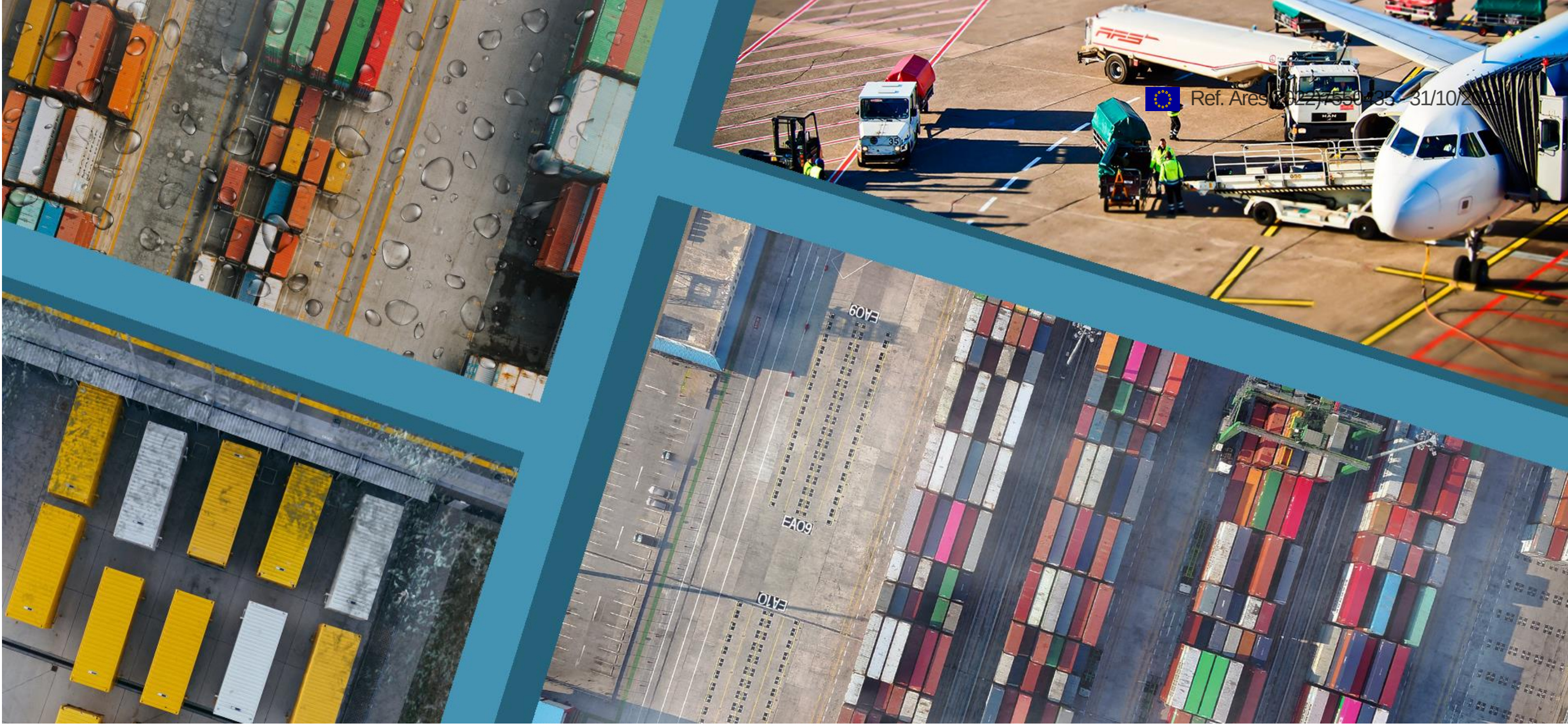

D4.4
Factory Acceptance Test report

—

Lead: EasyMile

Due date: 09/2022

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LEGAL DISCLAIMER

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v1.0	12/09/2022	Stephane POTIRON	EasyMile	Initial version
v1.1	17/10/2022	Stephane POTIRON	EasyMile	First version
v1.2	19/10/2022	Alexandre Troale	EasyMile	Technical review
v1.3	22/10/2022	Ted Zotos	IRU	Quality review
V1.4	26/10/2022	Magali Cottevieille	EasyMile	Last minor corrections

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List of acronyms

ADS	Automated Driving System
ADV	Autonomous Driving Vehicle
AGTS	Automated Guided Transport System
AV	Automated Vehicle
CAN	Controller Area Network
DBW	Drive by wire
ECU	Electronic Control Unit
FAT	Factory Acceptance Tests
GNSS	Global Navigation Satellite System
HDV	Heavy-Duty Vehicle
Kph	Kilometers per hour
OBU	On Board Unit
ODD	Operational Design Domain
RTK	Real-Time Kinematic
RSU	Road-Side Unit
V2X	Vehicle to everything

Glossary

Bring-up	EasyMile standard testing phase after platform reception following FAT tests phase
CAN	A Controller Area Network is a standard vehicle bus used to enable communication between automotive ECUs.
Factory Acceptance Test	Static and dynamic tests performed on the vehicle at the supplier factory to validate the basic functionalities of the platform.
GNSS /RTK	Global Navigation Satellite System is a mechanism aiming to obtain its proper position thanks to reception of a signal coming from at least four satellites. The GNSS receiver measures the transmitting time of satellite signals and computes its position according to reception time of signals. Real-Time Kinematic is a process used for correcting positioning errors from GNSS positioning calculation.

1. Executive Summary

The objective of the Factory Acceptance Test report is to present the results of the unit tests on the different vehicles which validate the AWARD Autonomous Driving System (ADS), the Drive-By-Wire solution for each platform (DBW) and the different interfaces of communication and networks.

These tests focus on the validation of all the mechanical components mounting (e.g., sensors support, camera's position and field of view), the electrical wiring harness, communication buses and network connections/configuration. Objective is also to validate the platform specific low level control loop performance and ensuring the right communications and configurations networks between the different levels of the vehicle. At the end of this validation, the platform is ready to be delivered to the Easy Mile team for the autonomisation phase at EasyMile proving ground called the bring-up phase.

As an introduction, in chapter 2, this document first locates the Factory Acceptance Test phase within the general AWARD planning and emphasize the technical successful achievements of the different development phases required to enable this phase.

Chapter 3 describes the low and high-level platform system architecture cutting and how communication between ECUs of different levels, surrounding sensors and actuators can be achieved. Additionally, some generic control and mechatronic concepts and solutions are presented with the aim of explaining the goal of the different tests performed at the end of integration for each platform at the vehicle factory.

In chapter 4, the document presents a summary of the several tests that have been performed on the vehicle.

In the annex of this report, a highlight of the results of the Kamag Factory Acceptance Test (FAT) is presented.
The document concludes with the FAT results of the Terberg truck and the Dematic/KION forklift.

2. Introduction

2.1. Purpose and scope

This document initially locates the Factory Acceptance Test phase within the general AWARD planning and highlights the technical successful achievements of the different development phases required to enable the acceptance of the vehicles. It also describes the low and high-level platform system architecture cutting and how communication between ECUs of different levels, surrounding sensors and actuators can be achieved. It then presents some generic control and mechatronic concepts or solutions with the aim of explaining the goal of the different tests performed at the end of integration for each platform at the vehicles' factory.
Moreover, the results of the Kamag FAT tests are be presented in the annex of this document.

2.2. Confidentiality

This document is strictly confidential. The content of this report can be shared for internal use.

2.3. Factory Acceptance tasks in the AWARD project development

As described in the Grant Agreement, the FAT tests take place in task T4.2: Design, implementation, Integration and Autonomisation. Task T4.2 is divided into 3 main phases:

- Phase A: the design and implementation
- Phase B: the integration phase
- Phase C: the Autonomisation.

The Factory Acceptance Tests conclude and validate all the activities performed during phase A and B triggering the start of phase C as highlighted in figure 1.

