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## Interoperable GCDC AutoMation Experience

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## Executive Summary

GCDC 2016, which is organized by the project i-GAME, will gather teams from universities, research institutes, manufactures, etc., in one place to compete and test the newest technologies that will enable the future cooperative and automated vehicles. To perform the i-GAME scenarios both safely and efficiently, and to allow the organization to judge the performance in a quantitative way, participant teams shall fulfil certain requirements.

This document specifies initially the main requirements that participant teams shall follow and fulfil for vehicles to enter GCDC 2016. The main discussion includes requirements on the drivers, requirements on the vehicles' performance, as well as the functional requirements.

In GCDC 2016, the drivers will be in the vehicles during the scenarios and take control if any danger is found. Therefore, i-GAME specifies a set of requirements that drivers from the participating teams shall follow; these requirements are presented in this document.

i-GAME focuses on vehicles classified as "partial automation", where vehicles have the abilities to perform both longitudinal and lateral control, while drivers monitor the systems at all times. This document specifies the allowed participating vehicles, together with their automation levels. A general description on the vehicle requirements is presented, with also a brief description of scenario-based requirements. To enable both automated longitudinal and lateral control safely and efficiently, vehicle controllers shall be able to perform certain manoeuvres within the specified limits. Furthermore, vehicles sensors, such as GPS, must be able to provide information with enough accuracy. Those requirements are specified in the vehicle controller and sensor requirements.

Safety is of utmost importance in GCDC 2016 as drivers are physically in the competing vehicles. Sets of basic safety requirements are specified that vehicles and drivers must follow exactly.

The i-GAME scenarios will mainly rely on vehicle communications and cooperation. Vehicles exchange information and negotiate to resolve complicated realistic scenarios. Thus communication and interaction are the key and critical components in the vehicles' functional design. Communications must follow the EU regulations and shall be multi-vendor based and interoperable. Interaction must be efficient and robust to allow vehicles to resolve realistic scenarios safely and efficiently. To do this, i-GAME will design interoperable communication message sets as well as a set of interaction protocols. This document specifies the preliminary requirements on communications and interaction. These will be updated and specified in D1.4.

It is worth mentioning that requirements specified in this document are brief. The aim is to help participant teams to have an overview of the challenge and to get a general understanding on how to enable a safe and successful GCDC 2016. Certain parts of the requirements, such as detailed controller parameter settings, are open, and the teams will be able to discuss with the organizers in the coming months to influence the detailed requirements. Mutually agreed requirements will be frozen and published in the final version D1.4. Thereafter, all participating teams shall follow exactly the requirements for entering GCDC 2016.

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# 1 Introduction

**The i-GAME project**

The objective of i-GAME is to develop technologies that speed-up the real-life implementation of automated driving, which is supported by communication between the vehicles and between vehicles and roadside equipment.

**Background to requirement specification**

This requirement specification will function as a guideline for the participating teams as they develop their competition vehicles. The purpose of the document is that it should help the teams to create safe innovative automated vehicles. The level of details in the requirements should not constrain the design but rather inspire innovative solutions – yet safe and interoperable with other vehicles. The success of GCDC 2011 gave significant input to this document, requirements specified in this documents are based on the related parts in the rules & technology document[1] of GCDC 2011 with modifications to accommodate the GCDC 2016. This report will be a living document on requirements where the participating teams are able to influence the detailed specifications. A final version will be mutually agreed with the teams and published in November 2015 (month 25) in Deliverable D1.4 for ensuring a successful GCDC 2016.

**Contents and structure of this document**

This document consists of an executive summary and the description of the requirements related to the driver, the vehicle, the sensor system and the vehicle-to-vehicle communication.

[1] GCDC organization, “GCDC 2011, Rules & Technology Document”, Version 2.0, April, 2011.

