Summary of brake systems on Shift2Rail

TD 1.5 - Brake Systems Demonstrator：

New braking systems (TD 1.5) with higher brake rates and lower noise emissions will provide major capacity gains in terms of mass and volume in bogies, paving the way for a fresh revisit of bogie design. When these are combined with traction innovations, the next generation of passenger rolling stock will be able to offer improvements in acceleration and deceleration rates, leading to greater overall line capacity for trains.

新的制动系统将具有更高的制动率和更低的噪声，它的成功应用将使得转向架在重量和体积方面获益。新制动系统和牵引系统的联合创新设计，将使得下一代客运车辆在加速度、减速度方面获得提升，实现列车更大的运力。

制动系统的技术示范涉及 6 个 S2R 研究项目，分别是：

- PINTA：2016 年 9 月 1 日～2018 年 12 月 31 日
- CONNECTA：2016 年 9 月 1 日～2018 年 9 月 30 日（互补项目 SAFE4RAIL，2016 年 10 月 1 日～2018 年 12 月 31 日）
- SAFE4RAIL：2016 年 10 月 01 日～2018 年 12 月 31 日
- PIVOT：2017 年 10 月 1 日～2019 年 12 月 31 日
- PINTA2：2018 年 9 月 1 日～2020 年 11 月 30 日（互补项目 RUN2RAIL，2018 年 9 月 1 日～2019 年 9 月 30 日）
- PIVOT2：2019 年 10 月 1 日～2022 年 12 月 31 日

1.PINTA

2016.09.01-2018.12.31：TRACTION TD1 AND BRAKES TD5 – PHASE 1

D7.3: Performance Requirements Specification for Adhesion Recovery Systems
D8.1: Adhesion modelling Specification

WP07 - ADHESION DETECTION AND LOW ADHESION MANAGEMENT

The objective of this work package is to map different adhesion conditions occurring in rail traffic. With the resulting adhesion catalogue, predictions to adhesion conditions dependant on seasonal influences and locations can be given. This data collection is the basis for a standardized adhesion detection concept.

WP08 - ADHESION MODELING AND LABORATORY & TRACK REPRODUCTION SYSTEMS

The main objective of this WP is to specify and realise a WSP (Wheel Slide Protection) test bench demonstrator based on the results of WP7. Test bench design objectives are:

- Reproducibility of test results.
- Reproducibility of real track test results.
- Standardized interoperable test method and reporting.
- Reduce the number of track tests needed for certification of WSP systems.
- Proposal for EN, UIC, etc. standards up to date to promote standard test rigs for WSP certification

Within the work package objectives, an adhesion model will be developed to better reproduce in laboratory the real low adhesion conditions happening on track. Based on the adhesion model standard test benches will be defined for the realisation of approval tests for low adhesion management systems, e.g. friction and/or electrical wheel slide protection

制动系统的示范涉及 PINTA 项目的 2 个工作包：

- 工作包 7：粘着检测和低粘着管理。其目标是绘制出铁路交通中出现的不同粘着工况；根据识别出的粘着类别，可以对不同季节影响和位置的粘着工况做出预测。这方面数据的收集是标准化粘着探测的基础。
- 工作包 8：粘着建模和试验室&轨道再现系统。其目标是在 WP7 的基础上定义和制作一个车轮防滑测试台。

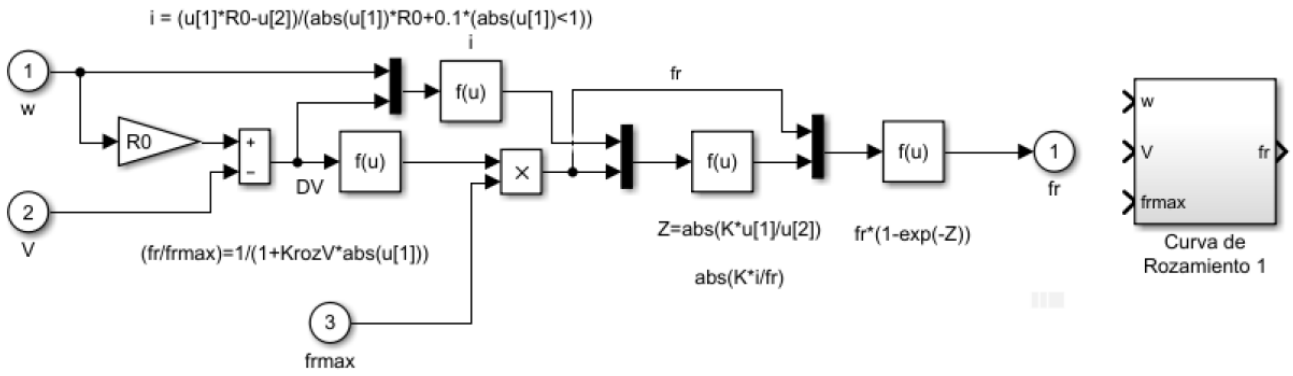
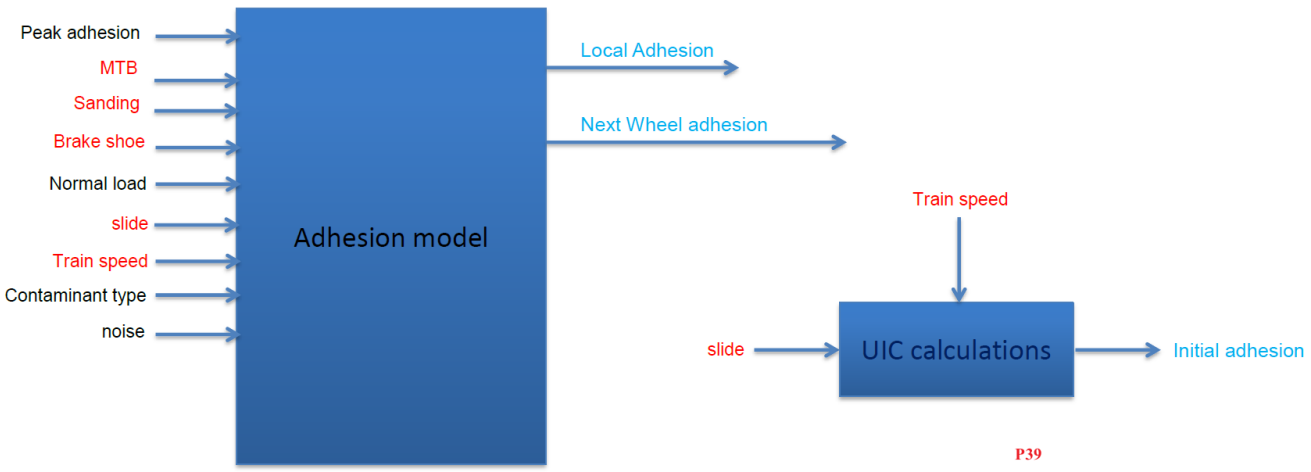


Figure 12: Adhesion curve model block in SIMULINK.

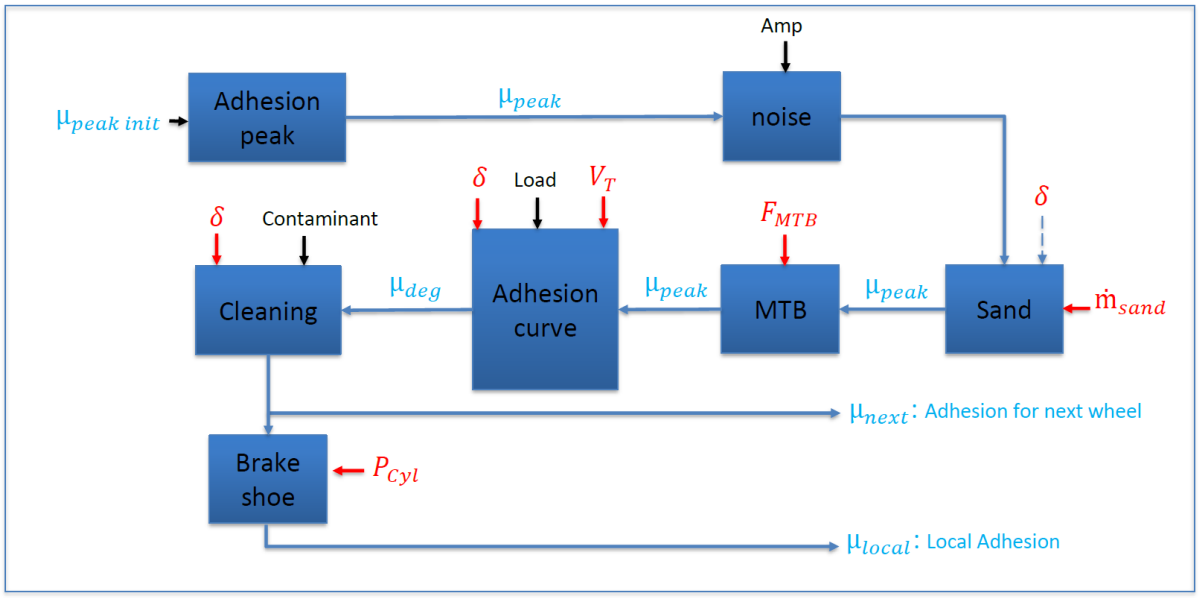
P34

Adhesion Model: Inputs/outputs

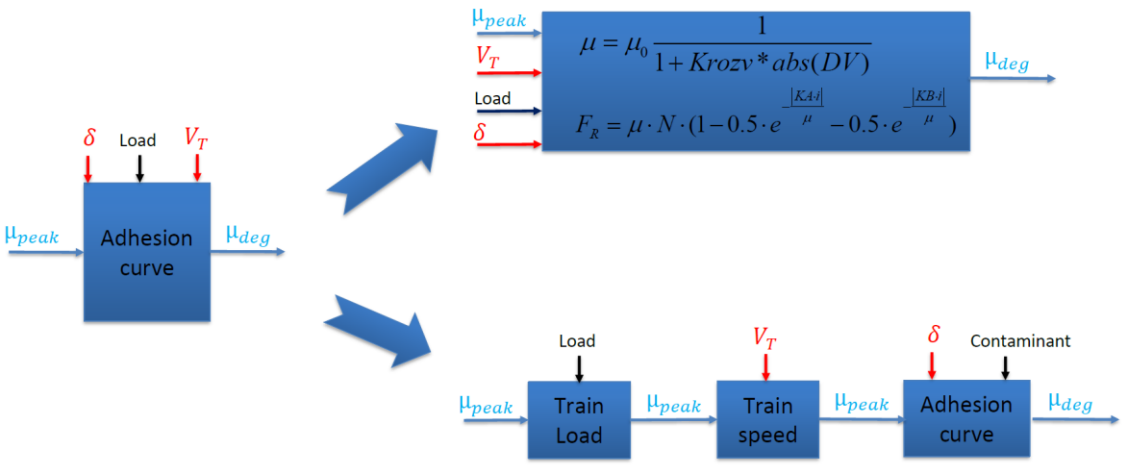


P39

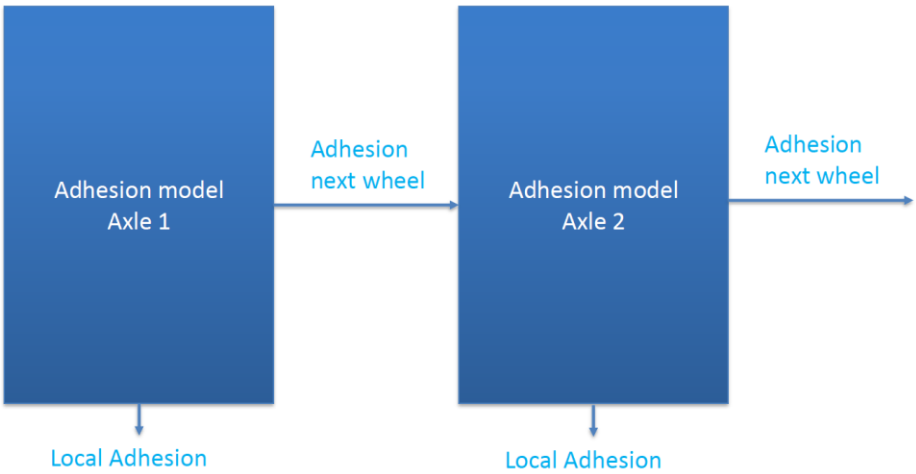
Adhesion Model: Submodels P40



Adhesion Model: Adhesion curve submodel P41



Adhesion Model: successive wheels P42



8.2.1.1 - Assessment of initial adhesion (braking force) P44

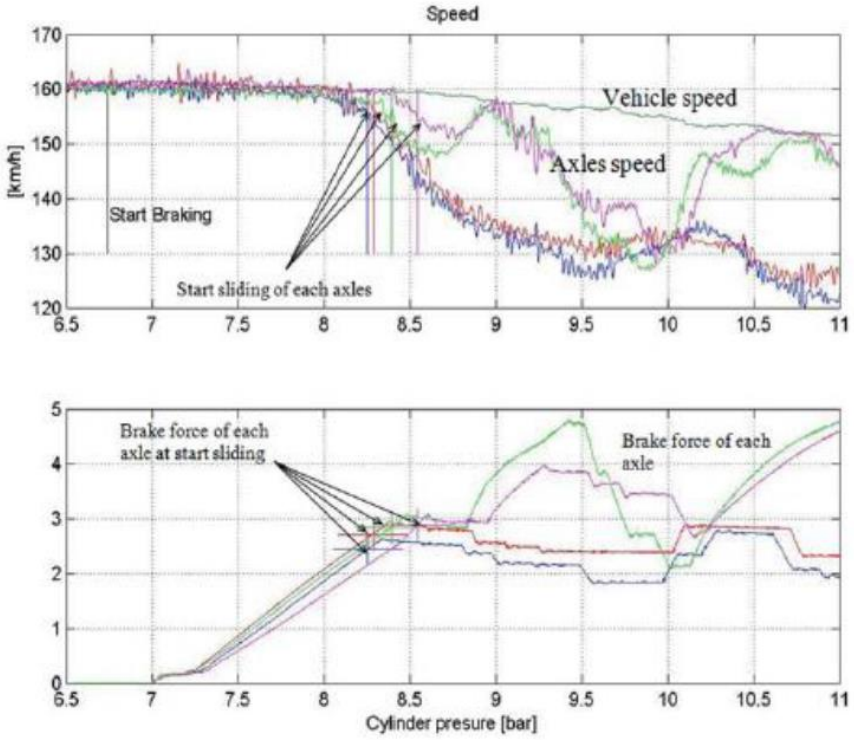
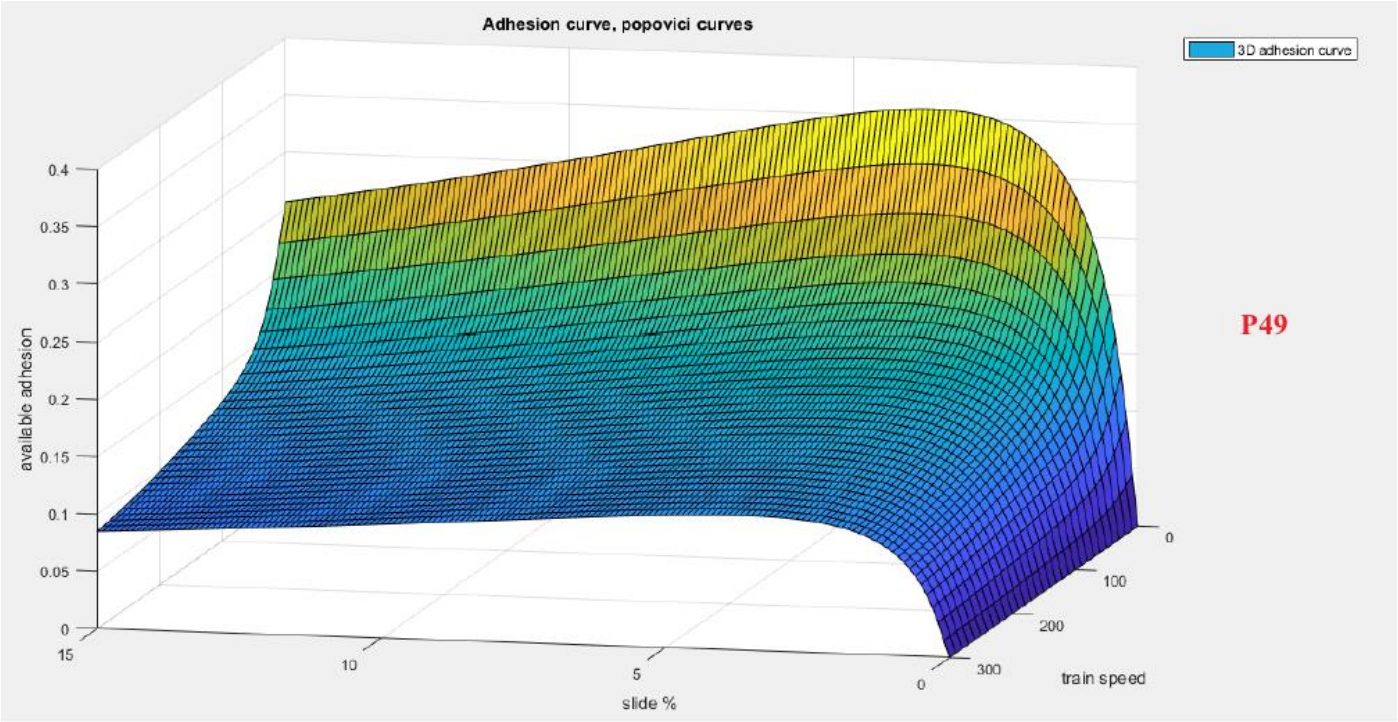


Fig. 6 - Assessment of initial adhesion



P49

Figure 20: 3D plot of the influence of the speed on the adhesion curve, using adhesion curve1 (Popovici, 2010)

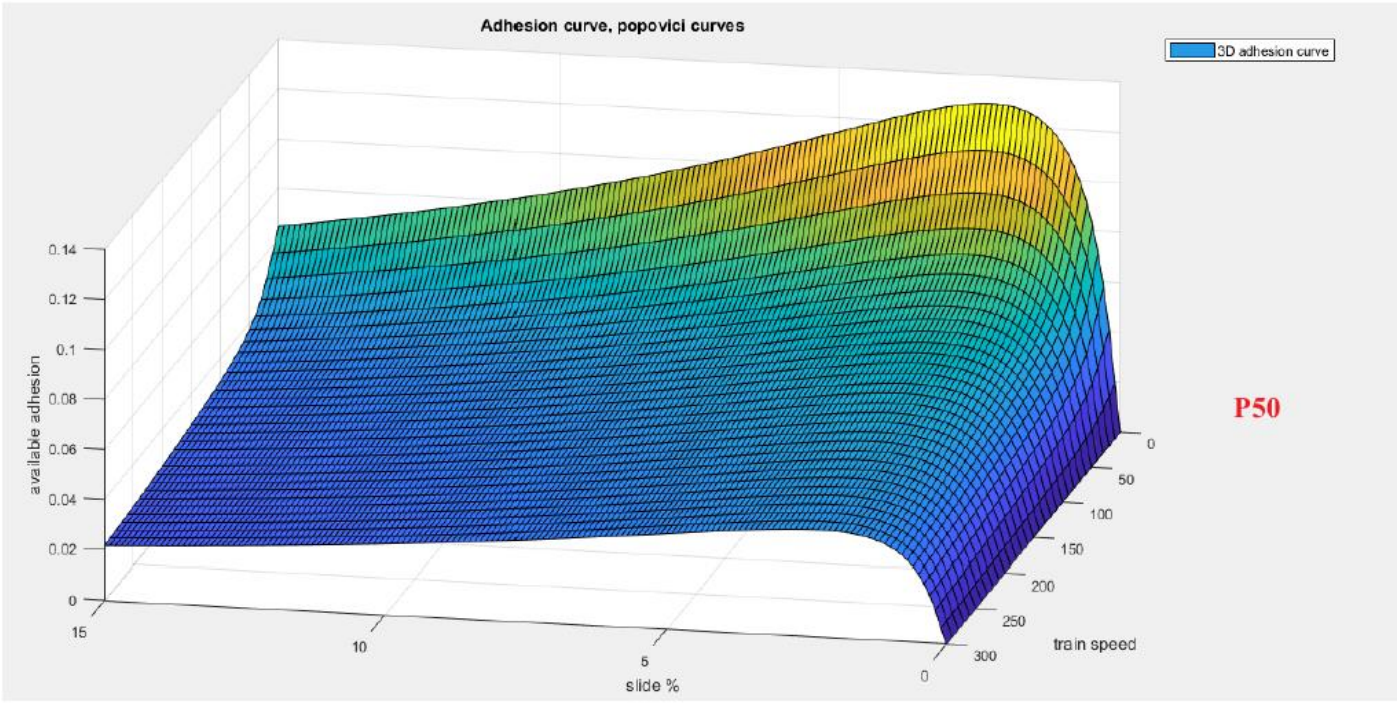


Figure 21: 3D plot of the influence of the speed on the adhesion curve, using adhesion curve3 (Popovici, 2010)

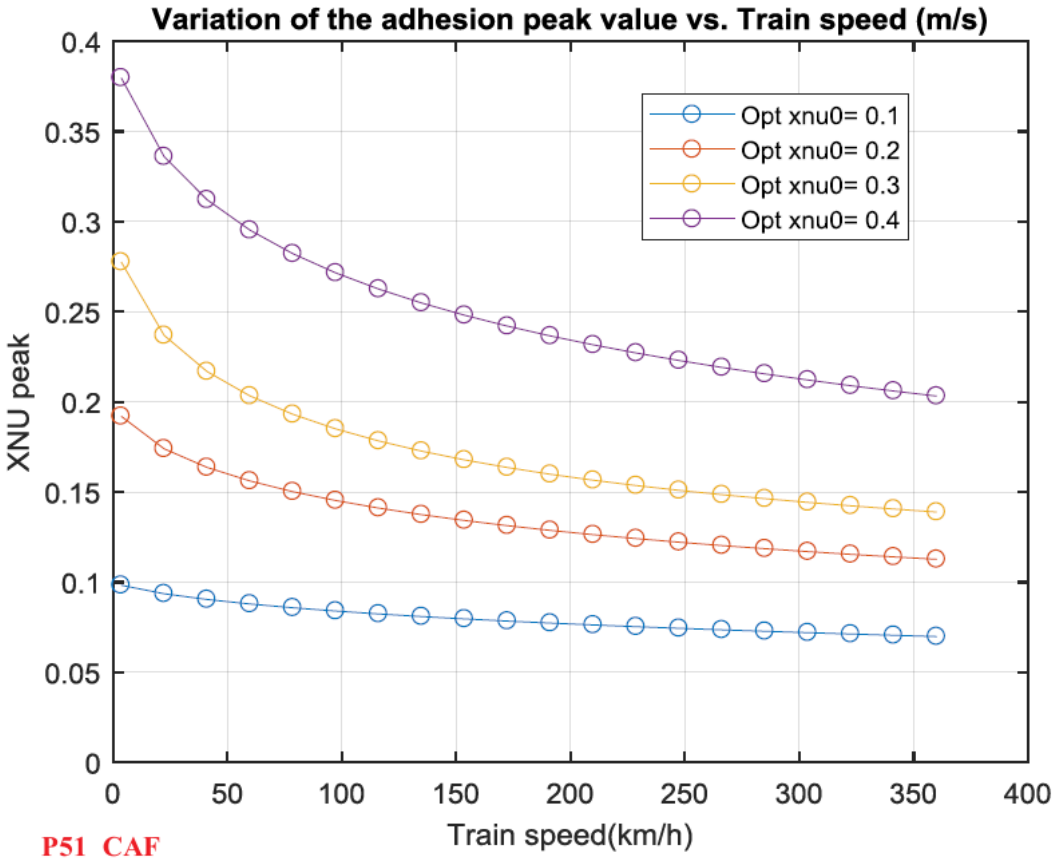
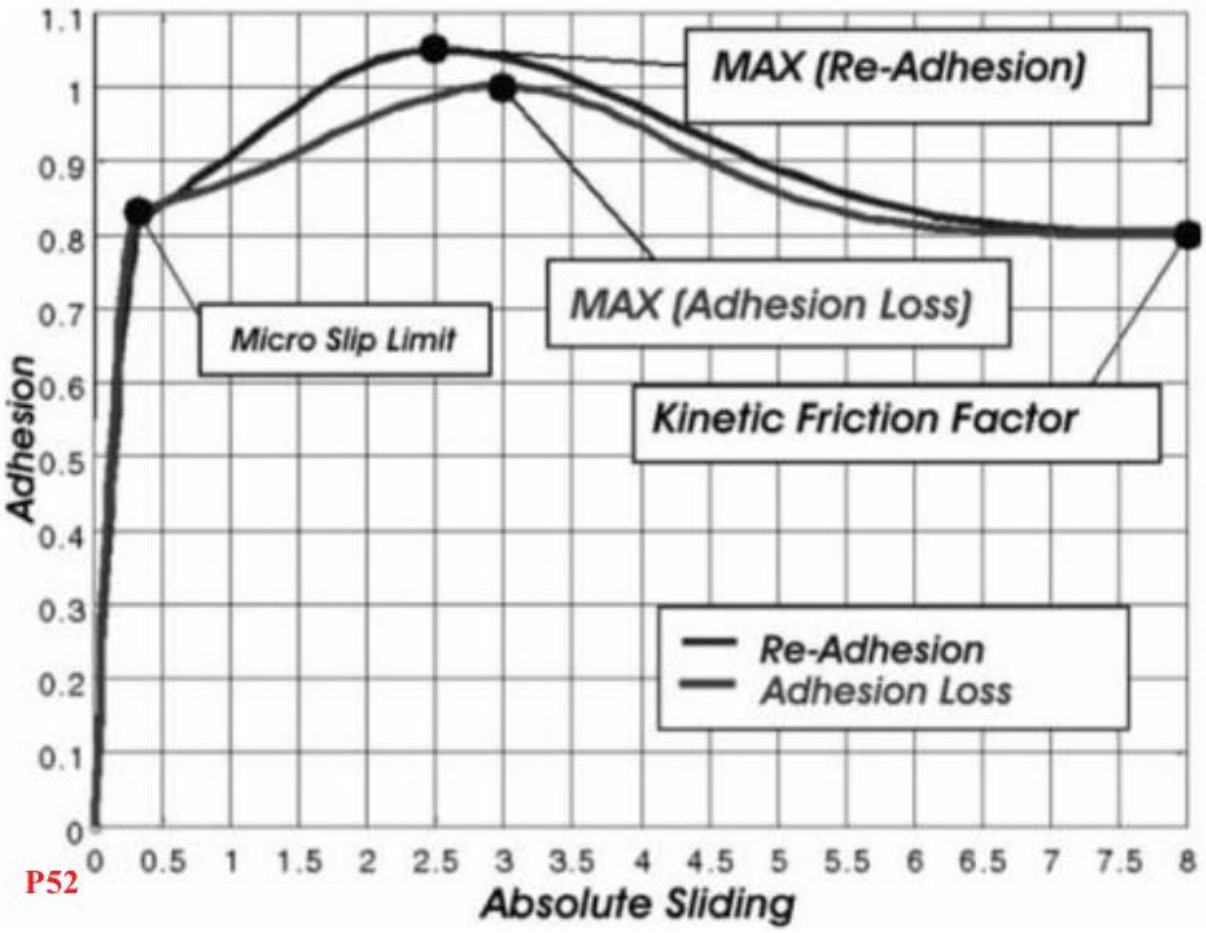
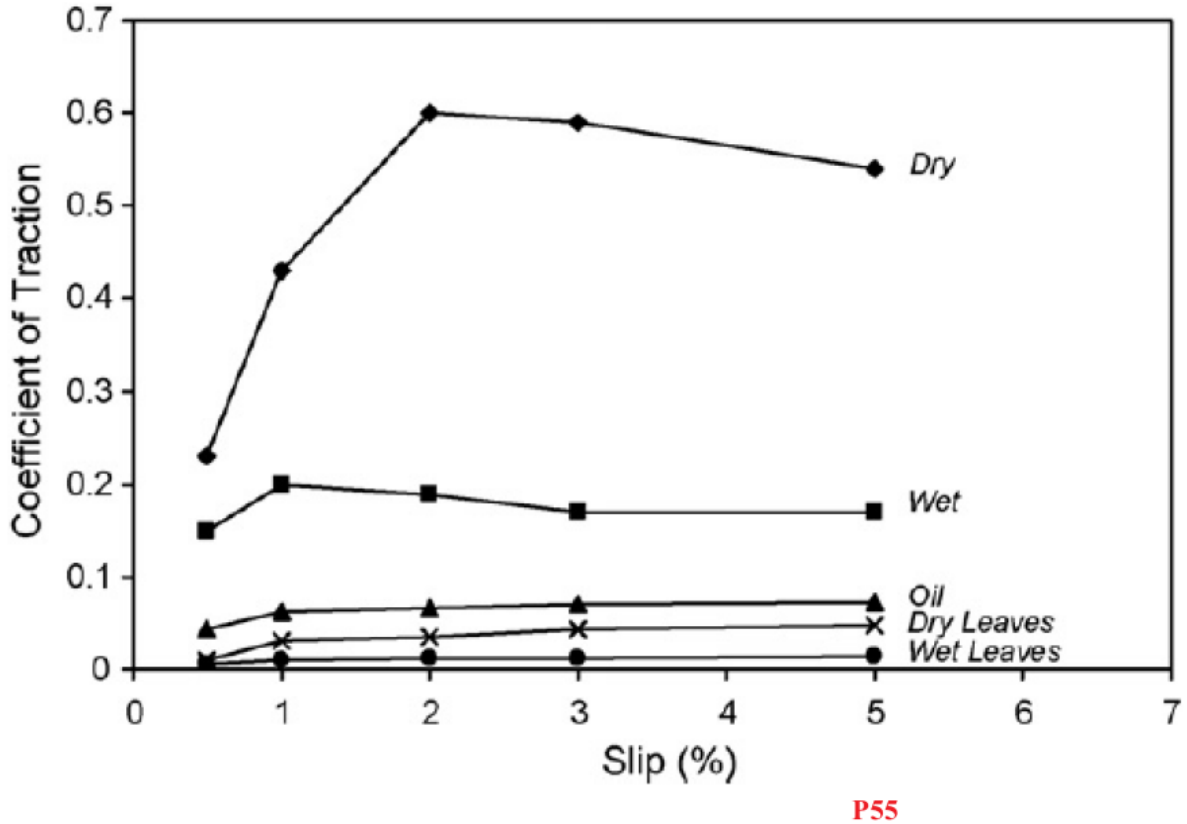


Figure 22: Adhesion peak variation with the speed for μ_0=0.1, 0.2, 0.3, 0.4.

Figure 23: Hysteresis phenomenon, first example (L. Pugi)



P52



P55

Figure 27: Dry and wet slip curves based on roller rig tests (Gallardo-Hernandez and Lewis)

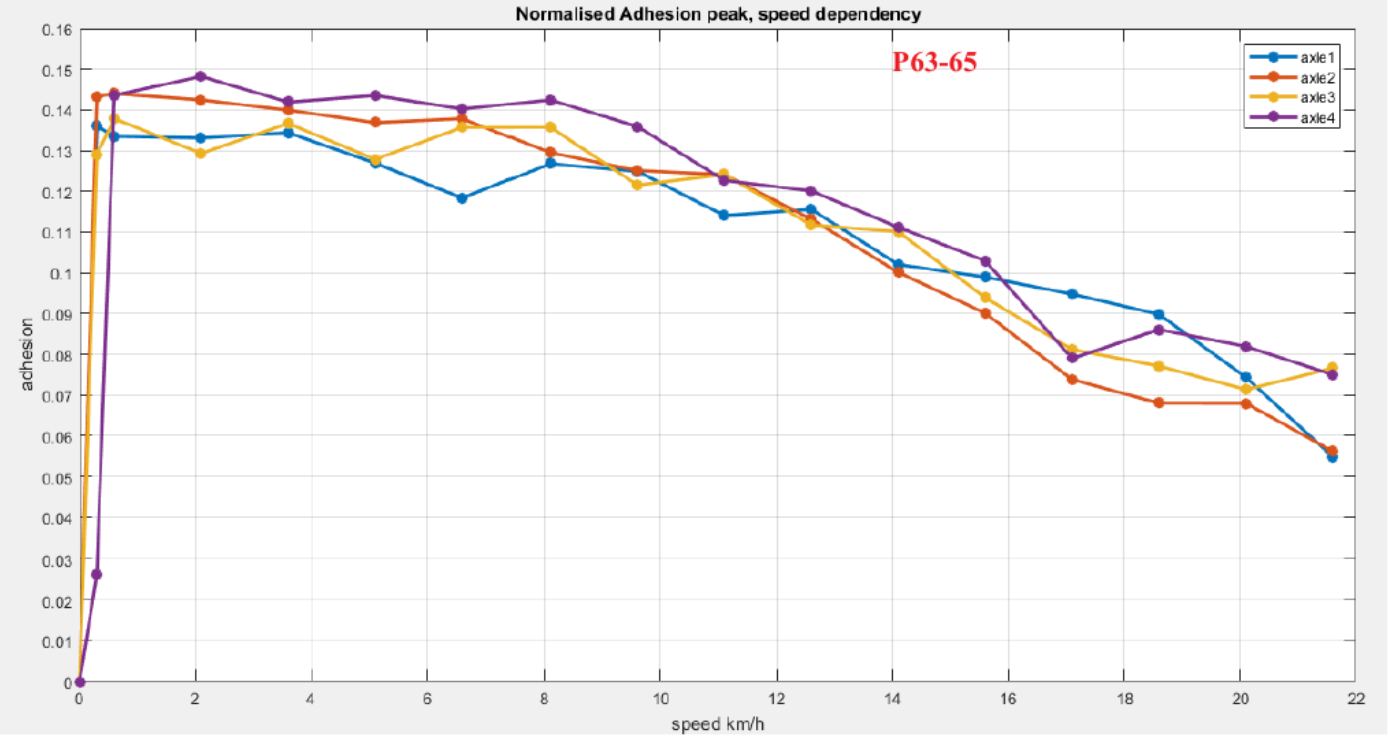


Figure 40: Adhesion curves with soap contaminant based on real data, Axle 1,2,3,4, second filter

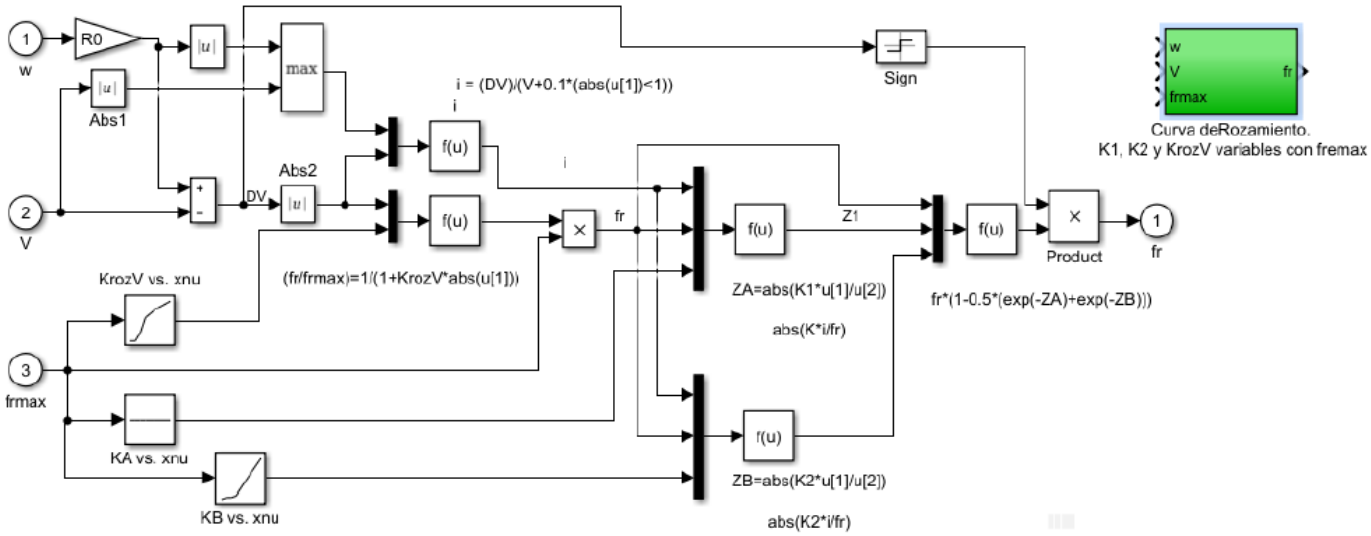
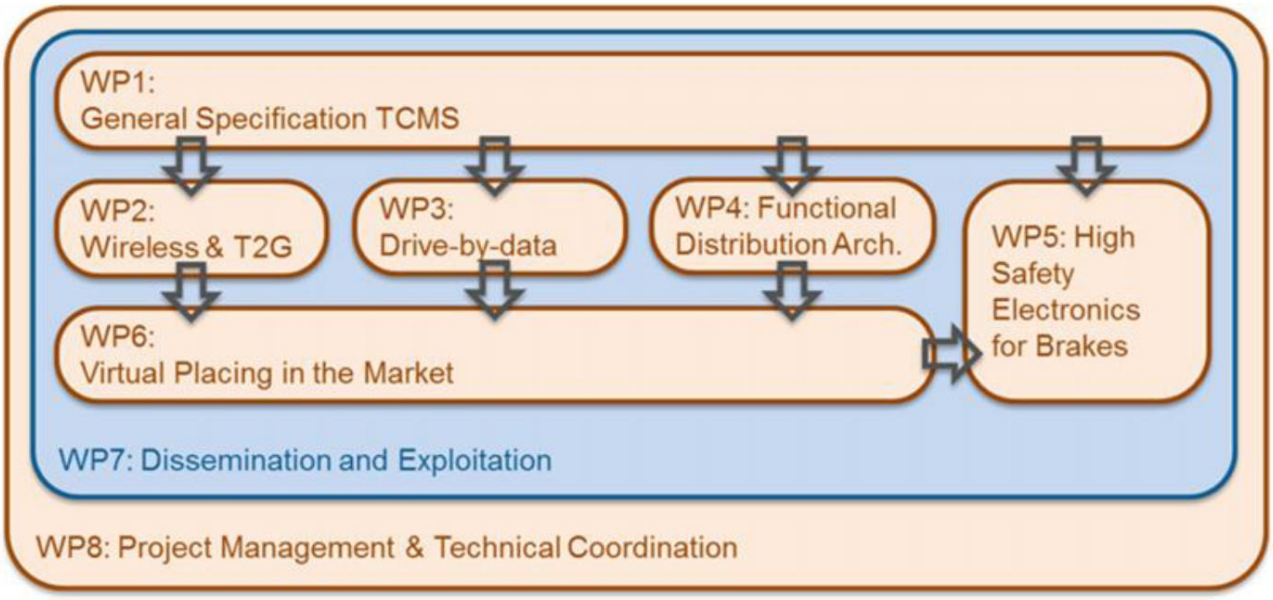


Figure 61: NEW Adhesion curve model block in SIMULINK. P86

在 D7.3 中定义了对于撒砂系统的需求。

2.CONNECTA

2016.09.01-2018.08.31： CONTRIBUTING TO SHIFT2RAIL'S NEXT GENERATION OF HIGH CAPABLE AND SAFE TCMS AND BRAKES



D5.1 System Brakes Architecture Report SySBAR

Architecture report for the new generation of brake electronics

Download

D5.2 Brake System Requirements

Specification of the new brake system with safe electronics

Download

D5.3 Preliminary Safety Report

Preliminary safety concept, planning, strategy, architecture and analysis for the next generation of safe brake electronics.

Download

D5.5 Safety Assessment Report

Final safety assessment report on the brake-by-wire technology

Download

D5.1: System Brakes Architecture Report

D5.2: System Requirements

D5.3: Preliminary Safety Assessment Report

Annex I

Annex II

D5.5: Safety Assessment Report

WP5 - HIGH SAFETY LEVEL ELETRONIC SOLUTIONS FOR BRAKE CONTROL

This work package aims to develop an electronic HW-SW architecture designed to manage all the braking functions (service, holding, emergency, safety brake, wheel slide protection) according to proper high safety levels (SIL3, SIL4).
Main objectives are:

- Performance improvement in safety relevant braking functions resulting in optimisation of the braking distances in safety braking
- On board system optimisation, reducing the number of sophisticated pneumatic components, improving overall LCC
- Use of communication standards carrying high SIL related information coordinated with WP3
- Validation of non-railway EN standards to be used in railways safety related application.

制动系统的示范涉及 CONNECTA 项目的 1 个工作包：

- 工作包 5：用于制动控制的高安全等级的电子解决方案。其目标是开发一个电子装置的软件-硬件架构，它将根据适当的 SIL 来管理所有制动功能（常用、保持、紧急、安全制动、车轮防滑）。

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4 Conclusions 145

和制动相关的各方面接口

制动力类型和制动功能分解

每一个功能的定义

制动各子功能细化

CTA-D5.1-3

1 EXECUTIVE SUMMARY

The contents cover and are well aligned with the CTA Grant agreement for WP5 Task 1 “Brake System Architecture”, in details:

分析的制动系统仅限制于高速列车和动车组

- Chapters from 3.1 to 3.3 describe the scope, gives an overview of brake system and describe the metodology used for the funtional analisys and the safety analisys. The analised brake system are limited to the High Speed train and Multiple Units. The functional analisys uses most of the concept and method of WP1 D1.1 “Workflow methodology”. The safety analisys method is based to the Europeean relevant standard.

It shows nearly all the actors and systems which are interacting with brake system on a train.

