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

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Revision history

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TABLES

Table 1: Overview of projects, programs and cooperation groups and possible topics for cooperation; x = identified interest, (x) identified interest, but timing issue. 31

1. EXECUTIVE SUMMARY

1.1. Context and need of a multi brand platooning project

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 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.

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 traffic safety, fuel economy, and throughput. This has been demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions. During the years, the project was organised as follows:

- Year 1: setting the specifications and developing a reference design;
- Year 2 and 3: implementing this reference design on the OEM own trucks, as well as performing impact assessments with several criteria;
- Year 4: focus on testing the multi-brand platoons on test tracks and public road.

The technical results were evaluated against the initial requirements, after which these were updated. Also, the impact on fuel consumption, drivers and other road users are established. In the end, all activities within the project aim to accelerate the deployment of multi-brand truck platooning in Europe.

1.2. Abstract of this Deliverable

This deliverable gives an overview of the running projects and programs and the active cooperation groups related to truck platooning. A list of these has been made and updated throughout the project. Overlapping or complementing aspects with ENSEMBLE have been identified and how ENSEMBLE should liaise. Connection and cooperation with other projects/initiatives/programs can have different ways: work together, share views, share experiences, share specific knowledge, share data for impact assessment, invite to each other's events & demonstrations, etc. Also, the "direction" of sharing information can be quite different and is obviously also affected by the timing and progress of projects.

A twinning agreement between ENSEMBLE and the "USDOT Human Factors Issues related to Truck Platooning Operations" project has been established. The purpose of twinning is to establish

a structured, but not contractual, partnership to maximize research outcomes, promote the exchange of knowledge and experience, and exploit synergies between EC and USDOT projects.

After an introduction in Chapter 2, Chapter 3 provides an overview and a brief description of the running projects, initiatives and cooperation groups related to Truck Platooning. Furthermore, overlapping aspects with ENSEMBLE are discussed. How ENSEMBLE cooperated with these projects is reported in Chapter 4.

2. INTRODUCTION

2.1. Background

Work package 6 of ENSEMBLE is about communication and exploitation. Within this work package, Task 6.4 is about the collaboration with other projects. Task 6.4 consists of two subtasks:

Subtask 6.4.1 Truck Platooning Projects, Initiatives and Programs is about completing a review of running projects and programs in EU, USA, Singapore and Japan. Overlapping or complementing aspects of these with ESNEMBLE are identified and how ENSEMBLE should liaise. Especially important are the projects which EC and US decide to twin together. Possible ways to cooperate are: share views, share experiences e.g. in acquiring exemptions, specific know-how, share data for impact assessment, invite to each other's events & demonstrations.

Subtask 6.4.2 Cooperation Groups addresses specific issues such as, but not limited to, regulations, test exemptions, data sharing, impact assessment, and common demonstration. Interested parties will convene a couple of international F2F meetings per year, as well as conference calls.

2.2. Aim

The objective of Task 6.4 is to gain more impact through connection to and cooperation with other projects. The aim of this report, deliverable D6.14, is to give an overview of the running projects and programs and the active cooperation groups related to Truck Platooning.

2.3. Approach

The following approach has been applied in Task 6.4:

- A list of running projects, initiatives and cooperation groups has been made and updated throughout the project.
  - Overlapping or complementing aspects of these with ENSEMBLE have been identified and how ENSEMBLE should liaise.
  - Possible US projects for twinning have been identified.
- Actions have been taken accordingly.

2.4. Structure of this report

In Chapter 3 an overview and brief description of the running projects, initiatives and cooperation groups is provided and overlapping aspects with ENSEMBLE are discussed. How ENSEMBLE cooperated with these projects is reported in Chapter 4. Finally, Chapter 5 provides references to

cited articles, deliverables and reports. Note that references to webpages of running projects, initiatives and cooperation groups are provided in Chapter 3.

3. TRUCK PLATOONING PROJECTS / INITIATIVES / PROGRAMS

This chapter gives an overview of the running projects and programs and the active cooperation groups related to Truck Platooning. The following projects, programs and cooperation groups (in alphabetic order) have been identified as relevant for ENSEMBLE during the course of the project.

- AEROFLEX
- ARCADE
- CAR 2 CAR Communication Consortium (C2C-CC)
- CETU (French National authority for tunnels)
- CONCORDA
- Electronic Drawbar - Digital Innovation (EDDI) project
- ETSI TC ITS
- European Truck Platoon Challenge (ETPC) network
- HEADSTART
- ISO TC204 Working Group 14
- Locomation
- Mont Blanc tunnel
- Peloton
- PIARC Technical committee TC4.4
- Resource road truck platooning technology Canada
- SECREDAS
- Sweden4Platooning
- U.S. Army “Leader-Follower” Kits
- UK Heavy Goods Vehicle (HGV) Platooning project
- USDOT Human Factors Issues related to Truck Platooning Operations
- USDOT Truck platooning early deployment assessment project
- 5G-MOBIX

In the next sections, these are briefly described. References are added to relevant web pages and documents, such that the interested reader can find more information. Also overlapping or complementing aspects with ENSEMBLE have been identified.

3.1. AEROFLEX

Acronym explanation: AEROFLEX – Aerodynamic and Flexible Trucks for Next Generation of Long Distance Road Transport

Type: EC project

Start date: 1 October 2017

Duration: 42 months with 6 months extension (48 months)

Reference:

- https://aeroflex-project.eu/

Short description:

The AEROFLEX project was about developing and demonstrating new technologies, concepts and architectures for complete vehicles that are energy efficient, safe, comfortable, configurable and cost-effective, while ensuring that the varying needs of customers are satisfied by being flexible and adaptable with respect to the continuously changing operational conditions. The truck, the dolly and the trailer are considered.

Link to ENSEMBLE:

Both projects focus on trucks. Whereas ENSEMBLE focusses on platooning, AEROFLEX focusses on new technologies, concepts and architectures for complete vehicles. The identified overlapping part is about regulations and exemption procedures, as both projects work on new truck concepts that are not fulfilling existing regulations.

3.2. ARCADE

Type: Coordination and support action

Reference:

- https://www.connectedautomateddriving.eu/about/arcade/

Short description:

ARCADE is a Coordination and Support Action funded by the European Commission's Horizon 2020 programme, aimed at building consensus across stakeholders from all sectors for a sound and harmonised deployment of Connected, Cooperative and Automated Driving (CAD) in Europe and beyond.

ARCADE federates a CAD Stakeholder Network through the organisation of regular workshops and co-organisation, with the European Commission, of EUCAD Conferences and Symposia. The CAD network exchanges knowledge and experiences, builds up synergies and a common approach to development, testing, and validation of CAD. A main objective is to contribute to the definition of future research and innovation priorities in Europe for the main thematic areas related to the deployment and adoption of CAD (e.g. STRIA and ERTRAC Roadmaps on Connected and Automated Transport).

