Electronic Brake by Wire

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Safe4RAIL – SAFE architecture for Robust distributed Application Integration in roLling stock (730830)

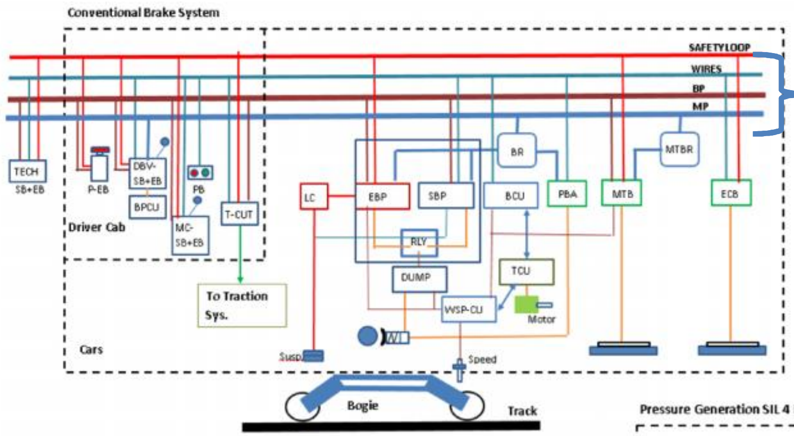
CONNECTA – CONtributing to Shift2Rail's NExt generation of high Capable and safe TCMS and brAkes (730539)

Why? Brake by Wire

Today	With Brake by Wire
Train brakes control largely based on mixed pneumatic electrical technologies	Train brakes control and communication based on safe electronic technologies
Emergency Brake based on pneumatic command and safety loop control	EB part of an electronic system able to work with safety requirements up to SIL4
Braking distances limited by pneumatic components behaviour	Electronic improves brake efficiency, reduces braking distances and increase railway traffic capacity
Different subsystems for different brakes functionalities (EB, ES, PB, WSP ..)	Integrated controller able to manage all the main brakes functionalities
Different brake parts	Optimisation, reducing the number of sophisticated pneumatic components. Improving overall LCC
Custom solutions to interface brakes and train technical systems	IMP to support safety system integration between brake and technical systems

WP5 Achievements

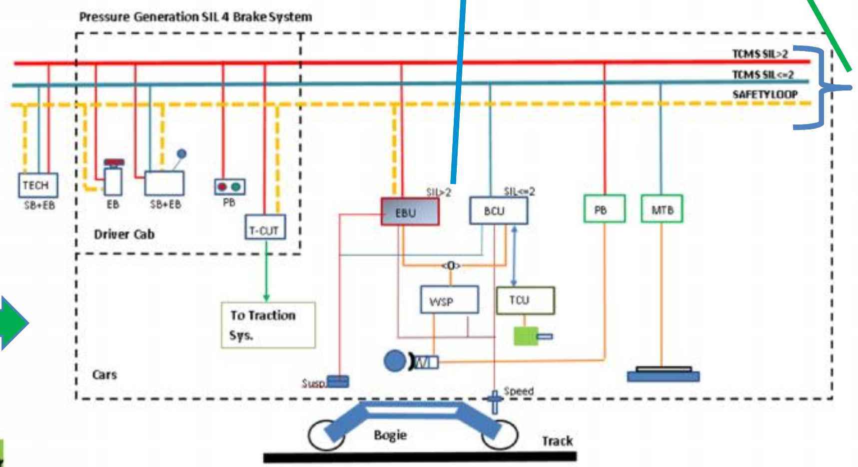
- Redu



- Reduce Complexity
- Improve Brake Performance (accuracy) Using High SIL Electronic