# 2 Requirements for participants

GCDC 2016 is a unique event where a number of scenarios are demonstrated in which cooperative and automated vehicles participate. The scenarios take place both on a highway and an intersection. To be able to participate in the challenge a number of requirements must be fulfilled by the competing teams. Some requirements are verified before the competition and others are evaluated during the scenarios through judging and evaluation. The rules about each scenario and how it is evaluated is described in Deliverable D1.1. This chapter describes the requirements that the teams and their vehicles should fulfil to be able to safely and successfully participate in GCDC 2016.

## 2.1 Driver requirements

The GCDC 2016 organization requires the following from the drivers:

- Shall have a valid driving license
- Shall have a valid insurance according to the contract
- Shall have a valid passport for identification
- Shall be physically fit and mentally alert
- Shall not be under the influence of any alcohol or drugs
- Shall be well experienced in driving and controlling the competition vehicle of the team
- Shall be aware of the safety and competition rules and instructions provided by the organization
- Shall be in the driver seat ready to take over control or to abort the scenario if anything unexpected occurs during the scenarios
- Shall be accompanied by a driver assistant during the competition (in the passenger seat)
- Shall make themselves known to the GCDC 2016 organization before the competition

## 2.2 Vehicle requirements

### 2.2.1 Vehicle automation categories

SAE standardized and published the taxonomy and definitions for vehicle automated driving systems in SAE J3016. Figure 1 shows the vehicle automation levels that have been defined. Similarly, the iMobility Forum also published definitions on vehicle automation proposed by BASt, where the level of “High automation” corresponds to both Level 3 and Level 4 in SAE’s definition. In this project the SAE standard is used to describe the automation required in GCDC 2016.

Vehicles competing in GCDC 2016 can be divided into the following two categories:

1. LEV 1 – where vehicles have full longitudinal support but require manual input for lateral manoeuvres (corresponds to Level 1 - Assisted, VDA).
2. LEV 2 – where vehicles do not require any intervention from the driver. Longitudinal and lateral controls are automatic (corresponds to Level 2 – Partial Automation, VDA).

To be able to participate in GCDC 2016 the vehicle needs to have at least Level 1 (Assisted, VDA) where the driver may be in control of lateral movements. The vehicles must have the ability to start and stop without the intervention of the “driver”. Furthermore, it is required that LEV 2 vehicles must have the ability to drive in LEV 1 mode, i.e. with only longitudinal control in function.

The allowed vehicle types in GCDC 2016 include personal cars, trucks and vans. All vehicles are cooperative with platooning capabilities, e.g., at least longitudinal control without driver intervention. They also have the ability to cooperatively position and open gaps to allow new cars to join the platoon from the back, the side and the front, as well as at any time leave the platoon in the same manner.

Autonomous vehicles (level 4 and 5) are defined as having the ability to drive with full automation on their own, hence with a higher degree of automation built on sensor information. However they are not necessarily cooperative (V2V) *which is a requirement in GCDC.* From a performance perspective in GCDC there is no difference between an autonomous vehicle and a LEV 2 vehicle.

