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ENabling **S**af**E** **M**ulti-**B**rand p**L**atooning for **E**urope

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1. EXECUTIVE SUMMARY

1.1. Context and need of a multi brand platooning project

1.1.1. Context

Platooning technology has made significant advances in the last decade, but to achieve the next step towards deployment of truck platooning, an integral multi-brand approach is required. Aiming for Europe-wide deployment of platooning, 'multi-brand' solutions are paramount. It is the ambition of ENSEMBLE to realize pre-standards for interoperability between trucks, platoons and logistics solution providers, to speed up actual market pick-up of (sub)system development and implementation and to enable harmonization of legal frameworks in the member states.

1.1.2. Project scope

The main goal of the ENSEMBLE project is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. This will be demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions across national borders. The project goals for each year are:

- Year 1: setting the specifications and developing a reference design with acceptance criteria.
- Year 2: implementing this reference design on the OEM's trucks as well as performing impact assessments with several criteria.
- Year 3: focus on testing the multi-brand platoons on test tracks and international public roads.

The technical results will be evaluated against the initial requirements. Also, the impact on fuel consumption, drivers and other road users will be determined. In the end, all activities within the project aim to accelerate the deployment of multi-brand truck platooning in Europe.

1.1.3. Abstract of this deliverable

The purpose of this deliverable is to describe testing procedures and definition in the ENSEMBLE project to validate the implemented function and to ensure interoperability between different brands.

Earlier testing phases such as testing as system level, integration testing or mono-brand testing are outside the scope of this document and are expected to be carried by OEMs on their own responsibility.

In the deliverable D5.1 the first states of the test plan and the common methodology plan description was defined. The updated and complete test plan is now the topic of this deliverable D5.7.

In this deliverable (D5.7), a common methodology to assess complex platooning on test track and open road is defined. In order to develop this methodology, the KPIs to be recorded are defined and the tests that will be carried out are described. These KPIs relate to the following tests:

- Tests in a controlled environment (i.e. test track) for the validation and performance evaluation of the platoon capabilities and safety requirements.
- Tests in a controlled environment for the measurements of fuel consumption and emissions
- Tests on public roads for the measurements of fuel in interaction with traffic flow and real environment.
- Tests on public roads to validate the performance of multi-brand platooning in interaction with real traffic flow.

2. INTRODUCTION

The ENSEMBLE project's main objective is to define and implement a fully functional multi-brand platoon that can be adopted to unmodified public highways and interact with surrounding traffic. Therefore, the platooning vehicles not only need to be tested on the test track, but also on the open environment, public road. The main objective here is to test whether the platoon system behaves safely and as intended.

The general objective of Task 5.1 "Test and Demonstration Plan" is to define a methodology to evaluate the multi-brand solutions developed in the ENSEMBLE project, to define the scenarios and test execution for the multi-brand platoons and to select an appropriate route for the open road tests. To achieve this objective, each ENSEMBLE project work-package needs to identify requirements and KPI's that are used to define the test plan. The information that each work-package has provided is described below:

- WP2 has defined the specifications of the whole multi-brand truck platooning concept to be implemented in trucks from seven different OEMs and assessed within the testing carried out in WP5. In addition, the defined use cases and project requirements (V2X, Safety, etc) in this work package will be used as inputs to be included in the test plan and test case definition of WP5. There is a regular feedback between WP5 and WP2 to update the functional specifications due to newly acquired insights and experiences.
- WP3 is responsible for the development and implementation of the platooning technology in the trucks. One or more trucks per OEM are instrumented with a brand-specific layered platooning automation system, which enables the truck to operate in a multi-brand platoon.
- WP4 is responsible of the impact assessment for multi-brand platooning on road infrastructure, environment, other road users and logistics. The WP4 has defined a KPIs list to be verified and measured during test on proving ground and open road to analyse the impact on traffic flow, on fuel consumption and emissions, pavements, bridges and tunnels. This information has been included on the test plan definition.

The Scenarios Cases definition, system requirements and the overall KPIs are essential for the development of the test procedure.

3. TESTING OBJETIVES

In the testing phase of the project, the test object is handled as a black box. A detailed overview of the architecture of the complete vehicles or other single components and their architecture is not in the testing focus for this work package and is not explicitly handled or tested.

The process flow of the overall method is based on the V-cycle as it can be seen in Figure 1:

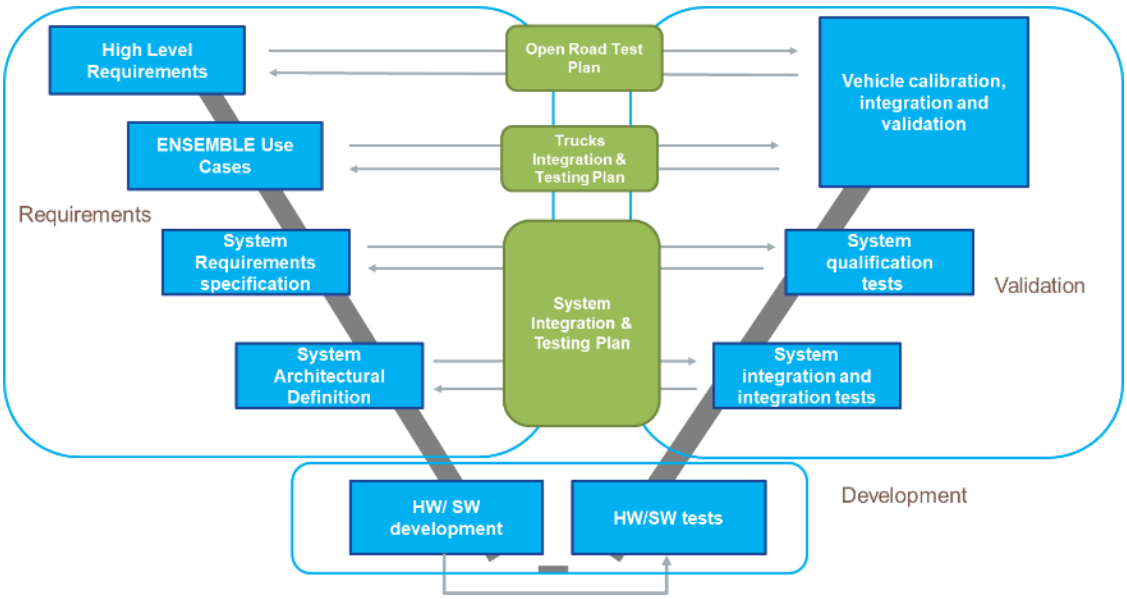

Figure 1: V-cycle testing Levels

The methodology defined for the verification and validation of the platooning function will be divided in three main levels:

- ***System Integration***: In this phase, both the developed platoon coordination and the individual platooning systems shall be verified. This task will be conducted in WP3.
- ***Trucks Integration:*** The vehicles developed will be tested at different levels:
    - In-house mono-brand platoons (tests conducted by each OEM).
    - Three-brand platoons.
    - Multi-brand platoons.
- ***Open Road:*** In this phase, the global platooning system shall be tested on open roads. Key aspects of this evaluation phase will be multi-brand platooning performance, interaction with other road users and the impact on traffic and infrastructure and real-world emissions.

4. TEST PLAN DEFINITION

The test plan of the ENSEMBLE project includes the overall activities of integration and testing at vehicle level. Once the testing activities at the vehicle system level from each OEM are completed, the multi-brand testing at vehicle level will take place. These activities will be carried-out in different sub-phases as described in Figure 2:

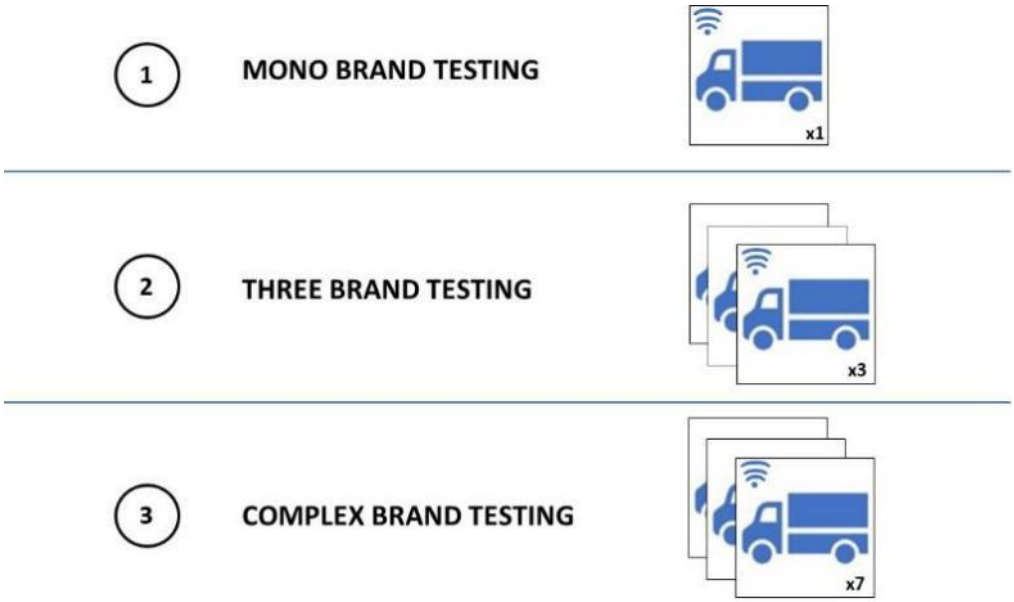

Figure 2: Test overview

Figure 2 shows the different testing phases. The first phase is the mono-brand testing that will take place at each OEM's facilities and will be carried out on January - February 2020. The second phase includes the three/four-brand testing and will take place between March and June 2020. Finally, the third phase will include the multi-brand testing (all seven brands) at IDIADA test tracks, followed by the open road testing in Catalonia (Spain) which will take place during August and September 2020.

4.1. Test objectives

The Platooning assessment methodology that is being developed in the ENSEMBLE project is based on the definition of scenarios to validate the requirements and specifications of multi-brand platooning and indicators of the system that relate to fuel consumption, emissions and traffic flow platoon impact, as well as evaluating the improvement of V2V communications for the platooning function. The following points will be verified during testing:

- Interoperability of the platoon: All vehicles in the multi-brand truck platoon are compatible with each other to ensure correct and safe operation.
- Safety of the multi-brand truck platoon: this is one of the key aspects to ensure acceptance of platooning technology.
- Impact of the multi-brand truck platoon in the real-life.

In the document 'V2 Platooning use cases, scenario definition and Platooning Levels' D2.3 (Willemsen et all, 2020) two platooning functions have been defined:

- Platooning Support Function: here the driver is responsible for the driving task
- Platooning Autonomous Function: the driver of the following trucks is not responsible anymore; the system performs the complete driving task within the specified operational design domain. The leading truck, instead, is still with driver in control.

The main properties of the Platooning Support Function are based on Adaptive Cruise Control (ACC) as defined in (ISO-15622, 2018):

- The driver is responsible for the full driving task taking account the weather conditions, slopes, traffic flow, etc.; in line with the current state of the art support functions, and this will be clearly indicated via the HMI.
- Longitudinal coordinated automated control for the complete speed range from 0 (brake to standstill; acceleration from standstill optional) to maximum cruise speed (depending on country regulations and OEM implementations).
- Following distances according to ACC (OEM specific) with minimum distances ranging between 1.4 s and 1.6 s. The driver selects the following distance. Decelerations will be limited accelerations to -3.5 m/s^2.

The main high-level use cases of the Platooning Support Function are:

- Engaging to platoon
  - Join from behind: either by a single vehicle or existing platoon
  - Merge in-between by single a vehicle in existing platoon
- Platooning
  - Steady state platooning
  - Follow to stop
  - Emergency braking
  - Platoon gap adaptation:
    - I2V interaction
    - Cut-in
    - System status (e.g. packet loss)
  - Cohesion request
- Disengage platoon
  - Leave
  - Split
  - Leave by steering away

4.2. Test requirements and performance indicators

In this section the test requirements and performance indicators, defined as part of the work of WP2, WP3 & WP4, are listed.

There are different requirements of the system defined in the D2.3 Version A (Willemsen et all, 2020) that will be checked during the tests:

- Seven requirements from Tactical Layer.
- Ten requirements from the interaction between trucks.
- Two requirements that determine the relationship between the infrastructure and the platoon.
- Ten requirements that all trucks must accomplish about their longitudinal control.
- Five sensors requirements.
- The interaction between the driver and the system is supported by an HMI. The HMI has eleven requirements to accomplish.

These requirements must be used as an input to define the test scenarios. As some details of these requirements are still under discussion and clarification, the final performance indicators are not frozen and will be defined to verify the accomplishment of every requirement during the tests.

To assess the energy efficiency and impact on traffic flow, the following performance indicators have been defined and will be monitored:

- Fuel consumption variation [l/km].
- Fuel efficiency variation [l/ton-km].
- Variation in CO2 emissions (tones/year).
- Variation in other emissions/pollutants (tones/year).
- Stability of traffic flow:
    - Space headway statistics.
    - Heterogeneous scenario.
    - Cumulated acceleration.
    - Time taken to engage/disengage.
    - Effective length of platoon (after disengagement).
- Impact on road capacity
    - Overtaking flow.
    - Speed. homogeneity: Platoon vs Traffic.
    - Total travel time.
    - Travel time reliability.
- Impact on road users + flow stability:
    - Traffic speed homogeneity.
    - % lane changing manoeuvres.
        - When gap opening.
        - When disengagement.
    - Number of cars that cut-in the platoon.

- Traffic acceleration (cut-ins).

4.3. Test cases methodology

The methodology followed to create the tests cases is detailed in this section. To have a common understanding of the concepts of use case and test case, a definition for each one has been written as follows:

- A Use-case represents a specific scenario in which a solution, usually the system that is being developed, needs to be implemented. The use case describes various conditions in which the system shall respond. These conditions can be interactions from the system's user, other traffic participants or road conditions
- A Test case is a set of requirements and variables against which the system will be tested and assessed. The results will determine whether the system complies with the requirements and satisfies the acceptance criteria. The process of developing test cases can also help to find problems in the requirements definition or design of an application

To define a test-run, is necessary to identify and describe the test scenarios with the use cases. Three levels are defined for each scenario:

- Functional scenario: this level contains the high-level description of the test procedure, using words and images to describe the sequence. In this level, the scope, testing procedure, needed operational domain and acceptance criteria will be defined. A complete list of parameters will be stated on this functional level description.
- Logical scenario: this level is to define a range for each of parameters defined during functional scenario. Test executions is described more in detail linking the defined parameters to each concept in the test description and execution steps.
- Concrete scenario: this level defines each specific parameter value and the step-by-step test sequence. The test results must be compared with the acceptance criteria, based on KPIs, signals behaviour and requirements.

Once the Concrete scenarios are defined, different test runs will be defined as a group of different test scenarios to be carried-out together, one just after the other.

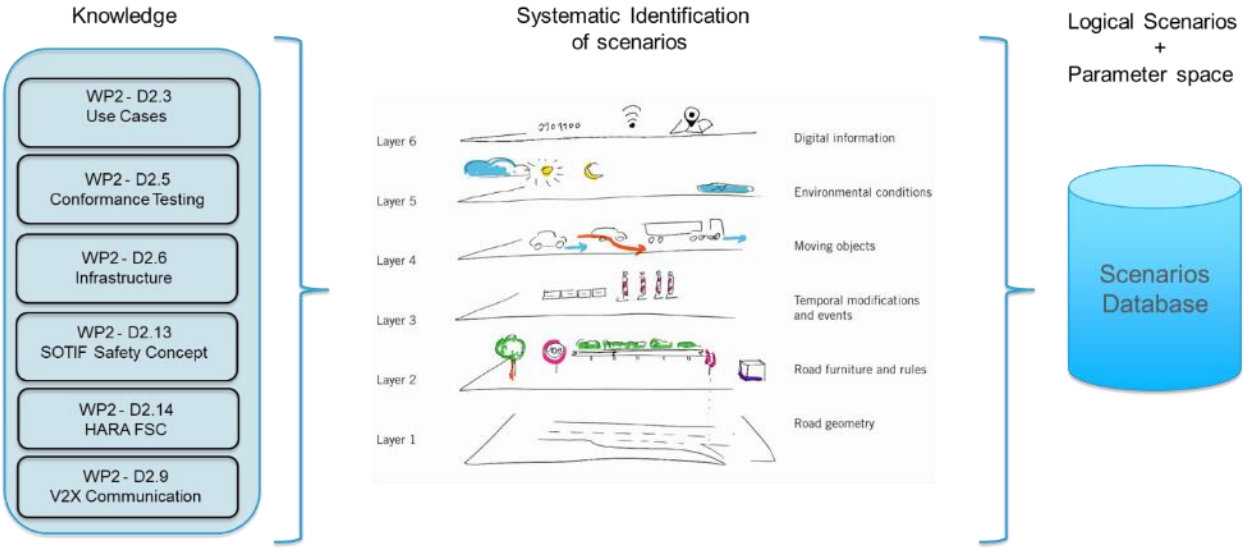

Figure 3: Inputs to generate the scenarios database

In Figure 3 the different inputs used to generate the scenarios can be observed. The main inputs are:

- Use cases
- V2X Communication definition.
- Requirements of the platoon system, deriving from:
    - HARA and Functional Safety Concept.
    - SOTIF Safety concept

For the specific description of the functionals scenarios the following sections are used:

- Scenario ID: Unique number to identify a scenario. The identifier has the format #XXYY where:
    - XX: Identifies a type of scenario.
    - YY: Sub-scenario of the XX scenario.
- Scenario Name: Title of each scenario in few words. Between parentheses the relate use case identification from D2.3 shall appear.
- Scenario description: It represents of the scenario in few words with the general manoeuvres and expected results.
- Objective: Main purpose of the scenario.
- Preconditions: Specification of the variables and environment necessary to realize the test.
- Initial state: Description of the initial conditions of the scenario, before the execution test (initial conditions for all vehicles involved during the test).
- Scenario steps: Description of the manoeuvres to be realised during the scenario execution.
- Acceptance criteria: Report of the expected consequences of each step of the "Scenario Steps", if applicable, and a checklist for making the decision to accept or reject the test on the scenario.
- Final state: Definition of the expected platoon configuration when all ‘Scenario steps’ are executed and ‘Expected results’ obtained without failure.

- Parameters (inputs): List of variables required to fully define the scenario. Numerical values must be assigned to each parameter.
- Signals (outputs): All measures, actions, warnings or marks to be monitored for analysis during the development of the scenario.

Figure 4: ENSEMBLE figure key below shows the key figures used in the image scenario setup definition:

Description	Icons
Other vehicle	
HMI	
Fault/ failure	
Decrease velocity	
Increase velocity	
Driver	
V2X	
Radar vehicle	
Platoon nomenclature	TRAILING FOLLOWING LEADING
RSU	
Other	50
Emergency Braking	

Figure 4: ENSEMBLE figure key

Next step after the functional scenarios is to define the “logical scenarios”. Functional scenario must be analysed to identify all elements, inputs and signals that must be classified with a unique name and assign a range of possible values, if necessary.

Finally, to create the "concrete scenario", a concrete numeric value is assigned to each of the parameters identified in the "logical scenario.

Once the scenarios have been stablished, the next step is to choose the location where each scenario will be tested, the results will be incorporated to a data base of test results (Figure 5). The mono and three brand testing will take place in WP3. The Mono-brand testing will take place at each OEM’s facility. The testing will be carried out with an instrumented truck which has the developed technology implemented. The implementation will consider *Platooning Support Function* as described in D2.3.

In three-brand testing, trucks will be tested in groups of three at two different proving-ground locations. The groups will be as follows:

- MAN & Scania & Volvo / Renault.
- DAF & Daimler Trucks & Iveco.

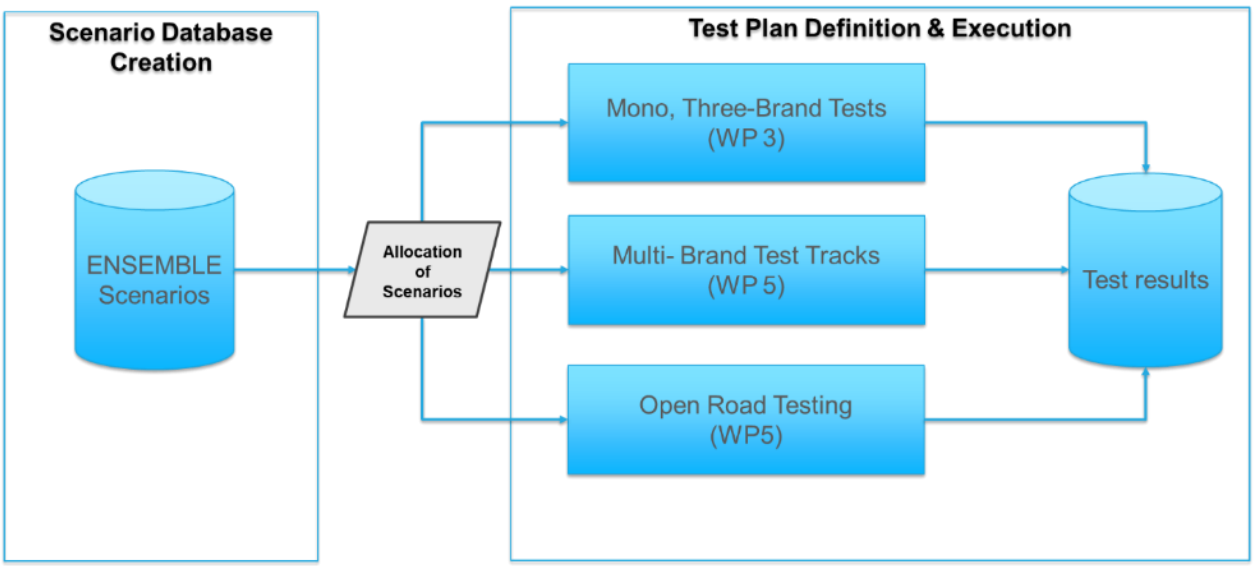

Figure 5: Tests steps

After the three-brand tests, next step will be the multi-brand (all seven brand) tests. In Appendix B. the test sequence is detailed . The test runs have two different phases: static tests and dynamic tests. The static tests are used to check the requirements of the V2V communications, the safety of the trucks and to install all the necessary equipment. In dynamic tests series, all concrete scenarios will be carried-out.

Finally, with all test results, evaluation metrics and pass criteria, the test will be evaluated and ranked obtaining an output result (Figure 6).

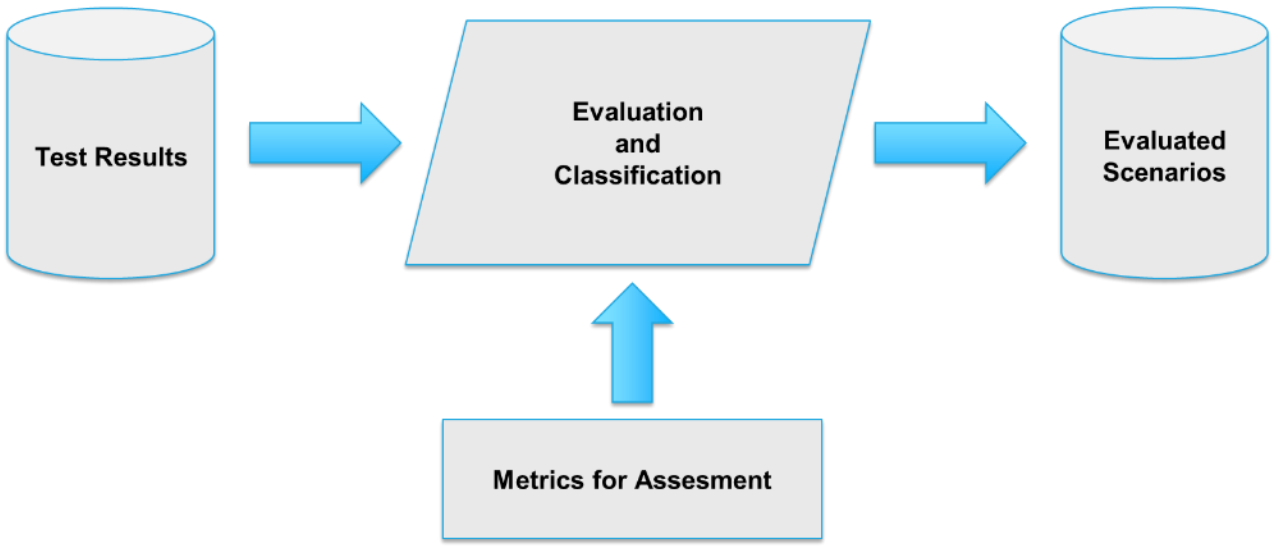

Figure 6: Evaluation procedure

4.4. Scenarios cases

The following scenarios cases have been accepted by all consortium members in one of the workshops realized by WP5. An example of these scenarios is detailed in the Appendix A.

- #00: Static test (V2V requirements)
- #01: Platoon join:
    - Joining from behind by single vehicle.
    - Joining from behind by an existing platoon.
    - Merge in between by single vehicle.
    - Merge in between by an existing platoon.
    - Refuse joining due to maximum number of trucks.
    - Non joinable situations.
- #02: Steady state platooning:
    - Steady state following constant speed.
    - Steady state acceleration.
    - Steady state deacceleration.
    - Steady state gap variation.
    - Follow braking target (use case 3.2).
    - Platoon in two adjacent lanes.
- #03: Emergency braking:
    - Lead vehicle doing an emergency braking.
    - Following vehicle doing an emergency braking.
    - Two instances off emergency braking in the platoon (LV & second FV).
    - Aborting emergency braking after TBD seconds (TBD which truck starts & abort).
- #04: I2V interaction:
    - New minimum distance policy (only HMI information).
    - New maximum speed policy (only HMI information).
- #05: Cut-in:
    - Cut-in (example: constant speed cut-in, cut-in and brake).
    - Cut-through.
    - Cut-out (example: cut-out and continue, cut-out and brake, cut-out and accelerate).
    - Steady state multiple vehicle cut-in.
- #06: System status (mono-brand OEM responsibility):
    - GPS failure.
    - Communication failure.
    - Package loss (V2V).
    - Forward range sensor failure.
- #07: Disengage platoon:
    - Leave by trailing truck.
    - Leave by following truck.
    - Leave by leading truck.

    - Split platoon (system initiated).
    - Leave by steering-out as following truck (+ deaccelerate).
    - Leave by steering-out by leading truck (+ deaccelerate).
- #08: Platoon cohesion:
    - Closing gap at maximum set speed.
    - Closing gap at maximum acceleration and speed performance (example: different truck loads).