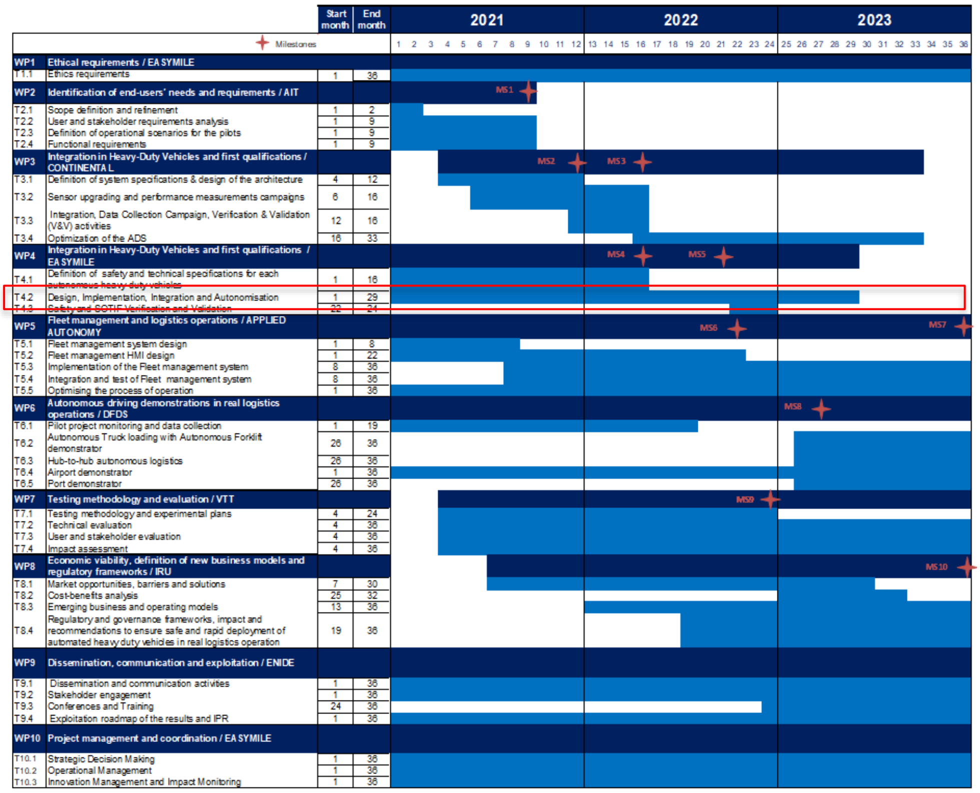

Figure 1: The AWARD global Gantt chart

To make an overview of all the different activities within the AWARD project performed previously and mandatory to trigger the Factory Acceptance tests, we have to describe first some of the principal activities of phases A and B. The FAT ends the integration phase B (figure 2).

- **Phase A: Activities performed during the design and implementation phase**

Autonomous legacy Driving System kit solution has been designed including both the hardware and the generic core software. The sensor set and electrical architecture has been defined and validated for each platform according to Work package 2 and 3 specifications. Starting from the requirements of the mechanical and electrical integration of each WP3 AWARD sensors, each platform manufacturer partners (Terberg, Dematic, Kamag, SAS) have worked together to design the AWARD sensors set supports and electrical supplies. All the sensors have been integrated on the vehicle in an optimal way. Electrical schematic of platform harness has been defined, shared and validated by partners' factory facilities.

The core control development has been done. This work consists of coding the core control software to correctly communicate with the vehicle Electrical Control Units considering the sensor set defined within AWARD. Sequence diagrams specifications, CAN databases and network architectures have been designed, shared and validated. The Vehicle Electrical Control Units embedded software has been implemented: coding software according to WP4 requirements was integrated to fulfill functional safety, drive by wire requirements, control command requirements, and intersystem communication.

PHASE B INTEGRATION	**FAT**	FAT weeks in partner premises
		integration adjustments by AWARD partner (if needed)
		vhc delivery to EM test site
PHASE C AUTONOMISATION	**Simu finalization**	VHC 3D update in simulation
		Upgrade test bench with EZShield
		Finalization of EZDrive image validation on testbench
	Low level bringUp	EZMove complementary devs (bug fix)
		EzMove validation (SimCCO + CCO ready)
		PLC bring up
		EZShield bring up (image, bench and vehicle)
		Safety belt configuration (anticollision areas, tests & validation)
		EzMove finalisation (documentation, EZdiag, etc.)
	High level BringUp	Drive Legacy - Sensor calibration
		Drive Legacy - Localisation bring up
		Drive Legacy - Detection first tuning
		Control bring up
		Drive Legacy - Detection bring up
		Drive Legacy - Navigation bring up
		Drive Legacy - SiteCC custom and vhc integration
		Test plan for BringUp definition
		bringUp test and validation
		demo post bringUp on test base (nav + safety + detection + fleet only)
	System release	specific features developed in simulation (AWARD V2X)
		complementary features test and tuning (station / intersection / V2X)
		specific features tests on the vehicle (AWARD teleoperation)
		release test plan document
		release test and validation
		release system
		integration of AWARD soft into release + network configuration (3 semaines)
		demo post release (before on site deployment)

Figure 2: FAT in the development phase

- **Phase B: Activities performed during the integration phase**

All the components of the AWARD solution have been mounted on the prototype platform (Sensor Electronic Control Units, low level legacy control unit, low level sensors and safety sensors). All the electrical harness are ready and connected, IP network and CAN connection are ready.
The platform is ready to perform the Factory Acceptance Tests. This validation triggers the reception of the vehicle by EasyMile and the delivery to proving ground for phase C.

- **Phase C: Autonomisation**

Once the vehicle integrated has been verified, the prototype vehicle will be shipped to EasyMile's proving ground for testing purposes. This phase will consist of adapting all the autonomy software for the new vehicle. This work will be done first in a simulation and will then be carried out on the real equipped vehicle. The following steps will be processed:

– **Test bench and simulation** building: some preliminary measures will be done on the vehicle to understand the dynamics of its behavior. It will allow the EasyMile team to produce a representative simulation of the vehicle.

- **Software Bring-Up:** when receiving the vehicle, the first task to be carried out will be to create the first software image that will allow the vehicle to run in autonomous mode. This activity involves configuration and parametrization of the software stack to the vehicle, its cinematics, sensor set and configuration. The localization, navigation, and perception algorithms will be adapted to the vehicle and its Use Case.
- **Software release:** this task corresponds to the finalization of the autonomous driving software. At the end of a robustness tests period, an EasyMile internal document is edited and the system is ready to be deployed on a first pilot-site.
- **Autonomous Material handling software:** this task corresponds to the finalization of the material handling software. These tests are realized by the truck manufacturer in order to pre-validate the material handling software.
- **Calibration tools** and/or physical test bench: validation of manufacturing process to guarantee that all produced vehicles will react as specified and according to validation during the development, setting and prototype validation phases

At the end of phase C, the platform will be ready to perform the safety and SOTIF tests planned in the WP4 activities prior to vehicle deployment.

2.4. Reminder: Applicability and target platforms

- **First platform: Electric baggage cargo Tow tractor:**

This platform, manufactured by TLD (based on the electric TLD JET 16), is the first platform that was used within AWARD to integrate the AWARD sensors and AWARD ADS to perform data acquisitions and testing activities.
This vehicle is usually used in factories, warehouses and airports to carry trailers embedding goods. Its top speed is around 25 kph and it can operate in complex outdoor/indoor environments and shall be able to interact with doors, barriers, or traffic lights.

- **Other targeted platforms**

The AWARD sensors set and ADS has been integrated on all project platforms from the forklift to heavy Duty Port Truck (Dematic/Kion, Kamag and Terberg) to tackle the different project use-cases (figure 3).

Forklift *Truck (Kamag)* *Truck (Terberg)*

Figure 3: AWARD autonomous driving vehicle platforms

For each of these platforms, the ADS AWARD system is connected to the drive by wire robotized platform to provide safe and efficient solutions proving the high level of adaptability of the AWARD solution to low-level architecture.

3. Platform description generalities

3.1. High-level/Low-level platform architecture:

An autonomous vehicle can be described as a two level system (figure 4).

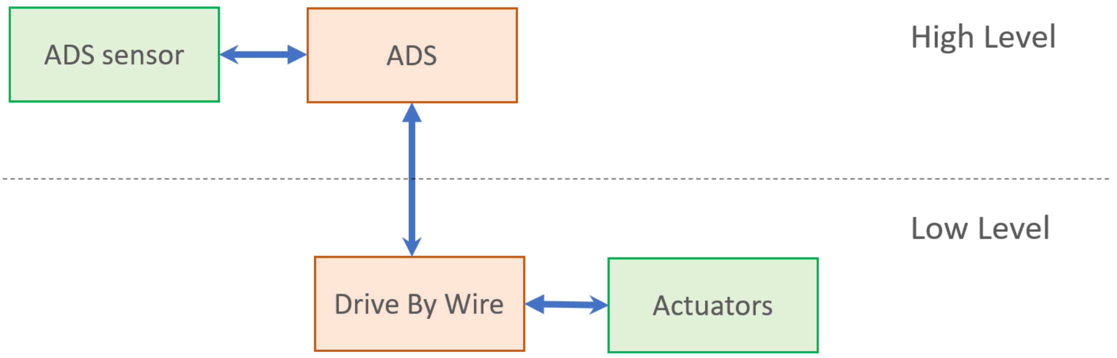

Figure 4: High/low platform level

- The High Level: the ADS and sensors perform the perception and localization functions. It is connected to a suite of sensors that ensure aggregation of information of the surrounding environment (static and dynamic objects, ego position) to feed the platform. The ADS then perform the computation of these information with embedded algorithms to localize the vehicle (localization) and define the path of the vehicle based on sensors inputs analysis (perception). The ADS algorithm then creates the different command to follow these paths (e.g.: torque or speed request, braking level or acceleration) and transmit theses information to the "Low-Level", the drive by wire.

