Public Demonstration

ENSEMBLE CONSORTIUM

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Multi-brand specifications and communication protocol

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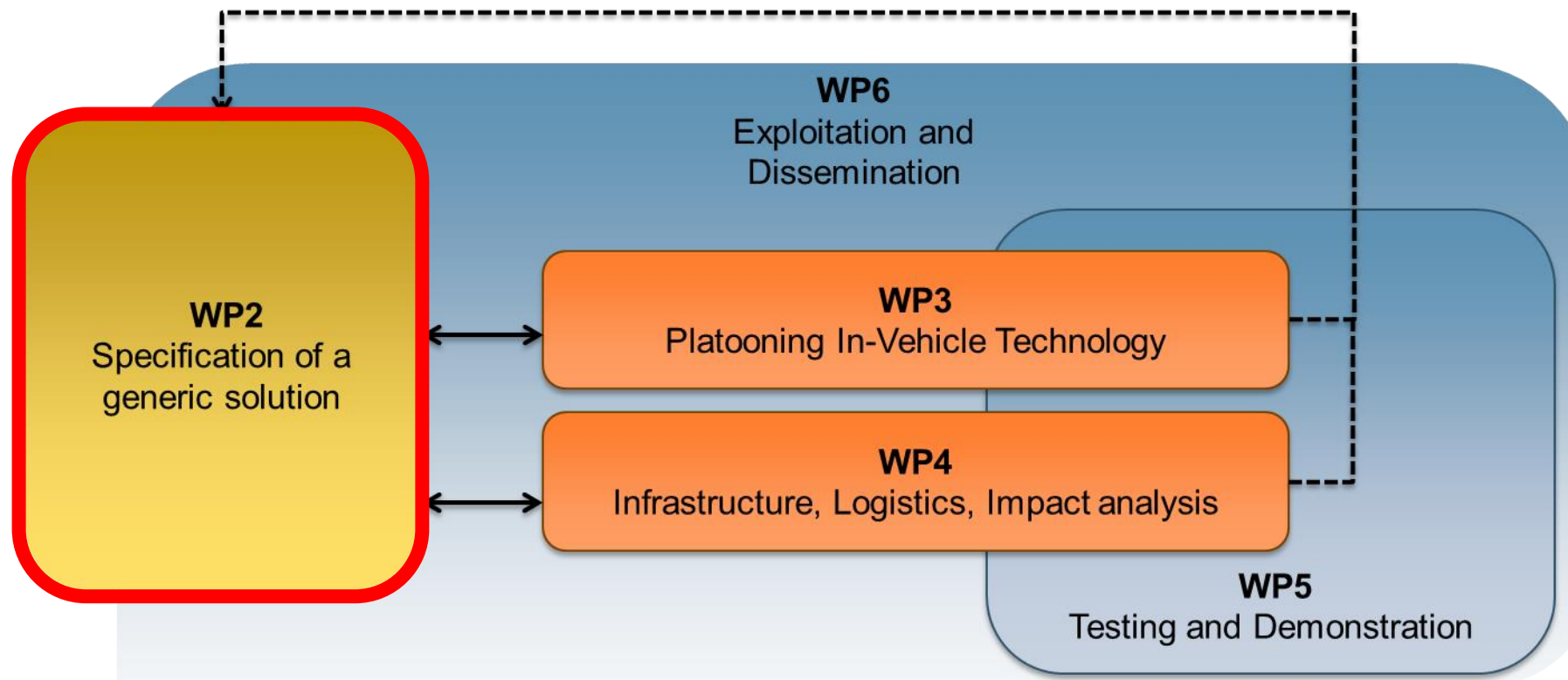- Platooning phases
- Communication
- Security

Conclusions

Introduction

Introduction – Designing a safe platoon

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WP2 – Specification of a generic solution

In charge of defining the specification for the whole multi- brand truck platooning concept

WP2 *Define Platooning Levels, use cases and req/spec*

WP3 use *WP2* inputs for implementation

WP4 use *WP2* inputs for impact analysis etc.