5. TESTING ENVIRONMENTS

5.1. Test Tracks

The three-brand tests will be carried out in 2 groups of 3 to 4 brands on two different test tracks:

1. DAF, DAIMLER and IVECO will test at Testcenter Pferdsfeld (see Figure 7. Pferdsfeld proving ground)
2. MAN, SCANIA and VOLVO/Renault will test at Testcenter AstaZero (see Figure 8. AstaZero proving ground)

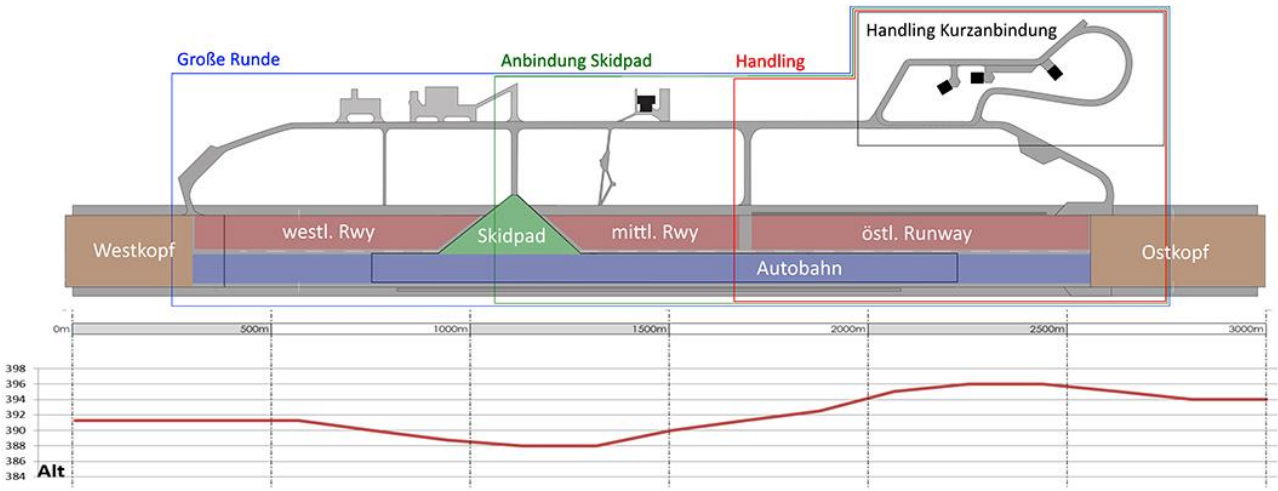

Figure 7. Pferdsfeld proving ground

Pfersfeld is a test track in the south of Germany of 2,8 km with a 3 lane motorway and 900 m 2 lane rural road.

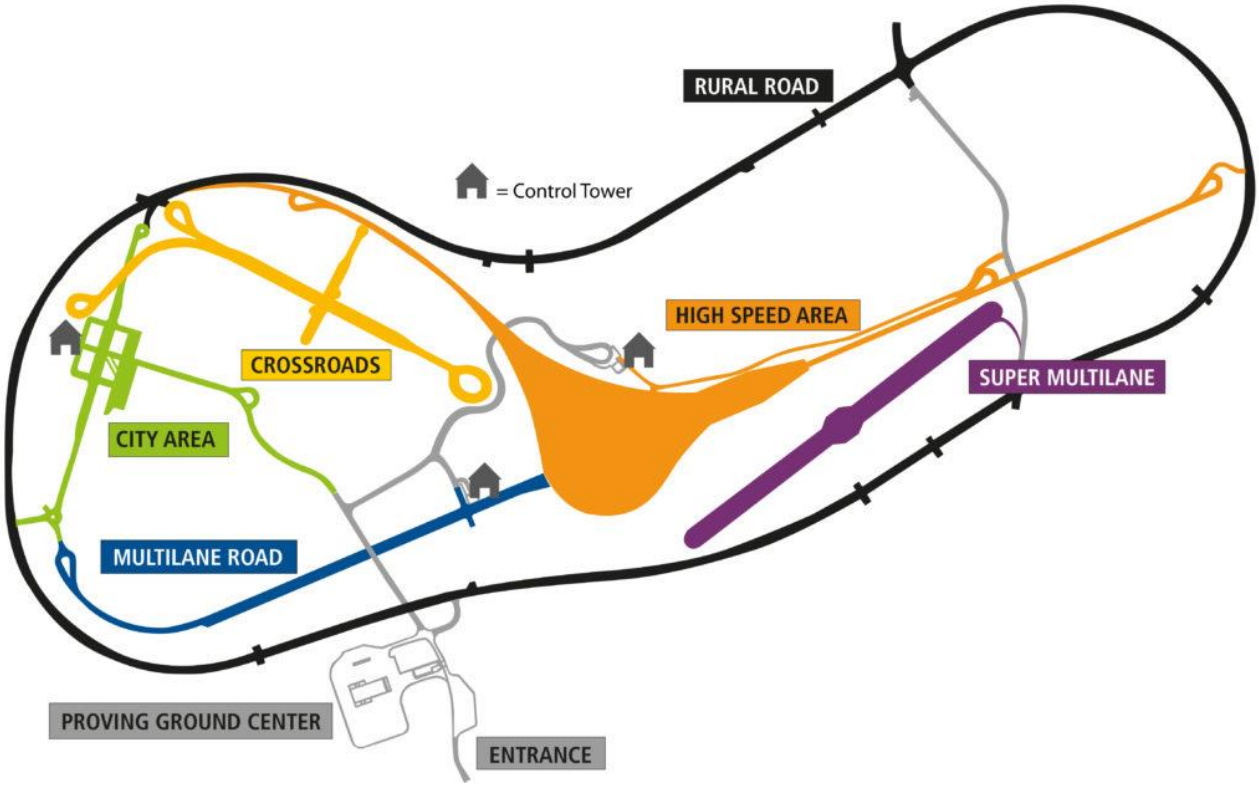

Figure 8. AstaZero proving ground

AstaZero's test environments comprise of a 5.7 km rural road lane, a city area with four districts of buildings and streets, a multi-lane road for multi-lane traffic and a high speed area for high speed tests.

The multi-brand testing (with all brands) will be carried out at the IDIADA Proving Ground which is placed at 70 km south-west of Barcelona. Figure 9: Aerial view IDIADA's proving ground shows an aerial view of IDIADA's proving ground.

Figure 9: Aerial view IDIADA's proving ground

The test track selected is the High-Speed Track (see Figure 10: High-speed track map), it is an oval track of 7,5 km, with four lanes of 4 meters width, north and south straights of 2 km long and a maximum banking bend of 80% (38,66°) on the west and east curves. The travel direction is always clockwise, and the speed limit is 250 km/h in shared use.

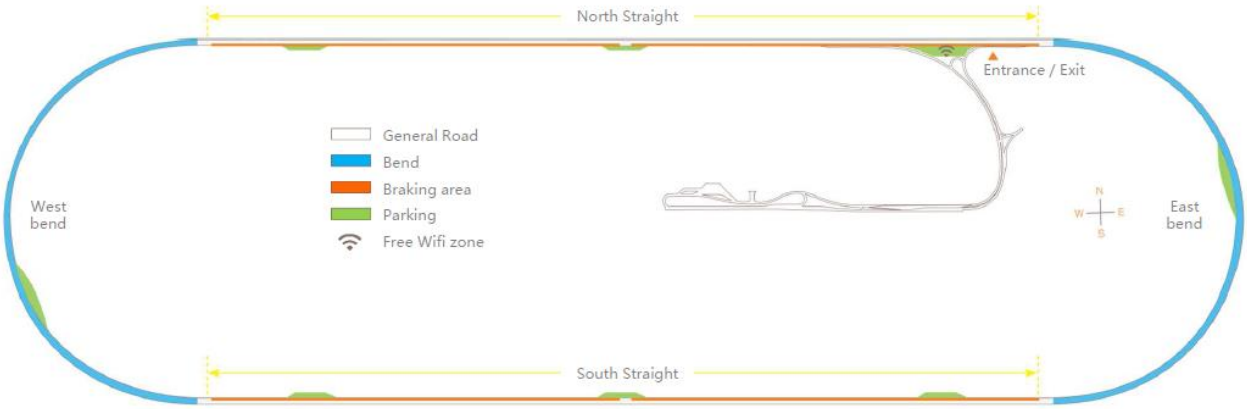

Figure 10: High-speed track map

Depending on the performance of the test case, it could be necessary to ask for the exclusivity of the test track as a platoon of 7 trucks making manoeuvres can compromise the safety of the others in the High-speed track.

5.1.1. Test track equipment

IDIADA's proving ground has the following availability of equipment for use by customers.

5.1.1.1. Connectivity Lab

The Connectivity Lab is in IDIADA's proving ground with a set of test tracks equipped with state-of-the-art communication technologies for Cooperative and Connected Vehicles. The deployed network (see Figure 11: IDIADA Infrastructure map) compliances with Europe and US international standards.

Figure 11: IDIADA Infrastructure map

The project is developed within the scope of Europe, so the standards available in the IDIADA's proving ground according with the international standards in Europe are:

- Physical Layer: IEEE 802.11-2016: IEEE Standard for Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments.
- Access Layer:
    - ETSI EN 302 571 (V2.1.1): Intelligent Transport Systems (ITS); Radio communications equipment operating in the 5855 MHz to 5925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive.
    - ETSI EN 302 663 (V1.2.1): Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band.
    - ETSI TS 102 724 (V1.1.1): ITS Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band.
    - ETSI TS 102 792 (V1.2.1): ITS Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range.
    - ETSI TS 102 687 (V1.1.1): Decentralized Congestion Control Mechanisms for Intelligent Transport Systems operating in the 5 GHz range; Access layer part.

- ETSI EN 302 636-4-2 (V1.1.1): Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media-dependent functionalities for ITS-G5.

- Network Layer:
  - ETSI EN 302 636-4-1 (V1.3.1): Vehicular Communication; GeoNetworking; Part 4 Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media- Independent Functionality.
  - ETSI EN 302 636-5-1 (V2.1.1): Vehicular Communication; GeoNetworking; Part 5: Transport Protocols; Sub-part 1: Basic Transport Protocols.
  - ETSI EN 302 931 (V1.1.1): Vehicular Communications; Geographical Area Definition.
  - ETSI TS 102 636-6-1 (V1.2.1): Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 6: Internet Integration; Sub-part 1: Transmission of IPv6 Packets over GeoNetworking.
  - ETSI TS 103 097 (V1.2.5): Security Header and Certificate Formats.
- Facilities Layer
  - ETSI EN 302 637-2 (V1.3.2): Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service.
  - ETSI EN 302 637-3 (V1.2.2): Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service.
  - ETSI TS 102 894-1 (V1.1.1): Intelligent Transport Systems (ITS); Users and applications requirements; Part 1: Facility layer structure, functional requirements and specifications.
  - ETSI TS 102 894-2 (V1.2.1): Intelligent Transport Systems (ITS); Users and applications requirements; Applications and facilities layer common data dictionary.
  - ETSI TS 103 301 (V1.1.1): Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services.
    - The data elements of SPATEM payload are defined in CEN ISO/TS 19091.
    - The data elements of MAPEM payload are defined in CEN ISO/TS 19091, Annex G.
    - The data elements of the IVIM message payload are defined in CEN ISO/TS 19321.
    - The data elements of the SREM and the SSEM payload are defined in CEN ISO/TS 19091.
  - ETSI EN 302 895 (V1.1.1): Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Local Dynamic Map (LDM).

Due to the availability, a private mobile network (2G, 3G, 4G, 5G…) with full control of the network parameters including radio access network and back-end systems could be used for development, validation, and testing of cooperative and connected vehicle applications.

5.1.1.2. Impact of Platooning on Pavement Structure

One goal of ENSEMBLE is measuring the impact of the platoon in the infrastructure and pavement, to assure the capabilities. Several sensors were installed in the IDIADA's proving ground to assess the impact of the platooning on the pavement in order to identify pulses, loads and deformation experienced by the structure when platoon is passing through.

In order to select the most appropriate location for the sensor's installation; IDIADA considered WP4's requirements for data acquisition as well as constrains related to the test activities conducted in the technical centre. The location selected for sensors installation was one particular spot of the General Road South (Figure 12: Pavement validation track) straight because it includes the following conditions:

- Perfect conditions for vehicle stabilization before measuring spot – vehicles with 1km in straight conditions at 0% longitudinal slope after a soft curve that allows certain velocity at the beginning of the straight.
- It is next to Dynamic Platform A parking area that offers a space were people collecting data can safely stand during data acquisition process segregated from test traffic.
- Electrical power supply and WIFI is available.

In Figure 12: Pavement validation track IDIADA track view is showed including schematic graphic references as follows:

Figure 12: Pavement validation track

- **Red spot** marks location selected for sensors installations.
- **Light blue line** marks the area available for vehicle stabilization.
- **Green line** marks the return trajectory in order to complete.
- **Black spot** marks a parking area available in the loop that allows running vehicles to be stop and verify data acquisition results and/or receive.

A plan view of the area selected for sensors installation showing the adjacent Dynamic Platform parking area can be find in Figure 13: Sensors installation location.

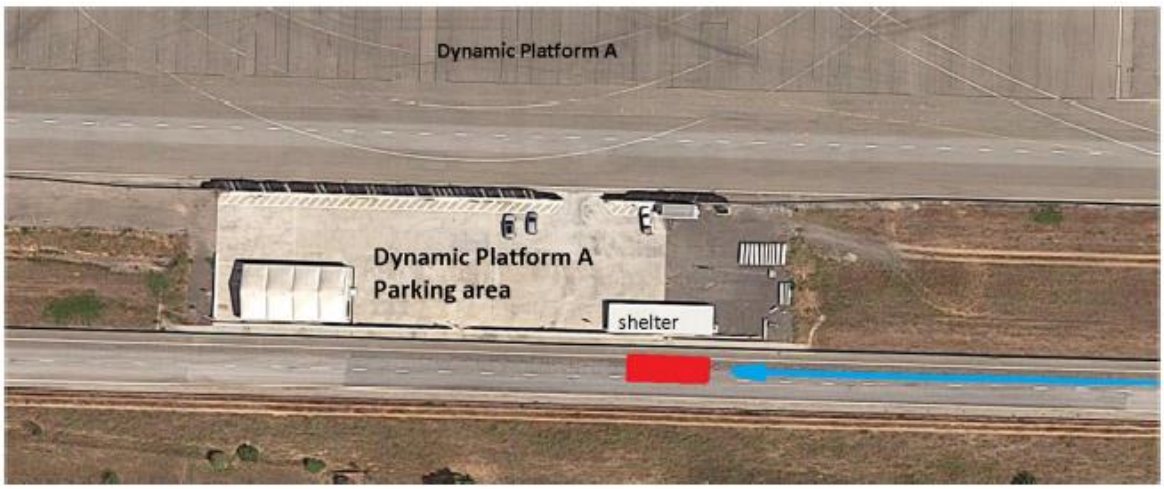

Figure 13: Sensors installation location

5.2. Open road

Three routes had been chosen for the test in real traffic and orography conditions, IDIADA-Lleida and IDIADA-Barcelona airport by two different routes. After discussion with the traffic authority of Catalonia, it was agreed to modify the final destinations of the routes to try to make the procedures easier and avoid potential issues. At the time this document was written, the final routes are awaiting approval by the national traffic regulatory authorities. These final routes have different challenges to test the platoon system.

Figure 14: Ruts select for open road tests shows the track of the three routes, IDIADA–Lleida through AP-2 (blue line), IDIADA–El Prat de Llobregat through AP-7 (green line) and IDIADA–El Prat de Llobregat through C-32 (red line).

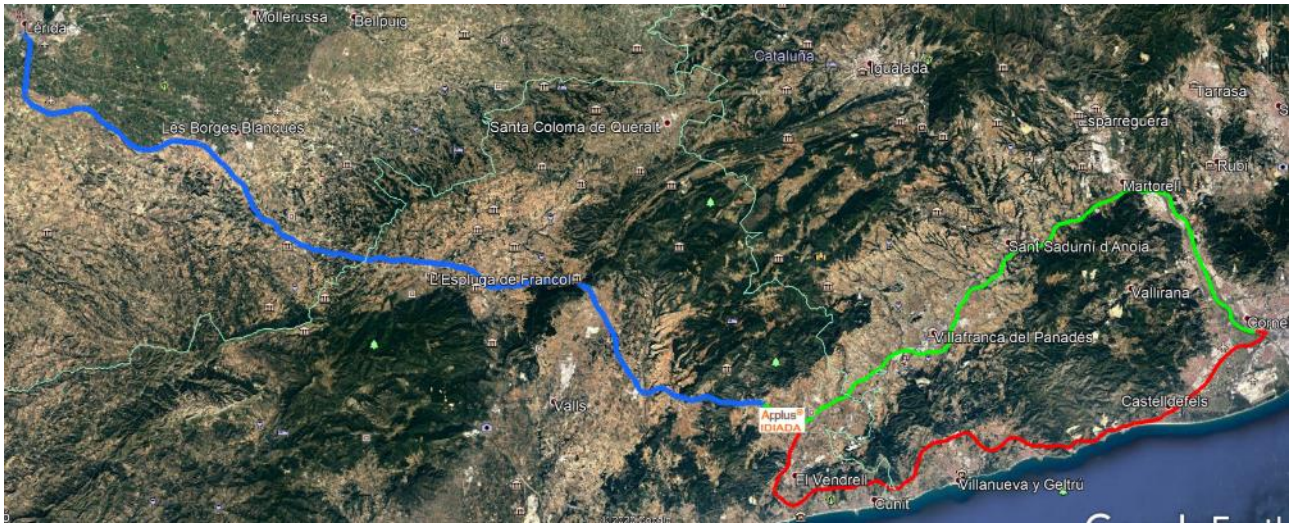

Figure 14: Ruts select for open road tests

The slope of the route IDIADA-Lleida is showed in Figure 15: IDIADA – Lleida through AP-2 and the main characteristics in Table 1 and Table 2, this route is usually used by IDIADA to carry out the fuel consumption tests since the flow of traffic is low and there are sections of the road with constant slopes.

Figure 15: IDIADA – Lleida through AP-2

Table 1: Details of the route IDIADA – Lleida through AP-2

Characteristic	Value
Distance	99 Km
Altitude min/max	96 / 571 m
Maximum Speed	90 km/h

Slope max / min	11,5 / -7 %

Table 2: Route AP-2 characteristics data

IDIADA - Lleida		Lleida - IDIADA	
Exits	14	Exits	14
Entries	13	Entries	14
Tool	1	Tool	1
Incorporation	3	Incorporation	1
Deviation	1	Deviation	1
Maximum of lines	3	Maximum of lines	3
Minimum of lines	1	Minimum of lines	1
Mode of lines	2	Mode of lines	2

The slope of the route IDIADA-–El Prat de Llobregat through AP-7 is showed in Figure 16: IDIADA–El Prat de Llobregat through AP-7 and the main characteristics in Table 3 and Table 4, this route was selected because the traffic flow is high, there are several active highway crossings and tolls. Another reason for choosing this route is the existence of the smooth slopes. These will be very useful to study the behaviour of the system to check the stability of the peloton.

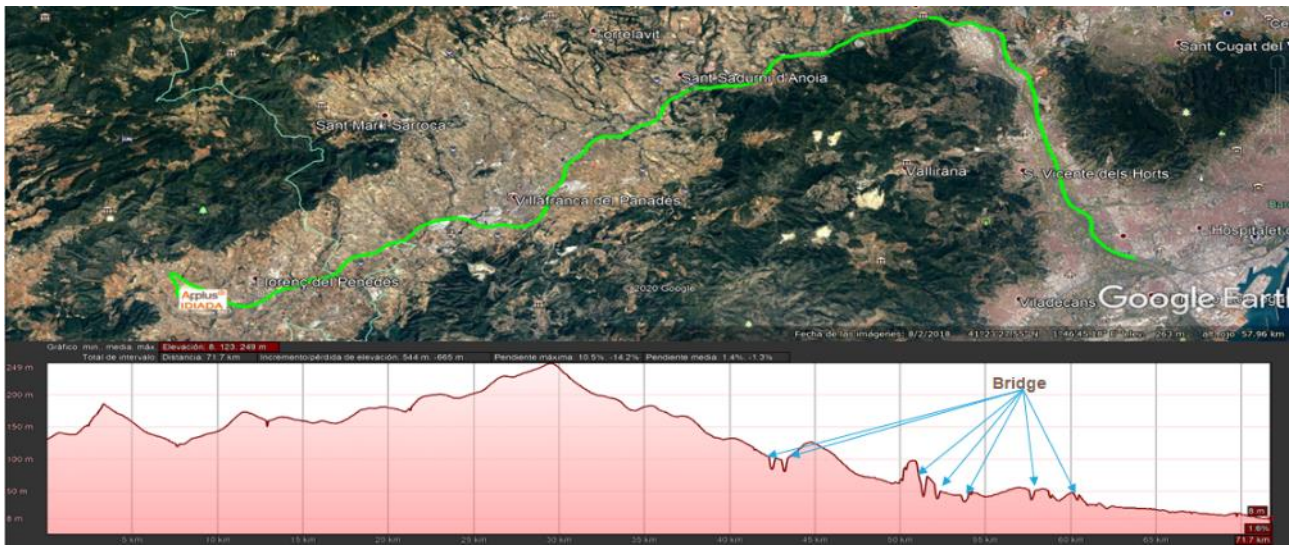

Figure 16: IDIADA–El Prat de Llobregat through AP-7

Table 3: Details of the route IDIADA–El Prat de Llobregat through AP-7

Characteristic	Value
Distance	71.7 Km
Altitude min/max	1 / 249 m
Maximum Speed	90 km/h
Slope max / min	7.7 / -5.2 %

Table 4: Route AP-7 characteristics data

IDIADA - El Prat de Llobregat		El Prat de Llobregat - IDIADA	
Exits	12	Exits	15
Entries	14	Entries	10
Tool	1	Tool	1
Incorporation	3	Incorporation	4
Deviation	3	Deviation	2
Maximum of lines	4	Maximum of lines	5
Minimum of lines	1	Minimum of lines	1
Mode of lines	3	Mode of lines	3

The slope of the route IDIADA-–El Prat de Llobregat through C-32 is showed in Figure 17: IDIADA–El Prat de Llobregat through C-32 and the main characteristics in Table 5 and Table 6. This route was selected because the traffic flow is low, there are several active tolls, tunnels and narrow passages. The tunnels and narrow passages will be useful to test the conduct of the platoon when the GPS signal and communication could be failed. Another reason for choosing this route is the existence of the smooth slopes. These will be very useful to study the behaviour of the system to check the stability of the peloton.

Figure 17: IDIADA–El Prat de Llobregat through C-32

Table 5: Details of the route IDIADA–El Prat de Llobregat through C-32

Characteristic	Value
Distance	75.2 Km
Altitude min/max	1 / 180 m
Maximum Speed	90 km/h
Slope max / min	5.4 / -4.4 %

Table 6: Route C-32 characteristics data

IDIADA - El Prat de Llobregat		El Prat de Llobregat - IDIADA	
Exits	20	Exits	21
Entries	20	Entries	21
Tool	3	Tool	3
Incorporation	5	Incorporation	5
Deviation	3	Deviation	3
Tunnels	8	Tunnels	8
Maximum of lines	4	Maximum of lines	4
Minimum of lines	1	Minimum of lines	1
Mode of lines	2	Mode of lines	2
Minimum tunnel distance	156	Minimum tunnel distance	156
Maximum tunnel distance	1714	Maximum tunnel distance	1714
Median tunnel distance	667	Median tunnel distance	667

6. MEASURING MULTI-BRAND TRUCK PLATOONING PERFORMANCE - DATA LOGGING EQUIPMENT

In the ENSEMBLE project, IDIADA could adapt a data acquisition system called iDAPT which is a multi-purpose, flexible OBU development tool for connected and autonomous prototyping and development activities. This data acquisition system integrates the NVIDIA Jetson platform, with a selection of modular connectivity and positioning technologies with standard and emerging automotive I/O inside one safe and reliable tool.

This device provides the ability to "retro-fit" connected vehicle capabilities into an existing system for prototyping/development needs. With its modular design, components can be removed/upgraded as required. IDAPT also provides the ability to start-up without any user interaction using 3 different mechanisms: wake on CAN, wake on ignition and wake on RTC (configurable specified time).

This tool is perfect for:

- ADAS & CAV Field Operational Test (FOT)
- Connected vehicle projects
- V2X application development
- Cyber-security development
- Camera imaging and object detection
- Automotive IoT prototyping
- Sensor development (LiDAR, RADAR)
- Automated vehicle controls
- Machine learning algorithm development
- Prototype datalogging

In Figure 18: iDAPT setup configuration an overview of the setup that could be integrated.

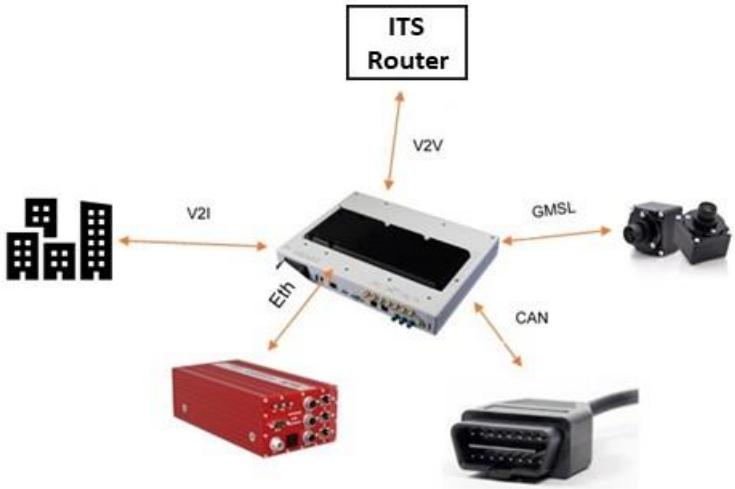

Figure 18: iDAPT setup configuration

Table 7 is a summary of the equipment that will be used for multi-brand validation, this system could be integrated in an external vehicle to monitor the platoon:

Table 7: List of equipment

Tool	Type	Description
iDAPT	Hardware	This tool will be in charge of recording all the data necessary for the verification of the test cases defined for proving grounds.
Reference GPS	Hardware	This device will be used as the reference positioning system.
Cameras	Hardware	The cameras will be used for recording the driver behaviour and the front view and rear view of the truck.
OBD	Hardware	OBD will be used for recording all the necessary data from the internal sensors of the truck.
SDR	SW/HW	Radio communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on an embedded system.

To obtain a good quality of measurement of the tests run this system shall be installed in each vehicle involved in the tests. The system could also be integrated in an external vehicle to monitor the platoon.

7. MEASURING TRAFFIC DATA

As an input for the work in WP4 on the effects of truck platooning on traffic flow and safety, the following KPIs are measured during the open road tests. The way of measuring these KPI's is either by filming from a helicopter above the traffic, or by capturing the movements of the traffic by LIDAR's installed on a vehicle in front and behind the truck platoon. Filming from a drone turned out not to be possible with regard to the road authorities regulations.

- **Dynamic Performance and Operation**: *Measure dynamic characterization of a multiple brand platoon* is important for this purpose. The main objective here is to quantify the stability of the time gap, headway space and acceleration profiles for specific manoeuvres and within determined trips. Quantification on variation of these variables can impact the stability of traffic flow regimes, during steady flow conditions.
- **Impact on traffic flow**: The existence of platoons in traffic inherently causes changes in the behaviour of traffic surrounding the platoon. Drivers approaching a platoon may tend to keep safer distances, overtake under specific conditions or simply modify driving speed. Being able to capture specific traffic indicators related to the presence of platoons may help to quantify this behaviour.
- **Platoon behaviour during manoeuvres**: Given the different levels of platoon specifications, determining the impact of specific platoon manoeuvres performed under the presence of several traffic conditions is important to assess the impact of truck platoons in traffic flow. Truck platoon manoeuvres such as: Joining a platoon, dissolving an existing platoon, real cut-in manoeuvres from external drivers can be characterized in time and space and they can provide insight on how the deployment of such strategies may lead to an effect in traffic flow.