ARCADE also consolidates the Knowledge Base of CAD knowhow, including an overview of impact assessment, testing and evaluation methodologies, regulations, policies and standards, roadmaps and strategic plans at European, Member State and even international levels.

Link to ENSEMBLE:

As platooning is a CAD application it is important to share views and experiences with the ARCADE network.

3.3. CAR 2 CAR Communication Consortium (C2C-CC)

Type: Stakeholder consortium

Reference:

- https://www.car-2-car.org/

Short description:

The CAR 2 CAR Communication Consortium (C2C-CC) aims at assisting towards accident-free traffic (vision zero) at the earliest possible date. It further aims at supporting the highest safety level at improved traffic efficiency anywhere, anytime at the lowest cost to the end user and the environment. While working on solutions supporting all driving levels from manual to fully automated it considers specific needs of stakeholders, types of vehicles and users. The C2C-CC contributes to the development and specification of robust and reliable solutions that allow for a continuous and seamless evolution of required functionalities. It enables technologies driven by innovation and competition, thereby fostering concepts of cooperation between the road users and with the road infrastructure. This is based on sharing information, awareness, perception and intentions while focusing on tactical level and considering strategic and planning level as required.

Link to ENSEMBLE:

Platooning is also a car-2-car application based on communication between vehicles and the infrastructure. One of the envisioned benefits of platooning is that it also contributes to accident-free traffic (vision zero). It is important to share views and experiences with the CAR 2 CAR

Communication Consortium in particular about how the ENSEMBLE platooning protocols fit into the car2car communication protocols of passenger cars.

3.4. CETU (French National authority for tunnels)

Acronym explanation: CETU - Le Centre d'Etudes des Tunnels

Type: National authority for tunnels

Reference:

- http://www.cetu.developpement-durable.gouv.fr/le-centre-d-etudes-des-tunnels-r5.html

Short description:

The Centre for Tunnel Studies (CETU) is a central technical service to provide the French Transport Ministry with expertise in all techniques and methods relating to the design, construction, maintenance, operation and safety of tunnels.

Link to ENSEMBLE:

ENSEMBLE has analysed the impact of Platooning for tunnels. In this context it is interesting to connect to tunnel authorities. The case of the Mont Blanc tunnel was twice a subject in the ETPC (European truck platooning Challenge) meetings (WP6.2)

3.5. CONCORDA

Acronym explanation: CONCORDA - Connected Corridor for Driving Automation

Type: EC project

Start date: October 2017

Duration: 10/2017 - 06/2020

References:

- https://www.connectedautomateddriving.eu/project/concorda/
  (Note: official project website is off line)
- https://ertico.com/concorda/
- https://www.rijkswaterstaat.nl/en/mobility/projects/concorda

Short description:

CONCORDA focused on preparing the European motorways for automated driving and high-density truck platooning with adequate connected services and technologies. CONCORDA aimed at enhancing and upgrading the environment for existing pilot projects for three main use cases: automated highway chauffeur, truck platooning and automated collision avoidance functionalities. More specifically, the project sought to identify the potential of hybrid, safe and secure communications and digital infrastructures, as well as tackling challenges it these fields.

With regards to high density truck platooning, there is a need for ultra-reliable, low latency V2V safety-relevant communication between the platoon leader and the trucks following in the platoon. There is a need for critical adaptations on the side of the trucks, as well as for the establishment of close cooperation between mobile network operators and the truck industry, to guarantee that the requested minimum service level agreements for truck platooning are enacted. CONCORDA combined 802.11p and LTE-V2X connectivity without affecting existing services in terms of interferences and interoperability to ensure backwards C-ITS service interoperability with the services harmonized by C-ROADS under real traffic situations.

Link to ENSEMBLE:

In both projects truck platooning is considered. Cooperation with CONCORDA is essential to harmonise communication protocols for platooning to avoid fragmentation. ENSEMBLE mainly focusses on the multi-brand V2V communication protocol for truck platooning, whereas CONCORDA focussed on V2X connectivity, hybrid communication and C-ITS services.

3.6. EDDI: Electronic Drawbar - Digital Innovation

Type: National project in Germany

Start date: June 2017

Duration: June 2017 to January 2019

References:

- Project report: (Brandt,2019)

Short description:

For the first time anywhere in the world, truck platoons went into practical operation in June 2018 as part of the EDDI project. This joint project was run by MAN Truck & Bus, DB Schenker and the Hochschule Fresenius. As part of the project, professional drivers drove two electronically linked MAN trucks on the Autobahn 9 between the Nuremberg and Munich branches of the logistics company DB Schenker over the course of seven months. Having covered some 35,000 test kilometres, the truck drivers, who drove at a distance of only 15 to 21 meters, praised the driving comfort and the general sense of safety. The platooning system installed in the MAN trucks operated

smoothly 98 % of the time. Active interventions by the driver in second position were necessary only once every 2,000 kilometres. In addition, the pilot project demonstrated a 3 to 4 percent reduction in fuel consumption. It was shown that platooning has the potential to contribute to the reduction of fuel consumption and CO2 emissions. Furthermore, it was demonstrated that the system works reliably and can increase safety on the motorway. Accordingly, it was concluded that platooning is an important step on the way to automation.

Link to ENSEMBLE:

MAN is also a project partner in ENSEMBLE. The results of the project are interesting as input for ENSEMBLE. Due to the different timing of the projects, ENSEMBLE cannot contribute much to EDDI, i.e. ENSEMBLE started at the moment the piloting in EDI was already ongoing.

3.7. ETSI TC ITS

Acronym: ETSI TC ITC - European Telecommunications Standards Institute Technical Committee on Intelligent Transport Systems

Reference:

- https://www.etsi.org/technologies/automotive-intelligent-transport

Short description:

ETSI's Technical Committee on Intelligent Transport Systems (TC ITS) has developed an ecosystem of V2X protocols for supporting a plethora of safety applications using a single wireless technology to be operated on the 5.9 GHz frequency band set aside for cooperative ITS in Europe. The so-called Day-1 applications work alongside Day-2 applications such as platooning and collective perception. ETSI TC ITS was tasked through an EC mandate in 2010 to develop ITS protocols to create an interoperable, sustainable V2X system, and the first set of protocols were finalised in 2014. Deployment based on this set of protocols for supporting Day-1 applications was launched in 2019. It is a continuous process of refining current and fostering new standards for supporting upcoming V2X applications in ETSI TC ITS. There is febrile activity around developing protocols for Day-2 applications such as platooning, cooperative ACC, collective perception and manoeuvre coordination.