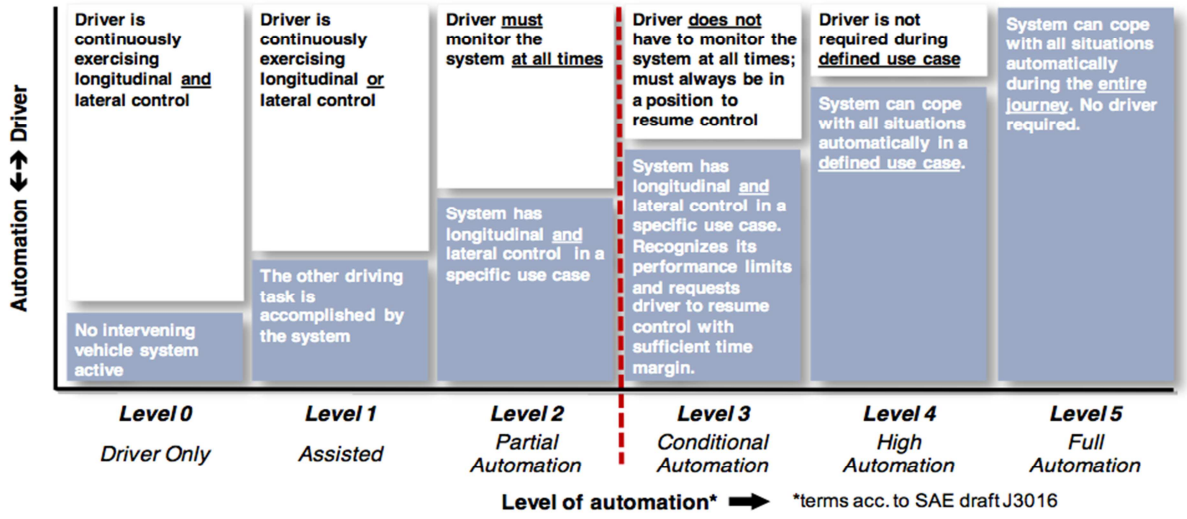


**Figure 1: Automation levels defined by VDA**

Generally in GCDC all vehicles are equal in the sense that there is no particular functional requirement to be expected from the first vehicle in a platoon. It is simply the first vehicle in the platoon and will be referred to as the FV. The FV may drive with the technology at hand which means at any degree of automation (from manual to autonomous).

### 2.2.2 General vehicle requirements

A number of general requirements are defined in order to perform the i-GAME scenarios and maintain safety. The following items are minimum vehicle requirements and detailed implementation methods will be specified in D1.4.

- Actuators and sensors to satisfy the LEV1 and LEV2 automation levels
- Vehicle communication devices
- Front/rear lights
- Seatbelts in all driver and passenger seats
- Emergency button for switching back to manual driving
- Clearly visible green (right side of car roof) solid-light for indicating automatic driving
- Clearly visible red (left side of car roof) solid-light for indicating manual driving
- Vehicle identification (logo, advertisement, etc.)
- FM radio for (voice) communication with the organizers

For the i-GAME scenarios, each scenario will involve a number of competitions, also referred to as heats, with different teams executing a scenario under exactly the same conditions. To ensure this, and also for the purpose of measurements and judgements, scenario based requirements are needed. Those requirements are based on the scenarios described in D1.1 and are defined from an abstract level that does not involve detailed parameter settings. One example is for the scenario of cooperative intersection, all participant teams should be able to arrive at the competing zone at the same time and with the required speed. Also, communications should start exactly when entering the competing zone. Further scenario-based requirements will be specified in detail in D1.4. Both the teams' requirements for entering the challenge and the organizer's requirements for a successful challenge, such as a reasonable judging solution, will be considered.

### 2.2.3 Vehicle controller requirements

Generally, when the automatic controlling system is engaged, the green solid-light is on. Furthermore, when the brake is engaged during the automatic driving, the standard red rear braking light should be on. The throttle and brake should be able to achieve the required performance listed inTable 1.

For the purpose of safety, the maximum allowed lateral/longitudinal parameters shall never be exceeded by any of the participating vehicles during the competition. Meanwhile, all participating vehicles shall satisfy the required lateral/longitudinal capabilities in order to conduct manoeuvres needed to safely and efficiently perform the scenarios. The parameters are set according to the challenge site environment, the scenario requirements, as well as further considerations of the teams' individual performance. In summary, the main purpose of these requirements is that the vehicle should behave as the "driver" commands.

**Table 1: Automation levels defined by VDA**

| *Parameters for normal automated operation conditions* | *Cars* | *Trucks* | *Comment* |
|---|---|---|---|
| Velocity range (km/h) | [0, 90] | [0, 90] | |
| Maximum allowed lateral acceleration ($m/s^2$) | 2.0 | 2.0 | |
| Maximum allowed longitudinal acceleration/deceleration ($m/s^2$) | +/-2.0 | +/-2.0* | |
| Longitudinal control accuracy (speed) (m/s) | 0.5 | 0.5 | |
| Lateral control accuracy (m) 2$\sigma$ | 0.20 | 0.20 | To avoid large lateral variations within a lane |

*assuming unloaded truck

In case of an unexpected event during automated driving the scenario may need to be aborted, this may for example be a simple warning message or it may require controlled emergency braking while maintaining safety. The warning message may be issued by the organization. The parameters in Table 2 will define the values of the vehicle requirements in such an event.