Traffic can be characterized at multiple scales: at microscopical scale specific vehicle interactions are aimed to be measured. At macroscopic level aggregated behaviours of a group of drivers are intended to be examined. Example of microscopic characteristics are individual vehicle speed, space headway, acceleration. At a macroscopic level, aggregation of microscopic variables is regularly measured at fixed points in space. Examples of this traffic data are average speed, flow, occupancy. Each technology captures two different type of behaviours that are important to understand variations in traffic flow. This sensor scheme can be observed in Figure 19: Catalonia Living Lab testbed.

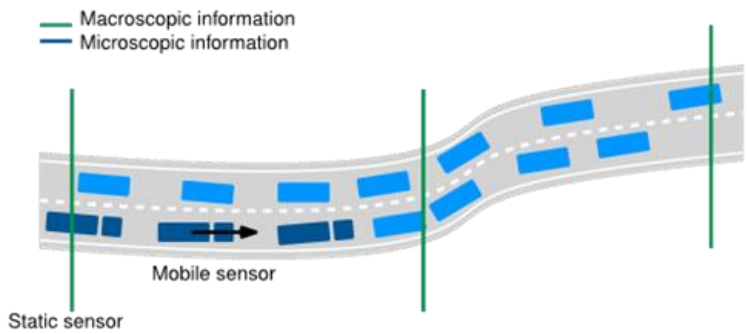

Figure 19: Catalonia Living Lab testbed

Road-traffic sensors can capture different types of traffic data which in terms of level of aggregation allows a better estimation of the traffic states, as well as levels of detail. Data availability is important to characterize the traffic behaviour in different scales of space and time.

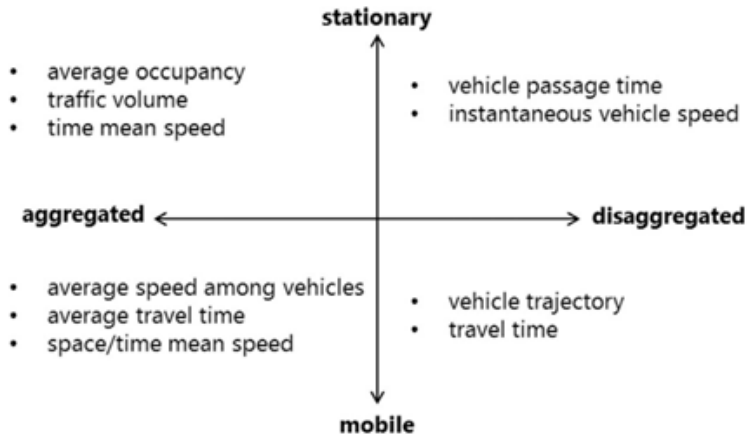

Figure 20: Aggregation data levels and details on the captured information

Mobile data is data associated with specific vehicles that usually provide measurements along a vehicle trajectory. It is a big source of interest for monitoring traffic due to the introduction of sophisticated ADAS functionalities that appear more often in new vehicles such as ACC. Nevertheless, the interaction of these technologies may lead to traffic instabilities. Examples of mobile data for traffic are GPS data, Bluetooth technologies and more recently radar sensors widely used in autonomous vehicles.

8. EMISSIONS AND FUEL CONSUMPTION

As an input for the work in WP4 on the effects of truck platooning on fuel consumption, the following KPIs are measured during the test track and open road tests:

- Effect of platooning on a test track under stable conditions following the standardized SAE testing method comparing a single truck with different formations of the platoon
- Possible impacts of real traffic and road conditions on platoon behaviour and fuel consumption. To determine whether these conditions can influence the fuel consumption compared to the test track and base case (no platooning i.e. individual truck).
- Modelling estimation of the effect of multi-brand platooning on fuel consumption and CO2 emissions and other emissions (NOx and NH3) of individual vehicles for a typical case (e.g. a corridor).
    - Percentage of saving fuel, l/100km normalized.
    - Percentage of saving CO2, g/km normalized.
    - Percentage of saving other emissions (NOx and NH3), g/km normalized.

The measurements will be carried out during IDIADA test tracks and open road test. Each truck will be equipped with special sensors. The data of these sensors will be captured and analysed by Smart Emissions Measurement System (SEMS). SEMS is a specific equipment developed by TNO to capture and analyse the fuel consumption and emissions from a vehicle. Figure 21: SEMS block diagram shows the SEMS block diagram and the different connections available.

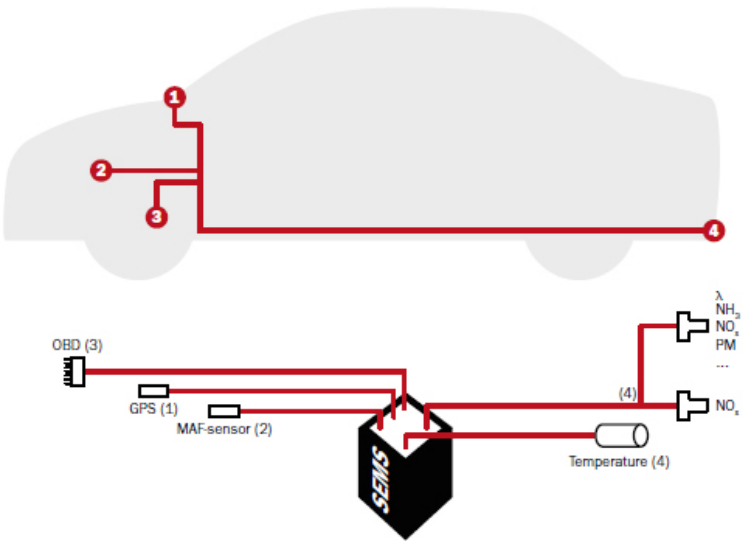

Figure 21: SEMS block diagram

- Fuel consumption measured using the OBD connector integrated in SEMS,
- GPS tool integrated in SEMS,

- External emissions sensors,
- 24V switched measurements using external sensor,
- GRPS to send data to central TNO server,
- SEMS can record additional I/O.

8.1. Emission and fuel consumption test phases

The goal of the fuel consumption task is to determine possible impacts of real traffic and road conditions on platoon behaviour and fuel consumption.

The tests of fuel consumption will be divided in two phases: tests in the IDIADA's proving ground and tests in open road.

The tests carried-out on proving ground will be used to measure fuel consumption and emissions under a controlled condition so that a basis for comparison can be established without the influence of traffic and orography. These tests will be done as a speed ([70,85] Km/h) and time gap between trucks of ([1.4, 2] sec).

Every fuel consumption and emission test day will be composed of different phases:

- 1 warm-up of 60min.
- 60min testing + break (10-15 min)
- 60min testing + break (10-15 min)
- 60min testing + break (10-15 min)

The open road route tests will be used to measure fuel consumption in realistic conditions. The main characteristics of open road id the different type/topologies and traffic conditions:

- Effect of road grade on lateral gaps. Mountains and slope roads.
- Effect of cut in on lateral gaps.
- Effect of catching up.
- Unforeseen real-world conditions

9. DATA MANAGEMENT

The objective of data management is to create a methodology and the tools to collect and manage the test data that will be collected in the different tasks of the project.

Building upon the relevant results from field operational tests and automation projects an inventory of these tools for the whole procedure of tests, including data acquisition, transmission, database structure, quality assurance, and data storage will be created.

Figure 22: Data management methodology in ENSEMBLE shows a block diagram of the proposed data management plan in ENSEMBLE. The main idea is to create a server to upload all data collected during the corresponding project validation phase.

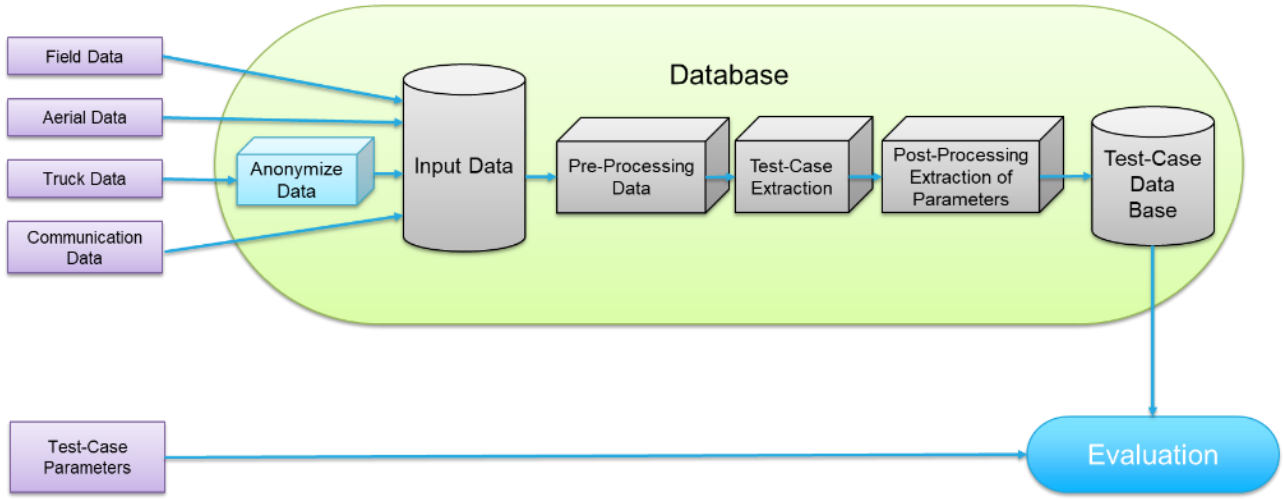

Figure 22: Data management methodology in ENSEMBLE

One of the key points is that data recorded from trucks will be anonymized, as the goal of the project is not to evaluate truck's performance but the performances of the communication and interaction between them and the platoon performance in the different environment and test conditions.

Then, data will be stored on IDIADA's database and only analysed by persons authorised by the project management team. Then, every data requested by other WPs or anybody in the ENSEMBLE-project consortium will be provided in the agreed format and only after discussion and agreement with the project coordinator on the procedure to follow for data sharing.

9.1. Data acquisition

WP4 and WP5 have identified the necessary variables to be monitored and acquired during the tests. The variables, unit of measurement, range, tolerance, minimum measurement frequency and a possible source of the data logger are showed in Table 8.

It is also necessary to save all the V2V messages received by each vehicle in order to analyse the data and the behaviour of the system, such as detecting a possible lost message, communication failures and sensor issues. Table 9 specifies the information and the device used for storing it, as well as the partner responsible for acquiring this information.

Table 8: Variables to measure in the test runs

Variable	Unit	Range	Tolerance	Min freq. (HZ)	Data source
Fuel rate	l/h		as provided	1	SEMS
% engine torque	%	[0, 100]	as provided	1	SEMS
% friction torque	%	[0, 100]	as provided	1	SEMS
Engine speed	Rpm	[0, 2000]	as provided	1	SEMS
Coolant, oil temps	ºC	[-10, 100]	as provided	1	SEMS
DPF regen status	Boolean	[0, 1]	as provided	1	SEMS
Brake activation	Boolean	[0, 1]	as provided	1	SEMS
Throttle position	%	[0, 100]	as provided	1	SEMS
Gear	integer			1	SEMS
Exhaust temp	ºC	[0, 500]	+/-2 ºC	1	SEMS
NOx Concentration	ppm	[0, 2000]	+/- 10%	1	SEMS
NH3 Concentration	ppm	[0, 100]	+/- 20%	1	SEMS
Fuel flow	l/h	[0, 120]	+/- 1%	1	SEMS
Front pressure	KPa			1	-
Rear pressure	KPa			1	-
Temperature	ºC	[-80, 60]	[-80, 20] → ±(0.226 – 0.0028 x temperature) °C (20, 60] → ±(0.055 + 0.0057 x temperature) °C	1	Local Weather station
Asphalt Temperature	ºC	[-5, 95]	+/- 0.3 ºC	1	Local Weather station
Atmospheric Pressure	mb	[500.0, 1100.0]	+/- 0.6 mb @ (0, 40)º +/- 0.3 mb @ 20º	1	Local Weather station
Relative Humidity	%	[0, 100]	± (1.0 + 0.008 × reading) % RH	1	Local Weather station
Wind speed	m/s	[0, 100]	+/- 0.3 m/s	1	Local Weather station
Wind direction	º	[0, 360]	+/- 3 º	1	Local Weather station

Variable	Unit	Range	Tolerance	Min freq. (HZ)	Data source
Tire pressure	KPa			1	-
Vehicle weight	Kg			1	-
Gap distance	m		+/- 0.1 m	20	V2V system & Truck log
Position in platoon	integer	[0, 7]	-	20	V2V system & Truck log
Speed	m/s	[0, 100]		20	V2V system & Truck log
Longitudinal acceleration	m/s^2			20	V2V system & Truck log
Brake activation	Boolean	[0, 1]		20	V2V system & Truck log
Torque demand				1	V2V system & Truck log
Coordinates	(º, º)	([-90-90], [-180,180])º	+/- 0.02 m	10	RT-Range
Speed	m/s	[0, 100]	+/- 0.06 m/s	10	RT-Range
Lateral position	m		+/- 0.02 m	10	RT-Range
Position of surrounding vehicles	m	[0, 300]		1	Lidar
Speed of surrounding vehicles	m/s	[0, 100]		1	Lidar

Table 9: Information and logs

Information	Device/log	Acquire responsibility
All V2V messages (send and receive)	OBU truck	Each OEM is responsible for his OBU's trucks
V2X information	RSU proving ground	IDIADA
Status platoon vehicles information	Vehicles' logs	Each OEM is responsible for his truck's logs
Weather information	Local weather station	IDIADA
Consume & emission data	SEMS	TNO
Position and speed of platoon vehicles with high accuracy	RT-Range	Under discussion
Dynamic characteristics of surrounding vehicles	Lidar	Under discussion

Data will be recorded in a separate file for each test run and device. All devices that record data must be synchronized with the GPS time and have unique identification. Sensors connected to the data logging device shall be identified with a unique tag. Each line of the log file must begin with device identification, device time stamp, and sensor tag that produces the measurement or measurements.

10. TEST DATES

Figure 23: ENSEMBLE testing time shows the ENSEMBLE validation test plan for multi-brand tests in proving ground and open road.

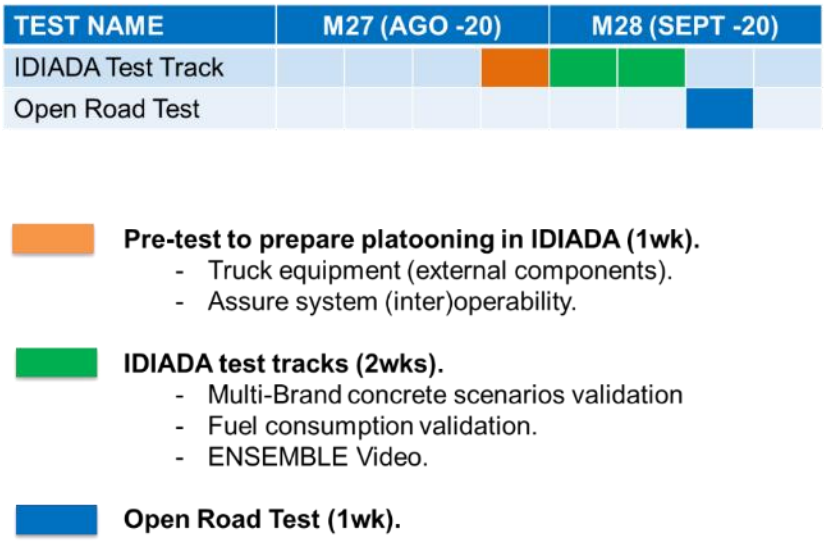

Figure 23: ENSEMBLE testing time

11. SUMMARY AND CONCLUSION

This report defines the methodology used in the ENSEMBLE project to define the scenarios and test run. This is the second version of this definition, following the deliverable D5.1. The scenarios defined in this document will be concrete and test plan refined following other test results and new information that will be available from other work-packages.

Using the inputs from WP2, WP3, WP4 and the consortium members a test plan for verification, validation and demonstration of multi-brand platoon solution have been described. Moreover, a plan for the data management was presented.

11.1. Test plan methodology

A common methodology for multi-brand testing (including three-brand testing) has been introduced, been divided in three phases or levels to define the different scenarios:

- Functional scenario or high-level description of the test procedure. In this phase, the scope, test procedure, required operational domain and acceptance criteria are described in words and pictures only to clarify the scenario sequence. A complete list of parameters is also identified in the process of defining this level.
- Logical scenario: at this level the description of the scenario is detailed by identifying the different variables and labelling them. A range of values and/or positions is defined for each variable.
- Concrete scenario: It is the low-level scenario, in this level each parameter is defined with a value. The sequence of actions is completely defined. The acceptance criteria must be defined with values and tolerance ranges. Concrete scenarios will be groped on different test runs.

11.1.1. Scenarios

In the ENSEMBLE project eight general scenarios have been identified for testing. These scenarios have at the same time sub-scenarios, each sub-scenario being a specific test case:

- 00: Static test (V2V requirements)
- 01: Platoon join
- 02: Steady state platooning
- 03: Emergency braking
- 04: I2V interaction
- 05: Cut-in
- 06: System status (mono-brand OEM responsibility)
- 07: Disengage platoon
- 08: Platoon cohesion

11.2. Testing environments

Different tracks have been chosen to test all scenarios, requirements and emissions, fuel consumption and traffic flow.

Three brand tests will be carried-out at two different locations in Europe, AstaZero in Sweden and Pferdsfeld in Germany. Then, multi-brand testing with all OEMs at the IDIADA facilities in Spain were the High-Speed Track has been chosen to perform the tests.

On the open road, three different routes have been chosen to measure fuel consumption, traffic flow and the general behaviour of the platoon system.

12. BIBLIOGRAPHY

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13. APPENDIX A.

In this section the project scenarios are detailed at functional level. First scenario will also be defined at logical and concrete levels as an example. All scenarios will be defined at concrete levels. These scenarios will be updated based on the evolution of the project, mainly based on the experience gotten with three-brand tests.

13.1. SC_01 Platoon join

The scenarios for the platoon join are:

- Joining from behind by single vehicle
- Joining from behind by an existing platoon
- Merge in between by single vehicle
- Verification of the maximum number of trucks in a platoon
- Refuse joining due to maximum number of trucks
- Non joinable situations

13.1.1. SC_0101: Joining from behind by single vehicle

13.1.1.1. Functional level

The Figure 24Figure 24: SC_0101 diagram states is the graphic description of the scenario.

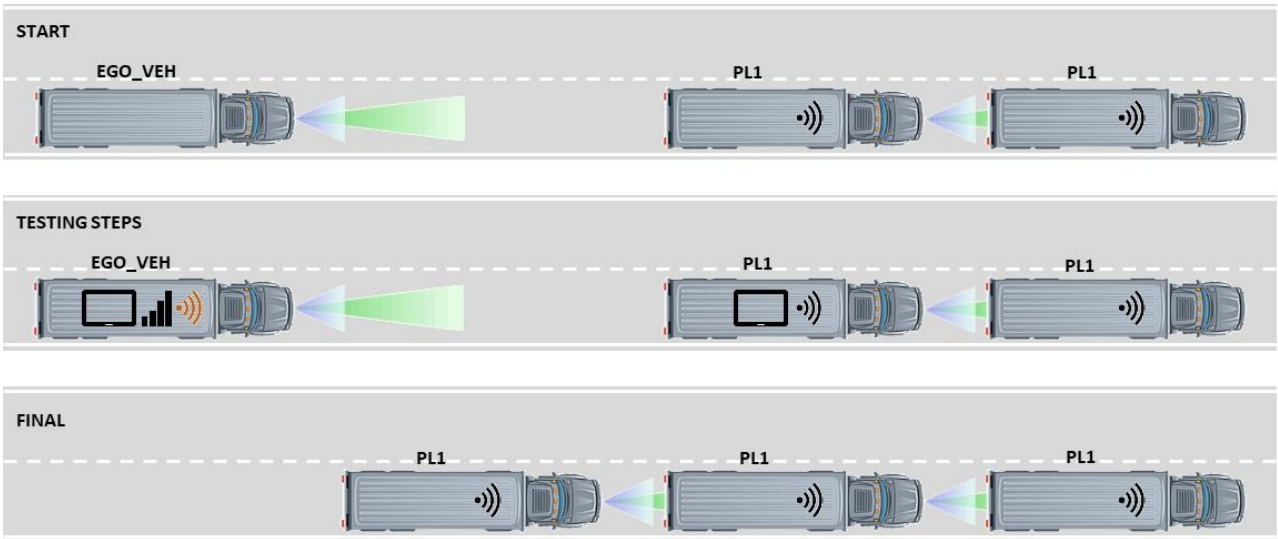

Figure 24: SC_0101 diagram states

The Table 10 contains the functional description of the joining from behind by single vehicle scenario:

Table 10: Functional scenario SC_0101

ID	**SC_0101**
Use Case	Platoon Join
Scenario Name	Joining from behind by single vehicle (Use case 2.1 as per D2.3 specification)
Scenario description	An ego vehicle behind sends a joining request to an existing platoon in front. The ego vehicle is accepted and joins the platoon.
Objective	Validate a correct vehicle joining behind to an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) (internal & V2X). - No warnings. - Platoon already existing. - At least 2km of free road lane. - Define all brands payload involved in the scenario.
Initial State	- The ego vehicle is driving behind an existing platoon at the same lane. - Ego vehicle is driven at a defined speed (with tolerance). - The existing platoon in front is formed and in steady stable condition with a specific number of trucks. - The existing platoon is driving at a specific speed. - The platoon is joinable (Only the trailing vehicle).
Trigger	- The driver of the ego vehicle activates the system (joinable == TRUE). application and the platoon application are in 'Joinable' mode.
Testing Steps	1) The Ego vehicle is receiving the joinable information from the trailing vehicle of the platoon in front. 2) The driver of ego vehicle starts the joining procedure. 3) The trailing of the existing platoon receives the V2V joining message and evaluates the correct joining conditions. 4) The ego vehicle performs the join procedure (V2V).
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204. - No system failures. - The limit distance gap between trucks is respected during overall the procedure. - No undesired acceleration greater than the acceleration limit.
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	- EGO vehicle brand - EGO vehicle payload - EGO vehicle speed - EGO vehicle distance - Platoon ID - Platoon speed

	- Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.1.1.2. Logical level

The Table 11 contains the logical description of the joining from behind by single vehicle scenario:

Table 11 Logical scenario: SC_0101

ID	**SC_0101**
Use Case	Platoon Join
Scenario Name	Joining from behind by single vehicle
Scenario description	An ego vehicle (EGO_VEH) with a certain payload (EGO_VEH_PLD) at a certain distance (EGO_VEH_DIST) behind sends a joining request to an existing platoon (defined by a PLx_SIZE_INIT and a PLx_FORM) in front circulating at constant speed (PLx_SPEED). The ego vehicle is accepted and joins the platoon.
Objective	Validate a correct vehicle joining behind to an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload (BRAND_PLD) involved in the scenario
Initial State	- The ego vehicle (EGO_VEH) is driving behind (EGO_VEH_DIST) an existing platoon (PLx) at the same lane. - Ego vehicle is driven at a certain speed (EGO_VEH_SPD). - The existing platoon (PLx) in front is formed with a specific number of trucks (PLx_SIZE_INIT). - The existing platoon is driving a specific speed (PLx_SPEED).
Trigger	- The driver of the ego vehicle (EGO_VEH) activates the system (joinable == TRUE) application and the platoon application are in 'Joinable' mode.
Testing Steps	1) The driver of the ego vehicle starts the joining procedure. 2) The trailing of the existing platoon receives the V2V joining message and evaluates the correct joining conditions. 3) The ego vehicle performs the join procedure (V2V).
Acceptance Criteria	- Ego vehicle is in the platoon using V2V communications - HMI shows the correct information of the platoon - HMI show no warnings and no system failures

	- the limit distance gap (NOMINAL_TIME_GAP) between trucks is respected during overall the procedure. - No undesired acceleration greater than the acceleration limit.
Final State	A final platoon PLx with a new platoon size is formed with a PLx_SPEED in steady state platooning.
Parameters (inputs)	- EGO_VEH: Name Brand - EGO_VEH_PLD - EGO_VEH_SPD [30,90] - EGO_VEH_DIST - PLx - PLx_SPEED [30,89] - PLx_SIZE_INIT [1,6] - PLx_FORM (BRAND1 ... BRAND[PLx_SIZE_INIT]) - BRAND_PLD (BRAND_PLD1 ... BRAND_PLD[PLx_SIZE])
Signals (outputs)	- PLx - PLx_SIZE _FINAL - PLx_SPEED - PLx_FORM (BRAND1 ... BRAND[PLx_SIZE_FINAL]) - EGO_VEH_ACC

13.1.1.3. Concrete level

The Table 12 are listed the concrete test cases for this scenario:

Table 12: Concrete scenario SC_0101

Concrete Scenario ID	Parameters Values	Signals Values	Acceptance Criteria
01	- EGO_VEH: DAF - EGO_VEH_PLD: Y - EGO_VEH_SPD: 30 (+/-5) km/h - EGO_VEH_DIST: ~30-50 m - PL1 - PL1_SPEED: 30 km/h - PL1_SIZE_INIT: 1 - PL1_FORM: MAN - BRAND PAYLOADS to be defined in run scenario	- PL1 - PL1_SIZE _FINAL: 2 - PL1_SPEED: 35 km/h - PL1_FORM: [1-MAN, 2-DAF] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_SIZE _FINAL: 2 - PL1_FORM: [1-MAN, 2-DAF] - PL1_SPEED: 35 Km/h
02	- EGO_VEH: DAI - EGO_VEH_PLD: N	- PL1 - PL1_SIZE _FINAL: 3	- PL1_SIZE _FINAL: 3

	- EGO_VEH_SPD: 30 (+/-5) km/h - EGO_VEH_DIST: ~30-50 m - PL1 - PL1_SPEED: 30 km/h - PL1_SIZE_INIT: 2 - PL1_FORM: [1-DAF, 2-SCA] - BRAND PAYLOADS to be defined in run scenario	- PL1_SPEED: 35 km/h - PL1_FORM: [1-DAF, 2-SCA, 3-DAI] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_FORM: [1-DAF, 2-SCA, 3-DAI] - PL1_SPEED: 35 Km/h
03	- EGO_VEH: REN - EGO_VEH_PLD: N - EGO_VEH_SPD: 60 (+/-5) km/h - EGO_VEH_DIST: ~60-80 m - PL1 - PL1_SPEED: 60 km/h - PL1_SIZE_INIT: 3 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI] - BRAND PAYLOADS to be defined in run scenario	PL1 - PL1_SIZE _FINAL: 4 - PL1_SPEED: 45 km/h - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_SIZE _FINAL: 4 - PL1_FORM: [1-DAI, 2-VCC, 3-IVE, 4-RSA] - PL1_SPEED: 45 Km/h
04	- EGO_VEH: SCA - EGO_VEH_PLD: Y - EGO_VEH_SPD: 60 (+/-5) km/h - EGO_VEH_DIST: ~80-100 m - PL1 - PL1_SPEED: 60 km/h - PL1_SIZE_INIT: 4 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN] - BRAND PAYLOADS to be defined in run scenario	- PL1 - PL1_SIZE _FINAL: 5 - PL1_SPEED: 60 km/h - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_SIZE _FINAL: 5 - PL1_FORM: [1- RSA, 2-IVE, 3-VCC, 4- DAI, 5-SCA] - PL1_SPEED: 60 Km/h
05	- EGO_VEH: IVE - EGO_VEH_PLD: Y	- PL1 - PL1_SIZE _FINAL: 6 - PL1_SPEED: 85 km/h	- PL1_SIZE _FINAL: 6

	- EGO_VEH_SPD: 85 (+/-5) km/h - EGO_VEH_DIST: ~120-150 m - PL1 - PL1_SPEED: 85 - PL1_SIZE_INIT: 5 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA] - BRAND PAYLOADS to be defined in run scenario	- PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA, 6-IVE] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_FORM: [1- RSA, 2-IVE, 3-VCC, 4- DAI, 5-SCA, 6-VCC] - PL1_SPEED: 85 Km/h
06	- EGO_VEH: VOL - EGO_VEH_PLD: Y - EGO_VEH_SPD: 85 (+/-5) km/h - EGO_VEH_DIST: ~150-180 m - PL1 - PL1_SPEED: 85 - PL1_SIZE_INIT: 6 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA, 6-IVE] - BRAND PAYLOADS to be defined in run scenario	- PL1 - PL1_SPEED: 85 km/h - PL1_SIZE_FINAL: 7 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA, 6-IVE, 7-VOL] - EGO_VEH_ACC: <= 3.5 m/s^2 - V2V Join request - V2V Join response	- PL1_SIZE _FINAL: 7 - PL1_FORM: [1-DAF, 2-SCA, 3-DAI, 4-REN, 5-SCA, 6-IVE, 7-VOL] - PL1_SPEED: 85 Km/h

13.1.2. SC_0102: Joining from behind by an existing platoon

13.1.2.1. Functional level

The Figure 25Figure 25: SC_0102 diagram states is the graphic description of the scenario.