- The Low level: The drive by wire is different for each vehicle as each platform has different supplier and functions. Indeed, a high-power electro-pneumatic truck braking system (Terberg) is different of an electro-hydraulic heavy duty tractor brake (TLD). However, each platform can be seen as an addition of mechatronic systems (function controller and actuator) able to control "remotely" each vehicle functions and supervised by a master controller. The "master controller" receive the command from the ADS but also from the various low-level platform controllers themselves (it can include safety controllers, ABS or EBS ECUs, steering wheel controllers or direct sensor information (braking pressure, seat sensor, steering wheel angle). It compares and prioritize each command source and compute the command. The target (steering wheel angle or brake pressure target is sent to each function ECUs that regulate via closed loop control the actuators accordingly (position, pneumatic or hydraulic pressure).

3.2. Low-level drive by wire description

3.2.1. introduction

As described previously, an autonomous platform can be described as a two-level system, the drive by wire platform connected to an ADS supervisor. The goal of the factory tests is to validate the complete system (both levels). In this section, we make a focus on the description of "the low-level", the drive by wire (figure 5).
The objective of the FAT tests is mainly to validate the platform control loop performances and other critical functions (emergency braking solution). It consequently implies hardware and software verifications.

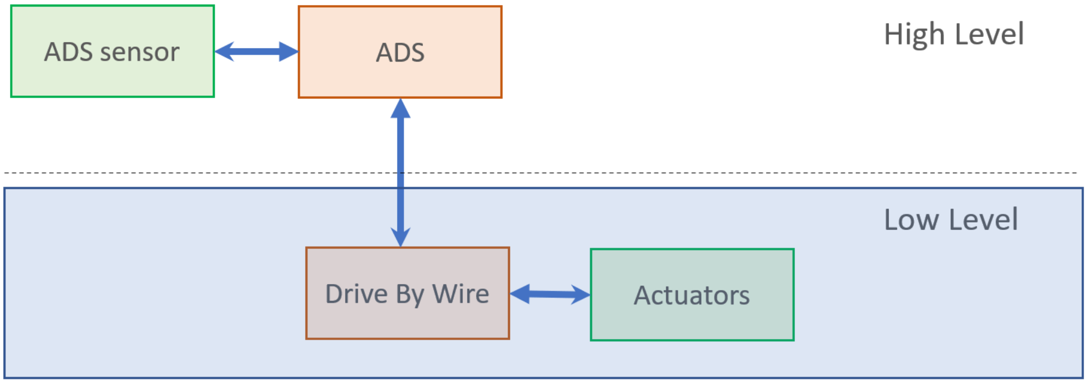

Figure 5: Overview of the platform low level

3.2.2. Low-level control

The drive by wire technology uses electrical or electro-mechanical systems for performing vehicle functions traditionally achieved by mechanical linkages. This technology replaces or takes control, whenever possible, the traditional mechanical control systems with electronic control systems coupled by electro-mechanical actuators. Closed loop regulations as presented in figure 6 are commonly used and allow a safe and precise control for each vehicle's functions.

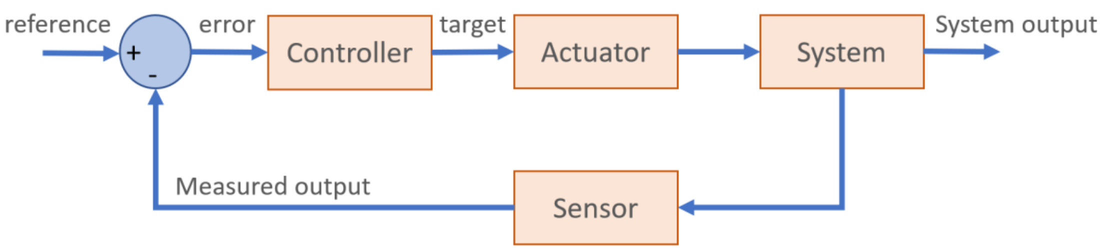

Figure 6: Example of generic closed loop controller

3.2.3. Low-level platforms functions

– The steering wheel (simplified KAMAG platform solution – figure 7):

In many HDVs, the steering wheel function is controlled via an electro-mechanical steering wheel column. It is an electro-mechanical system (electric motor, power stage – inverter – and ECU for control) mounted on the steering wheel column able to assist the driver to steer. For robotized platforms, it is also used to apply the right steering wheel angle without any driver by adding stronger motor and communication bus to the platform for sending the steering wheel target and feedback.

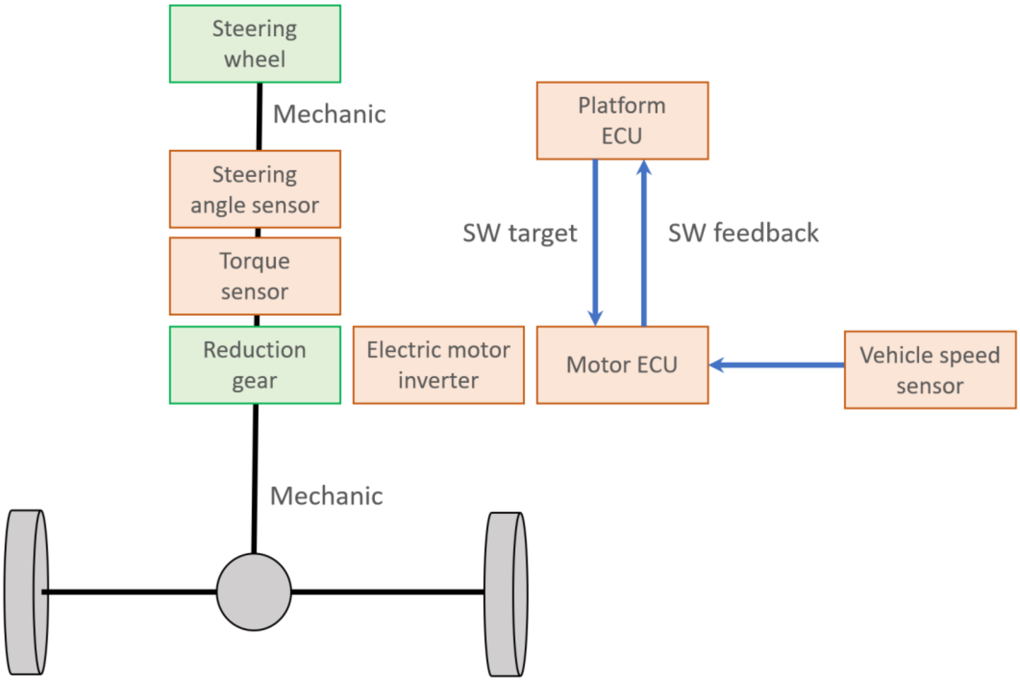

Figure 7: Example of electrical power steering

– The Braking system (figure 8):

The air braking system called EBS by the addition of an EBS central ECU (Electrical Braking System) to a classic truck pneumatic brake system is a mechatronic (electro-pneumatic) system that can be controlled by a closed loop regulation. It applies the right air pressure to the disk brake calipers without need for any force by the driver on the brake pedal.

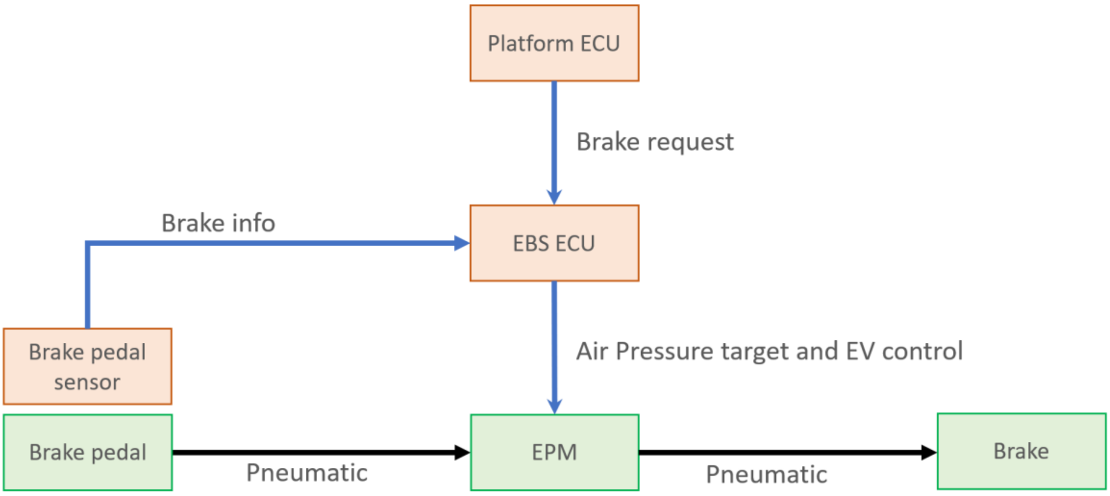

Figure 8: Example of electrical power steering system

Other functions like the acceleration (torque control supervisor or speed control) or/and the driving mode selector (Rear gear, Reverse gear, Neutral gear and Parking gear) are also robotized through mechatronic or electronic solutions and tested before the vehicle leaves the factory to the proving ground.