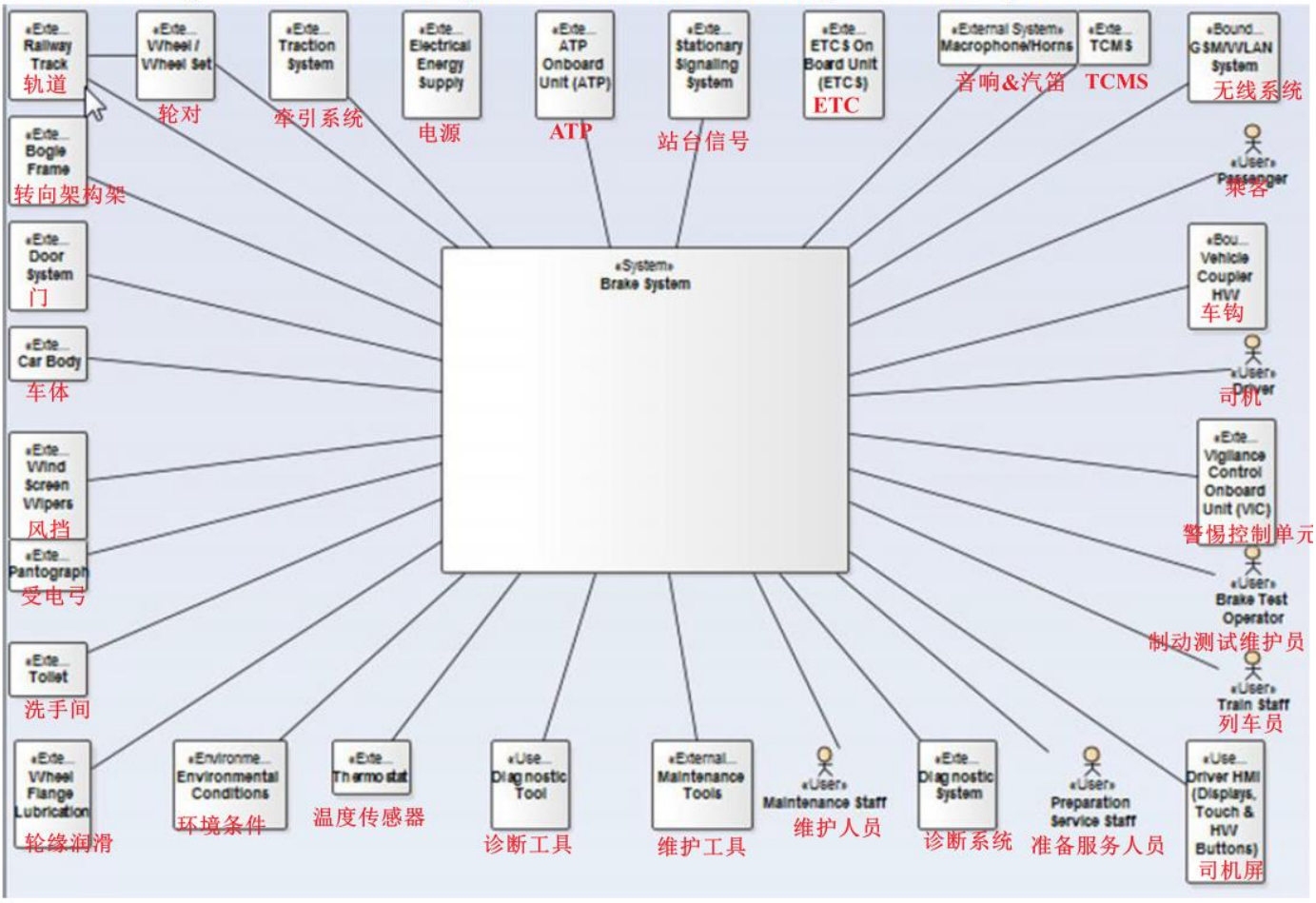


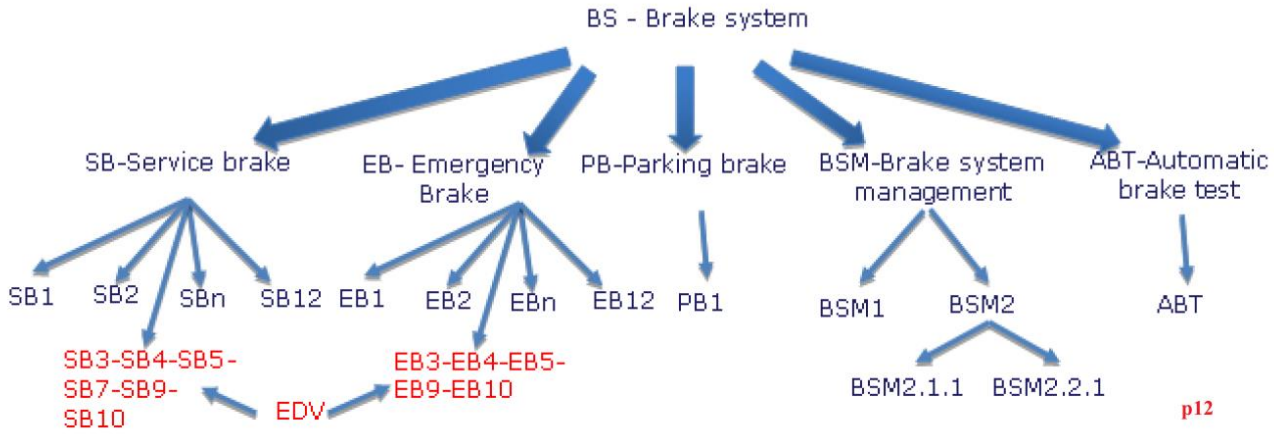
Figure 1: Context Diagram of the Braking System

Brake system can involve different type of brakes used to generate brake forces:

- friction brake,
  - disc brake (adhesion dependent),
  - tread brake (adhesion dependent),
- dynamic brakes
  - ED brake (adhesion dependent),
  - eddy current brake (adhesion independent),
- magnetic track brake (adhesion independent),
- Parking brake
  - Hand brake (adhesion dependent),
  - Spring brake (adhesion dependent),

p15

EB、SB、PB、LAM 低黏着管理、BMS 制动管理、ABT 自动制动测试



S4R

3.4.4.1 BSM - Brake System Management sub-functions P59

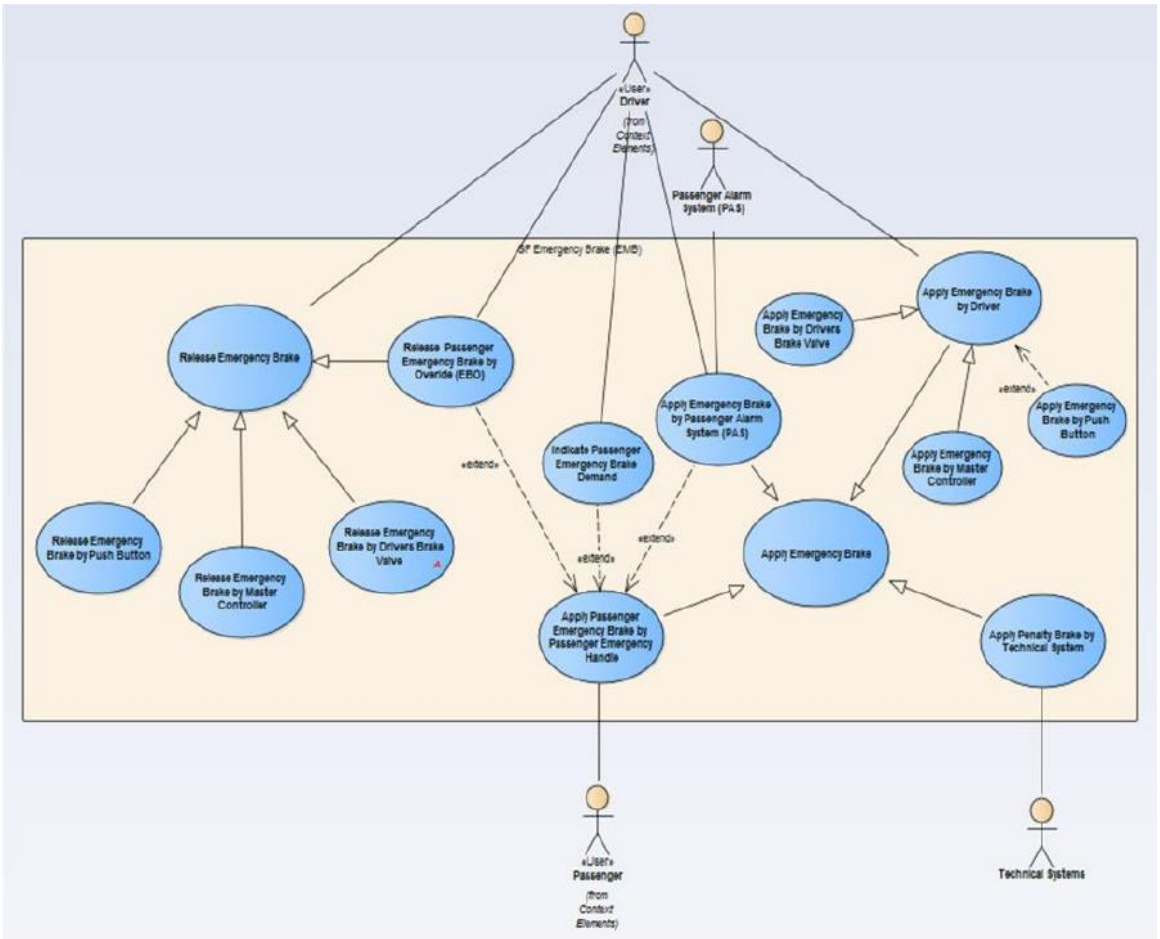
- BSM1. Train Topology and Brake System Integrity
- BSM2. Manage brake operating modes.
  - BSM2.1. Normal mode
  - BSM2.2. Degraded mode
  - BSM2.3. Towing mode

3.4.4.2 SB - Service brake sub-functions

- SB1. Service brake train retardation request
  - SB1.1. Driver request acquisition
  - SB1.2. Technical system request acquisition.
- SB2. Service brake request transmission
- SB3. Train Load Calculation
  - SB3.1. Local (bogie/car) load acquisition
  - SB3.2. Train load calculation
- SB4. Train Brake Force Calculation
- SB5. Blending
  - SB5.1. Service Brake Acquisition of the Brake Availability of all brake subsystems
  - SB5.2. Train brake force distribution on different type of brakes
    - SB5.2.1. Train Electro-Dynamic Brake Force Calculation.
    - SB5.2.2. Train Friction Brake Force Calculation
    - SB5.2.3. Train Eddy current brake force Calculation
    - SB5.2.4. Train Electro-hydraulic retarder brake force Calculation
    - SB5.2.5. Electro-Dynamic Local Brake force request
    - SB5.2.6. Friction Local Brake force request
      - a. Direct

3.4.4.3 EB - Emergency brake sub-functions P60

- EB1. Emergency brake command generation
  - EB1.1. Driver request acquisition
  - EB1.2. Technical system request acquisition.
  - EB1.3. Passengers Alarm request acquisition.
- EB2. Actual Emergency Braking Power Calculation
  - EB2.1. Emergency Brake Acquisition of the Brake Availability of all brake subsystems
  - EB2.2. Emergency Braking power calculation
  - EB2.3. Emergency Braking power indication to driver
  - EB2.4. Emergency Braking power transmission to technical systems
- EB3. Emergency brake command transmission
- EB4. Emergency Local brake force generation
  - EB4.1. Local load acquisition
  - EB4.2. Friction brake force generation (load dependent and speed dependent)
  - EB4.3. Local electro dynamic brake force generation (load dependent and speed dependent)
  - EB4.4. Local Electro-hydraulic retarder brake force generation (load dependent and speed dependent)
  - EB4.5. Adhesion independent brake force generation (speed dependent)
    - EB4.5.1. Magnetic track brake
    - EB4.5.2. Eddy Current brake
- EB5. Emergency brake energy storing
- EB6. Traction cut off
- EB7. Emergency brake state and fault detection and indication.



CTA-D5.1-P33-EB-i

Figure 6: Use Case Emergency Brake

Use Case	Apply Emergency Brake by Drivers Brake Valve for stopping the train
ID	EMB1
Actor	Driver
Goal	G_EMB1: Stop the train in case of emergency situation detected by the driver

Use Case	Apply Emergency Brake by Master Controller for stopping the train
ID	EMB2
Actor	Driver
Goal	G_EMB2: Stop the train in case of emergency situation detected by the driver

Use Case	Apply Emergency Brake by Push Button for stopping the train
ID	EMB3
Actor	Driver
Goal	G_EMB3: Stop the train in case of emergency situation detected by the driver

Use Case	Apply Emergency Brake by Passenger Emergency Handle for stopping the train
ID	EMB4
Actor	Passenger
Goal	G_EMB4: In case of emergency situation Passenger want to inform the driver or stop the train.

Use Case	Apply Penalty Brake by Technical System
ID	EMB5
Actor	The Technical System represents ATP On Board Unit (ATO), ETCS On Board Unit (ETCS), Vigilance Control (VIC), Emergency Overdrive (EBO), Parking Brake (PBC).

Use Case	Release Emergency Brake by Drivers Brake Valve
ID	EMB6
Actor	Driver
Goal	G_EMB6: Release the Emergency Brake System by the driver in case that the EMB is applied while driving even though it is less risky to continue driving

Use Case	Release Emergency Brake by Master Controller
ID	EMB7
Actor	Driver
Goal	G_EMB7: Release the Emergency Brake System by the driver

Use Case	Release Emergency Brake by Push Button
ID	EMB8
Actor	Driver
Goal	G_EMB8: Release the Emergency Brake System by the driver

In the next chapters the following 3 new solutions are proposed improving the above mentioned drawback of the conventional solutions:

I. High Safety Electronic Emergency Brake Load Compensation
II. High Safety Electronic Emergency Pressure Generation
III. High Safety Electronic Emergency Pressure Generation and Electric Brake in Emergency PPT

The main improvements introduced by the EDV concept are:

i. Safe bus/safety loop emergency brake command (no brake pipe) 无制动管的紧急安全环路

ii. Replacement of pneumatic components (distributor, EP modules, switch-over valves, relay valve - load dependent or not load dependent, etc) with less and simpler electronically controlled pneumatic devices, performing both service and emergency brake. 用少而简单的电控气动设备代替气动部件，执行常用和紧急

iii. Safe electronic continuous regulation of the adhesion dependent friction braking force. 安全的黏着摩擦制动力的电控连续调整

iv. Safe electronic detection of the load and safe force load dependency of the braking force 安全电控载荷检测和依附制动力的安全力载荷

v. Accuracy of the cylinder pressure, with possibility to compensate drifting linked to temperature influence and components degradation 制动缸压力精度，可以补偿温度和部件故障的影响

In the following chapters linked advantages are described:

- Space and weight optimization 空间和重量优化
- LCC reduction LCC降低
- Emergency brake performances 紧急制动性能
- Train speed control 列车速度控制
- Commissioning/Tuning activities 调试和运行测试

Conventional train	EDV innovative solution
▪ Brake cylinders	▪ YES, possible less
▪ Relays valves, load or not load dependent, single or double stage	▪ YES, simplified (no load dependent, single stage)
▪ Load valve	▪ NO, loading is done by electronic control
▪ Load averaging valve	▪ NO, loading is done by electronic control
▪ Distributor	▪ NO, replaced by brake/release valves
▪ Interlock valve	▪ NO, replaced by brake/release valves
▪ Double stage valves	▪ NO, replaced by brake/release valves
▪ Direct brake control electro-pneumatic panel (brake and release valves, pressure regulator)	▪ YES
▪ Safety valve	▪ NO, replaced by brake/release valves
▪ Isolation cocks	▪ YES
▪ Air suspension pressure sensors	▪ YES
▪ Safety loop	▪ NO, replaced by safe bus information
▪ BCUs	▪ YES, with high SIL
▪ WSP-CU	▪ NO, integrated in BCU
▪ Brake communication bus	▪ YES, able to transmit safe bus signals
SPACE AND WEIGHT	OPTIMIZATION

Table 4 – Conventional train brake system / EDV solution comparison

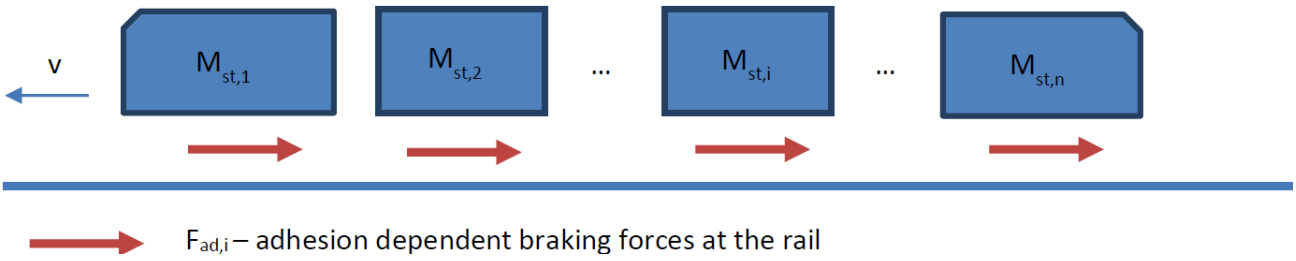
3.3.2 Train reference model

3.3.2.1 Brake model hypothesis

The braking dynamics and kinematics of the train model is defined based on the following hypothesis:

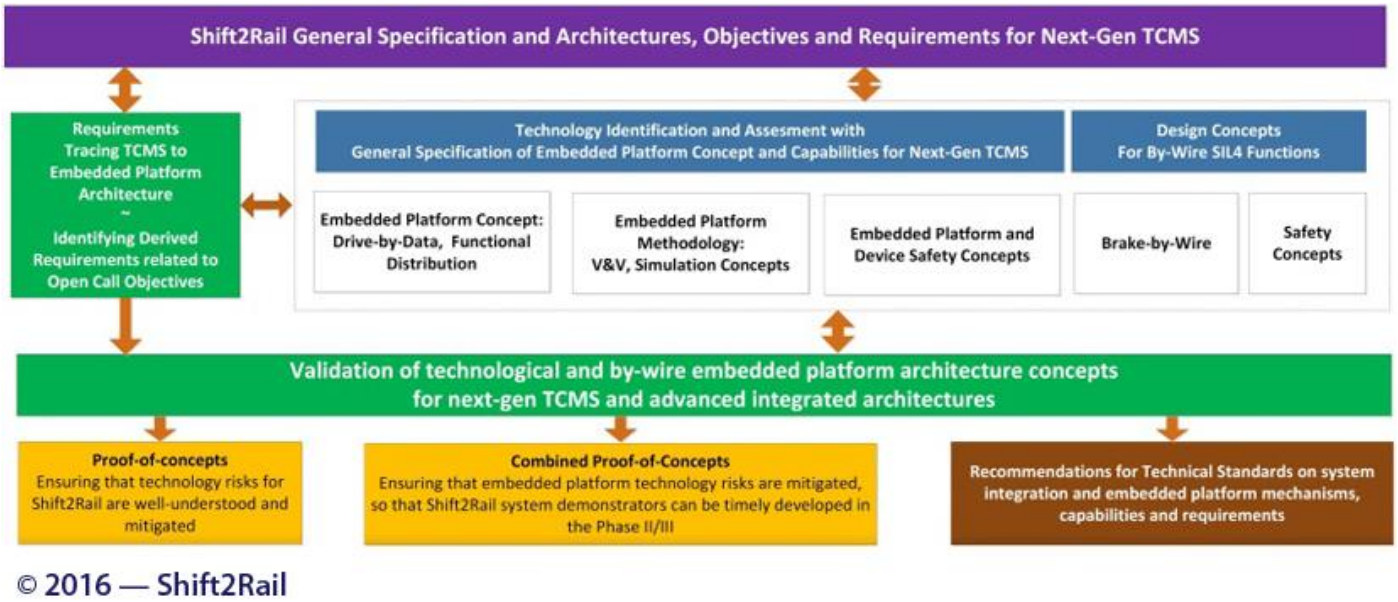
1. No running resistance force, to simplify the model 无运行阻力
2. Only adhesion dependent brake applied (because EDV operate on adhesion dependent friction force and the goal is to evaluate the improvement respect the conventional train of this type of brake) 只有黏着制动力施加
3. Maximum adhesion limit according TSI 按照TSI最大黏着限制建立
4. Maximum speed 350 km/h, according TSI 按照TSI，列车最大速度350km/h

It is supposed to have a train composed of n cars, each of them with a static mass $M_{st,i}$, with a braking force at the rail $F_{ad,i}$.



3.SAFE4RAIL

2016.10.01-2018.12.31： Safe architecture for Robust distributed Application Integration in rolling stock



D4.1: Requirements definition for Brake by Wire

D4.2: Requirements definition for Brake by Wire and safety concept

SAFE4RAIL 是 CONNECTA 的互补项目，它的工作包 4 与制动系统相关：

工作包 4：线控制动（Brake by Wire）。它将在现有的线控驱动技术的基础上，开发一个先进的完全

电子化的架构理念。

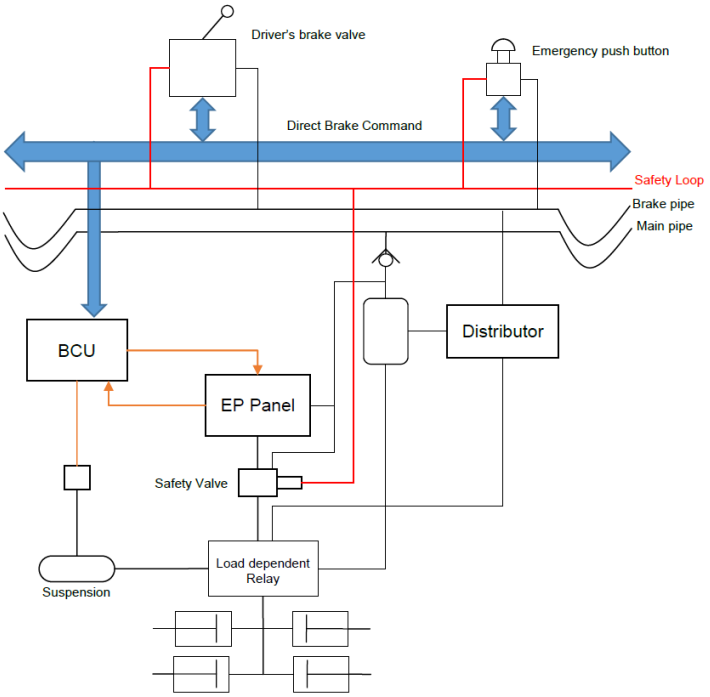


Figure 11: EP Direct Brake with load dependent relay valve P38

Improvement at control architecture depends from the command transmission architecture. According to what described in the previous clauses the following solution could be considered for the local control, mitigating limits from 3) to 7). P60

Solution 1.1 and 1.2 are the closer to the existing one; it is still with several control unit and diffused control principle. The main advantage referred to the existing are:

- the simpler command management (replacement of safety loop by bus safe signal),
- extension of the flexibility given by electronic control to the emergency brake (blending, force regulation based on speed),
- removal of pneumatic components (safety valve) or simplification (relay valve).

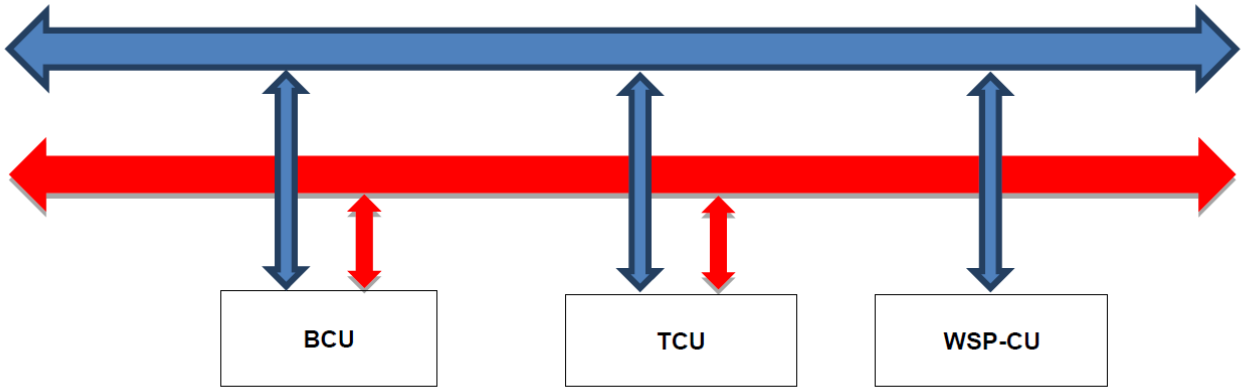
Solution 1.3 and 1.4 are the most innovative; they require electronic device, hosted by the communication infrastructure, for every single component with possible impact on reliability; the main advantage are:

- big reduction of local control units;
- optimized control at train level of all the functions (blending, WSP) also in emergency;
- centralized control.

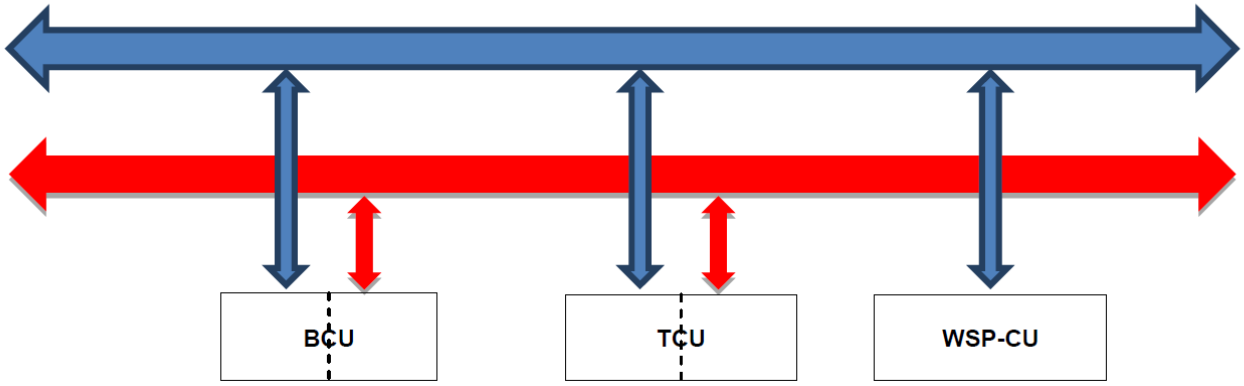
Solution 1.5 and 1.6 are in between the other ones, having partly the advantages of both but with the following disadvantages:

- in case of failure of the integrated unit both braking system (friction and dynamic) are lost and WSP as well, having a bigger impact on risk analysis cases in §1.1.5 cl. 2). If redundant unit is necessary cost impact has to be evaluated.

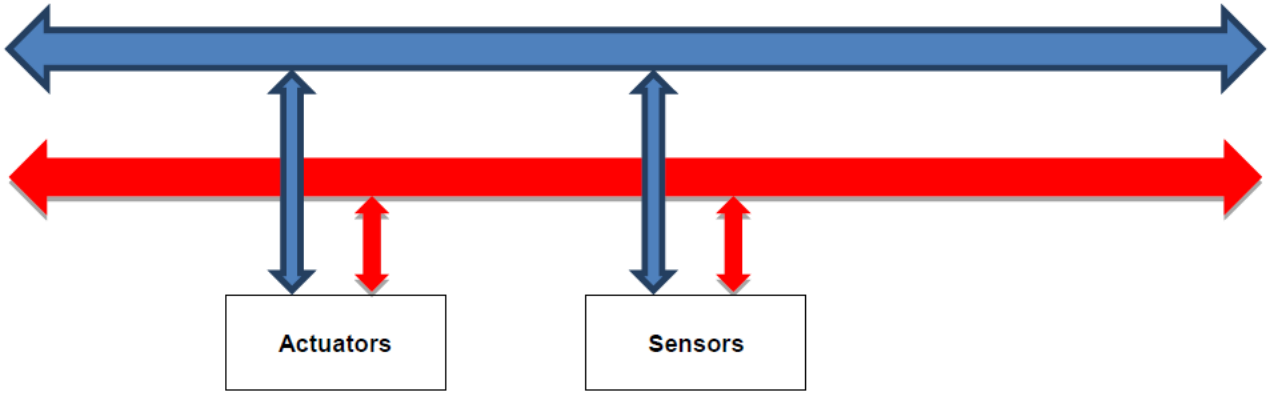
1.1) High safety level BCU and TCU. Independent WSP system



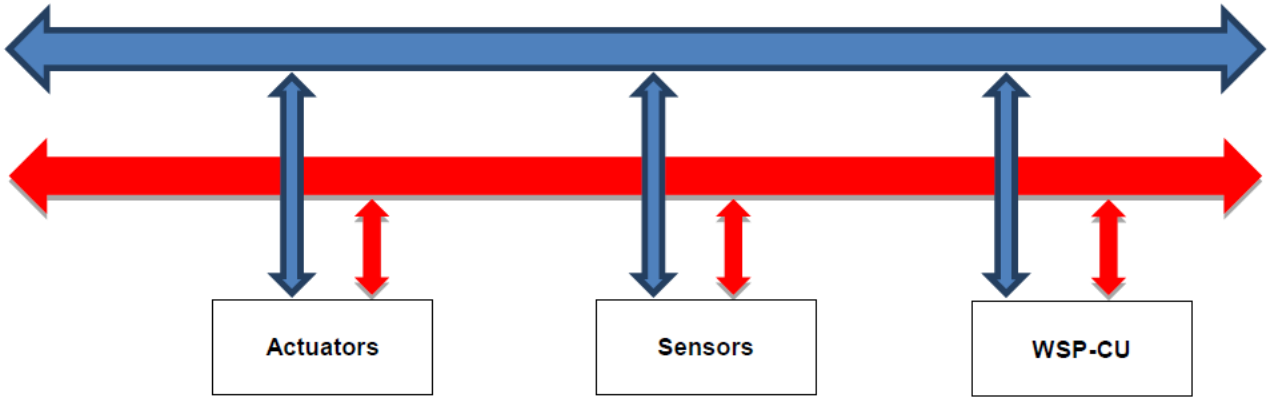
1.2) BCU and TCU with two control “layers”, one for safety related function and the other one for not safety related functions. Independent WSP system.



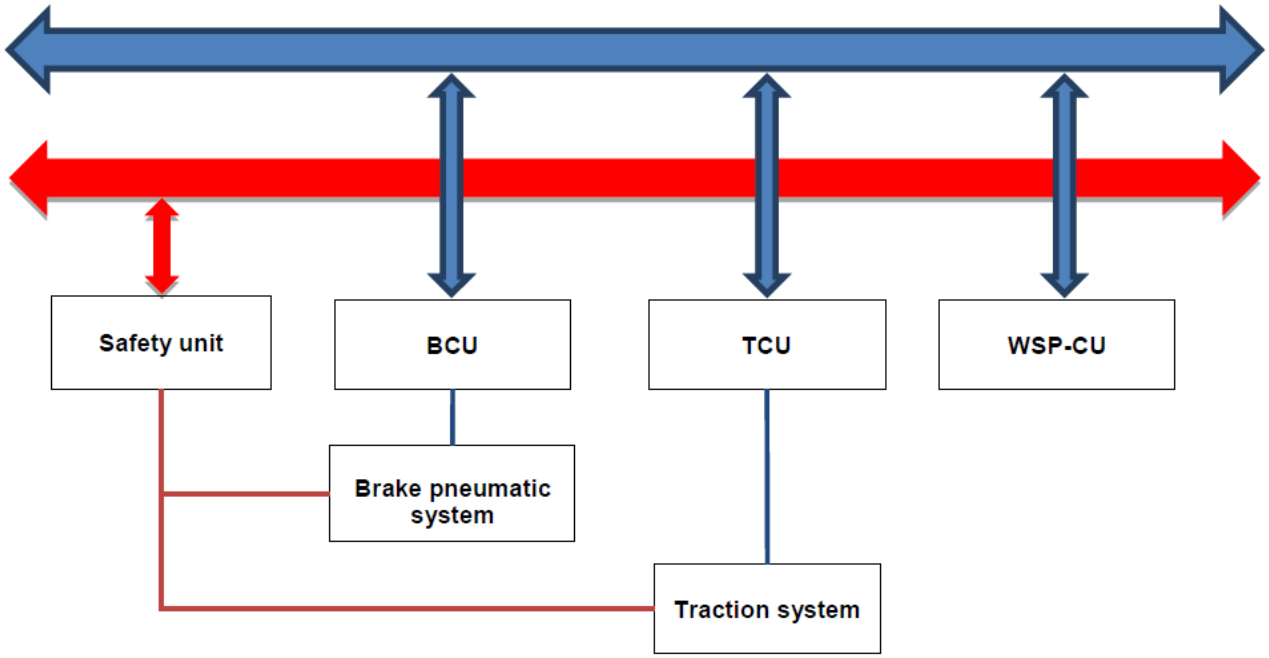
1.3) BCU, TCU and WSP-CU removed, everything controlled by TCMS



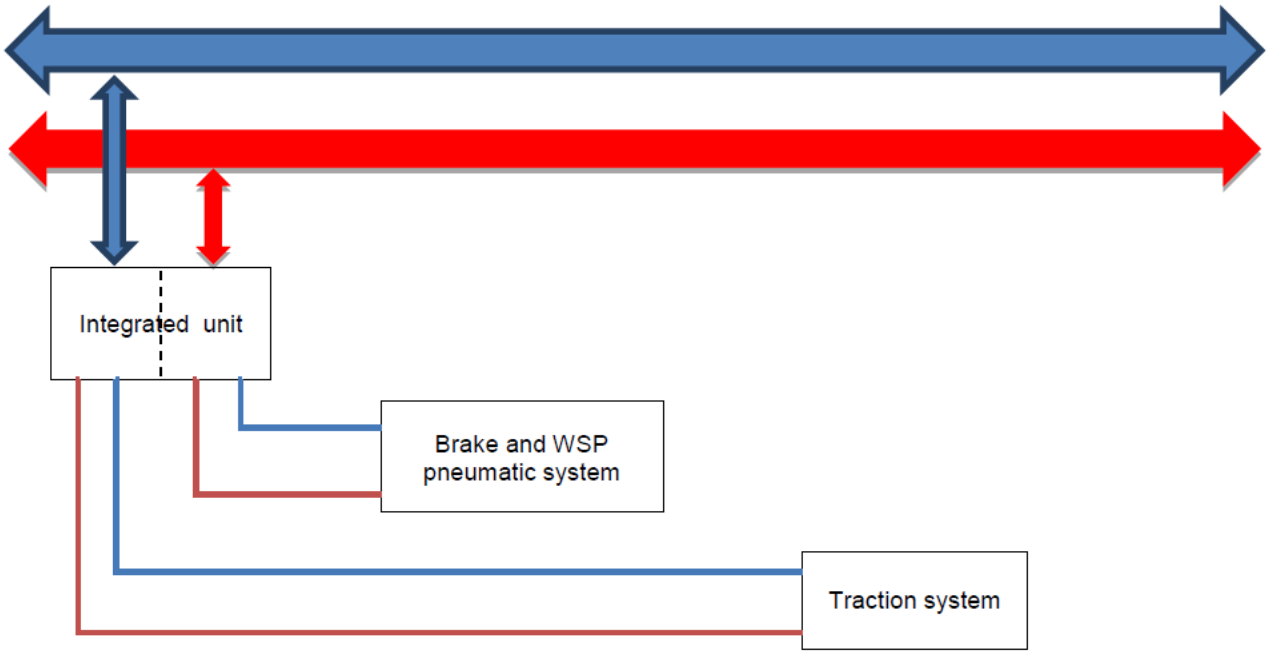
1.4) BCU and TCU removed. Local WSP-CU, but with reference speed by the bus.



1.5) One unit at vehicle level managing all the safety related functions (traction and brake), bypassing the local BCU and TCU in emergency. Independent WSP.



1.6) One single unit at vehicle level controlling traction, brake and WSP with two control "layers", one for safety related function and the other one for not safety related functions.



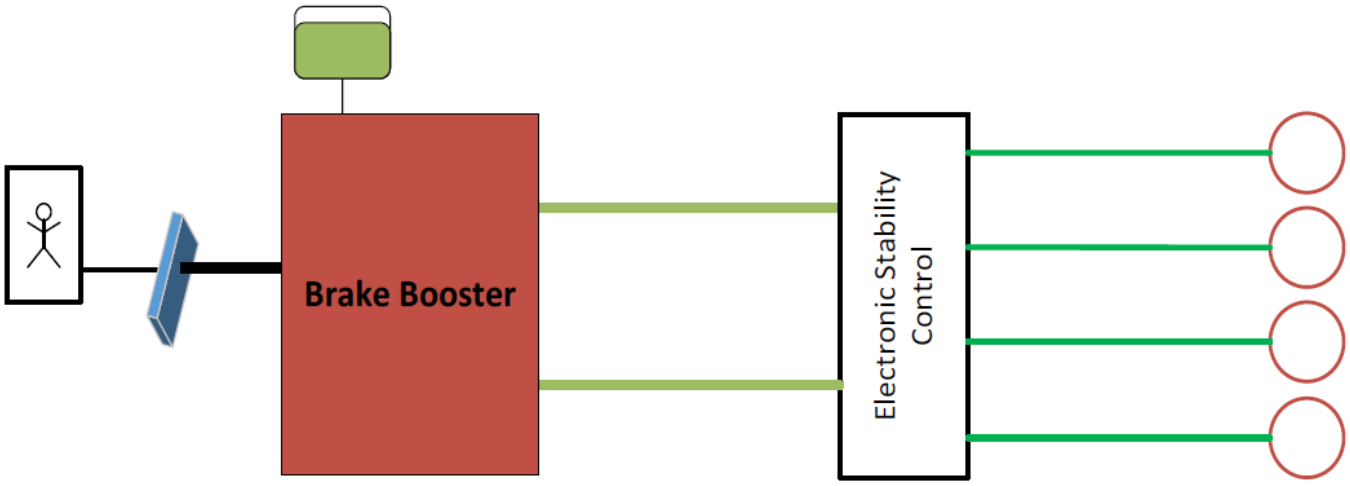


Figure 20: Schematic of Hydraulic Brake System P68

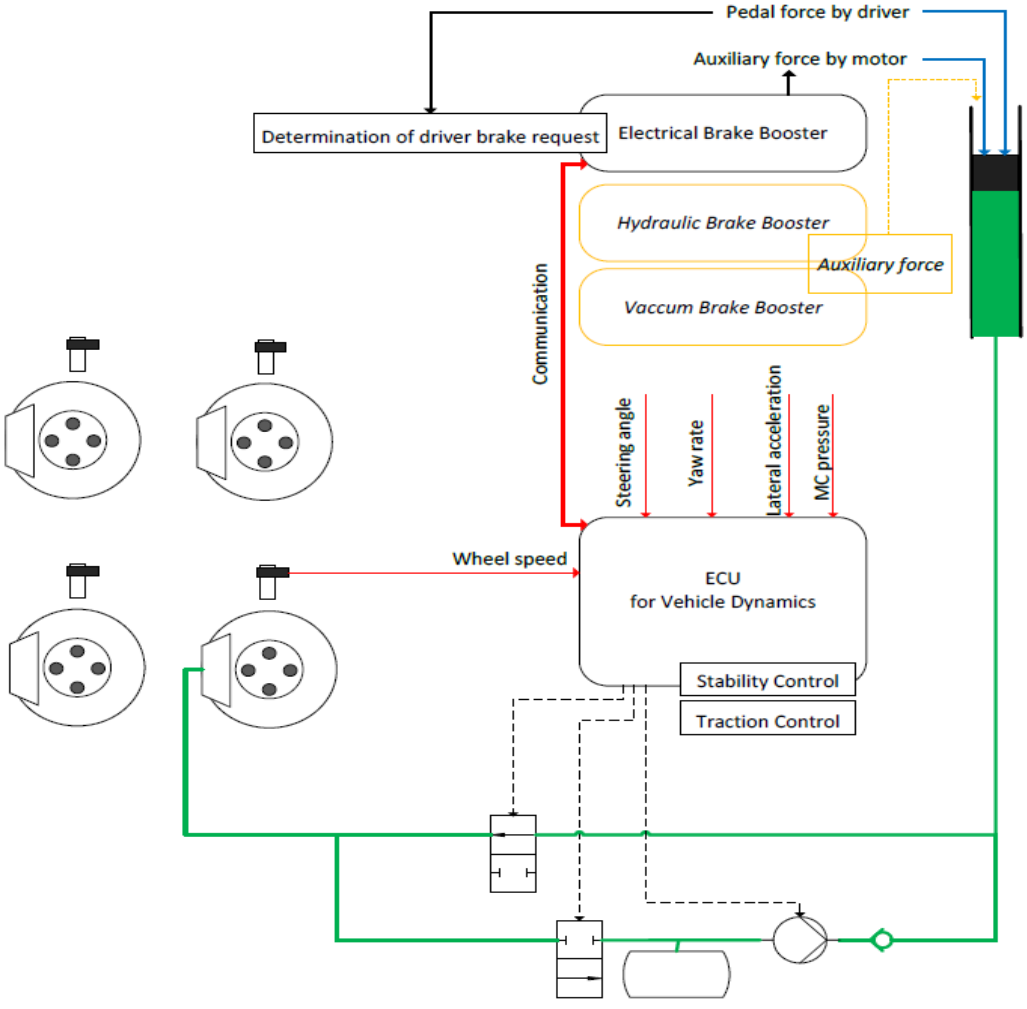


Figure 21: Principle of a car braking system P70-automatical car

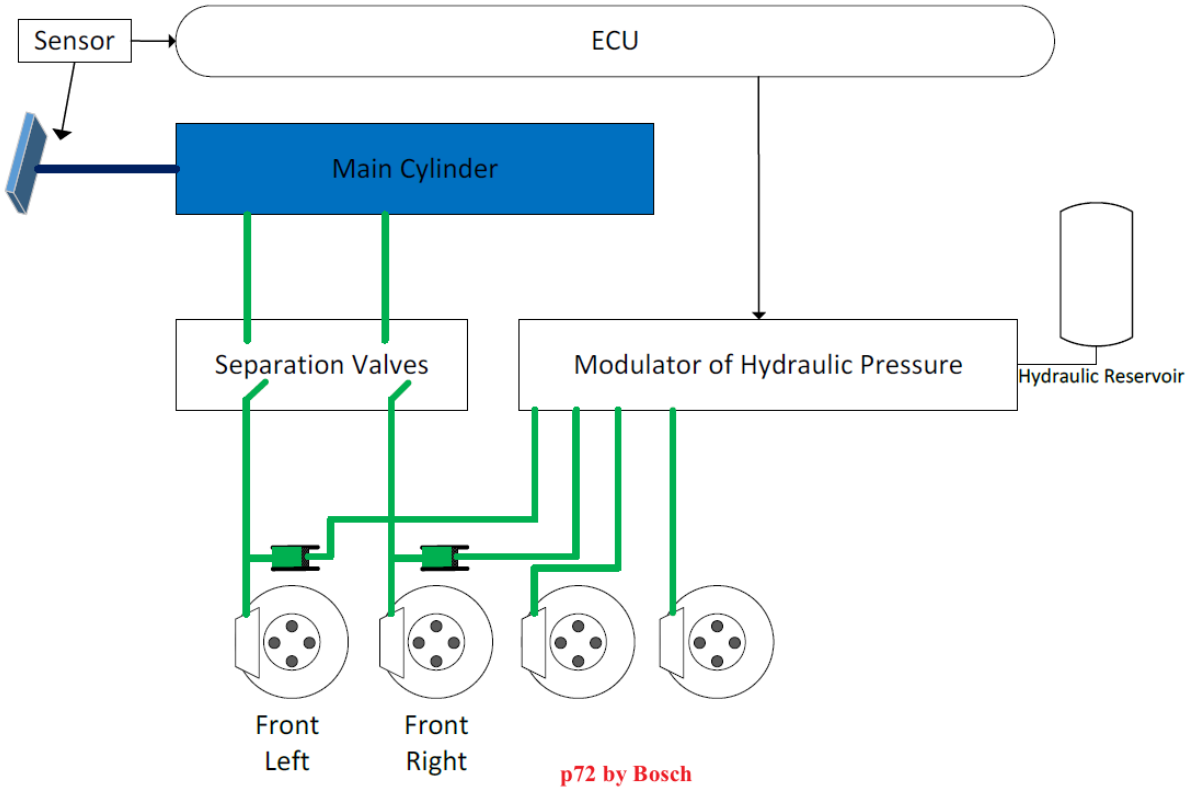
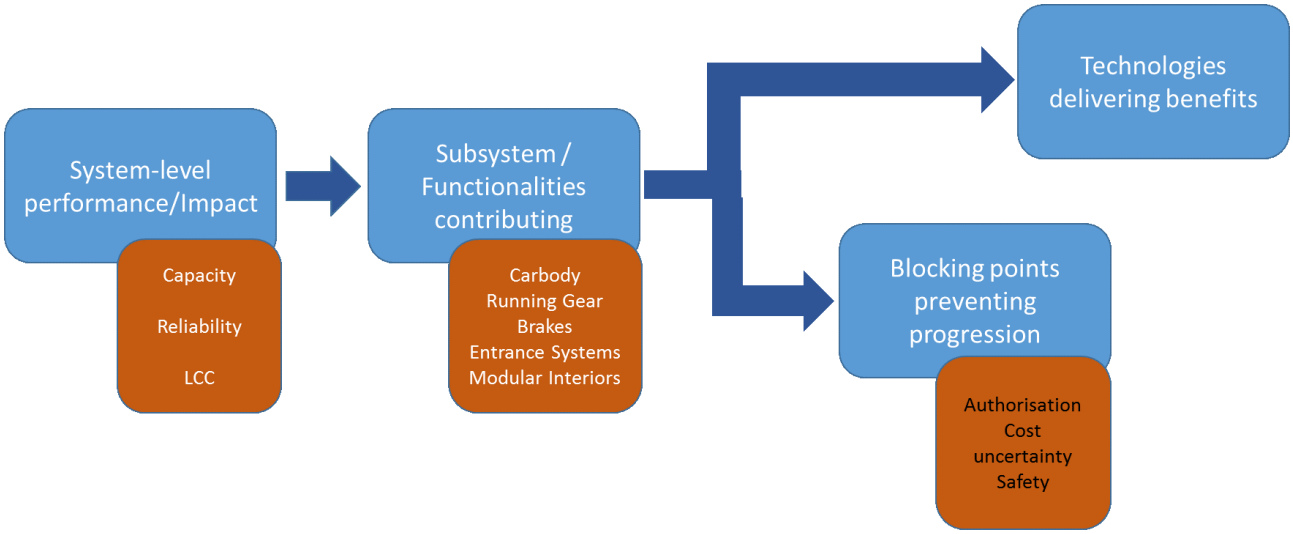
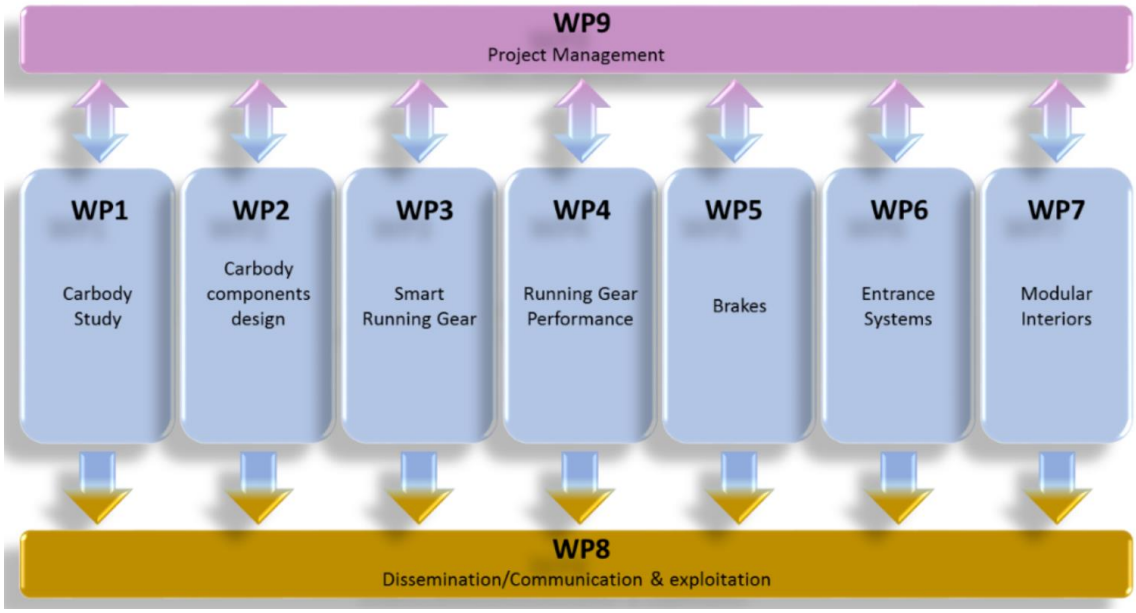