WP5 use *WP2* inputs to draft test cases

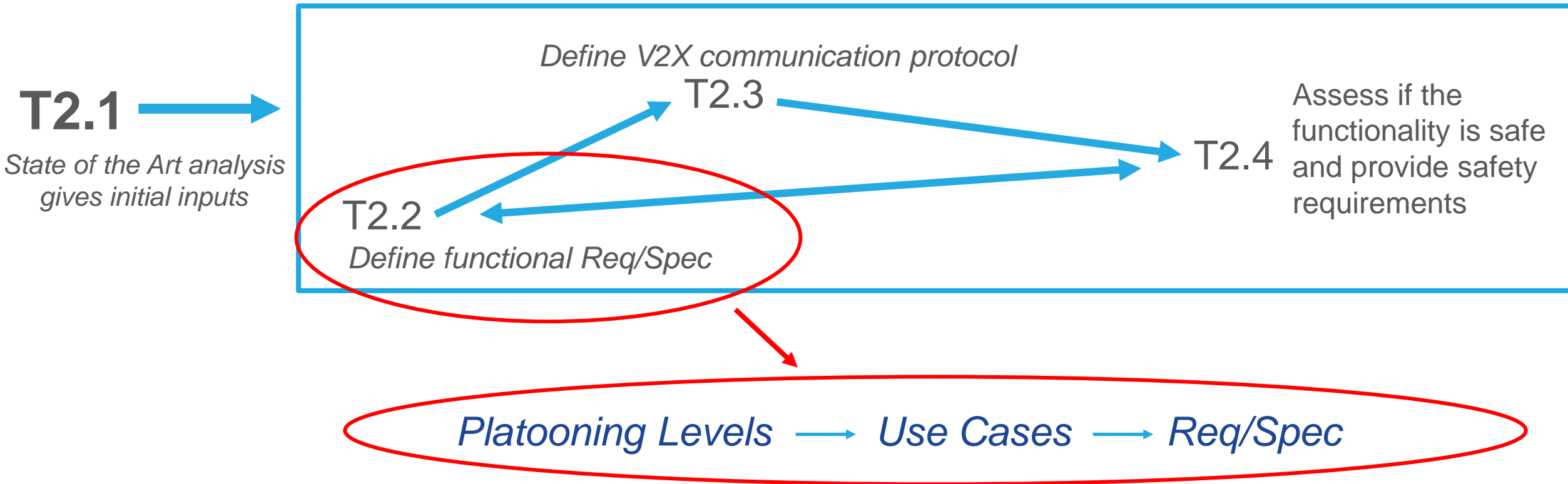**WP2** *receive inputs from WP3/WP4/WP5 to update spec/req*

Definition of Levels, Use Cases, Requirements and V2X Communication protocols

T2.1

State of the Art analysis gives initial inputs

Define V2X communication protocol

T2.3

T2.4

Assess if the functionality is safe and provide safety requirements

T2.2

Define functional Req/Spec

Platooning Levels → Use Cases → Req/Spec

Platooning Levels – Use Cases – Specifications and Requirements

Platooning Levels

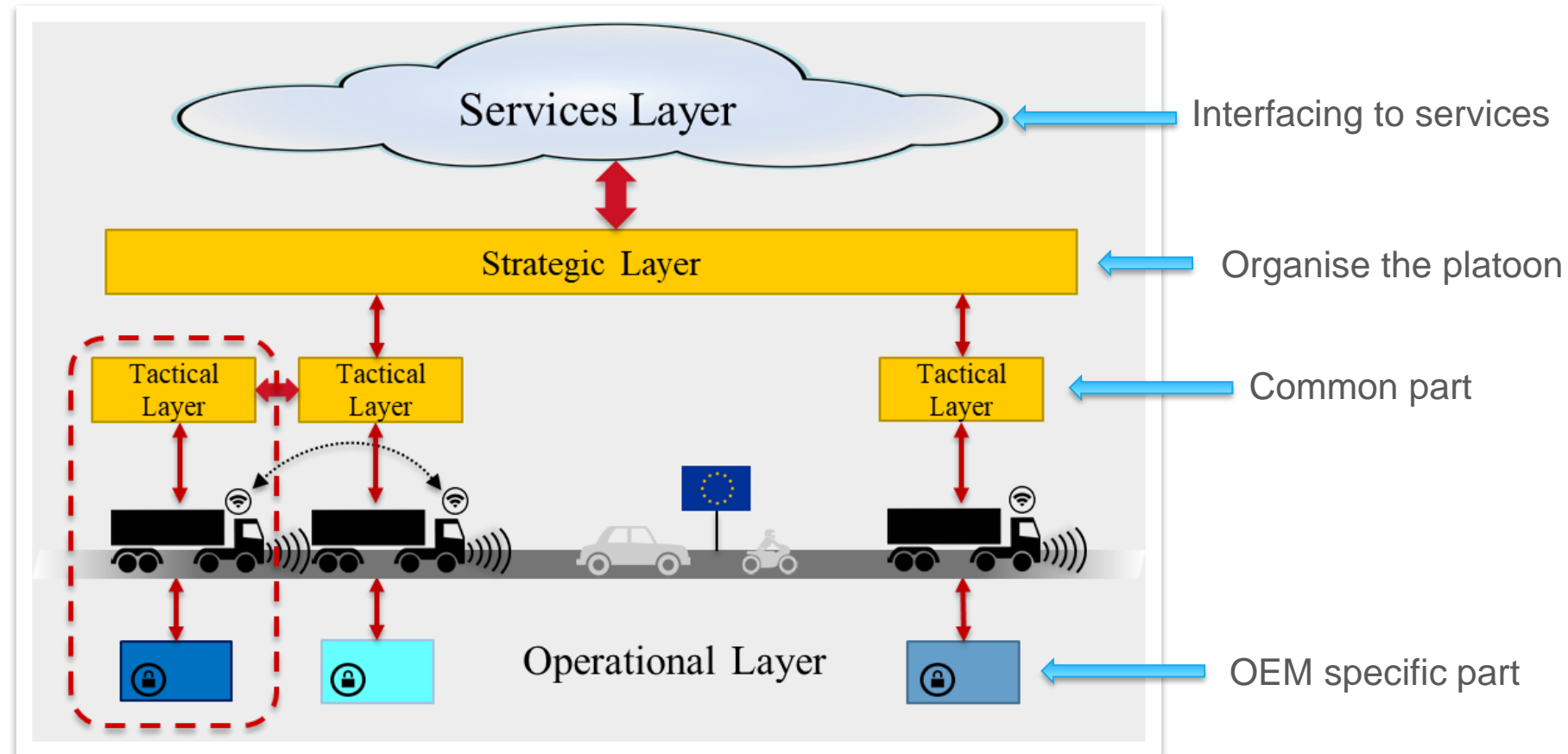1. **Platooning Support Function** (implemented – demonstrated)