From Conventional
To Future

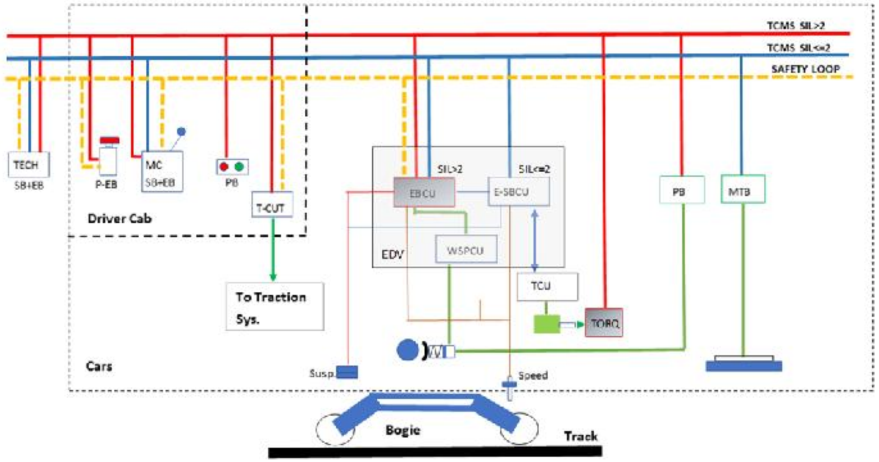
Task 1 Architecture



- High Safety Electronic pressure control, used to implement Electric Brake in Service and Emergency with integrated WSP:

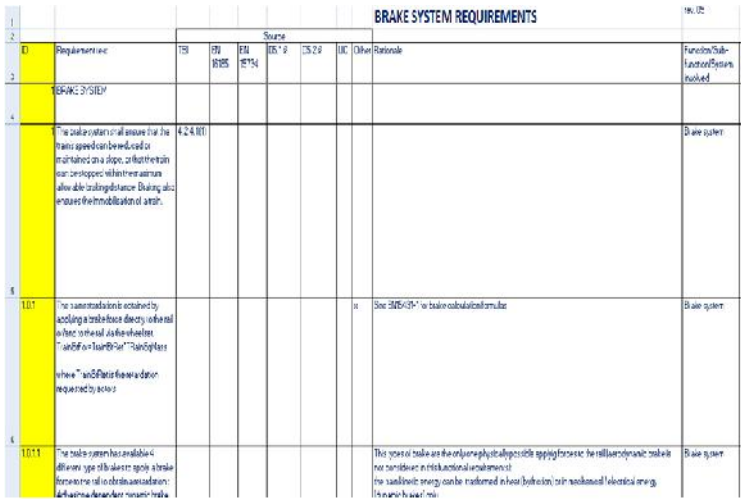
Advantages:

1. Improvement of the cylinder EB pressure output accuracy.
2. Simplification of train wiring & piping
3. Regulate emergency brake effort based on actual speed in a continuous way.
4. Simplification & scalability of brake system: possibility to use Electro Dynamic brake in Emergency
5. advantages LCC, noise reduction and energy saving.



Process Approach

- The conceptual organization of the technical activities is provided through a **V-cycle** tailoring the generic representation provided by the EN 50126.
- Functional model and Functional Requirements have been jointly defined by CTA & S4R
- Requirements taking care:
  - TSI safety requirements
  - Pre HAZARDs outputs
- Result:
  EDV Brake Function REQs
  & NG-TCN Communication Data



Safety

Brake system Safety analysis performed jointly with S4R

Inputs

- Brake System functional model and use cases
- Collection of the main hazardous scenario related to brake system

Output

- List of **Countermeasures** to be applied in the System Design
- List of **Application Conditions**
- List of **Safety Recommendations**

		THR	SIL
EB1.	Emergency brake command generation	≤ 10-9	SIL4
EB2.	Actual Emergency Braking Power Calculation	≤ 10-9	SIL4
EB3.	Emergency brake command transmission	≤ 10-9	SIL4
EB4.	Emergency Local brake force generation	≤ 10-9	SIL4
EB5.	Emergency brake energy storing	≤ 10-9	SIL4
EB6.	Traction cut off	≤ 10-9	SIL4
EB7.	Emergency brake state and fault detection and indication (applied/ released/ faulty/ isolated/ no info)	≤ 10-9	SIL4
EB8.	Emergency brake isolation	≤ 10-9	SIL4
SB1.	Service brake train retardation request	10-7 < THR ≤ 10-5	SIL1-SIL2
SB2.	Service brake request transmission	10-7 < THR ≤ 10-5	SIL1-SIL2
SB3.	Train Load Calculation	10-7 < THR ≤ 10-5	SIL1-SIL2
SB4.	Train Brake Force Calculation	10-7 < THR ≤ 10-5	SIL1-SIL2
SB5.	Blending (speed and/or adhesion and/or load and/or brake disk temperature dependent)	10-7 < THR ≤ 10-5	SIL1-SIL2
SB6.	Service brake force application energy storing	10-7 < THR ≤ 10-5	SIL1-SIL2
SB7.	Holding brake	10-7 < THR ≤ 10-5	SIL1-SIL2
SB8.	Traction cut off	-	-
SB9.	Service brake state and fault detection and indication (applied/ released/ faulty/ isolated/ no info)	-	-
SB10.	Service brake isolation	10-7 < THR ≤ 10-5	SIL1-SIL2
PB1.	Parking brake command generation	≤ 10-9	SIL4
PB2.	Parking brake train command transmission	≤ 10-9	SIL4