Figure 22: Sensotronic Brake Control (adapted from [29])

4. PIVOT

2017.10.01-2019.12.31: Performance Improvement for Vehicles On Track





D5.1: General specification regarding implementation and validation of high SIL braking functionality
D5.4: Report of the results made by competitive development and revision of the requirements
D5.8: Assessment Report of Processes and Procedures Allowing Virtual Certification of Brakes

制动系统的示范涉及 PIVOT 项目的 1 个工作包：

- 工作包 5：未来制动系统解决方案的开发。这个工作包在一些互补技术的基础上、并同时考虑粘着相关和非粘着相关的方法（比如创新的摩擦副方案、电子-机械解决方案和无摩擦低噪声解决方案），开发出未来制动系统的理念；还包括了制动系统评价和虚拟认证方面的技术标准化方案的开发。另外，将开发一个电子式的软件-硬件架构，用来管理 SIL3 或 SIL4 的制动功能。综合这些工作，将形成一个完整系统的技术示范。

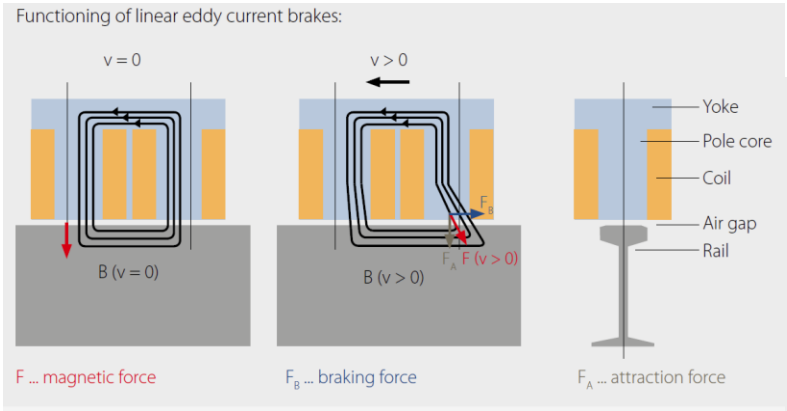
WP5 - Development of future brake system solutions

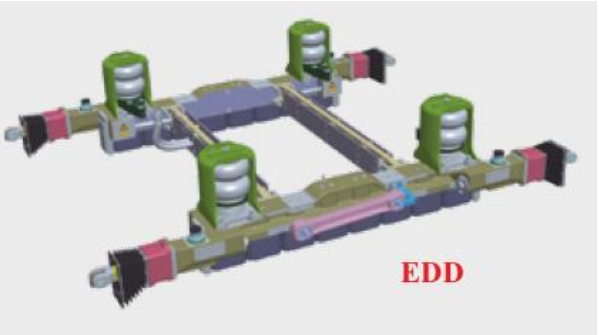
This work package aims to develop the future brake system concept based on complementary technologies and consideration of both adhesion-dependent and adhesion-independent approaches such as innovative friction pair solutions, designed to dissipate all the braking energy for service braking and for emergency braking and for emergency braking and designed to achieve better LCCs of the components, electro-mechanical solutions and frictionless low-noise solutions, including the development of proposals for technical standardization in the assessment of brake systems and virtual certification. In addition, an electronic HWSW architecture is to be designed to manage the braking functions service brake, emergency brake, and wheel slide protection for high safety levels (SIL3, SIL4). In synergy, these actions will result in a full-system-approach technology demonstrator. Several sub-objectives are defined and will be developed: 需要达成一些子目标

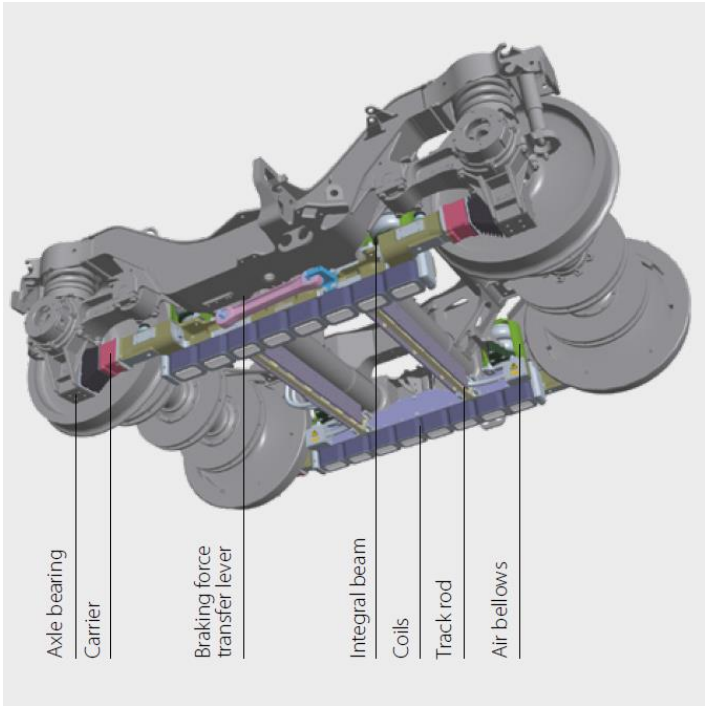
高安全等级，电控软件和硬件实施的气动方案的安全性功能实施

- Implementation of safety functions based on pneumatic solutions suitable to be implemented by electronic HW&SW, with high safety levels (SIL3, SIL4)
- An interoperable, standardized and highly safe next-generation frictionless low-noise brake system (eddy current brake) 互通，标准，高安全下一代低摩擦、低噪音制动（涡流）
- Innovative friction pair solutions with performances improvement in the friction pairing regarding friction level itself, behavior friction level (reduced spread, temperature, pressure dependency, ...) as well as behavior of friction level on bad conditions (wet, dust, ...), higher energy consumption, and the environmental impact reduction. Moreover, the plan is for performance improvement in the wear conditions regarding longer lifetime of brake pad and disk, better predictions of wear, reduced weight of the components (especially reduced rotary masses). 创新摩擦副，长寿命磨耗，环境友好，轻量化
- Considerably improved electro-mechanical brake solutions to fulfil increased requirements concerning reliability, the effective transfer of force, better control and diagnosis, eco-friendly maintainability – and competitive enough to be expanded to other vehicle types EMB电机械制动
- Defining virtual certification standards and processes to enable cheaper and faster certification and authorization of brake systems and their components

通过虚拟认证，便宜，快速进行认证

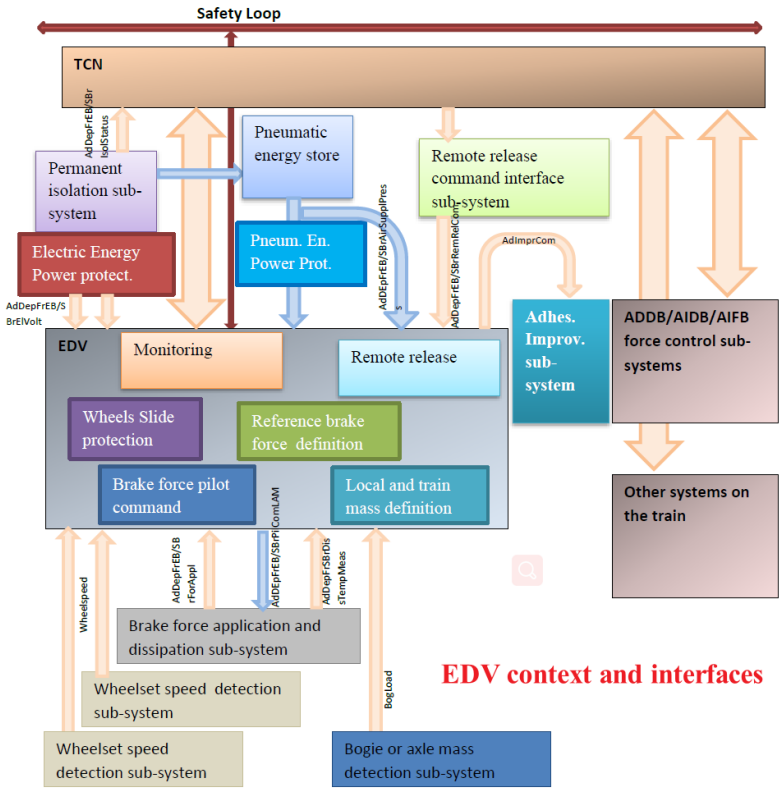




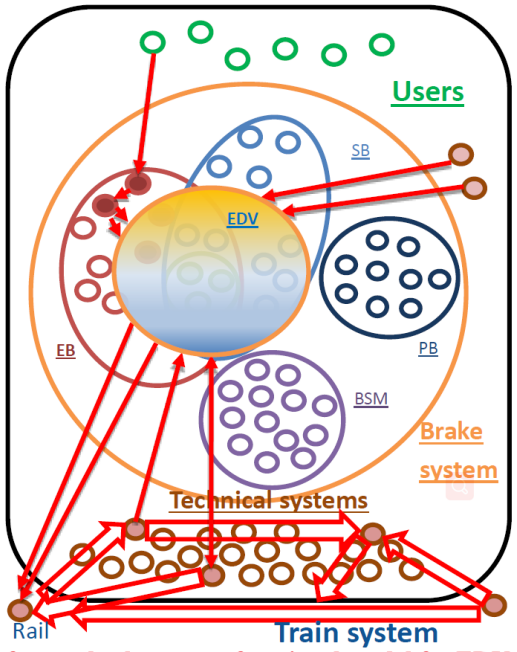


MTB-磁轨制动动画.mp4

D5.1:基于高 SIL 等级的制动功能验证的通用需求中定义了 EDV 阀的接口信息，具体如下-P26：



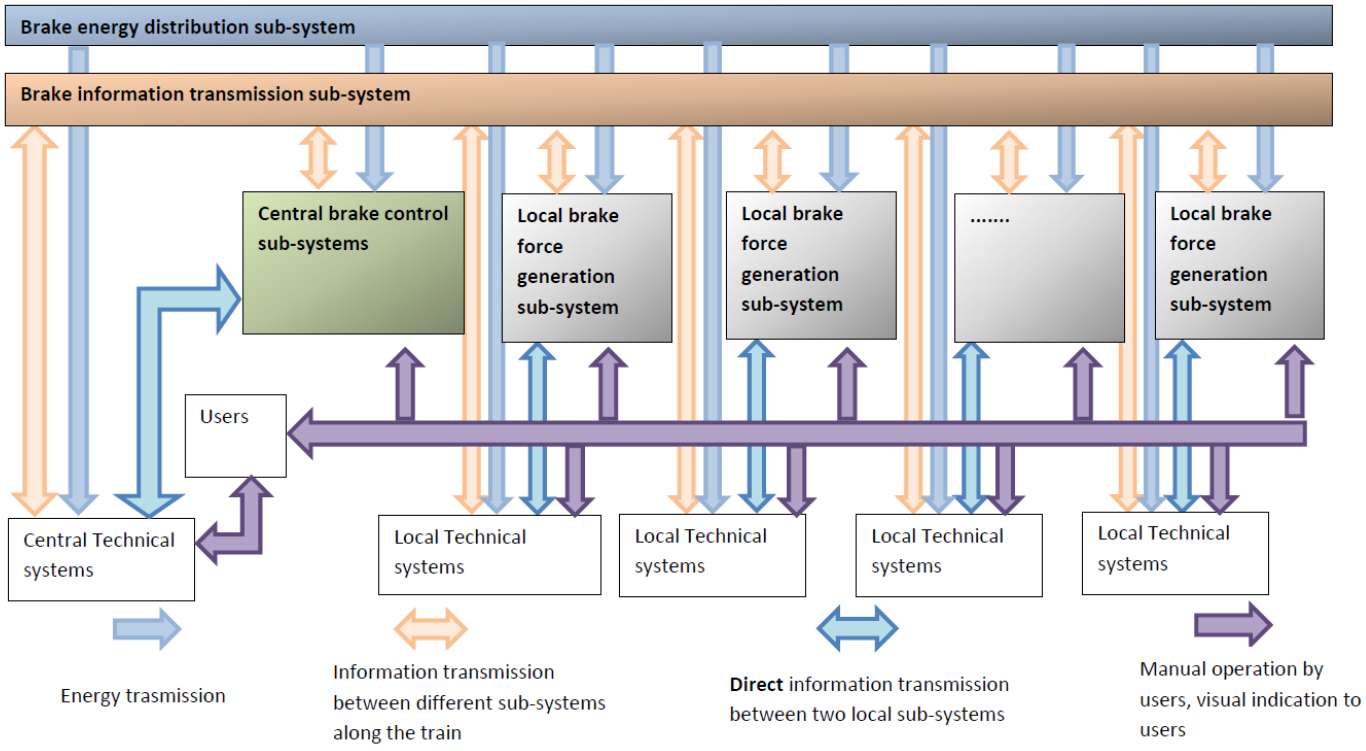
EDV context and interfaces



Reference brake system functional model for EDV

The result of above hypothesis is the consist and train brake system reference architecture of D5.4 §3.2 and §3.3. Below figure report an high level representation of the consist architecture, for **P30** details the mentioned D5.4 paragraphs shall be considered.

通过一系列假设，**ADH1-40**，形成下图的列车制动系统配置



The above requirements bring to the EDV interface scheme represented in Figure 4, applicable at axle or bogie level, where, as comnsequence of ADH-3 (optional safety loop) and ADH-27 **P36** (monitoring of permanent release), it is partially modified the EDV architecture of [5], by replacing the safety loop input with permamanent release signal

为了互操作需求，导致**EDV**接口变更，如下图

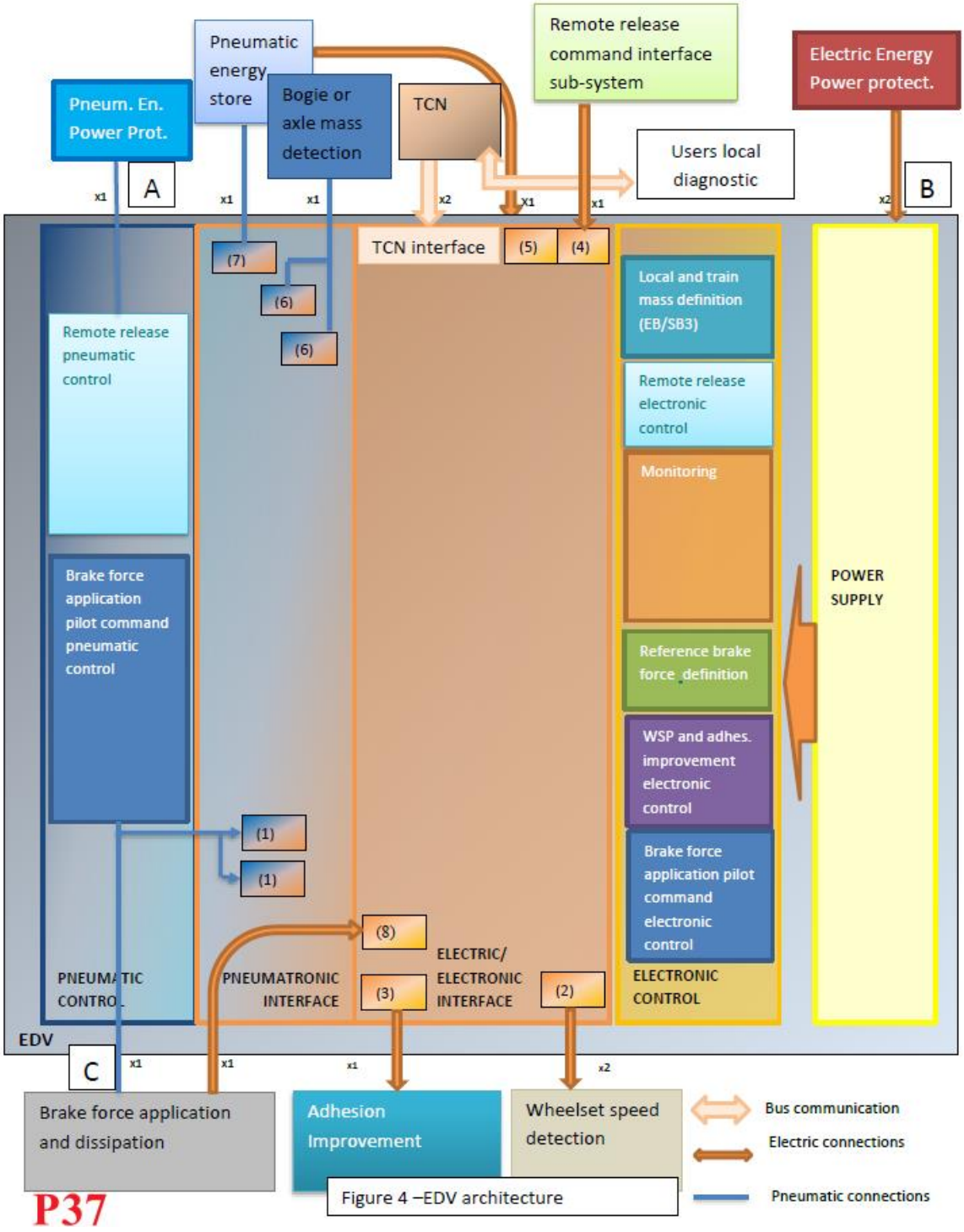


Figure 4 –EDV architecture

ID	Main Function	Requirement classification	Requirement text P47	Actor	Input Data	Input source	Output Data	Output destination
BS.1	BRAKE SYSTEM	Functional	The brake system shall ensure that the train's speed can be reduced or maintained on a slope, or that the train can be stopped within the maximum allowable braking distance. Braking also ensures the immobilisation of a train.	Brake system	TrBrReqUs, ImmReqUs; BrReqATP BrReqETCS TrBrReqATO TrBrReqTCMS; ImmReqTCMS; BrReqPAS BrReqBrSys, ImmReqBrSys	Driver Brake test operator Maintenance staff Maintenance tool ATP on board ETCS on board ATO TCMS PAS Brake System	TrainDecAppl TrainDecEqTimeAppl TrainImmForAppl	Train Train Train
BS.2	BRAKE SYSTEM	Definition	TrBrReqUs is the request of accelerate or decelerate the train by the driver (or any other user), provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.	Driver			TrBrReqUs	
BS.3	BRAKE SYSTEM	Functional	TrBrReqUs request can be provided by service brake, emergency brake and parking brake main functions	Brake system	TrSBrReqUs EBrReqUs	SB EB	TrBrReqUs	Brake system
BS.4	BRAKE SYSTEM	Definition	TrBrReqATO is the request of accelerate or decelerate the train by the ATO system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.	ATO			TrBrReqATO	
BS.5	BRAKE SYSTEM	Definition	TrBrReqTCMS is the request of accelerate or decelerate the train by the TCMS system, provided via proper interface. It is an acceleration(positive)/deceleration(negative) value.	TCMS			TrBrReqTCMS	
BS.6	BRAKE SYSTEM	Definition	BrReqATP is the request to decelerate the train by the ATP provided via proper interface. It is deceleration (negative) value.	ATP			BrReqATP	
BS.7	BRAKE SYSTEM	Definition	BrReqETCS is the request to decelerate the train by the ETCS provided via proper interface. It is deceleration (negative) value.	ETCS			BrReqETCS	
BS.8	BRAKE SYSTEM	Definition	BrReqPAS is the request to decelerate the train by the PAS provided via proper interface. It is deceleration (negative) value.	PAS			BrReqPAS	
BS.9	BRAKE SYSTEM	Definition	BrReqBrSys is the request to decelerate the train by the Brake system itself, provided via its functions. It is deceleration (negative) value.	Brake system			BrReqBrSys	
BS.10	BRAKE SYSTEM	Functional	BrReqBrSys request is provided by brake system management main function	Brake system	SBrReqBSM EBrReqBSM	BSM2.1 BSM2.2	BrReqBrSys	Brake system
BS.11	BRAKE SYSTEM	Definition	ImmReqUs is the request of immobilize the train by the driver or any other user, provided via proper interface	Driver			ImmReqUs	
BS.12	BRAKE SYSTEM	Functional	ImmReqUs request is provided by Parking brake and service brake main function	Brake system	PBrReqUs	PB1	ImmReqUs	Brake system

Annex 1 - INTEROPERABLE FUNCTIONAL MODEL REQUIREMENTS
附件1-互操作功能模型需求

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Annex 2 - BRAKE SYSTEM FUNCTIONS D5.3 COUNTERMEASURES LIST
附件2- 制动系统功能对策清单

ID	Countermeasures	Classification
PHA_BSM_1	The Brake system shall store permanently, assure the integrity and inhibit any modification (during service, i.e. restart mandatory) of the configuration data acquired during its initialization.	Correct operation
PHA_BSM_2	The Brake system shall verify: _during initialization, that the actual configuration of consist and brakes fulfil the minimum configuration assumed for brakes dimensioning; _during service, that configuration data acquired during service are availability and valid;	Detection of Faults
PHA_BSM_3	The Brake system shall react to a Major fault generated at consist level (i.e. affecting brakes at more than one axle / bogie) by notifying it to the driver and external systems (i.e. transition into the safe state) and by dispatching the brake command to all the local brake units (i.e. transition into the safe state)	Correct operation
PHA_BSM_4	The Brake system shall react to a Major fault generated locally (at axle or bogie level) according to the degradation in the braking power: _ by commanding the remote release of the faulted brake, if safe condition are still guaranteed by the residual braking power (i.e. permanence into the safe state); _OR otherwise by dispatching the Emergency brake command to all the local brake units (i.e. transition into the safe state) and by notifying the Major fault to the driver and external systems.	Correct operation
PHA_BSM_5	The Brake system shall react to the loss of capability to notify a Major fault to the external technical systems by the interruption of communication and the transition or permanence into safe state.	Action following Detection

Annex 3 - BRAKE SYSTEM FUNCTIONS D5.3 APPLICATION CONDITION LIST
附件3 - 制动系统功能应用条件清单

ID	Application condition
PHA_AC_01	Procedure(s) shall be specified for the driver and maintenance operator about the conditions and constraints to meet for the total or partial, permanent, isolation of brake and about the following restrictions.
PHA_AC_02	The external Technical systems exchanging safety-data with the Brake system shall: _ monitor the exchange of data and react to the inability to communicate as for the notification of a Major fault (e.g. warning to driver, restrictions); _ implement safety protection in the generation of safety-data to be exchange through the transmission system; _ verify the messages acquired in order to detect erroneous information (transmitter identity, type, value errors) and time errors (timing, sequencing error); _ discharge a message when a communication error is identified.
PHA_AC_03	The external system shall inform the Brake system about constraints coming from the infrastructure and from the vehicles in the use of regenerative dynamic brake, specifically for Emergency brake, if any.
PHA_AC_04	The Dynamic brake, if used in Emergency brake, shall be able to dissipate the energy also in case the external catenary cannot receive the energy (e.g. voltage limitation, protections, catenary interruption, ...).
PHA_AC_05	The external systems shall detect an emergency brake application (triggered by the Brake system as reaction to a Major fault) that leads the train to stop in a hazardous area. In this condition, the external system(s) shall wait till the train speed is under a predefined limit, then command a "global" remote release until the train exits from the hazardous area, and then command the emergency brake to achieve standstill condition.

P138-144

Annex 4 – EDV INTEROPERABLE INTERFACES
附件4 - EDV互操作接口

ID in Annex 1	Name	HW/SW	Description	Input to /Output from EDV	Source/ Destination	Type	Range	
BS.72	TrainSpeed	SW	TrainSpeed is the speed of the train measured by odometry system	I	TCN	Word	0-500 km/h	TCN
SB.36/EB38	SelfTestBrRes	SW	SelfTestBrRes is the result of the self test performed by friction brake when receive electric power supply	O	TCN	Boolean	1=OK 0=NOT OK	TCN
SB2.2	TrSBrReq	SW	TrSBrReq is the adimensional information (percentage) about traction and service brake deceleration request. It is in the range +100%/-100%. The value -100% correspond to a deceleration of TrainSBrDecMax. The value +100% correspond to TrainTractAccMax.	I	TCN	Byte	-100%/ 100%	TCN
SB2.3	TrainDir	SW	TrainDir is the information about train direction selected by the driver	I	TCN	Boolean	1=forward 0=backw.	TCN
SB3.3	TrainMass	SW	TrainMass is the mass of the complete train defined by friction brake	O	TCN	Word	0-500 t	TCN
SB3.9	DoorClLock	SW	DoorClLock is the passenger door status Closed and locked: active = closed and locked, not active: not closed and locked	I	TCN	Boolean	1=locked 0=unlocked	TCN
SB3.11/EB3.9	BogLoadMeas	SW	BogLoadMeas is the measured value of the Bogie Load information (BogLoad) by the EDV	O	TCN	Word	0-12 bar	(6)
SB3.11/EB3.9	BogLoadMeas (n)	SW	BogLoad Measis the measured value of the Bogie Load information (BogLoad) by the other EDV	I	TCN	Word	0-12 bar	TCN
SB3.14/EB3.12	BogLoadDef	SW	BogLoadDef is the default load insisting on the bogie to be considered in case of not available BogLoadMeas information	Parameter				
SB3.15/EB3.13	MJFBogLoadMeas	SW	MJFBogLoadMeas is the fault information indicating that it is lost the BogLoadmeas information (mass information lost)	O	TCN	Boolean	1=Fault active 0=Fault not active	TCN
SB3.15/EB3.13	MJFBogLoadMeas (n)	SW	MJFBogLoadMeas is the fault information indicating that other EDVs lost the BogLoadmeas information (mass information lost)	I	TCN	Boolean	1=Fault active 0=Fault not active	TCN
SB/EB4.6	TrackSlopeVal	SW	TrackSlopeVal is the slope of the track indicated in thousandths, positive in uphill, negative in downhill (optional)	I	TCN	Byte	0-50 ‰	TCN
SB/EB4.9	MJFTrSBrReq	SW	MJFTrSBrReq is is the fault information indicating that it is lost the TrSBrReq information (continuity lost)	O	TCN	Boolean	1=Fault active 0=Fault not active	TCN

D5.4 需求修正和竞争性开发形成的结果报告：

The aim of this document is to summarize the comments received and define any output task for the next phase of the project taking in account the comments P5

文件目标是总结接受的评论，考虑到这些评论定义项目下一阶段的输出任务

3 Feedback on requirements

The only comments received regards the safety requirements described in Annex 2 of [2]. Here below the comments and replies to them.

The only participant which made some comment is Siemens,

Requirements ID	Requirement	Feedback	Reply
PHA_BSM_3	The Brake system shall react to a Major fault generated at consist level (i.e. affecting brakes at more than one axle / bogie) by notifying it to the driver and external systems (i.e. transition into the safe state) and by dispatching the brake command to all the local brake units (i.e. transition into the safe state).	Not all external systems are relevant in this context	The external systems at which the major fault shall be notified shall be defined by the train builder based on train PHA.
PHA_SB_HB_03	The Brake system shall guarantee the inexhaustibility of the Holding brake: without any source of energy for brake actuation (pressure and air flow / electric energy), the Brake system shall guarantee the temporary immobilization of the train for a defined minimum duration (2 hours according to TSI).	Please name the chapter/ ID in the TSI	The TSI requires immobilization of the train for at least 2 hours in §4.2.4.2.1 (12) : "In the event of the braking energy supply being disrupted or the power supply failing, it shall be possible to hold in a stationary position a unit with maximum braking load (as defined in clause 4.2.4.5.2) on a 40 ‰ gradient by using the friction brake of the main brake system alone, for at least two hours." In the next revision of the D5.1.1 document or in any derived document it will be explicitly mentioned.

4 Feedback on results

No change requests on siftware development process by FTI and KB were received by partners during the review process. The submitted documents are therefore deemed valid.

5 Output to next tasks

The minor comments on requirements and no comments on results confirm the output of the former task: the prototype SW controls the adhesion dependent friction brake at axle level; using a plurality of prototype EDV integrated in a train system, the prototype SW is able to control the adhesion dependent friction brake at train level.

The train specific application dependent configuration and related TCMS communication requirements shall be defined in the next PIVOT2 project.

6 Conclusions

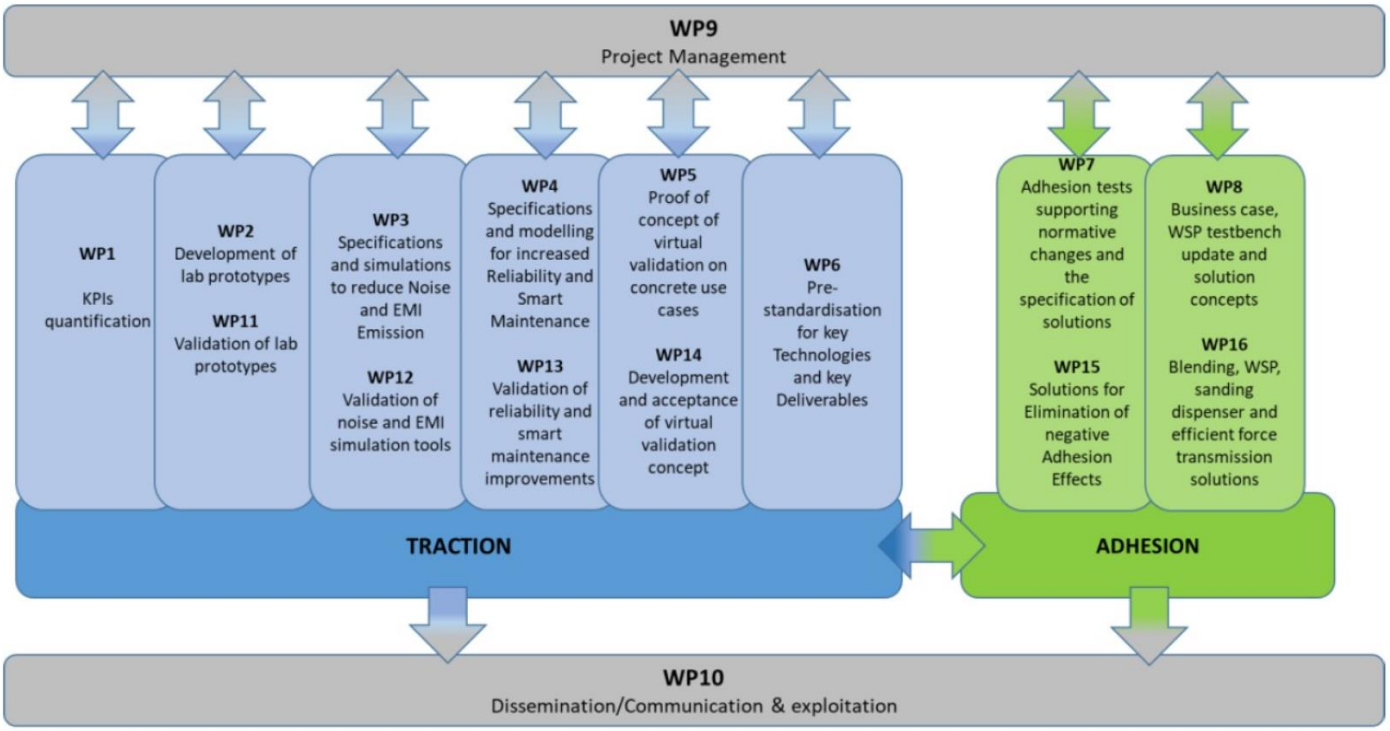
The only participant which made some comment is Siemens, which comments are related to secondary aspects. The fact that there are no significant comments from other project partners, means that the documents submitted are deemed valid. About to deliverables D5.2 and D5.3 the purpose of the review activity was to get comments on the software development process implemented independently by the 2 companies FT and KB.

This result is therefore confirming the suitability of the requirements definition process derived from Connecta project, at the base of the document [2] and of the robustness of the software development phase described in [3] and [4]. 最终结果就是：需求定义合理

5.PINTA2

PINTA2

2019.09.01-2020.11.30: TRACTION TD1 AND BRAKES TD5 – PHASE II



The main specific objectives of adhesion management for brakes are:

- Improvement of braking degradation limit in poor adhesion condition
- Management of all adhesion conditions in a way that brake distances are optimized
- Improvement of the overall train safety for braking, which relies substantially on the management of the wheel/rail contact
- Reduction of wheel Life-Cycle-Costs (LCCs) through optimized wheel/rail contact in braking

WP07 - ADHESION TEST AIMED TOWARDS NORMATIVE CHANGES

One objective of this work package WP7 is to set the basis for further collection of information on different adhesion conditions for the adhesion catalogue compiled within PINTA. The data collected later on will support the development of the adhesion related solutions. The main objective of this work package is to specify adhesion management solutions, based on the knowledge on adhesion from PINTA and the information gathered from the measurements therein. First feasibility studies of sub-functions will be done.

WP08 - Business case, WSP test bench update and solution concepts

The main objective of this WP is to specify new adhesion management prototypes. The first specification describes a WSP adaptive algorithm able to outperform current WSP devices in terms of extension of braking distances on a wide range of low adhesion conditions. This specification and the prototype produced in WP16 will lead to a demonstrator in PINTA3. From a performance point of view, it will reduce the braking distance extension from 25% to 15% and reduce the LCC due to a lower occurrence of wheel flats.

The second specification describes an adhesion improvement dispenser with the aim of minimizing the influence of the train speed on the number of particles reaching the contact point.

This WP will also propose new concepts for blending strategies, based on the communication between the TCU and BCU. proposed in order to use the Electrodynamic and Electropneumatic brakes without causing loss of performance or wheel flats. This will lead to a lower wear rate of the brakes and a higher efficiency of the braking sequence.

This WP will furthermore allow to update the activities started in PINTA on the topic of the WSP test bench with the knowledge acquired from the implementation of the specifications. Furthermore, a business case will be defined in order to understand where on the rail network these enhanced performances can be most beneficial.

WP15 - Solutions for Elimination of negative Adhesion Effects

One objective of this work package WP15 is to collect information on different adhesion conditions for the adhesion catalogue compiled within PINTA based on the available scenarios defined within WP7. The information gathered should further support the development of the adhesion related solutions. Beyond, based on this data the WSP test bench models defined within PINTA will be confirmed or updated (WP16). The generation of data might be done using test rigs, e.g. roller rigs, or if available trains on a test track. Based on the availability it is improbable to do measurement of data on public tracks during service.

The main objective of this WP15 is to develop adhesion management solutions up to TRL3-4 (technology validated in lab) based on the specifications made in WP7.

The requirements specified for adhesion related products and the proposals for normative changes will be detailed. Necessary changes/ updates will be made in order to prepare input for WP6 which is collecting all inputs for normative changes from the PINTA work packages.

WP16 - Blending, WSP, sanding dispenser and efficient force transmission solutions

The main objective of this WP is to develop and test new adhesion management prototypes according to the specifications created in WP8.

The assessment of the performance of the Adhesion improving dispenser and the Adaptive WSP prototype is made and related to the previously defined specifications. The WSP prototype will then lead to a demonstrator in PINTA3.

The assessment of the performance of a system for optimized adhesion utilization is also part of the scope of this WP. based on the knowledge on adhesion gathered within the previous PINTA phase, a SW prototype will be developed up to TRL3-4 in order to realise an optimised adhesion utilisation and efficient force transmission in low adhesion conditions. The prototype renders the possibility to use additional information in order to improve the performance compared to current solutions.

The evaluation of blending concepts proposed in WP8 will also take place, based on SW and simulations.

The follow up of the activities started in PINTA will continue concerning the Adhesion model. This allows an update of the specification with the knowledge acquired from the measurements and their analysis, and if necessary modify the structure to take into account a new phenomenon.

1.EuroBrake 2019_Development of a regenerative friction model to enhance braking simulation with the multibody software VOCO

2.EuroBrake2019_ Adaptive Wheel Slide Protection Algorithms

4.Impact of Slip at Low Adhesion conditions caused by various Contaminants

制动系统的示范涉及 PINTA2 项目的 4 个工作包：

- 工作包 7：面向范式变化的粘着测试。一个目标是为未来不同粘着条件下（PINTA 项目定义的类别）的信息收集打下基础，后续收集的数据将用来支持粘着相关的解决方案的开发。这个工作包的主要目标是定义粘着管理的解决方案；这里将完成该子功能的初步可行性研究。
- 工作包 8：商业案例、车轮防滑测试台更新和解决方案的理念。其主目标是定义新的粘着管理样机，也将基于 TCU 和 BCU 之间的通讯提出混合策略的新理念。同时根据知识的积累对车轮防滑测试台进行更新，并提出一个商业案例，用来分析性能的改进将在铁路网络的哪些方面获得收益。
- 工作包 15：消除负面粘着效应的解决方案。其主要目的是基于工作包 7 的成果，开发一个达到 SIL3/4 的粘着管理解决方案。
- 工作包 16：混合、车轮防滑、铺沙分配器和高效的制动力传输解决方案。其主要目的是基于工作包 8 的成果，开发和测试新的粘着管理样机。

PINTA2 是 Shift2Rail 计划中的一个重要项目，是牵引技术示范、制动技术示范的第 2 个项目。该项目的最终总结会议于 2021 年 1 月 27 日举行。这里整理了会议资料，介绍该项目取得的技术成果。

(https://mp.weixin.qq.com/s?__biz=MzU3Njc5ODk5NQ==&mid=2247487158&idx=1&sn=48303f00417b13c8ee67faf013d09fbe&chksm=fd0f26caca78afdcb3503b9b82c0

3714bbf330f3288e1971642f2384dae9f711e3038f4020c9&mpshare=1&scene=1&srcid=0406yamgqThXDKWEWQvrRDL1&sharer_sharetime=1617722462839&sharer_shareid=575e5b610b391061ed74858400a84403&version=3.1.2.2211&platform=win#rd)

整个资料分成了如下几个部分进行介绍：

5.1 PINTA2 项目简介

PINTA2 是 Shift2Rail 计划中的一个重要项目，是牵引技术示范、制动技术示范的第 2 个项目。该项目的最终总结会议于 2021 年 1 月 27 日举行。

主要内容包括：a)牵引系统的创新部件和测试：

1）SiC 牵引系统；

2）用于高速列车的轮毂电机；

b)低粘着制动

30 个月周期，2018.09 – 2021.02。2820 万欧元包括欧盟支持的 1270 万欧元。

合作伙伴包括：



- 有关牵引的工作包 WP 分为 8 个：

WP2——牵引的实验室样机的开发，WP11——牵引的实验室样机的验证；

WP3——降低噪声和 EMI 辐射的规范和仿真，WP12——噪声和 EMI 仿真工具的验证；

WP4——提升可靠性和智慧维护的规范和建模，WP13——可靠性和智慧维护提升的验证；

WP5——虚拟验证的要求和规范，WP14——虚拟验证理念的开发和认可。

- 有关制动的工作包 WP 分为 4 个：

WP7——用于规范性变更的粘着测试以及解决方案的规范，WP15——消除低粘着效果的解决方案的开发；

WP8——商业案例、WSP 测试台升级和解决方案的理念，WP16——混合、WSP、撒砂器和有效力传输的解决方案。

- 整合和接口工作方面的工作包 2 个：

WP1—— KPI 的量化和程序；WP6——关键技术和关键输出资料的预标准化。

- 项目管理方面的工作包 2 个：

WP9——项目管理和技术协调；WP10——传播、沟通和宣传。

5.2 牵引的实验室样机的开发和验证

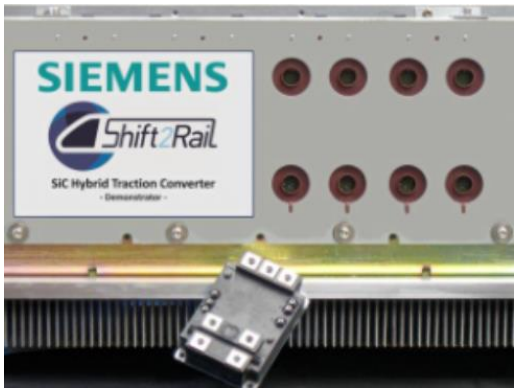
WP2——牵引的实验室样机的开发，WP11——牵引的实验室样机的验证；

三个内容：主要目标，开发、测试结果和输出资料，下一步的计划。

5.2.1 主要目标有:

- 创新的牵引系统组件和子系统样机的开发；
- 组件/子系统在测试台或列车上的测试和验证；
- 为 PINTA3 项目中牵引系统在列车上的测试做准备；
- SiC 半导体牵引在城市和区域列车的应用，以及高速列车的车轮电机。

5.2.2 有轨电车的成果:



- SiC 牵引逆变器硬件开发、测试完成，并在有轨电车安装；
- 载客示范在德国进行中（2020/8～2021/2）；
- 提升的 KPI：能耗降低 7%、重量和体积和噪声（纯音）减少 5%、可靠性提升 5%。

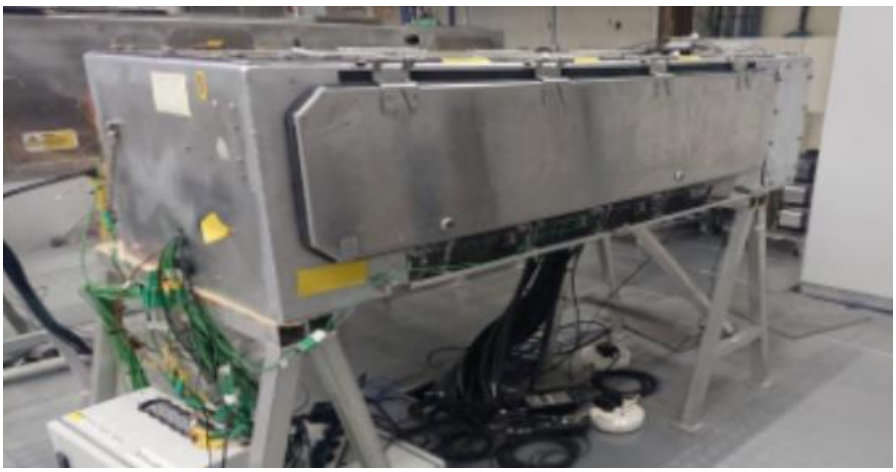
5.2.3 地铁列车的成果:

- 完全 SiC 变频器的系统设计和测试完成;
- 预计 2021 年 2 月在西班牙装车进行 2 年的示范（载客);
- KPI 的提升：能耗和维护减少 7%、重量和体积减少 25%、可靠性提升 6%、噪声降低了一些。



5.2.4 郊区列车的成果:

- SiC 优化的牵引系统设计、制造以及测试台的测试;
- （PINTA2 还来不及示范);
- 预计 KPI 的提升：能耗减少 8%、重量减少 10%、噪声降低 10%、维护减少 20%、体积减少 20%、可靠性提升 20%。



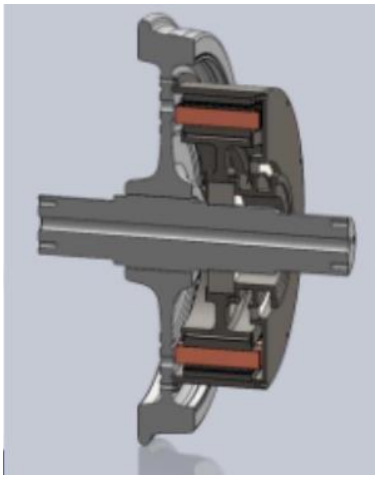
5.2.5 区域列车的成果:

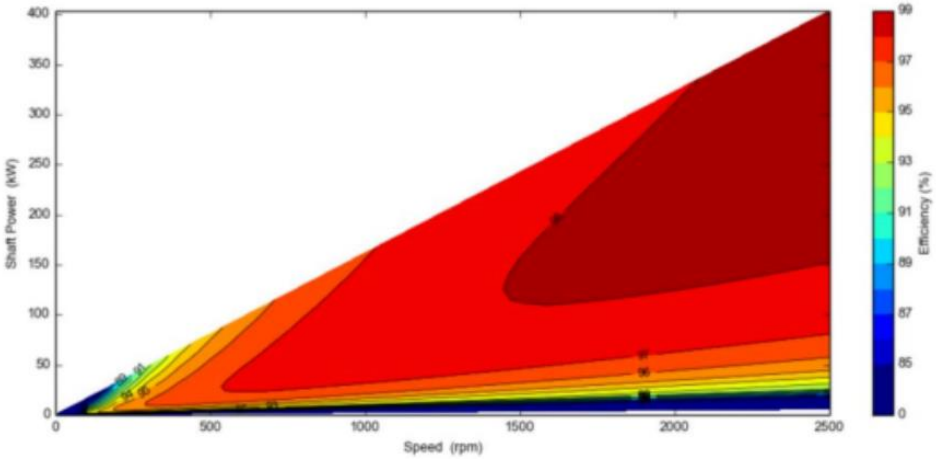
- 牵引的组件（变压器、SiC 牵引箱、高速电机和齿轮箱）已经完成了设计和制造，正在进行测试台测试;
- （PINTA2 来不及示范);