3.3. High-level: AWARD E/E architecture description

3.3.1. Introduction

An autonomous platform is composed of a drive by wire platform supervised by an ADS supervisor (Autonomous Driving System) connected to a sensor set. The goal of the factory tests is to validate all the mechanical component mountings, the electrical wiring harness, network connections and communication bus of the complete system of the two levels of the architecture.
In this section, we describe the electronic and electric architecture of the AWARD solution focusing on the high-level (figure 9). The "High-Level", basically the ADS and sensors perform the perception and localization functions. It is connected to a suite of sensors that ensure aggregation of information of the surrounding environment (static and dynamic objects, ego position) to feed the platform. The ADS perform the computation of these information with embedded algorithms to localize the vehicle (localization) and define the path of the vehicle based on sensors inputs analysis (perception). It creates the different commands: torque or speed request, braking level or acceleration and -Level", the drive by wire.

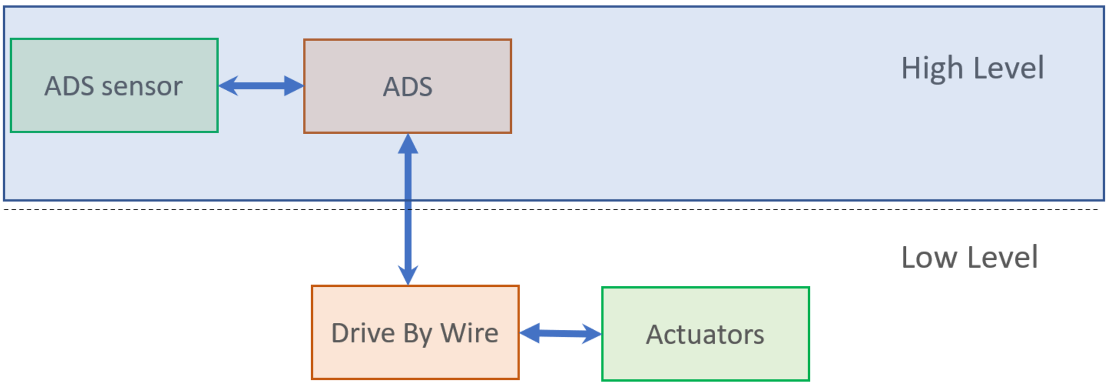

Figure 9: Overview of the platform high-level

3.3.2. AWARD general electrical architecture

The AWARD generic architecture is described in the deliverable D3.1 and shown in figure 10. It is composed of the power supply lines (12 V and 24 V), the IP ethernet network and the CAN bus network.
The general electrical architecture presents all the power supplies wiring diagram that describes all the connections from the power supply, network connection to the communication subnetworks (CAN buses).

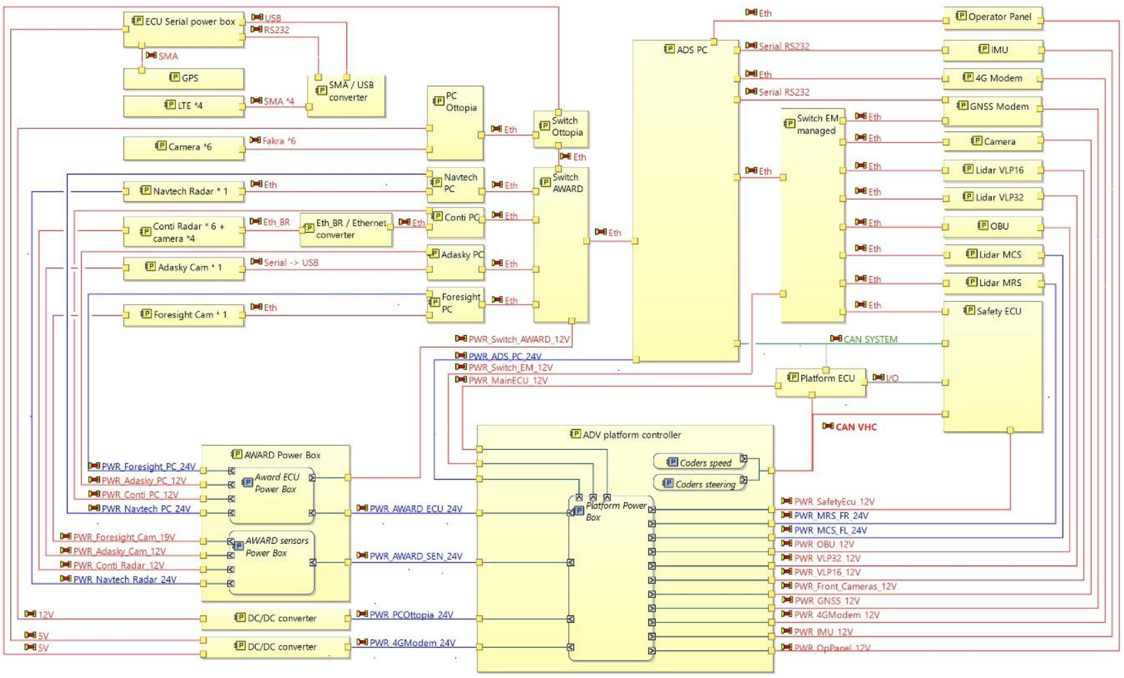

Figure 10: AWARD complete E/E architecture

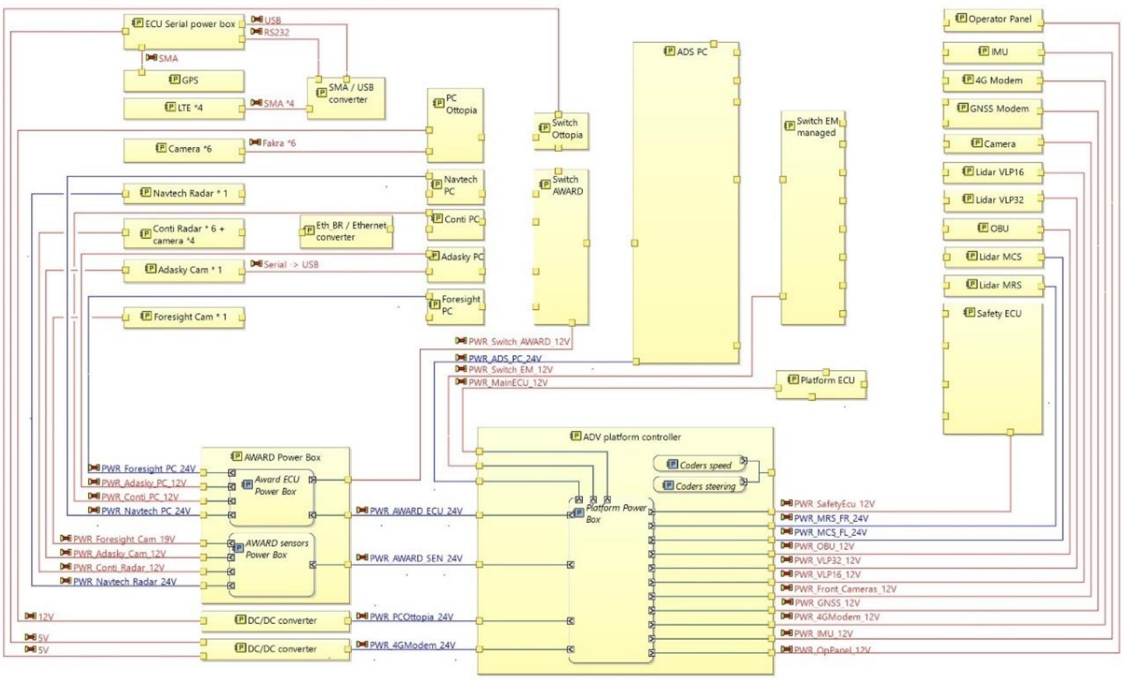

Figure 11: AWARD low-level (12V and 24V) power supply

During the FAT testing, the AWARD team validates by visual control, electrical measurement, or software tools that all the connections are done according to the architecture specifications.