Link to ENSEMBLE:

The ENSEMBLE communication protocol makes use of already standardized protocols by ETSI such as ITS-G5, GeoNetworking and BTP. Further, the security framework developed for C-ITS Day-1 applications based on Public Key Infrastructure (PKI) is used to create a trust domain with the addition of encrypting platooning data. The developed protocol resides together with other protocols such as the Cooperative Awareness Message (CAM) in the facilities layer. The outcome of the

ENSEMBLE project on platooning will be an essential input to develop the platooning protocol in ETSI TC ITS.

3.8. European Truck Platoon Challenge (ETPC) network

Acronym: ETPC - European Truck Platoon Challenge

Reference:

- https://erticonetwork.com/

Short description:

Since 2016 the ETPC consisting of CLEPA (European Association of Automotive Suppliers), ACEA (European Automobile Manufacturers' Association), ESC (European Shippers' Council), IRU (International Road Transport Union), CEDR (Conference of European Directors of Roads), EReg (Association of European Vehicle and Driver Registration Authorities), under joined ERTICO and UGE (University Gustave Eiffel) management is the multi-stakeholder group that embraces the progress and innovation of truck platoon technologies in Europe. In 2016 The ETPC has demonstrated the technical feasibility of platooning, by a prestigious demonstration of platooning of three trucks from the same brand, following each other on short distance, thereby assuring safety and fuel reduction. The ETPC holds periodical meetings.

Link to ENSEMBLE:

Periodical meetings are held together with the ETPC network to exchange the information of the current state of the project, and the feedback received will be used as an input. A dedicated Subtask 6.2.1 exists for this. Therefore, no further reporting will be done in this deliverable about the ETPC cooperation.

3.9. HEADSTART

Acronym explanation: HEADSTART - Harmonised European Solutions for Testing Automated Road Transport

Type: EC project

Start date: January 1st, 2019

Duration: 3 years

Reference:

- https://www.headstart-project.eu/

Short description:

The project aimed to define testing and validation procedures of Connected and Automated Driving functions including key technologies such as communications, cyber-security and positioning. The tests were in both simulation and real-world fields to validate safety and security performance according to the key users' needs. The project objectives were:

- Identify the existing methodologies, procedures and tools for testing, validation and certification;
- Harmonise the existing testing and validation approaches;
- Define and develop test, validation and certification methodologies and procedures for CAD functions;
- Demonstrate the developed methodologies, procedures and tools through testing four CAD use cases;
- Reach consensus by creating and managing an expert network of CAD testing to promote adoption of the project results considering multi-stakeholder needs.

Link to ENSEMBLE:

Testing and validation of CAD is a common aspect in both projects.

3.10.ISO TC204 Working Group 14

Acronym explanation: ISO - International Organization for Standardization

Type: Standardisation organisation

Reference:

- https://www.iso.org/committee/54706.html

Short description:

Working Group 14 (VEHICLE/ROADWAY WARNING AND CONTROL SYSTEMS) of ISO TC204 is working on standardization of truck platooning. This working group is part of ISO/TC 204 - INTELLIGENT TRANSPORT SYSTEMS, that is in charge of standardization of information, communication and control systems in the field of urban and rural surface transportation, including intermodal and multimodal aspects thereof, traveller information, traffic management, public transport, commercial transport, emergency services and commercial services in the intelligent transport systems (ITS) field. Excluded are: in-vehicle transport information and control systems (ISO / TC 22). Note: ISO / TC 204 is responsible for the overall system aspects and infrastructure aspects of intelligent transport systems (ITS), as well as the coordination of the overall ISO work

programme in this field including the schedule for standards development, taking into account the work of existing international standardization bodies.

Link to ENSEMBLE:

The aim of ENSEMBLE is to develop a multi-brand interaction protocol for platooning and provide this as input to standardisation bodies. Therefore, connecting with ISO TC204 Working Group 14 is important.

3.11.Locomation

Type: company

Reference:

- https://locomation.ai/

Short description:

Locomation was founded in 2018 by a team of experts on autonomous vehicles, robotics, and artificial intelligence from Carnegie Mellon's National Robotics Engineering Center and trucking industry experts. The company is working on electronically coupled autonomous trucks. They are working on a system of two platooning trucks with a driver in the first truck and a resting driver in the following autonomous truck. The idea is to periodically swap truck places to allow each driver to take turns leading the convoy and resting. Additional development phases of truck autonomy are defined: Drone Follower (no driver in following truck), standalone autonomous trucks.

Link to ENSEMBLE:

The electronically coupled autonomous trucks concept is similar to the defined Platooning Autonomous Function (PAF) in ENSEMBLE, and the vision is shared that the PAF could be an early deployable concept of autonomous trucks. Furthermore, their development phases of truck autonomy fit into the PAF thoughts. As Locomation is an US based commercial company, it is only interesting for ENSEMBLE to monitor their activities.

3.12.Mont Blanc Tunnel

Type: road/tunnel operators

Reference:

- https://tunnelmb.net/en-US

Short description:

The Mont Blanc Tunnel is a highway tunnel between France and Italy, under the Mont Blanc mountain in the Alps. The tunnel is 11.611 km long. The tunnel is located on a major transport route for long haul transport. It is in the top 5 of longest tunnels in the EU and the oldest one of those, opened in 1965.

Link to ENSEMBLE:

ENSEMBLE has analysed the impact of Platooning for tunnels. In this context it is interesting to connect to tunnel operators. The case was also presented during ETPC meetings (WP4.2)

3.13.Peloton

Type: company

Reference:

- http://peloton-tech.com/

Short description:

Peloton is a connected and automated vehicle technology company dedicated to improving the safety and efficiency of U.S. and global freight transportation. Peloton's automation systems combine the active safety systems, the skill, and expertise of professional drivers, and their Network Operations Cloud to connect trucks and constrain system operation to appropriate roads and conditions. Peloton solutions also aim to improve the safety of trucks by building on best-in-class collision mitigation systems and other safety features that are active both in and out of a platoon. Peloton's Level 1 driver-assistive system, PlatoonPro, links pairs of heavy trucks using electronic vehicle-to-vehicle communications, allowing them to travel at a shorter following distance due to the trucks' robust connected active safety systems. In July 2019, Peloton unveiled AutoFollow. This automated Following solution is an SAE Level 4 platooning system, which combines vehicle-to-vehicle (V2V) technology and advanced radar and sensor sets to enable a single professional driver to drive a pair of vehicles. At Peloton, they believe the race to autonomous driving will be won with a driver-centred approach. They belief that "Platooning is a direct path toward deploying commercial vehicle automation".