- KPI 的提升：能耗和维护减少 14%、重量减少 15%、体积减少 5%、可靠性增加 11%、减少了一些噪声（自然冷却的变压器和牵引箱）。

5.2.6 高速列车的成果：

- 完成了最终控制算法和动态研究；
- 轮毂电机正在结构实施阶段；
- （PINTA2 来不及示范）；
- KPI 的提升：能耗减少 3%、维护减少 5%、可靠性提升 12%，这个架构可以提升乘客的舒适度。





下一步，在 PINTA3 中将进行进一步的工作，包括：

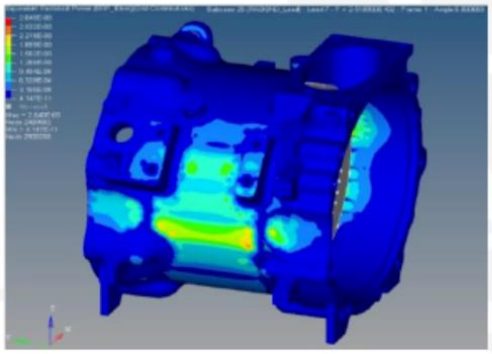
- 最终的示范（完成地铁列车和有轨电车示范、区域列车 SiC 在测试轨道的示范、在西班牙开展高速列车轮毂电机的示范）；
- 得出 S2R 牵引技术示范的 KPI 提升的最终结论；
- 策划一下创新在商业市场的快速引入。

5.3 噪声和 EMI（电磁干扰） 的预测和仿真

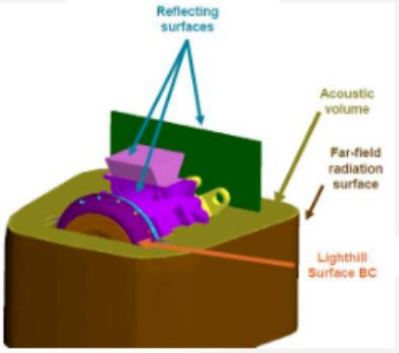
PINTA2 最终会议之：WP3——预测噪声和 EMI 辐射的规范和仿真，WP12——噪声和 EMI 仿真工具的验证。这一部分包含三个内容：预测声学噪声和 EMI 噪声的目标；开发过程和成果；结论。

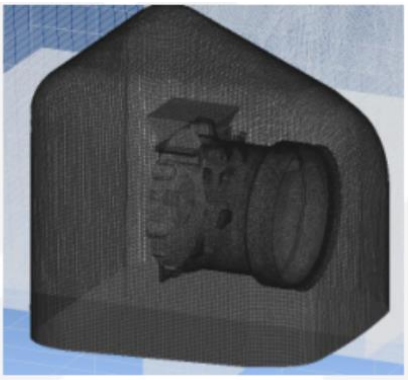
BOMBARDIER CAF SIEMENS DB SNCF

预测声学噪声的目标：更好的预测加速时由于电磁声引起的电机噪声；更好的预测牵引电机的冷却噪声；在车辆和组件水平研究纯音。



Result of acoustic simulation due to electro-magnetic forces on motor frame





Acoustic model and mesh of a traction motor to simulate aero-acoustic noise

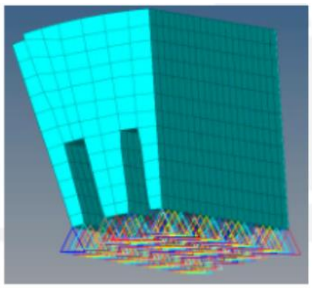
降低 EMI 辐射的目标：一个用来测量影响 ATP 系统的磁场发射的测试系统的定义和验证；通过测试进行共模电流仿真模型的描述和验证；研究牵引供电和车辆间的兼容性的仿真程序的开发和验证。

开展的开发工作中，有关源自牵引电机的噪声预测，涉及如下内容：

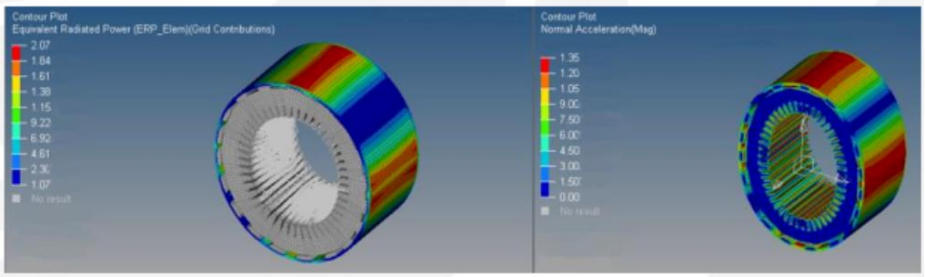
1）可以准确和高效的耦合电、磁和机械模型的方法的开发；

2）提升现有工具的能力的研究（比如：透明度、计算时间）；

3）稳健的验证方法的开发，这个方法在比较电机不同运行点的仿真和测量数据时，可以揭示模型中的强处和弱点。



Electro-magnetic forces applied on part of a 3D mechanical model



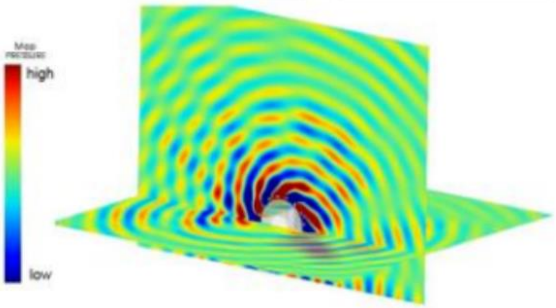
Examples of simulation results on a simplified stator model

预测电机中冷却噪声的一系列方法的开发：

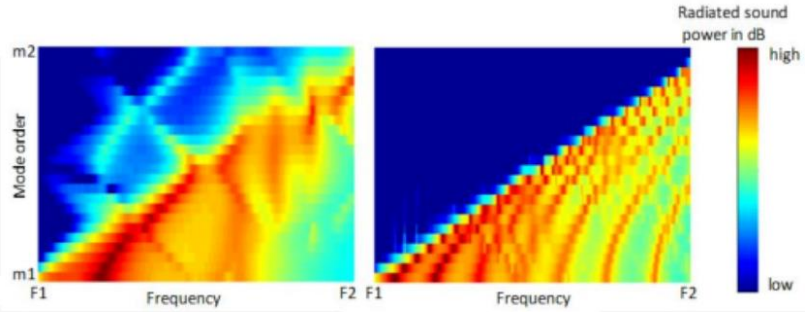
1）中间复合方法的开发和评价，这个方法基于耦合在声学模型的 CFD 仿真；

2）简单和快速方法的开发和评价，这个方法不需要借助 CFD，用来优化一些几何尺寸来实现更低的噪声；

3）所有已开发的气动噪声预测方法的总结和评价，评价依不同准则进行，比如计算时间、复杂度和准确性。



Sound pressure from a fan, indirect CFD coupling



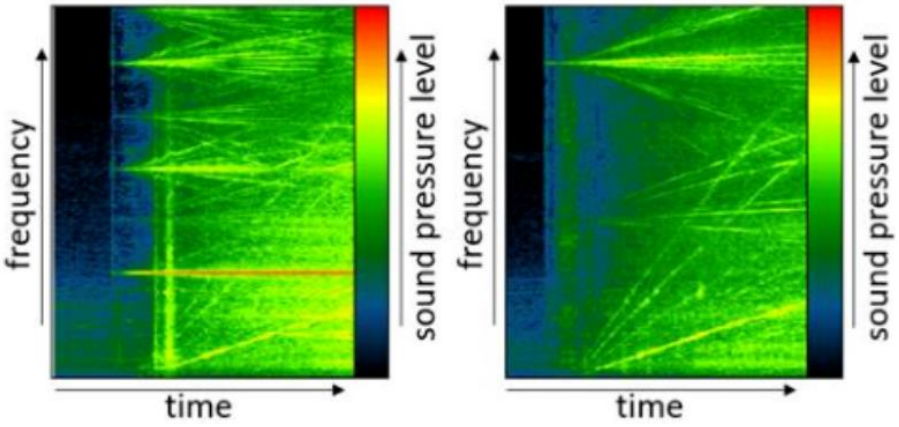
Results of acoustic simulations for two different motor outlet geometries

对于纯音：如何在组件水平上定义纯音的要求？

1）进行电力列车的内部和外部噪声记录的分析，来对各种规范进行评价；

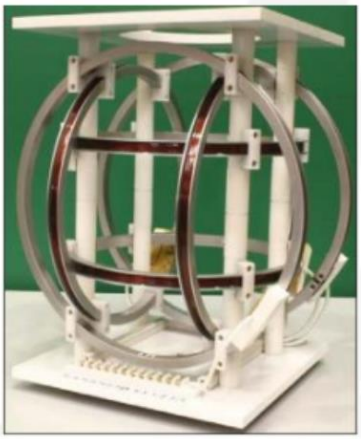
2）使用了 SiC 功率变频器供电的列车加速时纯音的分析，以及不同纯音准则的讨论。

Sound pressure level of the starting noise during tramway acceleration and different converter strategies



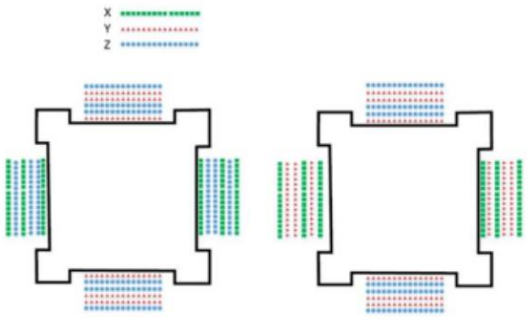
制作的测试系统，来测量影响 ATP 系统的磁场辐射：

1）测量影响运行在 100 kHz 的 ATP 系统的磁场发射测试系统的验证。



Helmholtz coil for the calibration of the magnetic field antennas

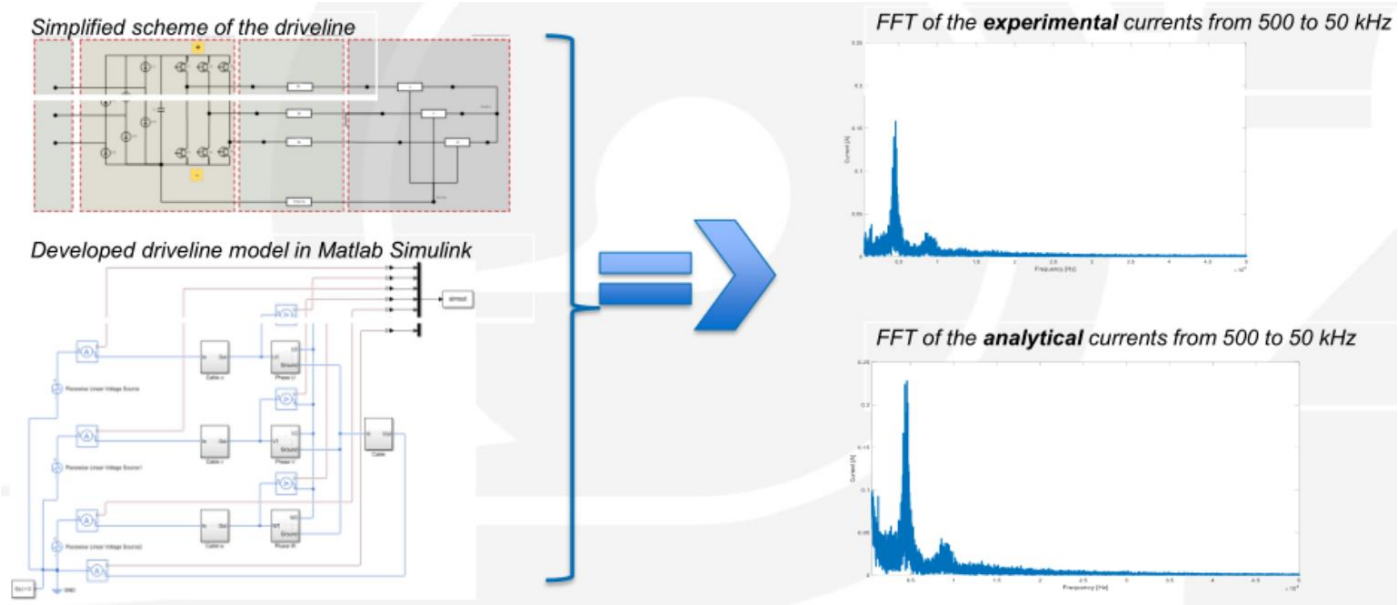




Constructed Triaxial Magnetic Field Probe for the assessment of compatibility between the rolling stock and ATP systems below 100kHz. And distribution of X, Y and Z windings in the different layers

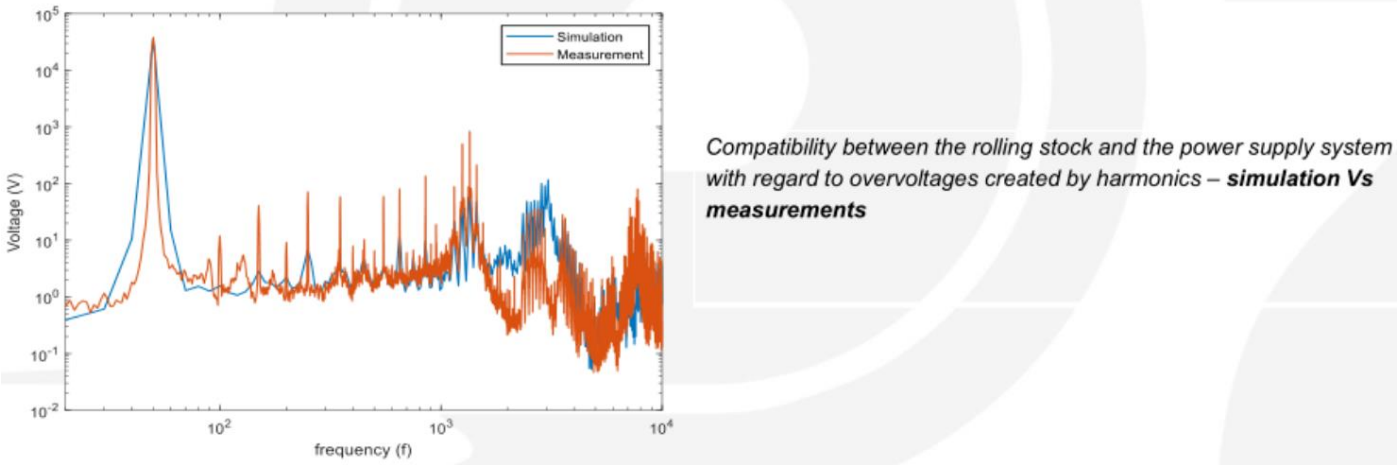
通过测试实现的共模电流仿真工具：

1）在实验室测试中进行 EMI 共模电流仿真工具的验证。



牵引供电和车辆间的兼容性的研究：

1）用来研究牵引供电和车辆间兼容性的仿真程序的验证。



这两个工作包的研究结论是：1）开发的方法和工具可以用于：a）预测来自电磁噪声源的噪声，并评估不同电机设计和变频器供电策略；b）使用不同的策略来预测来自牵引电机的气动噪声源的噪声（策略 1：复杂和计算密集型仿真工具来获得准确的结果；测量 2：简单和快速的方法，用来优化电机中的设计特征，实现更低的噪声）。2）使用上述所有技术，牵引电机中的声学噪声可以降低几个分贝。

结论：1）兼容 ATP。上述方法可用于测量牵引系统产生的磁场（频率 ~ 100 kHz）；测试系统在所有频率范围内具有线性的响应，使得结果的记录更容易。

2）通过使用共模电流仿真，因共模电流产生问题的可能性可以降低 25%，使用这个方法为每个项目带来的成本节约可以超过 5 万欧元。

3）分析由谐波产生的过压，实现列车和供电系统间的兼容性。开发的方法可以用于计算线路上的列车导致的电压失真。

5.4 牵引的可靠性、可用性和维修性的提升

这两个工作包的目标是牵引系统可靠性、可用性和维修性的提升：

WP4：提升的可靠性和智慧维护的规范和建模；

WP13：可靠性和智慧维护提升的验证。

这两个工作包分为了三个内容：1. 铁路特有的环境要求；2. 基于物理模型的可靠性建模；3. 智慧维护。取得的成果和输出材料包括：

- 车辆的微气候测量，用于变压器箱的有效要求
- 保证 PINTA 结果和后续活动得到认可的指标
- 考虑车辆任务轮廓的可靠性建模，可靠性提升
- 用于验证和推论的微气候仿真
- 基于现场数据的牵引变压器可靠性的调查
- 智慧维护的途径和方法。

最后对 PINTA3 项目和下一阶段的活动作出展望。



1. Scope and objectives of work package WP 4 &13

- WP4.1 / WP13.1: Railway specific environmental requirements
- WP4.2 / WP13.2: Reliability modelling based on physical models
- WP4.3 / WP 13.3: Smart maintenance

2. Results and deliverables

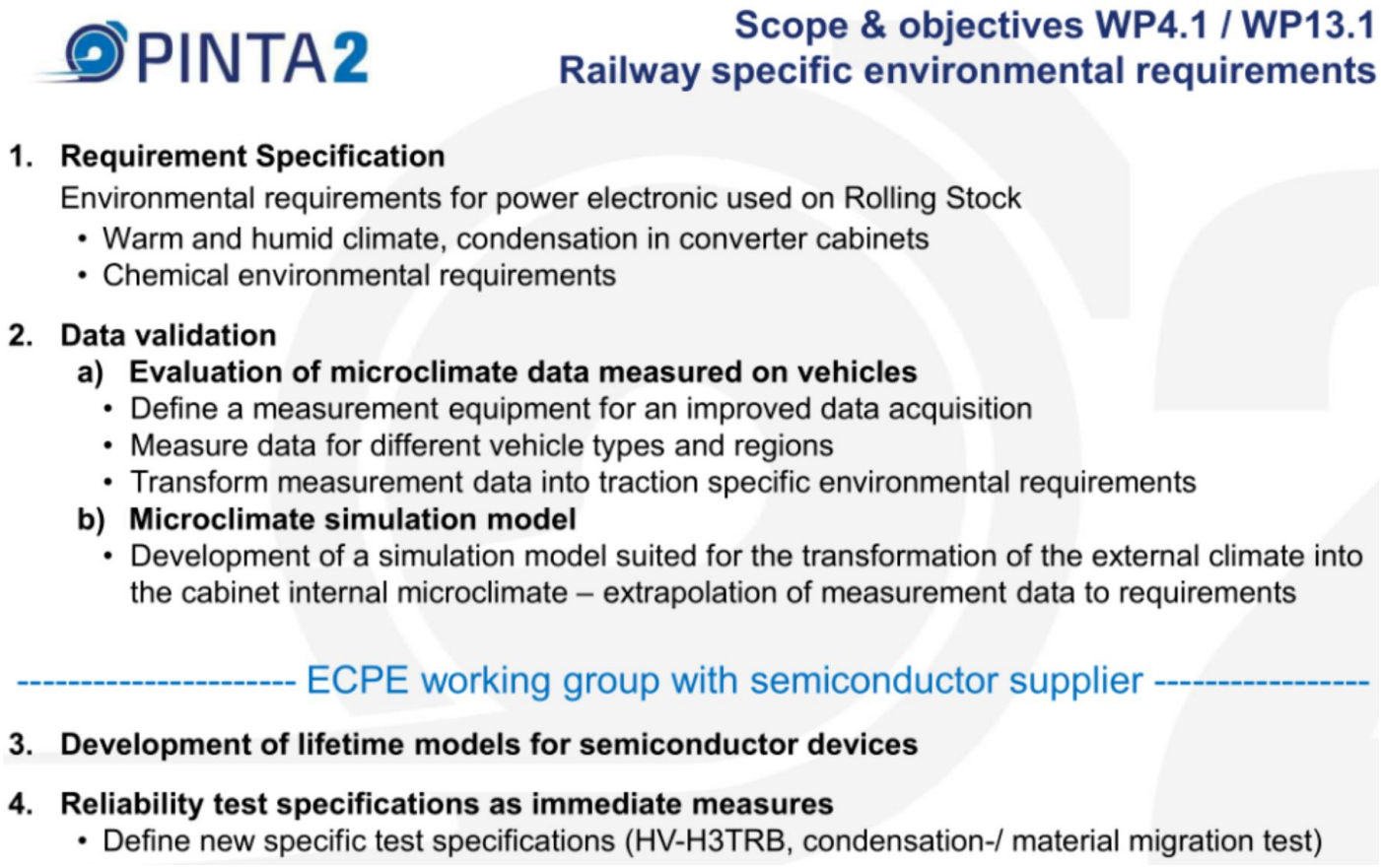
- Microclimate measurements on rolling stock for validated requirements in converter cabinets
- Measures to ensure acceptance of PINTA results, adjacent activities
- Reliability modelling, reliability improvements considering rolling stock mission profiles
- Microclimate simulation for validation and extrapolation
- Survey on reliability in traction converters based on field data
- Smart maintenance approaches, methodologies

3. Outlook on PINTA 3, next steps

第 1 个研究内容：铁路特有的环境要求。有关规范定义了车辆中使用的功率电子器件的环境要求，包括：温暖和潮湿气候以及变压器箱内的冷凝、化学环境要求。

数据的验证工作包含：在车辆上测量的微气候数据的评价（定义一个可以改进数据采集的测量设备、对不同的车辆类型和区域进行数据测量、把测量的数据转换为牵引特有环境要求），以及微气候仿真的模型（开发一个仿真模型包，用于把外界气候转换为变压器箱内部微气候——把测量数据推演成规范要求）。

与半导体供应商联合开展的工作有二：一是半导体装置的生命周期模型的开发；二是定义了一个新的测试规范（HV-H3TRB，冷凝-/材料迁移测试）。



这个表格列出了不同线路的不同列车中所做的（绿色）和计划做的（黄色）测试数据采集。

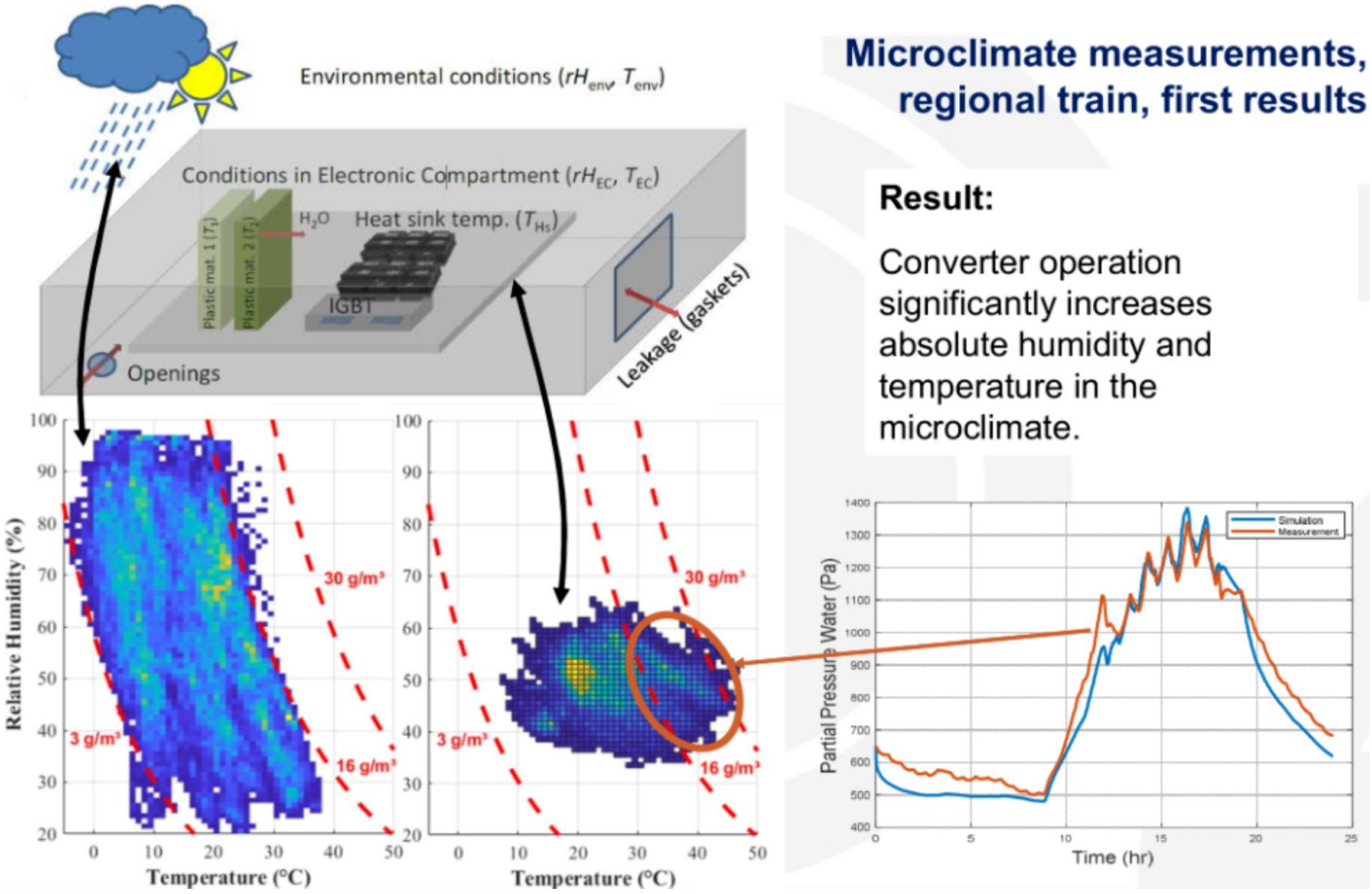
PINTA2

Vehicle measurements

Green: Campaign completed **-or-** first data available **Yellow**: Campaign planned

Campaign	Type of Rolling Stock	Operator	Location	Max. Speed (km/h)	Working Hours	Converter type	Cooling type	Converter location			Measured Positions			Track character-istics		Add. Data	
								Roof	Underfloor	Machine Room	Close to module	Heatsink	Outside of Cabinet	Tunnel sections	Operational height	Vehicle Status Data	GPS
CITYJET ECO (SIEMENS)	Regional, Intercity	ÖBB	Austria	160	16	DC/DC Motor inverter	Water										
ICE 4 (SIEMENS)	Intercity	DB	Germany	230	18	Motor inverter	Water										
Regiolis (ALSTOM)	Regional	SNCF	France	Max 160	10 to 16	Motor Inverter	Water										
Twindexx Vario BR446 (BOMBARDIER)	Regional, Double deck	DB	Central Germany	160	16 (Specified)	Motor Inverter	Water										
EUSKOTREN (CAF)	Regional, Intercity	CAF	Spain (Basque Country)	90	15	Motor Inverter	Natural cooled										
UBx (Siemens)	Metro	Wiener Linien	Austria	80	Tbd.	Auxiliary Inverter	Force Cooled										
Avenio (Siemens)	Tram	SWM	Germany	70	18	Motor Inverter	Force Cooled										

区域列车中微气候测量的结果：结果显示，变压器的运行可以极大的提高微气候中（箱内）的绝对湿度和温度。左侧的两个图分别是外界和变压器箱内的温度（横轴）、相对湿度（纵轴）和绝对湿度（红色虚线）。右侧的图是不同时刻变压器箱内空气水蒸气分压的比较（蓝色是仿真值，红色是测量值）。



工作包的输出成果 D4.1 可靠性和可用性提升的最终报告“用于车辆的功率半导体的气候条件要求规范”。这个报告中包括了三个主题：1. 功率半导体的环境要求，定义了考虑静态和动态运行的热湿运行条件；2. 车辆的使用案例，考虑了比如可以在箱内产生冷凝水的环境条件；3. 一般车辆运营和运行时间的估计，用于真实寿命计算和预计。

PINTA2

Deliverable 4.1.

Objectives of the deliverable

Three subjects are addressed in the deliverable:

- **Environmental requirements valid for the power semiconductors**. Definition of thermal and humid operational conditions considering stationary and dynamic operation.
- “**Use Cases**” of rolling stock considering environmental conditions which e.g. can generate condensation in the container interior.
- **Generic rolling stock operation and operation time estimation** necessary for a realistic lifetime calculation and forecast.

PINTA2

IP1 TRACTION TD1 AND BRAKES TD5 – PHASE 2

D4.1 Final report reliability and availability improvement

Requirement specification for climatic conditions for power semiconductors used on rolling stock

Due date of deliverable: 30/11/2019
Actual submission date: 04/11/2019

Leader/Responsible of this Deliverable: Bernd Laska - SIEMENS

Reviewed: 2019-09-18
Final Review: 2019-10-30

Document status		
Revision	Date	Description
0.1	20/07/2019	Draft version: Excel to Word transfer, changes based on the document: 2019-06-27_PINTA_Requirement-Specification_Change-Request-List_V2
0.2	26/08/2019	Draft version: Update according to the agreed Change Request: 2019-06-27_PINTA_Requirement-Specification_Change-Request-List_V3
0.3	02.09.2019	Draft version: Transformation into the PINTA2 template
0.4	25.09.2019	Draft version: Agreed modification from the review Meeting 2019-09-18
0.5	15.10.2019	Chapter 4.1 High Speed Train operation
1.0	31.10.2019	Release version, submitted for voting

工作包的输出成果 D13.1“包含 RAM 现场数据的牵引组件清单”。这个报告的目的是对牵引组件的可

靠性数据进行分析，识别用于牵引变压器中的关键组件的故障率。获得了如下组件的故障率：功率模块、门驱动单元、冷却组件、电容、线束等。分析了不同类型的车辆，包括：通勤列车、地铁列车、有轨电车、EMU。

PINTA2

Objectives of the deliverable

Analysis of reliability data of traction components in order to identify the failure rates for key components used in the traction converter.

Failures rates are available for:
- Power modules
- Gate drive units
- Cooling components
- Capacitors
- Harness
- Etc.

Different **types of rolling stock** were analyzed:
- Commuter train
- Metros
- Tramways
- Electric Multiple Units (EMU)

Deliverable 13.1.

PINTA2

IP1 TRACTION TD1 AND BRAKES TD5 – PHASE 2

D13.1 List of traction components with RAM field data

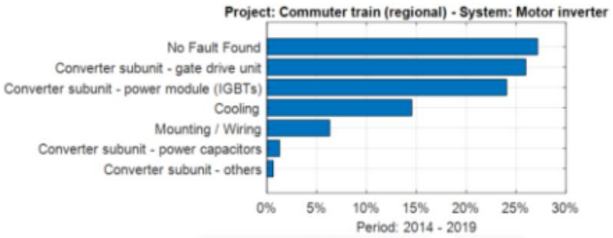
Due date of deliverable: 31/07/2020[1]

Actual submission date: 27/07/2020

Leader/Responsible of this Deliverable: Andrei ILISAN - SIEMENS

Reviewed: Yes

Document status		
Revision	Date	Description
0.1	15/07/2020	First issue in Word Format. Import from the different contributors' sources
0.2	20/07/2020	Review Siemens
0.3	20/07/2020	BT contribution update
0.4	22/07/2020	BT plots standardized
0.5	23/07/2020	Contributors review
1.0	24/07/2020	Contributors review #2
1.1	25/08/2020	Proposal after TMT review



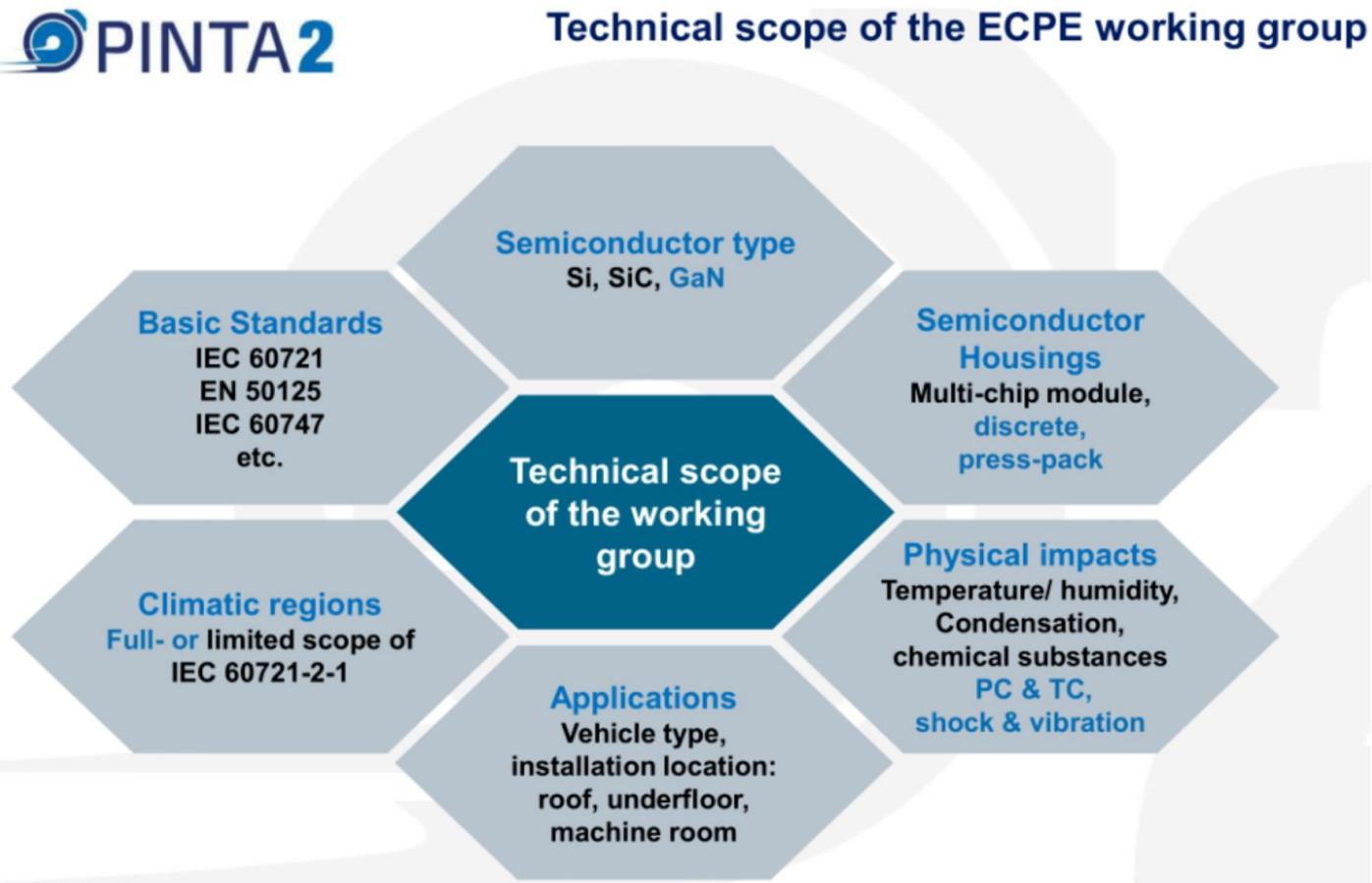
ECPE Railway Working Group Members

Zurich February 2018



In cooperation with the European PINTA Project in the Shift2Rail Joint Undertaking

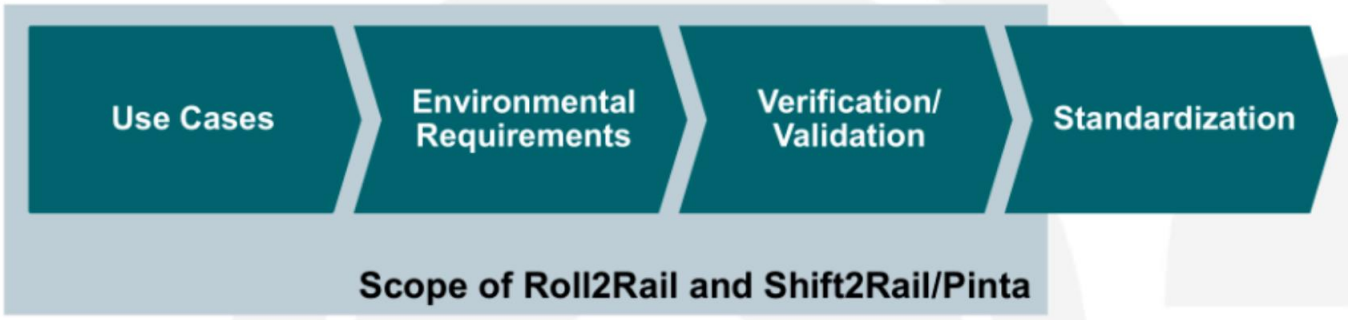
ECPE 工作组技术研究范围：半导体类型（Si、SiC、GaN），半导体外壳（多芯片模块、分散式、压接封装），物理影响（温度/湿度、冷凝、化学物质、压力循环&热循环、振动和冲击），应用（车辆类型、安装位置-车顶、车底、机械间），气候区域（IEC 60721-2-1 全部或受限范围），基本的标准（IEC 60721、EN 50125、IEC 60747 等）。



研究途径：使用案例→环境要求→验证和认证→标准化，Roll2Rail、Pinta 等项目负责前面三项。具体方法和目标：

- 定义运行使用案例，包含对变压器箱内部微气候的影响
- 总结标准中的现有气候要求，识别适用于安装在电子仓内的功率半导体模块等效要求
- 考虑不同安装位置（车顶、车底、机械间）的影响，使用车辆测量的数据验证这些值
- 气候要求应该作为设计和认证的基础。应该由供应商准备适用于装置认证的测试。
- PINTA 项目组希望准备一个 ECPE 技术指南，这个指南将提交标准化组织，比如 CENELEC 或 IEC。

PINTA2



Approach/ Target

- Define operational use cases with an impact on the container internal micro climate
- Review current climatic requirements from standards, identify the relevant requirements for the power semiconductor modules installed in the electronic compartment.
- **Validate these values with data from vehicle measurements considering the impact of different installation locations (roof, underfloor, machine room).**
- Climatic requirements shall be used as a design and qualification basis. Appropriate tests for the device qualification should be prepared by the suppliers.
- PINTA project team intends to prepare an ECPE Technical Guideline planned to be submitted to standardization bodies e.g. CENELEC or IEC as a proposal for a New Work Item.

这个表列出了有关有害气体要求的测量点。其目标是测量含有氯和硫含量的有害气体。

PINTA2

Measurement locations for harmful gas requirements

	Location	Partner	Contact person	Status
Germany	Nuremberg	Siemens	Dr. Bernd Laska	Measuring in progress
	Ratingen	Mitsubishi	Eugen Wiesner	Transport and installation
	Halle	Fraunhofer IMWS	Klegel Sandy	Transport and installation
	Ostfilden-Kemnat	Wevo-Chemie	Terence Kerns	Transport and installation
Europe	Paris (FR)	Schneider Electric	Philippe Loizelet	Transport and installation
	Rennes (FR)	Mitsubishi	Andreja Rojko	Export management
	Cornella (ES)	Siemens	Dr. Bernd Laska	Export management
	Cartagena (ES)	Ayuntamiento de Caragena	Pedro Yepes Martinez	Export management
	Maidenhead (UK)	Hitachi	Chris White	Measuring in progress
	Milan (IT)	Alstom	Mantoan Gianni	Export management
	Lyngby (DK)	TU Denmark	Prof. Rajan Ambat	Export management
	Tallinn (ES)	Doranova Oy	Mati Fjodorov	Applying for permission
	Krakow (PO)	ABB	Maciej Orman	Applying for permission
	Helsinki	ABB	Kjell Ingman	Applying for permission
Laboratory IISB	Erlangen (DE)	Fraunhofer IISB	Weiyi Chen	Measuring in progress

Objective: Harmful gases with Chlorid and sulfor content

- Nuremburg in Germany



- Maidenhead in the UK



环境要求定义的下一步工作：将完成有关规范（2021 年 12 月，包括湿度、温度、冷凝等方面要求的环境条件；2022 年 12 月，包括有害气体和相关电气载荷等方面要求的环境条件）。

取得成就：与牵引装置的半导体供应商合作完成了一个可靠性测试规范，成为一个欧洲范围的公共

ECPE 指南。内部半导体装置的冷凝效应的测试规范正在准备中。

PINTA2

Next Steps on the definition of environmental requirements

The **requirement specification** will be completed within two issues

- 12/2021 Environmental conditions including requirements regarding humidity, temperature, condensation etc.
- 12/2022 Environmental conditions including requirements regarding harmful gases (Fraunhofer) and relevant electric loads (e.g. isolation voltage)

Achievements

In cooperation with the semiconductor suppliers for traction devices a reliability test specification was issued as an Europe wide public avaliable ECPE guide line.

TECHNICAL SPECIFICATION

October 23rd, 2019

Railway applications
HV-H3TRB tests for Power Semiconductor

A test specification for condensation effects in semiconductor devices internal is in preparation.

第二个工作内容：基于物理模型的可靠性建模。用于可靠性和寿命建模的合适方法的开发是提升车辆牵引系统可靠性和可用性并满足铁路运营商期望的关键。还有一点很重要的是这个方法要应用于新一代基于 SiC 的半导体（SiC MOSFET）。

在这组工作包中，PINTA 项目的第一阶段中开发的通用方法将用于真实的案例，提议了一个详细的微气候的仿真工具，并提供了一个特定 SiC MOSFET 故障机制的可靠性模型的更新。这项工作的主要输入材料是 D4.1 报告。

PINTA2

Scope & objectives WP4.2 / WP13.2
Reliability modelling based on physical models

Development of appropriate **methodologies for reliability and lifetime modelling** is key to improve reliability and availability of traction systems used on rolling stock and meet railway operator expectations. It is also very important to **adapt and tune the methodologies to the emerging new generation** of semi-conductors based on SiC (SiC MOSFET).

In this work package, the **generic approach developed** in the first phases of PINTA is applied on a realistic case, a detailed simulation work on micro-climate is proposed and an update on **reliability modeling** of specific SiC MOSFET failure mechanisms is provided.

The main inputs for this work are PINTA 2/D4.1.