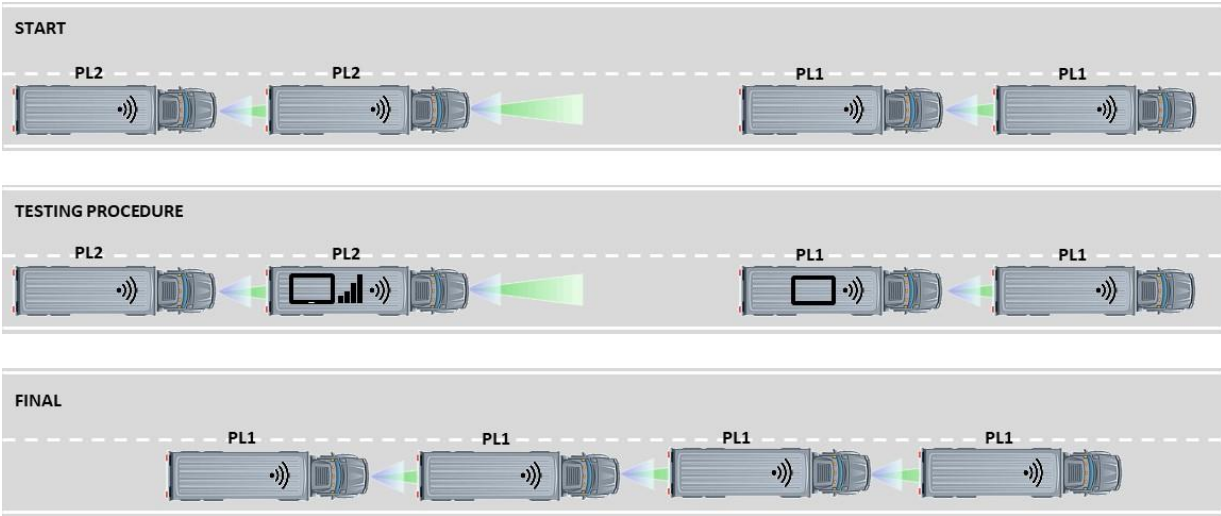

Figure 25: SC_0102 diagram states

The Table 13 contains the functional description of the joining from behind by an existing platoon scenario:

Table 13: Functional scenario SC_0102

ID	SC_0102
Use Case	Platoon Join
Scenario Name	Joining from behind by an existing platoon (Use case 2.1 as per D2.3 specification)
Scenario description	An existing platoon behind sends a joining request to an existing platoon in front. The platoon behind is accepted and joins the platoon in front.
Objective	Validate two different platoons joining (joining behind) and driving at the same lane. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) (internal & V2X) - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- A formed platoon and stable is driving behind to an existing platoon at the same lane. - The existing platoon is driven at a defined speed (with tolerance). - The existing platoon in front is formed and in steady stable condition with a specific number of trucks.

	- The existing platoon is driving at a specific speed.
Trigger	- The ego platoon system and the platoon system are in 'Joinable' mode.
Testing Steps	1) The Ego Platoon is receiving the joinable information from the trailing vehicle of the platoon in front. 2) The leading driver of the platoon behind starts the joining procedure. 3) The trailing of the existing platoon in front receives the V2V joining message and evaluates the correct joining conditions. 4) The leading vehicle of the platoon behind performs the join procedure (V2V).
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The limit distance gap between trucks is respected during overall the procedure. - No undesired acceleration greater than the acceleration limit.
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	(platoon in front and behind) - Platoon ID (X2) - Platoon speed (X2) - Platoon size initial (X2) - Platoon line-up (X2) - Brand payload (X2)
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.1.3. SC_0103: Merge in between by single vehicle

13.1.3.1. Functional level

The Figure 26Figure 26: SC_0103 diagram states is the graphic description of the scenario.

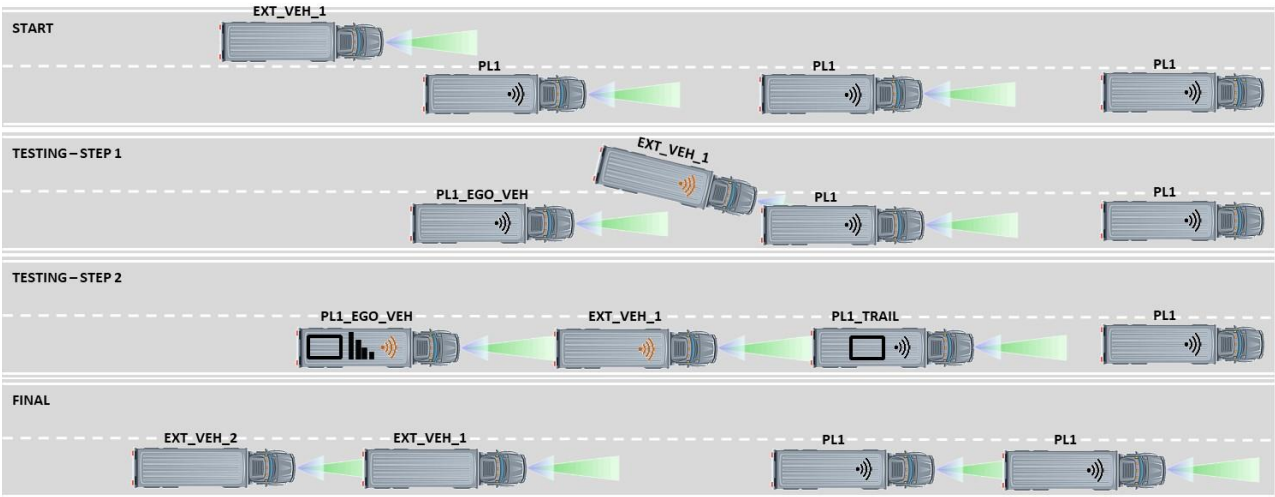

Figure 26: SC_0103 diagram states

The Table 14 contains the functional description of the merge in between by single vehicle scenario:

Table 14: Functional scenario SC_0103

ID	SC_0103
Use Case	Platoon Join
Scenario Name	Merge in between by single vehicle (Use case 2.2 as per D2.3 specification)
Scenario description	A joinable external vehicle merge-in an established, steady state driving and an existing platoon in front.
Objective	Validate a correct merge-in from an external vehicle to an existing platoon in front, a split procedure occurs if the new vehicle wants to join. Validate the different manoeuvres and the communication.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - 2 road lines - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An external vehicle is driving behind in the left lane to an existing platoon in the right lane. - The external vehicle is driving at specific speed (with tolerance).

	- The existing platoon in front is formed and in steady stable condition with a specific number of trucks.
Trigger	- The external vehicle cuts-in the existing platoon.
Testing Steps	1) The external vehicle in the left lane cuts-in the existing platoon in front. 2) The ego vehicle behind detects the cut-in vehicle and reduces speed to increase the distance to this vehicle. 3) The platoon system of the ego vehicle detects that the cut-in vehicle is joinable. 5) The ego vehicle starts the split procedure from the former platoon (front split).
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The limit distance gap between trucks is respected during overall the procedure.
Final State	Platoon is split.
Parameters (inputs)	- Ext_Veh vehicle brand - Ext_Veh vehicle payload - Ext_Veh vehicle speed - Ext_Veh vehicle distance - Platoon ID (x2) - Platoon speed (x2) - Platoon size initial (x2) - Platoon line-up (x2) - Brand payload (x2)
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.1.4. SC_0104: Verification of the maximum number of trucks in a platoon

13.1.4.1. Functional level

The Figure 27Figure 27: SC_0104 diagram states is the graphic description of the scenario.

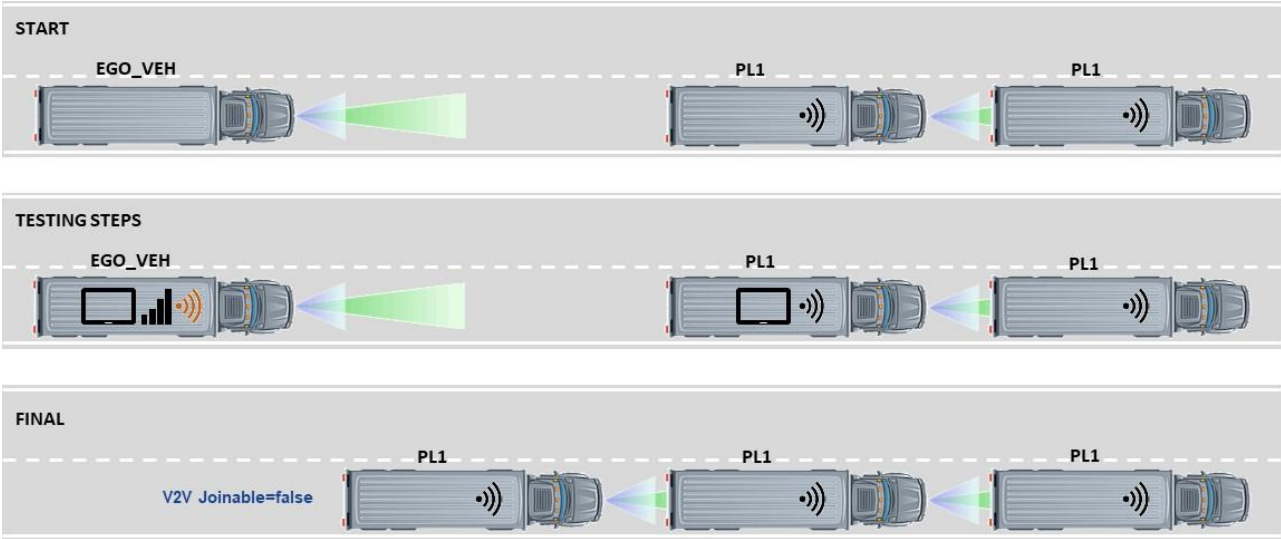

Figure 27: SC_0104 diagram states

The Table 15 contains the functional description of validation of the maximum number of trucks in a platoon scenario:

Table 15: Functional scenario SC_0104

ID	SC_0104
Use Case	Platoon Join
Scenario Name	Verification of the maximum number of trucks in a platoon
Scenario description	An ego vehicle from behind proceed to join to the platoon. When the ego vehicle is joining the platoon, the platoon acquires the maximum number of trucks allowed.
Objective	Validate the correct functionality of the flags joinable of the system.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The ego vehicle is driving behind an existing platoon at the same lane. - the ego vehicle is not joinable - Ego vehicle is driven at a defined speed (with tolerance).

	- The existing platoon in front is formed and in steady stable condition with a maximum number of trucks allowed minus one. - The existing platoon is driving at a specific speed.
Trigger	- The driver of the ego vehicle starts the joining procedure.
Testing Steps	1) The Ego vehicle is receiving the joinable information from the trailing vehicle of the platoon in front. 2) The ego vehicle starts the joining procedure. 3) The trailing of the existing platoon receives the V2V joining message and evaluates the correct joining conditions. 4) The ego vehicle performs the join procedure (V2V).
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure. - The ego vehicle is not joinable
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	(platoon in front and behind) - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.1.5. SC_0105: Refuse joining due to maximum number of trucks

13.1.5.1. Functional level

The Figure 28Figure 28: SC_0105 diagram states is the graphic description of the scenario.

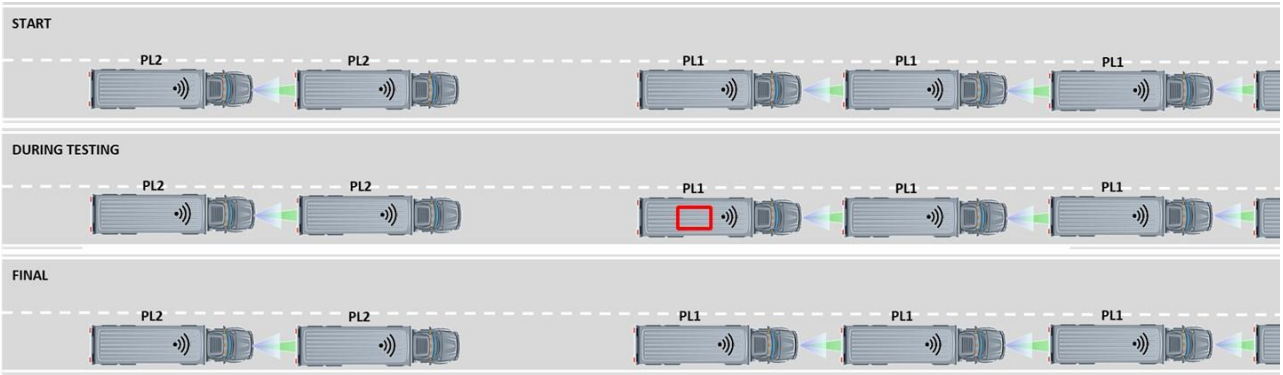

Figure 28: SC_0105 diagram states

The Table 16 contains the functional description of the refuse joining due to maximum number of trucks scenario:

Table 16: Functional scenario SC_0105

ID	SC_0105
Use Case	Platoon Join
Scenario Name	Refuse joining due to maximum number of trucks (Use case 2.1 as per D2.3 specification)
Scenario description	An existing platoon behind try to check the inevitability of a not joining request to an existing platoon in front. The joining procedure cannot start.
Objective	Validate the join refusing by existing platoon in front due to maximum vehicles reached. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The ego vehicle is driving behind an existing platoon at the same lane. - Ego vehicle is driven at a defined speed (with tolerance). - The existing platoon in front is formed and in steady stable condition with a specific number of trucks. - The existing platoon is driving at a specific speed.
Trigger	- The leading driver of the platoon behind detects the joinable signal via V2V communication.
Testing Steps	1) The leading driver of the platoon behind starts the joining procedure.

	2) The trailing of the existing platoon receives the V2V joining message and evaluates the correct joining conditions. 3) The system of the trailing vehicle of the existing platoon rejects the joining procedure due to maximum vehicles reached.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure.
Final State	The ego vehicle is not joined to the existing platoon in front. The existing platoon continues with the desired speed in steady state platooning.
Parameters (inputs)	- EGO vehicle brand - EGO vehicle payload - EGO vehicle speed - EGO vehicle distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.1.6. SC_0106: Non-joinable situations – intruder vehicle

13.1.6.1. Functional level

The Figure 29Figure 29: SC_0106 diagram states is the graphic description of the scenario.

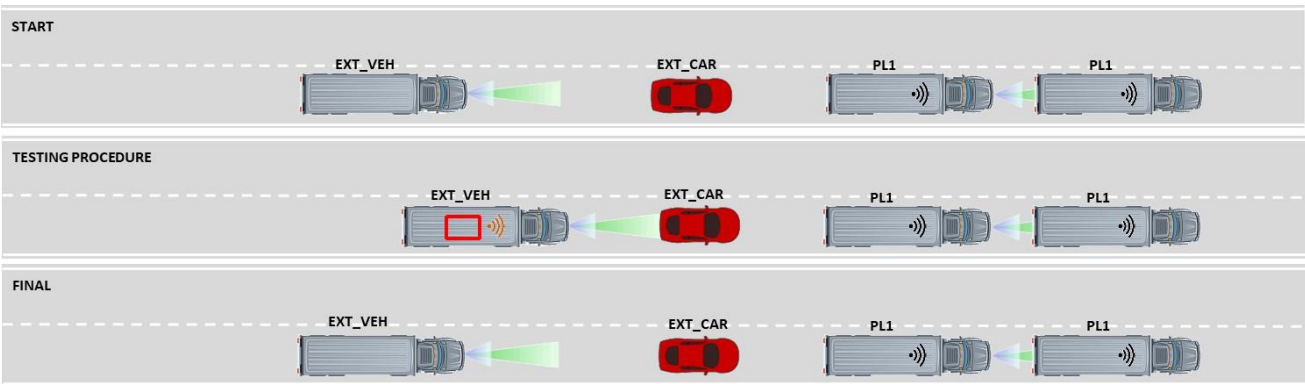

Figure 29: SC_0106 diagram states

The Table 17 contains the functional description of the non-joinable situations (intruder vehicle) scenario:

Table 17: Functional scenario SC_0106

ID	SC_0106
Use Case	Platoon Join
Scenario Name	Non joinable situations - intruder vehicle (Use case 2.1 as per D2.3 specification)
Scenario description	A vehicle sends an engaging request to an existing platoon in front, the joining procedure are not reached due to an external vehicle in front is detected during this joining procedure.
Objective	Validate the join refusing by the ego vehicle since an external vehicle is in between the platoon and the ego vehicle. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The ego vehicle is driving behind to an existing platoon in front at the same lane. - An external vehicle is driving between the ego vehicle and an existing platoon in front at specific speed and distance. - External vehicle is driven at a defined speed (with tolerance). - The existing platoon in front is formed and in steady stable condition with a specific number of trucks. - The existing platoon in front is driving at a specific speed. - The external vehicle is driving at a specific speed. - The ego vehicle is driving at a specific speed.
Trigger	- The driver of the external vehicle behind detects the joinable signal via V2V.
Testing Steps	1) The driver of the ego vehicle starts the joining procedure. 2) The trailing of the existing platoon receives the V2V joining message and evaluates the correct joining conditions. 3) The trailing sends the joining approval response (V2V). 4) The ego vehicle performs the join procedure (V2V). 5) Cut-in external vehicle is detected by ego vehicle occurs during joining procedure. 6) The system detects this situation and refuse the joining procedure.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure.

	- System refuse the joining procedure due to an intruder vehicle is detected.
Final State	The ego vehicle behind is not joined to the existing platoon in front. The existing platoon continues with the desired speed in steady state platooning.
Parameters (inputs)	- EGO vehicle brand - EGO vehicle payload - EGO vehicle speed - EGO vehicle distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.2. Steady State Platooning

The scenarios for the steady state platooning are:

- Steady state following a constant speed
- Steady state acceleration
- Steady state deacceleration
- Steady state gap variation
- Follow a braking target
- Platoon in two adjacent lanes

13.2.1. SC_0201: Steady state following a constant speed.

13.2.1.1. Functional level

The Figure 30Figure 30: SC_0201 diagram states is the graphic description of the scenario.

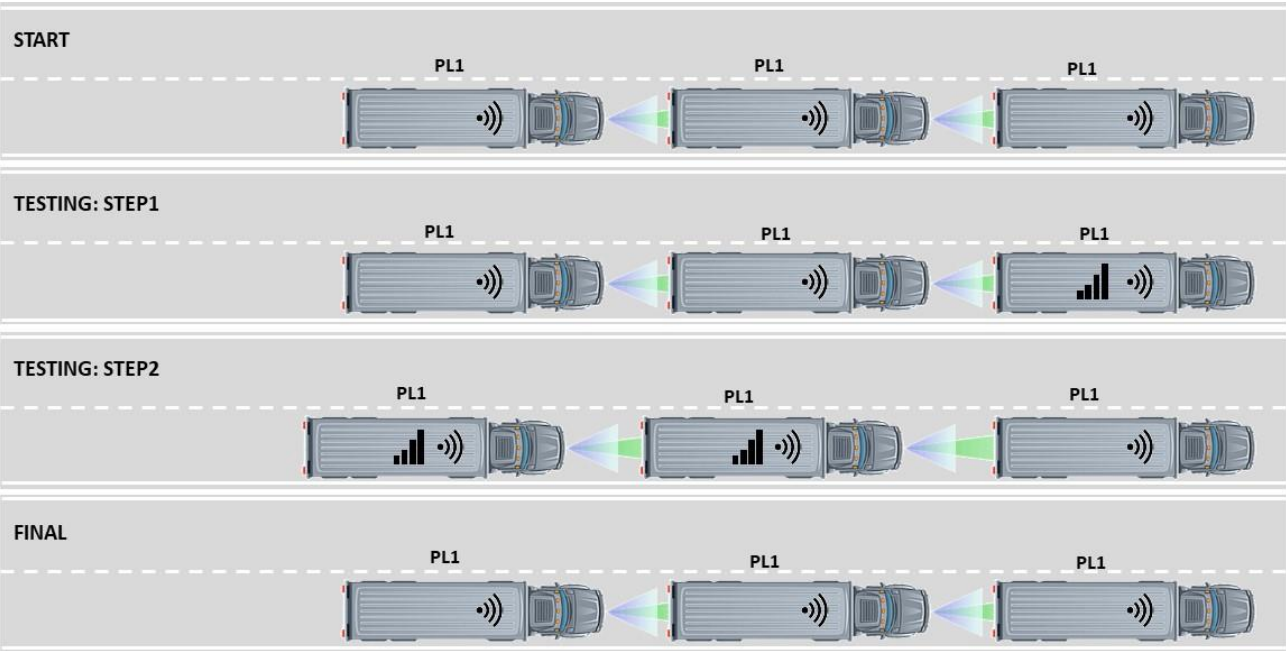

Figure 30: SC_0201 diagram states

The Table 18 contains the Steady state following a constant speed scenario:

Table 18: Functional scenario SC_0201

ID	SC_0201
Use Case	Steady state platooning
Scenario Name	Steady state following a constant speed (Use case 3.1 as per D2.3 specification)
Scenario description	An existing platoon in steady state maintains a constant speed.
Objective	Validate the correct constant speed stability in an existing platoon formation in steady state condition. Validate different communication procedures.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing in a steady state - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The existing platoon is in steady state condition with a specific number of trucks.

	- The existing platoon is driving at specific speed. - The ego vehicle belonging to an existing platoon is communicating via V2V with the surround vehicles in the platoon
Trigger	- The leader vehicle in the platoon modifies the speed.
Testing Steps	1) The ego vehicle sends/resend the new constant speed via V2V to the back vehicle of the platoon. 2) This new constant speed value is received for all members of the existing platoon and accepted.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - Speed of each truck approximatively equal to the speed target, considered the allowed tolerance.
Final State	The existing platoon continues with the final constant speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.2.2. SC_0202: Steady state acceleration

13.2.2.1. Functional level

The Figure 31Figure 31: SC_0202 diagram states is the graphic description of the scenario.

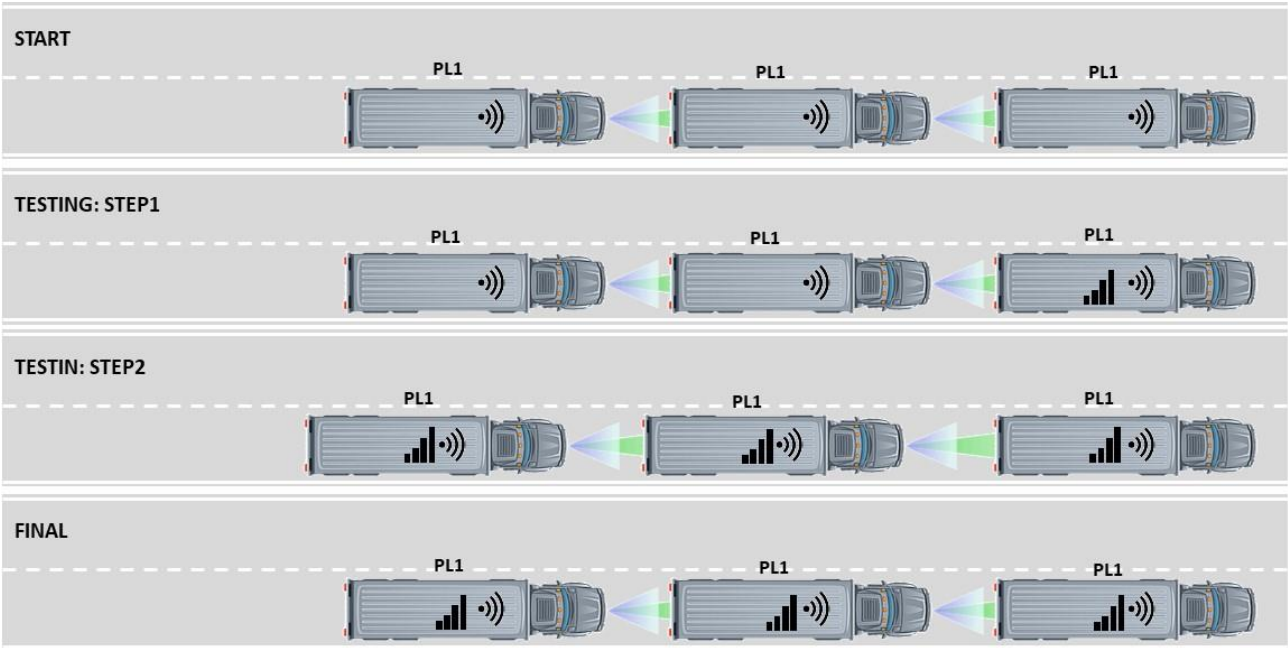

Figure 31: SC_0202 diagram states

The Table 19 contains the Steady state acceleration scenario:

Table 19: Functional scenario SC_0202

ID	SC_0202
Use Case	Steady state platooning
Scenario Name	Steady state acceleration (Use case 3.1 as per D2.3 specification)
Scenario description	An existing platoon in steady state maintains a constant acceleration.
Objective	Validate the correct acceleration stability in an existing platoon formation in steady state condition. Validate different communication procedures.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing in a steady state - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The existing platoon is in steady state condition with a specific number of trucks. - The existing platoon is driving at specific speed.

	- The ego vehicle belonging to an existing platoon is communicating via V2V with the surround vehicles in the platoon
Trigger	- The leader vehicle in the platoon increase the speed with a constant acceleration.
Testing Steps	1) The ego vehicle sends/resend the new acceleration value via V2V to the back vehicle of the platoon. 2) This new constant acceleration value is received for all members of the existing platoon and accepted.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - Acceleration of each truck approximatively equal to the acceleration target, considered the allowed tolerance
Final State	The existing platoon continues with the final constant speed and acceleration value in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.2.3. SC_0203: Steady state deacceleration

13.2.3.1. Functional level

The Figure 32Figure 32: SC_0203 diagram states is the graphic description of the scenario.