Hazard Analysis / Inputs / Safety Targets Allocation

SAFETY REQs for EDV

LCC Analysis

LCC costs reduction

- EDV architecture

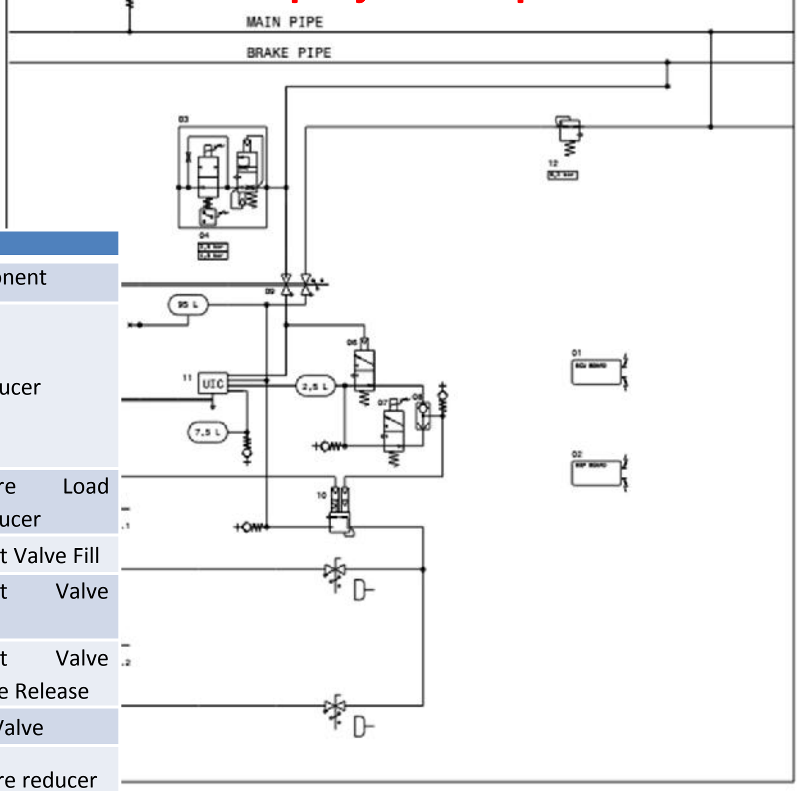
compared ⟷

- EMU regional

Equivalent components are identify

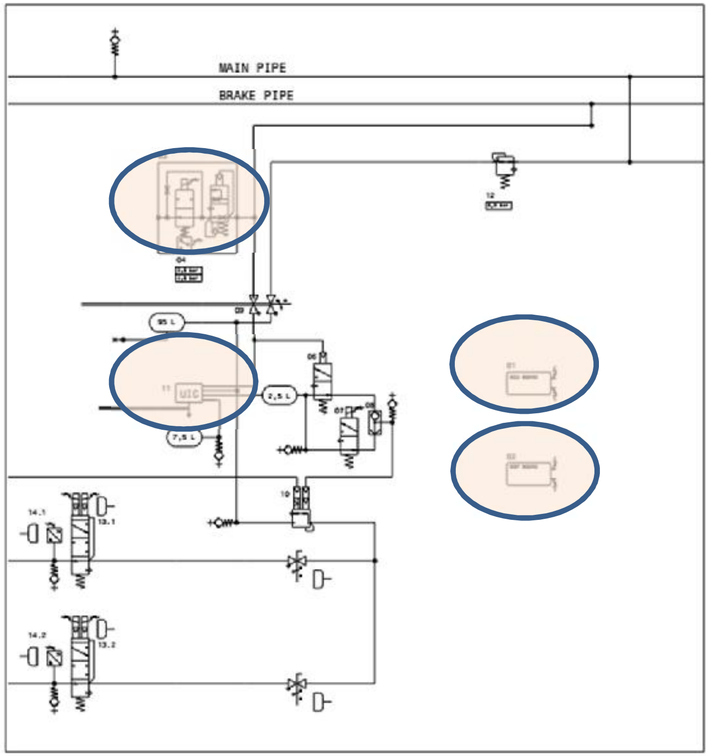
EMU			EDV		
Nr.	Cd.	Component	Nr.	Cd.	Component
2	(14.1) (14.2)	Pressure Transducer	2	P_BC	Transducer
1	(05)	Pressure Transducer	2	P_Load	Pressure Load Transducer
1	(07)	Magnet Valve	1	mvF	Magnet Valve Fill
			1	mvS	Magnet Valve Vent
			1	mvRR	Magnet Valve Remote Release
1	(10)	Relay Valve	1	RV	Relay Valve
1	(12)	Pressure Reducer	1	PnRg	Pressure reducer

