EUROPEAN COMMISSION

SEVENTH FRAMEWORK PROGRAMME

Theme: ICT

Small or medium-scale focused research projects (STREP)

FP7-ICT-2013-10

Objective ICT-2013.6.5 Co-operative mobility

a) Supervised Automated Driving

GA No. 612035

Interoperable GCDC AutoMation Experience

Deliverable No.	i-Game D4.1.1	
Deliverable Title	D4.1.1 Publishable summary on workshop on validation of vehicle performance	
Dissemination level	RestrictedPublic	
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Approved by	Rutger Beekelaar (TNO)	10-10-2016
Status	Final	10-10-2016

Please refer to this document as:

DEL_i-GAME_D4.1.1 Publishable summary on workshop on validation of vehicle performance

Acknowledgement:

The author(s) would like to thank the partners VIKTORIA, TU/e, TNO and IDIADA collegues for their valuable comments on previous drafts and for performing the quality assurance on the final draft.

Disclaimer:

SEVENTH FRAMEWORK PROGRAMME

i-GAME is co-funded by the European Commission, DG Research and Innovation, in the 7th Framework Programme. The contents of this publication is the sole responsibility of the project partners involved in the present activity and do not necessarily represent the view of the European Commission and its services nor of any of the other consortium partners.

Executive Summary

This document is intended to give a brief overview of the vehicle performance evaluation activities in the Safety/Performance activities that took place at IDIADA the last week of March 2016 in order to assess the GCDC participant teams' status. The safety/performance workshop had a two-fold benefit: from one side the teams could understand their progress according to the GCDC rules and on the other, the organisation could assess the particular and global situation of the team roster and set up the preparation week activities and, consequently, the necessary tests accordingly.

The deliverable offers an overview of the tests that were developed during the WP4 activities of the iGAME project and the organisation of the workshop. WP4 builds on the previously developed work in WP2, WP3 and WP7 and follows the guidelines defined by WP1 towards the common objective of having a successful and safe GCDC. A final overview of the teams' status at the end of the Workshop, the challenges faced and some lessons learned in the organisation of the workshop are summarised at the end of the deliverable.

This deliverable makes use of other deliverables that give a more detailed insight of the activities performed in some of the tasks and are consequently being referenced. To have a complete overview of the complexity of the safety and performance evaluation of the participant vehicles, it is recommended to consider the rest of the deliverables of WP4 as well.

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1 Introduction

The i-Game Safety/Performance workshop was held at IDIADA from the 29th of March to the 3rd of April and was a great opportunity, both for the project consortium and the GCDC teams, to interact with each other, make good progress and assess the status of development of the vehicles.

Moreover, everything was done in a friendly environment with all possible amenities where any possible missing requirement was solved in very short time, giving the teams all necessary tools to develop and test their systems (i.e. differential corrections, lane markings, test tracks availability, power supply for electric vehicles, elevators, electronic components…).

We also had the collaboration of expert drivers (cars and trucks) that assessed the safety status of the vehicles prior to any performance tests on the High Speed Track.

1.1 Organization of the workshop

Due to logistic requirements from the teams, the workshop had to be splitted in two groups so that some of the participants could attend regional events in their countries. This ended with one group participating from the 29th of March to the 1st of April and another group participating from the 31st of March to the 3rd of April, where during days 31st of March and 1st of April the two groups could interact and a dinner was celebrated with the teams and the consortium.

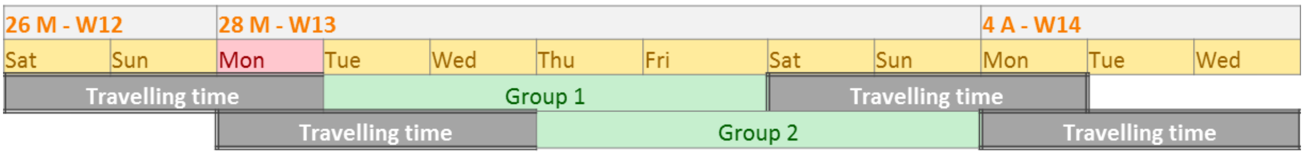


Figure 1: Workshop organization

The teams participating in group 1 where:

- Chalmers (truck), Latvia, ATeam, Heudyasic and Drivertive.

And the teams participating in group 2 where:

- Chalmers (car), KTH Experimental vehicle, Halmstad and Annieway

This made a total of 9 teams with 7 passenger cars, one experimental vehicle and one truck, plus the two benchmark vehicles from TNO that were used during the performance tests. The workshop had the participation of different colleagues from the i-GAME partnership, leaders in the development of the different WPs. Their expertise and hard work were key in the succes of the event.

Table 1. i-GAME Safety/Performance workshop organisers and responsible crew

IDIADA (host) Safety testing and monitoring Organisation of the workshop	Aitor Ruano, Lorena Garcia-Sol, Alex Vallejo, Victor Pascual, Álvaro Arrúe, with the collaboration of several IDIADA experts, technicians and event managers.
TNO Communication protocol checks Performance testing Benchmark vehicles Project coordination	H. (Jacco) H.D. van der Sluis, Jan de Jong, Jeroen Ploeg, Ellen van Nunen, Elham Semsar Kazerooni, Almie van Asten
TU/e Data accuracy checks Performance testing Team leadership	Hrishikesh L. Salunkhe Alejandro Morales Laurens Schrijnemakers

During the workshop a professional marketing company was hired to perform interviews with the teams and to record some of the performance scenarios with a drone camera, so that the consortium would have nice marketing material to promote the GCDC.

Figure 2: All the workshop participants

In this document we are summarizing the vehicle complete performance assessment done during the workshop. For more details about some of the tests and stations please refer to the appropriate deliverables.

1.2 Workshop testing overview

Prior to the workshop there were about three months of intense preparation, both for the workshop organization and the logistics, where a lot of communication took place between the teams and the consortium, through email and phone conference to ensure good coordination and fast reactions.

During this preparation phase, preliminar information on the attributes and development status of the vehicles was required to the teams, both for organizational purposes and to do a prior assessment on the safety of the vehicles. This was planned in the testing stations approach as the design and administrative checks.

During the first day of each group the drivers of the teams where involved in a safety course at IDIADA premises, they learnt about safety measures and rules and they were given access to the test tracks.

Finally, for the organisation and during the workshop there were 9 different type of stations with a set of tests and organisation requirements in each of them:

- **S1 – Design planning activities:** A document required to the teams providing some insight about the design methodologies and choices followed in their implementation regarding functional safety.
- **S2 – Administrative checks:** All the information required from the organisation of the workshop and the GCDC necessary for its succesful execution i.e. driver name, license, type and characteristics of the vehicle, insurance conditions, etc

- **S3 – Visual Inspection** Based on an internal procedure followed in IDIADA for any vehicle to perform tests in the tracks, a number of variables of the vehicle, measured in static, is done before any dynamic test is allowed in order to identify potential safety risks.
- **S4 – Vehicle manual control:** This station will test the vehicles' dynamic performance as well as the possibility of the driver to override the mode of their vehicle. In the GCDC, the last safety mechanism is the driver.
- **S5 – Communication protocol checks:** Consistency of messages format and content is checked, as well as correct usage of channels and interpretation of the i-Game protocol.
- **S6 – Braking safety check:** The braking capabilitites of the vehicles are tested a dedicated test track to assess its status.
- **S7 - Data validation and accuracy checks:** Logs of the sensors data provided by the teams are compared against logs coming from high-accuracy equipment to look for any inconsistencies.
- **S8 – Benchmark platooning scenario:** Highway scenario related performance tests with different vehicles and configurations.
- **S9 – Benchmark intersection scenario**: Intersection scenario related performance tests with different vehicles and configurations.

The static and Vehicle Manual Control are blocking stations, this means that teams were not allowed to go into performance tests without passing them, for safety reasons. To optimize time efficiency team members were allowed to perform communication tests while waiting for their vehicle to pass the safety checks so that once done they could participate directly in the performanc scenarios or spend time improving their implementations.

1.3 Safety relevant topics

Functional safety

Before starting with the definition and development of the safety check list detailing all issues that shall be taken into account during the evaluation, it is important to understand concepts as ISO26262 [1], MISRA or hazard, which are all explained in detail in deliverable D4.5 [2].

Functional safety is a vehicle property, rather than an application domain. Functional safety is defined in ISO 26262 as the absence of unreasonable risk due to hazards caused by malfunction of Electric & Electronic (E/E) systems. Zero risk cannot be achieved and, therefore, there is always a residual risk that something goes wrong.

It is important to point out that system safety is a wider concept than functional safety and, therefore, they shall be used depending on the context. Functional safety is not the overall safety of a product; this role shall be taken by the system safety. It shall include functional safety along with fire safety, electrical safety, chemical safety, mechanical safety, radiation, toxicity, reactivity, corrosion and release of energy, since other causes different from electric & electronic could cause safety issues. Therefore, system safety shall be covered by different standards covering the above domains.

Risk is a combination of the likelihood and severity of an unplanned, undesirable event.

Hazards are potential unsafe events or conditions that could lead to undesired consequences or events. The hazards can therefore be caused by faults or unanticipated sequences of interactions between components or subsystems.

ISO 26262

Figure 3: ISO 26262 work products is a Functional Safety standard titled "Road vehicles – Functional safety". The standard is an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems.