**Table 2: Control parameter setting to handle unexpected events during automated driving required for GCDC 2016 participating vehicles**

| *Parameters for automated unexpected events* | *Cars* | *Trucks* | *Comment* |
|---|---|---|---|
| Maximum allowed longitudinal deceleration ($m/s^2$) | 4.0 | 4.0 | Automated controlled braking |

The set of parameters indicate the limits of the vehicle performance, obtained during manual driving. These are e.g. required in case of an emergency situation. These parameters are found in Table 3.

**Table 3: Control parameter setting required for GCDC 2016 participating vehicles**

| *Parameters for manual mode* | *Cars* | *Trucks* | *Comment* |
|---|---|---|---|
| Minimum required lateral acceleration ($m/s^2$) | 4.0 | 2.0 | Manual steering |
| Minimum required longitudinal deceleration ($m/s^2$) | 8.0 | 6.0 | Manual braking |

It is noticed that the current tables list the initial parameter settings. The control requirements will be continuously updated through discussion with the teams. The final requirements specifications will be mutually decided and finalized in D1.4.

### 2.2.4 Vehicle sensor requirements

Related to the vehicle performance are the vehicle sensors enabling automated navigation and control. For vehicles to cooperate and coordinate themselves there needs to be an agreement on measures and description of the environment. Additionally, the different kind of measures should also be known to facilitate interpretation. Therefore, each vehicle needs to be able to position itself with some accuracy and they also need to be able to estimate their relative distance to the surrounding vehicles/objects with some accuracy. Vehicles may use GPS as one mode for positioning. RTK-DGPS correction signals will be available on the GCDC competition site but is not required in the competing vehicles. This means competing vehicles cannot rely solely on RTK-level accuracy from other teams. They will need to analyse the precision of the other vehicles' position and act accordingly. 2D positioning accuracy can be described by Distance Root Mean Square (DRMS). DRMS is calculated as the square root of the average of the squared horizontal position errors, as shown below, where $\sigma_x$ and $\sigma_y$ are the position error in *x* and *y* direction respectively.

$$\text{DRMS} = \sqrt{\sigma_x^2 + \sigma_y^2}$$

In general, DRMS denotes that the positioning values have about 65% probability to be within the DRMS circle. GCDC 2016 has more stringent requirements so that positioning accuracy is described with 2DRMS that corresponds a probability of 95% for the values to fall into the DRMS circle.

The minimum requirements on sensors are the following:

- All vehicles shall have positioning methods to locate itself and be able to provide the accuracy of the location data
    - The position accuracy: 2DRMS <= 1m
- All vehicles shall be able to detect and estimate the distance to neighbouring vehicles and be able to provide the accuracy of the estimate
    - Distance accuracy to neighbouring vehicles: 2DRMS <= 1 m
- All vehicles shall have sensors for detecting the velocity, the acceleration and deceleration with a certain accuracy and with a certain update frequency
    - Velocity accuracy <= 0.5 m/s
    - Acceleration accuracy <= 0.2 $m/s^2$
    - Deceleration accuracy <= 0.2 $m/s^2$
    - Vehicle motion data update frequency 10 Hz

## 2.3 Functional requirements

### 2.3.1 Basic safety requirements

Safety and Functional requirements include the minimum set of requirements that needs to be implemented in order to restrain the scenarios in GCDC 2016.