Link to ENSEMBLE:

PlatoonPro is similar to the defined Platooning Support Function in ENSEMBLE. AutoFollow shows similarities with the Platooning Autonomous Function (PAF) of ENSEMBLE. ENSEMBLE shares the vision that the PAF could be an early deployable concept of autonomous trucks. As Peloton is an US based commercial company, it is only interesting for ENSEMBLE to monitor their activities.

3.14.PIARC Technical committee TC4.4

Acronym explanation: PIARC - Permanent International Association of Road Congresses

Type: road association

References:

- https://www.piarc.org/
- TC4.4: https://www.piarc.org/en/PIARC-Association-Roads-and-Road-Transportation/PIARC-Technical-Committees/Strategic-Theme-Resilient-Road-Infrastructure/Technical-Committee-Road-Tunnels

Short description:

PIARC (World Road Association) is an international forum for the discussion of all aspects of roads and road networks. The Association now boasts 122 government members worldwide and retains consultative status to the Economic and Social Council of the United Nations. The Association was founded in 1909, following the first international road congress held in Paris when it was called the Association Internationale Permanente des Congrès de la Route (AIPCR), or in English, the Permanent International Association of Road Congresses (PIARC). In 2019, it formally adopted the name PIARC. Its head office is located in Paris where its origins began in 1908. PIARC creates and coordinates Technical Committees, organizes a quadrennial World Road Congress, a quadrennial Winter Road Congress and various technical seminars and publishes a large number of documents including a quarterly magazine ("Routes/Roads"). One of these Technical Committees is TC4.4 specialising in tunnels about C-ITS and V2x.

Link to ENSEMBLE:

ENSEMBLE has analysed the impact of Platooning for tunnels. In this context it is interesting to connect to TC4.4.

3.15.Resource road truck platooning technology Canada

Type: Project of FPInnovations, which is a private not-for-profit research and development centre supporting the Canadian forest sector's global competitiveness.

Start date: 2021

Duration: 2021 to 2026

References:

- https://web.fpinnovations.ca/truck-platooning-a-technology-to-help-out-maneuver-the-driver-shortage/

- https://web.fpinnovations.ca/news-release-robotic-research-and-fpinnovations-partner-to-develop-resource-road-truck-platooning-technology/?utm_source=blog&utm_medium=blogpost&utm_campaign=20211221TruckPlatooning&utm_content=text

Short Description:

FPInnovations has partnered with Robotic Research to develop SAE level 4 autonomous trucks for the transportation of goods on resource roads. The test program will be carried out with Class 8 quad axle semi-trailer log trucks supplied by a specific truck OEM. The target completion of the Truck Platooning Initiative is in 2026 at which time the project aims to have an autonomous and connected vehicle platooning system capable of working with any truck OEM. Although the initiative's primary mandate is to find solutions to support the forest industry, the development of this technology will greatly benefit other sectors, including mining operations and the transportation of products to northern communities. It is well-known that labour shortages in all industries is a world-wide issue. The goal of the Platooning Initiative is not to replace truck drivers, but to supply a technological solution that will reliably transport goods using the experienced truck drivers that are currently available.

Link to ENSEMBLE:

Timing-wise this project started when ENSEMBLE was finishing. The functionality to be developed is similar to the PAF, but the ODD is very different. Therefore, it is only interesting for ENSEMBLE to monitor these type of projects.

3.16.SECREDAS

Acronym explanation: SECREDAS – Cyber Security for Cross Domain Reliable Dependable Automated Systems

Type: EC project

Start date: 1 May 2018

Duration: 1 May 2018 to 31 October 2021 (3 years)

Reference:

- https://secredas-project.eu/

Short Description:

SECREDAS aimed to develop and validate multi-domain architecting methodologies, reference architectures & components for autonomous systems, combining high security and privacy protection while preserving functional safety and operational performance. Their focus was on making future autonomous driving safe from external malicious interference or hacking that would put car passengers or other road users in danger. To achieve this, a common security, safety and privacy reference framework was created that allowed to design, develop and test technology solutions that span all three domains simultaneously. Results were tested across a range of realistic 'on-road' driving scenarios and hacking/vulnerability threats. The project also covered new safety and security functions in rail applications and health monitoring applications. The project was coordinated by ENSEMBLE partner NXP. SECREDAS partner Commsignia demonstrated the feasibility of using the DSRC channel to send encrypted messages between C-ITS stations (i.e., the OBU and the RSU). In traditional systems, the messages broadcasted by a vehicle on the V2X channel is signed but not encrypted, such that any other vehicle within range can receive and decode them. In some special cases, like in case of platooning, there is need to form a closed vehicle group where only those vehicles can decode each other's messages who are part of the group. This was solved by an encrypted message sending service offered by the Commsignia V2X stack.

Link to ENSEMBLE:

The developed communication protocol in ESNEMBLE also used encryption next to signing. Furthermore, the DSRC is like ITS-G5.

3.17.Sweden4Platooning

Acronym: S4P - Sweden4Platooning – Sweden for Platooning

Type: National, funded by Vinnova (Sweden's innovation agency)

Start date: 01-01-2017

Duration: 01-01-2017 to 31-12-2019

References:

- Public report: (Dellrud, 2020).
- Closing conference: https://sites.google.com/view/s4pcc/presentations

Short description:

The Sweden4Platooning project has in a pilot study demonstrated the feasibility of longitudinally controlled platooning trucks from Scania and Volvo (dual brand platooning) at the haulage company Nordanå Transport AB for 12000 km in normal goods transport operation on the public road E4

between Malmö and Jönköping in Sweden. The project has also demonstrated platooning with both longitudinally and laterally controlled trucks with trucks from Volvo and Scania at the Astazero test site (close to Borås in Sweden) resulting in follower trucks driven without human intervention.

Link to ENSEMBLE:

Scania and Volvo are partners of ENSEMBLE. Sweden4Platooning has handed over their V2V protocol. Volvo and Scania also contributed to the use case and safety analysis in ENSEMBLE and brought in their knowledge regarding parts of the use case study and risk analysis of Sweden4Platooning.

3.18.U.S. Army “Leader-Follower” Kits

Type: U.S. Army

References:

- https://www.nationaldefensemagazine.org/articles/2022/1/21/army-sees-progress-with-leader-follower-vehicle-technology
- https://www.roboticresearch.com/leader-follower/

Short description:

Together with Robotic Research the U.S. Army has been developing and testing, so-called “Leader-Follower” kits. The level of automation is L1 and L4. The army application has dedicated functional specifications.

Link to ENSEBLE:

Due to the different application, no direct link is seen with ENSEMBLE. Nevertheless, the underlying platooning technology could be similar. Therefore it is interesting to just monitor the activities.