   – Driver fully responsible of the Dynamic Driving Task
   – Support Functions like Platooning Longitudinal Control and Platooning FCW (Forward Collision Warning)
   – Time Gaps between 1,4s and 1,6s (OEM decision)
   – Improvement from V2X Communication

2. **Platooning Autonomous Function** (specifications and requirements only)

   – First truck driven by human
   – Following trucks with driver out of the loop (manned or unmanned)
   – Hub-to-Hub functionality with requirements for intelligent infrastructure
   – Time Gap between 0,3s and 1,2s (dependent on braking performance of ego truck)

Platooning Layers

- Basis concept of ENSEMBLE

- Common to both platooning levels

- Ensures multi-brand platooning

Services Layer — Interfacing to services

Strategic Layer — Organise the platoon

Tactical Layer — Common part

Operational Layer — OEM specific part

Introduction – P. Support Function

Platooning Levels → Use Cases → Req/Spec

- **Starting point is ACC (that has not been changed to still comply with regulations):**
  - *SAE Level 1 automation (support only), (ISO 15622, 22179)*
  - *Speed/distance regulation with minimum gap size setting between 1.4s and 1.6s (driver can anyway set different, larger, distances if preferred)*
  - *Limited decelerations (ACC cannot brake more than -3.5 m/s^2)*
  - *Lane keeping is optional (SAE Level 2) depending on specific OEM implementation*
  - *Follow to stop is mandatory*
  - *Automated start from standstill is optional*
- **The driver is therefore responsible for:**
  - *Entire Dynamic Driving Task (DDT)*
  - *Respecting traffic rules*

Introduction – P. Support Function

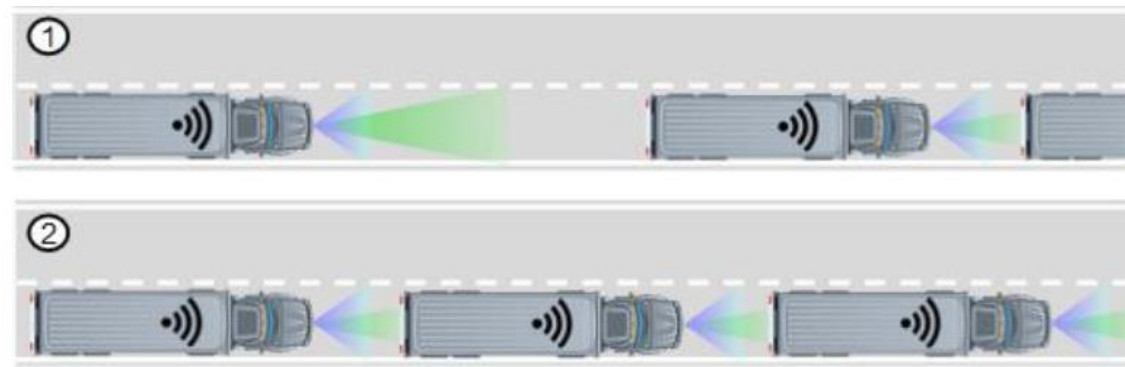**Platooning Levels** ⟶ *Use Cases* ⟶ *Req/Spec*

- **ENSEMBLE added the V2X communication part:**
  - *Earlier notification of emergency braking, due to V2V communication being faster than an onboard sensor (e.g. radar)*
  - *Platoon coordination: cohesion control, limited speed differences, better shockwave damping ('string stability'), roadside information (I2V)*
  - *More comfort and less stress for the driver (who is anyway still responsible)*
  - *Technology for communication is ITS-G5 but the protocol is technology neutral*
  - *This is different from a C-ACC (Cooperative Adaptive Cruise Control) and we have a set of messages designed for the specific platooning functionality*