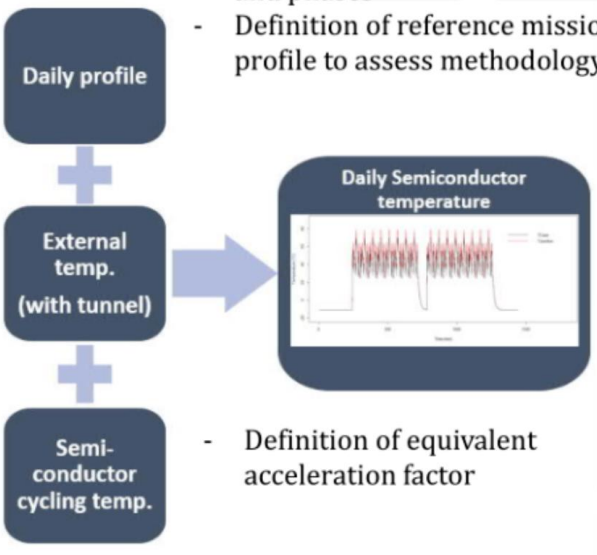
主要结果有：复杂任务轮廓的描述 + 微气候的仿真。任务的描述包括了不同应力和相的联合、用于评估该方法的参考任务轮廓的定义、以及等效加速因数的定义。微气候仿真的工作开发了简单和通用拓扑的变压器模型、温度和湿度的解耦、以及变压器箱内的微气候的预测模型。

PINTA2

WP4.2 / WP 13.2
Main results

COMPLEX MISSION PROFILE DESCRIPTION

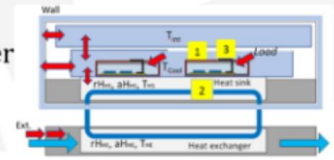
- Combination of different stresses and phases
- Definition of reference mission profile to assess methodology

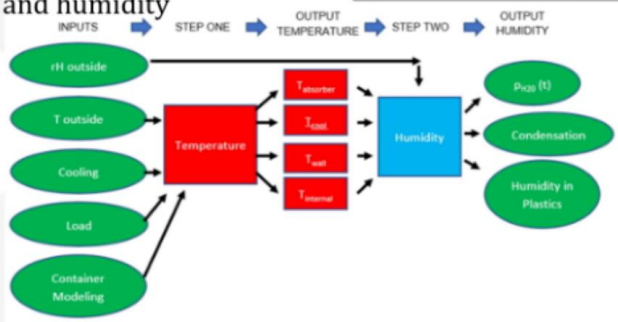


- Definition of equivalent acceleration factor

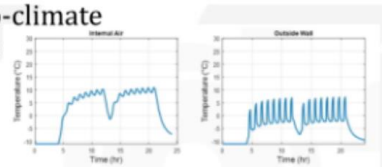
MICROCLIMATE SIMULATION

- Simple and general topology-based converter model
- Decoupling temperature and humidity

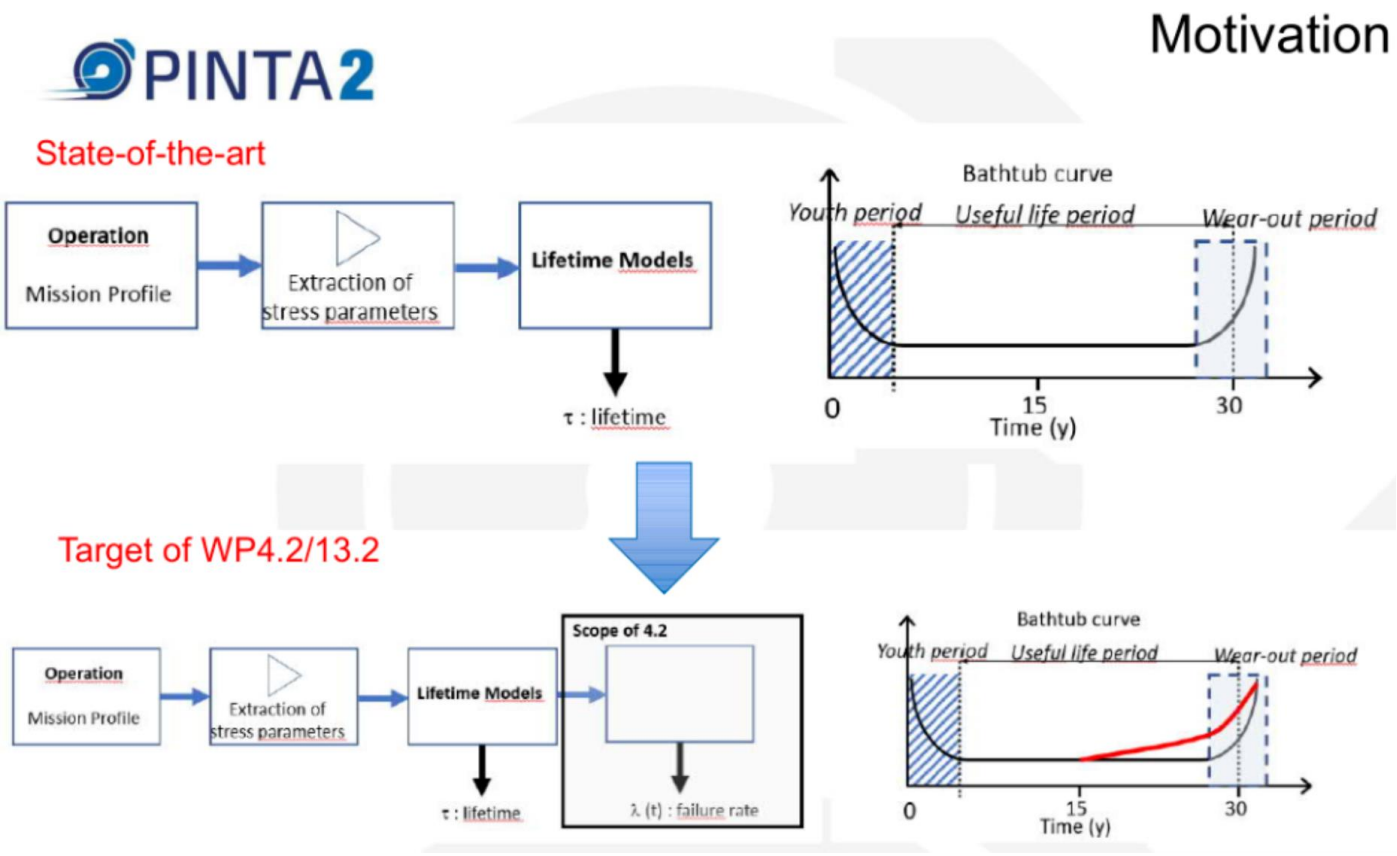




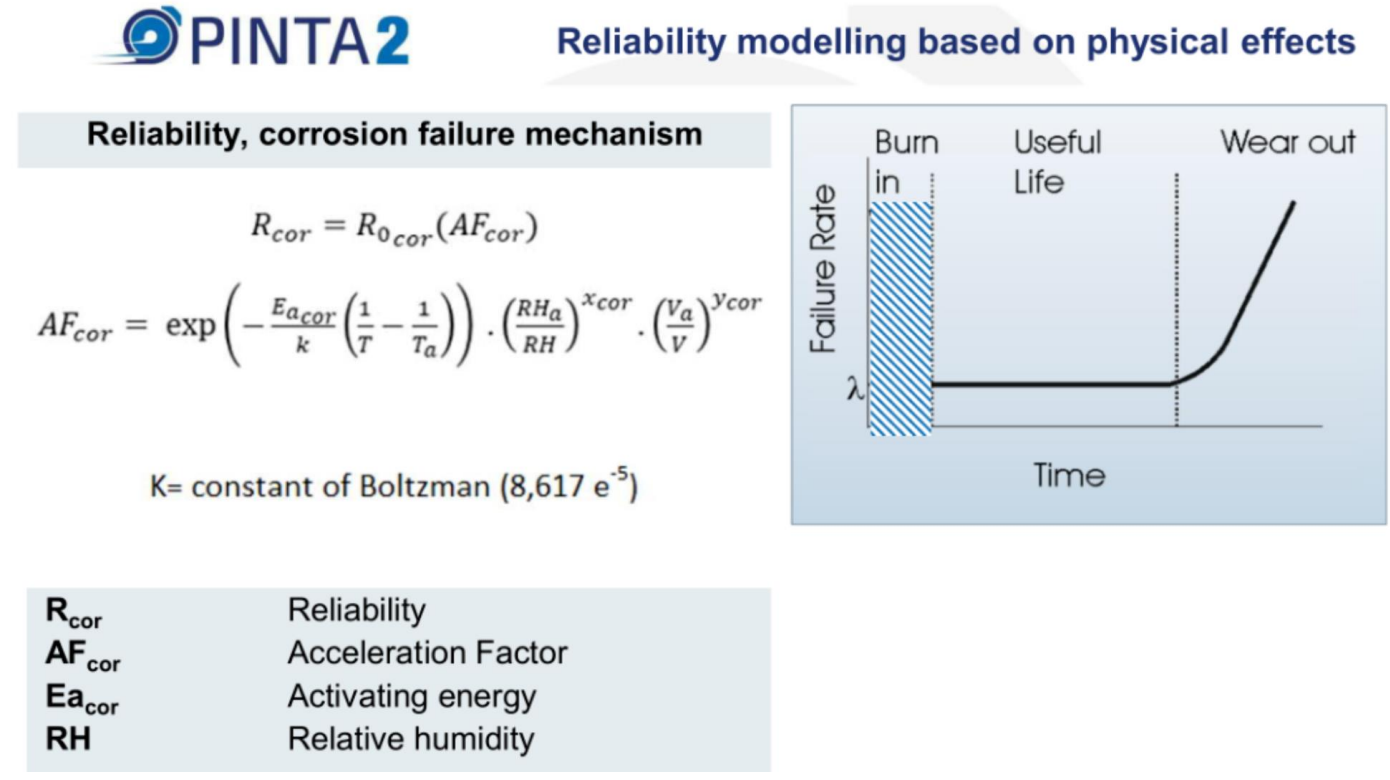
- Prediction of micro-climate inside converter box



上图中比较了该工作的开发和既有模型的差异（增加了故障率模型），也是这项工作的动机。



解释基于物理效应的可靠性建模：可靠性、腐蚀失效机理。



该项工作的两个输出材料：

- D4.2 可靠性和寿命（半导体）模型的中间描述
- D13.2 可靠性提升的最终报告

PINTA2

Deliverable D 4.2

- Status of activities towards reliability modelling of semi-conductors with the objective to cover SiC MOSFET multi-chips modules are described
- Lifetime equations for the different failure mechanisms are included in the document
- This modelling approach is completed by the work of WP13.2.


PINTA2

IP1 TRACTION TD1 AND BRAKES TD5 – PHASE 2

D4.2 Intermediate Description of Model for Reliability and Lifetime (Semiconductors)

Due date of deliverable: 31/12/2019

Actual submission date: 18/11/2019

Leader/Responsible of this Deliverable: Maider Estecahandy - Marion Soussens – Michel Piton / ALSTOM

Reviewed: Y

Document status

Revision	Date	Description
1	23/09/19	First draft
2	17/10/19	Second draft
3	08/11/19	Third draft
1.0	22/11/19	Revision 1.0
1.1	26/11/19	Revision 1.1 [Correction of mistake in table 7]

Deliverable D13.2

- Appropriate methodologies for reliability & lifetime modelling
- Methodologies consider rolling stock mission profiles
- Models are based on physical phenomena
- Methodology is suited for Si and the emerging new SiC generation
- A detailed simulation work on micro-climate conditions is proposed


PINTA2

IP1 TRACTION TD1 AND BRAKES TD5 – PHASE 2

D13.2 Final report on reliability improvements

Due date of deliverable: 31/12/2019

Actual submission date: 15/11/2020

Leader/Responsible of this Deliverable: <Michel Piton / ALSTOM>

Document status

Revision	Date	Description
1.0	20/11/2020	First issue

第三项工作是有关智慧维护：

- 提升牵引系统和相关牵引组件的可靠性和可用性；
- 智慧维护的理念：远程诊断、健康监控、预测型维护；
- 为运营商改进智慧维护：数据采集、数据传输和数据分析方法；
- 实车数据的分析。

PINTA2

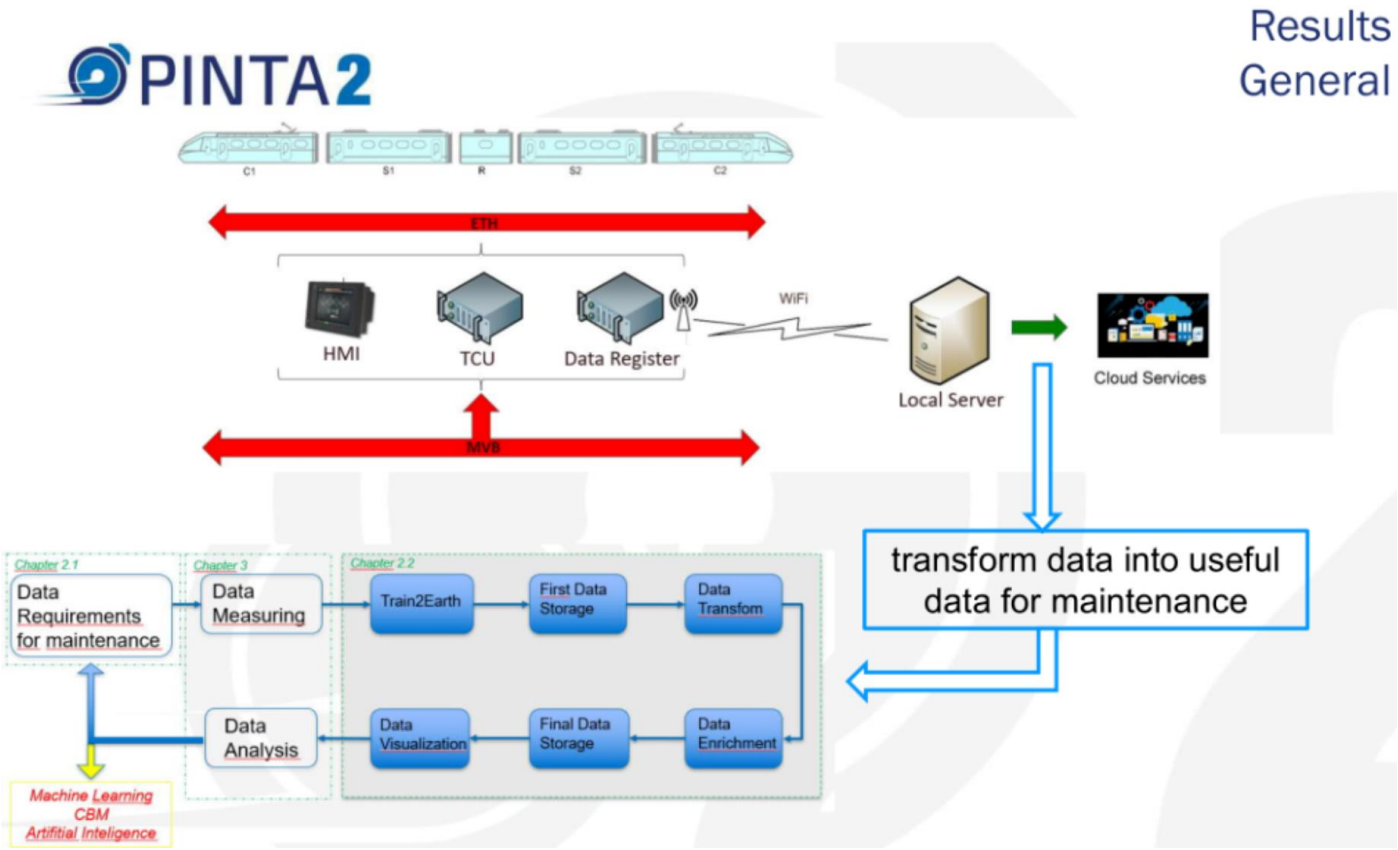
Scope & objectives WP4.3 / WP 13.3 Smart maintenance

- **Increase reliability and availability of the traction system and related traction components.**
- **Concept for smart maintenance: remote diagnostics, health monitoring, predictive maintenance**
- **Adapt process of smart maintenance especially for the operator**
  - **Data acquisition**
  - **Data transmission**
  - **Data analysis methods**
- **Real train data analysis.**

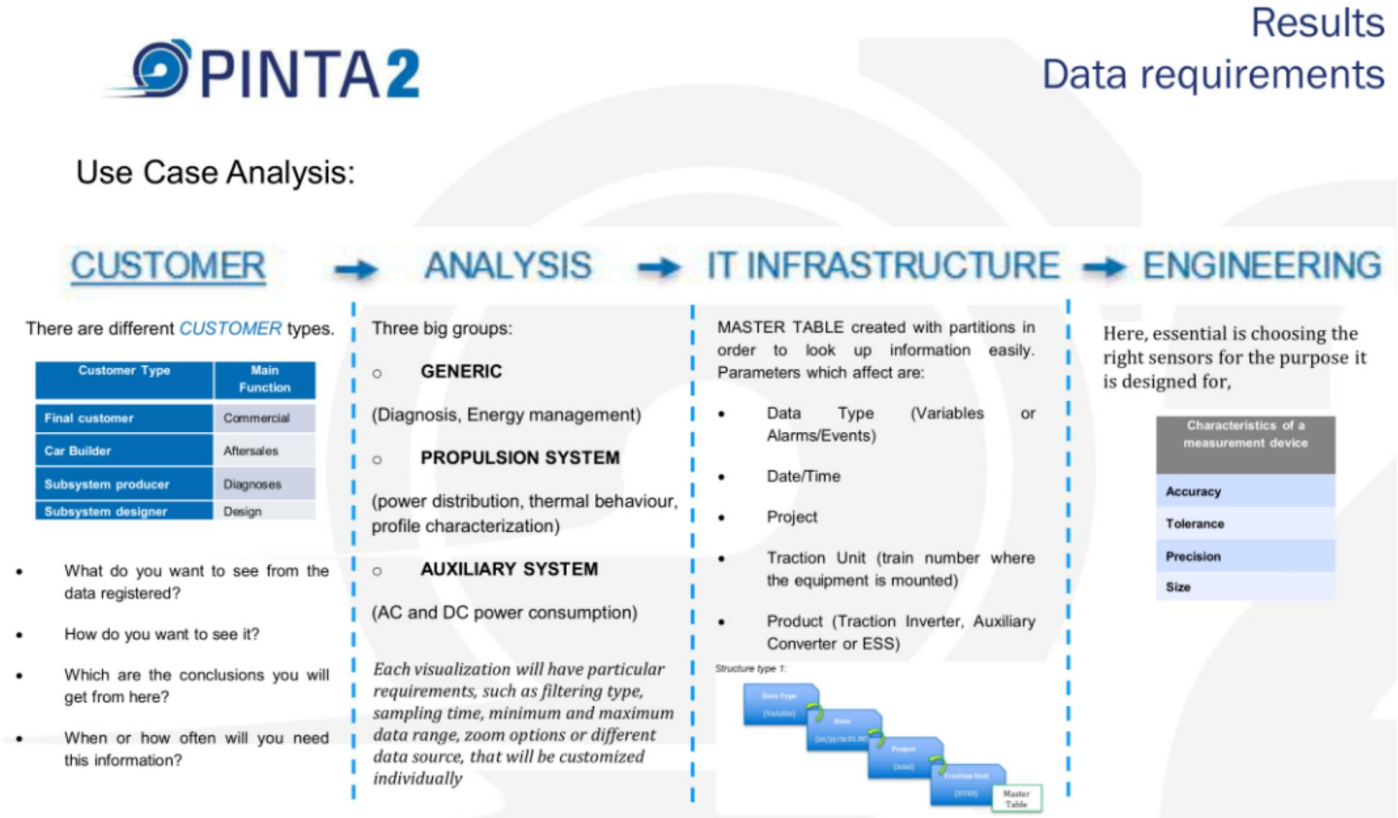
D4.3	Intermediate report on smart maintenance improvements

D13.3	Final report on smart maintenance improvements

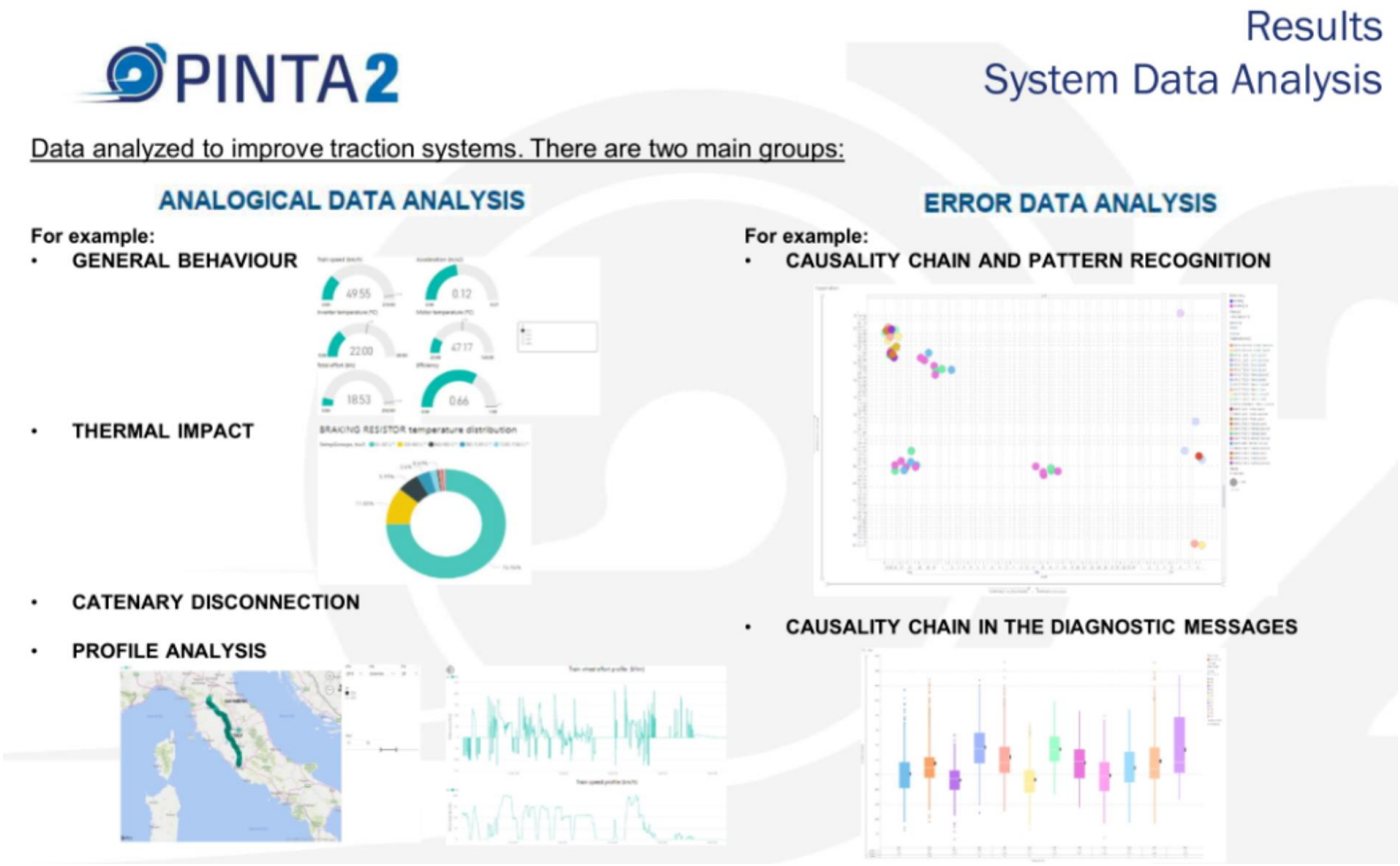
取得的成果（通用）：把数据转换为对维护有用的数据。



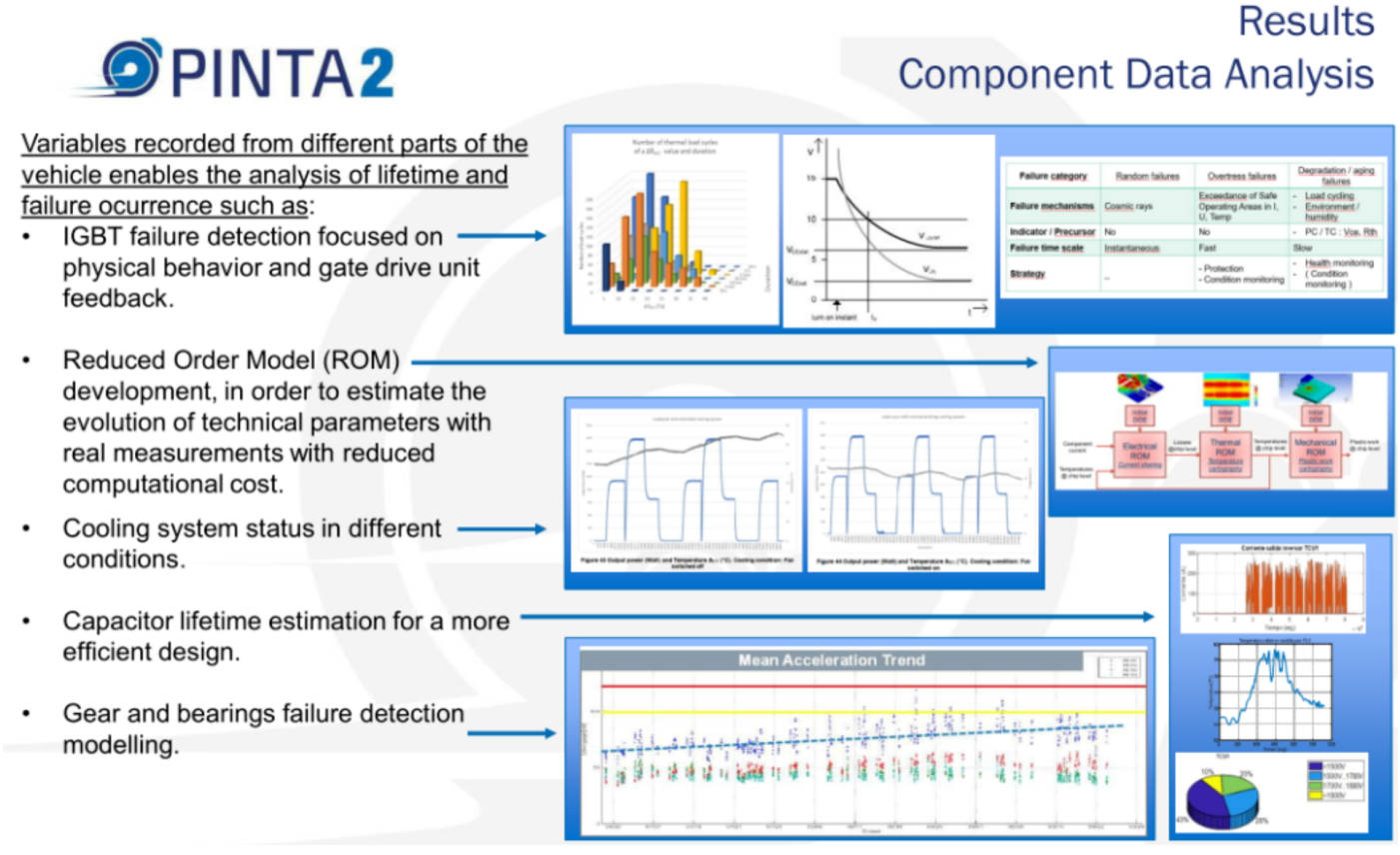
取得的成果（数据的要求）：使用案例的分析（针对用户的问卷调查➞分组分析➞IT 工具➞工程设计）。



取得的成果（系统数据的分析）：把系统数据进行分析来提升牵引系统；数据分为两类，一是类比数据分析，二是错误数据分析。

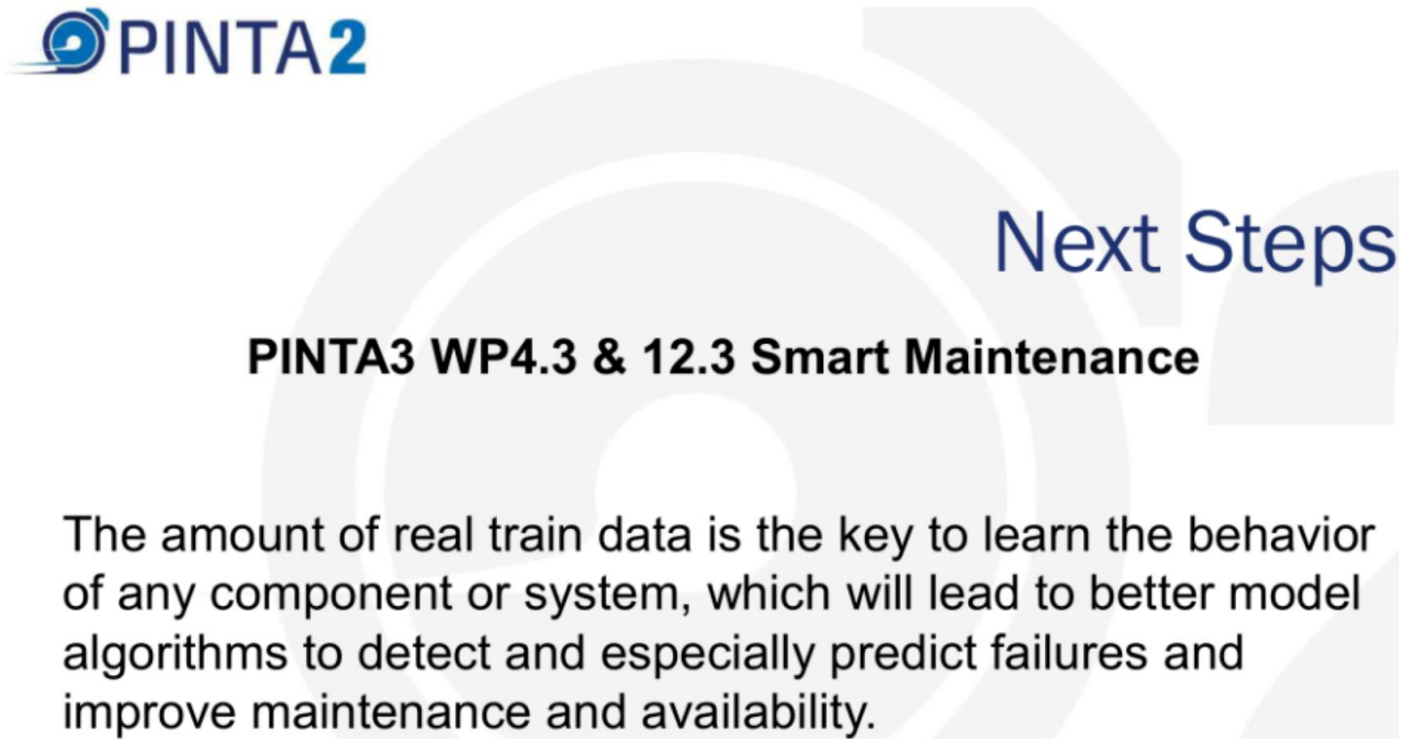


取得的成果（组件数据的分析）：记录车辆不同部件的变量，用于一些寿命和故障事件方面的分析。比如：IGBT 故障的探测（关注物理特性和门驱动单元的反馈）、估计技术参数的发展规律（ROM 的开发）、不同工况下冷却系统的状态、电容寿命的预测、齿轮和轴承的故障探测建模



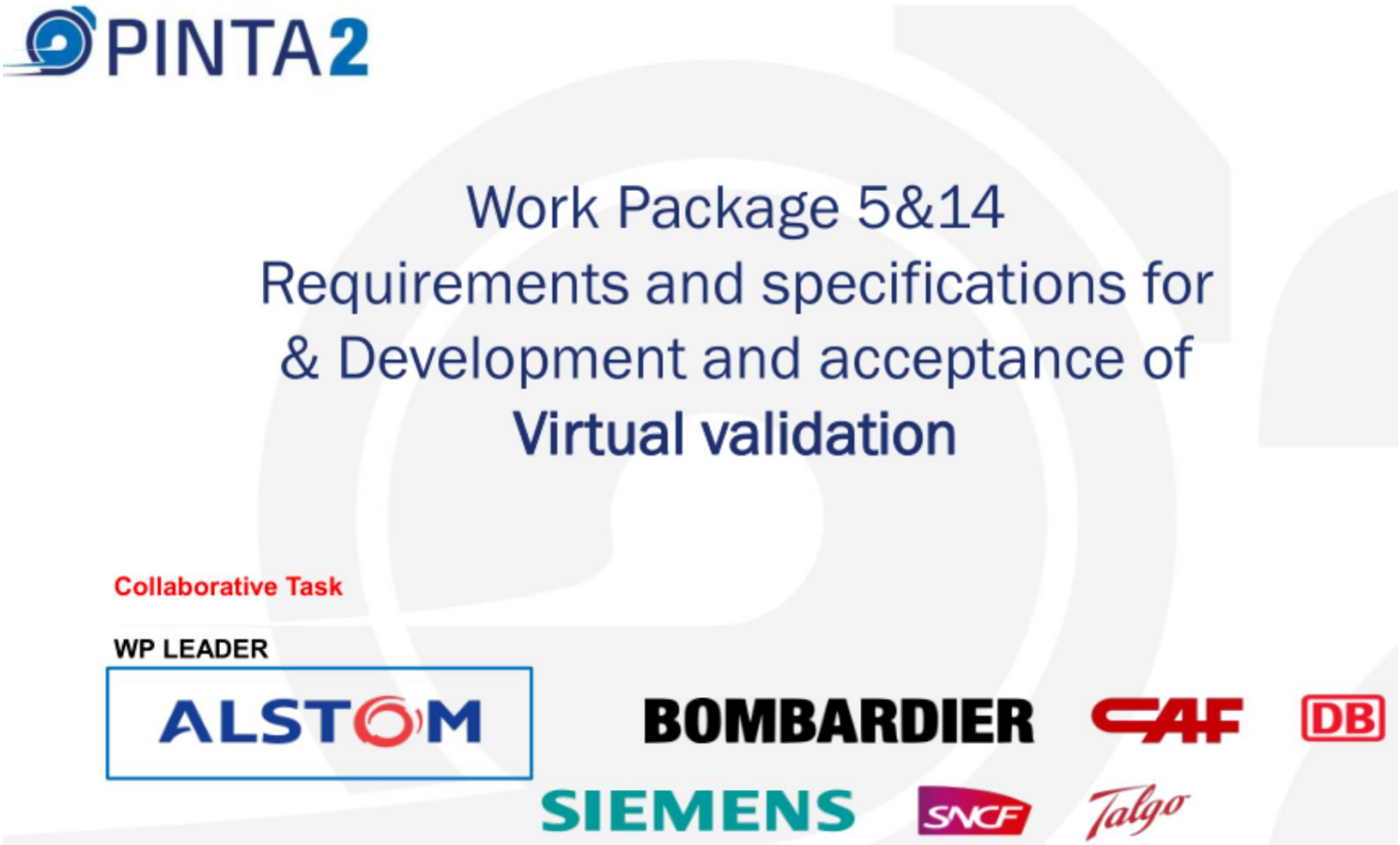
在 PINTA3 项目中，继续进行智慧维护的开发。实车数据量是学习任一组件和系统的特性的关键，

用于得到更好的模型算法，最终实现故障的探测和预测（特别是预测）、提升系统的维修性和可用性。



5.5 虚拟验证的开发

工作包 5 和 14：虚拟验证的要求和规范的定义，及其开发和认可。



三个内容：仿真质量的保证、标准化、结论和展望。

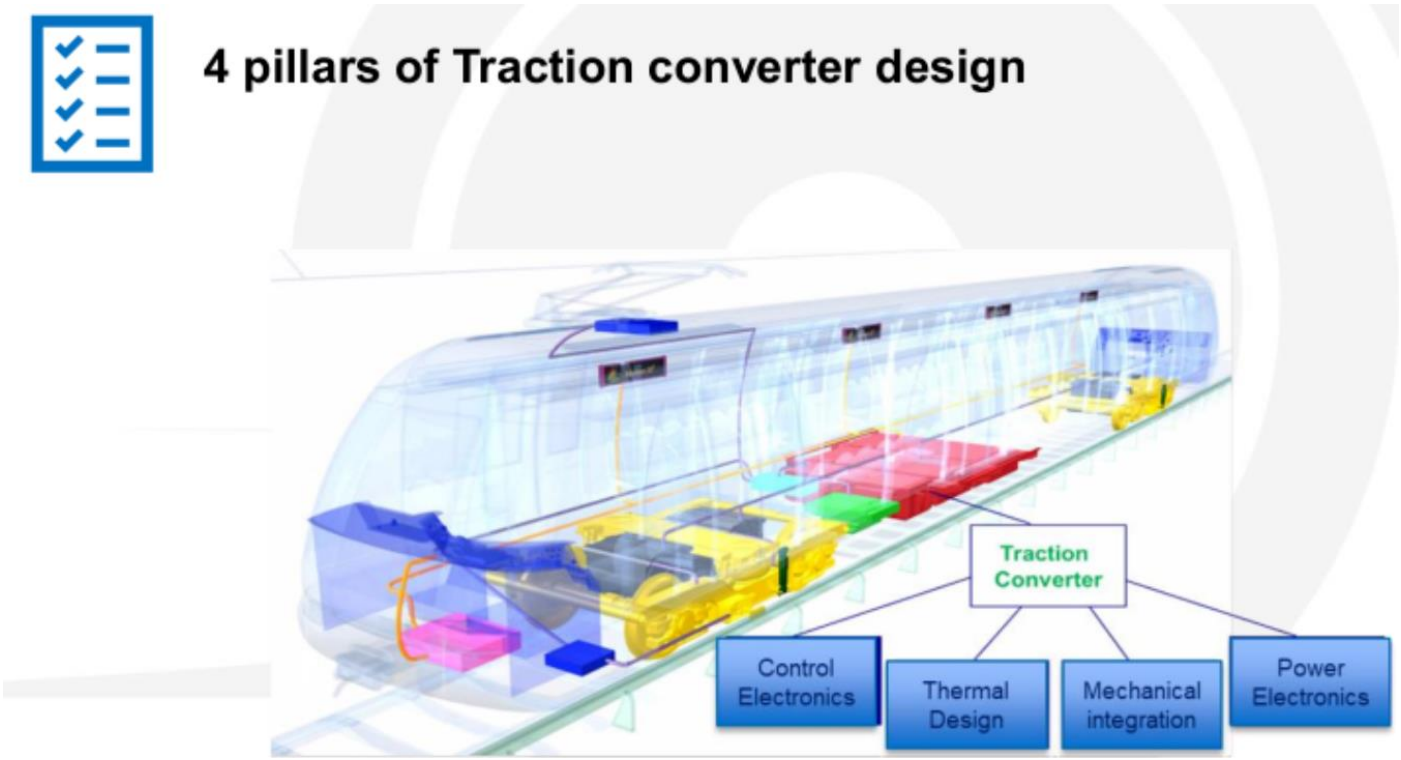
INTRODUCTION

Part I: Simulation Quality justification

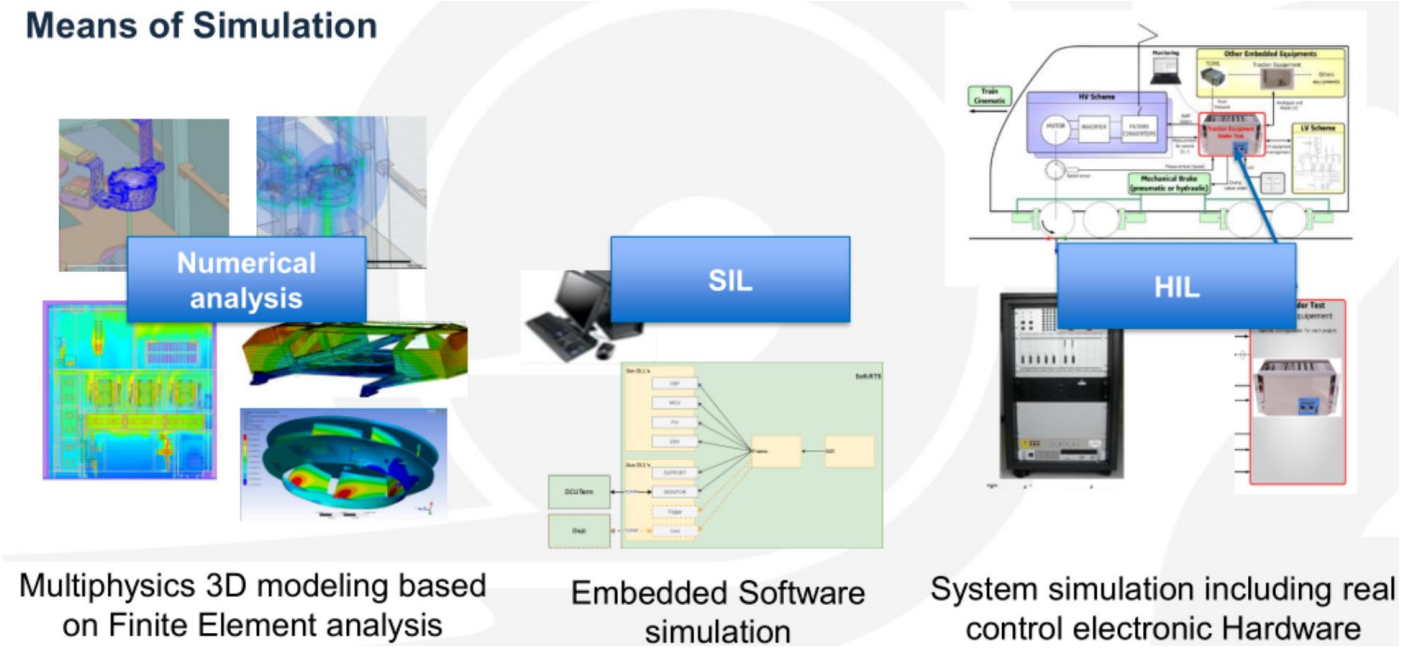
Part II: Standardisation

Conclusion & Perspectives

牵引变压器设计的 4 个支柱：控制电子、热设计、机械集成、功率电子。



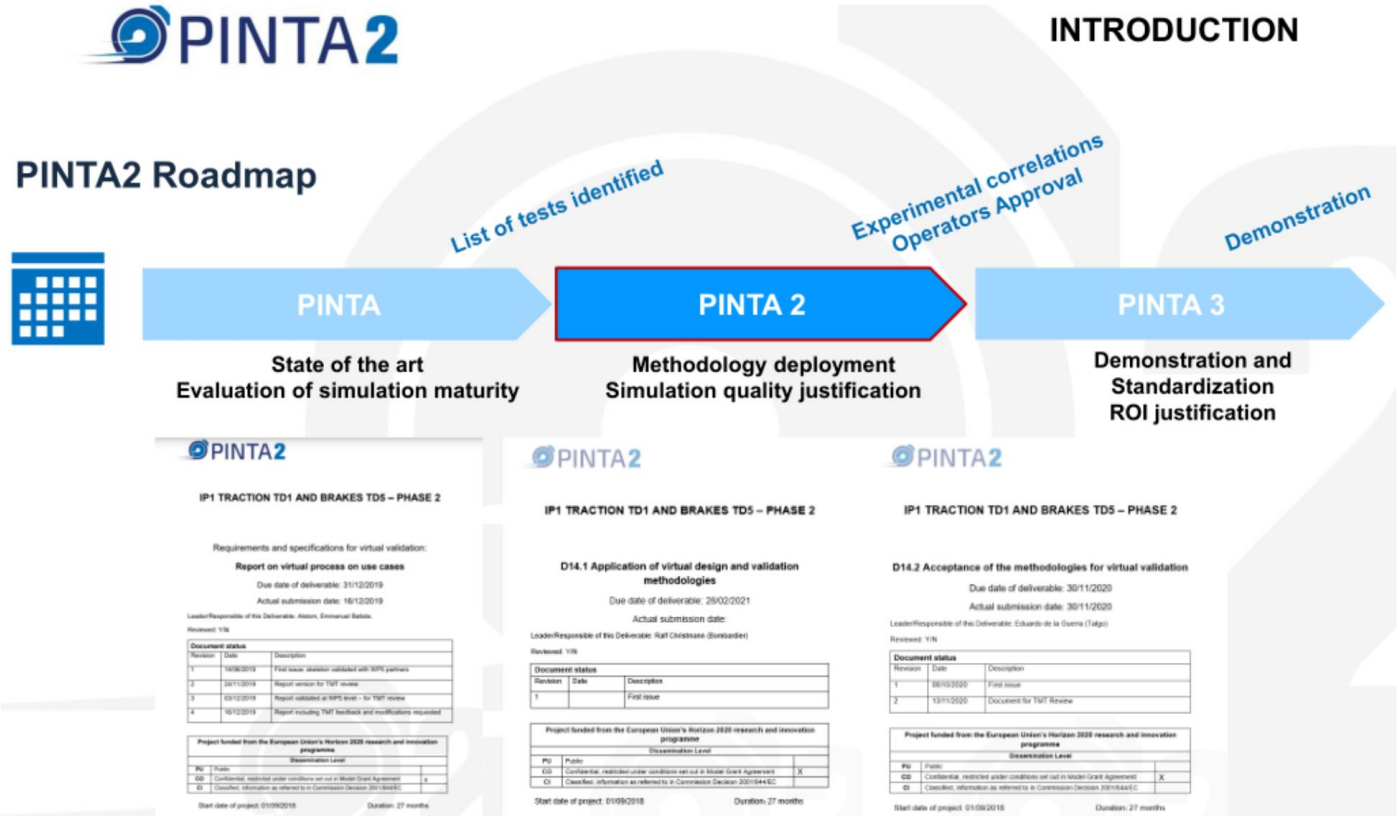
仿真的方法：1. 数值分析（基于有限元分析的多物理 3D 建模），2. 软件在环（嵌入式软件仿真），3. 硬件在环（包含真实控制电子硬件的系统仿真）。



虚拟验证的目标：宏观——缩短投放市场的时间、降低开发成本，增强竞争力；技术——因多物理和系统仿真，带来型式和例行试验预测和设计及验证时间和成本的降低。



PINTA 系列项目有三个，PINTA2 是关键的中间项目。



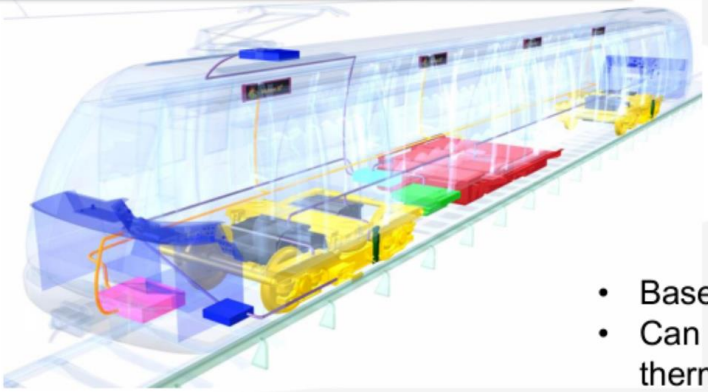
工作内容的第一项是关于仿真质量的保证。多物理模型的建立：基于准确的 3D 模型来建立，可以产生复杂的特性（热、机械和电磁的）。

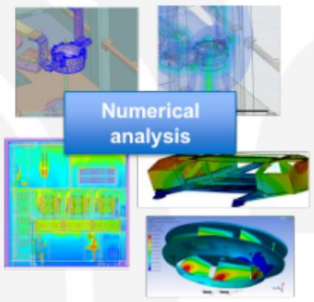
PINTA2

Part I: Simulation Quality justification

Main results : Multiphysics

Hardware components validation tests anticipation





Multiphysics 3D modeling based on Finite Element analysis

- Based on accurate 3D models
- Can reproduce complex behaviour for thermal, mechanical and electromagnetics