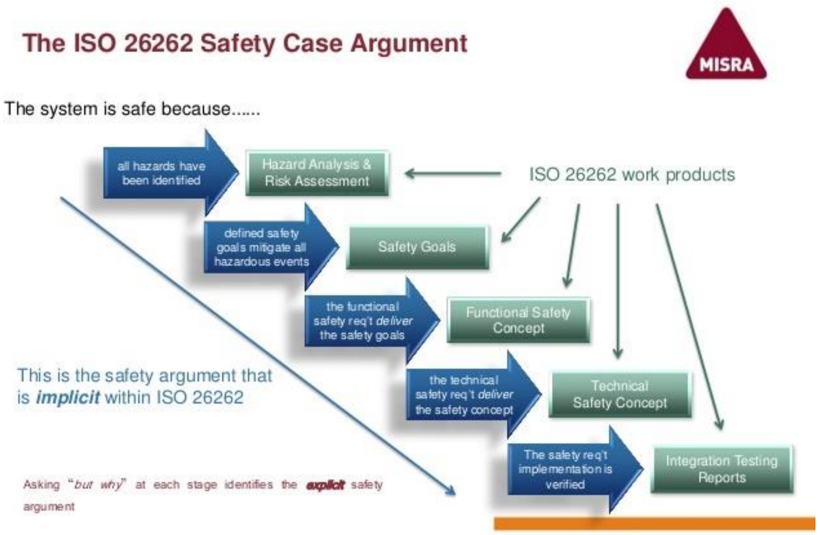


Figure 3: ISO 26262 work products

ISO 26262 is intended to be applied to safety-related systems that include one or more electrical and/or electronic E/E systems (and interaction of these systems) and that are installed in series production passenger cars with a maximum gross vehicle mass up to 3,500 Kg.

ISO 26262 is based on the V-model concept. This model contains specifications of the functional requirements, technical requirements, the system architecture, the system design and implementation on the left branch and the integration, verification and validation and functional assessment on the right hand branch.

Based on the development of past and current projects on ISO 26262, IDIADA recommends taking into account the following actions:

1. Safety activities shall be integrated in the master project plan with all regular project activities.
2. Safety plan shall be unique for each project containing all relevant information and it shall filter what work products shall be available in each project phase.
3. Safety plan shall be connected to the DIA (Development Interface Agreement) with the supplier.
4. The DIA with the supplier shall have no inconsistencies with respect to understandings and responsibilities. RACI (Responsible, Accountable or Approver, Consulted, Informed table) shall be agreed and signed upfront.
5. Defined the work product formats to be exchanged in order to avoid different expectations or interpretations.
6. Process-wise, the following guidelines shall be followed: not only using appropriate tools, but also coaching and learning all stakeholders. Tools requirements shall be agreed with suppliers.
7. Important to define test criteria when requirements are specified.
8. Set up and maintain bidirectional traceability along the complete project.
9. Evaluate requirement status and progress against planning.

10. Ideally, the tool shall support the complete safety project cycle from concept to service ensuring a single source and engineering data for all the project.

According with the previous figure, Figure 3, the different phases have been defined and developed in order guarantee that to the vehicle becomes safe.

Hazard Analysis & Risk Assessment (HARA)

In order to know in more detail the HARA which was performed by the organizers, it is very important to review the documentation related with this, deliverable D2.5, chapter 3 [4].

In resume, there was one HARA per scenario: Highway, Intersection and Emergency Vehicle scenario, each scenario performs an specific function, and each HARA is composed by 7 parts.

a. HAZOP (HAZard and OPerability study)

The HAZOP is a study of the deviations of the functions performed by the scenarios at system level, where system level is defined as the behaviour and manoeuvres of the vehicles while performing the scenarios.

b. Situation analysis

Here is indicated where the functions of different scenarios will be performed, and what are the conditions of roads.

In the Highway scenario, the locations will be in an urban area with a maximum speed of 30 Km/h, and in a highway with a maximum speed of 80 Km/h. In the intersection scenario, the location will be a country road or a street in a city with a maximum speed of 30 Km/h.

The road conditions for both scenarios will be paved dry and wet road; dry road will be the normal road friction and wet, the low road friction. The safe conditions on a dry road are better than in a wet road.

c. Hazard

The different unintended manoeuvres are identified and described as hazards provoked by only one vehicle, but taking into account that the combination of the unintended manoeuvres is also possible. The hazards are classified depending on the type of unintended manoeuvres, independently of the scenario performed.

d. Hazard Events

The combination of hazards and malfunction behaviours leads to the hazard events. Depending on their priority, these hazard events are classified as low, medium or high.

e. ASIL determination

Automotive Safety Integrity Level (ASIL) determination is a function of three parameters: severity (S), exposure (E) and controllability (C) and as per ISO International Standard 26262:

Table 2: ASIL Levels and determination

Severity class	Probability class	Controllability class		
		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

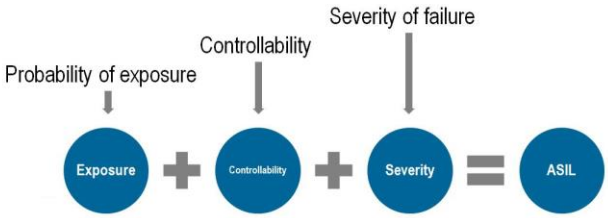


Figure 4: Automotive Safety Integrity Level parameters

- Severity (S): estimate of the extent of harm to one or more individuals that can occur in a potentially hazardous situation.
- Exposure (E): state of being in an operational situation that can be hazardous if coincident with the failure mode under analysis.
- Controllability (C): ability to avoid a specified harm or damage through the timely reactions of the persons involved, possibly with support from external measures.

A part from this, levels range from A to D, with criticality increasing from A to D, has been defined. Depending on that level, certain rules of development and documentation have to be followed.

f. Safety goals

Safety goals are the results of the hazard analysis and risk assessment, they are composed by four safety goals and their associated ASILs for the functions of the scenarios:

(SG1): No sudden unintended full acceleration

(SG2): No sudden unintended full braking in highway/intersection scenarios

(SG3): No fast transversal vehicle movement when not requested

(SG4): Minimize inconsistency in system state perception among all vehicles, leading to unintended action

SG1, SG2 and SG3 can be identified taking a vehicle centric perspective. However, SG4 is a kind of safety goal that is difficult to be identified from that perspective since SG4 does not point out any particular failure in one single vehicle, but rather in the cooperation itself.

SG4 is clearly identified when a cooperative perspective is taken. Therefore, functional safety requirements can be allocated to V2V/V2I communications.

The safety goals are an important part to take into account in the HARA and are a step to define in order to guarantee that the system becomes a safe product.

As a final remark, as appointed by ISO26262, it is extremely difficult to develop a fault free system as there will always be the possibility that unknown faults or sequences of interactions may lead to hazardous situations. The derived safety goals address that full accelerations, breaks or fast lateral manoeuvres should be avoided if not requested, allowing for a certain tolerance that minimizes risks while maximizing safety.

g. Prevention and detection on scenarios

One of the most important parts of the HARA is the prevention and the detection of possible malfunction behaviours, so one time the hazard events with their malfunction behaviour is detected and paired, the malfunction/s is/are detected.

The most common malfunctions detected in the highway and intersection scenarios are:

1- Communication degrades/fails disengaging the platooning functionality

2- Inaccurate sensor inputs providing non-trustworthy information.

3- Cut-in of an external vehicle during vehicles platooning

4- Acceleration triggered by an unexpected error.

5- Emergency brake triggered by an unexpected error.

1.4 Other challenges for safety and performance

In the increasingly complex field of cooperative automation testing, functional safety might need to be updated in view of to the presence of threats to the safety of the vehicle which currently are not covered by the ISO 26262. This standard is mainly based in the safe and secure software and hardware development of vehicle silo functions (a function working alone with no interaction with other vehicle functions), however the trend to advance in integration of connectivity and different functions through centralized controlled architectures which interact with external users or devices expose the future of the next generation of vehicles. Although not in the scope of iGAME project, the commercial deployment of cooperative & automated vehicles will have to face different challenges affecting the whole lifecycle of the vehicle.

Software configuration management

This is not rather a threat but a change in the traditional way of passing the Type approval process at vehicle and component level. Traditionally OEMs and Tier1s provide a set of sample units, reference of the final market device to overcome the different tests set by the regulator. These approved units should not significantly change during their whole lifetime, having the periodic inspections as a watchdog of its performance. Connectivity allows remote Over-The-Air (OTA) update at the software level and thus the characteristics of the vehicle (safety, fuel efficiency, emissions, maximum speed) might change with respect to the sample unit. Regulators and technical centres are working hard to create a suitable framework for this new scenario as well as the tests that should be in place in order to guarantee it fulfils the current legislation. In the case of connected and automated vehicles, it might be even more critical as the knowledge gathered simply by having the vehicles on the road, learning from the different situations and events found on its way, could be assessed and processed to increase the number and quality of the CAD vehicles capabilities through software updates.

Cybersecurity

Aligned with the OTA updates, the connectivity of future vehicles opens the door to cybersecurity attacks and thus the disruption of the functionalities of the vehicle, including safety and even control when dealing with automated vehicles. It is an important issue currently being tackled by several international standardisation groups, regulators and policy makers. Cybersecurity is a field that not only threats automation but the whole connected vehicle industry. In current automated driving vehicles license exemption procedures, guaranteeing the security of the vehicle from external, unauthorized users is already being contemplated although it is very difficult to define best practices towards the creation of tamper-proof vehicles. Both ISO26262 and Type-approval are describing how to interact with this challenge in the near-future.

Environmental (EMC)

Electromagnetic compatibility (EMC) concerns the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment. The goal of EMC is the correct operation of different equipment in a common electromagnetic environment[1]. Electro-Magnetic compatibility is also important not just for automated vehicles but for the traditional industry too. Regulation 10[2], in its fifth version, sets the necessary tests a commercial vehicle or component needs to pass to be allowed to be introduced in the market.