3.19.UK Heavy Goods Vehicle (HGV) Platooning project

Acronym: HelmUK

Type: National, led by Highways England and the Department for Transportation (DfT)

Start date: September 2017

Duration: till 2022 (note: initial plan was April 2020)

Reference:

- https://www.helmuk.co.uk/

Short description:

Real-world trials to gather the objective evidence necessary to understand what is required to put a heavy goods vehicle (HGV) platoon on UK roads. The idea is to have trials in a live operating environment to quantify real-world benefits. The project has the following objectives:

- Deliver safety & cyber security evidence: for platooning drivers and other road users, cyber security V2V control systems, platooning risk rated Strategic Road Network map;
- Quantify environmental benefits: fuel consumption, emissions;
- Determine commercial viability: effects on logistics schedules, vehicle maintenance, driver workload;
- Evaluate & assess Impact: infrastructure, traffic management, human factors & behaviour, platooning operators;
- Acceptance of technology & standards: engage and educate general public, inform industry bodies, influence standards & regulations.

Link to ENSEMBLE:

ENSEMBLE partner DAF is involved in HelmUK. The timing of the projects is/was different. The trucks for HelmUK were developed earlier than those for ENSEMBLE, consequently with different specifications, e.g. shorter following distances. In January 2022 the programme of on-road trials was completed. The programme is now in its final phase of data analysis and preparation of reports. This means that the results of HelmUK will be available after finalising all ENSEMBLE deliverables. Although, on the one hand this limits interaction, it also provides the opportunity of having two independent benefit and impact analyses.

3.20. US DOT Human Factors Issues related to Truck Platooning Operations

Type: USDOT project (US Department of Transportation)

Start date: Tuesday, August 18, 2020

Duration: Friday, April 15, 2022

Reference:

- https://highways.dot.gov/research/projects/human-factors-issues-related-truck-platooning-operations

Short description:

The objective of this project is to address some of the critical human factors issues on road users and how they travel in the presence of truck platoons. The study shall determine the following:

- Assess the current state of research on human factors issues related to the behaviour of road users in the presence of truck platooning operations.
- Conduct human factors behavioural driving studies in the Turner-Fairbank Highway Research Center's miniSim™ based on these the following set of research questions:
  - Will a road user's ability to enter and exit a freeway be impacted by the operation of truck platoons on the freeway?
  - Will an external visual display on platooning trucks improve a road user's ability to travel in the presence of truck platoons?
- Document the results and recommendations of this research in technical memos/letter reports and a final report, as described in more detail below.
- Develop a letter report for a test track experiment where drivers would undergo a number of 2 to 3 driving scenarios in the presence of truck platoons.
- Produce a final report that includes the study results, discussion, letter report high level design for a test track experiment, and recommendations regarding the research issues investigated, as well as recommendations for further research to be conducted.

Link to ENSEMBLE:

Timing wise and content wise this project was assessed to be a good candidate for twinning. Twinning agreements were established in the 2013 Implementing Arrangement between EC and USDOT to support cooperative activities in research, development, technology and innovation for all transport modes. The Horizon 2020 Work Programme for "Smart, green and integrated transport" further identified several topics in the areas of safety, infrastructure, intelligent transport systems, and road automation for potential twinning with USDOT projects. The purpose of twinning is to establish a structured, but not contractual, partnership to maximize research outcomes, promote the exchange of knowledge and experience, and exploit synergies.

3.21.USDOT truck platooning early deployment assessment project

Type: USDOT project (US Department of Transportation)

Start date: March 2019

Duration: March 2019 to January 2023

References:

- https://highways.dot.gov/research/laboratories/saxton-transportation-operations-laboratory/Truck-Platooning
- https://highways.dot.gov/research/projects/truck-platooning-early-deployment-assessment-phase-ii

Short description:

Truck Platooning Early Deployment Assessment builds on prior FHWA research in truck platooning. The goals and objectives of the project are as follows:

- Understand truck platooning in real-world operations (i.e., real fleet operators carrying real loads).
- Assess benefits and impacts across key areas of interest.
- Inform future state/local departments of transportation (DOT) about planning process and decision making.

The project consists of 2 phases:

Phase 1 (March 2019–December 2019) — completed:

- Awardees developed the concept, partnerships, and evaluation plan.
- Awardees completed the proposal for phase 2.
- Independent evaluation team supported performance measures and evaluation planning.

Phase 2 (July 2020–January 2023) — in progress:

- Awardee will finalize the plans and make sure the truck platooning systems are ready for deployment testing.
- Awardee will conduct a field operational test (FOT).
- Independent evaluator will conduct an evaluation.

Regarding the FOT, the proposed route goes through California, Arizona, New Mexico, and Texas. The FOT will utilize 4 trucks and 20 drivers. The plan is to complete one round trip per week for 1 year, resulting in data for 145,000 mi driven. The trucks are equipped with a CACC system that has selectable time gaps in the range of 0.6 to 1.8 s.

Link to ENSEMBLE:

Timing wise the FOT are much later than the finalisation of ENSEMBLE. Furthermore, the platooning concept is different. Although both projects use the PSF (or Level 1 platooning, as it is called in the US), there are differences in the specifications. The main difference is that in the USDOT project identical trucks are used, i.e. homogeneous and not multi-brand, and that the ODD is different, e.g. arranging the heavier vehicle in the front in a platoon. Possibly this allows the much lower CACC

time gaps. Furthermore, the approach is different. In ENSEMBLE quick deployment of first multi-brand platooning applications are pursued, whereas the USDOT project is more a research project to assess deployment. Anyhow, it is interesting for ENSEMBLE to monitor the progress of the USDOT project.

3.22. 5G-MOBIX

Acronym: 5G-MOBIX - 5G for cooperative & connected automated MOBIlity on X-border corridors

Type: EC project

Start date: 1 November 2018

Duration: 1 November 2018 to 31 July 2022

Reference:

- https://www.5g-mobix.com/

Short description:

The 5G-MOBIX project aims to identify and investigate the most promising solutions for provisioning seamless Cooperative Connected and Automated Mobility (CCAM) services over neighbouring 5G networks for cross border traffic. The inherent mobility of vehicles and the stringent service requirements of CCAM applications create multiple challenges when a CAV is served by its Home 5G network and crosses the border to another country while an autonomous driving application is engaged. That means that the vehicle's connectivity will have to change from its Home network to the Visited network without causing long interruption in the vehicles connectivity with the application server and without significantly degrading the performance of the service.

