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## Specifications for Multi-Brand Truck Platooning



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### Abstract

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. 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. This paper provides with definition of the specifications of the whole multi-brand truck platooning concept to be implemented within the testing and demonstration trucks of the 6 OEMs. It describes the functional architecture, captures all minimum set of operations layer requirements and tactical layer specifications for Platoon level A. The building blocks of truck platooning consist of in-vehicle requirements (Longitudinal, sensors, HMI interaction), infrastructure (V2I), information among trucks in platoon, and platooning strategy (coordination mode, gap regulation, formation, dissolution, and vehicle mix).

**Keywords:** truck platooning, specifications, automated driving.

### Résumé

La technologie de peloton a fait des progrès significatifs au cours de la dernière décennie, mais pour franchir la prochaine étape du déploiement de pelotons de camions, une approche multimarques intégrée est indispensable. Le projet ENSEMBLE a pour ambition de mettre en place des pré-normes en matière d'interopérabilité entre les camions, les pelotons et les fournisseurs de solutions logistiques, d'accélérer le développement et la mise en œuvre de (sous-) systèmes sur le marché et de permettre l'harmonisation des cadres juridiques dans les États membres européens. Ce document fournit une définition des spécifications du concept de groupement de camions multimarques à mettre en œuvre dans les camions de test et de démonstration des 6 constructeurs. Il décrit l'architecture fonctionnelle, capture l'ensemble des exigences minimales de la couche d'exploitation et des spécifications de la couche tactique pour le niveau A. Les éléments constitutifs du groupement de camions sont les exigences embarquées (longitudinal, capteurs, interaction IHM), infrastructure (V2I), informations entre camions du peloton et stratégie de peloton (mode de coordination, régulation des écarts, formation, dissolution et combinaison de véhicules).

**Mots-clés:** peloton de camion, spécifications, conduite automatisée.

## **1. Introduction**

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 realise 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 harmonisation of legal frameworks in the member states.

### **1.1 Main goal of ENSEMBLE**

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.

When evaluating the different platooning projects such as CHAUFFEUR II (2000 - 2003), KONVOI (2005 - 2009), SARTRE (2009 - 2012), i-GAME (2013 - 2016), COMPANION (2013 - 2016), AUTONET2030 (2013 - 2016), ROADART (2015 - 2018), CONCORDA (2017 – 2020), it can be seen that these projects mostly concentrate on developing the in-vehicle platooning technology, whereas later projects more concentrate on either a specific technological challenge (e.g. antennae design and placement) or on the use of platooning technology (e.g. platoon coordination). With respect to use cases and in-vehicle architectures, many commonalities are seen on a high level. However, details are often not published. This also holds for the low-level controllers used in the different projects. Moreover, tactical layer functionalities and operational layer functionalities have mostly been implemented as one ‘controller’, i.e. there was no separation between ‘common’ and ‘truck specific’ functionalities, which is needed for ENSEMBLE’s tactical and operational layers. Hence, a clear task is reserved for ENSEMBLE to separate these functionalities in a way that the technology is still usable for all OEMs. Besides that, the impact of non-homogeneous platoons is still unclear. Heterogeneous platooning may stem from different sources: different operational implementations (spacing policies, control algorithms and information used for control, for instance), different vehicle capabilities in accelerating and decelerating (vehicle total mass, available engine power, brake capacity). Additionally, road profile may affect platoon performance. Despite the substantial academic work on platooning, applied control design for (heterogeneous) platooning is still an open issue. Only very limited publications deal with implementation relevant aspects and/or heterogeneity of platoons. This thus is still an open area also for ENSEMBLE.