- All ITS-Stations shall follow exactly the regulatory instructions, such as the maximum allowed speed, acceleration & deceleration requirements, etc., that are specified in this document and may also be broadcasted from the control centre and roadside units
- Once the automated system is engaged, the vehicle shall perform the scenario on its own (LEV 2) or only steering from the human driver (LEV 1)
- The vehicles' controller shall indicate the mode of driving through information sent such as cooperative awareness messages (CAM) as well as physical indicators
    - Automated: GREEN solid-light ON, RED solid-light OFF
    - Manual: RED solid-light ON, GREEN solid-light OFF
    - Controlled abort: RED and GREEN solid-light ON
- The drivers are required to be ready to take over control throughout the competition. In case the driver judges a situation to be unsafe, he/she should take over the control by any of the following
    - Press the emergency button
    - Applying the brake
    - Applying the acceleration

  and thus switching to manual driving. Meanwhile, the status of the physical indicators should change automatically, e.g., red solid-light on and green solid-light off
- Vehicles will switch to manual driving if any of the other vehicles are detected to be driven manually, thus aborting the heat
- The GCDC organization will define detailed safety procedures to deal with potential dangerous situations. The drivers are required to follow exactly the procedures after they take over control of the vehicle
- Participant vehicles shall have no automatic emergency stops, e.g., all means of automatic breaking systems must be disconnected before the competition
- The vehicle interior and exterior shall follow the organizer's instructions
- All vehicles shall keep the limits of controlling, such as the speed limits, the acceleration and deceleration limits, and so on
- All vehicles must keep the safety distances
- All vehicles must be able to follow the local traffic rules (the Dutch road regulations)

Detailed requirements, such as the safety procedures for each of the scenarios, the exterior and interior setting, the calculation of safety spacing, the transition from automatic driving to manual driving, and so on, will be further specified in D1.4.

### 2.3.2 Communication requirements

i-GAME is building knowledge on cooperative and automated driving in order to speed up implementation of such systems in traffic. Thus, one of the most important parts of i-GAME and the GCDC is V2X communication. For accelerating the realistic deployment of cooperative system and multi-vendor interoperability, V2X communication aligns with the ETSI C-ITS standards. Detailed specification of communications can be found in ETSI TR 101 607.

General communication requirements of i-GAME are listed below.

- All vehicles shall support ITS-G5 standard and the frequency specification therein
- All vehicles transmitter power profile shall follow the C-ITS standard and related EU regulations
- All vehicles shall ensure a proper communication (both sending and receiving messages) range of at least 200m in all directions through a proper setting of antenna height and transmission power.
- Latency of the received valid estimate/measured values <= 200 ms
- Time synchronization to GPS time <= 10 ms
- All vehicles shall ensure a maximum communication delay of 100 ms
- All vehicles shall ensure a certain periodic message frequency (typically >= 10 Hz)
- Information included in the communicated messages (GPS coordinates, velocity, etc.) shall match that provided by the vehicle sensors

Communication platform for enabling an interoperable cooperative driving environment will be designed and specified in WP3 and the related documents D3.1. The detailed communication requirements will be specified therein and will also be updated in D1.4. It is noticed that the communication performance depends on the environmental conditions and certain requirements may not hold during the challenge. Therefore, communication performance will firstly be tested in the pre-contest verification. The complete communication process will be logged in detail during the challenge for further analysis and evaluation. i-GAME does not require implementation of communication security and the shared data will solely be used for research and judging.

### 2.3.3 Interaction requirements

The communication enables interaction between vehicles. This is crucial for the success of GCDC challenge. All scenarios to be conducted in GCDC 2016 will be based on interaction and cooperation between the involved vehicles. All vehicles shall be able to receive, analyse, reason and negotiate with each other. Mutual decisions shall be achieved through the negotiation and the corresponding scenario shall be resolved safely and successfully. For facilitating the interaction, a set of interaction protocol will be developed and tested in WP2. Meanwhile, message sets including the CAM and DENM that have been standardized, as well as potential extended i-GAME message sets will be developed in WP3. In general, interaction requirements include:

- All vehicles shall be able to construct and interpret message sets such as CAM, DENM and their extended version
- All vehicles shall be able to judge the relevance of the received messages and act accordingly
- All vehicles shall be able to negotiate and coordinate (request and acknowledge) with each other for resolving the scenario (such as negotiating the intersection passing) according to the interaction protocol
- All vehicles shall make sure that safety procedures are followed strictly from start to completion
- All vehicles shall be able to halt the operation (such as lane merge) and warn the driver via HMI in case of danger

### 2.3.4 Data logging

Data logging, especially from the communication, is important for analysing the performance of the cooperation between the vehicles during the challenge and will play a central rule in the juding process. Log files may not only help the development of individual vehicles, but also improve the development of a common interaction protocol and message sets since it enables thorough investigation of the spread of the transmitted data. It also enables tracing of how the vehicles behave according to the transmitted data. The logged i-GAME data will only be used for research purposes.