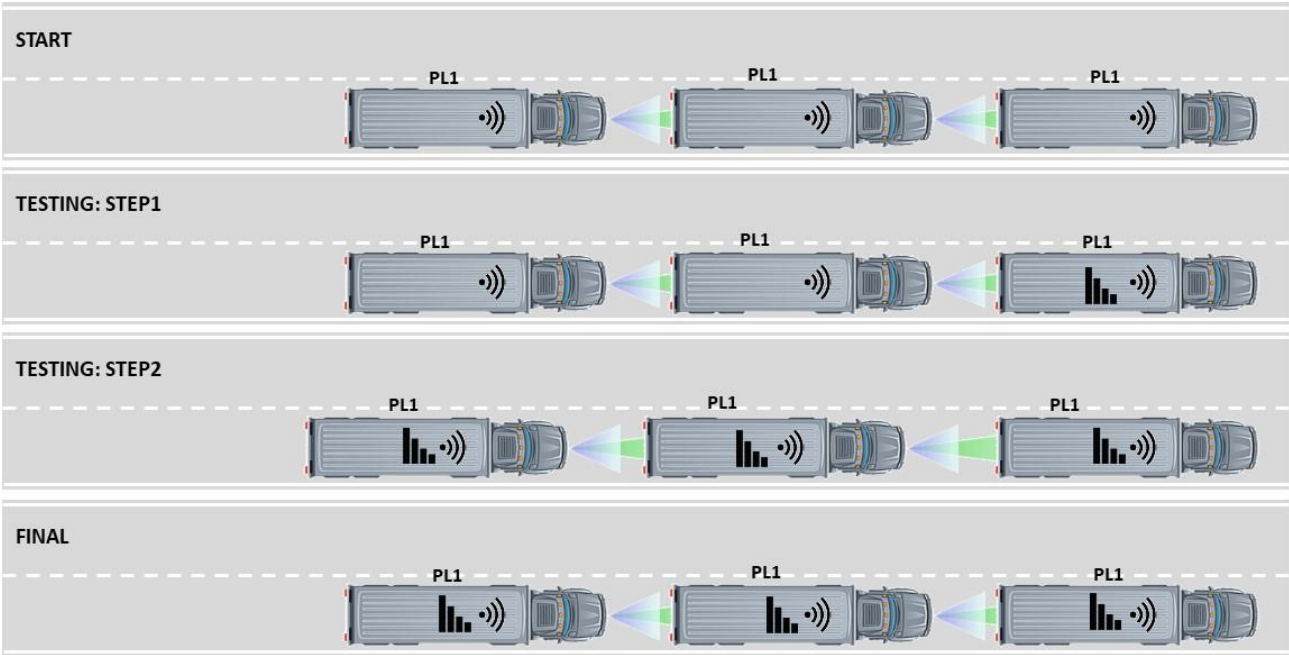

Figure 32: SC_0203 diagram states

The Table 20 contains the Steady state deacceleration scenario:

Table 20: Functional scenario SC_0203

ID	SC_0203
Use Case	Steady state platooning
Scenario Name	Steady state deacceleration (Use case 3.1 as per D2.3 specification)
Scenario description	An existing platoon in steady state maintains a constant deacceleration.
Objective	Validate the correct deacceleration stability in an existing platoon formation in steady state condition. Validate different communication procedures.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing in steady state - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The existing platoon is in steady state condition with a specific number of trucks. - The existing platoon is driving at specific speed.

	- The ego vehicle belonging to an existing platoon is communicating via V2V with the surround vehicles in the platoon
Trigger	- The leader vehicle in the platoon decrease the speed with a constant deacceleration, the speed always must be higher than 30 km/h.
Testing Steps	1) The ego vehicle sends/resend the new deacceleration value via V2V to the back vehicle of the platoon. 2) This new constant deacceleration value is received for all members of the existing platoon and accepted.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - Deacceleration of each truck approximatively equal to the deacceleration target, considered the allowed tolerance - No undesired gap value lower than the gap value limit
Final State	The existing platoon continues with the final constant speed and deacceleration value in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.2.4. SC_0204: Steady state gap variation

13.2.4.1. Functional level

The Figure 33Figure 33: SC_0204 diagram states is the graphic description of the scenario.

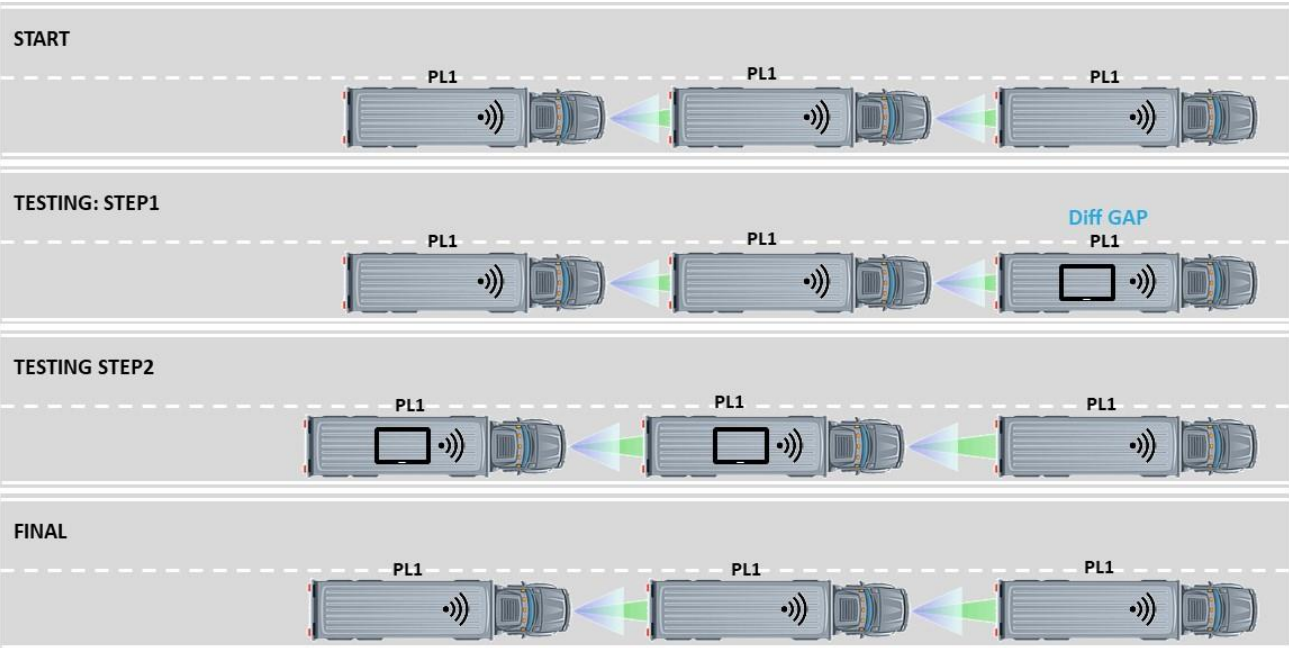

Figure 33: SC_0204 diagram states

The Table 21 contains the Steady state gap variation scenario:

Table 21: Functional scenario SC_0204

ID	SC_0204
Use Case	Steady state platooning
Scenario Name	Steady state gap variation (Use case 3.1 as per D2.3 specification)
Scenario description	An existing platoon in steady state maintains a stable gap distance.
Objective	Validate the gap variation stability in an existing platoon formation in steady state condition. Validate different communication procedures.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing in steady state - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- The existing platoon is in steady state condition with a specific number of trucks. - The existing platoon is driving at specific speed.

	- The ego vehicle belonging to an existing platoon is communicating via V2V with the surround vehicles in the platoon
Trigger	- The leader vehicle in the platoon modify the gap parameter.
Testing Steps	1) The ego vehicle sends/resend the new gap value via V2V to the back vehicle of the platoon. 2) This new gap value is received for all members of the existing platoon and accepted.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - No undesired gap value lower than the gap value limit
Final State	The existing platoon continues with the final constant speed and new gap value in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.2.5. SC_0205: Follow a braking target

13.2.5.1. Functional level

The Figure 34Figure 34: SC_0205 diagram states is the graphic description of the scenario.

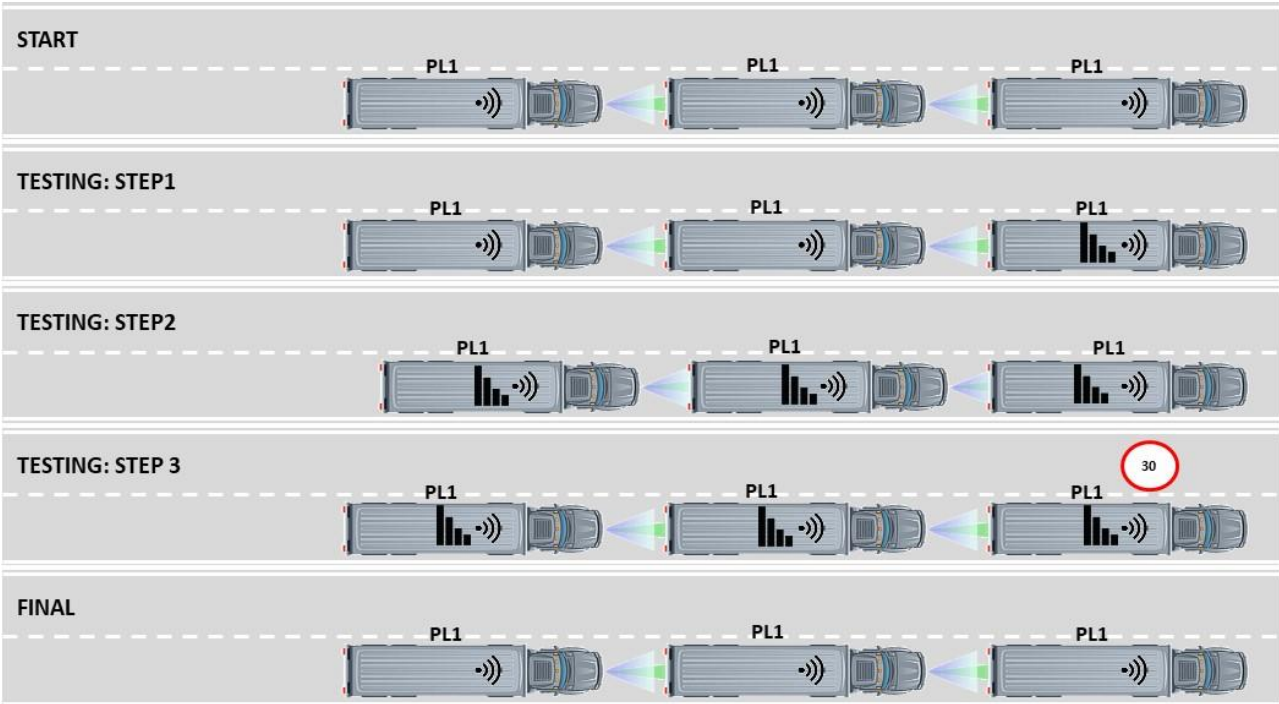

Figure 34: SC_0205 diagram states

The Table 22 contains the Steady state following a braking target scenario:

Table 22: Functional scenario SC_0205

ID	SC_0205
Use Case	Steady state platooning
Scenario Name	Follow braking target (use case 3.2 as per D2.3 specification)
Scenario description	An existing platoon in steady state reduce the speed until less than 30 km/h even stop it.
Objective	Validate the gap stability in a deacceleration under 30 km/h
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing in steady state - At least 2km of free road lane - Define all brands payload involved in the scenario - Must be able to reduce the speed under 30 km/h in the road
Initial State	- The existing platoon is in steady state condition with a specific number of trucks.

	- The existing platoon is driving at specific speed. - The ego vehicle belonging to an existing platoon is communicating via V2V with the surround vehicles in the platoon
Trigger	- The leader vehicle in the platoon decrease the speed with a constant deacceleration.
Testing Steps	1) The ego vehicle sends/resend the platoon characteristics via V2V to the back vehicle of the platoon. 2) This new platoon characteristics is received for all members of the existing platoon and accepted. 3) The platoon speed is lower to 30 km/h.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - No undesired gap value lower than the gap value limit
Final State	The existing platoon continues with the final constant speed and gap value in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.2.6. SC_0206: Platoon in two adjacent lanes

13.2.6.1. Functional level

The Figure 35Figure 35: SC_0206 diagram states is the graphic description of the scenario.

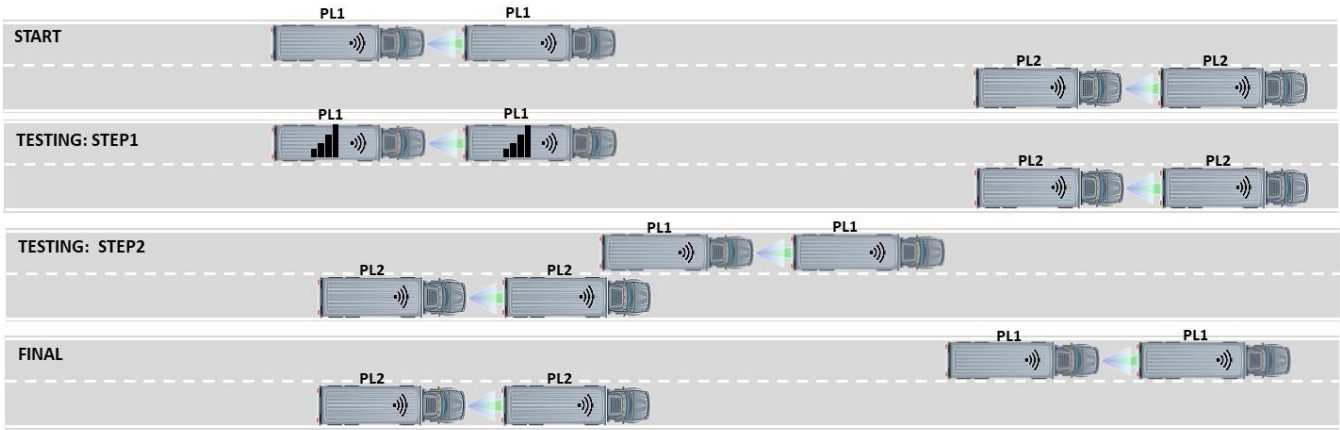

Figure 35: SC_0206 diagram states

The Table 23 contains the Steady state platoon in two adjacent lanes scenario:

Table 23: Functional scenario SC_0206

ID	SC_0206
Use Case	Steady state platooning
Scenario Name	Platoon in two adjacent lanes (use case 3.2 as per D2.3 specification)
Scenario description	An existing platoon in steady state overtake to another platoon in steady state.
Objective	Validate the V2V system to be able to difference multiples platoons in the same area.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Two platoons already existing in steady state - 2 road lines - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- Ego platoon is in steady state condition with a specific number of trucks. - Existing platoons are in steady state condition with a specific number of trucks - Both platoons are driving at specific speed. - Each platoon is in a different line of the road - The ego platoon behind the other platoon.

Trigger	- The leader vehicle in the ego platoon increase the speed.
Testing Steps	1) The ego platoon overtakes the other platoon
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures
Final State	The existing platoons continue with the final constant speed and gap value in steady state platooning.
Parameters (inputs)	- Platoon ID (x2) - Platoon speed (x2) - Platoon acceleration (x2) - Platoon deacceleration (x2) - Platoon gap (x2) - Platoon size initial (x2) - Platoon line-up (x2) - Brand payload (x2)
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.3. Emergency braking

The scenarios for the emergency braking are:

- Lead vehicle doing an emergency braking
- Following vehicle doing an emergency braking
- Two instances off emergency braking in the platoon (LV & second FV)
- Aborting emergency braking after TBD seconds

13.3.1. SC_0301: Lead vehicle doing an emergency braking

13.3.1.1. Functional level

The Figure 36Figure 36 SC_0301 diagram states is the graphic description of the scenario.

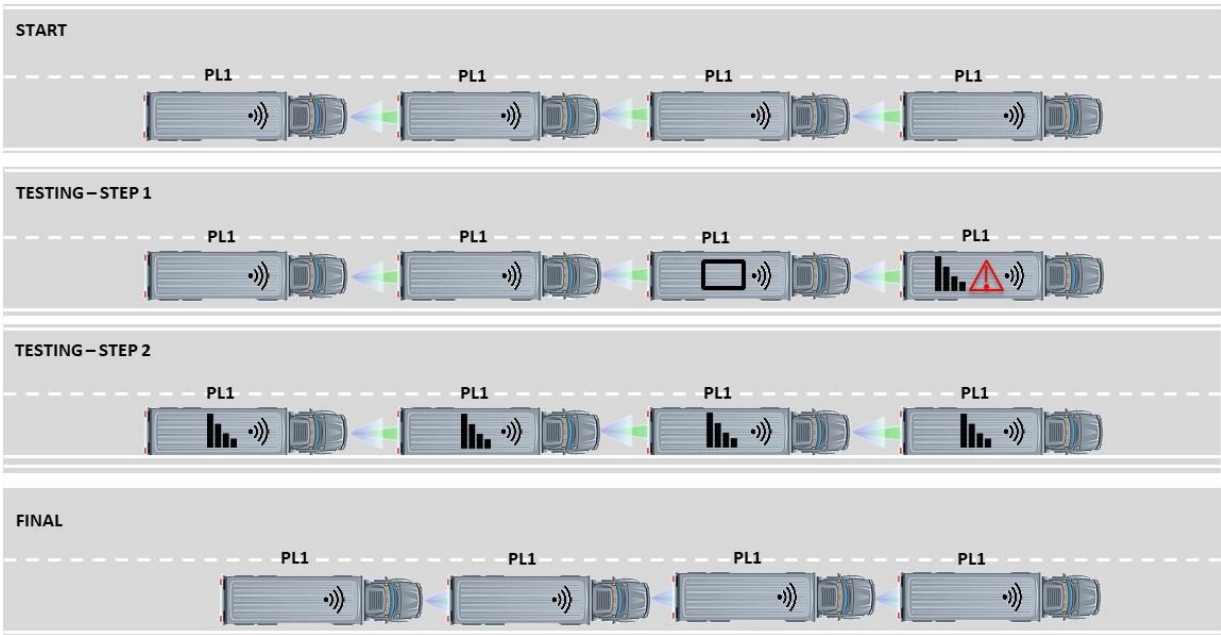

Figure 36 SC_0301 diagram states

The Table 24 contains the lead vehicle doing an emergency braking scenario:

Table 24 Functional scenario SC_0301

ID	SC_0301
Use Case	Emergency braking
Scenario Name	Lead vehicle doing an emergency braking
Scenario description	The leading vehicle performs an emergency braking and communicates it to the platoon via V2V. The platoon reacts as well as required.

Objective	Validate a correct platoon behaviour in terms of V2V communication, time gaps and trucks deceleration when an emergency braking is done by the leading vehicle.
Pre-conditions	- System full operating (internal & V2X) - No warnings
Initial State	- A platoon is working with a specified distance gap and speed in steady state platooning.
Trigger	- The leading vehicle performs an emergency braking procedure.
Testing Steps	1) The leading vehicle that performs the emergency braking communicates via V2V to the follower vehicles the emergency braking situation. 2) The ego vehicle recognizes the emergency braking of the front vehicle via V2V, emergency warning activated in HMI. 3) The ego vehicle starts to decelerate with maximum allowed deceleration. 4) The driver of the ego vehicle verifies the emergency braking (V2V) with its onboard sensors. 5) After specific time, a full AEBS is initiated by the ego vehicle: starting with the AEB warning and 1.4s later, starting the braking.
Acceptance Criteria	- The communication between trucks shall be performed correctly and in-time, respecting the delay between the warning and the emergency braking reaction. The HMI warns correctly the driver of the trucks involved in the "emergency braking situation". The distance gap shall never keep a closer headway than the allowed one overall the testing procedure and the ego truck decelerations shall never exceed the accepted limit.
Final State	- The platoon is engaged and the limit distance gap between trucks is respected. The trucks involved in the "emergency braking reaction" are in "Stand-by" platooning status. The V2V communication between trucks is stable and without errors. The "emergency braking" warning flag is cleared.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.3.2. SC_0302: Following vehicle doing an emergency braking

13.3.2.1. Functional level

The Figure 37Figure 37 SC_0302 diagram states is the graphic description of the scenario.

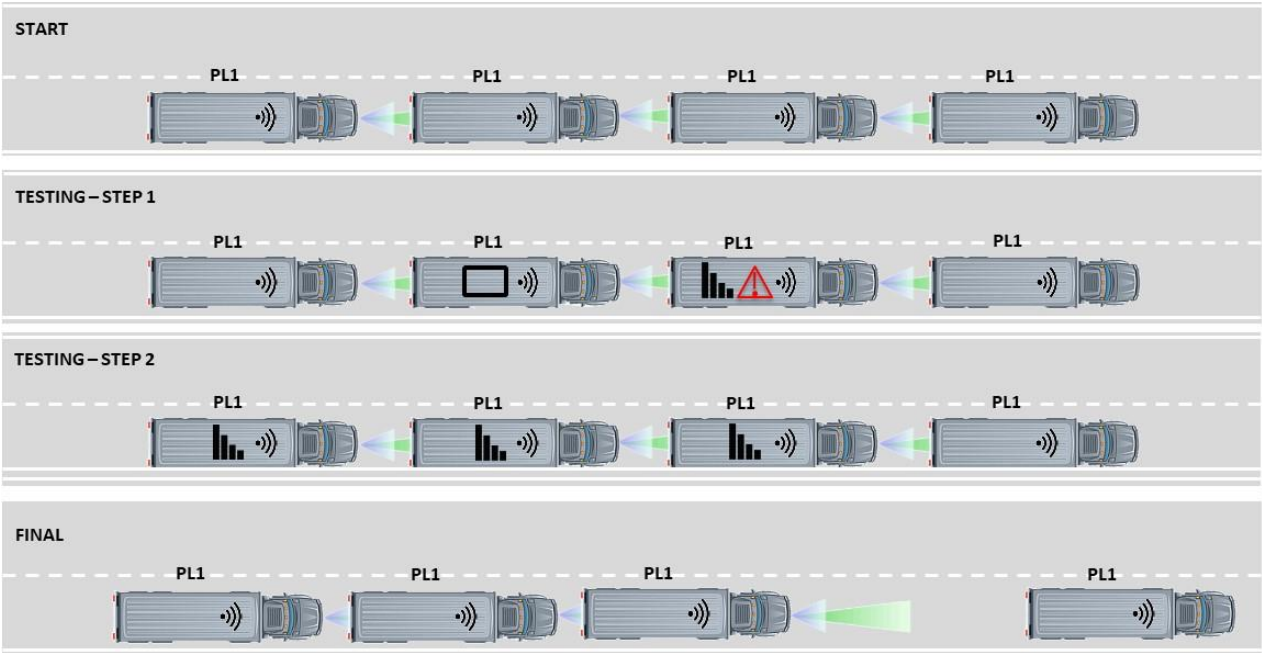

Figure 37 SC_0302 diagram states

The Table 25 contains the following vehicle doing an emergency braking scenario:

Table 25 Functional scenario SC_0302

ID	SC_0302
Use Case	Emergency braking
Scenario Name	Following vehicle doing an emergency braking
Scenario description	One of the following vehicles perform an emergency braking and communicate it to the platoon via V2V.
Objective	Validate a correct platoon behaviour in terms of V2V communication, time gaps and trucks deceleration when an emergency braking is done by one of the following vehicles.
Pre-conditions	- System full operating (internal & V2X) - No warnings
Initial State	A platoon is working with a specified distance gap and speed in steady state platooning.
Trigger	- One of the following vehicles performs an emergency braking procedure.

Testing Steps	1) The following vehicle that performs the emergency braking communicates via V2V to the follower vehicles the emergency braking situation. 2) The ego vehicle recognizes the emergency braking of the front vehicle via V2V, emergency warning activated in HMI. 3) The ego vehicle starts to decelerate with maximum allowed deceleration. 4) The driver of the ego vehicle verifies the emergency braking (V2V) with its onboard sensors. 5) After specific time, a full AEBS is initiated by the ego vehicle: starting with the AEB warning and 1.4s later, starting the braking.
Acceptance Criteria	-The communication between trucks shall be performed correctly and in-time, respecting the delay between the warning and the emergency braking reaction. The HMI warns correctly the driver of the trucks involved in the "emergency braking situation". The distance gap shall never keep a closer headway than the allowed one overall the testing procedure and the ego truck decelerations shall never exceed the accepted limit.
Final State	- The platoon is engaged and the limit distance gap between trucks is respected. The trucks involved in the "emergency braking reaction" are in "Stand-by" platooning status. The V2V communication between trucks is stable and without errors. The "emergency braking" warning flag is cleared.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.3.3. SC_0303: Two instances off emergency braking in the platoon

13.3.3.1. Functional level

The Figure 38Figure 38 SC_0303 diagram states is the graphic description of the scenario.

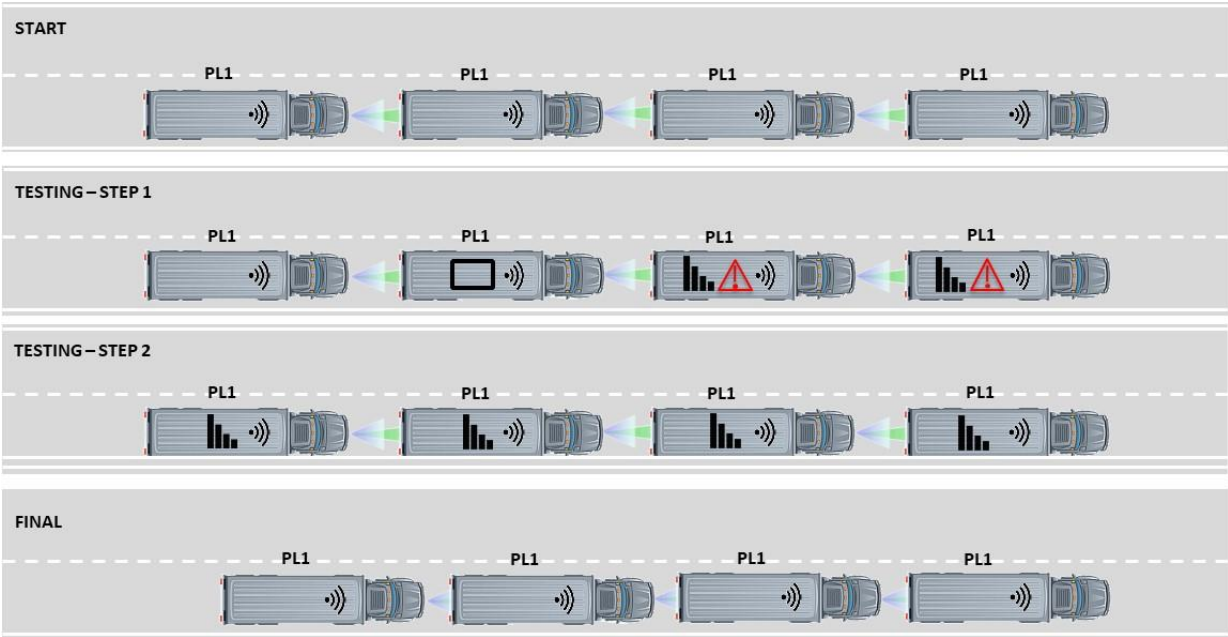

Figure 38 SC_0303 diagram states

The Table 26 contains the two instances off emergency braking in the platoon scenario:

Table 26 Functional scenario SC_0303

ID	SC_0303
Use Case	Emergency braking
Scenario Name	Two instances off emergency braking in the platoon (LV & second FV)
Scenario description	The leader vehicle and an ego vehicle far from the leader vehicle perform two different emergency braking and communicate it to the platoon.
Objective	Validate a correct platoon behaviour in terms of V2V communication, time gaps and trucks deceleration when an emergency braking is done by leading and following vehicle.
Pre-conditions	- System full operating (internal & V2X) - No warnings
Initial State	A platoon is working with a specified distance gap and speed in steady state platooning.
Trigger	The leading and the following vehicles performs an emergency braking procedure at the same time.