Reliability of data & service providers

Connected vehicles, including cooperative vehicles and partial to fully automated vehicles rely on information coming from external sources, not just from other vehicles but from service providers (digital maps providers, traffic conditions status), both public and private. The C-ITS expert platform from the EC in its first year final report[3] concluded that the inaccuracy of the data provided in a non-timely manner by external providers is not a cause of liability as the driver is still in control of the vehicle and thus, the final responsible of its own and third-party safety. Nevertheless, automated vehicles will require this information to be accurate and always updated as they will fully rely on it as an extra sensor for its navigation and decision making.

[1] https://en.wikipedia.org/wiki/Electromagnetic_compatibility
[2] http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/updates/R010r5e.pdf
[3] http://ec.europa.eu/transport/themes/its/doc/c-its-platform-final-report-january-2016.pdf

2 Safety and performance Workshop

2.1 Aim of the safety and performance Workshop

The aim of the performance workshop was to determine the minimum performance of the vehicles and respect the performance rules in order to allow the teams and vehicles to participate in the GCDC.

In order to assess the functional-performance mechanisms implemented into the vehicles, a list of potential activities was defined and structured in different stations with specific tests for each of them.

The aim of this list is to guarantee that vehicles can compete in the scenarios with a level of performance and, therefore, risks during competition are minimized as much as possible.

A vehicle was qualified as GCDC participant once all performance stations were passed satisfactory.

A comprehensive number of tests was performed in the week prior to the event to ensure that the vehicle was still up to GCDC requirements.

To assess the performance of each vehicle, the following aspects had to be taken into account:

- Organization: Be sure about the behaviour of the vehicle of the GCDC. Nothing is 100 % safe, but it is better to be close.
- Teams: Have the vehicles evaluated by professionals. It is very important to determine the potential risks beyond the GCDC.
- In terms of active safety: “official” Euro NCAP ratings of the vehicle platform cannot be trusted, because the vehicle sensors and control have been tinkered with and new functionalities have been added.

Note that this was the first opportunity to have the vehicles together, which allowed to include a basic check of performance, a basic check of interoperability with the vehicles validating the interoperability and interaction tools, and finally to allow the teams to solve critical problems in advance.

The performance workshop also gave the possibility to test between the different teams (while using professional proving ground) to interact with the other vehicles in a safe and controlled environment. While some teams were passing the “official” tests, the others had time to make “free” tests alone or interacting with other team vehicles.

IDIADA provides to their clients the most comprehensive independent proving ground in Europe. It offers a high level of customer support combined with first-class test tracks and fully-equipped confidential workshops.

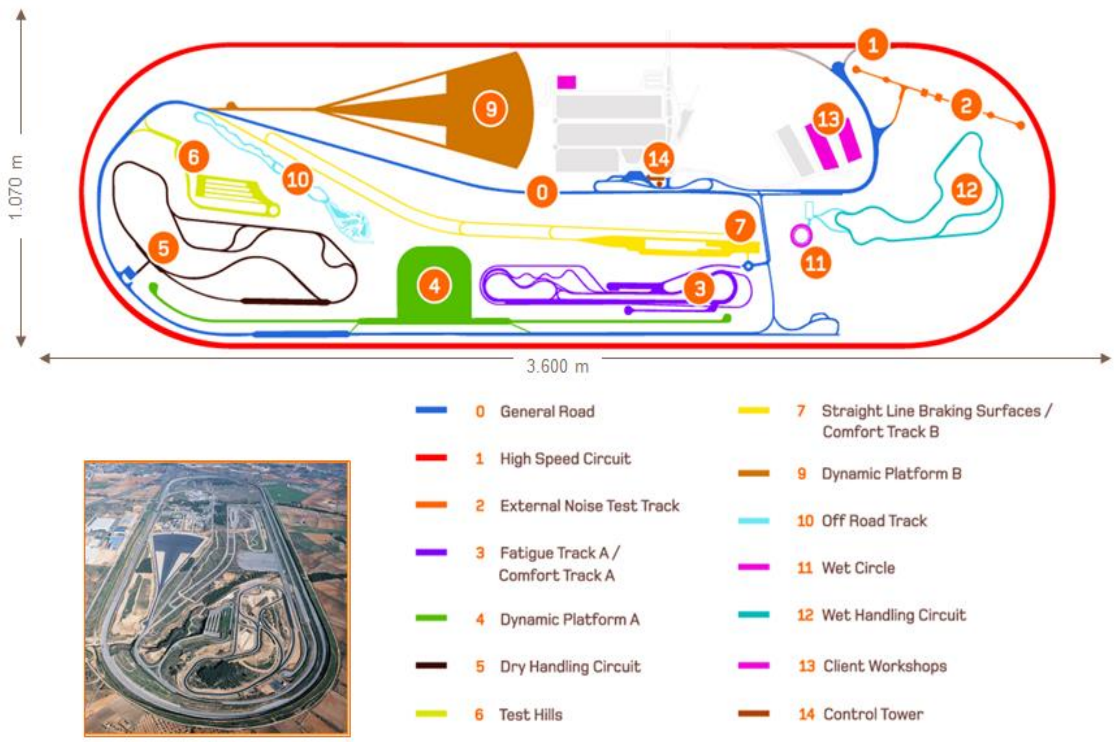


Figure 5: IDIADA Proving Grounds

The teams will perform the different activities in different tracks including, dynamic platforms (4), high speed circuit (1), braking track (7) and a general road intersection (0). Each test track was chosen so it best suits the types of test under execution.

2.2 Support on the safety/performance workshop

IDIADA scheduled the transportation during the days prior to the workshop and the tests during the workshop at IDIADA's headquarters. 4 days of testing and 2 to 3 days of transportation.

Moreover it provided the necessary tools and team of professional drivers and technicians to solve any request or issue the teams may find. Also, of course, the teams were provided with all the needed ammenities to make it easier for them to work hard during the long days in the safety workshop.Three stage approach for validation of the vehicle performance

In order to become a safe vehicle, each team has to pass these three following stages:

1. <u>Documentation</u>: The team must provide a technical description of the vehicle characteristics, team details and other.
2. <u>Inspection</u>: A physical inspection with special relevance of the safety elements of the vehicle.
3. <u>Dynamic validation</u>: Proving ground tests to assess vehicle performance.

The manner to proceed is as shown in the following figure:

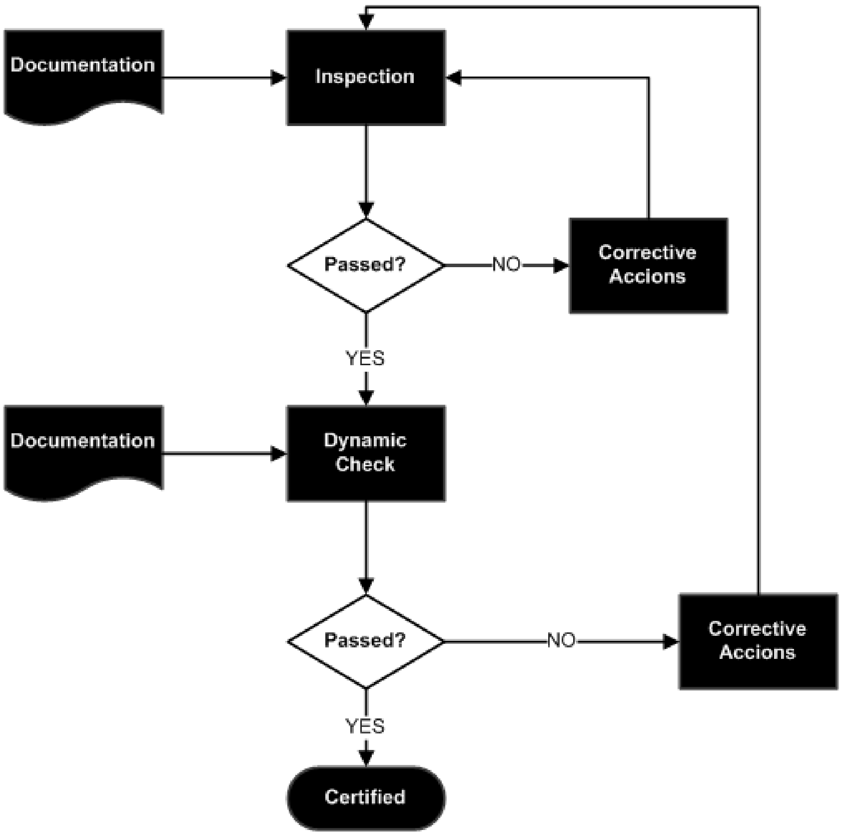


Figure 6: Three stages approach for safety validation

These three stages are conformed by nine different stations, each one explained in more detail in the next sub-chapter. During the workshop, the stations and their associated tests were executed in different blocks in order to be more efficient during the testing as there were many different vehicles and a very strict schedule.

Table 3: Nine stations for safety validation

STAGE	STATION	DESCRIPTION	WORKSHOP BLOCK
Documentation	1	Design planning activities	Previous to the Workshop
Documentation	2	Administrative checks	Previous to the Workshop/recheck onsite
Inspection	3	Visual inspection	Visual inspection/Safety Briefing
Dynamic Check	4	Vehicle manual control	Vehicle manual control and Data accuracy
Inspection	5	Communication protocol checks	Communication protocol checks
Dynamic Check	6	Braking safety check	Braking checks
Inspection	7	Data validation and accuracy check	Vehicle manual control and Data accuracy
Dynamic Check	8	Benchmark platooning scenario	Performance tests
Dynamic Check	9	Benchmark intersection scenario	Performance tests

These stages and their associated stations were divided in several working blocks during the Safety/Performance workshop

2.3 Stations

As stated, a number of verifications have to be performed to teams and vehicles so they can participate in the GCDC. These will ensure the safety of drivers and facilitate the planning and preparations once the teams are on site in Helmond. Verification as described below took place 2 months before the competition in Helmond with the purpose to avoid teams to be disqualified at the event. Verification was mandatory for all teams before the participation in GCDC and took place at IDIADA (Spain) onApril 2016.

