality. Working with dirt roads is also another differential for such vehicles, where streets are unstructured, often narrow and irregular. In addition, dirt roads are easier to change, which increases the range of possible experiments. Considering this scenario, Figure

presents the area for off-road experiments of the LMT, with an approximate area of 5850 m^2.

Another kind of experiments is associated to the vehicles power capabilities. Tractors, for example, depend on several factors linked to their dynamics during their usage. For that, it is important to define the power capacities of a vehicle/tractor to perform certain jobs, understanding how your engine works to improve e.g. the fuel consumption and some elements that directly interfere with the precision farming and mobility. Thus, the LMT test track also has a space focused on dynamics and power tests of large vehicles, such as the agricultural tractors, illustrated in Figure 6. With the typical dimensions of other large Brazilian centers, the lane has concrete and compressed dirt tracks of 200 m each. The advantage of this proposal is the integration of all the environments in one place.

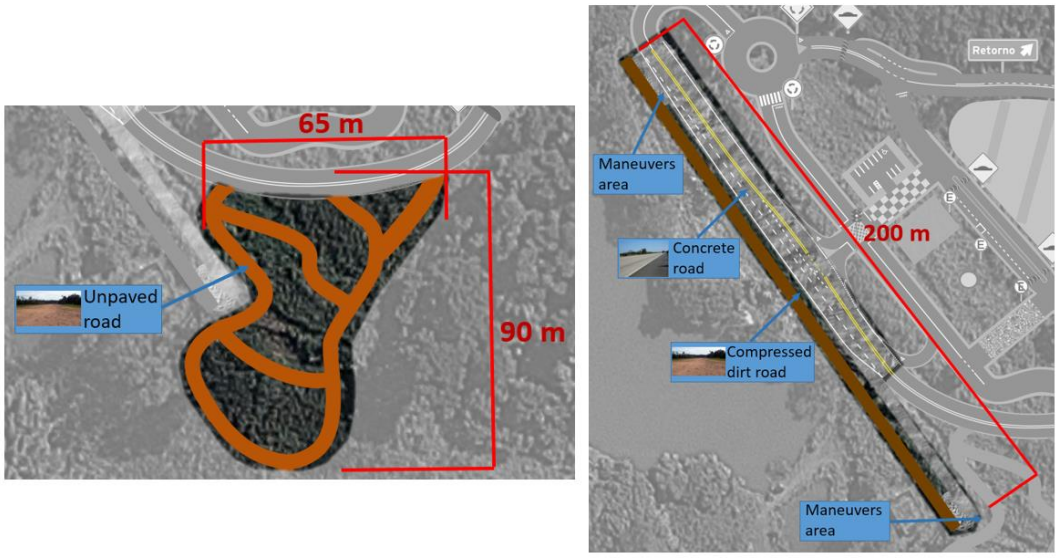

Figure 6 – Designated area for the off-road tests (on the left), and power experiments track for tractors and heavy vehicles (on the right).

2.4 Expansion possibilities and the simulation environment of the test track

The previous areas described in the original proposal are subject to new projects and the adaptation of the test track, allowing some expansions, is of fundamental importance. Figure highlights the possibilities for expansion of the initial project, approximately doubling the total available surface area. In addition to this local expansion, it is important to note that UFLA's own road network can be connected to the current project, composing a diverse environment for testing of different natures.

Although having all these test capabilities on UFLA, deploying AVs on real scenarios requires the robustness of the entire system, including their algorithms developed for it. They must be tested exhaustively for every new vehicle configuration and modification on the code. Thus, it can cause some dangerous situations and possible crashes if the system was modified wrongly. In order to improve the efficiency of the tests and avoid accidents in the initial tests phase, we are providing a simulation environment[13] with the same metrics and technical devices of the real test track proposed in this text. Focusing on the most commons systems used in the development of AVs worldwide, like ROS (Robot Operating System), the simulation environment has been designed for Morse[14] free robot simulation tool that provides an interface to these systems. In addition, the MORSE rendering is based on the Blender Game Engine, which is optimized for the most Graphic cards on market.