Platooning Levels ⟶ **Use Cases** ⟶ *Req/Spec*

Engaging to platoon:

- *Two different situations to join from behind:*
  - *Join as a single vehicle*
  - *Join as a platoon*
- *Merge in-between as a single vehicle also possible*
- *This is the stage where the V2V communication is established, including cyber-security features*

Use Cases – Platooning Support Function 2

Platooning Levels → **Use Cases** → Req/Spec

Platooning:

- *The behaviour of the platoon is described*
- *Specific situations considered*
  - *Follow to stop*
  - *Emergency Braking*
  - *Gap adaptation*
  - *Cut-In*
  - *Cohesion Request*
 - *Warning for system issue*

Use Cases – Platooning Support Function 3

Platooning Levels ⟶ **Use Cases** ⟶ *Req/Spec*

Disengage Platoon:

- *Specific situations described depending on the role of the truck that is leaving:*
    - *Trailing Truck – Last one*
    - *Following Truck – In the middle of the platoon*
    - *Leading Truck – First truck*
- *Leave can be done by:*
    - *Activating a button*
    - *Pressing the brake pedal*
    - *Steering out from the platoon*
    - *Other issues (e.g. connection lost)*
- *The split of the platoon is also considered*
    - *Final condition with 2 smaller platoons*

Specifications – Overview – Platooning Support Function

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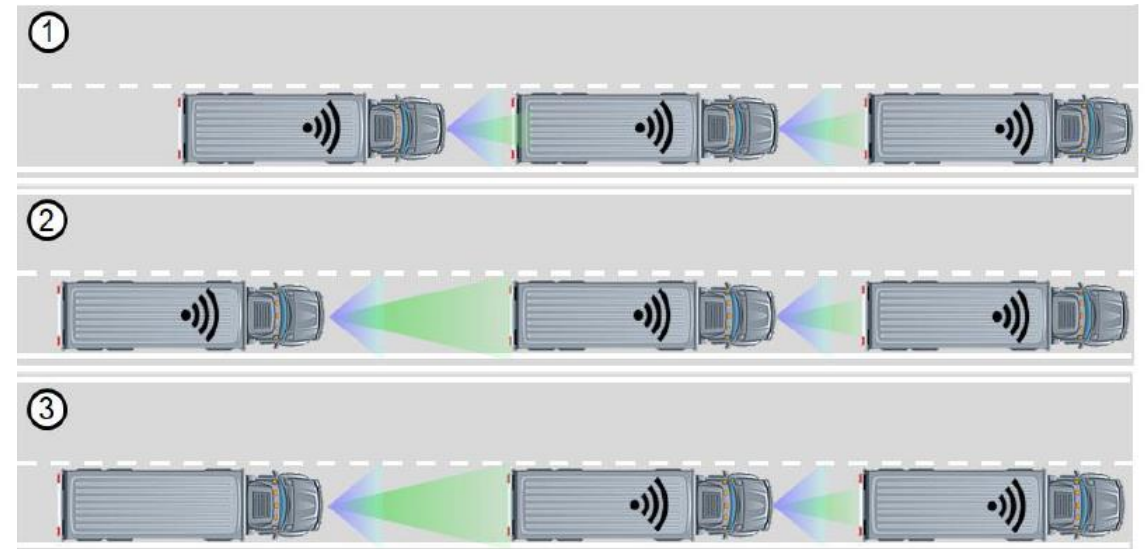
Platooning Levels ⟶ *Use Cases* ⟶ **Req/Spec**

Definition of functional Specifications/Requirements on:

- *Tactical Layer (Platoon Formation/Cohesion/Leaving)*
- *Longitudinal Support / Actuators (Speed/Gap adaptation/Emergency Braking)*
- *Sensing Technologies (Measuring distances, accelerations, positions…)*
- *V2V*
- *I2V*
- *HMI (Human Machine Interface)*

e.g. Long_Control_001: The driver shall be able to select a time gap to the preceding vehicle.

Functional Safety

Automotive Safety Integrity Level (ASIL):

| Probability of Exposure | **+** | Severity of harm | **+** | Controllability (by the people) | **=** | ASIL |

Low — ASIL (Automotive Safety Integrity Level) — High

QM   A   B   C   D

Higher degrees of risk result in more rigorous engineering requirements to ensure appropriate risk mitigation.

Platooning Support Function with deceleration limited to -3.5 m/s² has been declared as ASIL B.