Different layers are used to describe the low-level power supply 12 V and 24 V DC connections. Those schematics are used as references during the validation tests to facilitate the validation phase.
The AWARD low-level power supply architecture presented in figure 11 describes the power supply for the ADS system. Grounds connections are not presented as the ground plane details is in the electrical schematic done by each platform supplier. Power boxes are used for supply management and are equipped with supply protection (fuse). Corrections measures have been taken in case of wrong connection or diagram error. As the FAT takes place at the supplier factory, the AWARD team has all the tools needed to perform the corrections.

For modern vehicles and even more autonomous platforms, multiple connections are mandatory for the communication between the different ECUs and sensors. Complex and IP Ethernet network and CAN (Controller Area Network) ensure the real time transmission of these data. The FAT tests ensure by testing hardware connection, IP address configuration and message analysis that the AWARD system perform as specified.

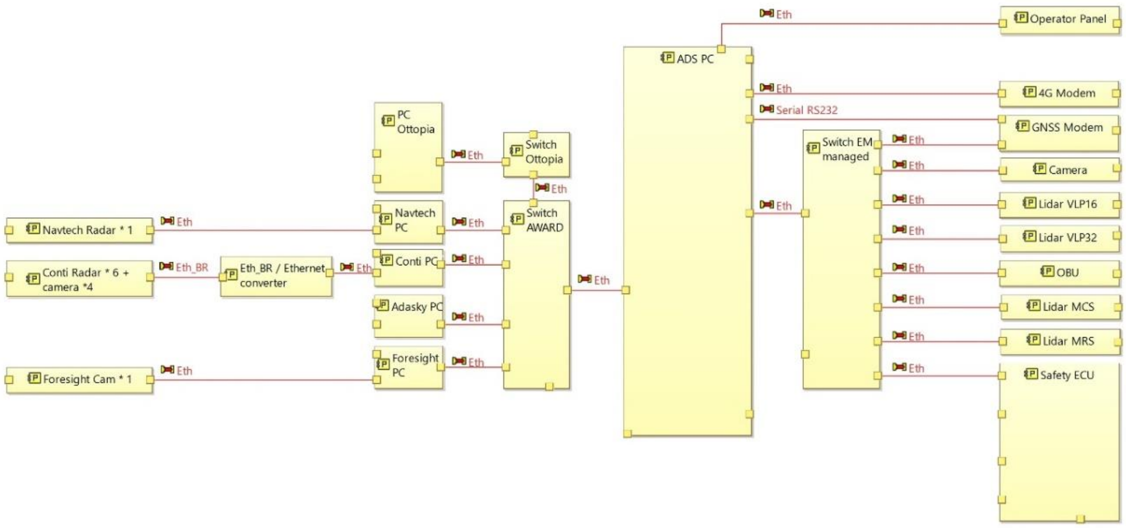

Figure 12: AWARD Ethernet Network

The Factory Acceptance Tests also include the complete hardware testing of the physical network connection as well as the validation of the correct network configuration integration (each ECUs, Sensor IP address are tested and validated). Figure 12 presents the AWARD network.

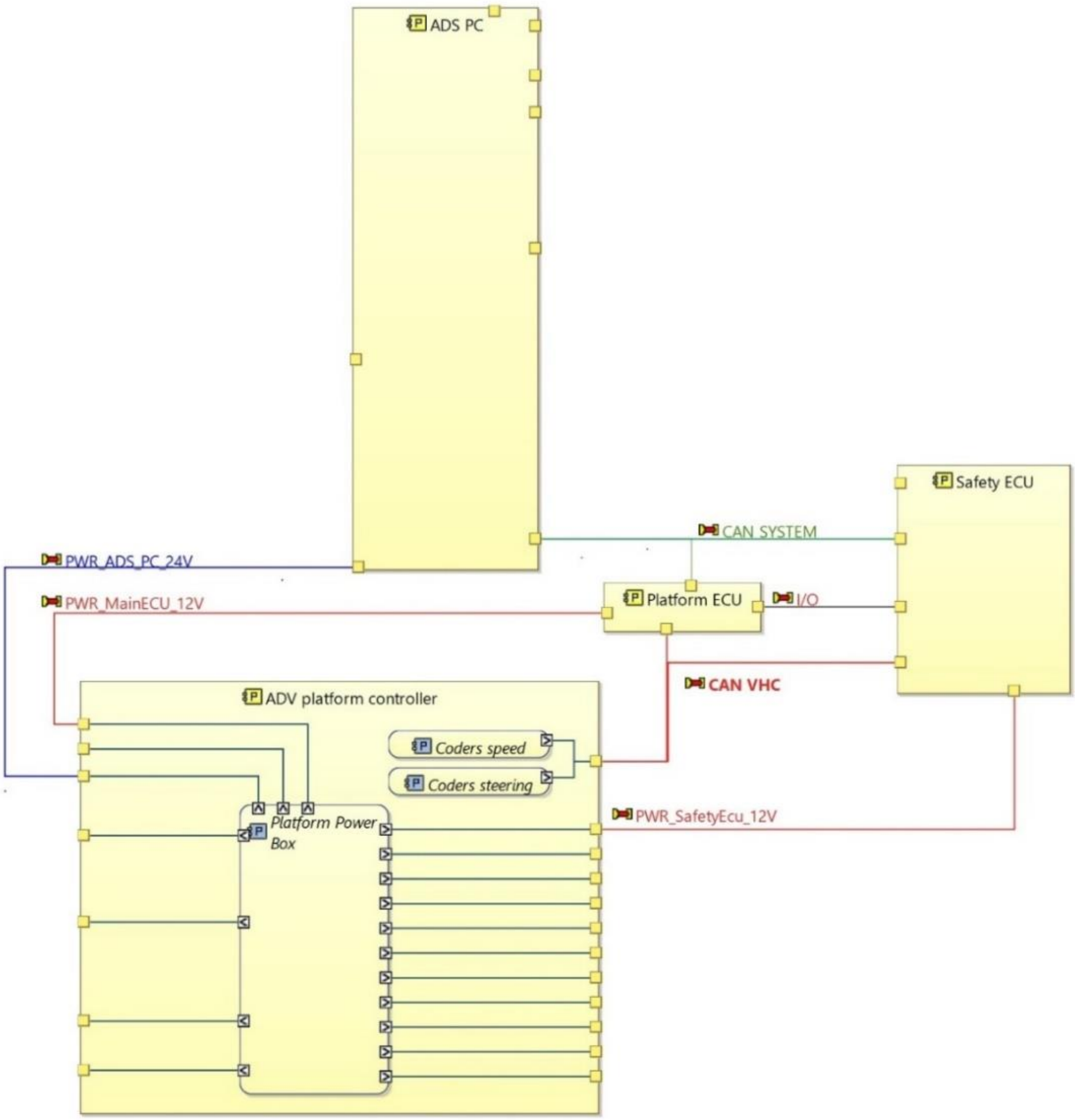

Figure 13: AWARD CAN bus network (CAN VEHICLE and CAN SYTEM)

The CAN (Controller Area Network) busses (figure 13) has been validated including the verification of each node and messages format according to the specifications and CAN diagrams definition. It implies electrical verification on the bus (120 ohms termination resistance – figure 14) and communication tests.

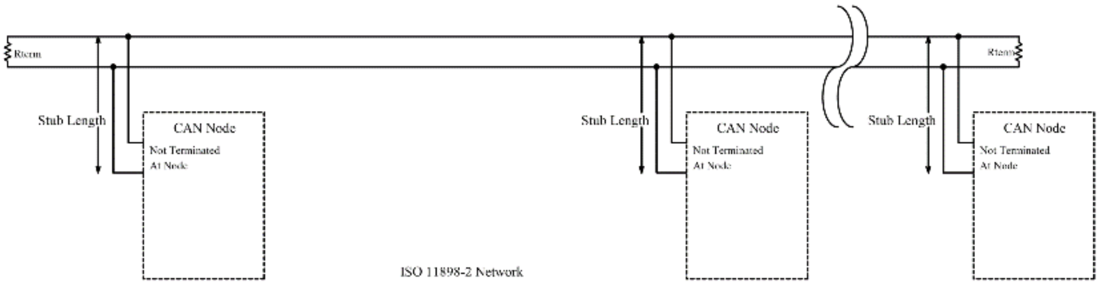

Figure 14: Example of CAN network configuration (daisy chain)

3.4. Test descriptions – Test phases:

3.4.1. introduction

The FAT tests follow a 6-phase plan (figure 15); phase 5 regroups the tests of the specific features for each platform. It is performed at the platform factory and involves the sensor suppliers, ADS suppliers and platform suppliers. It validates that the platform is at the right level to start performing more advanced dynamic testing.