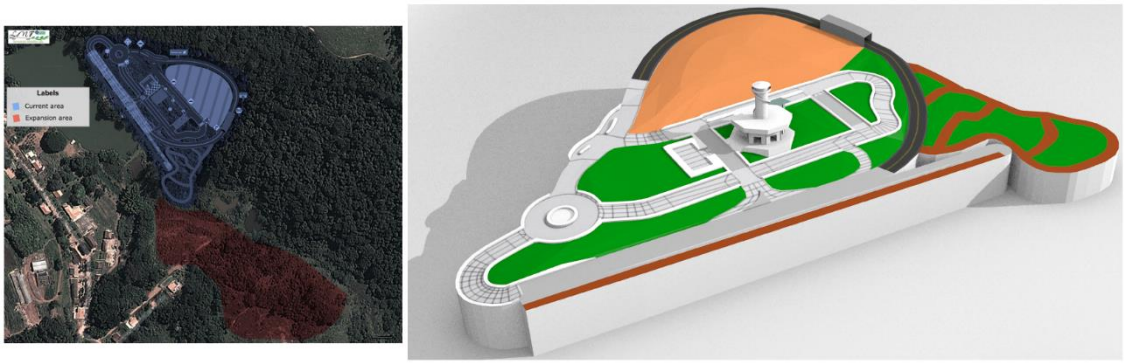

Figure 7 - Area available for possible expansion of the intelligent vehicles test track project (on the left), and the simulation track created in Morse/Blender (on the right).

Almost all real tests can be simulated, where the vehicle dynamics, navigation, and control capabilities can be replicated. However, there is a limitation for these scenarios related to the perception capabilities, even been possible to add cameras, laser scanners, radars, GPS, etc. Only real scenarios can provide the true texture of the elements present in the track. Thus, the simulation environment proposed is just the initial step for further applications.

[13] https://youtu.be/wp8J20yQWrM
[14] Available in https://www.openrobots.org/morse/doc/latest/what_is_morse.html.

3 Operational implementation

In view of the given magnitude of the proposed project, its implementation will be divided into three main stages.

The first stage will contemplate the streets with different pavements, public lighting, traffic signs, lane markings on the ground and the LMT facilities (garage and laboratories). It will be installed the control tower and the charging station. The control tower will be the basis for wireless communication and localization systems. Once operational, this stage will allow several experiments with different national and international partners.

In the second stage will be performed the instrumentation of the track, important for the design of a smart city. It will include the installation of the traffic light and sensors that will aid the navigation of AVs.

The third and final stage will be responsible for the operational and sustainability improvements on the track. Thus, the charging station will be a set of sustainable power generation (solar panels, power storage system, and cabling) and charging system for electric vehicles.

The facility will open for testing, by January 1, 2018.

4 Additional Information

Brazilian authorities are struggling to find out how to take advantage of all those vehicle technologies, which are coming from every auto manufacturers including American ones, to public benefit, reducing congestion and increasing mobility, improving therefore quality of life for the public. Also to understand where to invest money in infrastructure to those vehicles, considering industry need and use, also customers' expectations. Nevertheless, Brazilian authorities are not just focusing on third parties; they are also trying to figure out how to take advanced from this newcomer technology to improve their assessment, facilitating the way they do their activities and making them more effective.

4.1 LMT' project to capture data from different Brazilian road with their specificities

The ambition of the data acquisition project is also to equip several non-autonomous vehicles with sensors and detection systems identical to those planned to be used in AV running in Brazil. In such a way, it will be possible to create in advance a database with different road typologies, traffic situations, user characteristics that will constitute a representative database of the Brazilian roads environment.

The situations that are going to be collected will be previously defined and integrated after a preparative work assembling future manufacturers interested in Brazilian deployment of AV, and that are going to be partners of this project.

The data is going to be stored, with the required correction of base time, row treatment and GPS high precision coordinates in such a way to serve for all participants. It can be used for example as input data to simulate, to analyze and to complete the preparation for AV before their introduction in Brazilian soil.

The milestones for this project is to record, on equipped vehicles, taxi data representative of the standard (road/motorway/urban) mission profiles and exploit them for, mainly:

- Identify and analyze risky situations for an AV;
- Dimensioning the environmental parameters that could define these situations like distance and speed between vehicles, how many motorcycles (distance/speed), data signature of different objects as seen by radar and LIDAR images convoluted with image camera;
- Determine accordingly the statistics of the occurrence of these events and the associated ASIL levels as well as the performance criteria of the perception and supervision blocks;
- Create a proper datasets to be injected into AV simulators allowing the specification and verification of autonomous intelligent systems:
    - Integrate a hardware/software package enabling;
    - The robust and synchronous recording of all the data from the sensors in the vehicle;
    - The repatriation of data on a big-data infrastructure;
    - The monitoring of the collection, in order to constitute the desired database.