Testing Steps	1) The leading and following vehicle that performs the emergency braking communicates via V2V to the follower vehicle the emergency braking situation. 2) The ego vehicle recognizes the emergency braking of the front vehicles via V2V, emergency warning activated in HMI. 3) The ego vehicle starts to decelerate with maximum allowed deceleration. 4) The driver of the ego vehicle verifies the emergency braking (V2V) with its onboard sensors. 5) After specific time, a full AEBS is initiated by the ego vehicle: starting with the AEB warning and 1.4s later, starting the braking.
Acceptance Criteria	The communication between trucks shall be performed correctly and in-time, respecting the delay between the warning and the emergency braking reaction. The HMI warns correctly the driver of the trucks involved in the "emergency braking situation". The distance gap shall never keep a closer headway than the allowed one overall the testing procedure and the ego truck decelerations shall never exceed the accepted limit.
Final State	The platoon is engaged and the limit distance gap between trucks is respected. The trucks involved in the "emergency braking reaction" are in "Stand-by" platooning status. The V2V communication between trucks is stable and without errors. The "emergency braking" warning flags are cleared.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.3.4. SC_0304: Aborting emergency braking after TBD seconds

13.3.4.1. Functional level

The Figure 39Figure 39 SC_0304 diagram states is the graphic description of the scenario.

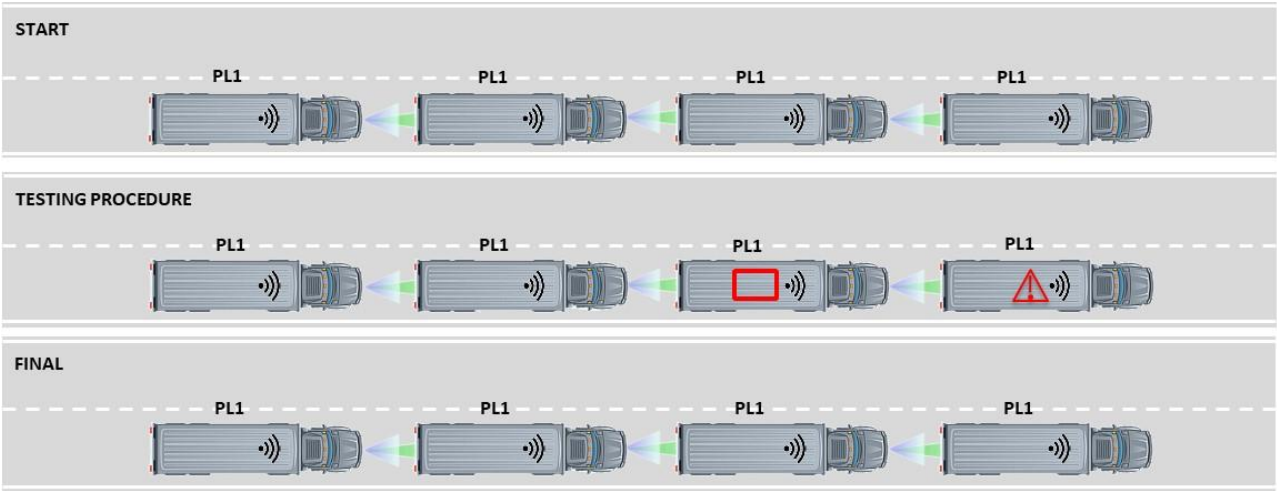

Figure 39 SC_0304 diagram states

The Table 27 contains the aborting emergency braking after tbd seconds scenario:

Table 27 Functional scenario SC_0304

ID	SC_0304
Use Case	Emergency braking
Scenario Name	Aborting emergency braking after TBD seconds (TBD which truck starts & abort)
Scenario description	An ego vehicle of an existing platoon performs an emergency braking. Before being validated, the emergency braking is aborted.
Objective	Validate a correct platoon behaviour in terms of V2V communication, time gaps and trucks deceleration when an emergency braking is aborted.
Pre-conditions	- System full operating (internal & V2X) - No warnings
Initial State	A platoon is working with a specified distance gap and speed in steady state platooning.
Trigger	One of the following vehicles performs an emergency braking procedure.
Testing Steps	1) The ego vehicle that performs the emergency braking communicates via V2V to the platoon the emergency braking situation. 2) Before to be validated, the emergency braking shall be aborted.
Acceptance Criteria	The communication between trucks shall be performed correctly and in-time. The HMI warns correctly the driver of the trucks involved in the "emergency braking situation", but no emergency braking reactions shall be initialized. Moreover, the emergency braking flag shall disappear. The

	distance gap shall never keep a closer headway than the allowed one overall the testing procedure.
Final State	The platoon is engaged and the limit distance gap between trucks is respected. The V2V communication between trucks is stable and without errors.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon acceleration - Platoon deacceleration - Platoon gap - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final

13.4. I2V interaction

The scenarios for the I2V interaction are:

- New minimum distance policy (only HMI information)
- New maximum speed policy (only HMI information)

13.4.1. SC_0401: New minimum distance policy

13.4.1.1. Functional level

The Figure 40Figure 40 SC_0401 diagram states is the graphic description of the scenario.

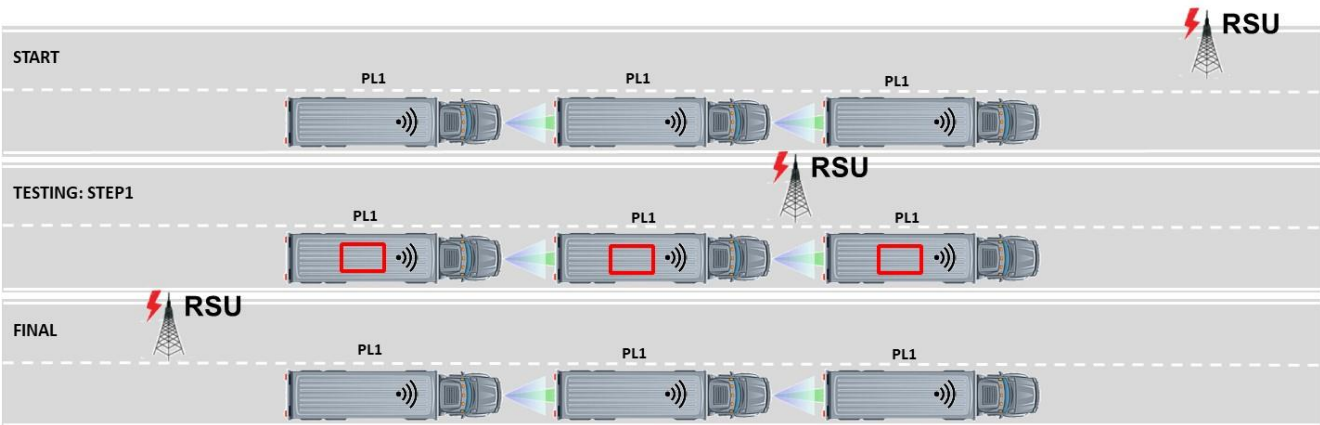

Figure 40 SC_0401 diagram states

The Table 28 contains the new minimum distance policy scenario:

Table 28 Functional scenario SC_0401

ID	**SC_0401**
Use Case	I2V interaction
Scenario Name	New minimum distance policy (Use case 3.4.1 as per D2.3 specification)
Scenario description	A platoon gap adaptation because of V2V interaction.
Objective	Validate the correct platoon reception in terms of I2V communication; new distance policy. This reception only appears in the HMI display.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing
Initial State	- The existing platoon in front is formed and in steady stable condition with a specific number of trucks. - The existing platoon is driving at a specific speed & distance.
Trigger	Reception of message from V2I (roadside unit).
Testing Steps	1) The new distance policy is broadcasted to all platoon vehicles. 2) All trucks in the platoon receive instructions from I2V to increase the vehicle distance. 3) The drivers of the platooning vehicles are informed of the new distance through HMI.
Acceptance Criteria	- I2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The new vehicle distance policy appears inside the HMI of each driver.
Final State	The platoon continues with the desired speed and distance in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon line-up
Signals (outputs)	- HMI actions - I2V Communication - Platoon group information

13.4.2. SC_0402: New maximum speed policy

13.4.2.1. Functional level

The Figure 41Figure 41 SC_0402 diagram states is the graphic description of the scenario.

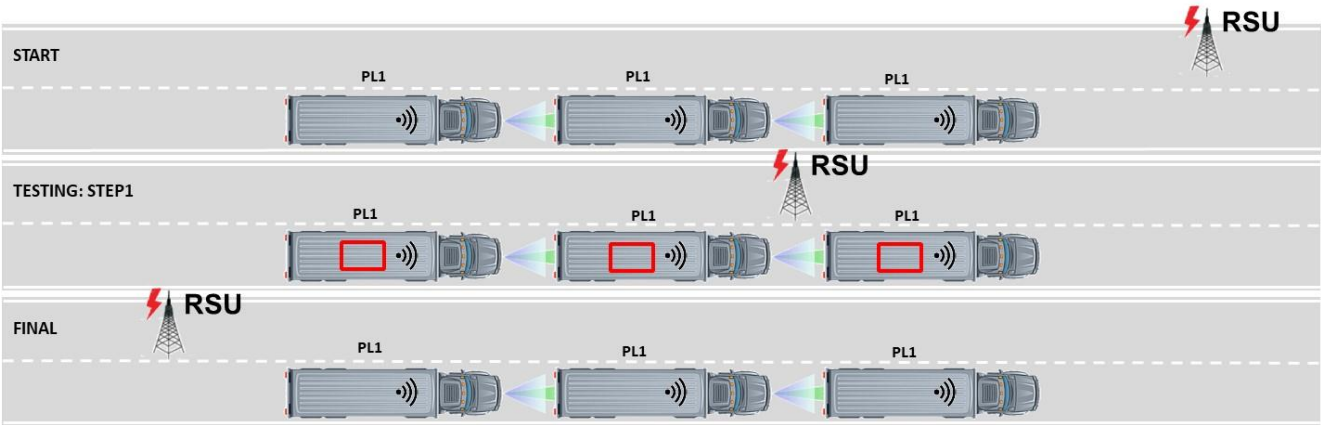

Figure 41 SC_0402 diagram states

The Table 29 contains the new maximum speed policy scenario:

Table 29 Functional scenario SC_0402

ID	SC_0402
Use Case	I2V interaction
Scenario Name	New maximum speed policy (Use case 3.4.1 as per D2.3 specification)
Scenario description	A platoon speed adaptation because of V2V interaction.
Objective	Validate the correct platoon reception in terms of I2V communication; new speed policy. This reception only appears in the HMI display.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing
Initial State	- The existing platoon in front is formed and in steady stable condition with a specific number of trucks. - The existing platoon is driving at a specific speed & distance.
Trigger	Reception of message from V2I (roadside unit).
Testing Steps	1) The new speed policy is broadcasted to all platoon vehicles. 2) All trucks in the platoon receive instructions from I2V to increase the vehicle speed. 3) The drivers of the platooning vehicles are informed of the new speed through HMI.
Acceptance Criteria	- I2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures

	- The new vehicle speed policy appears inside the HMI of each driver.
Final State	The platoon continues with the desired speed and distance in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon line-up
Signals (outputs)	- HMI actions - I2V Communication - Platoon group information

13.5. Cut-in

The scenarios for the cut-in are:

- Cut-in
- Cut-through
- Cut-out
- Steady state multiple vehicle cut-in

13.5.1. SC_0501: Cut-in

13.5.1.1. Functional level

The Figure 42Figure 42 SC_0501 diagram states is the graphic description of the scenario.

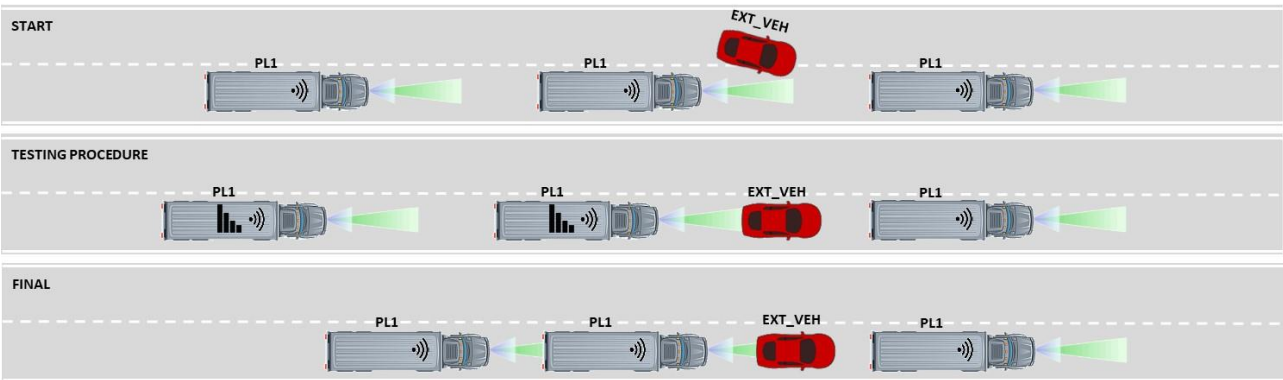

Figure 42 SC_0501 diagram states

The Table 30 contains the cut-in scenario:

Table 30 Functional scenario SC_0501

ID	**SC_0501**
Use Case	Cut-in
Scenario Name	Cut-in (Use case 3.4.2 as per D2.3 specification)

Scenario description	An external vehicle cuts-in a working platoon and remains within it.
Objective	Validate correct platoon behaviour in terms of V2V communication, detection of external vehicles, time gaps and trucks deceleration.
Pre-conditions	- System full operating (internal & V2X) - No warnings - An external vehicle available - 2 road lines
Initial State	- An existing platoon formed in a specified distance gap and speed in steady state platooning in the right lane. - An external vehicle on the left road line in a specific speed.
Trigger	The external vehicle cuts-in the existing platoon and is detected.
Testing Steps	1) The vehicle behind of the external vehicle is in platoon communication (ego vehicle). 2) The external vehicle stays between trucks. 3) The ego vehicle increases following distance towards cut-in vehicle by decelerating. 4) The drivers of the platoon members are informed about the cut-in by HMI. 5) The existing platoon reduces the distance again to the desired platooning distance.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure. - The cut-in is detected and informed to the rest of the platoon members by HMI.
Final State	A final platoon continues with desired speed and distance in steady state platooning
Parameters (inputs)	- Ext_veh speed - Ext_veh distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon group information

13.5.2. SC_0502: Cut-through

13.5.2.1. Functional level

The Figure 43Figure 43 SC_0502 diagram states is the graphic description of the scenario.

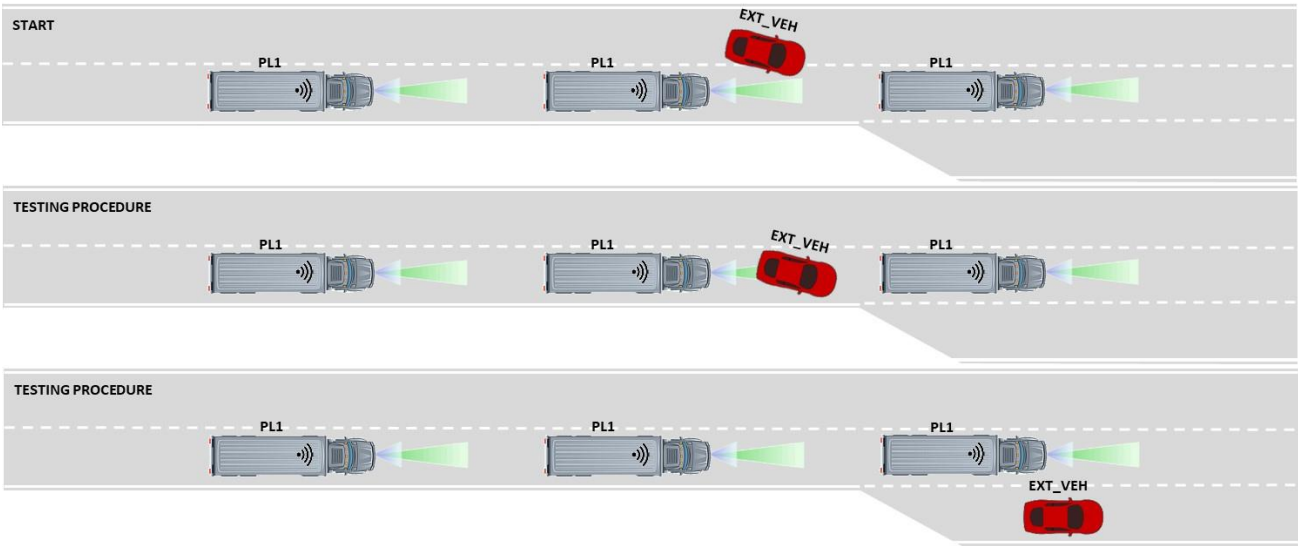

Figure 43 SC_0502 diagram states

The Table 31 contains the cut-through scenario:

Table 31 Functional scenario SC_0502

ID	SC_0502
Use Case	Cut-in
Scenario Name	Cut-through (Use case 3.4.2 as per D2.3 specification)
Scenario description	An external vehicle cut-through a working platoon.
Objective	Validate correct platoon behaviour in terms of V2V communication, detection of external vehicles, time gaps and trucks deceleration.
Pre-conditions	- System full operating (internal & V2X) - No warnings - An external vehicle available - 3 road lines (or 2 road lines and an exit lane)
Initial State	- An existing platoon formed in a specified distance gap and speed in steady state platooning in the right lane. - An external vehicle on the left road line in a specific speed.
Trigger	The external vehicle cuts-in the existing platoon and is detected.
Testing Steps	1) The vehicle behind of the external vehicle is in platoon communication (ego vehicle). 2) The external vehicle cut-out.

Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure.
Final State	A final platoon continues with desired speed and distance in steady state platooning.
Parameters (inputs)	- Ext_veh speed - Ext_veh distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon group information

13.5.3. SC_0503: Cut-out

13.5.3.1. Functional level

The Figure 44Figure 44 SC_0503 diagram states is the graphic description of the scenario.

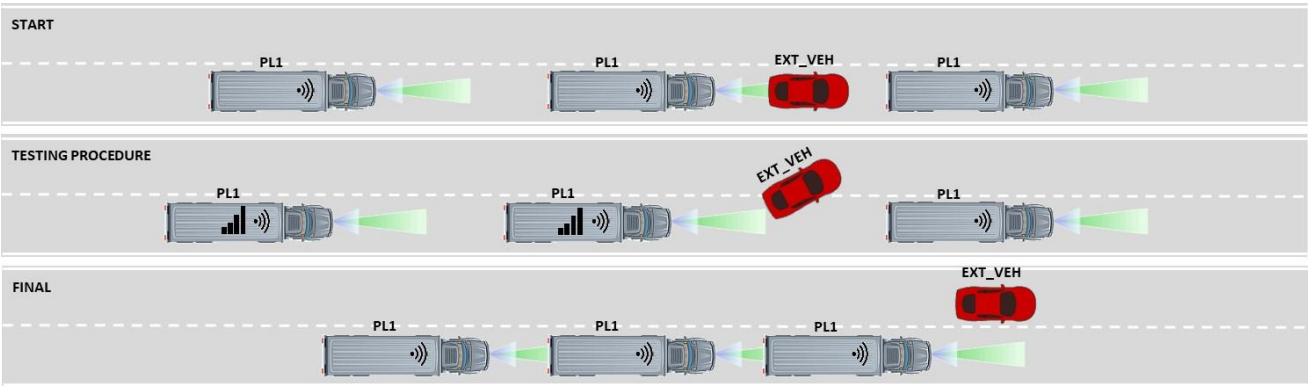

Figure 44 SC_0503 diagram states

The Table 32 contains the cut-out scenario:

Table 32 Functional scenario SC_0503

ID	SC_0503
Use Case	Cut-in
Scenario Name	Cut-out (Use case 3.4.2 as per D2.3 specification)
Scenario description	An external vehicle cut-out a working platoon.

Objective	Validate correct platoon behaviour in terms of V2V communication, detection of external vehicles, time gaps and trucks deceleration.
Pre-conditions	- System full operating (internal & V2X) - No warnings - An external vehicle available - 2 road lines
Initial State	- An existing platoon formed in a specified distance gap and speed in steady state platooning in the right lane. - An external vehicle is between trucks in an existing platoon.
Trigger	The external vehicle cuts-out the existing platoon and is detected.
Testing Steps	1) The vehicle behind of the external vehicle is in platoon communication (ego vehicle). 2) The external vehicle cut-out. 3) The Ego vehicle detects the cut-out of the external vehicle and reduce following distance by accelerating. 4) The drivers of the platoon members are informed about the cut-in by HMI. 5) The existing platoon reduces the distance again to the desired platooning distance.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure. - The cut-out is detected and informed to the rest of the platoon members by HMI.
Final State	A final platoon continues with desired speed and distance in steady state platooning.
Parameters (inputs)	- Ext_veh speed - Ext_veh distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon group information

13.5.4. SC_0504: Steady state multiple vehicle cut-in

13.5.4.1. Functional level

The Figure 45Figure 45 SC_0504 diagram states is the graphic description of the scenario.

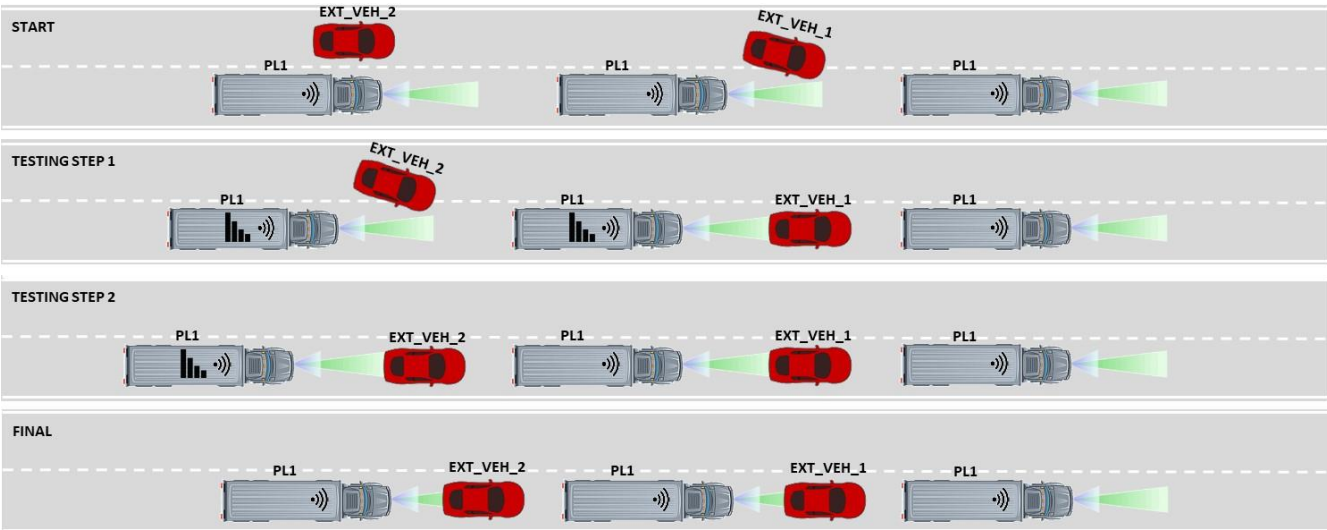

Figure 45 SC_0504 diagram states

The Table 33 contains the steady state multiple vehicle cut-in scenario:

Table 33 Functional scenario SC_0504

ID	SC_0504
Use Case	Cut-in
Scenario Name	Steady state multiple vehicle cut-in (Use case 3.4.2 as per D2.3 specification)
Scenario description	An external vehicle cuts-in a working platoon and remains within it.
Objective	Validate correct platoon behaviour in terms of V2V communication, detection of external vehicles, time gaps and trucks deceleration.
Pre-conditions	- System full operating (internal & V2X) - No warnings - An external vehicle available - 2 road lines
Initial State	- An existing platoon formed in a specified distance gap and speed in steady state platooning in the right lane. - Two external vehicles on the left road line in a specific speed.
Trigger	The first external vehicle cuts-out the existing platoon and is detected.
Testing Steps	1) The vehicle behind of the external vehicle is in platoon communication (ego vehicle). 2) The external vehicle stays between trucks.

	2) The ego vehicle increases following distance towards cut-in vehicle by decelerating. 3) The drivers of the platoon members are informed about the cut-in by HMI. 5) The second external vehicle cuts-out the existing platoon and is detected. 6) The vehicle behind of the external vehicle is in platoon communication (ego vehicle). 7) The ego vehicle increases following distance towards cut-in vehicle by decelerating. 8) The drivers of the platoon members are informed about the cut-in by HMI. 9) The existing platoon reduces the distance again to the desired platooning distance.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure. - The different cut-in are detected and informed to the rest of the platoon members by HMI.
Final State	A final platoon continues with desired speed and distance in steady state platooning.
Parameters (inputs)	- Ext_veh 1 speed - Ext_veh 1 distance - Ext_veh 2 speed - Ext_veh 2 distance - Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon group information

13.6. System status

The scenarios for the system status are:

- GPS failure
- Communication failure
- Package loss (V2V)
- Steady State multiple vehicle cut-in

13.6.1. SC_0601: GPS failure

13.6.1.1. Functional level

The Figure 46Figure 46 SC_0601 diagram states is the graphic description of the scenario.

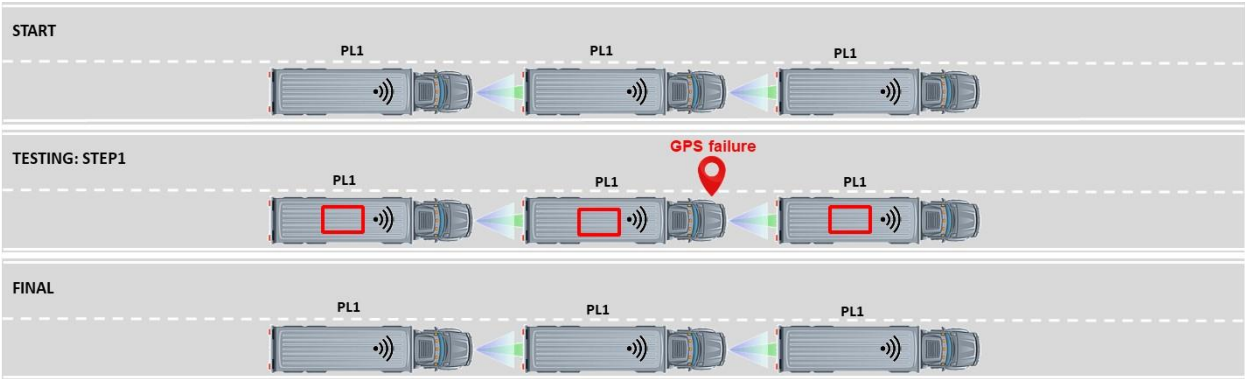

Figure 46 SC_0601 diagram states

The Table 34 contains the GPS failure scenario:

Table 34 Functional scenario SC_0601

ID	SC_0601
Use Case	System status (mono-brand OEM responsibility)
Scenario Name	GPS failure
Scenario description	A platoon vehicle detects that the platooning system is not performed as expected (GPS failure).
Objective	Validate the correct detection by one of the vehicles in a formed platoon that the communication is not correct anymore.
Pre-conditions	- System full operating - No warnings - Platoon active
Initial State	- A formed platoon and stable is driving at defined speed (with tolerance) in a steady state.
Trigger	- One vehicle of the platoon detects that the GPS function is not correct anymore.
Testing Steps	1) The drivers of the platoon will be warned (HMI display) on the status system (GPS failure).
Acceptance Criteria	- The drivers of the formed platoon are informed by HMI about system failure (GPS failure)
Final State	- Platoon is not formed and all vehicles are driving alone.
Parameters (inputs)	- Ext_veh formation - Ext_veh speed - platoon ID - platoon speed - platoon size initial - platoon line-up

	- Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.6.2. SC_0602: Communication failure

13.6.3. Functional level

The is the Figure 47Figure 47 SC_0602 diagram states graphic description of the scenario.