Next Step - Platooning Autonomous Function

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Outlook on a future function with autonomous following trucks:

- From a support function to an autonomous function:
    - First truck driven by human
    - Following trucks with driver out of the loop (manned or unmanned)
- The strategic layer will support the platoon organisation
- V2X connectivity as an enabler for a "follow me" functionality
- Hub-to-Hub with requirements for intelligent infrastructure
    - Split of the platoon needs to be avoided
- Time Gap between 0,3s and 1,2s
    - The Braking Performance Estimation functionality will support the selection of the correct Time Gap for safe platooning
    - Potential fuel saving thanks to short time gaps when possibile

To be discovered in the final event

Communication Protocol

Communication protocol

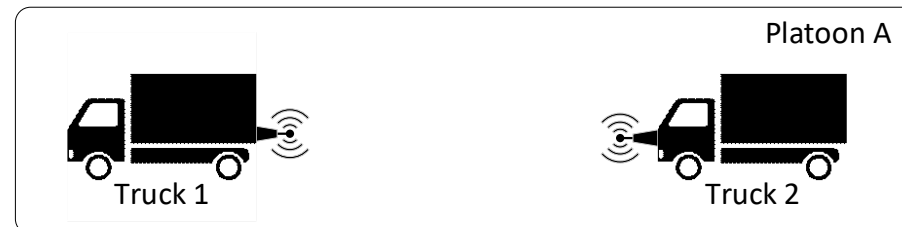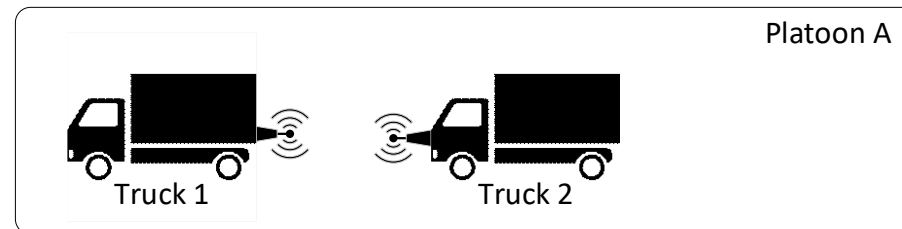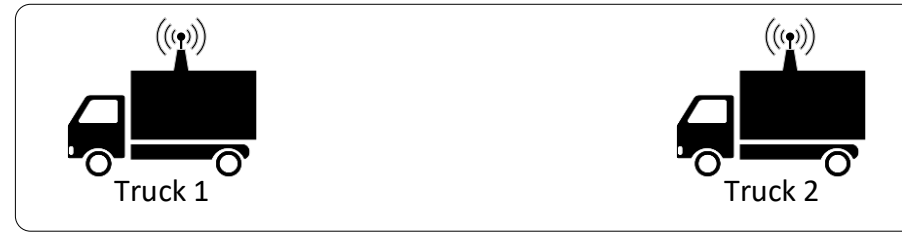**Key enabler for the platooning use cases:**

- Discovery of platooning capable trucks.

- Join trucks into a platoon.

- Drive stable at platooning distance.

- Orchestrate braking.

Platooning phases

Platooning phases

- Standalone trucks

- Platoon join

- Platooning trucks

- Platoon split/leave

Truck 1   Truck 2

Truck 1   Truck 2

Platoon A

Truck 1   Truck 2
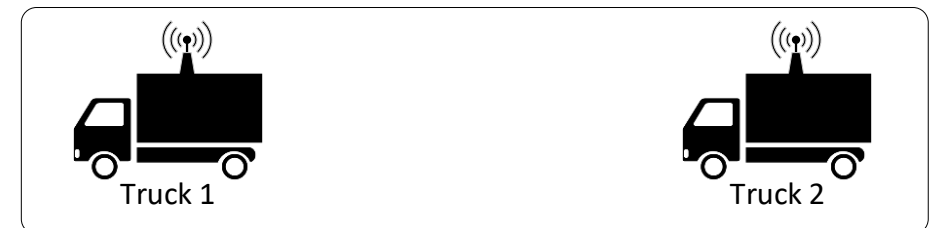
Platoon A

Truck 1   Truck 2

Communication

Communication

Standalone trucks:

- Truck is controlled by driver.

- Find another truck to platoon with.

- Each truck publishes its platooning capabilities.

- Use of ETSI CAM message.

  – Extended with PlatooningContainer. Through this container the platooning capability can be published.


Truck 1   Truck 2

Communication

Platoon join:

- Establish a relation between two trucks, to either create a platoon or join an existing platoon.

- The joining truck sends a request. The truck to be joined sends a response to either accept or reject the join.

- Use of new PlatoonManagement messages (PMM):
  - PMM JoinRequest.
  - PMM JoinResponse.

Truck 1   Truck 2

Communication

Platooning trucks:

- Keep platoon intact while driving at platoon distance.

- Eack truck broadcasts control information. This information is used by the neighboring trucks.

- Use of new PlatoonControl messages (PCM). This message contains information on position, configuration, control parameters, shared status.