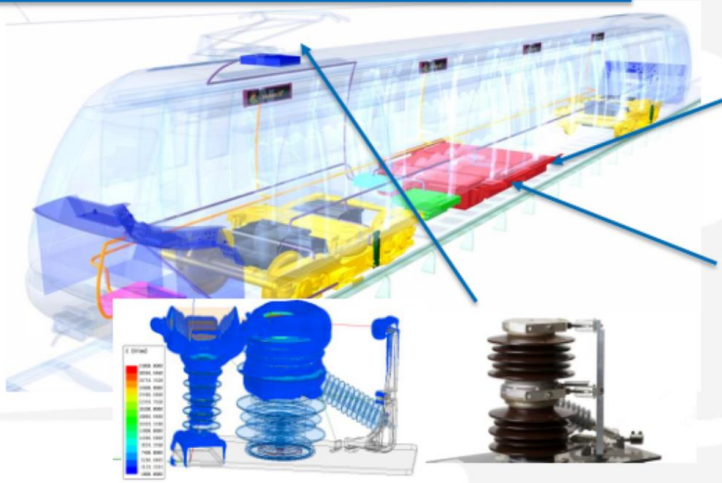
这些模型包括：高压部件的介电击穿建模，部件和箱体的热设计、热点和环境温度建模，冲击和振动仿真和测量的相关性。

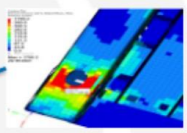
PINTA2

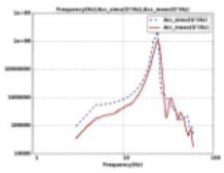
Part I: Simulation Quality justification

Main results : Multiphysics

Hardware components validation tests anticipation

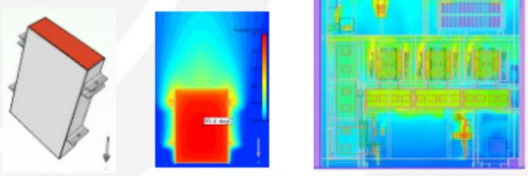






Shock and vibration simulation and measurement correlation

High voltage parts dielectric breakdown modeling

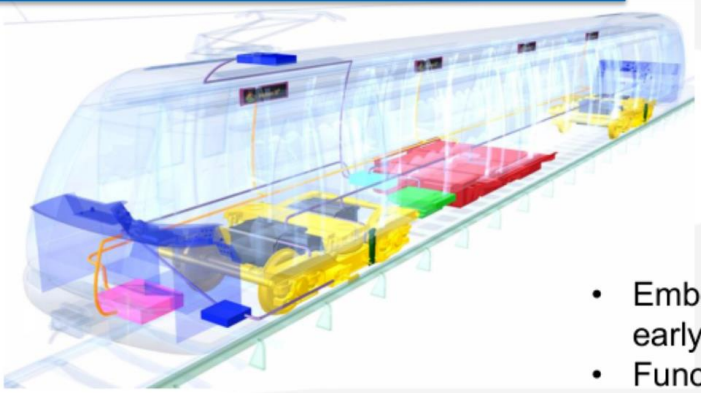


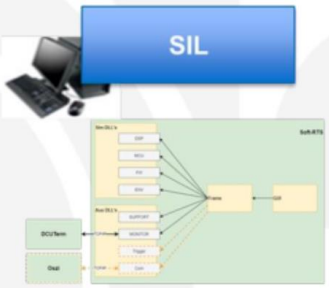
Thermal design of parts and cubicles, hot spots and ambient temperature modeling

软件在环：嵌入式软件验证和代码覆盖功能。嵌入软件功能可以在设计阶段早期、不需要借助样机和试验室进行验证；功能可以很容易的校正；计算时间比实施仿真器要快。

Main results : Software In the Loop

Embedded software validation and code coverage functions





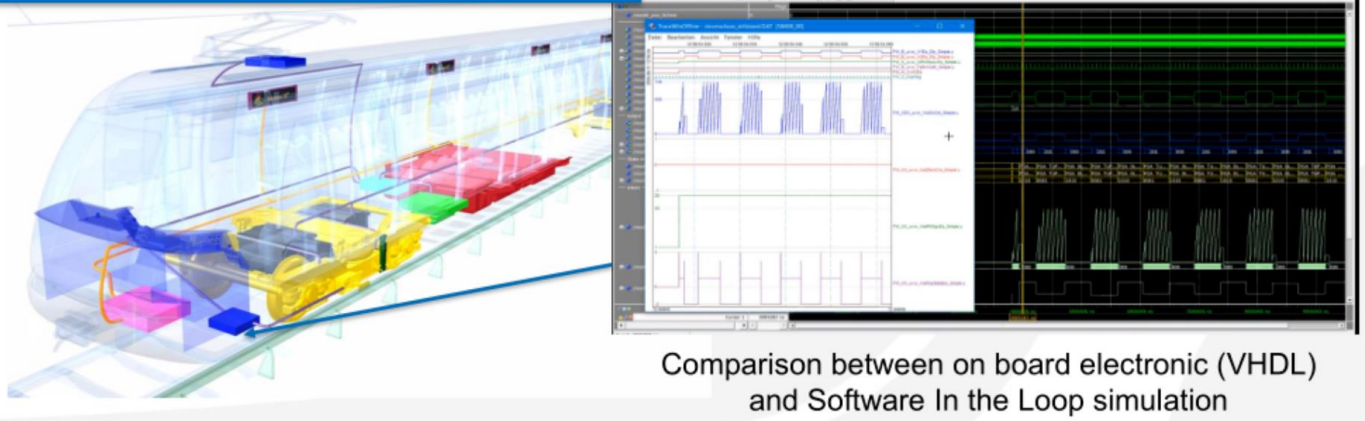
Embedded Software simulation

- Embedded software functions can be validated early in design phases without prototypes and lab
- Functions can be tuned easily
- Calculation time is faster than real-time simulator

车载电子装置（VHDL）和软件在环仿真的比较。

Main results : Software In the Loop

Embedded software validation and code coverage functions



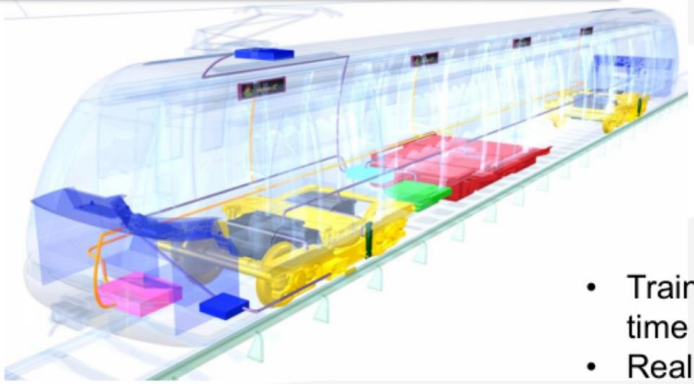
Comparison between on board electronic (VHDL) and Software In the Loop simulation

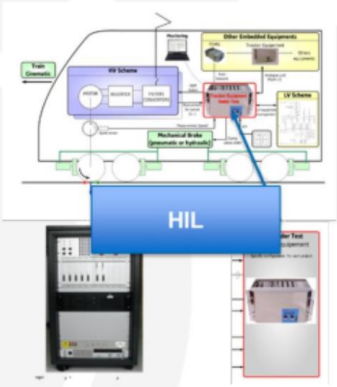
硬件在环：系统特性和性能预测。

列车和牵引系统在实时仿真器中进行模拟；包含了真实的电子硬件，并连接到仿真器上；取决于控制电子和嵌入软件的牵引的特性可以进行验证。

Main results : Hardware in The Loop

System behaviour and performance anticipation





- Train and traction system is emulated on a real-time simulator
- Real electronic hardware is included and connected to the simulator
- Traction behaviour depending on control electronic and embedded software can be validated

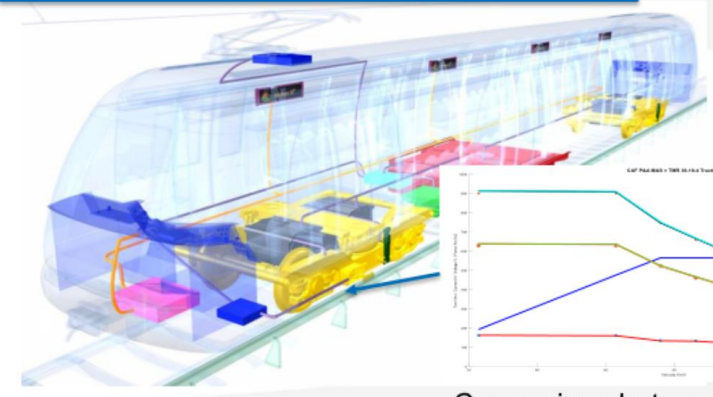
硬件在环：硬件组件（接触网、主变压器、燃料电池）特性仿真和测量的比较（上）；牵引性能测量和仿真（控制电子作为硬件在环实施仿真器）的比较（下）。

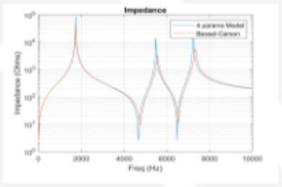
PINTA2

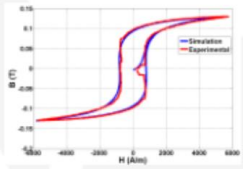
Part I: Simulation Quality justification

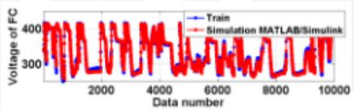
Main results : Hardware in The Loop

System behaviour and performance anticipation

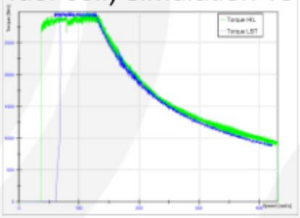








Hardware components behaviour (catenary, main transformer, fuel cell) simulation vs measurement



Comparison between Traction performance measurement and simulation with control electronic as Hardware In the Loop real-time simulator

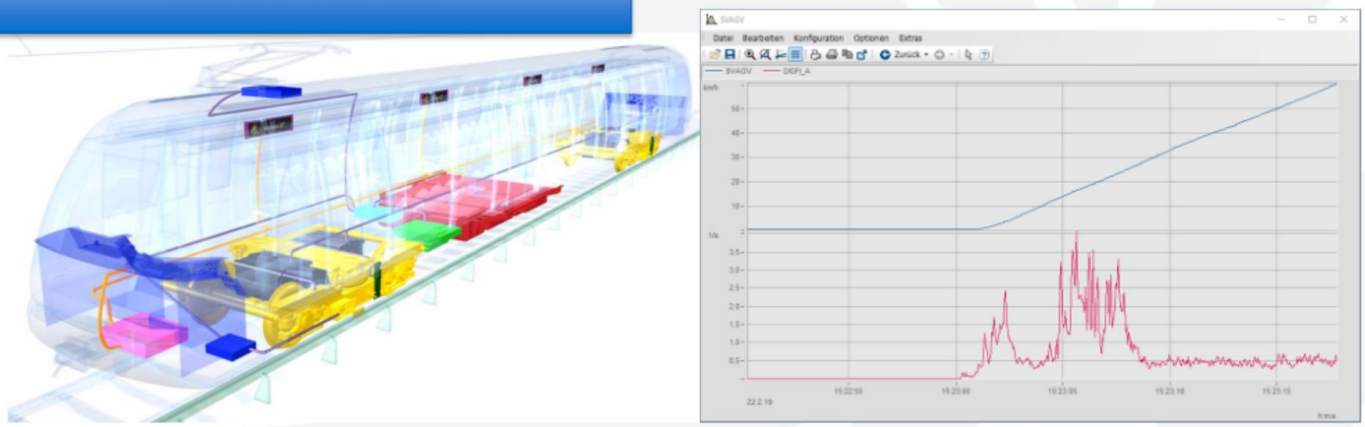
与现场数据的链接：漏电和颤振振动防护硬件在环控制器的测试。

PINTA2

Part I: Simulation Quality justification

Main results : Hardware in The Loop

Link with field data



Testing of the creepage and chatter vibration protection controller on HIL

工作的第二项：标准化。根据运营商 DB 和 SNCF 的反馈，他们完全支持仿真工具的使用，这些工具可以实现更敏捷的过程、使得更快作出正确的设计选择，可以减少新开发的时间，同时接受测量和仿真之间的好的关联性和误差。但是，仿真的成熟度取决于特性的复杂度，组件或系统需要进行验证；仿真和测量结果之间的轻微差别对于一些设备是恒定的，需要进行进一步的分析；需要有一个成熟的程序。

PINTA2

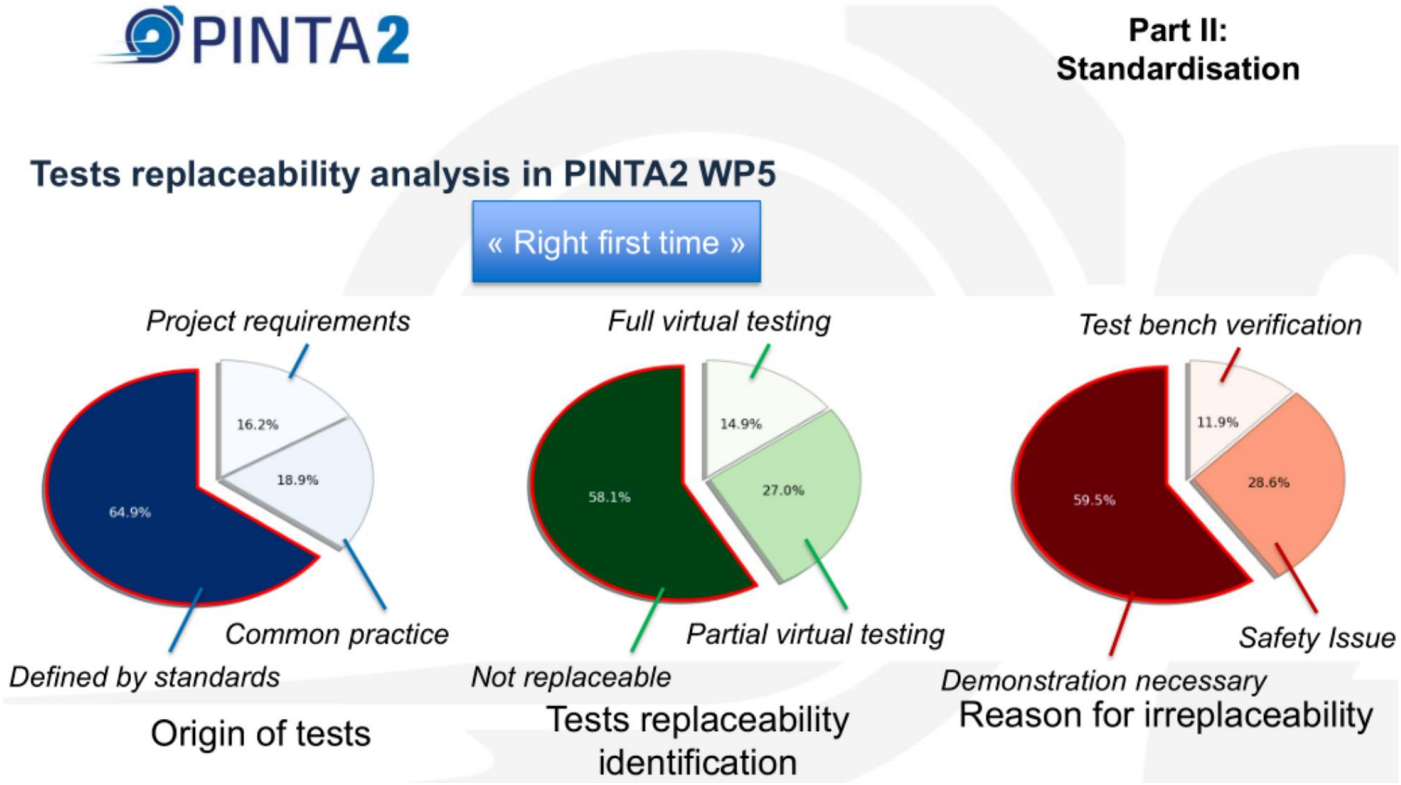
Part II: Standardisation

Operators feedback in PINTA2 D5.1 & D14.2 DB SNCF

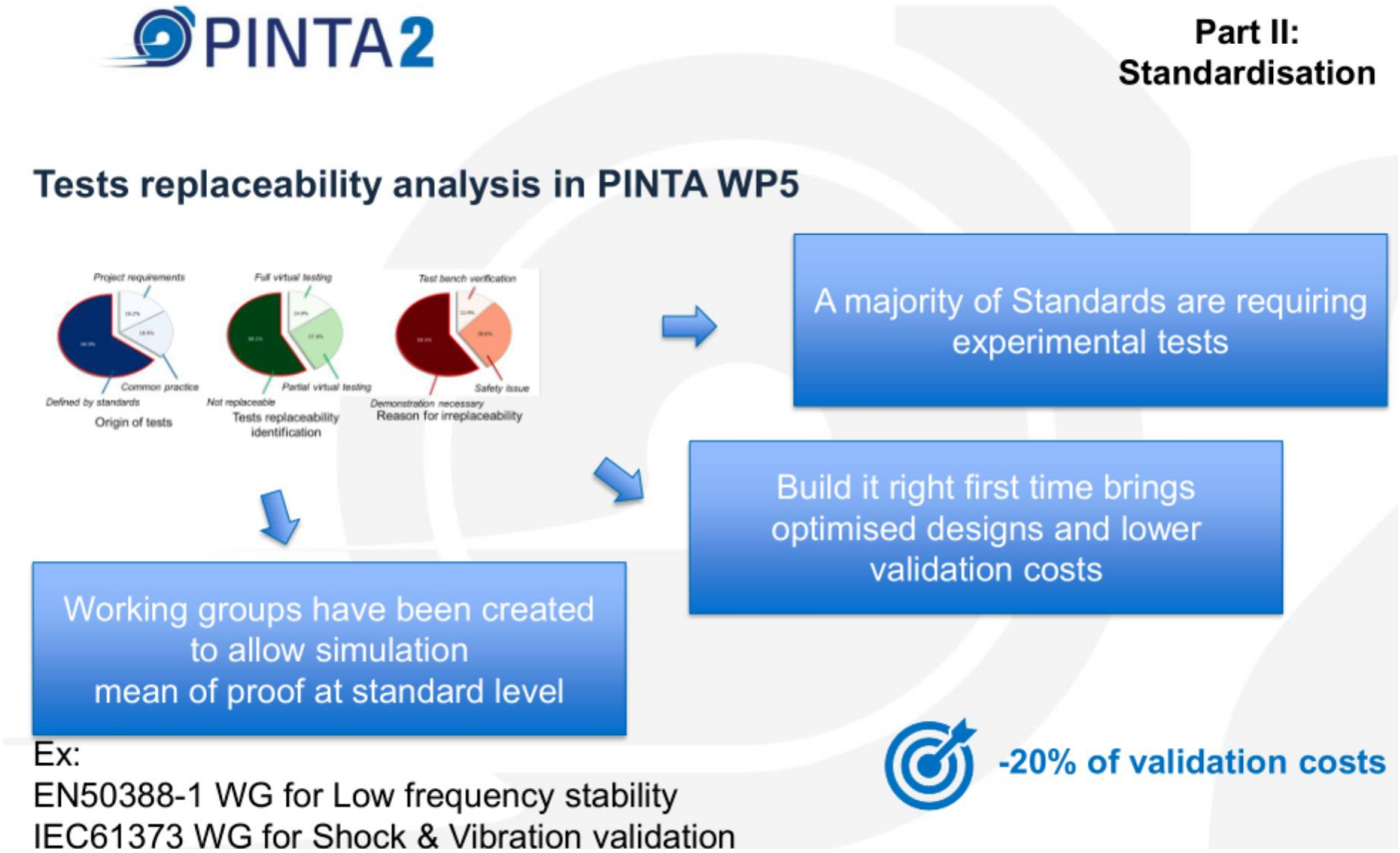
- **Operators are fully supportive about the use of simulation tools**
- Allow more agile process. Make right design choices quicker
- Reduce new development timeline
- Good correlation and differences between measurement and simulation are acceptable
- Simulation maturity will depend on the complexity of the behaviour and the component/system to be validated
- Slight differences between simulation and measurement are constated for some equipement and need to be analysed at deeper level
- **A maturity process need to be adressed**

在 PINTA2 工作包 5 中进行了测试可替换性的分析。在标准、通用实践和项目要求中定义的测试项点中，14.9% 可以完全被虚拟测试替代、27% 可以部分替代、58.1% 不能替代。不可能被虚拟的测

试替代的原因有示范的必要性、安全问题或测试台的认证等因素。



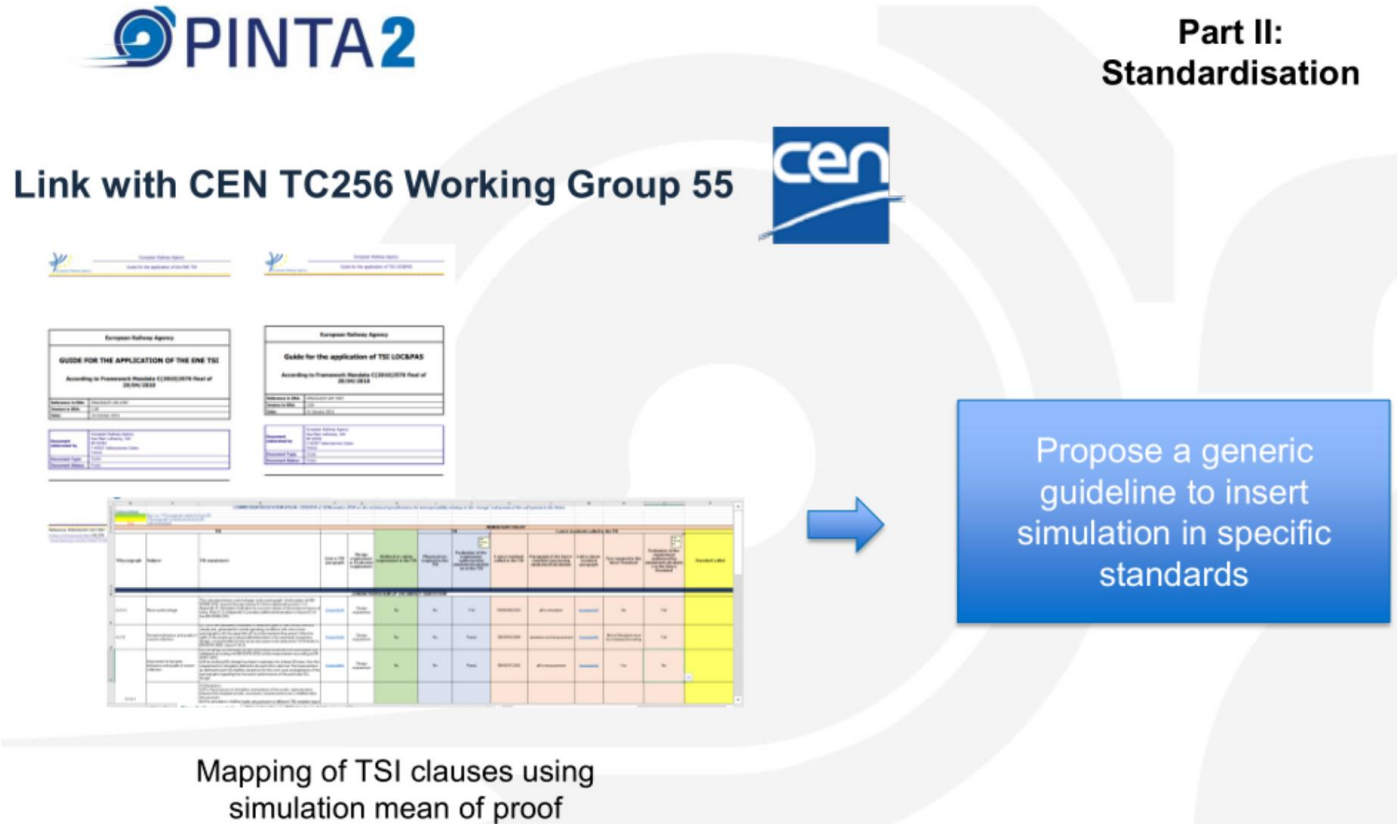
大部分标准对测试结果有要求。项目中，建立了若干个工作组（EN 50388-1 低频稳定性工作组，IEC 61373 冲击和振动验证工作组），希望在标准的水平上允许仿真验证方法的使用。其早期建立可以实现优化的设计以及更低的验证成本。



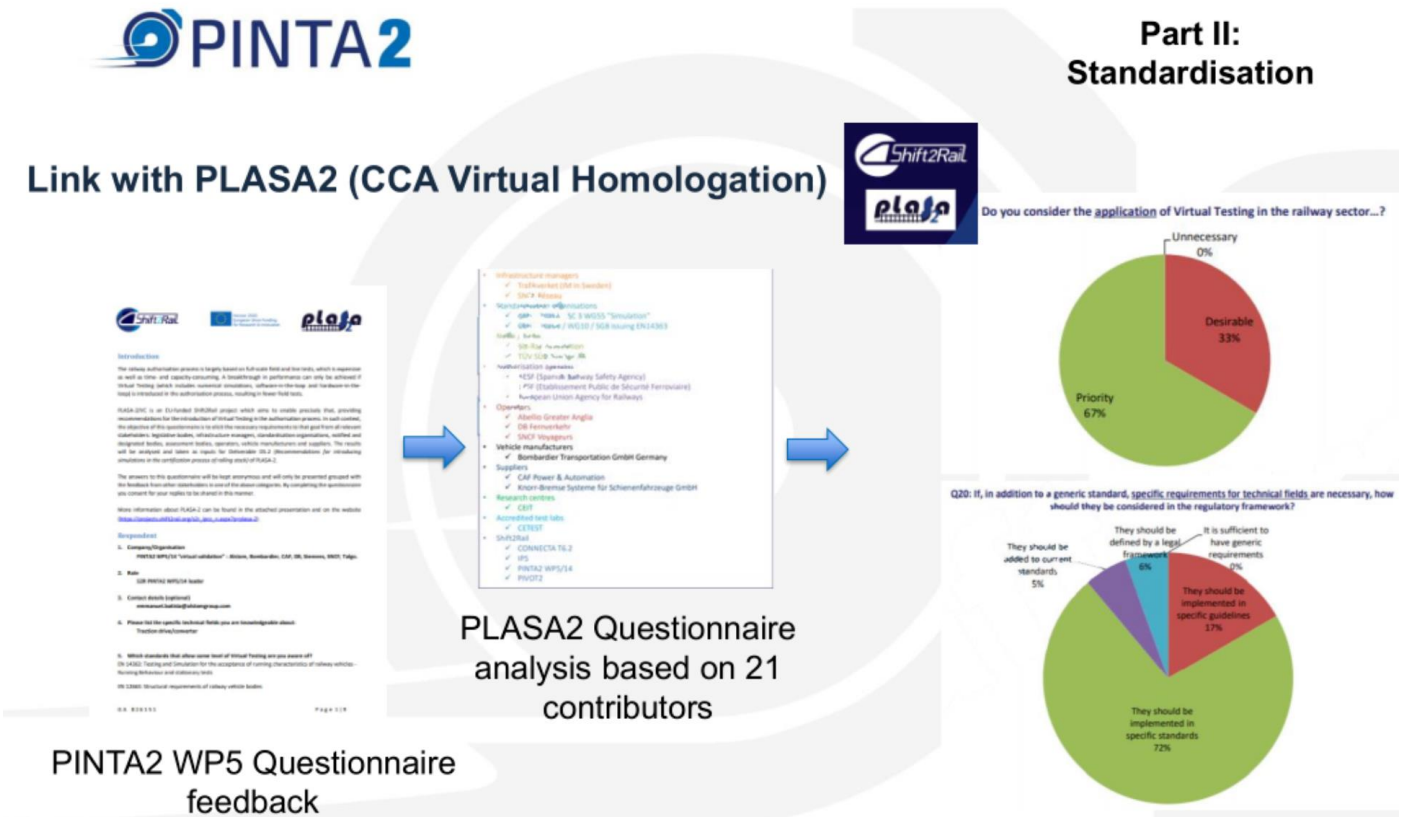
相关工作和 CEN/TC 256/SC 3/WG 55、S2R 的 PLASA-2 有关联。



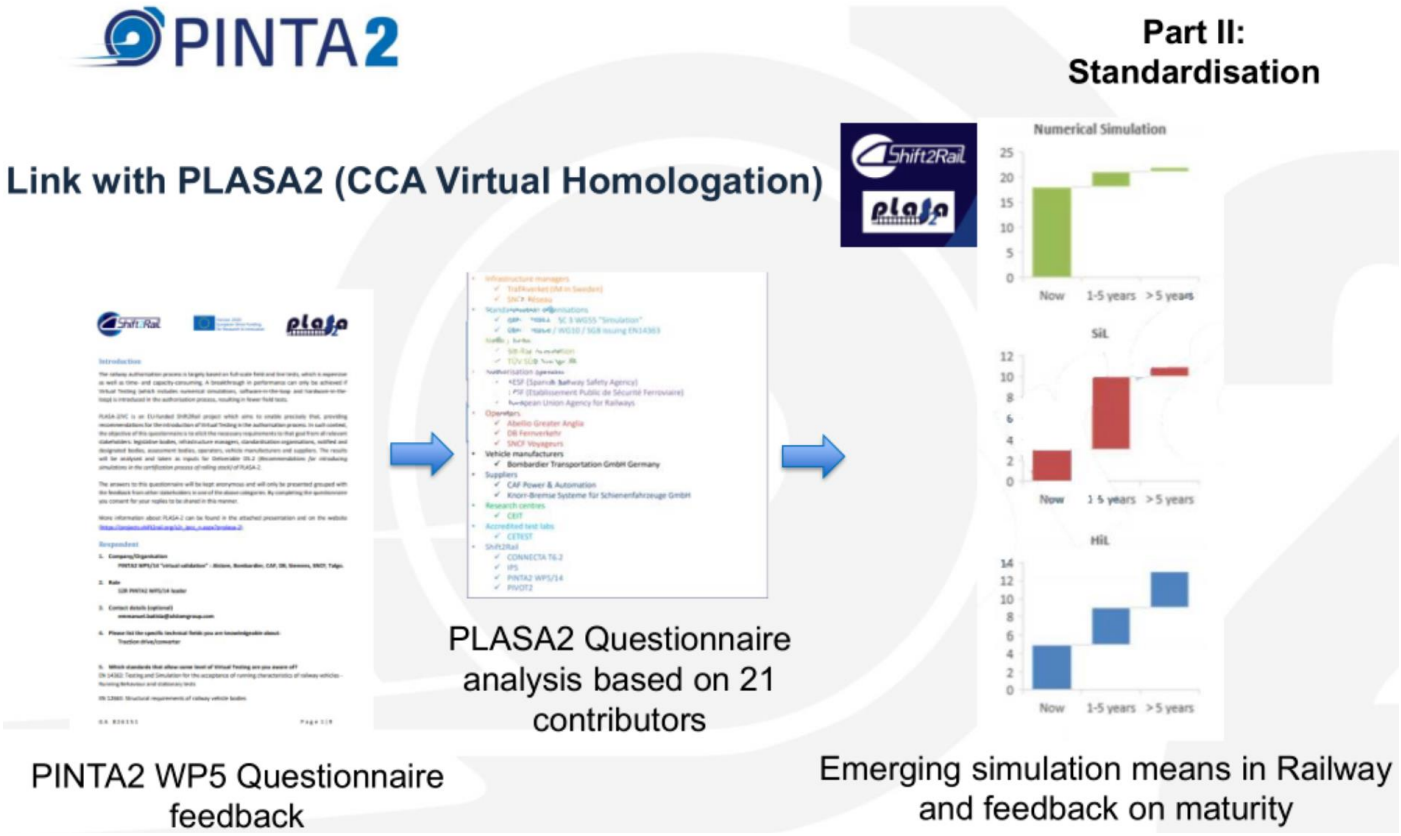
与 CEN TC256 的关联：提议一个把仿真插入特定标准的通用指南。



与 PLASA-2 （交叉项目：虚拟认证）的关联。



与 PLASA-2 （交叉项目：虚拟认证）的关联。

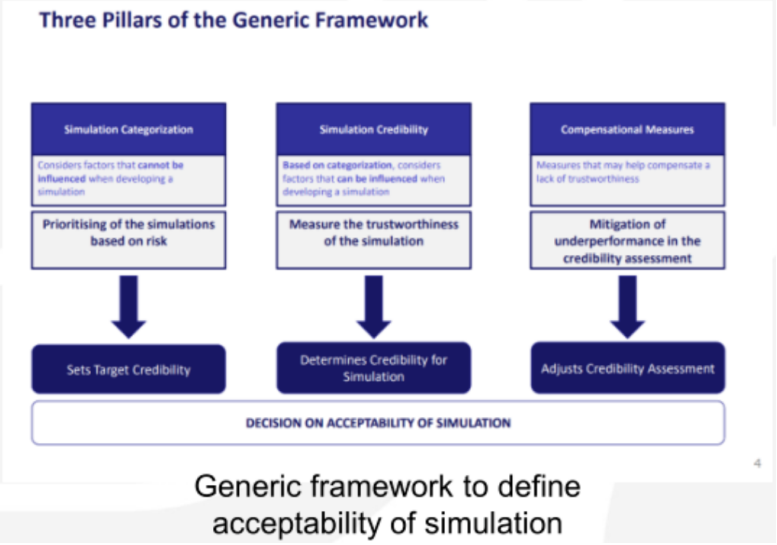


与 PLASA-2 （交叉项目：虚拟认证）的关联。

Link with PLASA2 (CCA Virtual Homologation)

Risk and quality credibility process

Compensational measures can be defined to adjust credibility assessment



Generic framework to define acceptability of simulation

综上，PINTA2 的 工作包 5 和 14 的主要成果有：

- 使用多物理、软件和硬件在环仿真得到了好的与试验数据之间的相关性；
- 评价仿真质量的通用程序是强制要求；
- 标准中引入虚拟验证是减少验证成本和时间的关键方面。

PINTA2 WP5&14 Main results

Good correlation with experimental results with Multiphysics, Software and Hardware in the loop simulations

Generic process to evaluate simulation quality is mandatory

Introduction in standards is a key aspect to reduce validation costs and time

Next steps

Accurate simulation is a first step toward Digital Twin

12/20 — PINTA 3 — Demonstration and Standardization ROI justification

12/22 — S2R2 — Digital twin, Smart maintenance, Data analysis

5.6 粘着测试以及负粘着效果的消除

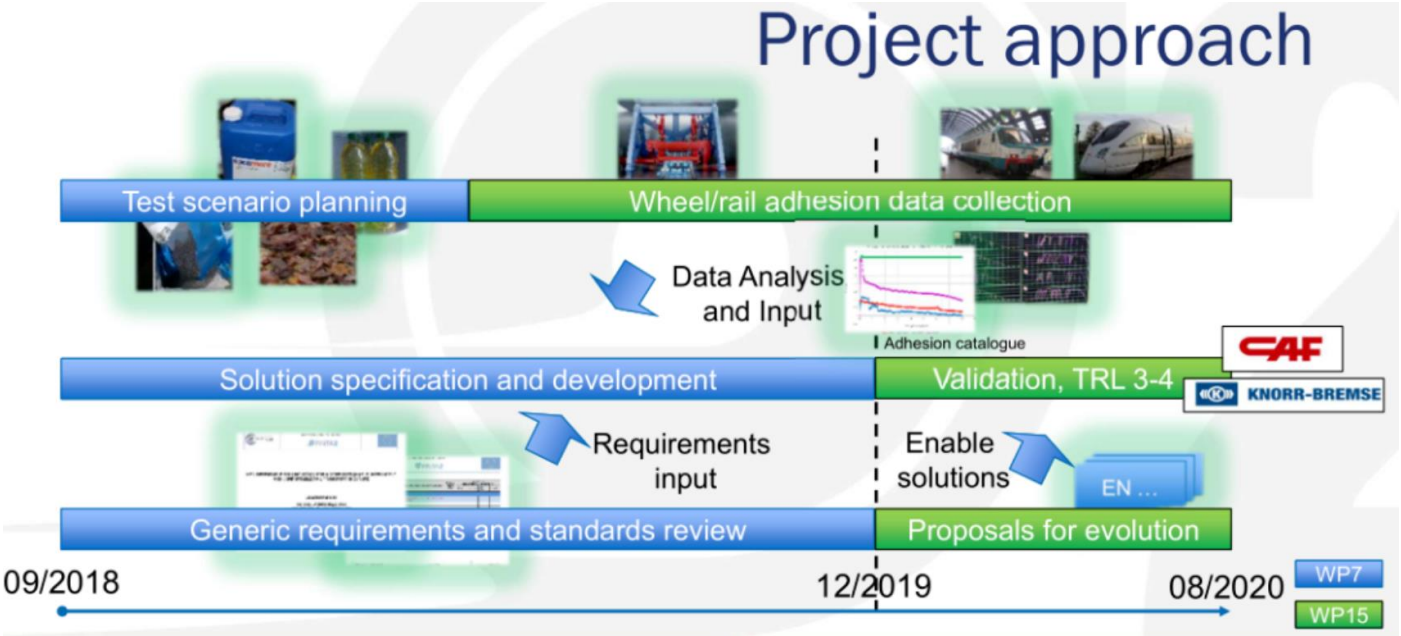
PINTA2 最终会议之 “WP7 粘着测试和解决方案的规范、WP15 负面粘着效果的消除方案”。

主要内容：工作包的目标；项目的开发方法；KPI 的达成和突破的潜力；主要成果；总结和下一步计划。

PINTA2 的研究创新工作是 PINTA 项目的直接延续。现状是由于低的轮轨粘着带来了运行和安全性方面的问题（比如信号/站台的超负荷、SPAD 信号通过危险等），这个项目的目标就是提升轮轨粘着方面的知识、作为开发粘着管理方案的基础。

取得的优势将包括：优化的、可靠的或更短的制动距离；更高的整体列车安全性；提升线路运载能力（间接效果）；降低的维护费用。

项目开发的方法：大致是通过定义测试场景、收集轮轨粘着数据，并总结通用要求和相关标准，提出解决方案的规范并进行开发。



KPI 的达成和突破的潜力：根据估计，目前全部达成 KPI。新的方案带来的潜力：制动（KB）= 更可靠的停止距离、更少的磨损和损坏；牵引/制动（CAF）= 降低的扭振、更高的加速度。

标准的革新带来的潜力：速度相关的撒砂带来列车安全性的提升；信号系统标准 ETCS 的使用带来线路运载能力的提升。

No.	PINTA2 KPI (global)	Brakes KPI (local)	KPI expectations (end of S2R)	Current status
1	LCC reduction *	Commission-ing costs	Reduction by 50%	Reduction by 50% (est.)
2	LCC reduction	Maintenance costs	Reduction by 15%	Reduction by 15% (est.)
3	Reliability	Reduction of braking distance extension	Reduction by 40% (from 25% to 15%)	Reduction by 40% (from 25% to 15%) (meas.)

* KPI on commissioning costs is addressed by WP8/WP16

主要的成果：完成了知识的建立（下图是粘着类型 Adhesion Catalogue 的例子）。完成了 6 个平台的测试，收集了 133 组数据用于定义粘着类型，进行了粘着数据的分析（速度、轨道上落叶的效果、撒砂效果、UIC 工况、MTB 效果、自清洁）。

Main achievements: knowledge build-up

- 6 measurement campaigns performed.
- 133 data sets for adhesion catalogue generated.
- Data analysis conducted on adhesion in relation to:
  - speed (CAF, KB/DB),
  - effect of leaves on the track (KB/DB),
  - sanding effect (KB, KB/DB).
  - UIC conditions (FT),
  - MTB effect (FT),
  - self-cleaning (CAF, FT).



aTL (KB/DB)



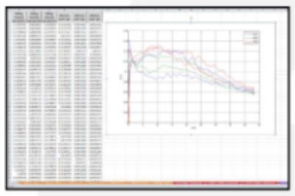
Euskotren (FT)



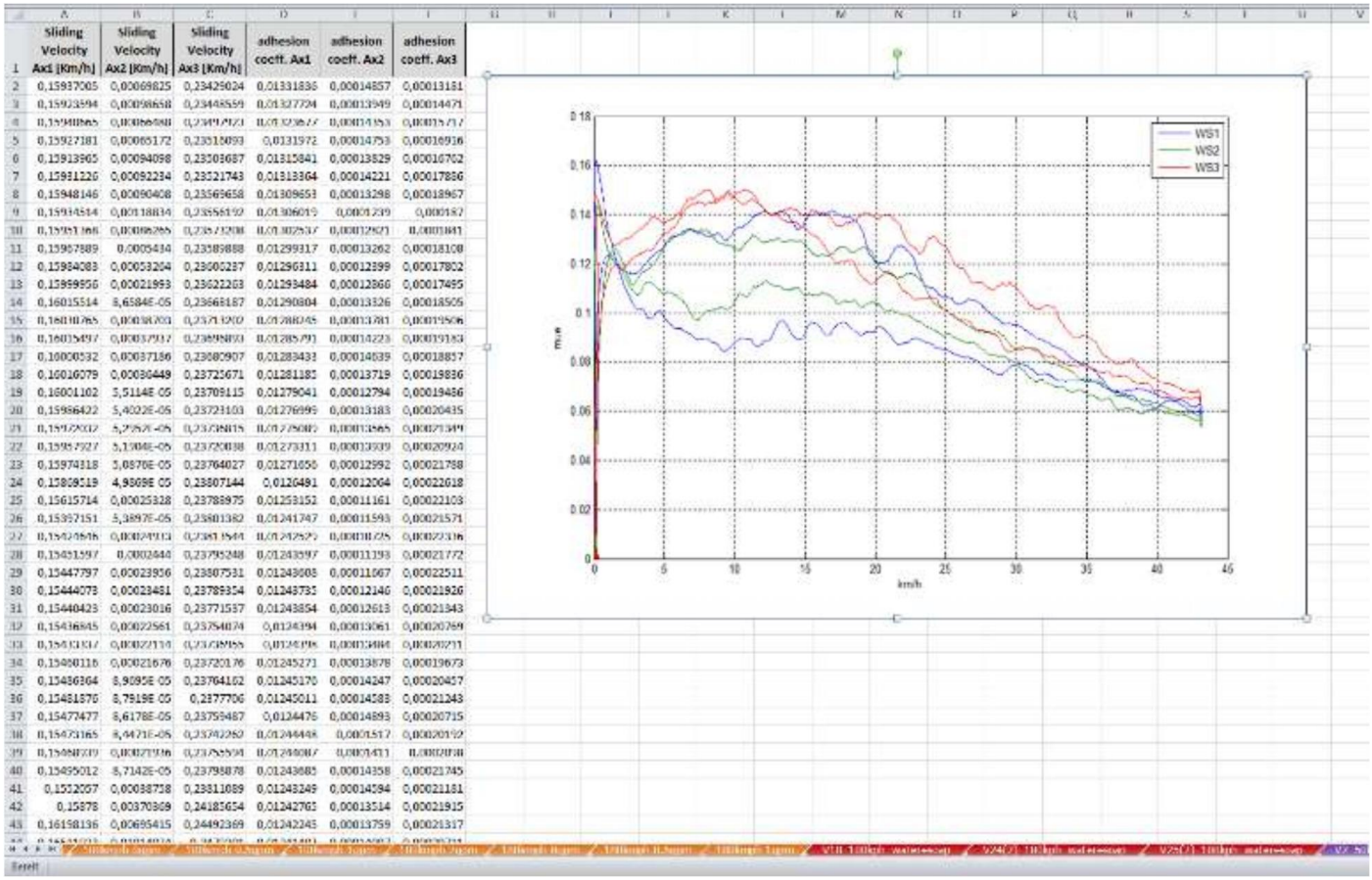
Tren-tram (CAF)



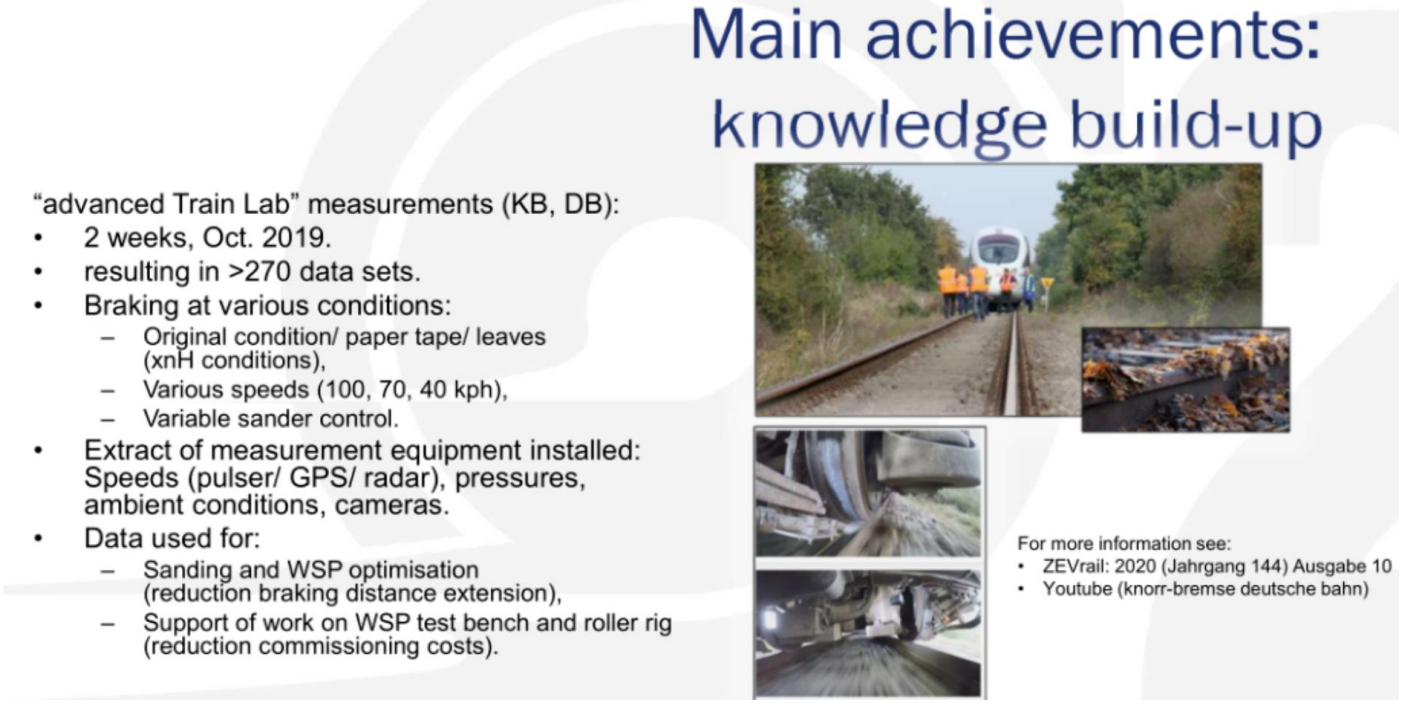
ATLAS (KB)



Adhesion catalogue example



完成了高级列车试验室的测量（克诺尔+DB），历时两周，得到了超过 270 组数据，测量了不同工况下（原始条件/胶带/落叶、不同速度、不同撒砂控制）的制动；所得的数据用于撒砂和 WSP 的优化、支持 WSP 测试台和滚动试验台的工作。



准备了调查问卷（可持续性/成本、噪声、轮轨粘着的使用、刹车距离），获得了直接来自运营商的输入（5 个回复）。

Main achievements: knowledge build-up

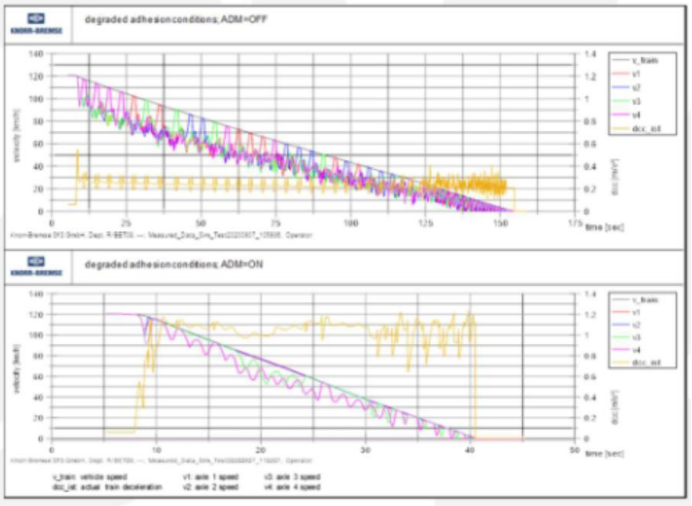
- Questionnaire prepared and distributed to get input directly from operation (European RU/IM).
- 5 responses.
- General requirements deflected concerning:
  - Sustainability/ costs,
  - Noise,
  - Wheel/rail adhesion usage, stopping distance.