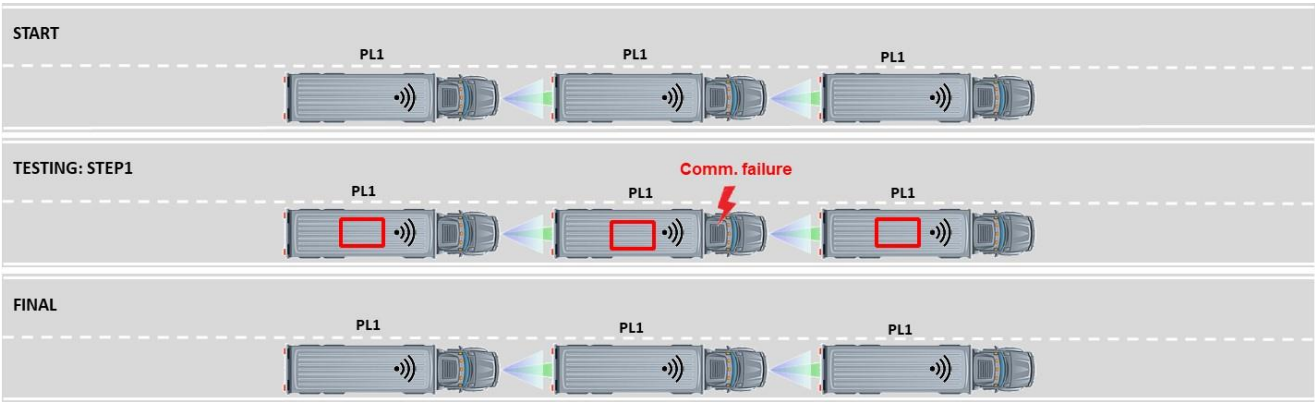

Figure 47 SC_0602 diagram states

The Table 35 contains the communication failure scenario:

Table 35 Functional scenario SC_0602

ID	SC_0602
Use Case	System status (mono-brand OEM responsibility)
Scenario Name	Communication failure
Scenario description	A platoon vehicle detects that the platooning system is not performed as expected (internal communication).
Objective	Validate the correct detection by one of the vehicles in a formed platoon that the communication is not correct anymore.
Pre-conditions	- System full operating (internal) - No warnings - Platoon active
Initial State	- A formed platoon and stable is driving at defined speed (with tolerance) in a steady state.
Trigger	- One vehicle of the platoon detects that the platooning communication status is not correct anymore.
Testing Steps	1) The drivers of the platoon will be warned (HMI display) on the status system (V2V failure).

Acceptance Criteria	- The drivers of the formed platoon are informed by HMI about system failure (communication)
Final State	- Platoon is not formed and all vehicles are driving alone.
Parameters (inputs)	- Ext_veh formation - Ext_veh speed - platoon ID - platoon speed - platoon size initial - platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.6.4. SC_0603: Package loss

13.6.4.1. Functional level

The Figure 48Figure 48 SC_0603 diagram states is the graphic description of the scenario.

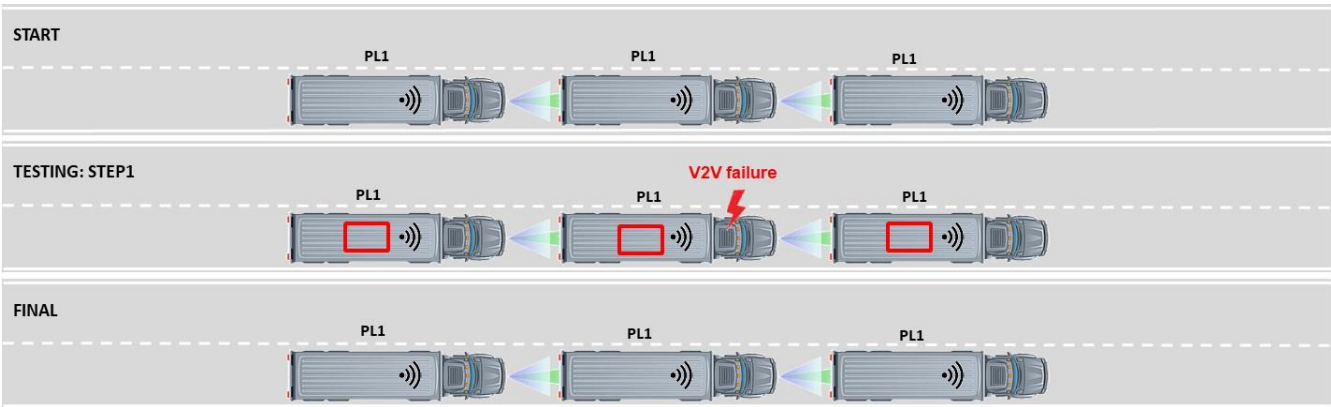

Figure 48 SC_0603 diagram states

The Table 36 contains the package loss scenario:

Table 36 Functional scenario SC_0603

ID	SC_0603
Use Case	System status (mono-brand OEM responsibility)
Scenario Name	Package loss - V2V (Use case 3.4.3 as per D2.3 specification)
Scenario description	A platoon vehicle detects that the platooning system is not performed as expected (V2V communication).
Objective	Validate the correct detection by one of the vehicles in a formed platoon that the V2V communication is not correct anymore.

Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon active
Initial State	- A formed platoon and stable is driving at defined speed (with tolerance) in a steady state.
Trigger	- One vehicle of the platoon detects that the platooning V2V status is not correct anymore.
Testing Steps	1) The drivers of the platoon will be warned (HMI display) on the status system (V2V failure).
Acceptance Criteria	- The drivers of the formed platoon are informed by HMI about system failure (V2V)
Final State	- Platoon is not formed and all vehicles are driving alone.
Parameters (inputs)	- Ext_veh formation - Ext_veh speed - platoon ID - platoon speed - platoon size initial - platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.6.5. SC_0604: Steady State multiple vehicle cut-in

13.6.5.1. Functional level

The Figure 49Figure 49 SC_0604 diagram states is the graphic description of the scenario.

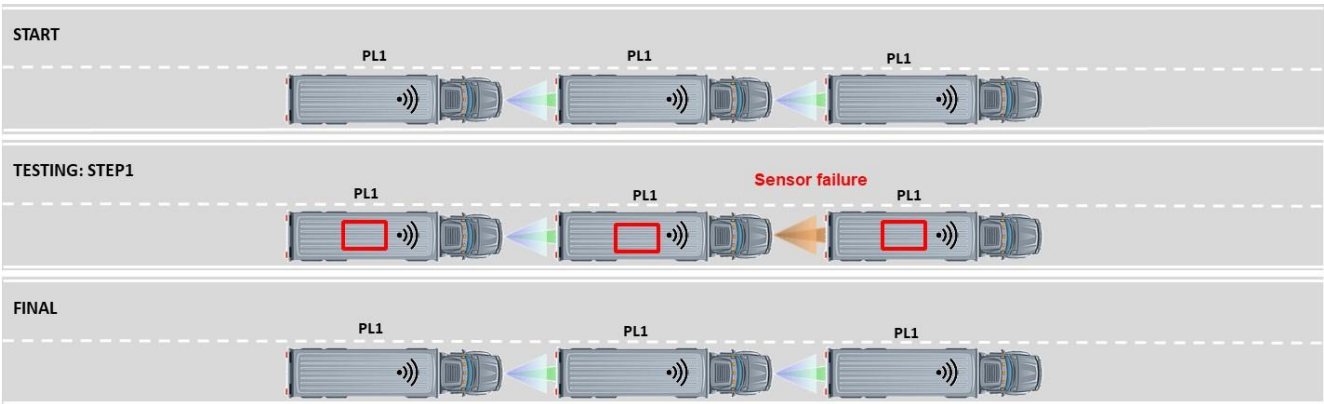

Figure 49 SC_0604 diagram states

The Table 37 contains the steady state multiple vehicle cut-in scenario:

Table 37 Functional scenario SC_0604

ID	SC_0604
Use Case	System status (mono-brand OEM responsibility)
Scenario Name	Forward range sensor failure
Scenario description	A platoon vehicle detects that the platooning system is not performed as expected (forward range sensor failure).
Objective	Validate the correct detection by one of the vehicles in a formed platoon that the forward sensor is not correct anymore.
Pre-conditions	- System full operating (internal & range sensor) - No warnings - Platoon active
Initial State	- A formed platoon and stable is driving at defined speed (with tolerance) in a steady state.
Trigger	- One vehicle of the platoon detects that the forward range sensor is not correct anymore.
Testing Steps	1) The drivers of the platoon will be warned (HMI display) on the status system (forward range sensor failure).
Acceptance Criteria	- The drivers of the formed platoon are informed by HMI about system failure (forward sensor)
Final State	- Platoon is not formed and all vehicles are driving alone.
Parameters (inputs)	- Ext_veh formation - Ext_veh speed - platoon ID - platoon speed - platoon size initial - platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7. Disengage platoon

The scenarios for the disengage platoon are:

- Leave by trailing truck
- Leave by following truck
- Leave by leading truck
- Split platoon (system initiated)
- Leave by steering-out as following truck
- Leave by steering-out by leading truck

13.7.1. SC_0701: Leave by trailing truck

13.7.1.1. Functional level

The Figure 50Figure 50 SC_0701 diagram states is the graphic description of the scenario.

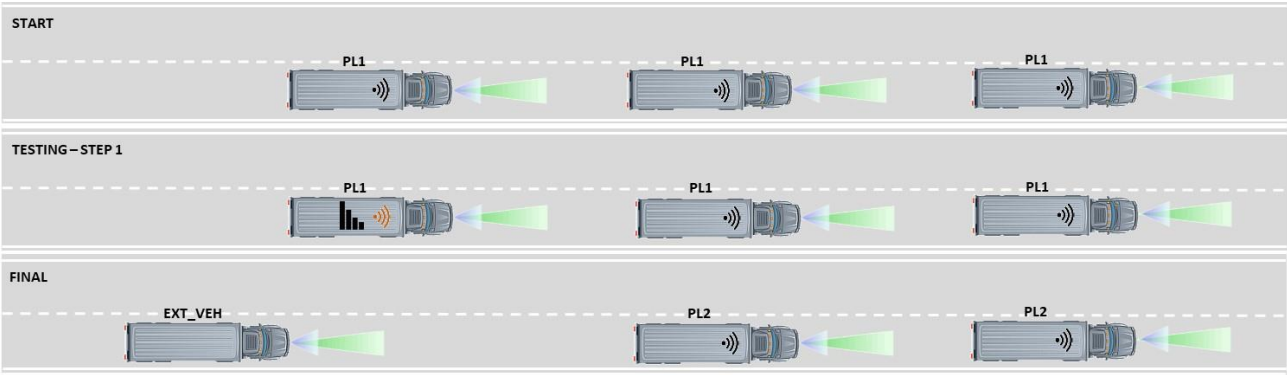

Figure 50 SC_0701 diagram states

The Table 38 contains the leave by trailing truck scenario:

Table 38 Functional scenario SC_0701

ID	SC_0701
Use Case	Disengage platoon
Scenario Name	Leave by trailing truck (Use case 4.1.1 as per D2.3 specification)
Scenario description	The ego vehicle sends a leaving request to an existing platoon in front. The leaving procedure is accepted and the ego vehicle leaves the platoon.
Objective	Validate a correct vehicle leaving (trailing vehicle) to an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon active - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An existing platoon is driving at the same lane. - The existing platoon in front is formed and in steady state condition with a specific number of trucks.
Trigger	-The ego driver starts the leaving procedure by pushing the leave button or pressing the brake pedal.
Testing Steps	1) The leaving procedure from the ego vehicle is broadcasted to the other platoon members through V2V communication. 2) The ego vehicle increases the inter-vehicle time-gap with the target vehicle. 3) The ego vehicle performs the leave procedure and the platooning communication is disconnected.

	4) The ego vehicle driver is informed that the platooning support is not available.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The limit distance gap between trucks is respected during overall the procedure.
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7.2. SC_0702: Leave by following truck

13.7.2.1. Functional level

The Figure 51Figure 51 SC_0702 diagram states is the graphic description of the scenario.

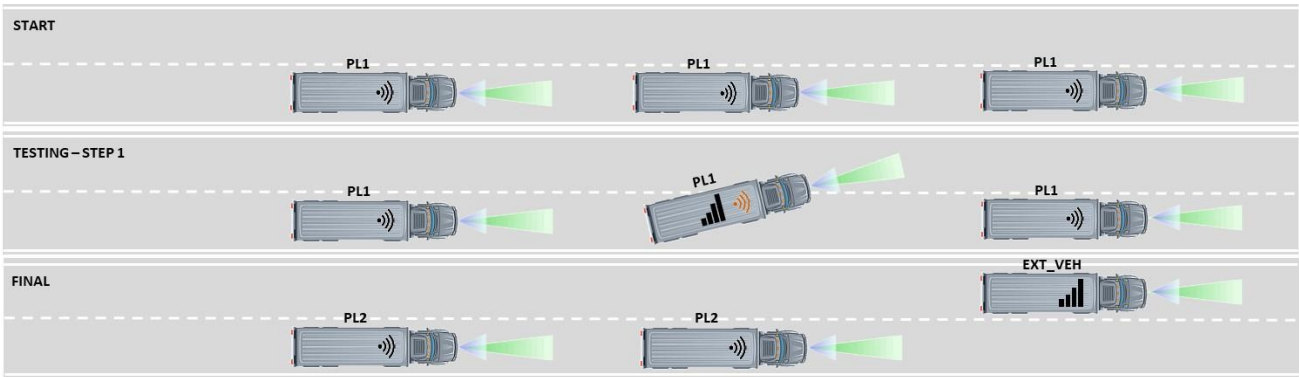

Figure 51 SC_0702 diagram states

The Table 39 contains the leave by following truck scenario:

Table 39 Functional scenario SC_0702

ID	SC_0702
Use Case	Disengage platoon
Scenario Name	Leave by following truck (Use case 4.1.3 as per D2.3 specification)

Scenario description	One of the following vehicles (not the leader nor the trailing vehicle) sends a leaving request to an existing platoon in front. The leaving procedure is accepted and the following vehicle leaves the platoon.
Objective	Validate a correct vehicle leaving (following vehicle) to an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon active - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An existing platoon is driving at the same lane. - The existing platoon in front is formed and in steady state condition with a specific number of trucks.
Trigger	- The ego driver starts the leaving procedure by pushing the leave button or pressing the brake pedal.
Testing Steps	"1) The leaving procedure from the ego vehicle is broadcasted to the other platoon members through V2V communication. 2) The target and ego vehicle increase the inter-vehicle time-gap with the preceding vehicle. 3) The ego vehicle performs the leave procedure and the platooning communication is disconnected. 4) The ego vehicle driver is informed that the platooning support is not available."
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The limit distance gap between trucks is respected during overall the procedure.
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7.3. SC_0703: Leave by leading truck

13.7.3.1. Functional level

The Figure 52Figure 52 SC_0703 diagram states is the graphic description of the scenario.

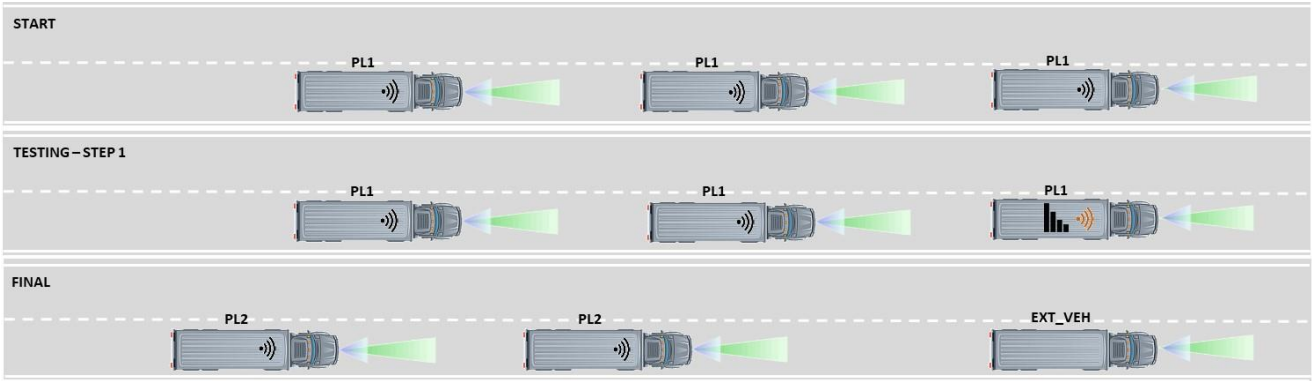

Figure 52 SC_0703 diagram states

The Table 40 contains the leave by leading truck scenario:

Table 40 Functional scenario SC_0703

ID	SC_0703
Use Case	Disengage platoon
Scenario Name	Leave by leading truck (Use case 4.1.2 as per D2.3 specification)
Scenario description	The leading vehicle sends a leaving request to an existing platoon in front. The leaving procedure is accepted and the following vehicle leaves the platoon.
Objective	Validate a correct vehicle leaving (leading vehicle) to an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Two roads - Platoon active - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An existing platoon is driving at the same lane. - The existing platoon in front is formed and in steady state condition with a specific number of trucks.
Trigger	- The ego driver starts the leaving procedure by pushing the leave button or pressing the brake pedal.
Testing Steps	1) The leaving procedure from the ego vehicle is broadcasted to the other platoon members through V2V communication. 2) The target vehicle increases the inter-vehicle time-gap with preceding vehicle.

	3) The target vehicle communicates being ready to continue as leading vehicle to the ego vehicle. 4) The ego vehicle performs the leave procedure and the platooning communication is disconnected. 5) The target vehicle becomes the new platoon leader and the driver is informed.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures - The limit distance gap between trucks is respected during overall the procedure.
Final State	A final platoon with a new platoon size is formed with the desired speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7.4. SC_0704: Split platoon

13.7.4.1. Functional level

The Figure 53Figure 53 SC_0704 diagram states is the graphic description of the scenario.

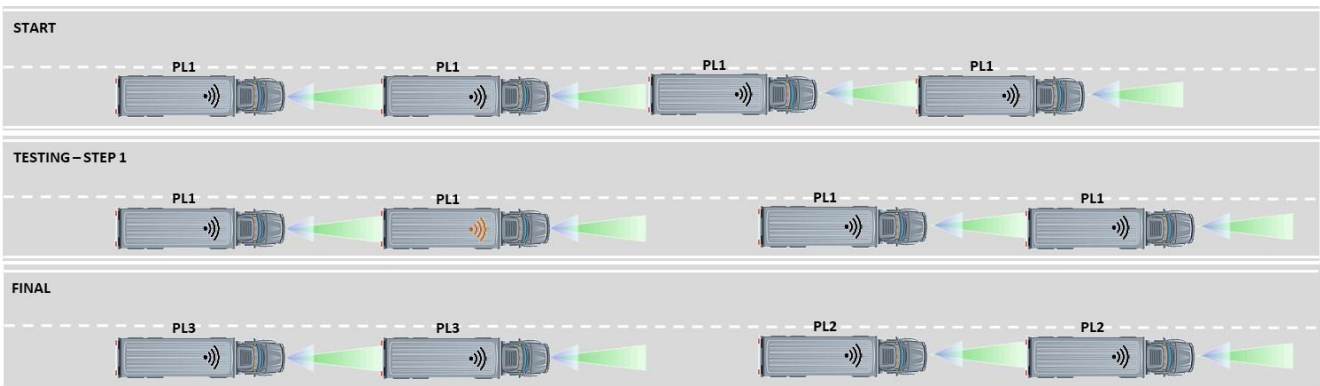

Figure 53 SC_0704 diagram states

The Table 41 contains the split platoon scenario:

Table 41 Functional scenario SC_0704

ID	SC_0704
Use Case	Disengage platoon
Scenario Name	Split platoon (Use case 4.2 as per D2.3 specification)
Scenario description	During a stable platoon, one of the follower vehicles (not the leader nor the trailer vehicle) starts the split procedure.
Objective	Validate a correct platoon split procedure executed by one of the follower vehicles (not the leader nor the trailer vehicle) in an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - 2 road lines - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An existing platoon is driving at the same lane. - The existing platoon in front is formed and in steady state condition with a specific number of trucks.
Trigger	- One of the follower vehicles (ego vehicle) of the existing platoon starts the split procedure.
Testing Steps	1) The ego application enters in "Split" mode. 2) The start of the splitting procedure from the ego vehicle is broadcasted to the target one through V2V communication and the ego vehicle increases the inter-vehicle distance. 3) The ego vehicle V2V communication to the target vehicle is disconnected. 4) The current platoon is split in two different branches. 5) The ego vehicle becomes the platoon leader of the new platoon formed."
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The limit distance gap between trucks is respected during overall the procedure.
Final State	A final two different platoons are formed with the desired speed in steady state platooning.
Parameters (inputs)	- EGO vehicle brand - EGO vehicle payload - EGO vehicle speed - EGO vehicle distance (platoon in front and behind) - Platoon ID (x2) - Platoon speed (x2) - Platoon size initial (x2) - Platoon line-up (x2) - Brand payload (x2)"

Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7.5. SC_0705: Leave by steering-out as following truck

13.7.5.1. Functional level

The Figure 54Figure 54 SC_0705 diagram states is the graphic description of the scenario.

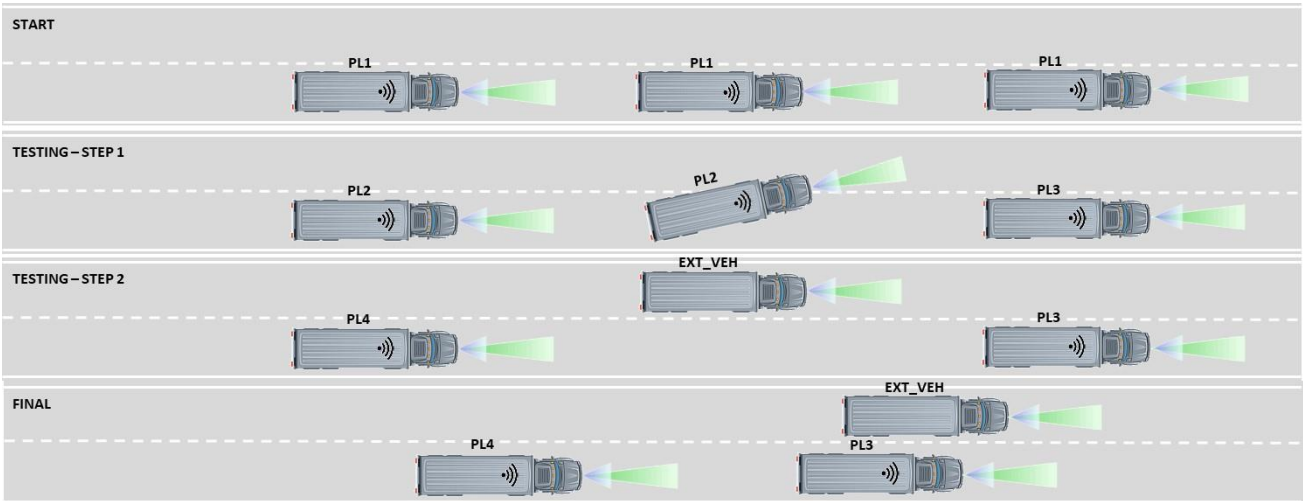

Figure 54 SC_0705 diagram states

The Table 42 contains the leave by steering-out as following truck scenario:

Table 42 Functional scenario SC_0705

ID	SC_0705
Use Case	Disengage platoon
Scenario Name	Leave by steering-out as following truck (Use case 4.3.1 as per D2.3 specification)
Scenario description	During a stable platoon, one of the follower trucks decides to leave and steers out and takes an exit.
Objective	Validate a correct steer out procedure by one of the follower vehicles in an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - 2 road lines - At least 2km of free road lane - Define all brands payload involved in the scenario

Initial State	- An existing platoon is driving at the same lane. - The existing platoon is formed and in steady state condition with a specific number of trucks.
Trigger	- The driver of one follower vehicles (ego vehicle) decides to steer out of the platoon without using the leave button as for a normal leave.
Testing Steps	"1) The ego vehicle detects that it's no longer following the vehicle in front and initiates a front split. 2) A two different platoons are formed with different platoon ID. 3) The follower vehicle detects that it is no longer following the ego vehicle and initiates a front split. 4) A new platoons ID change."
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The ego vehicle and follower do the front split communication correctly.
Final State	A final two different platoons are formed with the desired speed in steady state platooning.
Parameters (inputs)	- Ext_veh brand - Ext_veh payload - Ext_veh speed (platoon in front and behind) - Platoon ID (x4) - Platoon speed (x4) - Platoon size initial (x4) - Platoon line-up (x4) - Brand payload (x4)
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.7.6. SC_0706: Leave by steering-out by leading truck

13.7.6.1. Functional level

The Figure 55Figure 55 SC_0706 diagram states is the graphic description of the scenario.

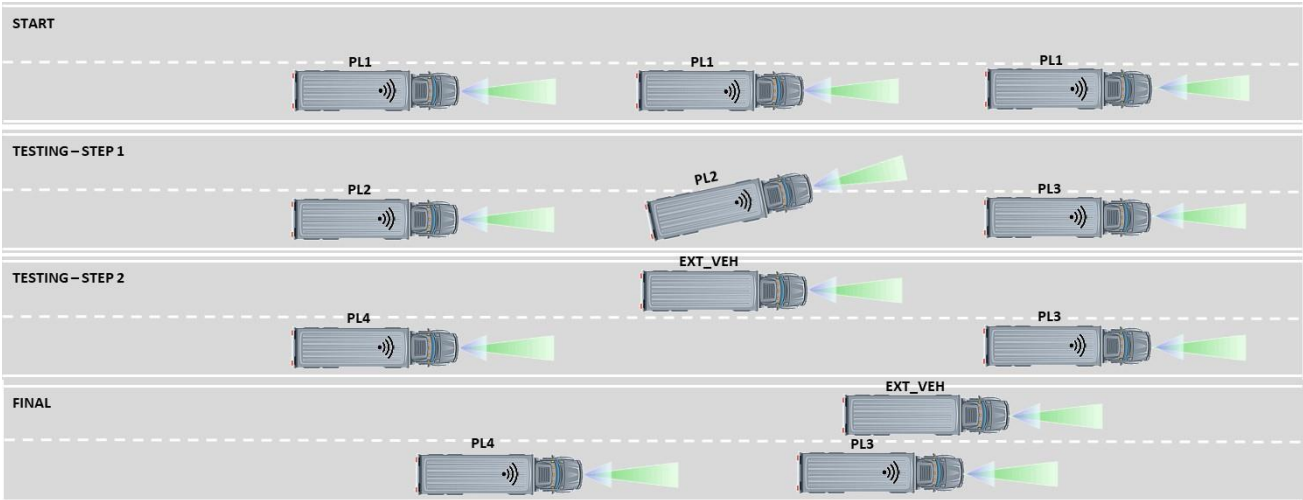

Figure 55 SC_0706 diagram states

The Table 43 contains the leave by steering-out as leading truck scenario:

Table 43 Functional scenario SC_0706

ID	SC_0706
Use Case	Disengage platoon
Scenario Name	Leave by steering-out by leading truck (Use case 4.3.2 as per D2.3 specification)
Scenario description	During a stable platoon, the leader truck decides to leave and steers out by changing lane.
Objective	Validate the correct steers out procedure by the leader vehicle in an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - 2 road lines - At least 2km of free road lane - Define all brands payload involved in the scenario
Initial State	- An existing platoon is driving at the same lane. - The existing platoon is formed and in steady state condition with a specific number of trucks.
Trigger	- The driver of leader vehicle decides to steer out of the platoon without using the leave button as for a normal leave.