Platoon A

Truck 1   Truck 2

Communication

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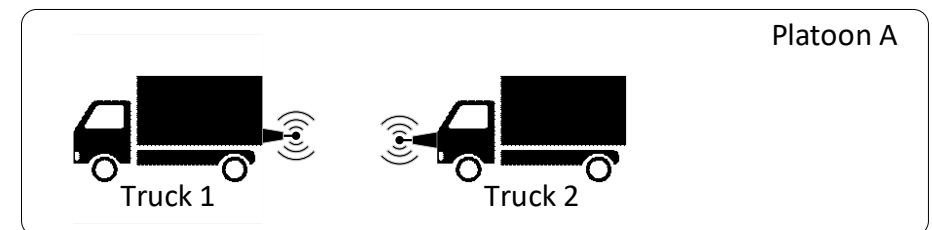
Platoon split/leave:

- Keep platoon intact while increasing distance.

- At safe distance control is given to the driver.

- Continued use of PCM messages until safe distance is reached.

Platoon A

Truck 1   Truck 2

Security

Security
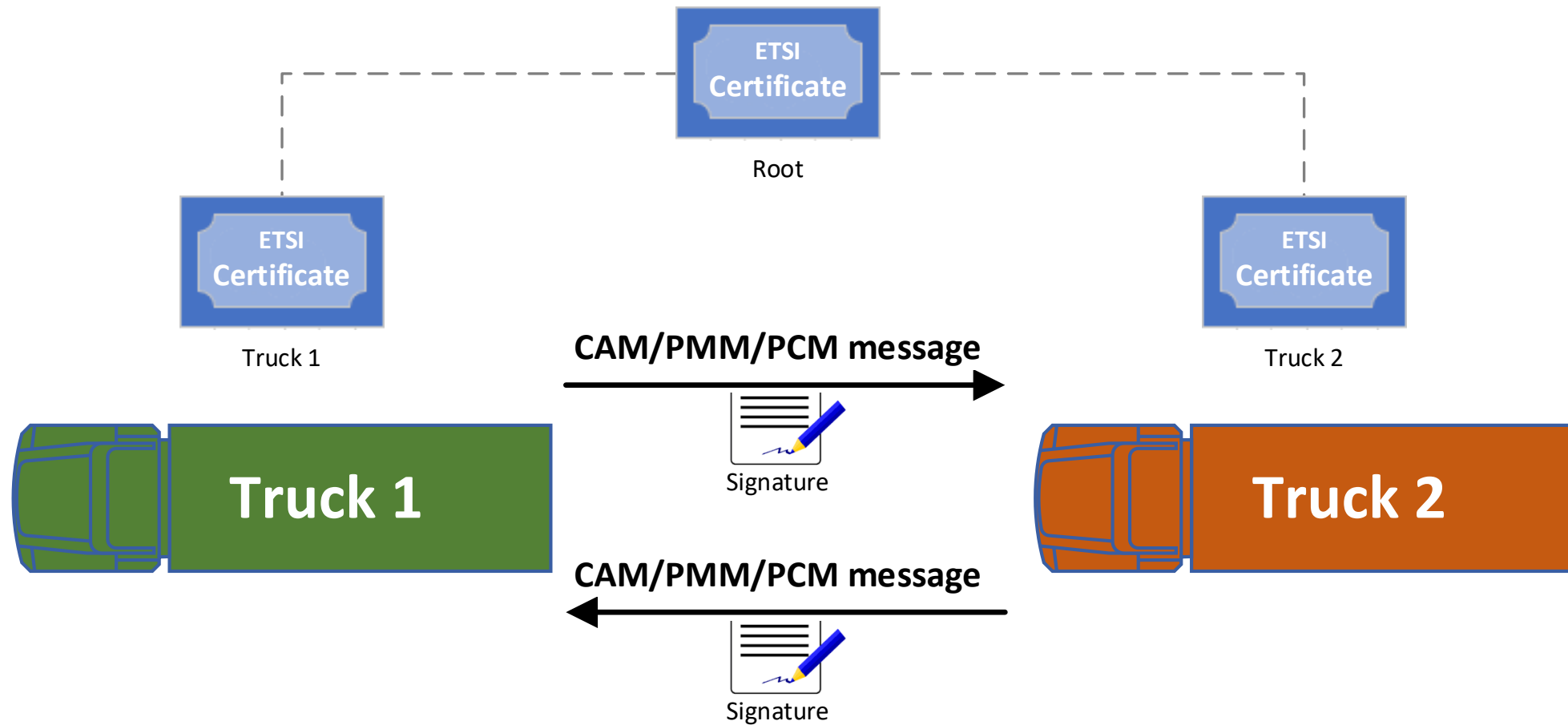
Protocol security goals:

- Well established security mechanisms:
  - Messages are not be changed.
  - Messages are sent by a trusted vehicle.
  - Contents of messages remain secret.

Security

Protocol security aspects:

- Message signing. Common in ETSI messages.

  – Message authentication: Message is not changed and coming from a trusted vehicle.

- Message encryption. New in platooning.

  – Asymmetric encryption: Used when joining a platoon.

  – Symmetric encryption: Used when a platoon is active.