5G-MOBIX will develop and test automated vehicle functionalities using 5G core technological innovations along multiple cross-border corridors and urban trial sites, under conditions of vehicular traffic, network coverage, service demand, as well as considering the inherently distinct legal, business and social local aspects. The project will evaluate benefits in the CCAM context as well as define deployment scenarios and identify and respond to standardisation and spectrum gaps. The expected benefit of 5G will be tested during trials on 5G corridors in different EU countries as well as China and Korea. Several automated mobility use cases are potential candidates to benefit from 5G such as cooperative overtake, highway lane merging, truck platooning, valet parking, urban environment driving, road user detection, vehicle remote control, see through, HD map update, media & entertainment.

Regarding platooning, the following trials are defined:

- Platooning with “see what I see” functionality in cross-border settings at Greece - Turkey cross-border corridor: transmitting a compressed (with H.265/HEVC codec standard) 4K video stream by the platoon leader that can be received by following vehicles.
- eRSU-assisted platooning at German trial site: eRSUs collect information that is shared with platooning vehicles via a platooning service.
- Cloud-assisted platooning at Chinese trial site: the leading vehicle communicates with the control centre (Platooning service) deployed in a cloud server through Vehicle-to-Network communication (V2N) to obtain tactical information, such as the global path planning (assisted move). This assisted move is amongst others based on information received by the service of other vehicles in the platoon. In the use case also LTE-V communication can be replaced by DSRC technology, and comparison between these two methods will be implemented.

Link to ENSEMBLE:

In principle the Platooning trials in 5G-MOBIX could benefit from the multi-brand interaction protocol of ENSEMBLE. However, there are also key differences between ENSEMBLE and 5G-MOBIX, such as: “see what I see” functionality is not part of the requirements for either the PSF or the PAF in ENSEMBLE, same holds for having a Platooning Service supporting the platoon, the PSF implementations developed in ENSEMBLE are based on ITS-G5 technology, whereas 5G-MOBIX focusses on 5G technology and related specific issues, e.g. switching between different (network) providers. Nevertheless, it is probably interesting for 5G-MOBIX to learn about the ENSEMBLE defined interaction protocol for platooning, which also is communication technology independent. Furthermore, the results of the technologies developed in 5G-MOBIX can be interesting for the PAF specified in ENSEMBLE, but the timing of the projects is different, i.e. ENSEMBLE is finished before 5G-MOBIX.

3.23.Summary

To explore cooperation possibilities, the cooperation topics were categorised:

- V2V / V2X: multi-brand interaction protocol;
- Standardisation: link to standardisation bodies;
- Exemption procedures: governmental procedures to comply with for platooning; related to Task 6.3: Regulatory framework evolution for platooning;
- Deployment: what is needed for deployment of multi-brand platooning;
- Impacts: what are impacts of having multi-brand platooning;
- General interest: interest in all topics, i.e. not-specific;
- Twinning: interesting for partnership with USDOT projects;
- Monitor: interesting to monitor progress, but not to directly cooperate with.

An overview of the identified projects, programs and cooperation groups and the categorised topics for possible cooperation are shown in Table 1.

	V2V / V2X	Standardisation	Exemption procedures	Deployment	Impacts	General interest	Twinning	Monitor
AEROFLEX			x					
ARCADE		x						
CAR 2 CAR	x							
CONCORDA	x							
EDDI project					x			
ETPC						x		
ETSI TC ITS	x	x		x				
HEADSTART								
ISO TC204 WG 14	x	x		x				
Locomation								x
Mont Blanc tunnel	x			x	x			
Peloton								x
PIARC TC4.4	x							
Resource road CA								x
SECREDAS	x							

	V2V / V2X	Standardisation	Exemption procedures	Deployment	Impacts	General interest	Twinning	Monitor
Sweden4platooning	x							
U.S. Army “kits”								x
UK: HelmUK				(x)	(x)	x		
USDOT Deployment assessment					(x)			x
USDOT Human Factors					x		x	
5G-MOBIX	x							

Table 1: Overview of projects, programs and cooperation groups and possible topics for cooperation; x = identified interest, (x) identified interest, but timing issue.

4. COLLABORATION WITH PROJECTS / INITIATIVES / PROGRAMS

In Chapter 3 and overview of the running projects and programs and the active cooperation groups related to Truck Platooning has been given. Overlapping or complementing aspects of these with ENSEMBLE have been identified and how ENSEMBLE should liaise. Furthermore, a US project for twinning has been found. This is the “USDOT Human Factors Issues related to Truck Platooning Operations” project.

Connection and cooperation with other projects/initiatives/programs can have different ways: work together, share views, share experiences, share specific knowledge, share data for impact assessment, invite to each other’s events & demonstrations, etc. Also the “direction” of sharing information can be quite different and is obviously also affected by the timing and progress of projects. In Chapter 3 quite some US projects/initiatives/programs were found that are interesting for monitoring, but not for direct cooperation. Apart from monitoring progress in the media, also some meetings with U.S. experts/consultants in the platooning field were held to stay informed, but also to exchange ENSEMBLE information.

In this chapter, a brief overview of the connection and cooperation with other projects is given and some aspects are highlighted. The details provided obviously depend on the way of cooperation but are also influenced by the relation to other tasks in ENSEMBLE. Often the results of cooperation and connections are already incorporated in other deliverables. In this deliverable, then simply reference is made to those tasks and deliverables. Special attention is also given to the twinning cooperation with the U.S.

Below, the connection and cooperation with the projects/initiatives/programs are briefly described, where the projects/initiatives/programs are listed again in alphabetic order.

- AEROFLEX
  - A number of meetings were held between ENSEMBLE and AEROFLEX. The main topic of interest identified for cooperation between the two projects was the “digitalized exemption procedures”. This is related to ENSEMBLE T6.3 and deliverable D6.18New insights on regulations and exemptions.
- ARCADE
  - ENSEMBLE provided input on the topic of gaps and challenges of standardization in the platooning domain.