EMU project in operation



LCC (II)

From the LCC analysis, the EDV device allows to reduce the use of pneumatic components



Preventive Maintenance

➡ **28% Reduction Off.**

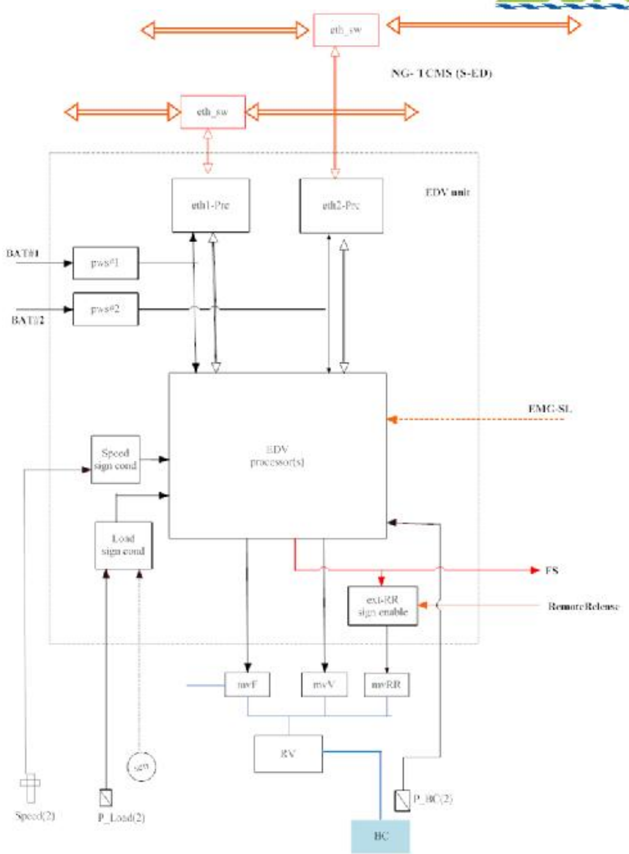
Corrective Maintenance

➡ **27% Reduction Off.**

EDV FT Architecture

WP5 Competitive Design

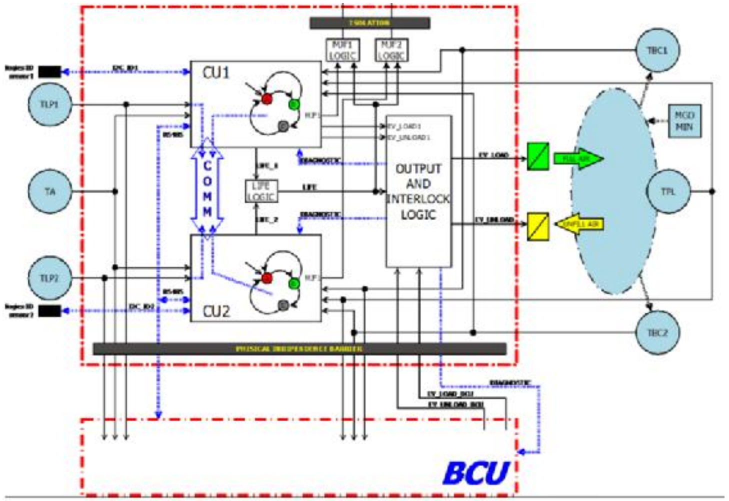
- EDV Sub System Design: the activity will be finalized to development of a control board for the HIGH SIL system, identified as Electronic Distributor Valve (EDV).
- integration with NG_TCN proposed architecture
  - embedded virtual A-Plane and B-Plane for scheduled data traffic (TSN domains)
  - Safety-End Device (e.g EDV) are connected to both planes