Asymmetric encryption	Symmetric encryption
🟢 No shared key required	🟢 Fast
🔴 Slow	🔴 Shared key required

Signing: All messages

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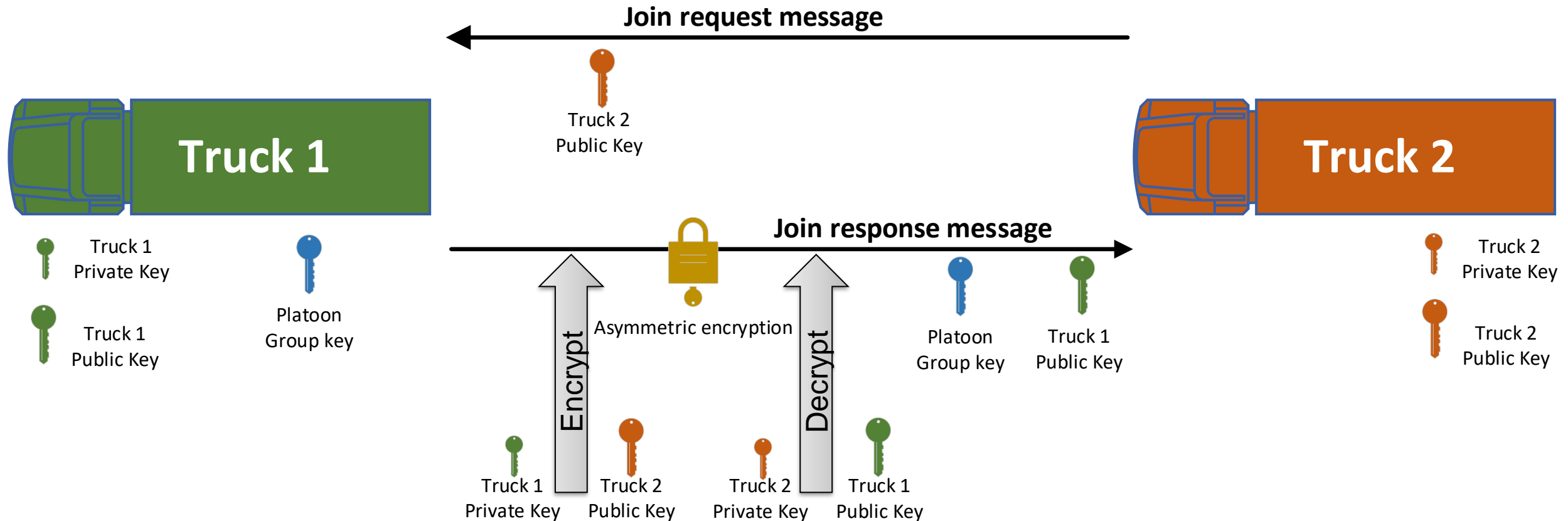
Encryption, asymmetric: Platoon join