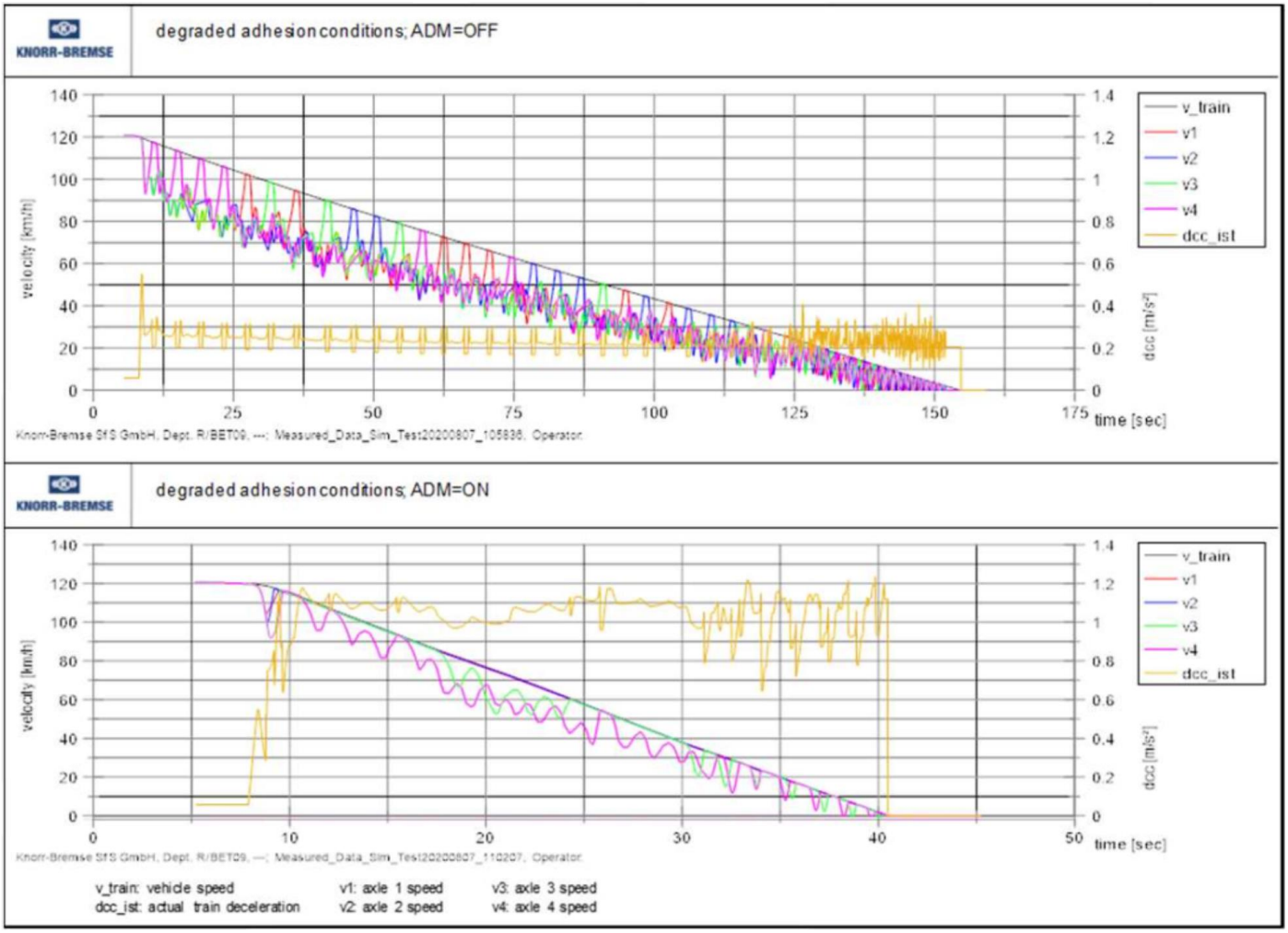


KB 有关制动的解决方案：开发的功能是在降级工况下轮轨粘着提升的激活。预计的收益是避免过长的制动距离、优化系统（比如降低 LCC）；在现有制动系统中实现并验证了样机软件模块，进行了集成测试、功能性测试。下一步：在 ATLAS 测试台中进行测试；为车上测试进行功能扩展和优化。

Main achievements: Braking related solution (KB)

- Developed function:
  Activation of wheel/rail adhesion improvement in degraded conditions.
- Benefits:
  - Avoid prolonged braking distances (KPI 3),
  - Optimised systems, e. g. related to reduction of LCC (KPI 2).
- Realised and validated as prototypical software module in a state-of-the-art brake system:
  - Integration test,
  - Functional test (detection and adequate reactions): higher decelerations/ shorter braking distances.
- Next steps:
  - Tests at ATLAS test rig (already ongoing, PIVOT2),
  - Functional expansion/optimisation for on-train tests.



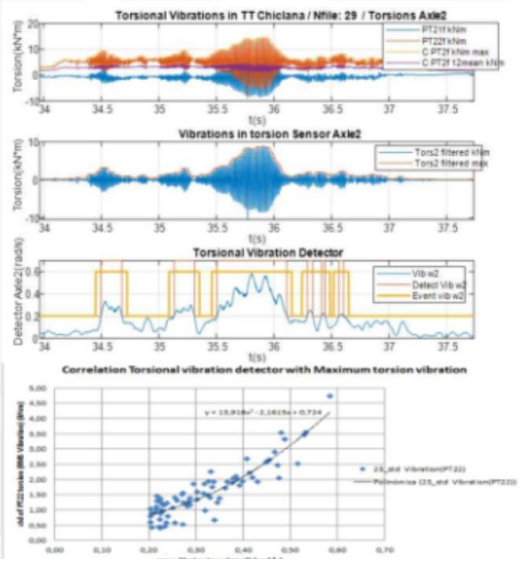


CAF 有关牵引的解决方案：开发的功能是机车和 EMU 在牵引和制动时的扭振和不稳定的预防，以及用于美国的机车中测试的蠕变控制策略（提升粘着使用）。预计的收益是实现粘着使用的改善、减少机械疲劳、不需要额外传感器实现解决方案。

实现和验证的探测器算法：在有轨电车 Chiclana 中示范的集成的可行性；扭振测量和扭振探测器信号的相关性。下一步工作是探测器在防侧滑、防滑牵引和 ED 控制中的集成（预期降低振动水平 20~30%）。

Main achievements: Traction related solution (CAF)

- Developed functions:
  1. Avoidance of torsional vibration and instability of locomotives and EMUs during traction and braking.
  2. Creep control strategy tested in a locomotive for USA in WP7, to improve adhesion utilization.
- Benefits:
  - Allowing improved adhesion utilisation (KPI 3).
  - Reduction of mechanical fatigue (KPI 2).
  - Solution works without any extra sensors.
- The detector algorithm realised (based on analysis of earlier test runs) and validated:
  - Feasibility of integration demonstrated in the Tram Train Chiclana,
  - Correlation between torsional vibration measurements and torsional vibration detector signal shown.
- Next steps:
  - Detector integration into anti-slip, anti-slide traction and ED control (expected reduction of vibration level: 20-30%).

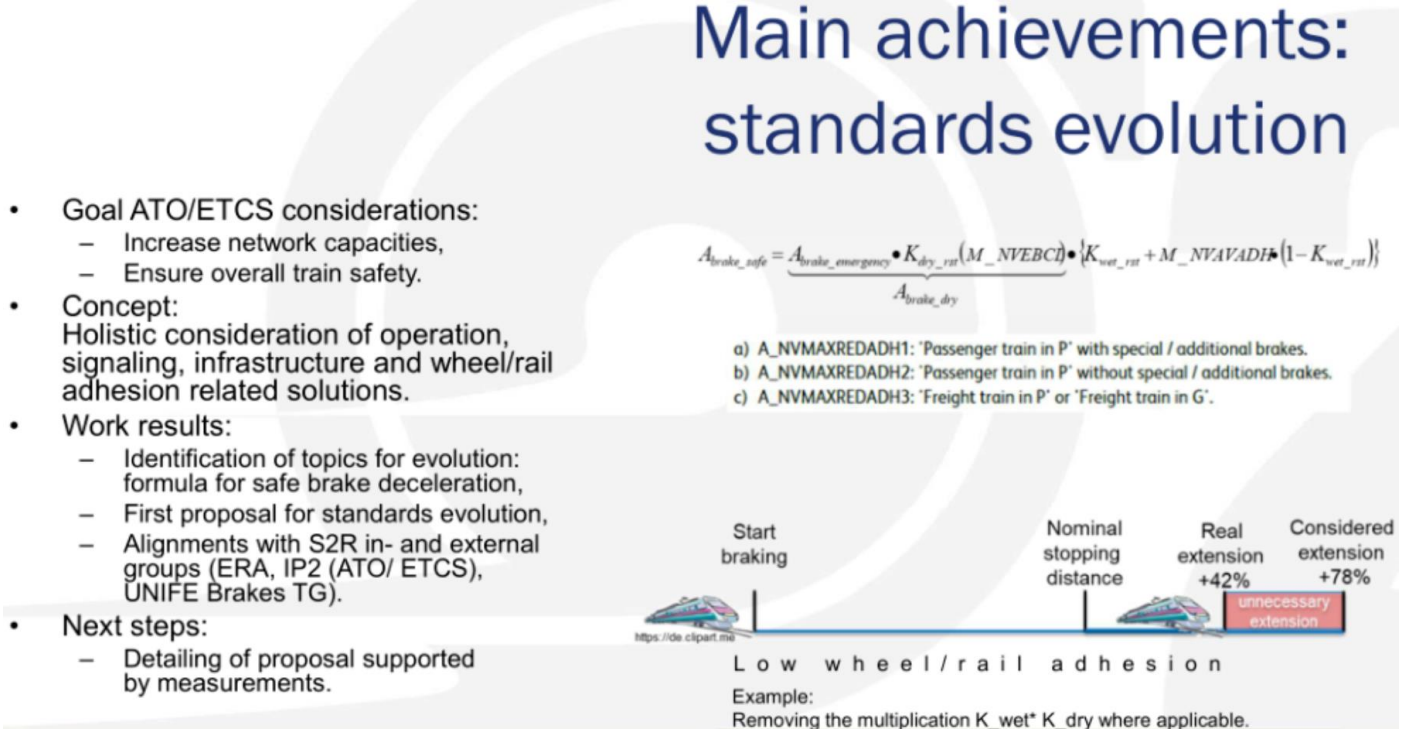


标准方面的革新：新轮轨粘着相关解决方案的使用可能需要标准方面的革新。这一部分工作是有关撒砂和 ATO/ETCS。

Main achievements: standards evolution

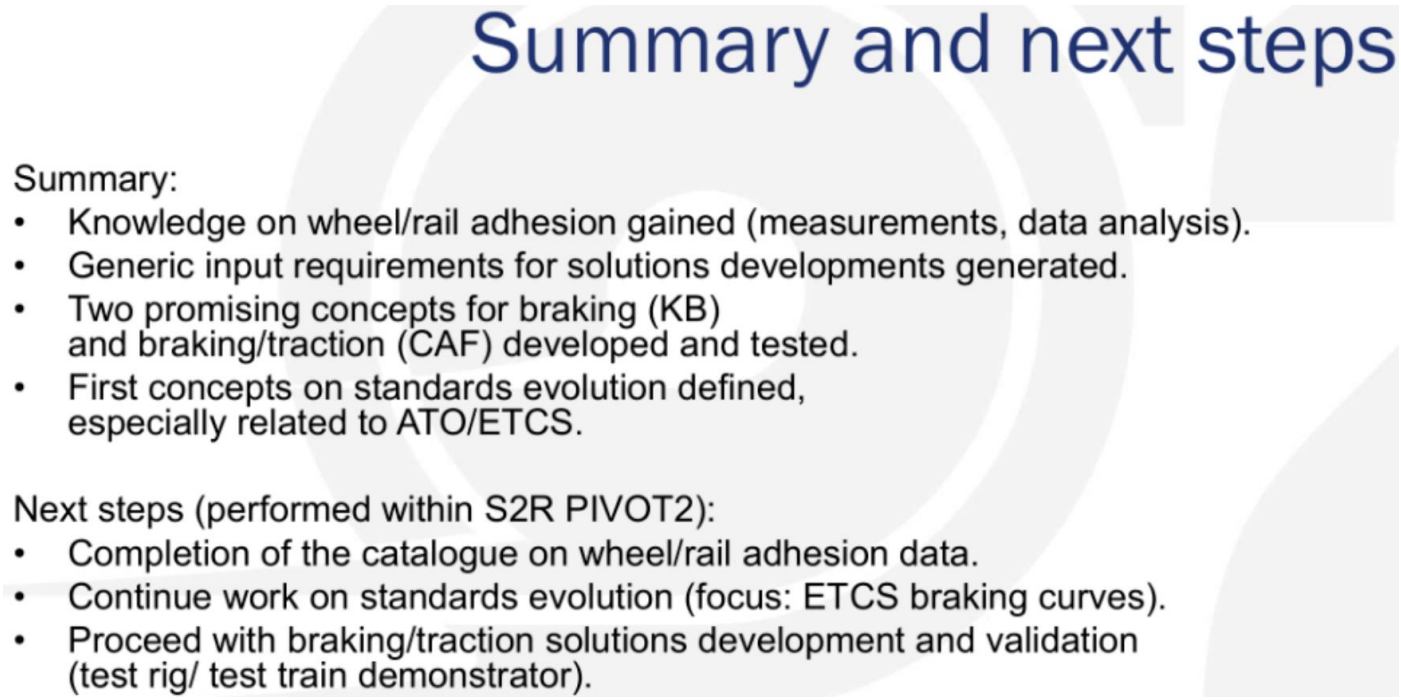
- Use of new wheel/rail adhesion related solutions might require standards evolutions.
- Focus of work was set on:
  - Sanding:
    Measurements done during PINTA2 to support work on prCEN/TS15427-3 if necessary (speed dependent sanding proposal for improved effect); topic led outside PINTA2,
  - ATO/ ETCS:
    Work on related to wheel/rail adhesion consideration within ETCS systems including the discussion of the “deceleration curve formula”.

目标：提升网络的运力、确保整体的列车安全性。工作的结果包括：识别的项点= 安全制动的减速公式，提出了第一个标准革新的提议，进行了与 S2R 和 外部团体（ERA、IP2、UNIFE 制动工作组）的结盟。下一步工作是通过测量的支持来完成提议的细节。



总结：通过该工作包的研究，获取了轮轨粘着方面的知识，生成了解决方案开发的通用输入要求，提出了两个改进理念（制动、牵引），定义了第一组标准革新的提议（特别是与 ATO/ETCS 相关的内容）。

下一步（在 PIVOT2 项目中开展）：完成轮轨粘着数据分类的工作，继续标准革新的工作（关注 ETCS 制动曲线），推进制动和牵引解决方案的开发和验证（测试台和测试列车示范）。



5.7 车轮防滑 WSP 相关

PINTA2 最终会议之：WP8 商业案例、WSP 测试台的更新和解决方案，WP16 混合、WSP、撒砂器和高效制动力传输的解决方案。

主要内容：工作包 WP8/16 的目标；主要的成果和贡献；传播的结果；下一步计划。

WP8 的主要目标是指定新的粘着管理方案：法维莱的 WSP 自适应算法、粘着提升撒砂器，CAF 的制动混合策略，KB 的制动力传输优化。并评估更好的制动性能在未来铁路交通中的影响，以及更新 WSP 测试台模型（用于高效和可靠的 WSP 虚拟验证）。

Objectives WP8

- The main objective is to **specify new adhesion management solutions**.
  - Faiveley **WSP adaptive algorithm** able to outperform current WSP devices in terms of extension of braking distances on a wide range of low adhesion conditions.
  - Faiveley **adhesion improvement dispenser** with the aim of minimizing the influence of the train speed on the number of particles reaching the contact point.
  - CAF braking blending strategies
  - KB **force transmission optimization** by use of various slip rates for better performance at very low adhesion situations.
- Evaluate the impact of better braking performance on the future rail traffic
- Update of the WSP test bench models for efficient and reliable WSP virtual validation

WP16 的主要目的是在实验室进行新粘着管理解决方案的测试：法维莱的 WSP 自适应算法、粘着提升撒砂器，CAF 的制动混合策略，KB 的制动力传输优化。并基于轮轨粘着测量和分析进行粘着模型的更新。

Objectives WP16

- The main objective is to **test in lab new adhesion management solutions**.
  - Faiveley **WSP adaptive algorithm** able to outperform current WSP devices in terms of extension of braking distances on a wide range of low adhesion conditions.
  - Faiveley **adhesion improvement dispenser** with the aim of minimizing the influence of the train speed on the number of particles reaching the contact point.
  - CAF braking blending strategies
  - KB **force transmission optimization** by use of various slip rates for better performance at very low adhesion situations.
- Update of the Adhesion model based on wheel-rail adhesion measurements and analysis

突破的潜力：降低 LCC（维护成本）、提升可靠性、提升线路运力（更高频率的列车）。

Breakthrough Potential

KPIs

PINTA2 KPI (global)	Brakes KPI (local)	KPI expectations (end of S2R)	Current status *
LCC reduction *	Commission-ing costs	Reduction by 50%	Reduction by 50%
LCC reduction	Maintenance costs	Reduction by 15%	Reduction by 15%
Reliability	Reduction of braking distance extension	Reduction by 40% (from 25% to 15%)	Reduction by 40% (from 25% to 15%)

- ✓ **LCC reduction (maintenance cost)**
- ✓ **Reliability**
- ✓ **Line capacity (higher frequency of train)**

WP8 的主要成果和贡献有四个：粘着优化混合理念（CAF）、自适应 WSP 算法 TRL4（FTI）、粘着提升撒砂器 TRL4（FTI）、高效制动力传输理念（KB）。粘着管理的有关成果在 D8.3、D8.4 和 D8.5 中发布。

PINTA2

Main Achievements and Contributions

Finalized on-time the deliverable D8.3, D8.4, D8.5 related to the innovative adhesion management solutions specifications

- Adhesion optimized blending concepts (CAF)
- Adaptive WSP algorithm TRL4 (FTI)
- Adhesion improving dispenser TRL4 (FTI)
- Efficient force transmission concept (KB)

Main Achievements and Contributions

Finalized on-time the deliverable D8.3, D8.4, D8.5 related to the innovative adhesion management solutions specifications

- Adhesion optimized blending concepts (CAF)
- Adaptive WSP algorithm TRL4 (FTI)
- Adhesion improving dispenser TRL4 (FTI)
- Efficient force transmission concept (KB)

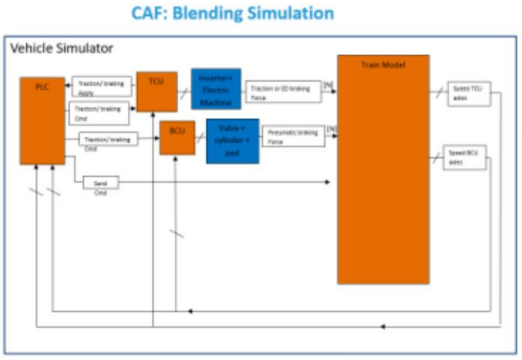
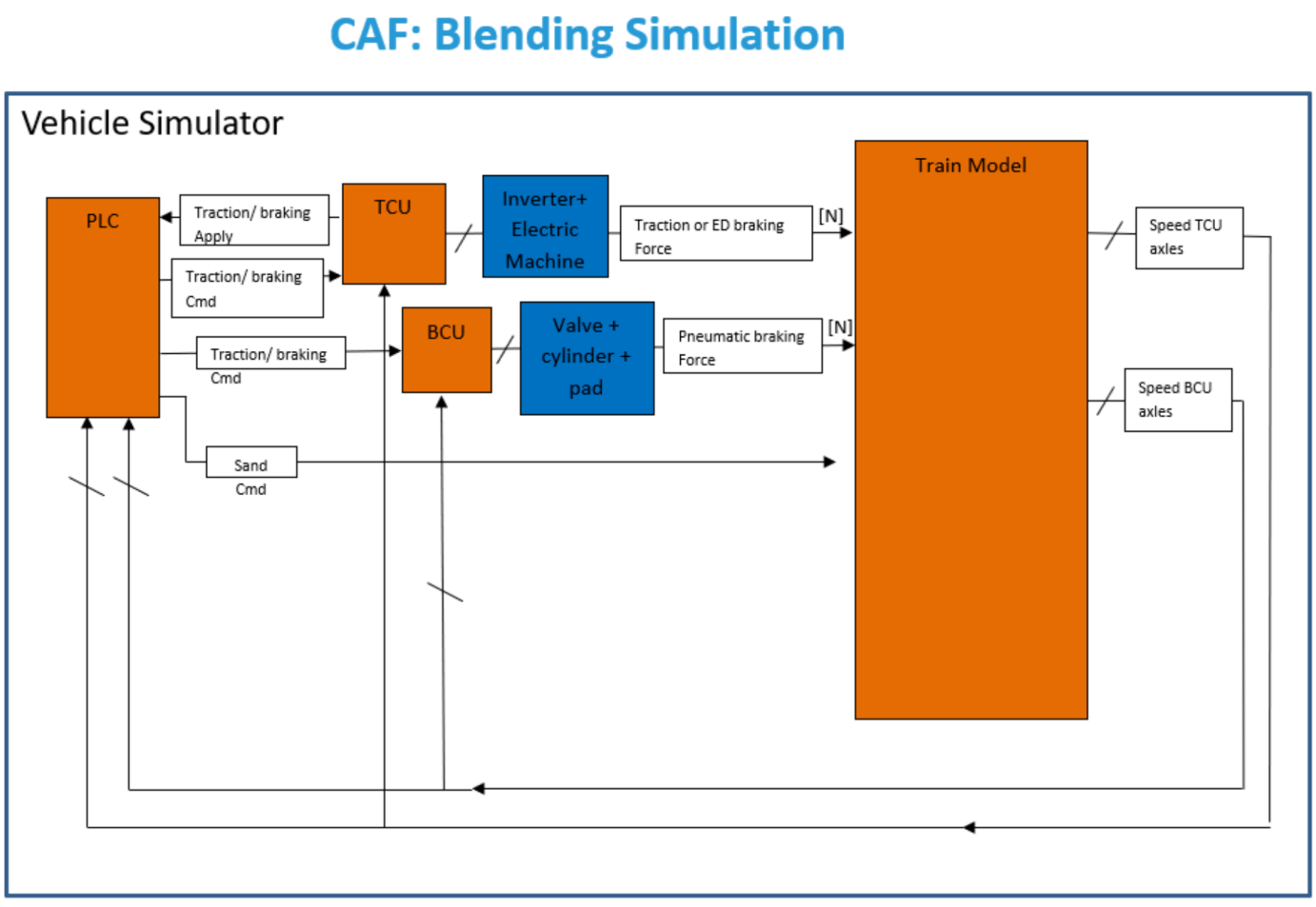


Figure 1: Blending block scheme, for optimized blending concepts

粘着优化混合理念（CAF）：图示是使用的车辆仿真器。



Main Achievements and Contributions

Finalized on-time the deliverable D8.3, D8.4, D8.5 related to the innovative adhesion management solutions specifications

- Adhesion optimized blending concepts (CAF)
- Adaptive WSP algorithm TRL4 (FTI)
- Adhesion improving dispenser TRL4 (FTI)
- Efficient force transmission concept (KB)

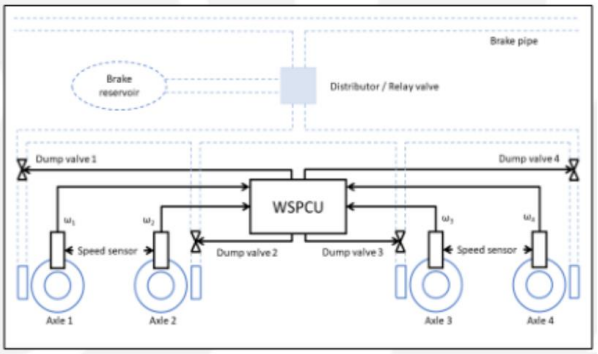
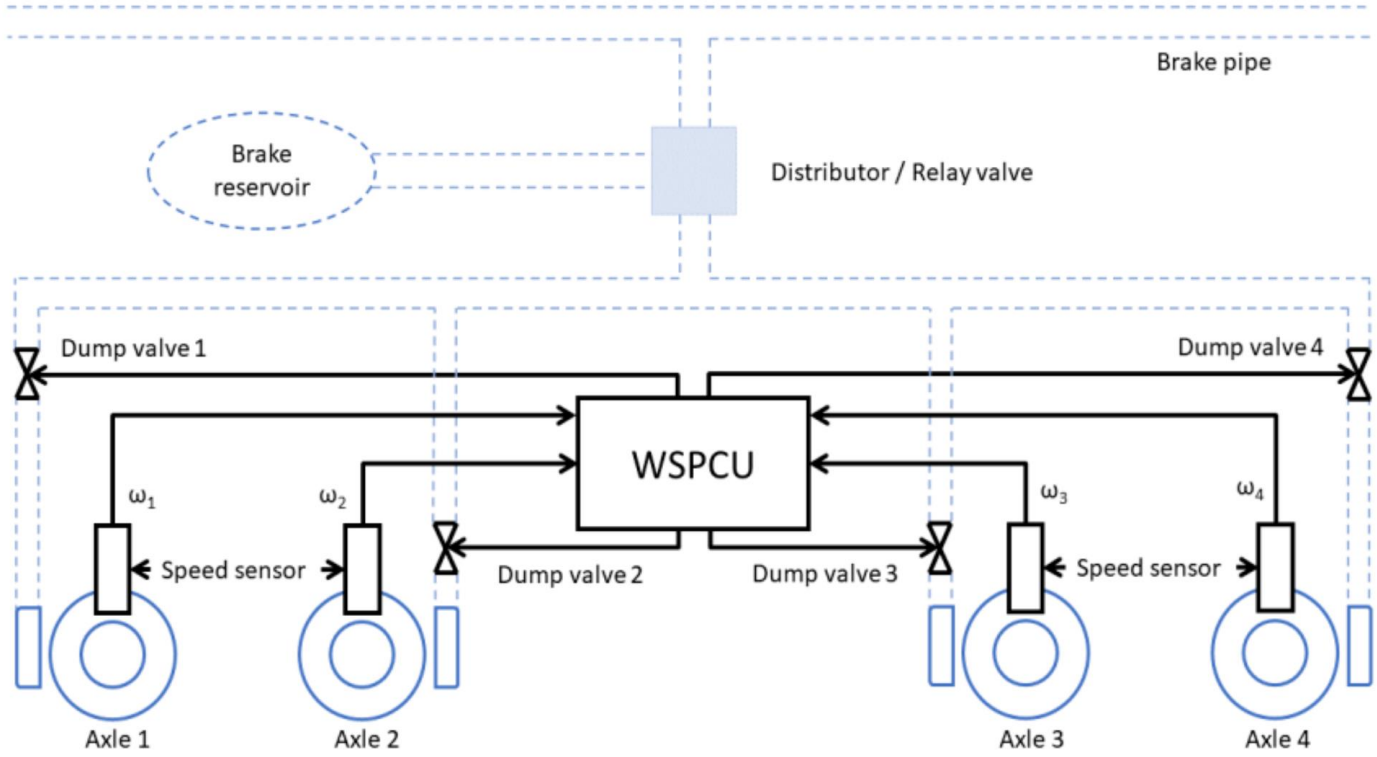


Figure 2: WSP architecture for axle control Adaptive WSP

自适应 WSP 算法 TRL4（FTI）：图示是轴控制自适应 WSP 的架构。



Main Achievements and Contributions

Finalized on-time the deliverable D8.3, D8.4, D8.5 related to the innovative adhesion management solutions specifications

- Adhesion optimized blending concepts (CAF)
- Adaptive WSP algorithm TRL4 (FTI)
- Adhesion improving dispenser TRL4 (FTI)
- Efficient force transmission concept (KB)

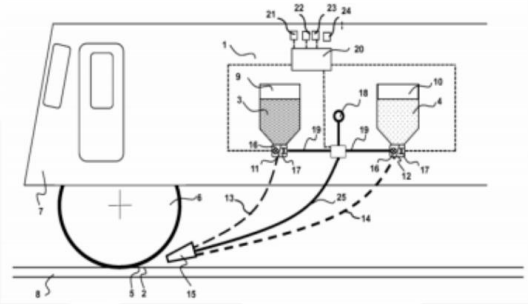
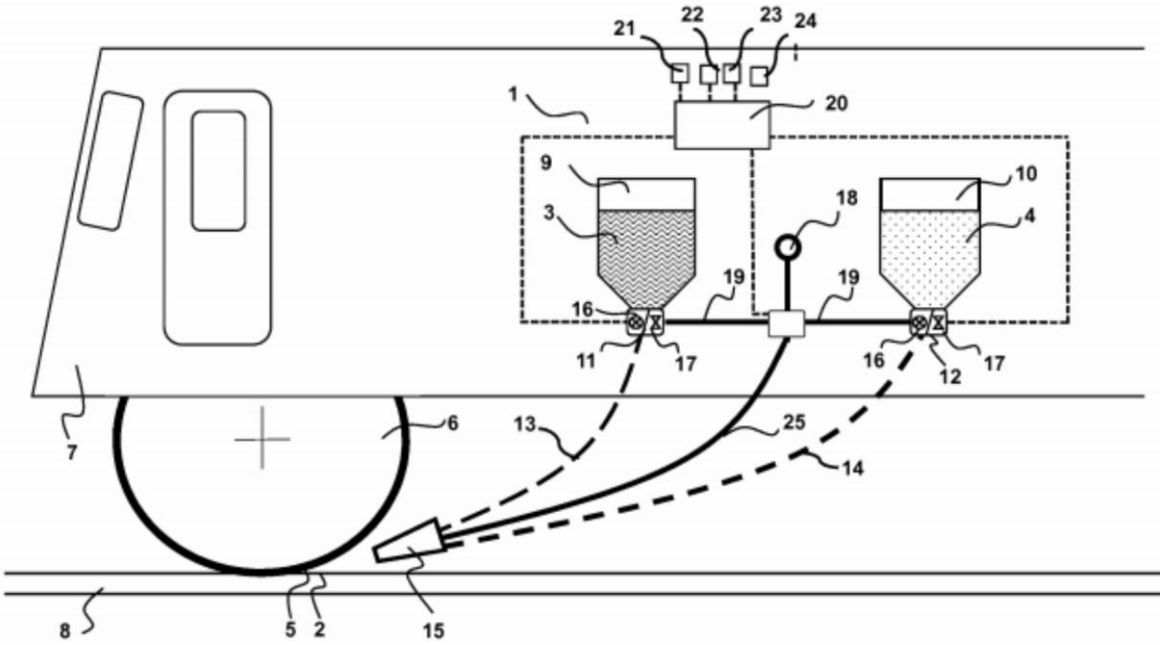


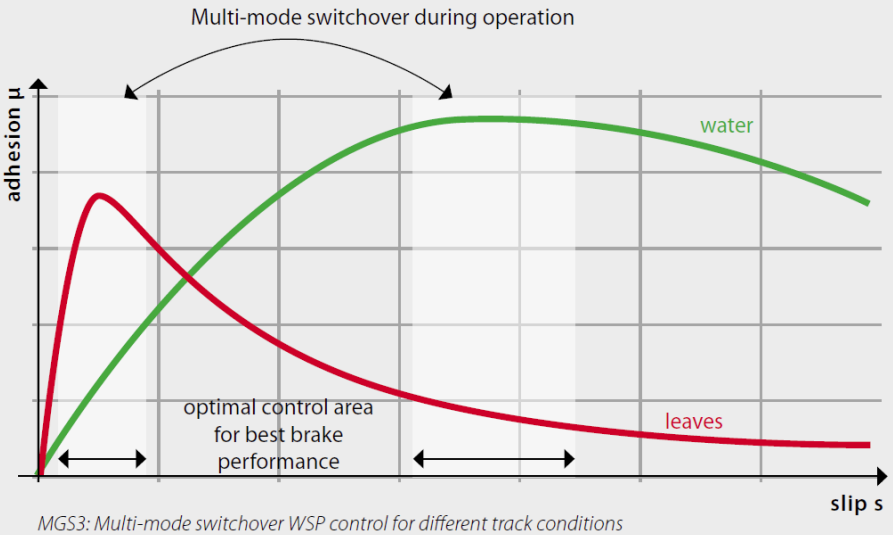
Figure 3: Adhesion improving dispenser integrating sanding and lubricant dispenser

粘着提升撒砂器 TRL4（FTI）：图示是安装了撒砂和润滑油的粘着提升装置。



ADDITIONAL FEATURES – HIGH-PERFORMANCE MGS3

- Multi-mode switchover WSP control between low and extremely low adhesion for shorter stopping distances
- The new algorithm is able to utilize friction anomalies when they occur under extreme low-adhesion conditions. Tests simulating leaves on track show significant reduction potential
- Higher pneumatic performance for shorter ventilation times
- Improved system control and diagnostics by pressure sensor integration



MGS3: Multi-mode switchover WSP control for different track conditions

Main Achievements and Contributions

Finalized on-time the deliverable D8.3, D8.4, D8.5 related to the innovative adhesion management solutions specifications

- Adhesion optimized blending concepts (CAF)
- Adaptive WSP algorithm TRL4 (FTI)
- Adhesion improving dispenser TRL4 (FTI)
- Efficient force transmission concept (KB)



Figure 4: Black layer on wheel and rail, from tree leaves

报告 D8.1：更好制动的建立对未来铁路交通的影响。为所有 PINTA2 成员促进信号系统规则在其国家的应用，信号系统将考虑降级的粘着的影响，为 ERA 对 ETCS 制动曲线的讨论建立基础。

Main Achievements and Contributions

Finalized on-time the deliverable D8.1: Establishment of better braking impact on future rail traffic

- Contribution of all the PINTA2 partners related to the signalling rules active in their specific country
- How the degraded adhesion is considered by signalling
- Set the basis for **ERA discussion on ETCS braking curves**



Figure 5: Map of the European signalling systems before ERTMS introduction (Task 8.1)

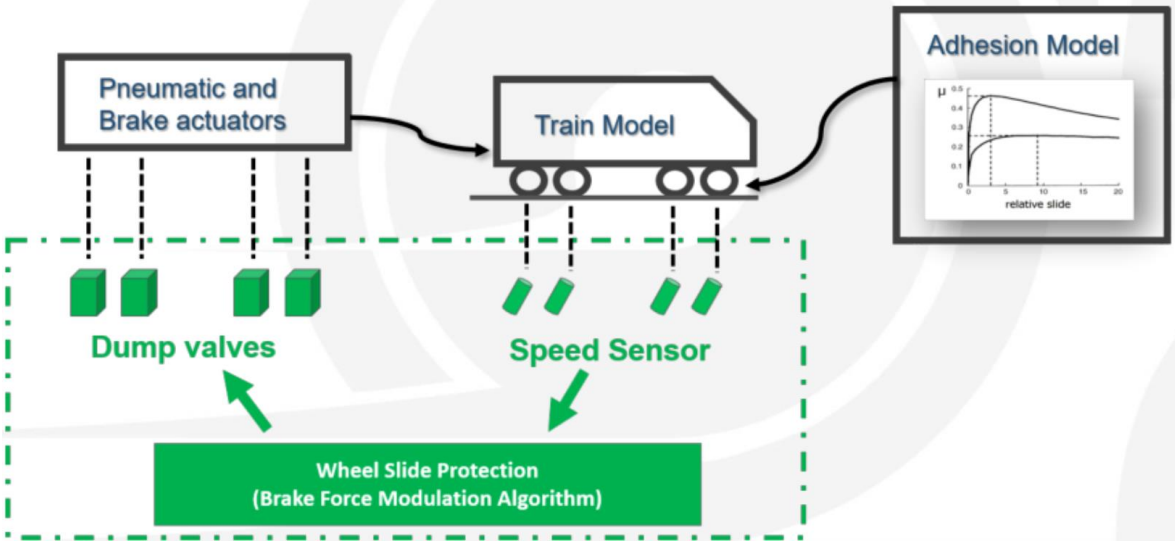
Main Achievements and Contributions

Faiveley Transport WSP test bench



Main Achievements and Contributions

Test bench for virtual validation of WSP



Main Achievements and Contributions

Finalized on-time the deliverable D8.2: Update of WSP test bench and Test Procedure

- **Test bench for virtual validation of WSP**
  (in accordance with EN 15595)

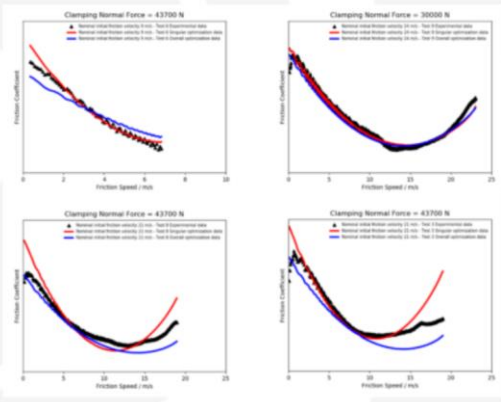
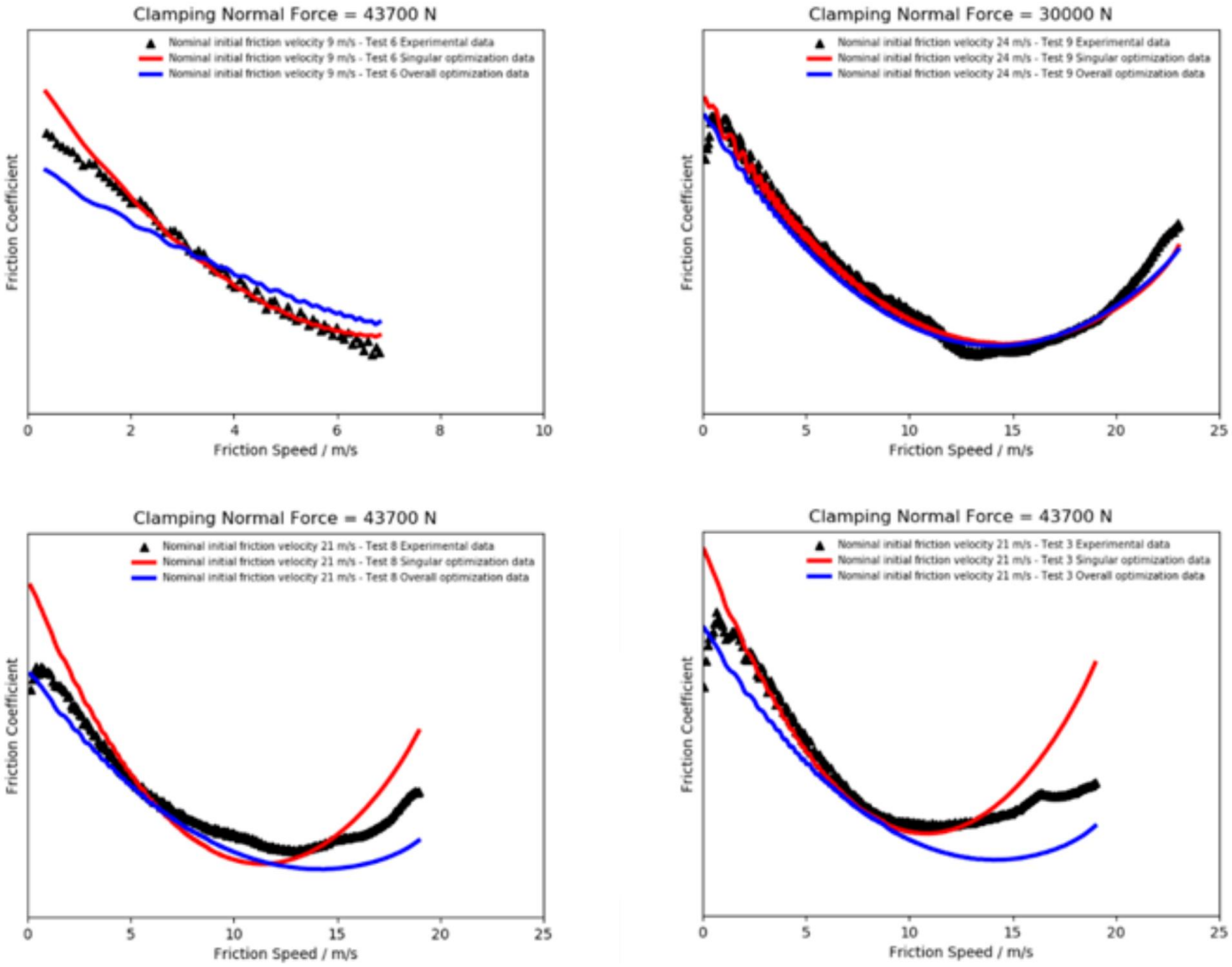


Figure 6: Function upgrade (pad/disk friction coefficient) for WSP test bench specification

用于 WSP 虚拟验证的测试台（符合 EN 15595）：输出了报告 D8.2 “WSP 测试台和测试程序的更新”。图示是测试台规范的功能更新。



工作包 16 的三个报告：D16.2、16.3 和 16.4：自适应 WSP 和粘着提升撒砂器样机测试报告（FTI）、低粘着时混合理念的验证和测试报告（CAF）、高效制动力传输样机的测试报告（KB）。

Main Achievements and Contributions

Finalized on-time the deliverable D16.2, D16.3, D16.4 related to the validation of the innovative adhesion management solutions

- Adaptive WSP and Adhesion improving dispenser prototypes Test Reports (FTI)
- Validation of blending concept(s) during low adhesion and test report (CAF)
- Test report of efficient force transmission prototype (KB)

自适应 WSP 和粘着提升撒砂器样机测试报告（FTI）：两图分别是自适应 WSP 的停止距离分配、依控制信号的砂子流量。

Main Achievements and Contributions

Finalized on-time the deliverable D16.2, D16.3, D16.4 related to the validation of the innovative adhesion management solutions

- Adaptive WSP and Adhesion improving dispenser prototypes Test Reports (FTI)