In order to assess the functional safety mechanisms implemented into the vehicles a list of potential activities are described below.

The aim of the list is to guarantee that the vehicles can compete in the scenarios with a certain level of safety and, therefore, minimizing risks during competition as much as possible.

The way the tests are listed below shall be the way they are performed. At each station some aspects of the required behaviour shall be evaluated in a controlled way.

Following the above process we ensured the vehicle was qualified in a gradually increasing complexity.

If a participant vehicle fails in one station, it will come back to the same station once a review is made. If it is not successful in passing the station or there is not enough time to repeat the tests, the team will be warned and declared not able for the competition yet. To change this, corresponding modifications shall be required, tested and verified by IDIADA before the competition.

A vehicle will be qualified as GCDC participant vehicle once ALL stages are passed satisfactory. Moreover, the tests will be performed again in the week prior to the event to ensure that the vehicle is still up to standard.

Some check activities are new and others are based on the ones carried out during the GCDC 2011 [3]. In all cases, the participant is always responsible for its own safety, for the safety of their vehicle and for not jeopardizing the safety of other people or vehicle in its vincinity.

Each vehicle shall be equipped with a radio to receive information from the organization via FM transmission.

Station 1: Design planning activities

In the first station, the design process followed by the teams to get the final implementation is evaluated. This evaluation is based on generic key activities highlighted in the ISO 26262 or MISRA Safety Guidelines [1]; the idea is to get the teams familiar with current automotive standards from a safety point of view.

The potential aspects to be evaluated will be:

- Safety design aspects: Coordinator, Project planning of activities, Content of the safety plan, Functional safety assessment, Judgement levels.
- HARA (or similar): Hazard identification. Safety goals. Technical safety requirements.
- Software development coordinated with product development at system/HW level:
  - Methodology of HW/SW development.
  - Final HW/SW architecture.
  - Software development coordinated with product development at system level and hardware level?

- System techniques used: FMEA, FTA, Other
- Elements and characteristics considered for of the HW/SW from safety point of view.
- Test methods or combination of them used at system and HW/SW level.

In order to evaluate the design development methodology carried out by the teams a selection of the above topics shall be chosen. Depending on the importance of each one, a different weight factor may be applied.

This activity must be done before the safety performance workshop in IDIADA.

The HARA performed by the organization team is available in deliverable D2.5 [4]. It should be taken as a reference for the participating teams to identify the hazards, the safety goals, and the technical safety requirements amongst others.

The first station is one of the most important part of the safety check list. During the execution of the scenarios (Highway or intersection, because the emergency vehicle scenario is a demonstration), if something goes wrong in any vehicle under test, it could be dangerous for the rest of teams. It is necessary to know what to do in case that, for example, the communication between vehicles fails or is degraded, if any sensor has inaccurate inputs or if the behaviour of some vehicle is wrong.

The **Error! Reference source not found.** shows a list of the requirements to the teams in advance to the workshop including logistics information, confidentiality agreements and the functional safety briefing self-assessment.

Station 2: Administrative checks

The second station consists in providing relevant information related with the people that conform the team, the vehicle documentation, vehicle characteristics and, if it is necessary, a list of any limitation of the vehicle which could compromise the competition.

The participants shall present the following documentation (further information may be required):

1. Team details

   Information related with the drivers, passengers, assistants and so on. More specifically, the team will inform about:

   - Who is the responsible of the test?
   - Who is the driver? Does he/she have a valid driver license?
   - Who is/are the possible co-pilots? Do they have valid driver licenses?

2. Vehicle documentation

   In this part it is necessary to indicate the documentation of the vehicle under test:

   - Brand, Model, Category, Insurance, License plate number, Chassis number, Country of consignment

3. Vehicle characteristics

   - Power, Fuel, Type of vehicle (Diesel, Hybrid, electric, etc.), Maximum speed (Km/h), Type of traction, Distance between axes (mm), Height at centre of gravity (mm), Width (mm), Stability factor, Weight of the vehicle (Kg.), ESP, ABS and Airbag

4. List of any vehicle limitation that could compromise the competition

   If there is any limitation of the vehicle under test which compromises the competition, or in other words, if some value indicated in the previous section differs from the limits indicated for the competition, this list must indicate what is it, and its limitation. These values should be speed limit, minimum acceleration, maximum deceleration, etc.

Station 3: Visual inspection

Once the stations 1 and 2 are passed, the third station will determine if the vehicle is safe to drive before starting the dynamic tests of the next stations. The vehicle under test has been submitted to some changes: external devices installed, sensors connected to the vehicle, emergency button installed, modified actuation, etc. For this reason it is necessary to perform a visual inspection through a static safety check of the vehicle, paying attention to the most important topics:

- Are there any devices that obstruct the driver's tasks (steering wheel, brake and throttle pedals, gearbox, etc.)?
- Is the emergency button easily accessible for the driver and co-driver?
- Is the additional equipment safely installed and fixed into the vehicle?
- Is the participant identification number visible?
- Safety belts, airbags and other standard safety equipment shall work as intended.

From now on and until the last station, the tests will be performed at IDIADA during the safety/performance workshop. While some vehicles perform tests in the proving grounds with other vehicles, the rest of the teams will perform other stations in the boxes.

Station 4: Vehicle manual control

This station will assess if the vehicle maneouverability and dynamics are safe enough and the vehicle is allowed to perform tests in IDIADA PG. The station will also check if the automated features can be overriden by the driver by acting on the vehicle actuators and thus regaining and maintaining control of the vehicle in manual mode.

Dynamic safety check

Once the static safety check in Stations 3 has been performed and verified, a dynamic Safety Check will be performed. This consists of a series of checks on the proving ground in a defined order to ensure that the vehicle's behaviour is correct enabling it to be tested safely. More information can be found in Appendix C. To perform the dynamic Safety Check, the operator must have the IDIADA's C2 level driving license.

On the proving ground, the following verification is performed: speedometer, driving in a straight line, curve exit, swerving in the same lane, braking up to 0.5g braking to lock or ABS activation, with speeds up to 50 km/h, ¾ throttle acceleration up to 80 km/h, straight line driving up to 120 km/h, and an overall evaluation up to 120 km/h.

In the context of the iGAME Safety/Performance workshop there are two main differences with the usual IDIADA internal procedure:

- As some of the vehicles cannot go as fast as what the tests describes, the maximum speeds were set according to the speeds to be used in the GCDC Highway scenario.
- The dynamic safety check is divided in two stations: Station 4 and Station 6. This was done intentionally as the manoeuvre tests had to be made in the same dynamic platform as the override tests, while the braking checks had to be made in the braking test track and thus in terms of logical process and internal organisation it was decided to separate them.

Override of the automated mode

The automated mode must be instantly overridden by the driver going to manual mode by doing one or more of the following actions. Before the automatic mode will be overridden, the deviations, noises and anomalies will be checked. These actions are done in order to avoid any situation of risk. Below there are described the different test cases that are going to be performed to ensure the safety of the vehicle:

a) Emergency button

When the driver presses the emergency button due to an emergency situation, the driver takes over the control of the vehicle.

Table 4: Emergency button use case

Use case ID	UC_Emergency_Button
Goal	After the driver has pressed the emergency button, the automated mode is overridden and returned to manual mode as a safety manner.
Short description	Driving in automated mode an emergency situation is simulated. Then, the driver presses the button and the vehicle has to get the control back to the driver.
Pre-conditions	The automated mode of the vehicle is on when starting the test.
Main-flow	1. Driving through a lane in automated mode. 2. The driver detects some abnormal situation. 3. The driver presses the emergency button. 4. The automatic mode of the vehicle is disabled as a safety action and the driver gets the control back to him/her. 5. The vehicle is stopped.
Post-conditions	The performance of the automated mode has been intercepted due to abnormal conditions so the driver took over control and stopped the vehicle.

b) Throttle pedal override

To check the normal motion:

Straight line driving up to 50 Km/h: check deviations, noises or other anomalies.

Throttle override:

Table 5: Throttle pedal override use case

Use case ID	UC_Throttle_Pedal_Override
Goal	After the driver has pressed the throttle pedal, the automated mode is overridden and returned to manual mode as a safety manner.
Short description	Once the system detects that the driver has pressed the throttle pedal, the automated system of the vehicle is disabled and the driver takes over the control of the vehicle.
Pre-conditions	The automated mode of the vehicle is activated.
Main-flow	1. The vehicle starts in the automated mode in the straight line at 30 Km/h (or maximum speed allowed by the vehicle) and with asphalt with friction coefficient > 0.9. Max and mean decelerations measured as in ISO 43.040.40. 2. When the vehicle decelerates down to 25 Km/h the driver makes maximum acceleration
Post-conditions	The autonomous mode is disabled.

c) Brake pedal override

To check the normal motion:

1. 0,5G braking with initial speeds of 50 Km/h.
2. Braking up to blocking or ABS activation with initial speeds up to 50 Km/h.