Encryption, asymmetric: Platoon join

ETSI Certificate
Root

ETSI Certificate
Truck 1

ETSI Certificate
Truck 2

Join request message

Truck 2 Public Key

Signature

Join response message

Signature   Asymmetric encryption

Platoon Group key   Truck 1 Public Key

Truck 1

Truck 2

Truck 1 Private Key

Truck 1 Public Key

Platoon Group key

Truck 2 Private Key

Truck 2 Public Key

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Security
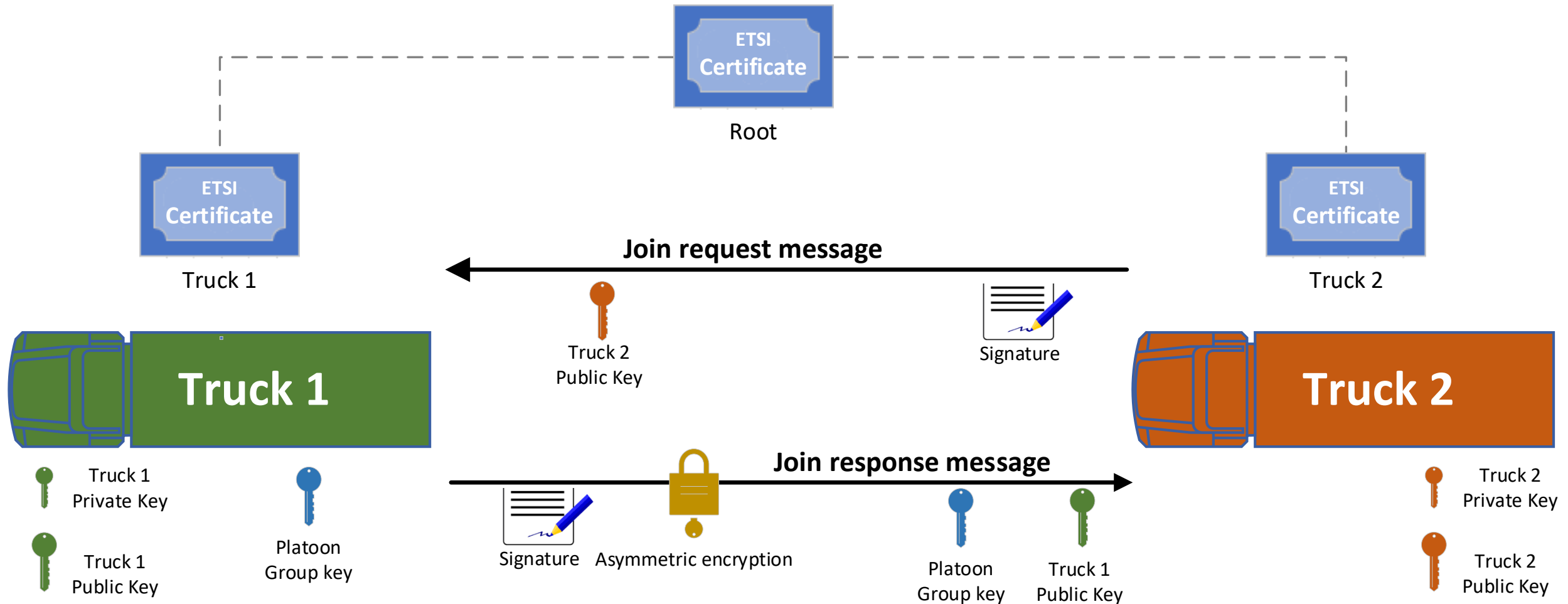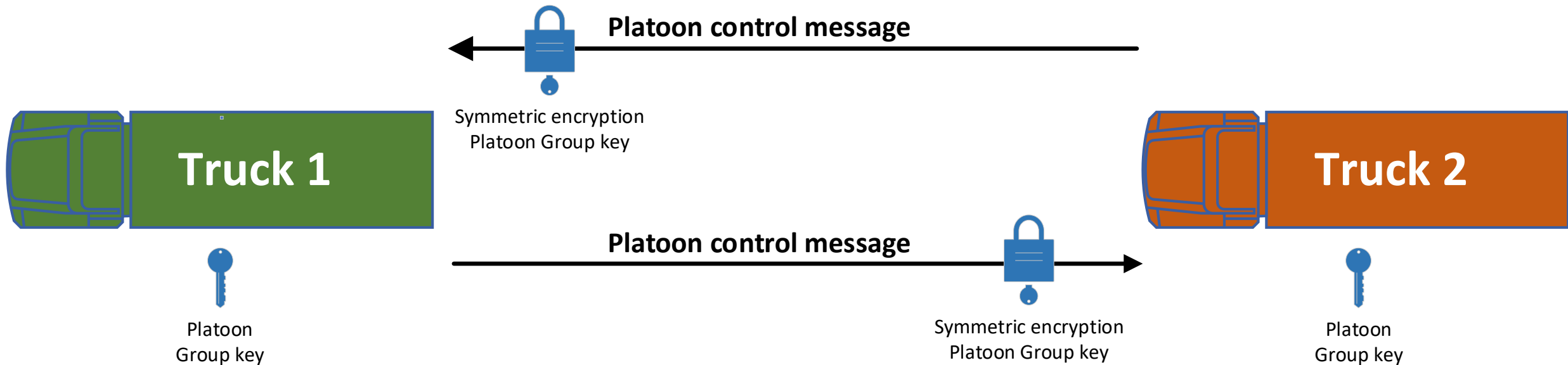
Encryption, symmetric: Platoon active

Platoon control message

Symmetric encryption
Platoon Group key

Truck 1

Platoon control message

Symmetric encryption
Platoon Group key

Truck 2

Platoon
Group key

Platoon
Group key

Encryption, symmetric: Platoon active

ETSI Certificate

Root

ETSI Certificate

Truck 1

ETSI Certificate

Truck 2

Platoon control message

Symmetric encryption
Platoon Group Key

Signature

Truck 1

Truck 2

Platoon control message

Signature

Symmetric encryption
Platoon Group Key

Platoon
Group key

Platoon
Group key

Security

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Platooning phases summary:

- Standalone trucks: Signing.

- Platoon join: Asymmetric encryption + signing.

  – The platooning key is distributed in the encrypted message.

- Platooning trucks: Symmetric encryption + signing.

  – The platooning key is refreshed every minute.

- Platooning split/leave: Symmetric encryption + signing.

  – The platooning key is refreshed every minute, using the new KeyUpdate mechanism.

Conclusions

Conclusions

- Multi-Brand Platooning has been made possible:
  - Specifications and Requirements agreed by 7 different OEMs
  - Iterative process into the project to ensure safety
  - A broad set of Use Cases has been taken into account
- A dedicated platooning communication protocol has been created:
  - Including cybersecurity features
  - Input for standardization bodies
- Next Step – Platooning Autonomous Function

Thank you for your attention

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