### **1.2 Platooning levels and SAE**

In order to break down the complexity of deploying multi-branded truck platooning on public roads different platooning Levels are defined. The Platooning Levels facilitate a stepwise approach to deployment of platooning on public roads, where the “first” Platooning Level defined in ENSEMBLE can be deployed in the *near* future. The idea of Platooning Levels has emerged since the commonly accepted automation levels of the SAE J3016 have shortcomings when applied to platooning. The first level in the SAE levels of driving automation involves either longitudinal or lateral vehicle automation, whereas the driver is responsible to detect safety-critical events and take appropriate action. Level 2 involves both longitudinal and lateral automation, with the same driver responsibility as in level 1. In level 3, the driver responsibility is decreased to only act upon a warning by the automation system. Only in level 4 and higher, the driver has no driving task anymore for part or all of the journey. Truck platooning, however,

involves driving at short inter-vehicle distances for an extended period. Therefore, the driver cannot be held responsible for timely intervention in case of safety-critical events such as hard braking. Furthermore, the platoon as a whole can be seen as a system of interconnected systems with specific requirements. Hence, the first three SAE automation levels are not directly applicable for the platooning application. Consequently, the need arises to create a different automation level classification for heavy duty vehicles that considers the explained needs of Platooning. The definition of “platooning levels of automation” will comprise elements like 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 seen for now – called platoon level A, B and C.

**Table 1-High level platoon levels overview**

	<b>Platoon level A</b>	<i>Platoon level B</i>	<i>Platoon level C</i>
Longitudinal automation	Leading truck: manual or advanced assist system (e.g. ACC) Following & trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)	<i>Leading truck: manual or advanced assist system (e.g. ACC) Following &amp; trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)</i>	<i>Leading truck: manual or advanced assist system (e.g. ACC) Following &amp; trailing vehicle: Autonomous longitudinal control (CACC, CAEB, Cxxx, ...)</i>
Lateral automation	Driver Optionally: in lane by system (standalone vehicle)	<i>In lane + lane changes (coordinated)</i>	<i>Full automation from A to B</i>
Operation area	Triggered by driver in dedicated areas (e.g. highway)	<i>Dedicated areas (e.g. highway)</i>	<i>Dedicated areas (e.g. highway + parking areas)</i>
Fault tolerance	Longitudinal degradation functionality	<i>Longitudinal &amp; lateral degradation functionality</i>	<i>Longitudinal &amp; lateral degradation functionality</i>
Platoon engaging	Only from behind (by single truck & existing platoon)	<i>From behind (by single truck &amp; existing platoon) and from the front by single truck</i>	<i>From behind (by single truck &amp; existing platoon), from the front by single truck and merging of single trucks in existing platoon</i>
System & environment monitoring	System itself + Driver (environment)	<i>System itself</i>	<i>System itself</i>
Fallback of the DDT (dynamic driving task)	Driver; as long it is safe and the driver can react in time	<i>System (for x seconds)</i>	<i>System</i>
Safe state	Fail-safe (driver in control after reaction time of the driver)	<i>Stopped in ego lane or rightmost lane</i>	<i>Stopped in safe stop area (e.g. fuel station)</i>
Timegap (Steady state @ 80 kph)	>0.8s	<i>&gt;0.5s</i>	<i>&gt;0.3s</i>
Maximum number of trucks	7 (maximum for simulations & verifications)	<i>No principle technical limitation as for now</i>	<i>No principle technical limitation as for now</i>
Platoon formation (orchestrated) possible	Yes	<i>Yes</i>	<i>Yes</i>

## 2. Functional Architecture

The white label truck representing a brand-less truck that has all the described specifications, Figure 1 gives an overview of the elements of the white label truck. The white label truck on the one hand comprises specifications: these are mainly elements specifically added for platooning. On the other hand, it comprises requirements: here OEM specific systems or connections to OEM specific systems are involved