Braking pedal override:

Table 6: Brake pedal override use case

Use case ID	UC_Brake_Pedal_Override
Goal	After the driver has pressed the brake pedal, the automated mode is overridden and returned to manual mode as a safety manner.
Short description	Once the system detects that the driver has pressed the brake pedal, the automated system of the vehicle is disabled and the driver takes over the control of the vehicle.
Pre-conditions	The automatic mode of the vehicle is activated.
Main-flow	1. The vehicle starts in automated mode at 30 Km/h (or maximum speed allowed by the vehicle under test) in straight line & with asphalt with friction coefficient higher than 0.9, and runs 200 meters without driver intervention (maximum and minimum decelerations measured as in ISO 43.040.40) 2. After 100 meters, the driver applies a maximum 300 N force on the brake pedal (Maximum deceleration above 0.8 m/s^2, average deceleration above 0.7 m/s^2). 3. The automated mode is overridden and returned to manual mode.
Post-conditions	The driver has taken over the control of the vehicle in safety conditions.

d) Steering override

To check the normal motion:

1. Curve up to 50 Km/h: check auto return of the steering wheel, vibrations, noises and other anomalies.
2. Slalom left-right to check stability and control.

Steering override:

Table 7: Steering override use case

Use case ID	UC_Steering_Override
Goal of use case	After the override, the automated mode must be turned off and the driver takes over the control of the vehicle.
Short description	Once the system of vehicle detects override of the automated mode with a maximum 10 N torque (torques higher than 10 N to override the automated mode is unacceptable), the automated mode must be completely off and the driver takes over the control of the vehicle.
Pre-conditions	The automated mode of the vehicle is activated.
Main-flow	1. The vehicle drives in automated mode at 30 ±1 Km/h during 100 meters in the straight line. 2. The torque applied to the vehicle (left or right) is less or equal to 10 N.

	3. The automated mode is overridden and disabled. 4. The driver takes over the control of the vehicle.
Post-conditions	The driver has taken over the control of vehicle in safe conditions.

e) Electronic parking brake (if installed)

In normal conditions, the electronic parking brake will be activated after the vehicle will be stopped, but if something goes wrong the electronic parking brake can be activated at any time. This test was not implemented in the GCDC but is left in this deliverable for information purposes.

Table 8: Electronic parking brake use case

Use case ID	UC_Electronic_parking _brake
Goal of use case	If something goes wrong can stop the vehicle at any time as safety manner.
Short description	Once a dangerous situation is detected by the driver, he/she can stop the vehicle through the electronic parking brake.
Pre-conditions	The automatic mode of the vehicle is on and the performing of the test is being done.
Main-flow	1. Normal performing of the test. 2. The driver detects some abnormal situation. 3. The driver activates the electronic parking brake. 4. The automatic mode of the vehicle is disabled as a safely manner. 5. The vehicle is stopped.
Post-conditions	The performing of the tests has been intercepted due to abnormal conditions so the vehicle stopped.

In the transition from automatic mode to manual mode the driver shall regain full vehicle control when disabling the controller. This intervention is meant to be the last safety mechanism in case of a total system failure.

To design all the override tests described in this Station, a Working Instruction (WI) was created by IDIADA and used to finally describe all the different stations. This WI gathers all the requirements and procedures which should be taken into account when performing such kind of tests. IDIADA internal and external Quality Controls (IDIADA is a certified ISO 170025 laboratory) are based in this kind of WI. The nature of the situation, which deals with prototype vehicles with non-commercial solutions and approaches, leads to adapt these procedures in the WI so it can be feasible to carry out all the testing needed to ensure the safety of the participants. Such WI can be found in Appendix A.

Station 5: Communication protocol checks

During the workshop the Teams communication implementation was individually assessed. When these tests were passed succesfully, teams could participate in more advanced Interaction performance assessments in dynamic GCDC scenario settings. The first two days for each group was used for the communication protocol checks. This is a basic assessment validation of the communication implementation of the teams. The checks are used to assess if the teams support the GCDC communication architecture and message sets (requirements coming from D3.1 [5] and D3.2 [6]).

For this two communication units are set-up as an Roadside unit (RSU) for logging and monitoring of the V2V messages during the workshop. In addition also a communciation unit is available for evaluation and testing of logging requirements as part of Judging criteria task (D7.1 [7]). Additional logging is also done on the communication units used by the Reference Vehicles.

The RSU's are also used to generate some test messages CAM, DENM and iCLCM messages to check if the teams can correctly receive and decode the messages needed for the GCDC. The teams must be able to generate CAM and iCLCM messages. This is basic generation (encoding and sending) of the messages with some preset values. For the Interaction performance testing teams must also be able to use the vehicle control system and application software to set some of the CAM and iCLCM message fields.

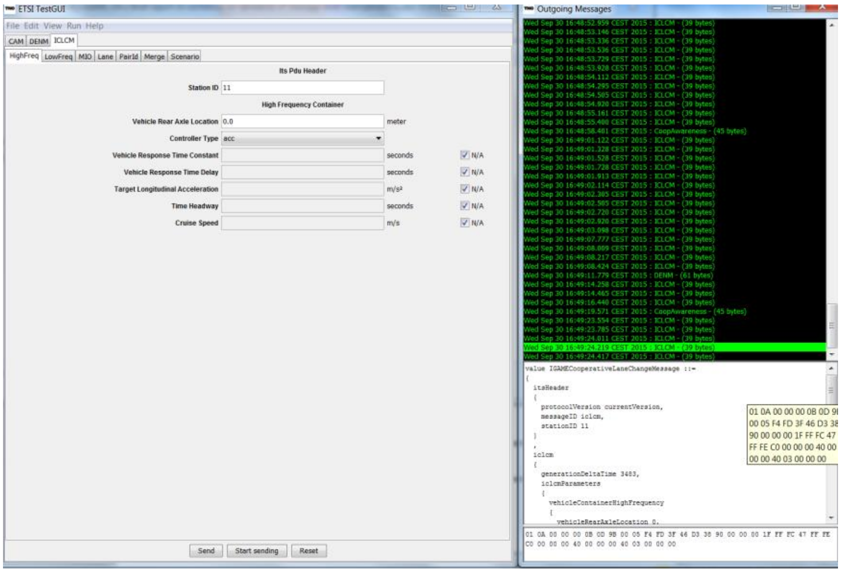


Figure 7: Message generation tool used by RSU during workshop

A detailed description of the communication performance tests, methodologies and tools can be found in D4.3 [8].

Station 6: Braking safety check

The aim of this test is to evaluate the performance of the vehicles brakes as part of the dynamic safety check (for organisation purposes these are divided in two different stations). This test is carried out by a professional driver from IDIADA with the required driver license.

Table 9: Braking system use case

Use case ID	UC_Braking_System
Goal	To brake till the vehicle stops.
Short description	This use case consist on evaluate the performance of the vehicle brake due to a simple test carried out by the driver.
Pre-conditions	Vehicle is driving properly.
Main-flow	1. The vehicle accelerates until to stabilize at 40 Km/h.
	2. Keep this speed stable for 4 seconds.

	3. Brake till the vehicle stops.
Post-conditions	The vehicle shall stop within the pass range criteria: - 15.3 meters (-5.2 m/s^2) - 18.9 meters (-4 m/s^2).

Station 7: Data validation and accuracy check

The teams should log the V2X message fields that are relevant for judging. These fields are shown in Table 4. Each entry (row) in the table provides information for a field: 1) its index, 2) its name, 3) the message type it belongs to, 4) the resolution of this field and 5) its default value when the actual value is unavailable. Each vehicle, during each test, should log these fields either in MAT or CSV format. These fields are also described in the deliverables D7.1 [7] and D3.2 [6]. and the complete procedure may be found in D4.3 [8].

Table 10: The message logging fields for judging

ID	Message field name	Protocol	Resolution	Default value (When unavailable)
1	CAM GenerationOrReceptionTime	-	MilliSeconds	0
2	DENM ReceptionTime	-	MilliSeconds	0
3	iCLCM GenerationOrReceptionTime	-	MilliSeconds	0
4	StationID	CAM	-	0
5	StationType	CAM	-	0
6	VehicleLength	CAM	0.1 Meters	0
7	VehicleWidth	CAM	0.1 Meters	62
8	Latitude	CAM	0.1 MicroDegree	900000001
9	Longitude	CAM	0.1 MicroDegree	1800000001
10	Heading	CAM	0.1 Degrees	3601
11	Speed	CAM	0.01 MeterPerSec (m/s)	16383
12	LongitudinalAcceleration	CAM	0.1 MeterPerSecSquared (m/s^2)	161
13	ReferenceTime	DENM	MilliSeconds	0
14	EventType CauseCode	DENM	-	0
15	VehicleRearAxleLocation	iCLCM	0.01 Meters	0
16	MioID	iCLCM	-	0
17	MioRange	iCLCM	0.01 Meters	65535
18	MioBearing	iCLCM	0.002 Radians	1572
19	MioRangeRate	iCLCM	0.01 m/s	32767
20	TimeHeadway	iCLCM	0.1 Seconds	361
21	CruiseSpeed	iCLCM	0.01 m/s	5001
22	MergeRequest	iCLCM	-	0
23	MergeSafeToMerge	iCLCM	-	0
24	MergeFlag	iCLCM	-	0
25	MergeFlagTail	iCLCM	-	0
26	MergeFlagHead	iCLCM	-	0
27	AcknowledgeFlag	iCLCM	-	0
28	ForwardID	iCLCM	-	0
29	BackwardID	iCLCM	-	0

30	PlatoonID	iCLCM	-	0
31	DistanceTravelledCZ	iCLCM	0.1 Meters	0
32	Intention	iCLCM	-	0
33	Lane	iCLCM	-	0
34	CounterIntersection	iCLCM	-	4
35	StartPlatoon	iCLCM	-	0
36	EndOfScenario	iCLCM	-	0

This station was organised in such a way that it could also take advantage of the other stations' tests as extra opportunities to log more data that could be assessed in this one.