- CAR 2 CAR Communication Consortium (C2C-CC)
  - ENSEMBLE was presented to the consortium.
  - A memorandum of understanding (MoU) has been drafted, approved and sent to the CAR 2 CAR consortium with the objectives to perform and promote international standardisation, to avoid duplication of technical work and benefit from adopting a complementary approach, and to exchange information.
- CETU (French National authority for tunnels)
  - Meeting and discussion about issues for a public tunnel operator (17/02/2020).
  - CETU assisted ENSEMBLE with the preparation of the questionnaire for subtask 4.1.3 of ENSEMBLE.
- CONCORDA
  - A memorandum of understanding (MoU) has been drafted with the objectives to perform and promote international standardisation, to avoid duplication of technical work and benefit from adopting a complementary approach, and to foster a close cooperation.
  - Common ENSEMBLE-CONCORDA sessions about platooning have been organised at the Virtual ITS European Congress 2020 and the 28th ITS World Congress, in Hamburg, 2021.
  - Communication protocol: The target in CONCORDA was to be as close as possible with the ENSEMBLE V2V protocol and check on this basis the performance with different communication channels. The Platooning protocol used in CONCORDA is strongly based on (earlier versions) of ENSEMBLE D2.8 and D2.9. CONCORDA had to start with the implementation of the V2V communication in an earlier state and could not use the latest version. Consequently, regarding security, CONCORDA did not use encryption, but only signing & verification. However, on the topic of signing & verification CONCORDA used a newer PKI version where the certificates were provided as online certificates from ESCRYPT using the ETSI standards, rather than using offline and local certificates as done in ENSEMBLE.
  - We addressed the complementarity of results between CONCORDA and ENSEMBLE in the ETPC meeting 23-02-2022.
- EDDI: Electronic Drawbar - Digital Innovation
  - ENSEMBLE was invited to the final event of EDDI in which results were shared.

- ETSI TC ITS
  - The platooning protocol of ENSEMBLE, as published in ENSEMBLE D2.8 and D2.9, is based on already standardized protocols by ETSI, but specific additions have been developed to support platooning.
  - The platooning protocol of ENSEMBLE will be an essential input to develop the platooning protocol in ETSI TC ITS. ENSEMBLE Task 6.5: Input for standardization, will provide the necessary information to ETSI TC ITS.

- European Truck Platoon Challenge (ETPC) network
  - Regular network meetings with the ETPC have been organised to exchange information. These meetings are part of ENSEMBLE Task 6.2 Stakeholder's Forum and specifically Subtask 6.2.1 ETPC networking meetings.
  - Meeting records of these meetings are provided in ENSEMBLE deliverables D6.6 (Odile Arbeit de Chalendar, Frank Daems , Carmela Canonico, 2020) and D6.16 (Odile Arbeit de Chalendar, Frank Daems, Milica Zizic 2022).

- HEADSTART
  - Information has been exchanged.
  - A HEADSTART-ENSEMBLE workshop was held on scenario-based assessment methodology: "ENSEMBLE expert group meeting Truck platooning/V2X communication" on 09-12-2020.
  - Discussions about testing tools, test procedures, assessment criteria, test data harmonisation, application of HEADSTART methodology on ENSEMBLE Truck Platooning.
  - Due to timing issues and the impact of COVID-19 had on testing, the HEADSTART methodology has not been applied in ENSEMBLE.

- ISO TC204 Working Group 14
  - ENSEMBLE (partner Volvo) had an informal meeting at the ITS World Singapore on 24-10-2019 with members of the TC.
  - ENSEMBLE shared results and contact information.
  - ENSEMBLE Task 6.5: Input for standardization, will provide the final information regarding the multi-brand interaction protocol to the TC.

- Locomation
  - Informed via U.S. contacts[1].

[1] ENEMBLE had close contacts with Richard Bishop of Bishop Consulting, Dr. Steven E. Shladover of California PATH and others involved in the USDOT projects. On 22-09-2022, a meeting for in-depth information exchange between ENSEMBLE and US projects was organised in Barcelona, Spain.

- Mont Blanc Tunnel
  - Discussions during WP4 workshop, 28/06/2018, explanations about the technical issues and potential issues for tunnel operators.
  - Answer of the questionnaire for 4.1.3 (Impact on tunnels).
  - Resulted in input for ENSEMBLE deliverable D4.1, regarding tunnels.
- Peloton
  - Informed via U.S. contacts[1].
- PIARC Technical committee TC4.4
  - Discussion about the ENSEMBLE work during their internal meetings.
  - ENSEMBLE sent out questionnaire to the members of the committee; 9 answers received from all over the world.
  - TC4.4 contributed also by reviewing of deliverable D4.1.
- Resource road truck platooning technology Canada
  - Informed via U.S. contacts[1].
- SECREDAS
  - ENSEMBLE had several correspondences with T5.2 (called “secure V2X communication”) of SECREDAS.
  - ENSEMBLE provided information about the developed multi-brand interaction protocol to SECREDAS, i.e. deliverables D2.8 (Atanassow, 2022a) and D2.9 (Atanassow, 2022b).
- Sweden4Platooning
  - The V2V protocol developed within Sweden4Platooning has been handed over to ENSEMBLE and has been the base for further development in ENSEMBLE.
  - Also parts of the use case study and risk analysis done in Sweden4Platooning were used in WP2 of ENSEMBLE.
  - ENSEMBLE was invited for and had a presentation at the Sweden4Platooning Closing Conference at the KTH in Stockholm, Sweden, on march 11, 2020.
- U.S. Army “Leader-Follower” Kits
  - Informed via U.S. contacts[1].

- Heavy Goods Vehicle (HGV) Platooning project
  - No specific cooperation; results of HelmUK are delayed and will be available after the ENSEMBLE work is done.
- US DOT Human Factors Issues related to Truck Platooning Operations
  - This project was selected for twinning with ENSEMBLE.
  - Representatives from the FHWA and ENSEMBLE groups established a twinning arrangement in 2018 that allows the groups to coordinate and exchange information on their parallel research questions.
  - From ENSEMBLE mainly IFSTTAR was involved.
  - US Twinning visit took place at IFFSTTAR on 23/9 – 27/9, 2019.
  - The final report is added in Appendix B.
  - The results have also been published in a joint ITE Journal article (Roldan, 2021).
- 5G-MOBIX
  - No specific cooperation due to focus on different technologies and timing of the projects.

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6. APPENDIX A. GLOSSARY

6.1. Definitions

Term	Definition
Convoy	A truck platoon may be defined as trucks that travel together in convoy formation at a fixed gap distance typically less than 1 second apart up to 0.3 seconds. The vehicles closely follow each other using wireless vehicle-to-vehicle (V2V) communication and advanced driver assistance systems
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
Legal Safe Gap	Minimum allowed elapsed time/distance to be maintained by a standalone truck while driving according to Member States regulation (it could be 2 seconds, 50 meters or not present)
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.
ODD (operational	The ODD should describe the specific conditions under which a given automation function is intended to function. The ODD is the definition of where (such as what roadway types and speeds) and when (under what conditions,

Term	Definition
design domain)	such as day/night, weather limits, etc.) an automation function is designed to operate.
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

Term	Definition
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

Term	Definition
	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).