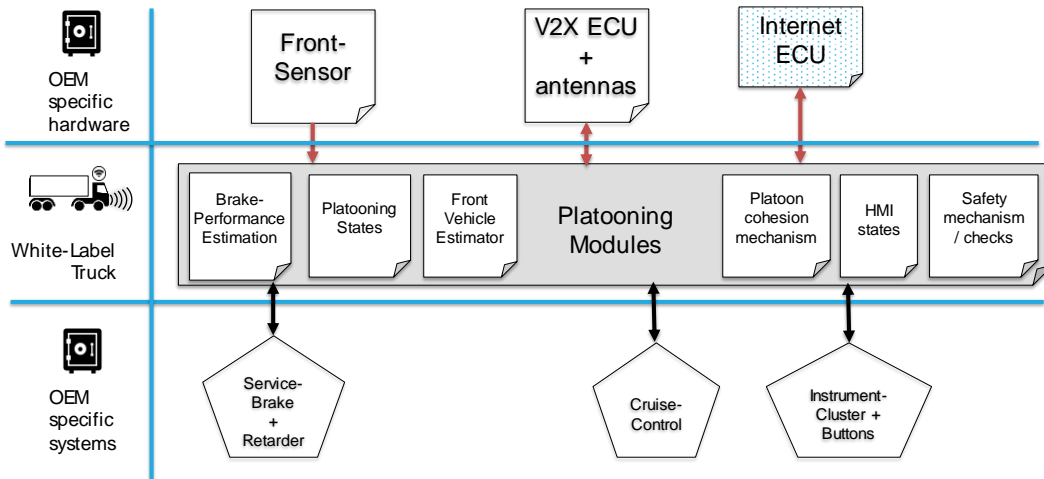


Figure 1- Elements on the white label truck

### 2.1 Platooning layers

The concept of the ENSEMBLE platooning system consists of a hierarchical system, with interacting layers. The envisioned concept is presented in Figure 2.

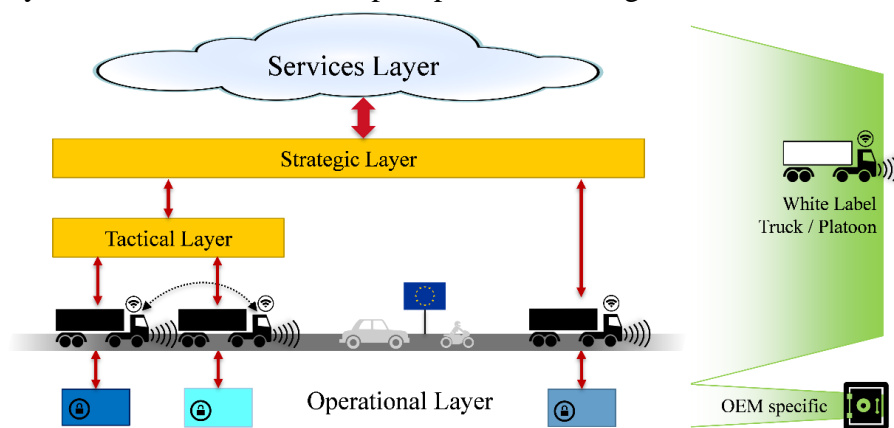


Figure 2 - ENSEMBLE platooning layers

The different layers have the following responsibilities:

- The service layer represents the platform on which logistical operations and new initiatives can operate.
- The strategic layer is responsible for high-level decision-making regarding scheduling of platoons based on vehicle compatibility and Platooning Level (see below), 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.

- The tactical layer coordinates 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 speed, 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 considering scheduling requirements due to vehicle compatibility.
- The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the 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 speed 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.

The white-label truck concept encompasses both the tactical and the strategic layer, whereas the operational layer will be brand specific and the services layer will focus on logistics, hence being unbranded. Hence, ENSEMBLE multi-brand truck platooning concept takes into consideration Platoon level A (e.g. driver responsibility) which will form the basis of the intended demonstration at the end of the project on public road.

### **3. Multi-Brand truck Platooning Specifications**

Summarizing, D2.4 captures all minimum set of operations layer requirements and tactical layer specifications for the white label truck platooning concept. The building blocks of truck platooning consist of in-vehicle requirements (Longitudinal, sensors, HMI interaction), infrastructure (zone policy), information (ranging, V2V and V2I exchange, and data sharing), and platooning strategy at tactical layer (coordination mode, gap formation, dissolution, and vehicle mix).