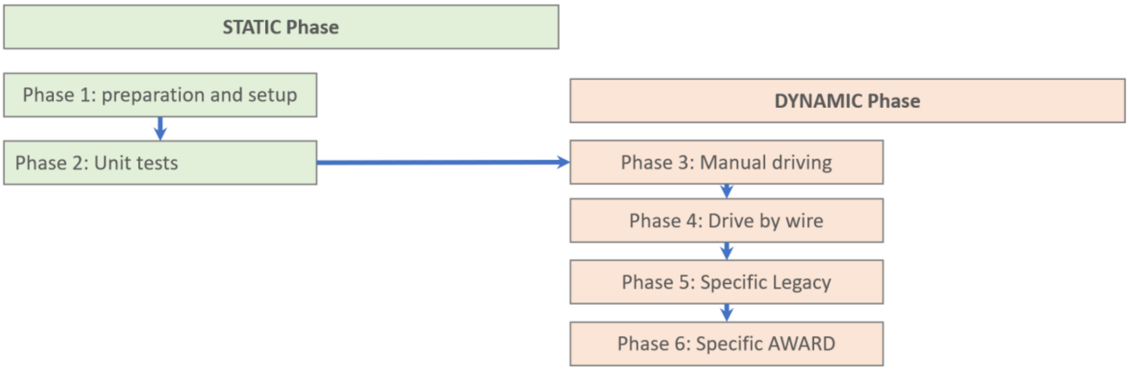

Figure 15: Overview of the static and dynamic test phases performed for each platform

3.4.2. Phase 1: preparation and setup - STATIC

This phase focuses on the preparation and setup of the onboard systems. It basically checks the mechanical, electrical, and electronic integration validation. These tests focus on visual inspection: identification, and mechanical tests mounting of the main components including all the sensors, switches, panels, Electronic Controller Units, or embedded computers.
All these tests are static tests and can be done indoor in the platform supplier garage. This phase is mandatory and prerequisites the next validation phase (figure 16).

Figure 16: KAMAG FAT phase 1 static tests at KAMAG Ulm Factory

For each validation phase, the software version of each ECU, sensors embedded computer, and validation tool are documented. Hardware S/N reference are also listed ensuring tracking of modifications during the validation process as presented in figure 17.

EASYMILE 1 boulevard de la Marquette, Bât B, eme étage 1000 TOULOUSE él : 05 32 10 81 90 Web : www.easymile.com	**AWARD AWL 3** Integration Test Plan	Ref : Ed./Rév. : Date :	ABE-EZ800165-TestsPlan-01-Integration-v3 1.0 13/6/2022

Phase 1 - Preparation and setup

This section will validate the mechanical, electrical and electronic integration.
For productivity needs and when it is possible, once plugged to the component, some setup will be done.
These testings will be done in a "garage", ie indoor, static on the ground.

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
EZBOX Fuse map	https://docs.google.com/spreadsheets/d/1mQgCw5SB2kEkqmY2hx5JKn5jBp0QEyJy1jfXMbN95_w
Modem configuration	https://docs.google.com/document/d/1GEBTcrNjOkM71ZwBY88S-HPgw8Pv6_Z5TvK52NhcIa4/edit
Multimeter	NA
External HDMI/VGA screen	Screen to connect with the PC Core
USB key with installed ISO	TBD
Software TCH_CAN	Software for MECU's configuration flash
Software Safety Designer	Software for PLC and MicroScan's configuration flash
Software Novatel	Software for GPS's configuration flash
Software SOPAS-ET	Software for MRS, LDMRS and LMS's configuration flash
Software MT Manager	Software for IMU's configuration flash
Software GigEConfigurator	Software for camera's configuration flash
MTI-USB cable	IMU communication cable
Flexisoft cable	PLC communication cable
Ethernet cable	Ethernet network communication cable
SIM card	Card for 4G connection
USB-PEAK cable	CAN EM and VHC communication cable
PC accessories	Mouse, Keyboard

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
EM Technical Panel (vehicle cabin box)						
EM Maintenance Panel (vehicle cabin box)						
EM Navigator Box (outside box)						
Check PC Navigation (outside box)						
Check OP Panel (vehicle cabin box)						
Check SCES A (outside box)						
Check MECU (outside box)						
Check PLC A (outside box)						
Check PLC B (outside box)						
Check MODEM (outside box)						
Check GPS (outside box)						
Check OUTDSC-FR						
Check OUTDSC-RCabin						
Check OUTDSC-RC						
Check MRS-FL						
Check MRS-FC						
Check MRS-RC						
Check VLP16-FL						
Check VLP16-FC						
Check VLP16-FR						
Check VLP16-RR ---- Takes the place of Rear left high res in network diagram						
Check VLP32-TOP or RCabin?						
Check VLP32-RL						
Check Encoder 1						
Check Ethernet Switch 1						
Check Ethernet Switch 2						
Check Cam Operator						
Check Outdoor Mode Lights						
Check EM CAN Bus (GREEN)						
Check VHC CAN Bus (RED)						
Check OBU						

Figure 17: KAMAG FAT phase 1 tests summary

Figure 18 illustrates the phase 1 tests for the Navigation embedded PC. It includes a checklist of hardware verification (connections of the ethernet ports to switches), mounting control and power supply verification as well as verification of ECUs firmware.

Each validation step has been realized as close as possible to the description, and every difference or remark have been written as a comment during the test realization.

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
EM Technical Panel (vehicle cabin box)						
EM Maintenance Panel (vehicle cabin box)						
EM Navigator Box (outside box)						
Integration_1.6	Check Cable Gland	- Well mount		TODO		
Integration_1.7	Check EZ-Navigator box	- Well mount		TODO		
Integration_1.8	Verify the risks due to the box and	- No Hurting shape		TODO		
Integration_1.9	Remove all the fuse from the	- No fuses		TODO		
Integration_1.10	Check distribution box input	>=24V		TODO		
Integration_1.11	Install Fuses "**F1**" (15A) and "**F2**"			TODO		
Integration_1.12	Check 12V input from EM box	>=12V		TODO		
Integration_1.13	Check 24V input from EM box	>=24V		TODO		
Check PC Navigation (outside box)						
Integration_1.14	Check fixings, vents	- Well mount,		TODO		
Integration_1.15	Check CAN BUS card presence	- Presence		TODO		
Integration_1.16	Ethernet port "**Eth0**":	- Presence		TODO		
Integration_1.17	Ethernet port "**Eth1**":	- Presence		TODO		
Integration_1.18	Ethernet port "**Eth2**":	- Presence		TODO		
Integration_1.19	Ethernet port "**Eth3**":	- Presence		TODO		
Integration_1.20	Ethernet port "**Eth5**":	- Presence		TODO		
Integration_1.21	serial port "**COM1**":	- Presence		TODO		
Integration_1.22	serial port "**COM2**":	- Presence		TODO		
Integration_1.23	PC "**CAN CARD**":	- Presence		TODO		
Integration_1.24	PC "**Power Connector**":	- Presence		TODO		
Integration_1.25	- Put the fuse "**F108**" (7.5A)	Power diod is green		TODO		
Integration_1.26	Check power boot	The PCN boot on the BIOS		TODO		
Integration_1.27	Check correct Setup	Install release note Core OS		TODO		

Figure 18: KAMAG FAT phase 1- NAVIGATION Computer tests

3.4.3. Phase 2: unit test - STATIC

The AWARD team has performed a complete check of the platform component by component (the electrical links, the correct basic setup, the data coherency, the mechanical setup and the actuator and accessories basic behavior). Figure 19 presents an overview of the AWARD ECUs installation in the truck's cabin. Figure 20 shows the ECUs and wirings installed at the rear of the truck.