Figure 6: Distribution of stopping distance for the Adaptive WSP

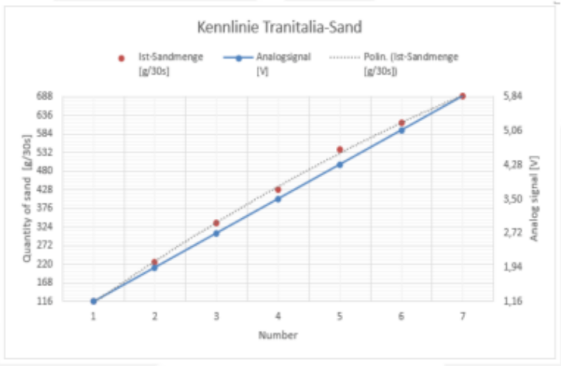
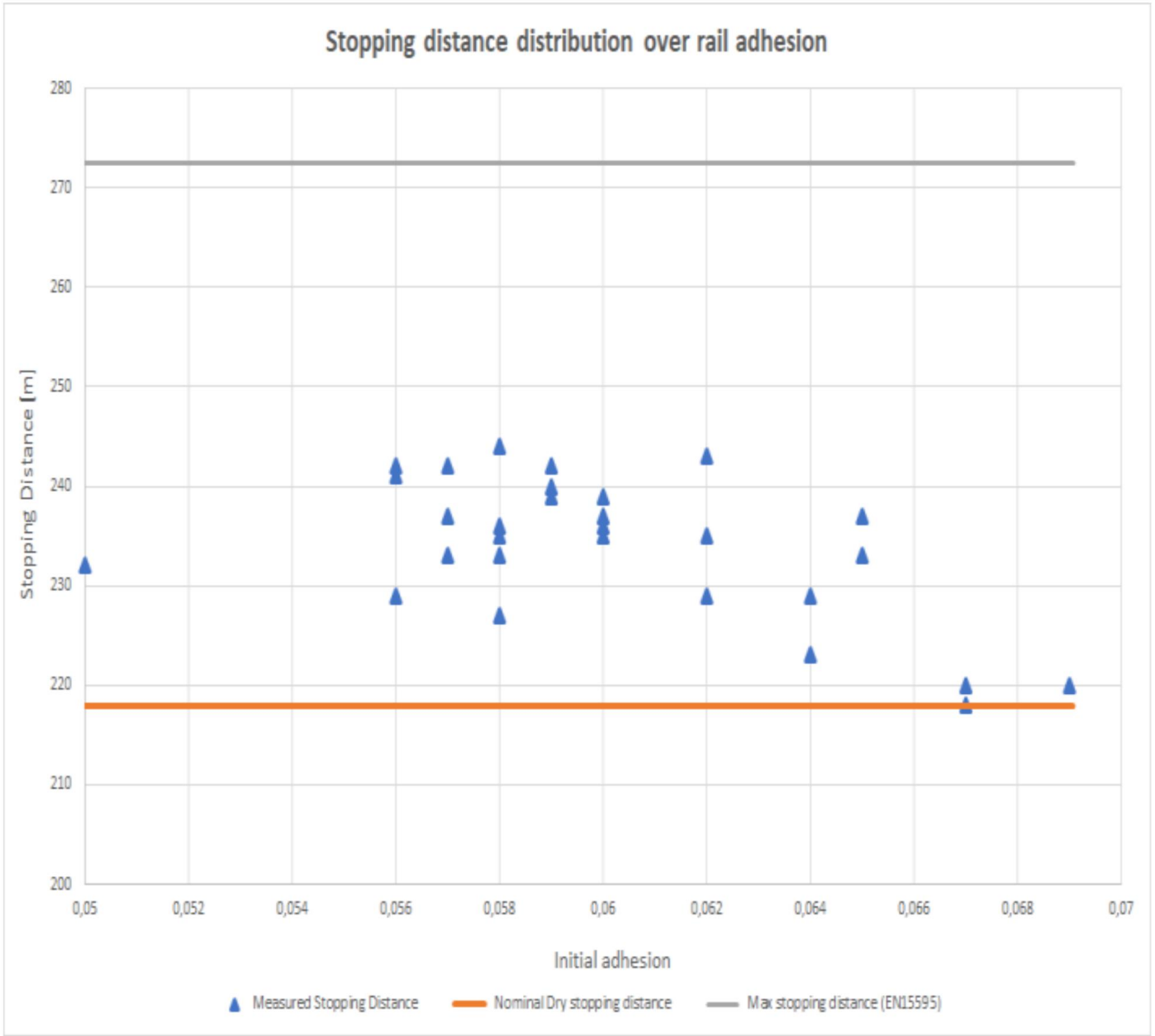
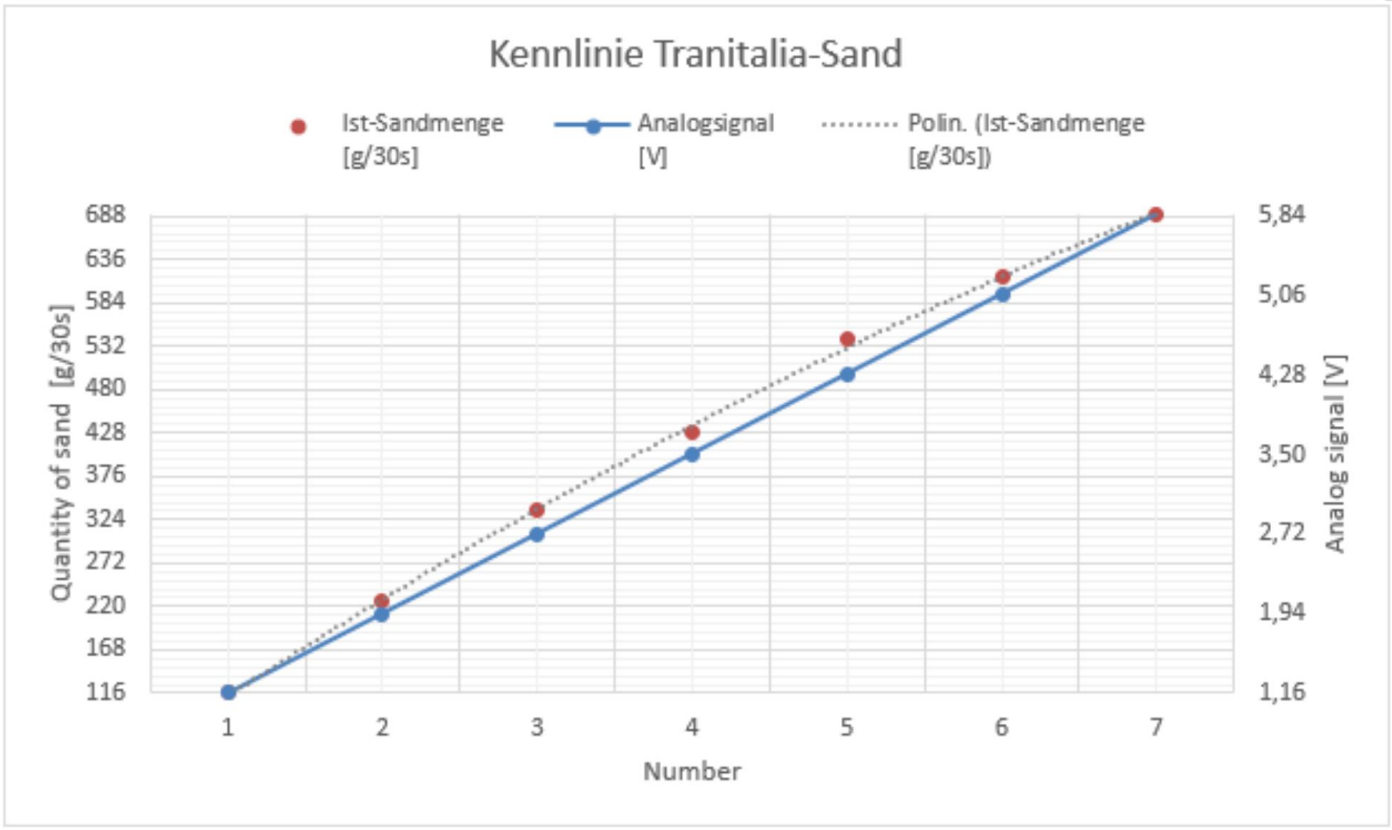


Figure 8: Sand flow according to control signal

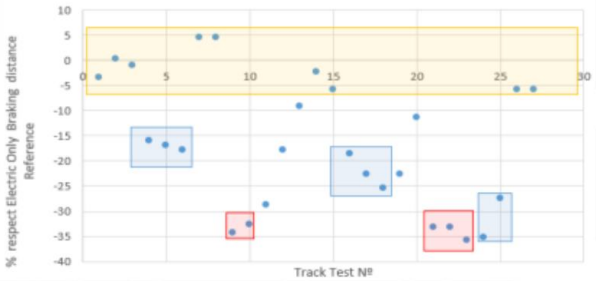




Main Achievements and Contributions

Finalized on-time the deliverable D16.2, D16.3, D16.4 related to the validation of the innovative adhesion management solutions

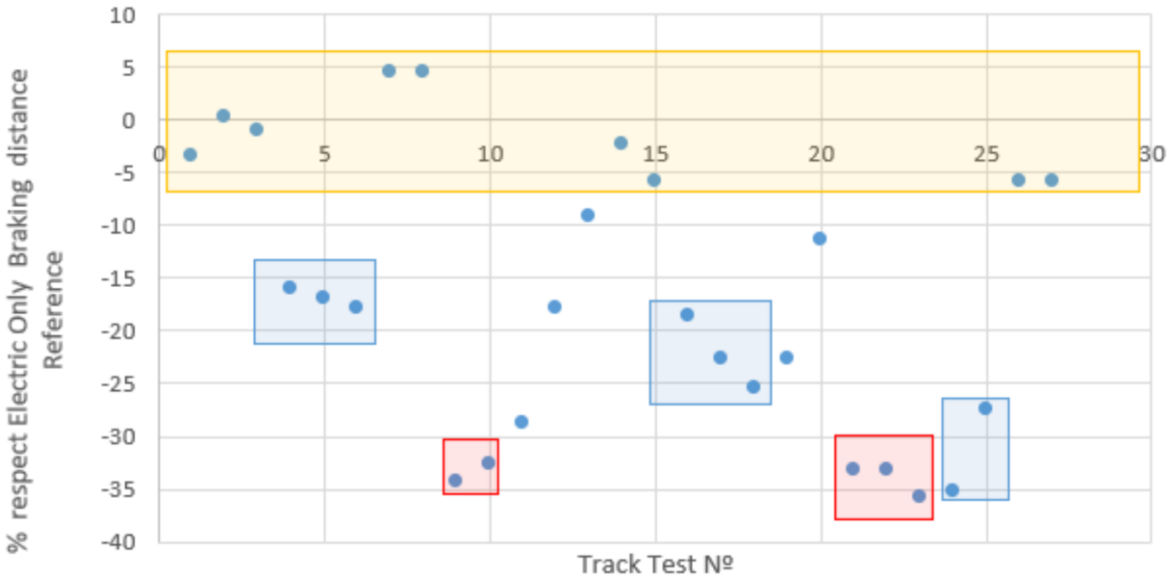
- Adaptive WSP and Adhesion improving dispenser prototypes Test Reports (FTI)
- Validation of blending concept(s) during low adhesion and test report (CAF)



Orange: ED
Blue: Blending concept
Red: Blending + sanding

Figure 9: Percentage gain from new blending concept

低粘着时混合理念的验证和测试报告（CAF）：图示是新的混合理念的百分比结果（桔色= ED，蓝色= 混合理念，红色= 混合+撒砂）。



高效制动力传输样机的测试报告（KB）：图示是平均减速度的比较（蓝色= 标准 WSP，桔色= 高效制动力 WSP）。

Main Achievements and Contributions

Finalized on-time the deliverable D16.2, D16.3, D16.4 related to the validation of the innovative adhesion management solutions

- Adaptive WSP and Adhesion improving dispenser prototypes
- Validation of blending concept(s) during low adhesion and te
- Test report of efficient force transmission prototype (KB)

  Blue: Std WSP
  Orange: Efficient force WSP

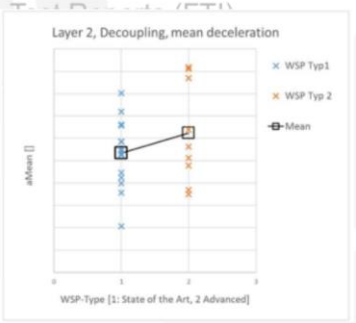
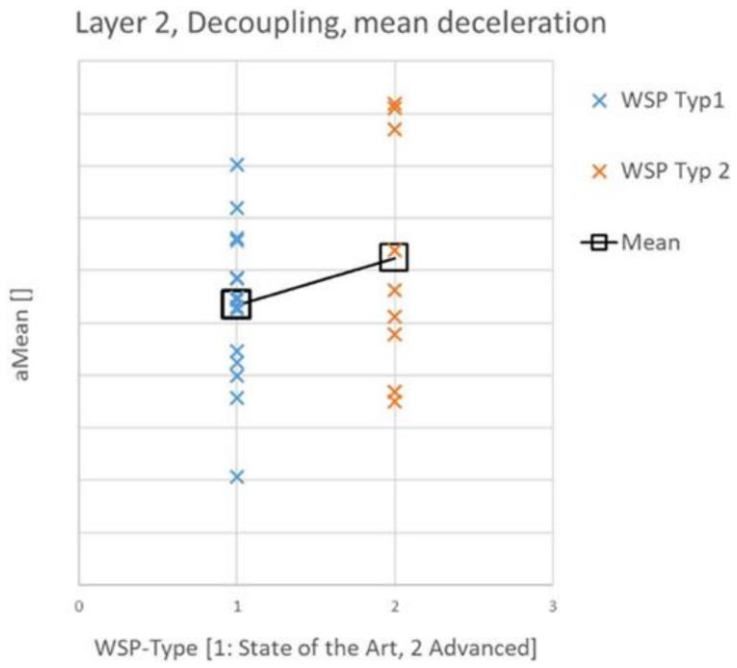


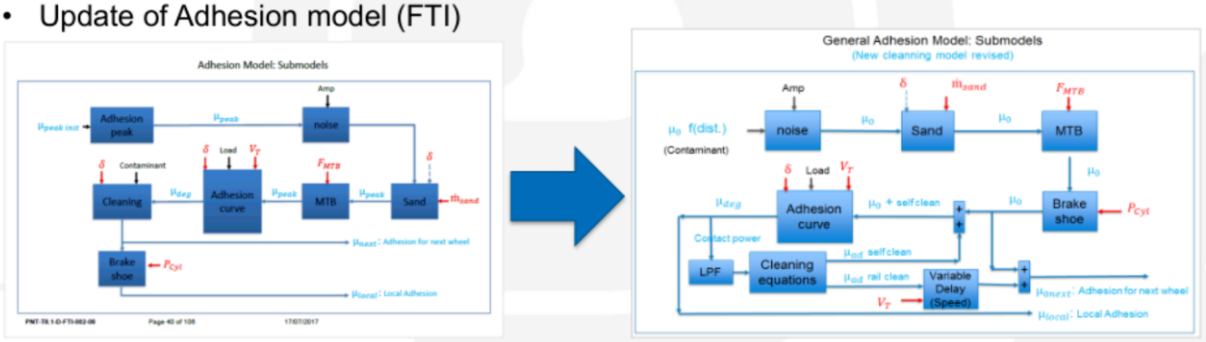
Figure 10: mean deceleration comparison



Main Achievements and Contributions

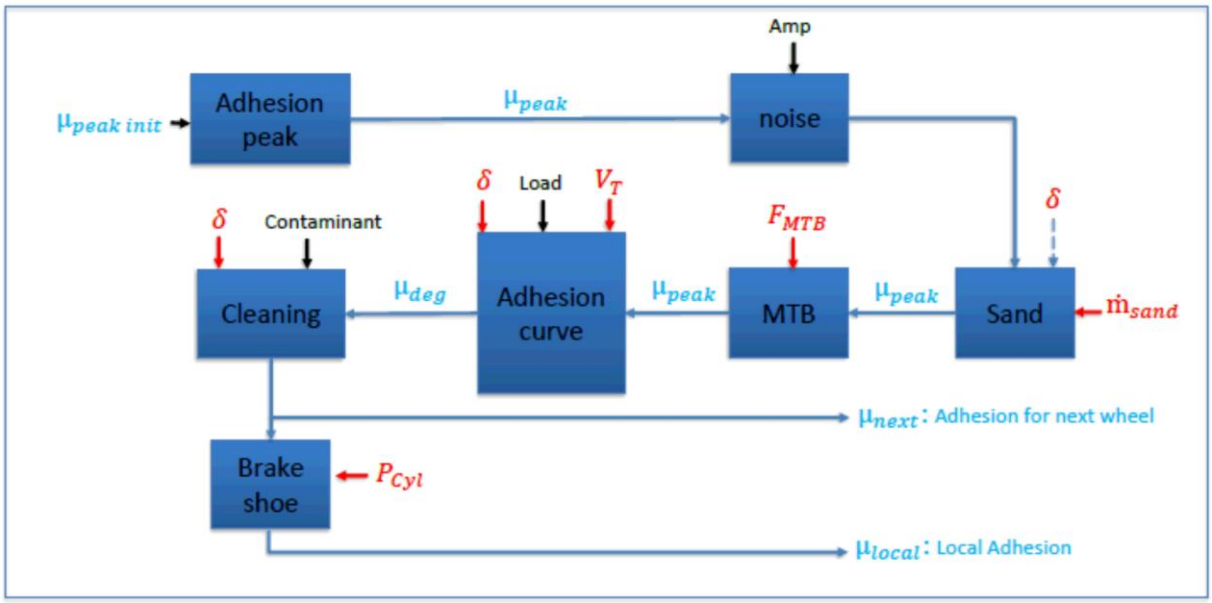
Finalized on-time the deliverable D16.1

- Update of Adhesion model (FTI)

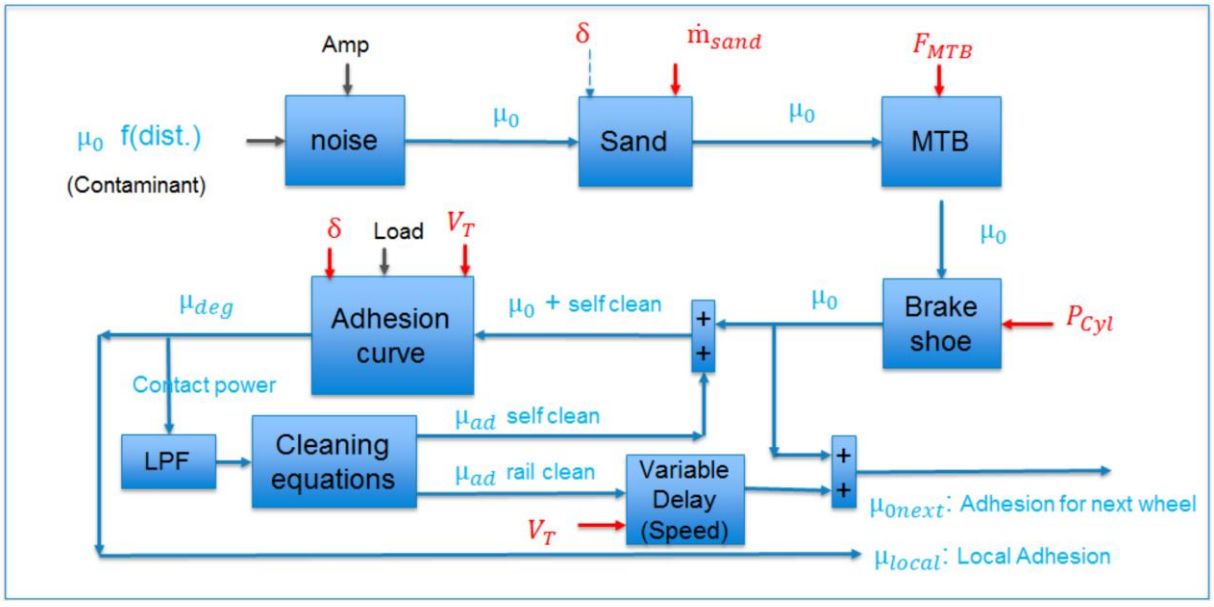


PINTA PINTA2

Adhesion Model: Submodels



General Adhesion Model: Submodels
(New cleanning model revised)

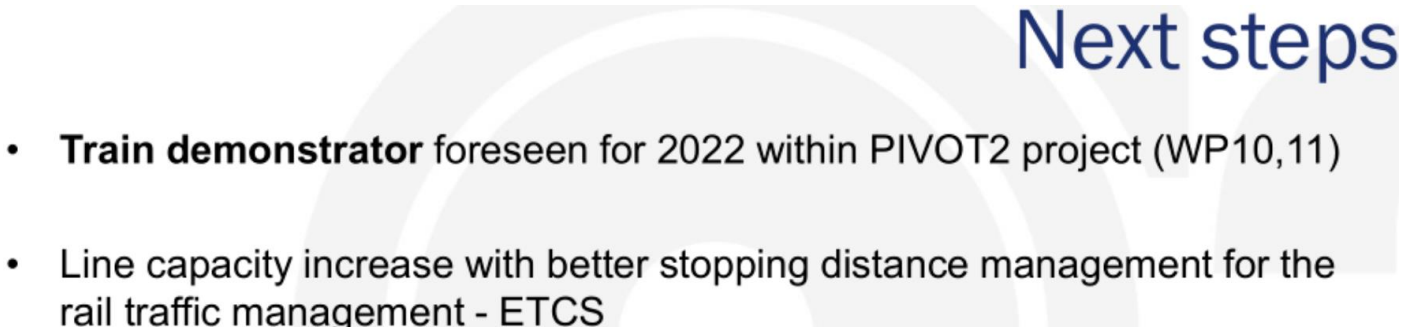


D16.1 报告：粘着模型的更新（FTI）。上下两图分别是 PINTA 和 PINTA2 中使用的粘着模型。

成果的传播：FTI 创新自适应 WSP 概念在 EuroBrake 2019 展示；KB/FTI/SIE 的 PINTA Vectron 测试结果在 EuroBrake 2019 发布。



下一步工作：2022 年在 PIVOT2 项目中会进行列车的示范；使用更好的用于铁路交通管理 ETCS 的制动距离管理来实现线路运力的提升。



5.8 关键技术的预标准化

工作包 6 是关于关键技术和输出成果的预标准化。

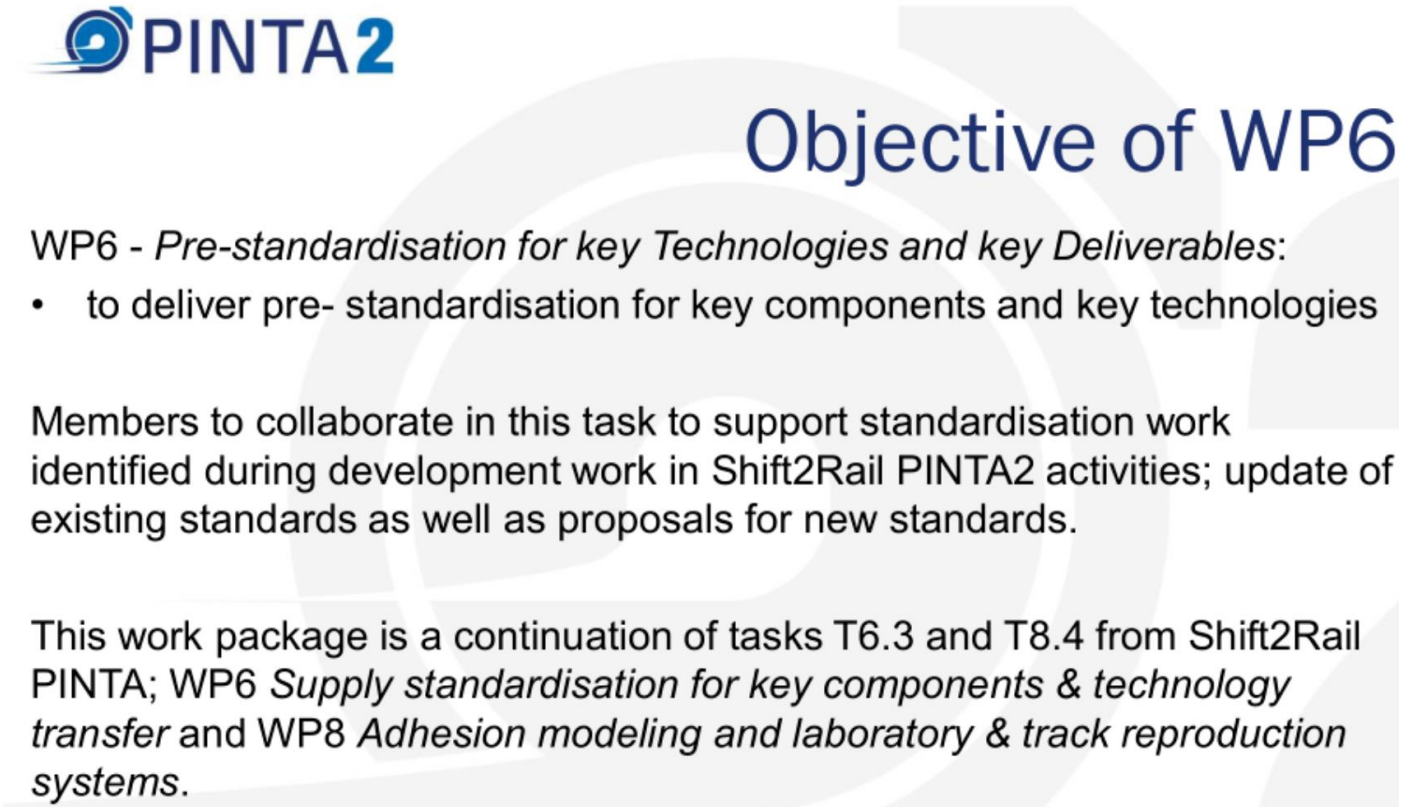




其目标是针对关键的组件和关键的技术输出预标准化。

合作成员一起支持 PINTA2 的开发过程中识别出的标准化工作，包括既有标准的更新，以及新标准的提议。

这个工作包是 PINTA 项目工作 6.3 和 8.4 的延续：WP6= 关键组件和技术传递的供应标准化；WP8= 粘着建模和试验室&轨道再造系统。

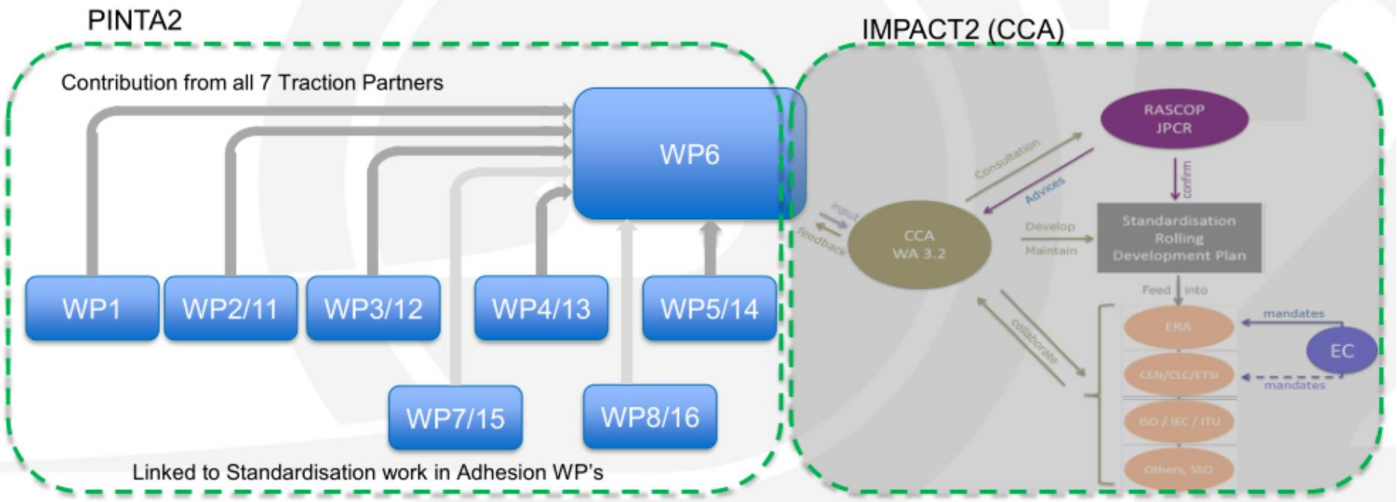


展示了 PINTA2 的标准化工作和交叉 CCA 项目（IMPACT2）的链接。

PINTA2

Environment of WP6

Linking Standardisation activities in PINTA2 to CCA of S2R



WP6 工作包的成果的一个例子是半导体测试标准领域——并联参照布置。

PINTA2 的合作伙伴定义并通过了一个用于并联装置的测量的参照布置方案，并发布了一个科研报告“PNT-WP06-J-SIE-005-02 并联参照布置 V1.1”，可用于半导体供应商和牵引供应商之间的技术接口。

PINTA2

Achievements WP6

Example

Area of semiconductor standard for testing - Paralleling Reference Setup.

The mechanical setup has substantial impact on the paralleling of Semiconductor devices.

The partners of PINTA2 have defined and agreed on a reference setup for measurements on paralleled devices.

A Scientific Paper has been issued on the S2R website (*PNT-WP06-J-SIE-005-02 Paralleling Reference Setup V1.1*) to be used as a technical interface between semiconductor suppliers and traction suppliers



From PNT-WP06-J-SIE-005-02 Paralleling Reference Setup V1.1: Installation guide of Rogowski coils for current sharing measurements

列出了 PINTA2 项目中的预标准化工作，如项目中涉及的牵引系统标准超过 92 个，识别了其中预标准化项点 19 项，完成的项点 4 项（粘着相关的工作类似）。

对于牵引系统，主要的标准更新是关于 SiC/半导体、虚拟验证和认证；对于粘着，主要的更新是关于虚拟验证和认证、撒砂例程。

Achievements WP6

Overview of pre-standardisation in PINTA2

	Traction	Adhesion
Standards referenced in PINTA2	>92	20
Pre-standardization topics identified in PINTA2	19	4
Addressed (on-going or closed) pre-standardisation topics in PINTA2	4	3

For Traction, predominant for updates are in area of
- SiC/semiconductor related topics
- Virtual V&V

For Adhesion, predominant for updates are in area of
- Virtual V&V
- Sanding routines

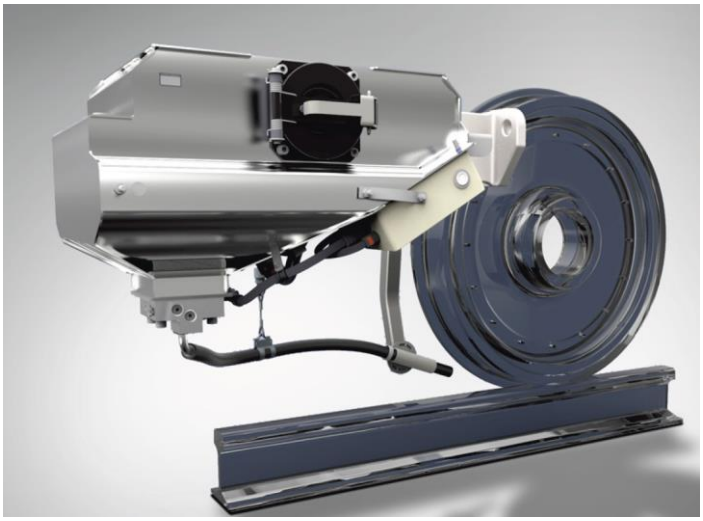
下一步的工作：这个工作包的成果将用于 PINTA3（牵引）和 PIVOT2（粘着）项目。PINTA3 中的进一步活动将包括空调系统方面的标准化项点以及 “碳中和”运输 的行动计划。牵引方面的预标准化将在 PINTA3 的工作中完成。

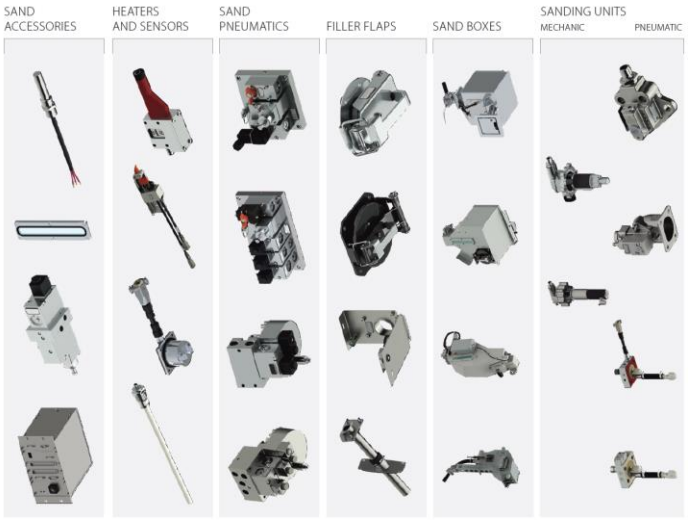
Next steps WP6

The results from WP6 -*Pre-standardisation for key Technologies and key Deliverables* will be used in PINTA3 (traction) and in PIVOT2 (adhesion).
- Continued follow up of pre-standardisation needs from active WP's
- Establish Roadmaps for new/updated standard,
- Coordination with CCA IMPACTx for the overall pre-standardisation work of S2R.

Additional activities in PINTA3 will include standardization topics for additional scope in HVAC and Road Map for Carbon Free Mobility.

The work of Pre-standardisation for traction will be done within the PINTA3 *WP6-Pre-standardi´sation for Key Technologies and key Deliverables,* including all PINTA3 partners.





6.PIVOT2

https://projects.shift2rail.org/s2r_ip1_n.aspx?p=pivot2

2019.10.01-2022.12.31：Performance Improvement for Vehicles On Track 2.

制动系统的示范涉及 PIVOT2 项目的 3 个工作包：

WP09 - Brake System Design Phase

The aim of this WP is to provide an innovative point of view in new brakes technology. The strict collaboration in this WP will lead to a new generation of brakes system able to bridge the gap between environmental aims and market needs.

WP10 - Brake System Implementation Phase

WP11 - Brake System Test Phase

The aim of this WP is to provide an innovative point of view in new brakes technology. The strict collaboration in this WP will lead to a new generation of brakes system able to bridge the gap between environmental aims and market needs.

- 工作包 9：制动系统设计阶段。在新的制动技术方面提供一个新的视点，其工作的开展将带来一个新一代制动系统，在环境目标和市场需求之间架起桥梁。
- 工作包 10：制动系统落实阶段。
- 工作包 11：制动系统测试阶段。

Brakes	The objective is to develop innovative braking systems to contribute to the achievement of key Shift2Rail Multi-Annual Action Plan (MAAP) objectives: improving performance, reliability and punctuality, increasing capacity and reducing life-cycle costs (LCC). In order to achieve these objectives, PIVOT2 builds on the results of the work done in Roll2Rail, PINTA, PINTA2, CONNECTA as well as PIVOT, PIVOT2 and focuses on developing innovative solutions in following areas; • High safety integrity level electronics;高SIL等级的电子控制器 • Adhesion management solutions;黏着管理方案 • Innovative friction pairing solutions;创新的摩擦副方案 • Electro-mechanic brake; 电机械制动 • Virtual verification and validation for certification of braking system. 对制动系统的认证进行虚拟验证和认证

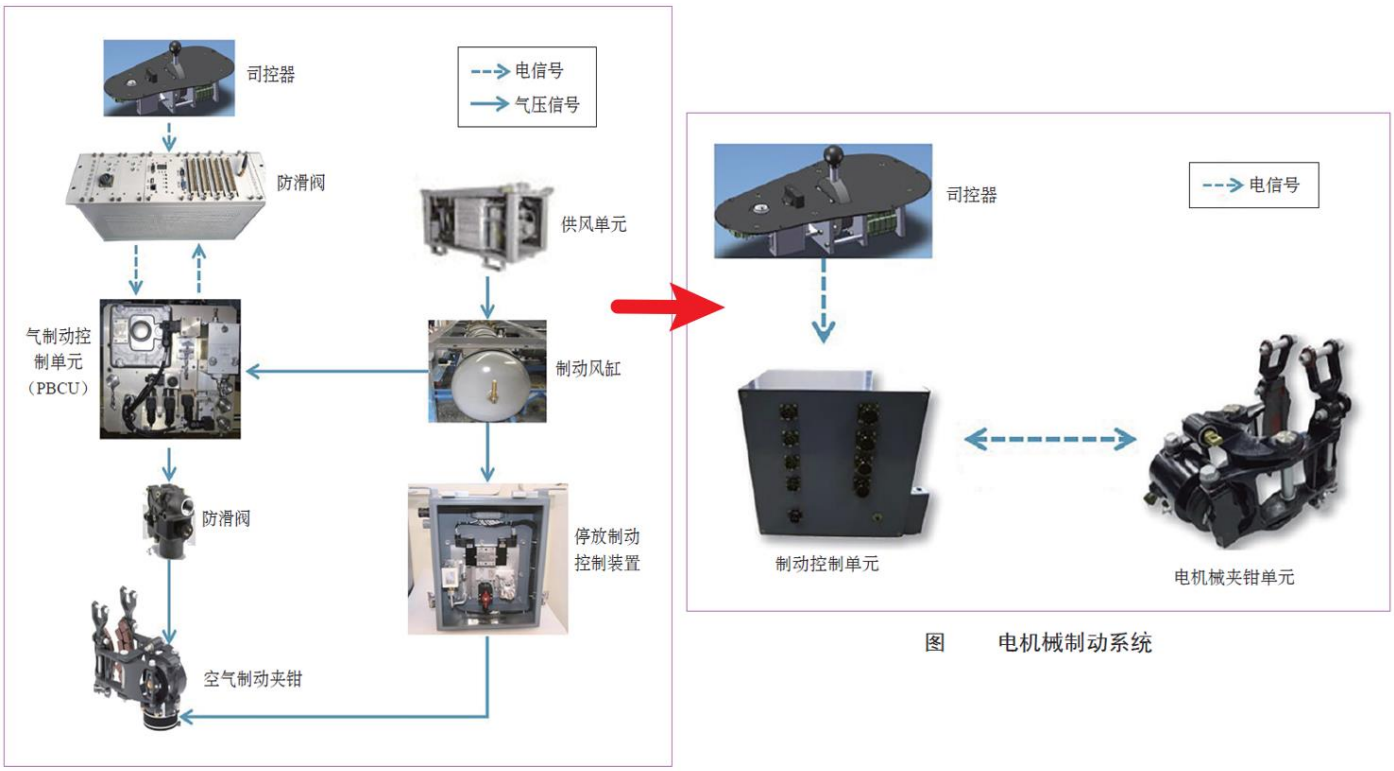


图　　微机控制直通电空制动系统

图　　电机械制动系统

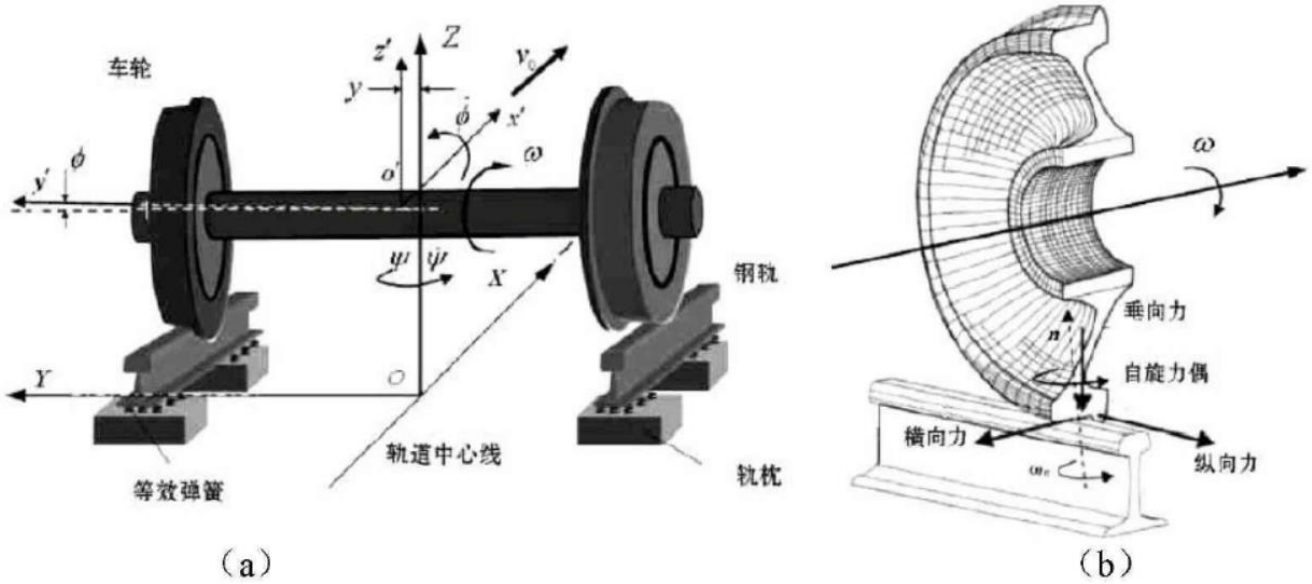
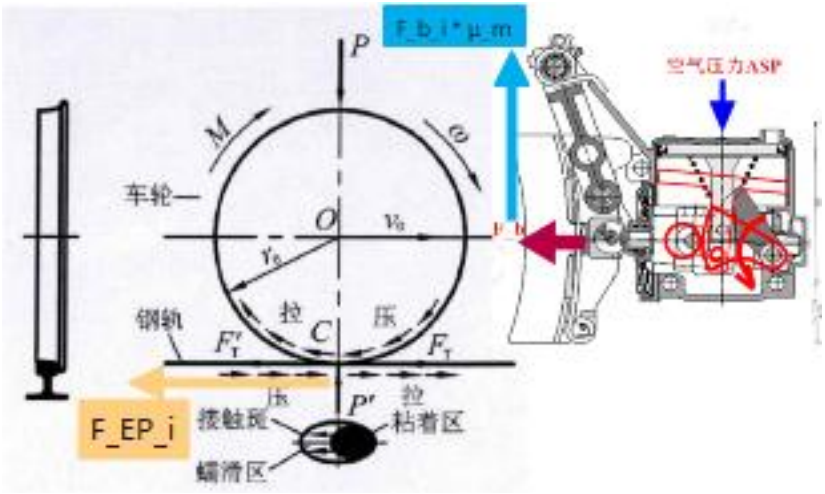


图　　轮对滚动接触运动及受力图



7.研讨概要

研讨题目：Shift2Rail 中的创新制动系统

研讨大纲：

1.高安全 SIL 等级电控单元；

（CONNECTA：2016 年 9 月 1 日～2018 年 9 月 30 日，

介绍传统制动系统方案、未来制动系统初步假设方案）

2.线控制动；

（SAFE4RAIL：2016 年 10 月 01 日～2018 年 12 月 31 日

线控制动系统需求定义及相关安全性分析）

3.黏着模型及低黏着管理方案；

（PINTA：2016 年 9 月 1 日～2018 年 12 月 31 日；

黏着检测和低黏着管理，实验室理论及测试再现；

PINTA2：2018 年 9 月 1 日～2020 年 11 月 30 日

黏着优化概念、防滑自适应算法、提升黏着设备、低黏着有效制动力传输概念）

4.创新摩擦副解决方案；

（PIVOT：2017 年 10 月 1 日～2019 年 12 月 31 日

新型摩擦副研发匹配、电-机械制动设备、无摩擦低噪声（EDD））

5.对制动系统进行虚拟验证和认证；

（PIVOT：2017 年 10 月 1 日～2019 年 12 月 31 日

介绍未来制动系统总体方案、功能分解、评价标准修订、虚拟验证和认证概念；

PIVOT2：2019 年 10 月 1 日～2022 年 12 月 31 日

未来制动系统设计、落实、测试）

本期研讨特色：1.介绍轮轨滚动接触黏着模型及低黏着管理对于制动力有效施加的意义；

2.制动系统虚拟验证的流程及所需的准备条件；

3.线控制动系统对于车辆制动性能的影响；

4.基于 S2R 对于未来制动系统定义，适用于城市轨道交通车辆的未来制动系统探讨。

8.总体摘要:

为匹配高性能无线传输技术在轨道列车上使用，实现制动系统的虚拟验证和认证。对传统制动系统进行功能细化分解，定义适用于线控制动的设计需求并对部分功能进行整合和相关安全性分析，以

此开发出一套高 SIL 等级的电子控制单元；同时基于对轮轨不同黏着实测数据的收集，对恢复黏着系统进行性能需求分析，介绍实验室黏着建模过程及仿真模型，开发一套防滑自适应算法并配合撒砂装置以满足低黏着条件下制动力有效施加；另外对新型摩擦副进行匹配研发，开发电机械制动设备和长寿命低磨耗的制动盘、制动闸片以及低摩擦低噪音的涡流制动系统。最后对制动系统的评估和验证流程进行分析，提出对其进行虚拟验证和认证的流程和方法。通过上述一些列技术研发，开发未来制动系统概念并进行全系统方案设计、技术示范及测试。