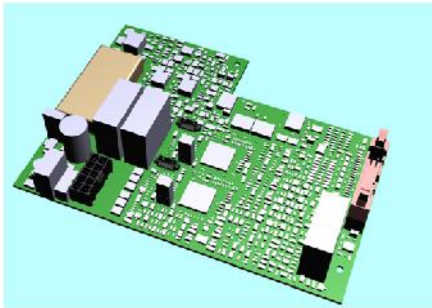


EDV FT Goal

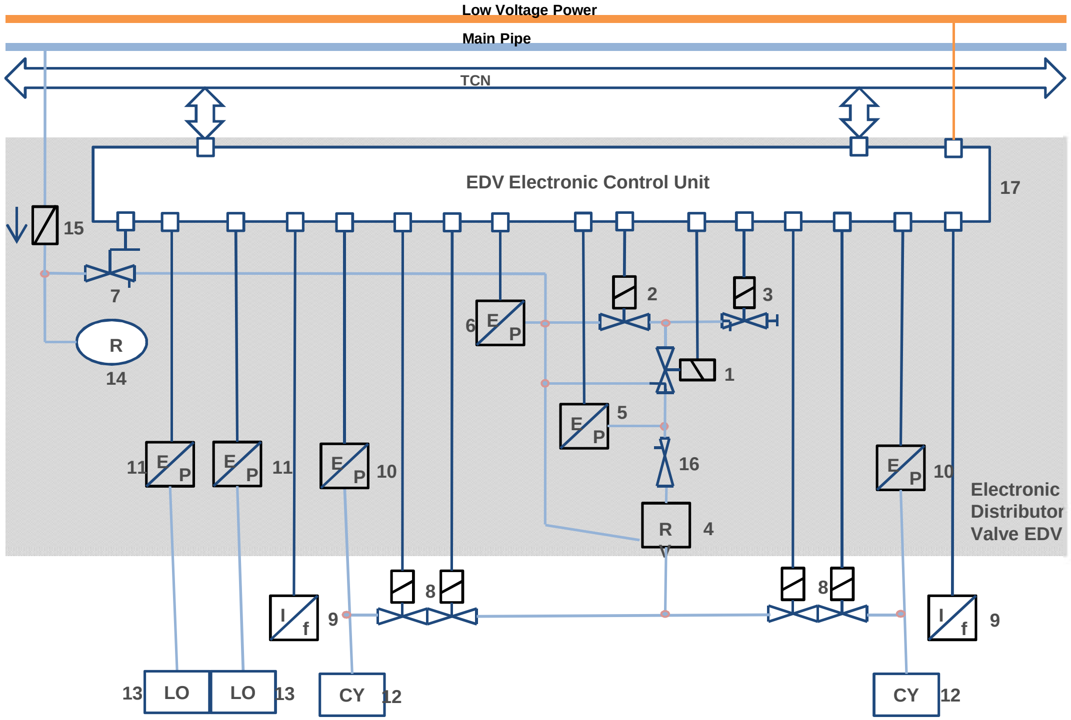
EDV FT hw architecture

- Safety requirements taking care of axle redundancy
  - THR applicable target
  - resilience to single fault not requested
- Architecutre is 2oo2 acting "reactive failsafety" as EN_50129
- LCU1 is the "main computation channel"
- LCU2 is the "checking channel".
- Interface to NG-TCN control is support by specific BCU I/O





KB EDV Architecture



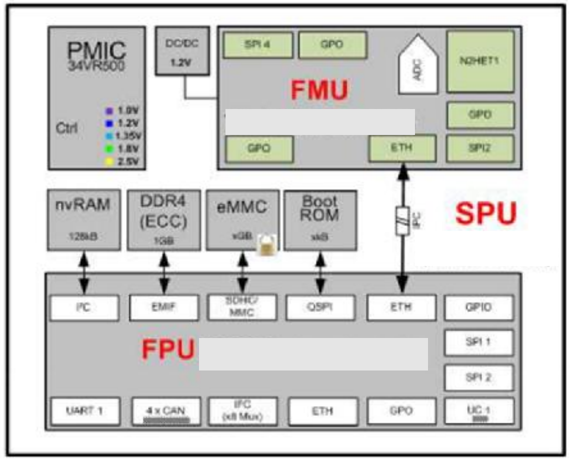
emergency valve (1)
brake valve (2)
release valve (3)
relay valve RV (4)
pilot pressure sensor (5)
air supply pressure sensor (6)
isolation cock (7)
dump valve (8)
speed sensor (9)
cylinder pressure sensors (10)
load sensors (11)
brake cylinder (12)
air suspension (13)
local reservoir (14)
check valve (15)
pressure limiting valve (16)
EDV electronic distributor valve (17)

Knorr-Bremse Goal

Local Application Device LAD with CPU sub device for High Safety Level Architecture

Technology:

- High Safety Level Electronic Architecture on SIL 3/4 Level for Brake Control
- LAD Application SW on SIL 3/4 Level
- NG TCN Communication to Brake Control Electronic Units
- SIL3/4 Assessment of the Local Application Device LAD



S4R Brake by Wire

- **S4R Brake by Wire project goal**
  - define the requirements and the safety concept for a high safety (SIL4) Brake Electronic Control (EC) based on the IMP

- **S4R Brake by Wire means**
  - system design down to electronic control
  - fully integrated with train technical systems
  - focused on the **E**mergency **B**rake as the highest safety demanding brake functionality (SIL4)

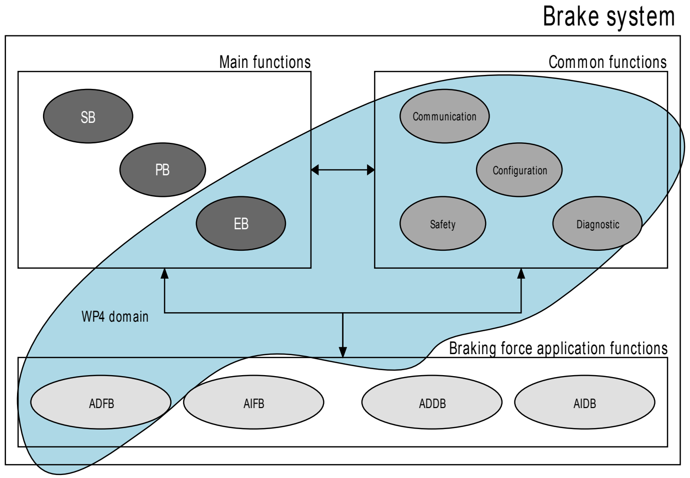
S4R Brake by Wire

- **development covers :**
  - functional model of an advanced train brake system
  - safety requirements added through an Hazard Analysis with safety countermeasures definition
  - System architectural development
  - Electronic Control requirements, parted in:
  - central control (**V**ehicle **C**ontrol **U**nit)
  - local physical brakes i/o control (**R**emote **B**rake **C**ontrol **U**nit)
  - requirements propagated to IMP and train technical systems

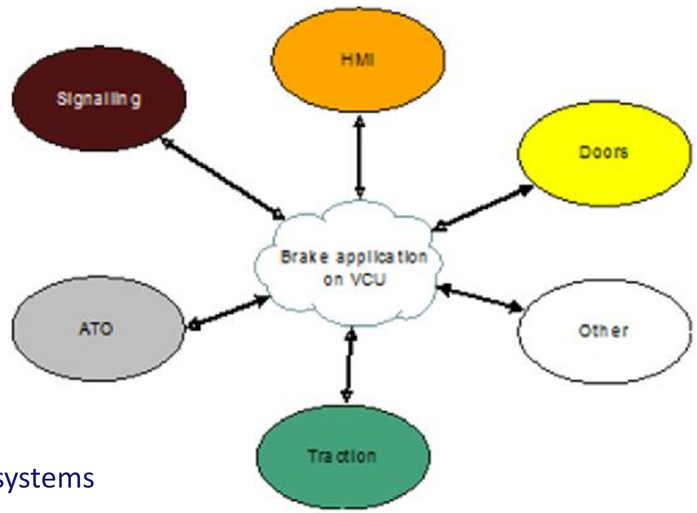
- **development executed :**
  - respecting railway standard EN50126 with :
    - top down V process
    - safety process
    - Safety V&V
    - Safety Indipendent A**s**sesment

S4R Brake by Wire : requirements

- **Project boundaries:**



- EB Emergency Brake
- ADFB (disk brake)
- Interface to other brake types subsystems and peripherals