The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. Related to platoon manoeuvre coordination, specifications indicate that the platoon shall have awareness of the status of the coordinated gap opening on platoon level and the target vehicle reports to the following vehicle the status of the gap opening procedure. During gap opening, the speed of the leader vehicle is distributed over the whole platoon. The tactical layer will gather several platoon status items (e.g. ego vehicle position) and distribute this over the platoon in a hopping type of method and this information is updated with a rate of 1 Hz. The tactical layer shares the vehicle status information in an equal method within the platoon as the platoon status and this information is

updated with a rate of 1 Hz. The setpoint limit/advice function will be send to the operational layer the combined advised value for the vehicle set speed and time gap as processed from information from the strategic layer and the platoon status. The requirements simulation process is supported by first-principles simulation in order to perform a reality check on the feasibility and the relevance of the specifications.

In order to allow an interaction with the trucks in the platoon, a communication link must be established between the platoon participants. The decentralized tactical layer running locally in the trucks needs information from the other trucks. Therefore, also the state machine on vehicle level is introduced.

For Platoon Level A, the Road Side Unit have been selected for the implementation of communication between the platoons and the infrastructure. The information that is needed is the ability for the individual vehicles of the platoon to receive communications on policy based on zone (zone policy or geofencing) and constantly to be up to date (refresh period to be defined). In addition, the ability for the individual vehicles of the platoon to adjust speed based on zone policy and interdistance based on zone policy is also an additional specification.

The requirements for the in-vehicle hardware components which are specific for platooning can be grouped into the following categories:

- HMI – the driver interface to the vehicle and in particular the platooning solution
- Longitudinal control system consists of sensors, control computation and communication and control actuation components.

The common HMI-logic should function as the “lowest common denominator” for each OEM’s HMI-design for platooning, regardless truck brand. The purpose of the common HMI-logic is to provide a structure for coherent interactions between the driver and the platoon system and still allow for OEM specific solutions.

Longitudinal control requirements are divided among requirements for how the minimum inter vehicle time gap is selected, requirements for safely handling braking in the platoon, requirements for how to increase the inter vehicle time gap in a safe way and requirements for how to close gaps and keep the platoon together. The latter one describing the platoon cohesion functionality is summarized in two requirements, where the first requirement is aiming for solving an existing cohesion issue, whereas the second requirement is about avoiding cohesion issues to occur. As regards sensing specifications, this report gave a focus to the sensor data and associated sensors required for a white label solution to assess the environment and which are specific for platooning. It was concluded that radar technology best fulfils the requirements for distance keeping in a platoon. V2X communication is also mandatory inside a platoon and can be used also as sensor functionality.

## **4. Axle loads and weigh-in-motion**

### **4.1 Weigh-in-motion systems**

Loads (axle loads or GVW) of the trucks with one multi-brand platoon can be obtained through various means:

- The loads can be obtained from weigh-in-motion systems installed on the road infrastructure, meaning in-pavement sensors or bridge weigh-in-motion. These solutions are especially interesting for road authorities, as a direct access to the data is always possible.
- Axle loads can also be obtained through on-board weighing which is installed on the axles on trucks, often originally on modern trucks. This data may be used directly by trucks for their route planning, or by road authorities by modalities for this data sharing have been installed.

## 4.2 Utility of loads

Axle loads do have several uses, for example:

- Some parts of the road infrastructure may not be able to cope with all types of platoons, because of the associated damage. For these, geofencing may be linked to the GVW and axles loads of the trucks with the platoon. In this case, communication V2I will be needed, and I2V for giving the driving instructions.
- Axle loads and GVW are also important for the platoon itself. Indeed, braking distances are linked to the carried loads, and the braking power of the truck. Therefore, it might be better to put a light truck with good braking distance, after a heavily loaded truck with weak braking power.