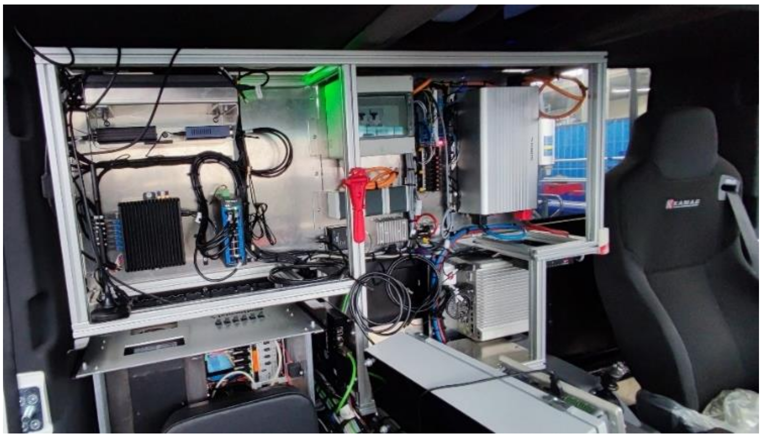

Figure 19: KAMAG AWARD sensor set ECU overview

Phase 2 (figure 21) controls the communication network and subnetwork (IP, CAN). CAN databases and IP configuration specification have been also validated. For each validation phase, the software version of each ECU, sensor, embedded computer, and validation tool have been documented. Hardware S/N reference have been listed ensuring tracking of modifications during the validation process.
The CAN database (message configuration), IP configuration (IP address) has been validated. At this end of this phase, the basic functionalities of the low-level drive by wire platform and high-level ADS electrical architecture, communication bus and network are done (figure 22). The end of phase 2 means the end of the static test phase.

Figure 20: KAMAG legacy ADS system overview

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Phase 2 - Unit tests

In this phase, we will proceed to a checking component by component:
- the electrical links
- the correct basic setup
- the data coherency
- the mechanical setup

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
EZBOX Fuse map	https://docs.google.com/spreadsheets/d/1mQgCw5SB2kEkqmY2hx5JKn5jBp0QEyJy1jfXMbN95_w
Modem configuration	https://docs.google.com/document/d/1GEBTcrNjOkM71ZwBY88S-HPgw8Pv6_Z5TvK52NhcIa4/edit
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software SOPAS-ET	Software for MRS, LDMRS and LMS's configuration flash
Software Safety Designer	Software for PLC and MicroScan's configuration flash
Software VeloView	Software for Velodyne's configuration flash
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_2.1	Power ON the vhc	The VHC and all components are ON		TODO		
PC Navigation						
OP Panel						
SCES A						
MECU						
PLC A						
PLC B						
Modem 4G						
GPS						
OUTDSC-FR						
OUTDSC-RCabin (front center in hardware.launch?)						
OUTDSC-RC						
MRS_FL						
MRS_FC						
MRS_RC						
VLP16-FL						
VLP16-FC						
VLP16-FR						
VLP16-RR						
VLP32-RL						
VLP32-TOP or RCabin?						
IMU						
Ethernet Switch 1						
OBU						

Figure 21: KAMAG FAT phase 2 tests

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Phase 2 - Unit tests

In this phase, we will proceed to a checking component by component:
- the electrical links
- the correct basic setup
- the data coherency
- the mechanical setup

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
EZBOX Fuse map	https://docs.google.com/spreadsheets/d/1mQgCw5SB2kEkqmY2hx5JKn5jBp0QEyJy1jfXMbN95_w
Modem configuration	https://docs.google.com/document/d/1GEBTcrNjOkM71ZwBY88S-HPgw8Pv6_Z5TvK52NhcIa4/edit
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software SOPAS-ET	Software for MRS, LDMRS and LMS's configuration flash
Software Safety Designer	Software for PLC and MicroScan's configuration flash
Software VeloView	Software for Velodyne's configuration flash
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_2.1	Power ON the vhc	The VHC and all components are ON		TODO		
PC Navigation						
Integration_2.2	- Check that PC Nav is power ON	Ping response from (**192.168.0.101**)	pre-install OS	TODO		
Integration_2.3	- Connect Dev computer to the	CAN Flow (**500Kbs**) from PC Nav	pre-install OS	TODO		
OP Panel						
Integration_2.4	- Check that OP Panel is power ON	Ping response from (**192.168.14.102**)	Pre-install OS	TODO		
SCES A						
Integration_2.5	- Check that SCES A is power ON	Ping response from (**192.168.12.103**)	pre-install OS	TODO		
Integration_2.6	- Connect Dev computer to the	CAN Flow (**500Kbs**) from SCES A	pre-install OS	TODO		
Integration_2.7	- Connect Dev computer to the	CAN Flow (25**0Kbs**) from SCES A	pre-install OS	TODO		
MECU						
PLC A						
PLC B						
Modem 4G						
GPS						
OUTDSC-FR						
OUTDSC-RCabin (front center in hardware.launch?)						
OUTDSC-RC						
MRS_FL						
MRS_FC						
MRS_RC						
VLP16-FL						
VLP16-FC						
VLP16-FR						
VLP16-RR						
VLP32-RL						
VLP32-TOP or RCabin?						
IMU						
Ethernet Switch 1						
OBU						

Figure 22: KAMAG FAT phase 2 focus PC Navigation, safety ECU

3.4.4. Phase 3: Manual driving – DYNAMIC (figure 23)

The main objective of the phase 3 manual driving tests is to ensure that the AWARD-ADS components do not affect the vehicle behavior in manual mode. It is mandatory to ensure that the AWARD system does not affect the platform behavior when driving “manually”.
All components are powered on and parametrized. The vehicle is on the road at the factory proving ground during the whole session. A specific focus on emergency stops is done to ensure the platform behavior meets the specification (figure 24).

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Phase 3 - Manual Driving

This testing phase verifies that the EM-Navigator components do not affect the vehicle behaviour in manual mode. All components are powered On and partialy parametrized.
Vehicle is on the road during this whole section.

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_3.1	Power ON the vehicle	The vehicle is power ON		TODO		
MANUAL MODE						
STANDBY MODE						

Figure 23: KAMAG FAT phase 3 – Manual mode

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Phase 3 - Manual Driving

This testing phase verifies that the EM-Navigator components do not affect the vehicle behaviour in manual mode. All components are powered On and partialy parametrized.
Vehicle is on the road during this whole section.

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_3.1	Power ON the vehicle	The vehicle is power ON		TODO		
MANUAL MODE						
Integration_3.2	The vehicle is in "**Manual**" Mode			TODO		
Integration_3.3	- Check that the area is free around	The vehicle is moving		TODO		
Integration_3.4	- Check that the area is free around	The steering is moving		TODO		
Integration_3.5	- Set the "**HARD STOP**" Emergency	- The vehicle isn't moving		TODO		
Integration_3.6	Release "**HARD STOP**" Emergency			TODO		
Integration_3.7	- Connect Dev computer to the	- No can error message		TODO		
Integration_3.8	- Connect Dev computer to the	- No can error message		TODO		
Integration_3.9	Test accessories:	- No can error message		TODO		
STANDBY MODE						

Figure 24: KAMAG FAT phase 3 – Manual mode test details

3.4.5. Phase 4: Drive by wire - DYNAMIC

In this phase and as described in figure 25, actuator targets or speed commands are sent on the CAN Bus. The aim is to check that they are well executed. The commands are sent manually (emulated) and match the commands sent by the navigation software during the driving phase. The commands are sent directly by the remote controller simulating the navigation PC or by a development PC connected to the diagnostic socket of the platform. This phase takes place with the security chain deactivated at very low speed at factory proving ground.

wiring issue

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Phase 4 - Drive by Wire

In this phase commands are sent on the CAN bus. The aim is to check that they are well executed. The commands sent manually will be similar to the commands sent by the navigation software during the driving phase. The commands will be sent directly by the remote controller simulating the navigation PC or by a development PC connected to the diagnostic socket. This phase takes place when the security chain is deactivated

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_4.1	Power ON the vehicle	The vehicle is power ON		TODO		
Integration_4.2	Remove the PCN fuse	The PCN is OFF		TODO		
Longitudinal Tests						
Steering tests						
Longitudinal + Lateral Tests						
U Turn						
Emergency Button						
E-Stop						
S-Stop						
Accessories						

Figure 25: KAMAG FAT phase 4 – Drive by wire test details

During this phase, the AWARD team performs (at low speed with a safety driver and with safety chain deactivated) a control of the command sent from the ADS to the drive by wire platform. For testing reasons, the validation engineers use specific software to directly send commands to the different mechatronics systems of the platform. Target and drive by wire feedbacks are validated (e.g., steering wheel tests). Emergency braking is also validated including all the different braking command level (soft to hard stops).