In addition to the data logging and monitoring methods deployed by the GCDC organizations, participating teams are also required to deploy related functionalities for proper data logging.

- All vehicles shall be able to log time-stamped in-vehicle data such as GPS location data, sensor data, and so on for future reference
- All vehicles shall be able to log time-stamped communication messages for the purpose of analysis
- Data log frequency and format shall follow the specifications presented in D2.6.

## 2.4 Pre-contest verification and judging

To ensure the safety and interoperability, the organization employs different methods for the testing, pre-contest verification and judging purposes.

Intermediate workshops will be held, such as through the online simulation and verification platform, to verify the communication, interaction, etc., between the participating teams. An alternative to workshops may be a witnessing process at the site of the teams by a representative from the i-GAME organization. This will give further input to the requirements and contribute to the final version of the requirements. A detailed description of the functional requirements with specific parameter settings that accommodate the i-GAME scenarios will be available in D1.4.

Before the challenge, all vehicles participating in GCDC will be subject to a rigorous verification process and safety checks regarding all requirements. The organization of GCDC deploys sophisticated testing and checking procedures at the test site. The verification process will involve all requirements that are listed in this document and the detailed control and communication requirements that will be published later in D1.4. Failure to comply with any of the requirements will lead to disqualification. A detailed testing and assessment procedure will be developed in WP4 including the assessment of vehicle performance, the assessment of the interaction implementation, as well as the assessment of safety. Workshops will be held for the verification purpose. Detailed specifications about the assessment will be published later in WP4 deliverables.

For the purpose of data log and judging, the organization deploys measuring and monitoring systems over the challenge site. Judging criteria will be defined on both individual and cooperative level in WP7 and specified in D7.1.

# 3 Conclusion

This document specifies an initial version of the main requirements that participant teams shall follow and fulfil for their vehicles to enter the GCDC 2016. The main discussion includes requirements on the drivers, requirements on the vehicles' performance and functional requirements.

The requirements specified in this document are brief. The aim is to help participant teams to have an overview of the challenge and to get a general understanding on how to enable a safe and successful GCDC 2016. Certain parts of the requirements, such as detailed controller parameter settings, are open, and the teams will be able to discuss with the organizers in the coming months to influence the detailed requirements. Mutually agreed requirements will be frozen and published in the final version D1.4 in November 2015. Thereafter, all participating teams shall follow exactly the requirements for entering GCDC 2016.

# 4 List of abbreviations and terminology

| | |
|---|---|
| **WP** | Work package |
| **LEV 1** | Automation level 1 defined in SAE J3016, full longitudinal automation |
| **LEV 2** | Automation level 2 defined in SAE J3016, full longitudinal and lateral automation |
| **FV** | First vehicles in a platoon |
| **DRMS** | Distance Root Mean Square |
| **V2V** | Vehicle-to-vehicle communications |
| **V2X** | Vehicle-to-vehicle and vehicle-to-infrastructure |
| **C-ITS** | Cooperative Intelligent Transportation Systems |
| **ITS-Station** | A set of functions and devices included in vehicles, infrastructures, control centres and mobile (pedestrians, cyclist, etc.) that enable V2X communications. |
| **V-ITS-S** | Vehicle ITS-Station |
| **R-ITS-S** | Roadside ITS-Station |
| **ITS-G5** | Communications standard specified by EU for vehicle-to-vehicle communications |
| **CAM** | Cooperative Awareness Message |
| **DENM** | Decentralized Environment Notification Message |
| **VDA** | Verband der Automobilindustrie |

# 5 List of Figures and Tables

## 5.1 List of Figures



## 5.2 List of Tables