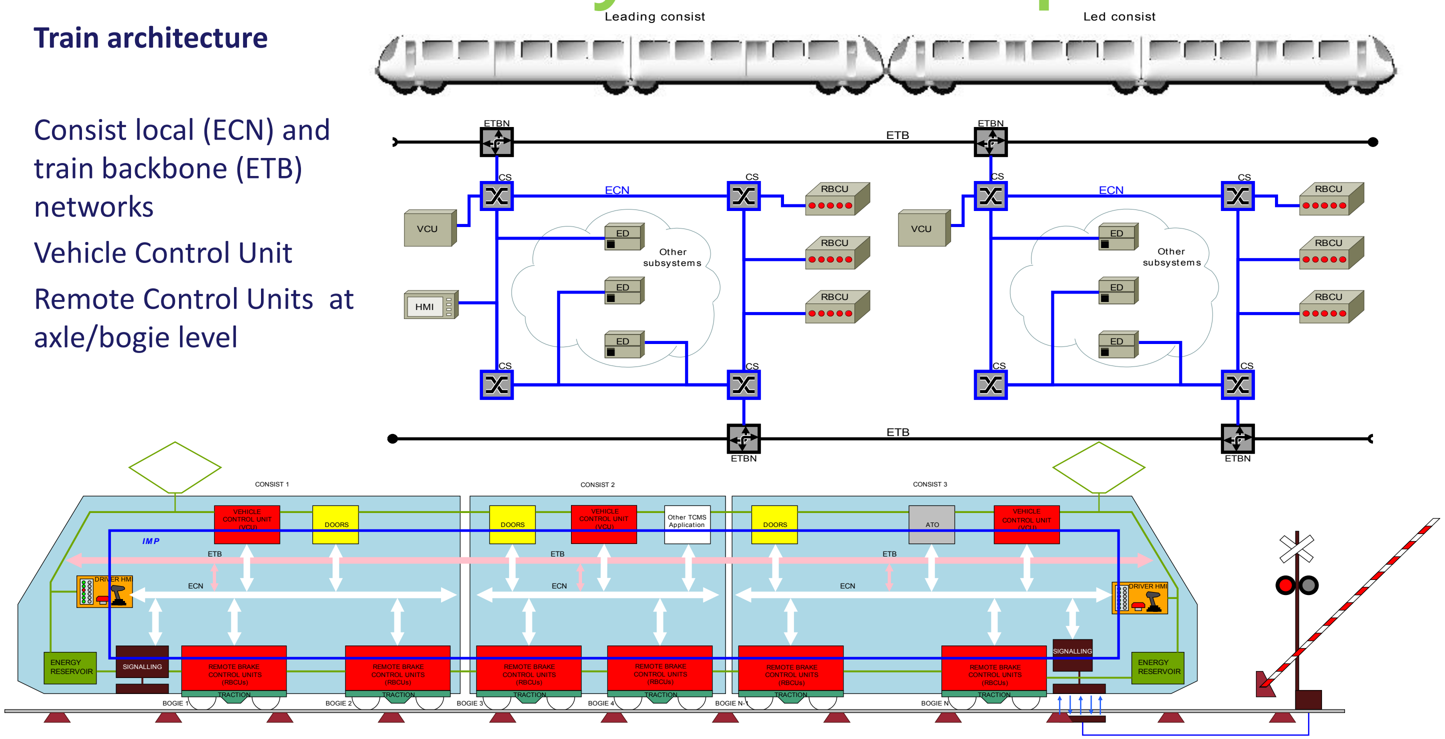


- Interfaces to train technical systems

S4R WP4 Brake by Wire : Requirements

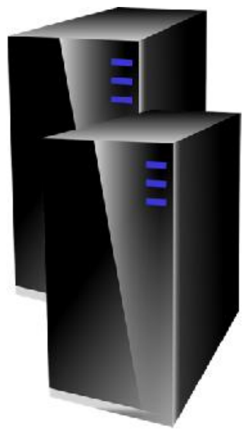
- **Train architecture**

- Consist local (ECN) and train backbone (ETB) networks
- Vehicle Control Unit
- Remote Control Units at axle/bogie level