Station 8: Benchmark platooning scenario

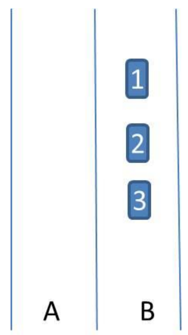
The objective of this test is to check the participant's ability to operate in a platoon, to follow speed commands, to communicate appropriately, and to provide the correct state information at the required update rate and with the required accuracy. It is the evaluation performance from the previous tests in a real situation. The tests are described in 'D4.3 Brief report on workshop on validation of interaction performance' in which more detail can be found. Two types of tests were defined:

1) **<u>platooning functionality and robustness</u>**

The first round of tests would be with three cars driving in a platoon, as seen in Figure 8. The middle car, car 2, would be the vehicle under test (VUT). All cars should be in an automated vehicle following mode. A range of tests with different velocities and headway time would be done as listed in Table 11. The purpose of these tests is to check:

1. Wireless message exchange
2. Vehicle following functionality
3. Capability of VUT to handle disturbances as applied through braking/acceleration of the lead vehcile, communication failure, and cut-in

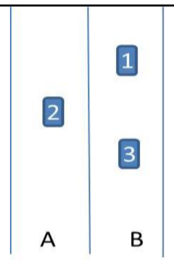
Table 11: Platooning functionality and robustness

	Testnr.	*Test description*
 **Figure 8: Cars driving in platoon**	**1.a.1-1.a.7 (vehicle following)**	• Stand still distance of r=2.5 m and different combinations of cruise speed and headway time are chosen as {50,1.5}, {80,1.5}, {100,1.5}, {100,1.2}, {100,1}, {80,1}, {50,1} • Vehicle following functionality as well as wireless message sent/receipt are tested.
	1.b (braking)	• Cruise speed of 50kph and h=1.5 s and r=2.5 m are chosen. • The lead Vehicle (1) will apply some hard braking (-2m/s^2 deceleration) and the safe braking reaction of VUT is verified.
	1.c (cut-in)	• Cruise speed of 50kph and h=2 s and r=2.5 m are chosen. • Vehicle 3 will overtake and cut in front of VUT
	1.d (communication failure)	• Cruise speed of 50kph and h=1 s and r=2.5 m are chosen. • The V2V communicatio is set off to see how teams respond to communication failure.

2) <u>Merging scenario with three cars</u>

In this part a simplified highway scenario with three cars was used for functionality tests in order to check the readiness of the teams to perform a simple merge of three vehicles.

Table 12: Merging scenario with three cars

	Testnr.	*Test description*
 **Figure 9: Three cars merged driving in platoon**	**2.a**	**3 Vehicles testing** The headway time is set at 1s. Vehicle 1: cruise control mode, acting as an OPC (Organization Pace Car), platoon ID=2, scenario=1 Vehicle 2: cruise control mode, platoon ID=1, scenario=1, lead vehicle flag=1 Vehicle 3: vehicle following mode, platoon ID=2,scenario=1

Station 9: Benchmark intersection scenario

The objective of this test is to qualify the participant's ability to operate in an intersection scenario, simulating a negotiation/coordination between the PV (Participant Vehicle) and other vehicles on the upcoming road intersection. The same methodology and data accuracy checks will be carried out as shown in the 'platoon scenario'. The tests are described in 'D4.3 Bief report on workshop on validation of interaction performance' in which more detail can be found.

The purpose of this test is to check the formation of the virtual platoon, and the safe crossing of vehicle 1, see Figure 10 where vehicle 2 is the VUT. Note that vehicle 1 always has higer priority to cross the intersection. The intersection data, such as the radius of the Competition Zone (CZ), the orientation and position of the Intersection Reference Frame [1], will be provided to the teams once the identification of the intersection has been performed. Two types of tests are planned, one with 2 vehicles involved and the other one with 3 vehicles if the previous one was succesful in which an extra merging is consequently performed.

- The test starts with the vehicles positioned at a distance *d*, which is described below, from the Competition Zone (CZ), see Figure 11.
- The vehicles are required to follow a velocity profile, described below, that will ensure that they enter the CZ at the same time with the same velocity *v*=30kph.
- Once inside the CZ, vehicle 2 has to modify its velocity to allow vehicle 1 to cross the intersection.
- When vehicle 1 has crossed the intersection, the interaction between vehicles has to be cancelled and vehicle 2 has to switch to Cruise Control.

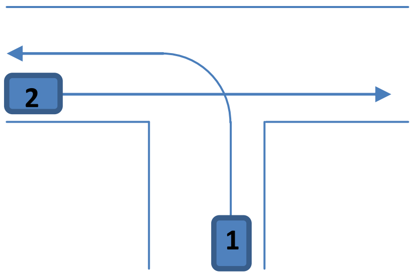


Figure 10: Intersection scenario

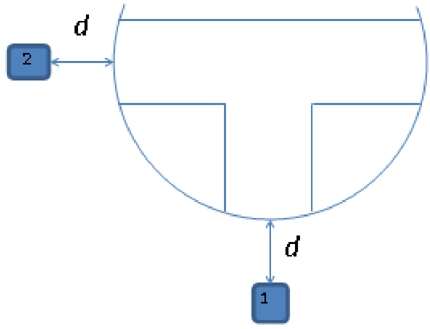


Figure 11: Competition Zone (CZ)

In order to enter the CZ at the same time with the same velocity, the vehicles have to be able to follow a linear velocity profile that goes from v=0 to v=30kph(8.3m/s) with a constant acceleration a=2m/s^2, this acceleration is specified in [4]. So, it is straight forward to calculate that the distance outside de CZ is given by

Table 13: Intersection scenario tests

Testnr.	*Test description*
3.a	**2 vehicles testing** The headway time is set at 0.5s. The stand-still distance is set at 15m. Vehicle 1: cruise control mode, acting as an OPC and leader of virtual platoon, scenario=2 Vehicle 2: cooperative intersection control mode, following vehicle 1 in the virtual platoon, scenario=2
4.a	**3 vehicles testing** The headway time is set at 1s. Vehicle 1: cruise control mode, acting as an OPC, platoon ID=2, scenario=1 Vehicle 2: platoon ID=1, scenario=1, lead vehicle flag=1 Vehicle 3: platoon ID=2,scenario=1

2.4 Working blocks

In order to be time efficient and be able to test all the vehicle safety and performance tests scheduled, the stations were allocated in different working blocks. There were several working blocks in parallel so each team was always performing some tests or collaborating with other teams. The working blocks, stations and tests were also organised so the blocking stations (stations that must be passed before moving to the next one i.e. safety check before dynamic check) could be passed sequentially. All these activities took place in different venues inside IDIADA, including workshops and test tracks.

Visual inspection / Safety briefing

In this working block two activities were done in parallel:

- Visual inspection of the vehicle according to the tests and requirements described in the associated stations. This station took place in the workshop IDIADA conditioned to be used during the event.
- Safety briefing for the team's drivers. Following the safety internal regulation, the designated drivers had a 2 hour session of theoretical information of IDIADA's rules to drive in the test tracks. The completion of this briefing grants the D-level driving license, minimum driving level according to IDIADA driving expertise criteria, which allows the driver to perform certain maneouvres in certain

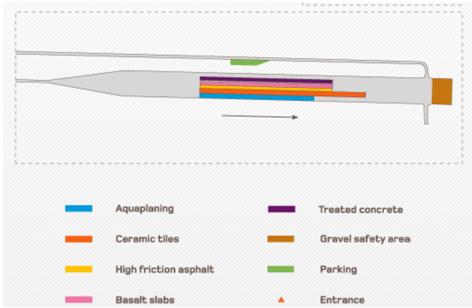
test tracks. The drivers with this license were allowed to drive during the performance tests and moving with their vehicles from one track to another. The maneouvres not covered by the license were performed by IDIADA professional drivers i.e. brakes check. The safety briefing took place in IDIADA auditorium and was imparted by our Labour Risk personnel.

Data communication protocols

The data communication protocol checks were executed in a testbed prepared in the iGAME reserved workshop box by WP3 technical leaders. Some images from the setup can be found in D4.3.

Braking checks

The brake evaluation according to the GCDC requirements and IDIADA safety check were performed in the brakes test track of IDIADA which is shown in Figure 12 and is track/area 7 in Figure 5.



Surface	Adherence	Water thickness	Width	Length	Longitudinal gradient	Transverse gradient	Max weight per axle
Ceramic tiles	0.1	1 mm	7,5 m	250 m	0%	1% double gradient	1.75 T
Asphalt	0.8	1 mm	5mm	200 m	0%	1%	16 T
Basalt slabs	0.3	1 mm	7,5 m	200 m	0%	1% double gradient	13 T
Concrete	0.4	1 mm	7 m	200 m	0%	1% double gradient	16 T
Aquaplaning		6 mm	3,5 m	150 m	0%	0%	16 T

Figure 12: IDIADA's brakes test track

Vehicle manual control and Data accuracy

The vehicle manual control included the dynamic safety check as well as the override tests. This working block took place in the Dynamic Platform C which is used for ADAS and C-ITS testing for development and type approval purposes and fulfills Euro NCAP testing requirements. The logged data can be used in Station 7 and WP7 judging requirements to the teams.

Figure 13: Dynamic Platform C

Performance tests

Platooning benchmark

The High Speed Track of Applus IDIADA was closed to other vehicles during the platooning performance testing. This track allows speeds up to 250 kph and has a neutral speed of 180 kph in its outer lane, allowing extremely high speed and accelerations in a safe environment that emulates a highway.