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Phase 4 - Drive by Wire

In this phase commands are sent on the CAN bus. The aim is to check that they are well executed. The commands sent manually will be similar to the commands sent by the navigation software during the driving phase. The commands will be sent directly by the remote controller simulating the navigation PC or by a development PC connected to the diagnostic socket. This phase takes place when the security chain is deactivated

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/file/d/1HZSy7GJZwrwHHJtJ-3KnYnUgkJFCXWfi
Network diagram	https://docs.google.com/drawings/d/1YBkmt2BTk6rFn3JCrJKbbtm8brwfO36u7UTFnzDokzk
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_4.1	Power ON the vehicle	The vehicle is power ON		TODO		
Integration_4.2	Remove the PCN fuse	The PCN is OFF		TODO		
Longitudinal Tests						
Integration_4.3	- The Dev PC is connected to the EM CAN bus on the Technical Panel - Busmaster software is running - The vehicle in "**Auto**" mode	Data flow present on Busmaster		TODO		
Integration_4.4	- Record CAN data - On a straight line, set the speed to 0.5 m/s - drive 20m - Set the speed to 0.0 m/s - Stop recording	- Visual validation of the vehicle movement - No error messages on the CAN bus - The log exists		TODO		
Integration_4.5	- Record CAN data - On a straight line, set the speed to 1 m/s - drive 20m - Set the speed to 0.0 m/s - Stop recording	- Visual validation of the vehicle movement - No error messages on the CAN bus - The log exists		TODO		
Integration_4.6	- Record CAN data - On a straight line, set the speed to 3 m/s - drive 20m - Set the speed to 0.0 m/s - Stop recording	- Visual validation of the vehicle movement - No error messages on the CAN bus - The log exists		TODO		
Integration_4.7	- Record CAN data - On a straight line, set the speed to 5 m/s - drive 20m - Set the speed to 0.0 m/s - Stop recording	- Visual validation of the vehicle movement - No error messages on the CAN bus - The log exists		TODO		
Steering tests						
Longitudinal + Lateral Tests						
U Turn						
Emergency Button						
E-Stop						
S-Stop						
Accessories						

Figure 26: KAMAG FAT phase 4 – drive by wire longitudinal tests

Team has performed the longitudinal tests (figure 26) at low speed (3 to 5 m/s). It consists of acceleration/deceleration tests in straight line. Records has been performed for traceability. Tracking of the errors and cause analysis (in both ECUs) has also been done.

3.4.6. Phase 5: STATIC and DYNAMIC

The specific functions testing (e.g., Terberg pneumatic leveling) regroups all the tests specific to each platform and linked to each pilot use-case operating domain. As an example, for the Terberg truck, the trailer pneumatic leveling was tested during this phase (sensors and electro-pneumatic system). Figure 27 shows a list of tests performed for validating the container leveling feature.

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Phase 5 - Interface tests

In this phase commands are sent on the CAN bus. The aim is to check that they are well executed. The commands sent manually will be similar to the commands sent by the navigation software during the driving phase. The commands will be sent directly by the remote controller simulating the navigation PC or by a development PC connected to the diagnostic socket. This phase takes place when the security chain is deactivated

Testing Means	
Platform	**Tested Platform**
Test Bench	
Vehicle	x

Tools	Description
Vehicle	AutoWiesel
Development computer	Provided by EM
Electrical schematic	https://drive.google.com/open?id=1NKG7lAChJ_QGGQC0i1tvHEgq9c79thA6
Network diagram	https://docs.google.com/drawings/d/1W7GXTpmNUbb9qwgXjkOIhl8LzkOYwXgCp8bIwb4mIoI/
Ethernet cable	Ethernet network communication cable
USB-PEAK cable	CAN EM and VHC communication cable
Software Busmaster	Software to read and write CAN Bus data

Test number	Action	Expected result	Requirement	Result	Comments	Date/ record name
Integration_5.1	Power ON the vehicle	The vehicle is power ON		TODO		
Integration_5.2	Remove the PCN fuse	The PCN is OFF		TODO		
Lifting Empty (Without Swap Body)						
Lifting Swap Body Up						
Lifting Swap Body Down						

Figure 27: KAMAG phase 5 – Specific function tests

3.4.7. Phase 6: DYNAMIC/STATIC AWARAD specific tests

This phase aims at validating the mechanical, electrical, and electronic integration of the AWARD sensor set components. All these tests are done in a “garage”, indoor tests, static. The list of tests to be done during the FAT are presented in figure 28.

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Test	Action	Expected result	Requirement	Result	Comments	Date/ record name
test_1	Check that all PCs and sensors are available (AWARD)	Have the same architecture as defined in the document	Multimeter, toolkit, access to the sensors cab	TODO		
test_2	Check the network configuration	Correct IP adresses on each PC	Access to PC ports and interface	TODO		
	Software check of EasyMile sensor set			TODO		
test_3	Check power supply of all AWARD sensor	All sensors functioning	Access to PC ports and interface	TODO		
test_4	Software check of Continental sensor set	Version, output, time sync are Ok	Access to PC ports and interface	TODO		
test_5	Software check of Foresight sensor set	Version, output, time sync are Ok	Access to PC ports and interface	TODO		
test_6	Software check of Adasky sensor set	Version, output, time sync are Ok	Access to PC ports and interface	TODO		
test_7	Software check of Navtech sensor set	Version, Frequency, output, time sync are Ok	Access to PC ports and interface	TODO		
test_8	Make a dummy test record: Continental	Ecal recording	Access to PC ports and interface	TODO		
test_9	Make a dummy test record: Foresight	Video and its generated metadata	Access to PC ports and interface	TODO		
test_10	Make a dummy test record: Adasky	64-bit camera record	Access to PC ports and interface	TODO		
test_11	Make a dummy test record: Navtech	colraw and bag record	Access to PC ports and interface	TODO		

Note: All tests are in static mode. We would only need to have the Kamag in an open space where we can simulate having a pedestrian in front of it

Figure 28: KAMAG phase 6 – AWARD specific tests

4. Conclusion

The objective of the Factory Acceptance Tests is to validate the low and high-level hardware and software components of the solution for each AWARD platform. During these tests, the Autonomous Driving System and the drive by wire systems have been tested with a step-by-step validation from the low level of the platform (mechatronic actuation solutions and control) to the high level (AWARD sensor communication to ADS embedded computer). It has started with static tests to ensure right component mounting, power supply connections and communications bus to continue with low-speed dynamic tests under validation team control. Specific AWARD features have also been verified at low speed or static mode.

The FAT validation is an important step for the AWARD project and the validation of the AWARD solution. It ensures that the drive by wire platform and ADS system solution are safe and it demonstrates the technical maturity of each level of the platform. The end of the Factory Acceptance Tests enables the start of the Bring Up phase where the ADV functions will be deployed dynamically (Q4 2022 to end of Q1 2023), tested, calibrated and validated (Perception, Localization).

KAMAG trucks FAT results can be found in annex 6.1 of this document. It summarizes the results of the tests ensure traceability and validation status of each component and function (software and hardware). Due to validation phase shift of other platforms, it will be completed with a summary of the results of the FAT testing phase for the other platforms (Dematic/KION forklift and Terberg Truck) during the AWARD project.

At the end of this validation, the vehicle is ready to be be delivered to the EasyMile team for the integration tests (BringUp) at EasyMile Daher and Francazal proving ground to continue validation and calibration of the vehicle.

Annex

KAMAG tests results summary

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Conclusion

Synthesis

Tab	To Do	OK	KO	Cannot Be Tested
Phase 1 - Preparation and setup	3	201	3	0
Phase 2 - Unit tests	5	49	0	0
Phase 3 - Manual Driving	0	14	0	1
Phase 4 - Drive by Wire	7	34	3	10
Phase 5 - Lifting by Wire	0	9	0	0
Total	15	307	6	11

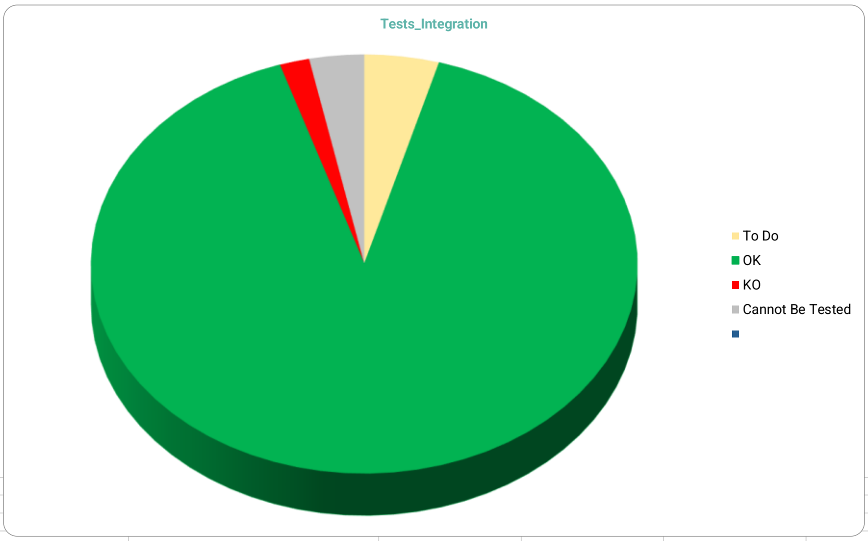

Figure 29: KAMAG FAT tests results summary