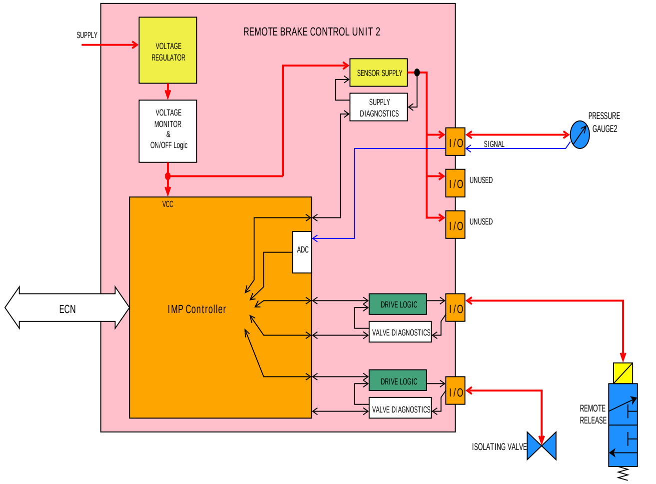
S4R Brake by Wire : Requirements

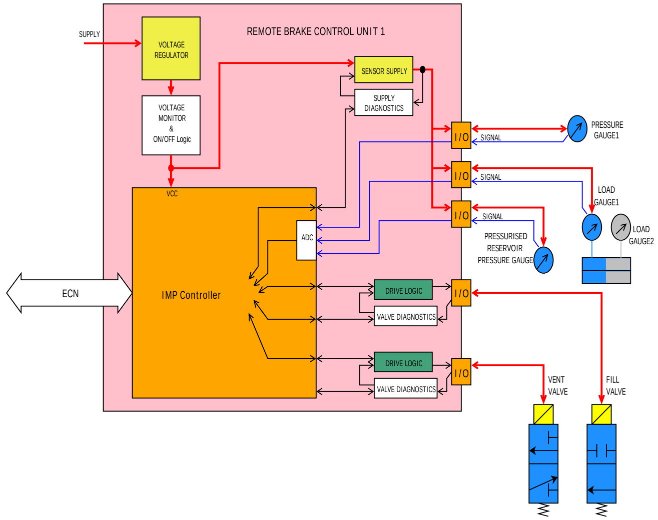
- **Central brake control (Vehicle Control Unit) :**
  - IMP high availability and SIL4 features
  - coordinates differents type of brake requests : Service Brake, Parking Brake, Emergency Brake
  - allows speed management aligned with the available brake capacity granting safety stopping distances
  - automatically manages running capability
  - manages single brake units isolation
  - manages single brake units remote release
  - manages train weight measure



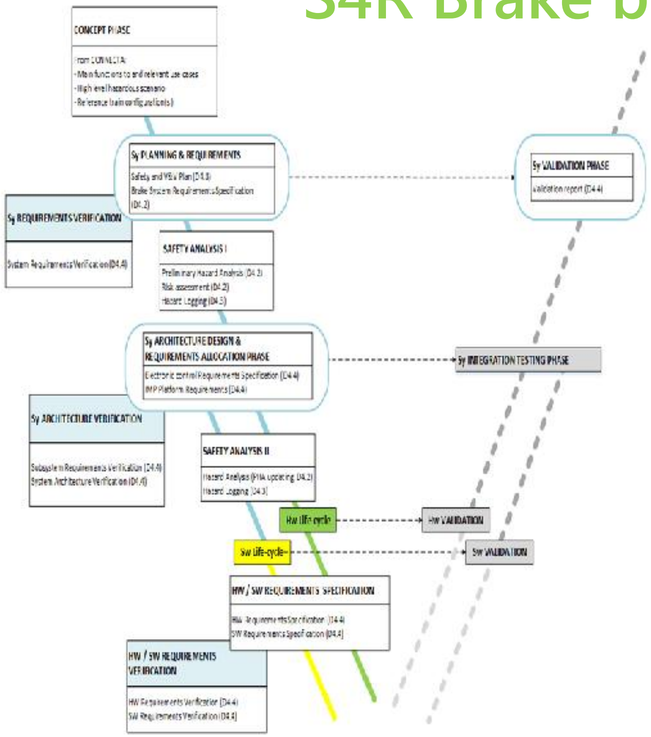
S4R Brake by Wire : Requirements

- **Local brake disk control (Remote Brake Control Unit RBCU) :**
  - remote i/o
  - safety monitoring fuctionalities
  - local pneumatic pressure loop control
  - i/o interfaces parted on the base of safety functional indipendency needs
  - IMP based controller





S4R Brake by Wire : Safety Process



- **Safety activities** defined consistently with EN 50126 and EN 50129
  - Process planned
  - Preliminary Hazard Analysis
  - Risk Assessment
  - FTA THR allocation
  - Safety Requirements Verification & Validation
  - Anomalies Management
  - Hazard Logging
  - Safety Assessment

S4R Brake by Wire : conclusion

- **System developments based on this concept work will :**
  - be able to substitute with a SIL4 electronic control the pneumatic and electric control technologies
  - deliver the innovative functionalities provided by the model jointly defined with Connecta
  - allow full integration for the whole braking functionalities
  - ask for the use of the IMP platform at its highest level of safety and availability features

- **The work delivers a clear evidence for the need of a train integrated high safety control and communication platform as the IMP :**
  - the brake system, surely for the emergency brake function, is a SIL4 application distributed all along the train with the need to interface at the maximum safety level almost all the other train technical system
  - the complexity of this task, since it involves the whole train control systems, seems affordable only if based a strong common safety platform