Direction of travel	Clockwise
Length lane 1	7.493 m
Length lane 2	7.513 m
Length lane 3	7.546 m
Length lane 4	7.579 m
Length of straights	2.000 m
Neutral steer speed	200 Km/h
Maximum banking bend	80% (38.66º)
Radius of the bends	471 m
Longitudinal gradient (straights)	0.3%
Transverse gradient (straights)	1.0%

Figure 14: IDIADA’s High Speed Track

Intersection benchmark

The intersection scenario took place in part of the general road of IDIADA. One week before the venue, the lane markings were painted again taking into account the testing requirements of the safety/performance workshop. This T intersection emulated the conditions of the intersection to be used during the GCDC. For the workshop, the intersection was closed to traffic and secured by our security management.

Figure 15: IDIADA's intersection scenario

2.5 Equipment used

During the dynamic tests different tools were used to guarantee accurate measurements of the vehicles. Thse tools and equipment are regularly used by IDIADA for commercial testing purposes and are periodically calibrated in order to guarantee maximum accuracy and minimise errors and noise in the measurements.

OXTS GPS receiver

The OXTS GPS receiver is a device that uses Intertial and GPS Navigation systems for measuring motion, position and orientation. It combines precision Angular Rate Sensors and navigation grade Accelerometers, a survey grade GPS receiver and an Advanced Navigation Computer to form an Inertial Navigation System aided by GPS in one very compact box. It was originally designed for automotive engineers to measure the behaviour of vehicles.

Using the intertial sensors for the main outputs gives the device system a fast update rate (100Hz) and a wide bandwidth. All the outputs are computed in realtime with a very low latency. The device outputs its realtime measurements over CANbus, RS232 and Ethernet and it can achieve measurements accurate to 0.01 meters (it requires differential corrections from a suitable base-station). It has 2GB for logging and an easy and short 5 minutes installation (also upgradeable in the future).

The best known applications for this device are: vehicle dynamics testing, slip angle measurement, brake testing, tyre testing, ESC testing and steering robot guidance.

Figure 16: OXTS GPS receiver

DGPS Radio-modem

Differential GPS Radio-modem transfers data wirelessly over a point-to-point or point-to-multipoint link. Radio modem based data transfer is usually used in mission-critical applications where reliability and latency of the data transfer are essential to the operation of the system. Radio modem network is independent of mobile and satellite network operators and no cost is associated with data transfer. Private radio modem networks can use either unlicenced or licenced frequency bands.

The operation range varies depending on the transmission power, antenna gain and mast height and environment. In rural areas a 1 W radio modem with a line-of-sight radio link may range over 20 km and even up to 50 km in ideal environments. In dense metropolitan areas, a corresponding range may vary from several kilometres to over 10 km. With a 35 W radio modem, a range of up to 100 km can be reached. By using a radio modem as a repeater station, much broader areas can be covered.

Figure 17: DGPS Radio-modem

DGPS Base Station

The DGPS Base Station is designed to improve positional accuracy by calculating and transmitting differential correction data. By programming the Base Station with a known position, it is able to accurately monitor the difference between its programmed position and the position that it is receiving via GPS. The difference is then transmitted via radio to allow a remote GPS system to correct its position. The differential correction message can be broadcasted in RTCM, CMR or proprietary RTK formats using an internal or mast mounted radio modem transmitter.Depending on the type of Base Station, position accuracies of up to 2cm are available.

The inputs are from the GPS antenna which has to be placed in a position away from any other obstacles that could cause satellite signals to be blocked or reflected and from the power which can be obtained either from the internal battery supply or from an external source via a front panel. The outputs are from the Radio

Antenna which has to be placed in the highest available position in order to realise the maximum possible transmission range.

Applus IDIADA has one of this base stations installed in its control tower and pays the license of a broadcasting band to offer DGPS coverage in all its test tracks.

Figure 18: DGPS Base Station

Euro NCAP target

The Euro NCAP vehicle target was developed to simulate the rear end of standard production car. Is uses the current standard vehicle image and is suitable for camera based systems. The cover also incorporates reflective elements to aid LiDAR based technology.

The vehicle target consist of one Balloon car, a cover, a tray frame and a bumper element. The balloon car is an inflatable balloon capable of impacts at 50kph. The cover is the outside which is covered with the image of the VW and the added reflective material. The tray supports the target allowing it to move along the ground when hit and the bumper element gives contour to the Target which contains radar reflective component. The radar signature is 77Ghz and the pressure 250mbar.

The most common applications for this product are Autonomous Emergency Braking (AEB), Emergency Steer Assist (ESA) and Forward Collision Warning (FCW).

Figure 19: Euro NCAP target

3 Summary of the workshop

3.1 Challenges and problems during the workshop

The big challenge was to organize all the tests to be performed by the teams, which were at different stages of implementation. The goal was to execute them in a common way in order to acquire useful and coherent data in a fast an efficient way taking into account that some stations were blocking, meaning that it was not possible to go to the next one before passing the previous one.

Another major challenge was to fit all the activities in a short period of time (one week) so the teams did not lose excessive development time while attending the workshop. Some of the teams were initially reluctant to participate because of fear for delay in their development taking into account the workshop itself and the transport time of the vehicles. Nevertheless at the end of the workshop they expressed to the organisation their satisfaction, not just for the results, but because of the big progress they were able to make during the workshop thanks to the constant dialogue with the organisation and other teams.

The breakup in working blocks allowed us to minimise the duration of the workshop and still allow the teams to have quality time for their own development or with other teams. As a trade-off, having several working blocks in parallel, lead to a more complex organisation as each team would be in different stations and test tracks which required more resources from the organisation at the same time.

It was also necessary to be versatile enough to cover the different team's needs in terms of tools and equipment as well as special requirements for each of them, e.g. a special charger for an electric vehicle of one of the teams.

The workshop also had different unpredictable problems that were solved at the moment and that affected the vehicles (damaged batteries, burnt electronic components) or the organisation itself (rain during one morning delayed part of the tests). Mitigation solutions were put in place in advance and some extra time was already taken into consideration so the delay and technical problems could be solved in a timely manner without impacting the objectives.

3.2 Documentation

Different documentation was requested from the teams in order to make all the arrangements needed before arriving to IDIADA.. The teams dilligently sent the information in time and according to our needs and requirements. Certain difficulties raised during the logistics organization specially because of the transport times to bring the vehicles to IDIADA. Easter holidays and the prohibition of heavy truck transport on Sundays in France and Germany, caused a time delay and consequently the vehicles had to be picked up before. As a lesson learned for future workshops in which the several stops have to be made to pick-up vehicles, these should be organised taking into account national legislation and holidays. The return trip, on the other hand, was very fast, even arriving earlier than expected.

3.3 Static Safety check

All the vehicles passed the static safety check, except one participants car, which needed brake pads and discs replacement and, consequently, the override tests were not made. This issue was solved before the GCDC and the different override functionalities could be checked before the competition, allowing the vehicles that were able to participate (that also passed the communication and interaction minimum performance) to finally take part in it.

3.4 Dynamic Safety check

Before the override tests, the dynamic safety check, which includes basic dynamic maneuvers to check the drivability of the vehicle, was performed for every team that passed the static safety check. All were successful and allowed them to start the override station.

3.5 Override tests

The override tests were performed on one of the IDIADA's dynamic platforms following the procedures described in the previous section.

As a summary, most of the tests were successfully passed for every team except several specific issues which were identified in some of the override tests. The mentioned participants car (which needed replacement parts) did not perform the overrides due to previously explained reasons, which were solved before the GCDC. Moreover, due to justified timing and implementation issues, not all of the teams were able to provide logging information about their automated driving system's behavior and not all of them had implemented their override systems according to the GCDC requirements, and those that could give us some information, would not follow the GCDC guidelines (so for the validation of results, taylor-made conversion scripts had to be implemented). For some of these teams, specific variations of the tests were executed with the mandate to solve their implementation and adjust it to the GCDC requirements before the competition. For instance, a team had the override functionality implemented but was not applied to the vehicle controls, just to the emergency button and a joystick control. To be able to assess the override functionality the joystick control was used instead of the steering wheel and a pre-programmed trajectory was set.

One of the lessons learned in the workshop and the iGAME project in general, is that the presence of the teams in these kind of events forces them to make big progress in their development in order to commit deadlines. The safety/performance workshop was, in words of the different teams, a great opportunity to make this progress a reality because of the direct contact with the organisation and the rest of the teams, being able to comment, learn and share views on the different topics and challenges and thus aligning their efforts more efficiently before the GCDC

In D4.4 [9] an overview of the safety status of the teams after the safety workshop can be found, including their status for the static and dynamic safety checks and the override tests.

3.6 Communication tests and data accuracy

The teams invested a lot of hours in the communication protocol tests and there was a huge improvement in their ability to communicate. An overview of the results in the communication tests and data accuracy can be found in D4.3.

Regarding the data accuracy, we experienced the same issue as in the override tests. Some of the teams had not implemented the logging functionality, and those who did, had not followed the guidelines and settings in terms of data format and accuracy from the organisation. Consequently, this put an extra difficulty in the accuracy assessment as well as in the detailed assessment of the results.

3.7 Performance tests

Due to the difficulties and lack of development of the communication protocols, the performance tests in both highway and intersection were not as succesful as originally planned. Some of the most mature teams, with the communications in place were able to participate in the tests together with the benchmark vehicle whereas other teams could only make preliminary tests of their implementations. More information on the performance tests can be found in D4.3

4 General impressions and conclusions

During the six days of the workshop both organization and teams worked hard in a full and extensive program, while at the same time enjoying a pleasant and quite informal environment. In the workshop box there were amenities such as kitchen and meeting rooms enabling a lot of interaction between teams and between teams and consortium. This helped the GCDC crew to create bonds and confidence, which proved to be very useful in the following weeks and before the competition.

In terms of organisation, the workshop can be considered a success as all the tests could be performed in a timely manner (although with different results) and there were no big issues that could not be solved. Some logistics issues raised before the workshop and some lessons were learnt in terms of timing and national transport legislation.