6.2. Acronyms and abbreviations

Acronym / Abbreviation	Meaning
ACC	Adaptive Cruise Control
ADAS	Advanced driver assistance system
AEB	Autonomous 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
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
ETSI	European Telecommunications Standards Institute
EU	European Union
FCW	Forward Collision Warning
FLC	Forward Looking Camera
FSC	Functional Safety Concept
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface

Acronym / Abbreviation	Meaning
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
ITL	In-The_Loop
ITS	Intelligent Transport System
IVI	Infrastructure to Vehicle Information message
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assist
LCA	Lane Centring Assist
LRR	Long Range Radar
LSG	Legal Safe Gap
MAP	MapData message
MIO	Most Important Object
MRR	Mid Range Radar
OS	Operating system
OBU	On board unit
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OOTL	Out-Of The-Loop
PAEB	Platooning Autonomous Emergency Braking
PMC	Platooning Mode Control
QM	Quality Management
RSU	Road Side Unit

Acronym / Abbreviation	Meaning
SA	Situation Awareness
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SIL	Software-in-the-Loop
SPAT	Signal Phase and Timing message
SRR	Short Range Radar
SW	Software
TC	Technical Committee
TOR	Take-Over Request
TOT	Take-Over Time
TTG	Target Time Gap
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)
WIFI	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package

7. APPENDIX B. TWINNING FINAL REPORT

US/EU Collaboration on Infrastructure Projects Final Report	
Twinning Project Names (US and EU)	Human Factors Issues related to Truck Platooning Operations (US) and ENSEMBLE - Enabling Safe Multi-Brand Platooning for Europe (EU)
Project Managers (US and EU)	• Szu-Fu Chao, Leidos (US) • Marika Hoedemaeker, TNO (EU)
Date of Report	January 21, 2022
Background of twinning relationship (original objective, today's objective, overview of relationship, etc.)	Twinning is being pursued for these projects due to a high overlap in research interests and to expand upon available knowledge regarding a rapidly emerging technology. Both projects are aimed at investigating and recommending solutions for the potential hurdles that face automated truck platooning in the next several years. Success and acceptance of partially automated truck platooning may well set the stage for further progress and development of automated driving technology. By sharing information and broadening the reach and breadth of research, the ability for both projects to successfully address the challenges of truck platooning before they become a public issue is improved. Twinning activities are focused on the human factors issues related to the effect of truck platoon operations on other road users, which are the main focus of the USDOT project and the portion of the ENSEMBLE project led by UGE. This objective remains in effect. Virtual and in-person visits have also encouraged exchange of experiences related to programmatic structure and larger organizational influences on research and science, thus offering a broader perspective on the conduct of research. National shifts in public perception of and industry approaches to partially automated truck platooning have also been observed and shared by both groups over time.

Progress (what was accomplished in terms of *concrete* results obtained through the twinning exercise, information/data/ software exchanged, teleconferences, communications, travel, etc.)	• Twinning agreement ratified in March 2019
	• Quarterly conference calls conducted from December 2018 to December 2021
	• In-person meeting held during TRB in USA in January 2019
	  ○ Attended by FHWA, Leidos, TNO, and UGE
	• Shared filed server established on the FHWA secure large file transfer server to improve communication and document sharing
	  ○ Regular meeting minutes shared on file server
	• In-person meeting held at UGE in France in September 2019
	  ○ Attended by UGE, TNO, FHWA, and Leidos
	  ○ Included tour of research facilities, discussion and demonstration of experimental scenarios, discussion of programmatic structure and vision, and cultural exchange
	• In-person meeting held during TRB in USA in January 2020
	  ○ Attendance by UGE, FHWA, and Leidos
	  ○ UGE toured FHWA Turner-Fairbank Highway Research Center

	○ Teams shared project updates and participated in cultural exchange • Regularly exchanged experimental scenarios, collected data, and research plans ○ UGE shared scenario plans for the driving simulator in June 2019 ○ Leidos shared survey results, Sign Lab research plan, and interim report, miniSim experimental plan in Spring/Summer 2020 ○ UGE shared preliminary results regarding driver's highway merge/exit location relative to the 3-truck/7-truck platooning with 0.8s/1.5s gap distances under low/high traffic scenarios in September 2021 ○ Leidos shared preliminary results regarding road users' highway entering and exiting behaviours, thru-traffic region driving behaviours, and feeling about the truck platoon in September 2021 ○ UGE shared additional results on subjective emotion measures, driving behaviours, and time gaps between trucks in December 2021 ○ Leidos shared data collection status and upcoming plan in December 2021 • Discussed experimental research questions and methodology during September 2019 visit to UGE ○ Compared strategies for conducting driving simulator research • Midterm deliverable article submitted to and accepted by ITE Journal: Preparing for Safe and Successful Truck Platooning on Public Roads (Collaboration between the United States and the European Union). Released in Nov 2021 (Page 35, https://www.ite.org/ITEORG/assets/File/ITEJ%20Published/2021/ITE_ITE_NOV2021.pdf) • Shared relevant conferences, presentations, or events during virtual and in-person meetings ○ ENSEMBLE Public Demo in Spain on 23 September 2021 ○ Upcoming and final EMSEMBLE workshop in March 2022 (hybrid) ○ Upcoming USDOT Truck Platooning Field Operational Test in 2022 • Shared insights from stakeholders during virtual and in-person meetings ○ EU shared news of recent policy shifts in European trucking companies ○ USDOT shared progress on US company advancements and goals for platooning
Assessment of Twinning Benefits (summary of benefits and impacts from twinning activities)	• Streamlined efforts in research of shared interests, where concepts, technologies, and knowledge can be quickly shared and applied in different contexts • Presented innovative findings of driver behaviour near partially automated truck platooning to increase community awareness

	• Enhanced the quality and efficiency of research projects by mutual collaboration to better pave the way for the development of automated truck platooning

Challenges (challenges encountered and how were they addressed)	• Applied an online meeting scheduling tool to efficiently coordinate virtual meetings among multiple diverse groups and across multiple time zones
	• Flexibly adjusted to shifts in project timelines, scope, and goals influenced by natural research progression as well as unanticipated shifts in stakeholder priorities
	• Shared upcoming events that required international travel to allow groups to plan ahead, especially FHWA representatives required advanced planning for international travel approval
	• COVID-19 pandemic caused delays for both groups, pushing back data collection and project schedules, and introduced difficulties to travel and attend in-person events
	  o Strictly followed the COVID-19 safety protocol and the research facility rules and regulations to conduct data collection as applicable
	  o Utilized virtual tools to continue sharing project progress and exchanging ideas
	  o Remained flexible to adapt to the delays caused by the pandemic
	• Policies for funding/supporting effort toward Twinning varied, such as FHWA requirements for deliverables was different from those of public institution (UGE); funding and time available to support Twinning activities varied over time and across groups
	  o Coordinated and collaborated to submit independent and joint deliverables in a timely manner