Testing Steps	1) The ego vehicle detects that it's no longer following lane and initiates a leave and initiates a leave. 2) The second vehicle detects that is no longer following the leader and initiates a split in front. 3) A new platoon ID change and the second vehicle will be the leader.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The second vehicle do the front split communication correctly.
Final State	- The leader vehicle is driving alone. - A new platoon is formed with the desired speed in steady state platooning.
Parameters (inputs)	- Ext_veh brand - Ext_veh payload - Ext_veh speed (platoon in front and behind) - Platoon ID (x2) - Platoon speed (x2) - Platoon size initial (x2) - Platoon line-up (x2) - Brand payload (x2)
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.8. Platoon cohesion

The scenarios for the platoon cohesion are:

- Closing gap at maximum set speed
- Closing gap at maximum acceleration and speed performance

13.8.1. SC_0801: Closing gap at maximum set speed

13.8.1.1. Functional level

The Figure 56Figure 56 SC_0801 diagram states is the graphic description of the scenario.

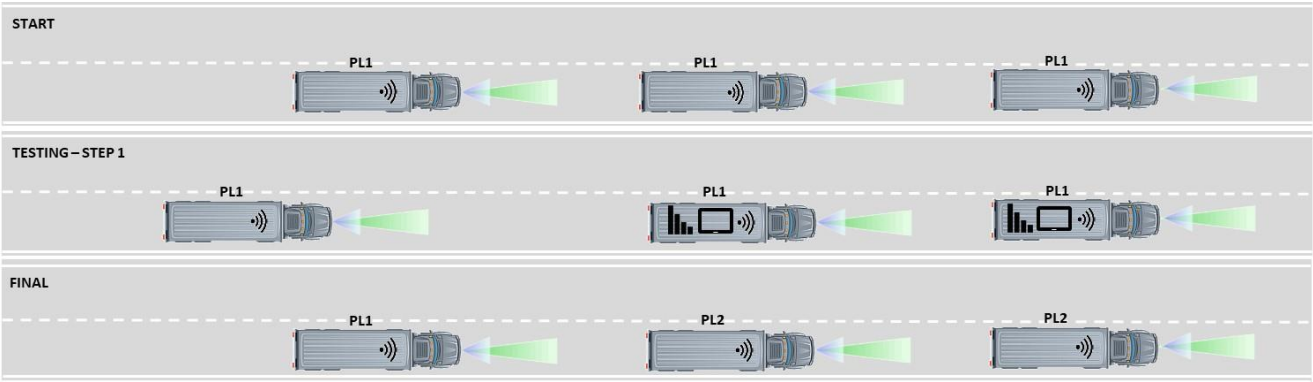

Figure 56 SC_0801 diagram states

The Table 44 Functional scenario SC_0801 contains the closing gap at maximum set speed scenario:

Table 44 Functional scenario SC_0801

ID	SC_0801
Use Case	Platoon cohesion
Scenario Name	Closing gap at maximum set speed (Use case 3.4.4 as per D2.3 specification)
Scenario description	During a stable platoon, one of the vehicles sends the maximum attainable speed.
Objective	Validate a correct cohesion request procedure by one of the slowest vehicles in an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X) - No warnings - Platoon already existing - At least 2km of free road lane - Define all brands payload involved in the scenario

Initial State	- The existing platoon is formed and in steady state condition with a specific number of trucks. - One of the existing vehicles (slow vehicle) is driving at certain distance to the following vehicle.
Trigger	- One of the vehicles in the current platoon sends to the preceding the changed maximum attainable speed.
Testing Steps	1) The lead driver receives the maximum attainable speed of one of the vehicles in the platoon (HMI display). 2) The driver of the lead vehicle set a lower speed. 3) The gap of the vehicles is closed as configured in the current platoon. 4) The slow vehicle changes the request back to its maximum attainable speed."
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The new speed value appears inside HMI display of the leader vehicle.
Final State	The platoon still formed with the desired speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication - Platoon size final - Platoon group information

13.8.2. SC_0802: Closing gap at maximum acceleration and speed performance

13.8.2.1. Functional level

The Figure 57Figure 57 SC_0802 diagram states is the graphic description of the scenario.

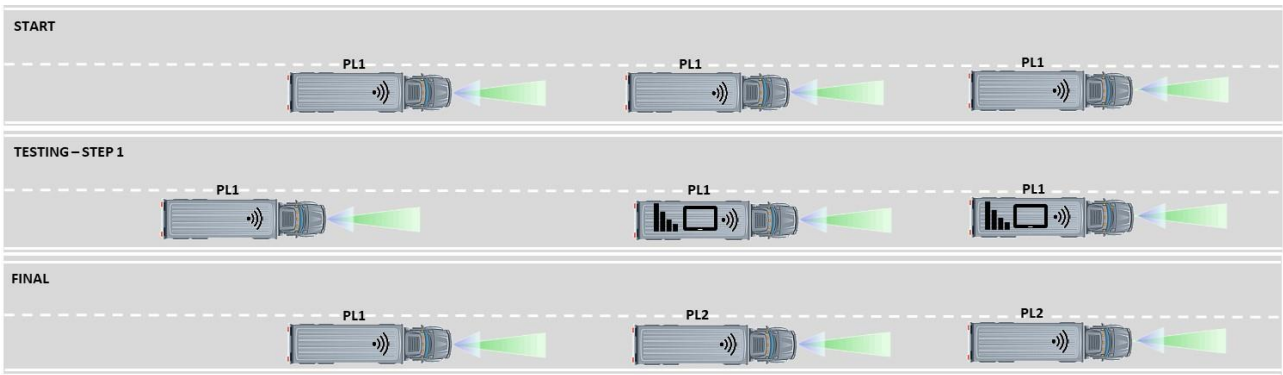

Figure 57 SC_0802 diagram states

The Table 45 Functional scenario SC_0802 contains the closing gap at maximum acceleration and speed performance scenario:

Table 45 Functional scenario SC_0802

ID	SC_0802
Use Case	Platoon cohesion
Scenario Name	Closing gap at maximum acceleration and speed performance (Use case 3.4.4 as per D2.3 specification)
Scenario description	During a stable platoon, one of the vehicles sends the maximum attainable speed and acceleration.
Objective	Validate a correct cohesion request procedure by one of the slowest vehicles in an existing platoon. Different manoeuvres and communication validation.
Pre-conditions	- System full operating (internal & V2X). - No warnings. - Platoon already existing. - At least 2km of free road lane. - Define all brands payload involved in the scenario.
Initial State	- The existing platoon is formed and in steady state condition with a specific number of trucks. - One of the existing vehicles (slow vehicle) is driving at certain distance to the following vehicle.
Trigger	- One of the vehicles in the current platoon sends to the preceding the changed maximum attainable speed & acceleration.
Testing Steps	1) The lead driver receives the maximum attainable speed & acceleration of one of the vehicles in the platoon (HMI display). 2) The driver of the lead vehicle set a lower speed. 3) The gap of the vehicles is closed as configured in the current platoon. 4) The slow vehicle changes the request back to its maximum attainable speed & acceleration.
Acceptance Criteria	- All V2V messages and parameters are according with the specifications of ENSEMBLE_platooning_M13_20200204 - No system failures. - The new speed & acceleration value appears inside HMI display of the leader vehicle.
Final State	The platoon still formed with the desired speed in steady state platooning.
Parameters (inputs)	- Platoon ID - Platoon speed - Platoon size initial - Platoon line-up - Brand payload
Signals (outputs)	- HMI actions - V2V Communication

	- Platoon size final - Platoon group information

14. APPENDIX B.

In this section the test scenarios and the proposed sequence to perform them are detailed.

14.1. Static & safety tests

In Table 46 is described the procedures and tests necessaries to obtain the authorization to conduct the tests at IDIADA's proving ground and open road, as well as the minimum number of repetitions to be carried out.

Table 46: Description of test in static and safety procedures.

TR description	TR	Location	Step	Step Description	Rep
install SEMS	1	BOX	Initial configuration	1 truck	7
			Install SEMS	TNO install SEMS device and configure it	
Check payload safety	2	BOX	Initial configuration	1 truck	7
			Check payload	safety according with the IDIADAs standards	
check V2V configuration and fields (Atanassow, Boris et all, D2.8 v20181210)	3	BOX	Initial configuration	1 truck	7
			Check OBU configuration	Check that all configurable parameters are with the correct values	
			Power output	Measure power with external device	
			Emission channel	External device sniffing in channel 180	
			CAM Analysis	With external device and Wireshark analysing CAMs	
			PMM Analysis	With external device and Wireshark analysing PMMs	
			PCM Analysis	With external device and Wireshark analysing PCMs	
			MAC Analysis	With external device and Wireshark analysing MAC layer	
safety check	4	BOX and IDIADA PG	Initial configuration	1 truck	7
			Pass safety check to all trucks	To access to test track is necessary pass the PG safety verification	

TR description	TR	Location	Step	Step Description	Rep
Test braking messages	5	brake zone in IDIADA PG	Initial configuration	1 truck	7
			1	Test emission warning braking	
			2	Test emission emergency braking	
			3	Test reception warning braking	
			4	Test reception emergency braking	

14.2. Test Run

Table 47 contains a detailed test-run example of what will be done for multi-brand testing in the proving ground. Every test run is composed of different scenarios from the list that can be found on Appendix A., as well as the minimum number of repetitions necessaries to do por each test run.

Table 47: Proving ground tests run

TR	Step	Description	Platoon members	Rep
1	Initial config	7 trucks in a line at a speed with almost 75 meters between each.	0	3
	SC_0101	truck 1 with 2 create a platoon	2	
	SC_0101	truck 3 join to the platoon by behind	3	
	SC_0101	truck 4 join to the platoon by behind	4	
	SC_0101	truck 5 join to the platoon by behind	5	
	SC_0101	truck 6 join to the platoon by behind	6	
	SC_0104	truck 7 join to the platoon by behind maximum number of trucks	7	
	SC_0201	Test steady state speed	7	
	SC_0203	Test steady state deacceleration	7	
	SC_0202	Test steady state acceleration	7	
	SC_0201	Test steady state speed	7	
	SC_0701	Disengage platoon by trailing truck	6	
	SC_0701 / SC_0705	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	5	
	SC_0701 / SC_0705	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	4	
	SC_0703 / SC_0706	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	3	

Table 47: Proving ground tests run

TR	Step	Description	Platoon members	Rep
	SC_0703 / SC_0706	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	2	
	SC_0703	Disengage platoon by leading truck	0	
2	Initial config	8 trucks in a line at a speed with almost 75 meters between each. Between trucks 4 and 5 there is almost 150 m	0	3
	SC_0101	truck 1 with 2 create a platoon (PL1)	2	
	SC_0106	truck 4 try to join at the platoon	2	
	SC_0101	truck 5 with 6 create a platoon (PL2)	2&2	
	SC_0101	truck 3 join to the platoon (PL1) by behind	3&2	
	SC_0101	truck 4 join to the platoon (PL1) by behind	4&2	
	SC_0101	truck 7 join to the platoon (PL2) by behind	4&3	
	SC_0101	truck 8 join to the platoon (PL2) by behind	4&4	
	SC_0105	Platoon PL2 try to join to platoon PL1, refuse due a maximum number of trucks are acquired	4&4	
	SC_0701	Disengage platoon (PL2) by trailing truck	4&3	
	SC_0102	Platoon PL2 join to platoon PL1	7	
	SC_0204	Steady state gap variation	7	
	SC_0401	New minimum distance policy (increase value)	7	
	SC_0401	New minimum distance policy (decrease value)	7	
	SC_0201	Test steady state speed (Maximum speed)	7	
	SC_0703	Disengage platoon by leading truck	6	
	SC_0104	truck 7 join to the platoon by behind maximum number of trucks	7	
	SC_0801	Closing gap at maximum speed	7	
	SC_0802	Closing gap at maximum acceleration and speed performance (example: different truck loads)	7	
	SC_0402	New maximum speed policy (decrease value)	7	
	SC_0703	Disengage platoon by leading truck	6	
	SC_0701 / SC_0705	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	5	
	SC_0703 / SC_0706	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	4	

Table 47: Proving ground tests run

TR	Step	Description	Platoon members	Rep
	SC_0701 / SC_0705	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	3	
	SC_0703 / SC_0706	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	2	
	SC_0701	Disengage platoon by trailing truck	0	
3	Initial config	7 trucks and 1 car, 4 trucks in a line at a speed with almost 75 meters between each. The other 3 trucks in the adjacent line with almost 75 meters between each. The car will maintain a safety distance until it will be needed.		3
	SC_0101	truck 1 with 2 create a platoon (PL1)	2	
	SC_0101	truck 5 with 6 create a platoon (PL2)	2&2	
	SC_0101	truck 3 join to the platoon (PL1) by behind	3&2	
	SC_0101	truck 7 join to the platoon (PL2) by behind	3&3	
	SC_0101	truck 4 join to the platoon (PL1) by behind	4&3	
	SC_0206	An existing platoon (PL2) in steady state overtake to another platoon (PL1) in steady state	4&3	
	SC_0206	An existing platoon (PL1) in steady state overtake to another platoon (PL2) in steady state	4&3	
	SC_0703	Disengage platoon (PL2) by leading truck (Tr 5)	4&2	
	SC_0103	Merging in a platoon (PL1) in between by a single vehicle (Tr 5)	5&2	
	SC_0703	Disengage platoon (PL2) by leading truck (Tr 6)	5	
	SC_0103	Merging in a platoon (PL1) in between by a single vehicle (Tr 6)	6	
	SC_0103	Merging in a platoon (PL1) in between by a single vehicle (Tr 7)	7	
	SC_0502	The car produces a cut-through in the position 6-7 of the platoon	7	
	SC_0501	The car produces a cut-in in the position 5-6 of the platoon and remains	7	
	SC_0503	The car produces a cut-out of the position 5-6 of the platoon	7	
	SC_0502	The car produces a cut-through in the position 4-5 of the platoon	7	
	SC_0501	The car produces a cut-in in the position 3-4 of the platoon and remains	7	
	SC_0503	The car produces a cut-out of the position 3-4 of the platoon	7	
	SC_0702	Leave platoon by a following vehicle and accelerate	6	

Table 47: Proving ground tests run

TR	Step	Description	Platoon members	Rep
	SC_0702	Leave platoon by a following vehicle and accelerate	5	
	SC_0702	Leave platoon by a following vehicle and accelerate	4	
	SC_0702	Leave platoon by a following vehicle and accelerate	3	
	SC_0702	Leave platoon by a following vehicle and accelerate	2	
	SC_0701	Disengage platoon by trailing truck	0	
	Initial config	7 trucks in a line at a speed with almost 75 meters between each.	0	
	SC_0101	truck 1 with 2 create a platoon	2	
	SC_0101	truck 3 join to the platoon by behind	3	
	SC_0101	truck 4 join to the platoon by behind	4	
	SC_0101	truck 5 join to the platoon by behind	5	
	SC_0101	truck 6 join to the platoon by behind	6	
	SC_0104	truck 7 join to the platoon by behind maximum number of trucks	7	
	SC_0205	An existing platoon in steady state reduce the speed until less than 30 km/h even stop it	7	
	Transition	increase speed of the platoon		
	SC_0704	split the platoon between position 2-3. Making two platoons (PL1 and PL2)	2&5	
	SC_0704	split the platoon PL2 between position 2-3. Making two platoons (PL2 and PL3)	2&2&3	
	SC_0102	joining platoons (PL1 and PL2)	4&3	
4	SC_0102	joining platoons (PL1 and PL3)	7	3
	SC_0702	Disengage platoon by leading truck	6	
	SC_0702	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	5	
	SC_0702	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	4	
	SC_0702	Disengage platoon by trailing truck or Disengage platoon by follower truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	3	
	SC_0702	Disengage platoon by leading truck or Disengage platoon by leading by steering truck by steering in function of the platoon position in the track (PAV exit pass through parking and it incorporates to the pav in the last position)	2	
	SC_0701	Disengage platoon by trailing truck	0	

Table 47: Proving ground tests run

TR	Step	Description	Platoon members	Rep
5	Initial config	7 trucks in a line at a speed with almost 75 meters between each.	0	3
	SC_0101	truck 1 with 2 create a platoon	2	
	SC_0101	truck 3 join to the platoon by behind	3	
	SC_0101	truck 4 join to the platoon by behind	4	
	SC_0101	truck 5 join to the platoon by behind	5	
	SC_0101	truck 6 join to the platoon by behind	6	
	SC_0104	truck 7 join to the platoon by behind maximum number of trucks	7	
	SC_0301	emergency braking	7	
		stabilize speed	7	
	SC_0302	emergency braking	7	
		stabilize speed	7	
	SC_0302	emergency braking	7	
		stabilize speed	7	
	SC_0304	Abort emergency braking	7	
6	Initial config	7 trucks in a line at a speed with almost 75 meters between each.	0	3
	SC_0101	truck 1 with 2 create a platoon	2	
	SC_0101	truck 3 join to the platoon by behind	3	
	SC_0101	truck 4 join to the platoon by behind	4	
	SC_0101	truck 5 join to the platoon by behind	5	
	SC_0101	truck 6 join to the platoon by behind	6	
	SC_0104	truck 7 join to the platoon by behind maximum number of trucks	7	
	SC_0601	Truck n GPS failure	?	
		all trucks switch off platoon system	0	
		all trucks switch on platoon system	7	
	SC_0601	All trucks GPS failure	?	
		all trucks switch off platoon system	0	
		all trucks switch on platoon system	7	
	SC_0602	Truck n Communication failure	?	
		all trucks switch off platoon system	0	
		all trucks switch on platoon system	7	
	SC_0603	Truck n Package V2V loss failure	?	
		all trucks switch off platoon system	0	
		all trucks switch on platoon system	7	
	SC_0604	Sensor failure in truck n	?	

15. APPENDIX C.

15.1.Glossary

15.1.1. Definitions

Term	Definition
Cut-in	A lane change manoeuvre performed by vehicles from the adjacent lane to the ego vehicle's lane, at a distance close enough (i.e., shorter than desired inter vehicle distance) relative to the ego vehicle.
Cut-out	A lane change manoeuvre performed by vehicles from the ego lane to the adjacent lane.
Cut-through	A lane change manoeuvre performed by vehicles from the adjacent lane (e.g. left lane) to ego vehicle's lane, followed by a lane change manoeuvre to the other adjacent lane (e.g. right lane).
Ego Vehicle	The vehicle from which the perspective is considered.
Emergency brake	Brake action with an acceleration of <-4 m/s2.
Event	An event marks the time instant at which a transition of a state occurs, such that before and after an event, the system is in a different mode.
Following truck	Each truck that is following behind a member of the platoon, being every truck except the leading and the trailing truck, when the system is in platoon mode.
Leading truck	The first truck of a truck platoon.
Manoeuvre ("activity")	A particular (dynamic) behaviour which a system can perform (from a driver or other road user perspective) and that is different from standing still, is being considered a manoeuvre.
Operational layer	The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the aforementioned manoeuvres, and the control of the individual vehicles in the platoon to automatically perform the platooning task. Here, the main control task is to regulate the inter-vehicle distance or velocity and, depending on the Platooning Level, the lateral position relative to the lane or to the preceding vehicle. Key performance requirements for this layer are vehicle following behaviour and (longitudinal and lateral) string stability of the platoon, where the latter is a necessary requirement to achieve a stable traffic flow and to achieve scalability with respect to platoon length, and the short-range wireless inter-vehicle communication is the key enabling technology.
Platoon	A group of two or more automated cooperative vehicles in line, maintaining a close distance, typically such a distance to reduce fuel consumption by air drag, to increase

	traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
Platoon Automation Levels	In analogy with the SAE automation levels subsequent platoon automation levels will incorporate an increasing set of automation functionalities, up to and including full vehicle automation in a multi-brand platoon in real traffic for the highest Platooning Automation Level. The definition of "platooning levels of automation" will comprise elements like e.g. the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc. Three different levels are anticipated; called A, B and C.
Platoon candidate	A truck who intends to engage the platoon either from the front or the back of the platoon.
Platoon cohesion	Platoon cohesion refers to how well the members of the platoon remain within steady state conditions in various scenario conditions (e.g. slopes, speed changes).
Platoon disengaging	The ego-vehicle decides to disengage from the platoon itself or is requested by another member of the platoon to do so. When conditions are met the ego-vehicle starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap is large enough (e.g. time gap of 1.5 seconds, which is depends on the operational safety based on vehicle dynamics and human reaction times is given). A.k.a. leave platoon
Platoon dissolve	All trucks are disengaging the platoon at the same time. A.k.a. decoupling, a.k.a. disassemble.
Platoon engaging	Using wireless communication (V2V), the Platoon Candidate sends an engaging request. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap. A.k.a. join platoon
Platoon formation	Platoon formation is the process before platoon engaging in which it is determined if and in what format (e.g. composition) trucks can/should become part of a new / existing platoon. Platoon formation can be done on the fly, scheduled or a mixture of both. Platoon candidates may receive instructions during platoon formation (e.g. to adapt their velocity, to park at a certain location) to allow the start of the engaging procedure of the platoon.
Platoon split	The platoon is split in 2 new platoons who themselves continue as standalone entities.
Requirements	Description of system properties. Details of how the requirements shall be implemented at system level
Scenario	A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its static environment, and its dynamic environment. From the perspective of the ego vehicle, a scenario contains all relevant events.

	Scenario is a combination of a manoeuvre ("activity"), ODD and events
Service layer	The service layer represents the platform on which logistical operations and new initiatives can operate.
Specifications	A group of two or more vehicles driving together in the same direction, not necessarily at short inter-vehicle distances and not necessarily using advanced driver assistance systems
Steady state	In systems theory, a system or a process is in a steady state if the variables (called state variables) which define the behaviour of the system or the process are unchanging in time. In the context of platooning this means that the relative velocity and gap between trucks is unchanging within tolerances from the system parameters.
Strategic layer	The strategic layer is responsible for the high-level decision-making regarding the scheduling of platoons based on vehicle compatibility and Platooning Level, optimisation with respect to fuel consumption, travel times, destination, and impact on highway traffic flow and infrastructure, employing cooperative ITS cloud-based solutions. In addition, the routing of vehicles to allow for platoon forming is included in this layer. The strategic layer is implemented in a centralised fashion in so-called traffic control centres. Long-range wireless communication by existing cellular technology is used between a traffic control centre and vehicles/platoons and their drivers.
Tactical layer	The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. In addition, this layer ensures platoon cohesion on hilly roads, and sets the desired platoon velocity, inter-vehicle distances (e.g. to prevent damaging bridges) and lateral offsets to mitigate road wear. This is implemented through the execution of an interaction protocol using the short-range wireless inter-vehicle communication (i.e. V2X). In fact, the interaction protocol is implemented by message sequences, initiating the manoeuvres that are necessary to form a platoon, to merge into it, or to dissolve it, also taking into account scheduling requirements due to vehicle compatibility.
Target Time Gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds, agreed by all the Platoon members; it represents the minimum distance in seconds allowed inside the Platoon.
Time gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds.
Trailing truck	The last truck of a truck platoon.
Truck Platoon	Description of system properties. Details of how the requirements shall be implemented at system level.
Use case	Use-cases describe how a system shall respond under various conditions to interactions from the user of the system or surroundings, e.g. other traffic participants or road

conditions. The user is called actor on the system and is often but not always a human being. In addition, the use-case describes the response of the system towards other traffic participants or environmental conditions. The use-cases are described as a sequence of actions, and the system shall behave according to the specified use-cases. The use-case often represents a desired behaviour or outcome.

In the ensemble context a use case is an extension of scenario which add more information regarding specific internal system interactions, specific interactions with the actors (e.g. driver, I2V) and will add different flows (normal & alternative e.g. successful and failed in relation to activation of the system / system elements).

15.1.2. Acronyms and abbreviations

Acronym / Abbreviation	Meaning
ACC	Adaptive Cruise Control
ABS	Anti-lock Braking System
ACSF	Automatically Commanded Steering Function
ADAS	Advanced driver assistance system
ADR	Agreement concerning the International Carriage of Dangerous Goods by Road
AEB	Automatic Emergency Braking (System, AEBS)
ASIL	Automotive Safety Integrity Level
ASN.1	Abstract Syntax Notation One
BTP	Basic Transport Protocol
C-ACC	Cooperative Adaptive Cruise Control
C-ITS	Cooperative ITS
CA	Cooperative Awareness
CAD	Connected Automated Driving
CAM	Cooperative Awareness Message
CCH	Control Channel
CS	Cyber Security
CSF	Corrective steering functions
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DITL	Driver-In-the-Loop
DOOTL	Driver-Out-Of-the Loop
DSRC	Dedicated Short-Range Communications
EC	European Commission
EMC	Electro Magnetic Compatibility
ESF	Emergency steering function
ESP	Electronic Stability Program
ETSI	European Telecommunications Standards Institute
EU	European Union

FAD	Fully Automated Driving
FCW	Forward Collision Warning
FLC	Forward Looking Camera
FSC	Functional Safety Concept
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRVA	Working Party on Automated/Autonomous and Connected Vehicles
GUI	Graphical User Interface
HAD	Highly Automated Driving
HARA	Hazard Analysis and Risk Assessment
HIL	Hardware-in-the-Loop
HMI	Human Machine Interface
HW	Hardware
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITC	Inland Transport Committee
ITS	Intelligent Transport System
ITS-S	Intelligent Transport Systems Station
IVI	Infrastructure to Vehicle Information message
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assist
LCA	Lane Centering Assist
LRR	Long Range Radar
MAP	MapData message
MIO	Most Important Object
MRR	Mid Range Radar
MVC	Modular Vehicle Combinations
OBD	On-Board Diagnostics
OS	Operating system
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OOTL	Out-Of-The-Loop
OTA	Over the air
PAEB	Platooning Autonomous Emergency Braking
PMC	Platooning Mode Control
QM	Quality Management
RCP	Remote Control Parking
RSU	RoadSide Unit
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SIL	Software-in-the-Loop
SOTIF	Safety of the Intended Function
SPAT	Signal Phase and Timing message

SRR	Short Range Radar
SW	Software
TC	Technical Committee
TF	Task Force
TOR	Take-Over Request
TOT	Take-Over Time
TTG	Target Time Gap
UNECE	United Nations Economical Commission of Europe
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to any (where x equals either vehicle or infrastructure)
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
VECTO	Vehicle Energy Consumption Calculation Tool
VMAD	Validation Method for Automated Driving
WLAN	Wireless Local Area Network
WIFI	Wireless Fidelity
WP	Work Package