Regarding the teams, it is also worth to mention that there were huge differences in their state of development. Although some of the teams had very advanced vehicles, others still were pretty “early-stage-of-developement” and could not take part in some of the tests. Nevertheless all the teams recognised that the workshop had been very helpful as they could make a lot of progress during that week and could go back home with good ideas and a clear path to follow to be able to participate in the challenge.

The defined tests proved to be very efficient in order to estimate the safety and performance status of the vehicles. The override test cases and methodology proved to be specially useful as many deviations from the teams regarding the safety requirements could be identified while setting a minimum safety for the GCDC.

Finally, it is needed to say that the safety/performance workshop has been a good initiative that has helped both organization and teams progress and share knowledge in preparation for the GCDC.These physical meetings where the vehicles are present are a key tool for both monitorizing the status of the teams but also boosting their productivity. However, they need to be carefully organised in terms of timing (not too late or too soon) and taking into account the financial support of the teams (which was highly variable).

5 References and documentation

[1] ISO International Standard, “Road vehicles – Functional safety,” ISO Standard 26262, Rev. Nov. 2011.

[2] i-GAME D4.5 “Safety analysis of scenarios and requirements”, P. Balaguer, A. Aparicio, A. Arrue, R.J. Bril, and J. Didoff, Final version.

[3] GCDC 2011, Rules and Technology Document, Grand Cooperative Driving Challenge, Final version 2.0.

[4] i-GAME D2.5 – “Protocol for the transition of control”, E. van Nunen, L. Garcia-Sol, P. Balaguer, D. Willemsen, J. Ploeg, Final version.

[5] i-GAME D3.1 – “Wireless communication basic specification document”, J. van de Sluis, Final version

[6] i-GAME D3.2 – “Proposal for extended message set for supervised automated driving”, J.van de Sluis, O. Baijer, L. Chen, H. Hoang Bengtsson, L. Garcia-Sol, P. Balaguer, Final version.

[7] i-GAME D7.1 – “GCDC judging criteria”, H. Salunkhe, H. Hooft van Huysduynen, B. Nijssen, J. Terken, Final version.

[8] i-GAME D4.3 – “Brief report on workshop on validation of interaction performance”, J. van de Sluis, E. Emsar Kazerooni, Final version.

[9] i-GAME D4.4 – “Brief report on workshop on validation of safety”, A. Ruano, Final version.

[10] Euro NCAP. (June 2015) Test protocol – AEB systems. Version 1.1.

[11] ISO 43.040.40: Braking Systems.

6 List of abbreviations and terms

Architecture
Representation of the structure of functions or systems that allows identification of building blocks, their boundaries and interfaces, and includes the allocation of functions to hardware and software elements. It could be applied to vehicle, software & hardware architecture

ASIL
Automotive Safety Integrity Level is one of four levels to specify the necessary requirements of ISO 26262

DIA
Development Interface Agreement is an agreement between customer and supplier in which the responsibilities for activities, evidence or work products to be exchanged by each party are specified

E/E System
Electric & Electronic System consists of electrical and/or electronic elements, including programmable electronic elements

FMEA
Failure Mode Effect Analysis. Failure mode refers to the way in which something might fail and includes any potential error that may occur; Effect analysis involves deciphering the consequences of those failures by determining how frequently a failure might occur, making sure that failures can be detected and identifying which potential failures should be prioritized.

FTA
Fault Tree Analysis is a top down deductive failure analysis in which an undesired state of a system analyzed using Boolean logic to combine a series of lower-level events

Functional requirement
Specification of implementation-independent behavior, or implementation-independent measure, including its related attributes

Hazard
Potential source of harm

HARA
Hazard Analysis and Risk Assessment is a method to identify and categorize hazardous events of items and to specify safety goals and ASILs related to the prevention or mitigation of the associated hazards in order to avoid unreasonable risk

ISO
International Organization for Standardization

Item
System or array of systems to implement a function at the vehicle level, to which ISO 26262 is applied

MISRA
Motor Industry Software Reliability Association

PSA
Preliminary Safety Analysis defines the proposed system and describes how it is intended to work

PV
Participant vehicle

RACI
Responsible, Accountable or Approver, Consulted, Informed table shows a responsibility assignment matrix that describes the participation by various roles in completing tasks or deliverables for a project

Requirement
What the end user expects from a system

Risk
Combination of the probability of occurrence of harm and the severity of that harm

Safety integrity
Degree of confidence in a safety-related system satisfactory performing the required safety functions under all the stated conditions within a stated period of time

SIL
System Integrity Level

System
Set of elements that relates at least a sensor, a controller and an actuator with one another

Traceability
Traceability links between various requirements, design and implementation choices

Validation
System fulfils its requirements implicit human needs (it shall answer the question: Did we build the right product?

Verification
System fulfils its requirements explicit specification (it shall answer the question: Did we build the product right?)

7 List of figures

8 List of tables

Appendix A Documentation requirements and deadlines

To be able to participate in the Safety/Performance workshop all required documentation listed in this chapter must be sent to aitor.ruano@idiada.com before the respective deadlines.

A.1 Logistics documentation requirements (07/02/2016)

If the team is willing to take the vehicle/s to IDIADA by means of the truck provided by IDIADA the following information must be sent to before the 7th of February:

- Number of vehicles
- Vehicle/s dimensions (total height, length and width)
- City/ies of procedence of the vehicle/s
- Group of preference (1 or 2).
- Copy of the insurance of the vehicle (if any)

Take into account that if you want IDIADA to organise the vehicle transport to Spain, IDIADA will decide which group you will be assigned to due to organisational reasons.

A.2 Participation documentation requirements (26/02/2016)

To enter into IDIADA's facilities and perform tests on the tracks the following documentation must be sent before the 26th of February:

- Name, ID or Passport Number of participants
- Passport photograph of participants
- Filled Risk Assessment document (attached with this document)
- Commitment to Secrecy: To be filled by each team member coming to IDIADA. Must be delivered BY HAND in the first entry to IDIADA, do not send it by email (attached with this document)
- Copy of the driving license of the participant willing to drive during the tests (we highly recommend to be the same person that will drive during the GCDC)
- Copies of the driver and vehicle insurance (if any)
- Hotel where you would like to stay (IDIADA manages booking for special offers)
- List of electronic devices you are willing to enter (laptops, tablets, phones…). For confidentiality reasons no cameras are allowed inside IDIADA's facilities.
- Indicate if your vehicle has cameras of any type, purpose, type of camera and location. IDIADA puts indicative stickers to those vehicles that have cameras installed to inform other users.
- Any special equipment or infrastructure needed to make the vehicle work correctly during the workshop should be communicated to IDIADA to set them up (i.e. lane markings, DGPS, RTK…)

A.3 Testing documentation requirements (18/03/2016)

As required by the Safety/Performance Workshop, each team must deliver a report between 10-20 pages explaining the procedure and measures taken during the design and implementation phases of the vehicle systems, taking especial attention to safety decisions (i.e. HARA tables, FMEA meetings, ISO 26262 procedures…).

The report must follow the i-Game template attached to this document. Report organization and table of contents is free but it should include any relevant information that can help the organization to know possible safety issues beforehand, if required and included in the final judging criteria it may also be used during the final judging. Deadline is the 18th of March.

Appendix B Workshop agenda and timing

The Safey/Performance Workshop will be held from the 29th of March until the 3rd of April. Due to logistic issues the execution of the workshop will be divided into two groups:

- Group 1: From the 29th of March until the 1st of April
- Group 2: From the 31st of March until the 3rd of April

Vehicles should be in IDIADA one day before the start date of the corresponding group, this are 28th or 30th of March.

26 M - W12		28 M - W13							4 A - W14		
Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed
Travelling time			Group 1				Travelling time				
		Travelling time			Group 2				Travelling time		

Workshop agenda is the following (subsceptible to changes):

Group 1	28-mar Monday	29-mar Tuesday		30-mar Wednesday		31-mar Thursday	01-abr Friday
08:30 - 09:30	Arrival of vehicles to IDIADA	Briefing		Briefing		Briefing	Briefing
09:30 - 10:30		Visual Inspection / Safety Briefing		Braking Safety Check	Vehicle Manual Control & Data Accuracy	Performance tests / Backup tests	Performance tests
10:30 - 11:30							
11:30 - 12:30							
12:30 - 13:30							
13:30 - 14:30		Lunch break		Lunch break		Lunch break	Lunch break
14:30 - 15:30		Vehicle Manual Control & Data Accuracy	Braking Safety Check	Communication protocol checks		Performance tests	Performance tests
15:30 - 16:30							
16:30 - 17:30							
17:30 - 18:30							
18:30 - 19:30		Debriefing		Debriefing		Debriefing	Debriefing

Group 2	30-mar Wednesday	31-mar Thursday	01-abr Friday		02-abr Saturday	03-abr Sunday
08:30 - 09:30	Arrival of vehicles to IDIADA	Briefing	Briefing		Briefing	Briefing
09:30 - 10:30		Communication protocol checks	Vehicle Manual Control & Data Accuracy	Braking Safety Check	Performance tests / Backup tests	Performance tests
10:30 - 11:30						
11:30 - 12:30						
12:30 - 13:30						
13:30 - 14:30		Lunch break	Lunch break		Lunch break	Lunch break
14:30 - 15:30		Visual Inspection / Safety Briefing	Braking Safety Check	Vehicle Manual Control & Data Accuracy	Performance tests	Performance tests
15:30 - 16:30						
16:30 - 17:30						
17:30 - 18:30						
18:30 - 19:30		Debriefing	Lunch break		Debriefing	Debriefing

* Special dinner on 31st of March