## 5. Conclusions and next steps

Finally, specifications are going to provide the specified functionalities for the project to implement and demonstrate in 2021. Verification and validation phase of the functionality of the equipped vehicles will be verified against the specifications and the developed functionality will be compared to the intended multi-brand functionality to validate the results. A list of KPIs like e.g. in impact of platooning on traffic flow, bridges, other road-user's behaviour, impact on the environment, possible business cases will be mapped against requirements. Finally, the requirements are consolidated towards pre-standards and recommendations and guidelines and are developed for future policy and regulatory frameworks for the wide scale implementation of multi-brand platooning. The updated report will provide with a mapping and gap analysis between the specified requirements and specifications and standardisation and regulation. The iteration process to validate and modify the specification during the whole project life-cycle is an essential part of the work.

There are still however open issues that need to be resolved and assumptions taken. The requirements are written as if the system is responsible because that is still the agreement for Platooning Level A and vision of the ENSEMBLE project. If the system is responsible it will probably put very strict requirements on the system, such as high accuracy brake capacity estimation and very high reliability on always being able to brake. This remains the task to be further defined for Platoon level B and C the definitions and use cases detailed in D2.3 and their respective requirements and specification which will be reflected in D2.5. For the platooning demonstration it is planned to use the actuators which are present in state-of-the-art vehicles. Thus, there are no specific requirements for the time being. This could change over time once the results of the HARA and SOTIF analysis are available. The communication requirements are already documented in other reports.

The HMI-logic presented in this deliverable is based on the current knowledge from platooning and from general Human factors guidelines in the field of driver-automated vehicle interaction. The HMI-logic has not been evaluated and validated, for example in field tests or in simulator



studies and, therefore, should be regarded as a draft and subject to changes as platoon systems are tested and evaluated from technical as well as from user (driver) point of view. Moreover, the HMI-logic is on a high level and does not stipulate specific messages, icons, symbols, colors or if and how multi-modal output (sounds and haptic) should be used to enhance the driver-platoon system interaction. These issues are important to investigate further once the overall HMI-logic is in place and be subjects for standardization. The results from the interviews with platoon drivers indicated that the verbal communication (via radio) between the drivers was important to maintain the platoon and to handle situations, such as Cut-ins, obstacles ahead, traffic at exits and entries etc. However, it is most likely drivers in future platoons speak different languages and don't understand each other. Therefore, the safety of a platoon should not be dependent on verbal communication between the drivers.

Another open issue is how drivers can recognize which truck(s) on the road is a pending co-platoon truck. This is also the case while driving in a platoon, i.e. how to know that the truck in front of the ego-truck is part of the platoon (and not a cut-in). A subsequent question is if and how other co- road users need to be informed about platoon driving on the road. Driver and system roles and task, the term "responsibility" is deliberately not used, because "responsibility" infers legal matters and not HMI-matters. The responsibilities of the driver and the platoon system in different use cases and possible critical incidents should be investigated from a legal point of view (not from an engineering or HMI-point of view).

Another consideration is that the definition of the specifications of the whole multi-brand truck platooning concept have not yet been mapped across functional safety analysis and SOTIF in order to assure that the white label truck platooning concept functions and acts safely during normal operations. The ENSEMBLE project will analyse the safety risks related to both functional safety and SOTIF and derive requirements to lower these risks to an acceptable level. Since these activities will not only define requirements for hazards arising from E/E malfunctions but also address hazards resulting from performance limitations or insufficiencies of the function itself, the safety activities carried out for the project are enough to have a safe platoon deployment on public roads. Functional Safety and SOTIF activities, will define new requirements and may restrict current Platoon Level A definition.

In addition, to that the project is going to assess how these specifications have impact to weight in motion strategies. Moreover, another important issue is that regulation and requirements by the road authorities and member states might also generate additional requirements and might impact testing and verification of trucks platooning systems on the roads. The project has also foreseen to organize in second quarter of 2019 a common workshop among the European Truck Platooning challenge (ETPC), C-Roads Platform, CONCORDA, CEDR in order to validate the ENSEMBLE requirements and to ensure convergence and agreement on the V2I topic and to suggest a unique proposal for the European Commission.

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