CLEARSY
Safety Solutions Designer

AUG 2022

AIX
LYON
PARIS
STRASBOURG

WWW.CLEARSY.COM

Safety railway engineering and products CLEARSY

CONTACT@CLEARSY.COM

Independent French Company

- Created in 2001 by **the team authors of the ATELIER B**, famous formal method tool
- **90% of the shares owned by employees**
- 2021 turnover: **14 M€, 130 engineers & PhDs**
- **15% abroad**: Brazil, Chile, Luxembourg, Sweden, Norway, Switzerland, Belgium, Germany, Azerbaijan, Cameroon, Macao, Japan, USA, Canada, Italy …
- **Partnership with Paris metro** (RATP) to develop and deploy innovative custom safety solutions
- Partnership with factories to provide industrial equipment and local companies for exportation/distribution

We are designer
CLEARSY Offer

Range of safety critical systems designed by CLEARSY

- Supply of safety systems already developed and in revenue service
- Adaption of existing systems to specific requirements

Safety critical systems design

- Design of turn-key safety critical systems (hardware and software) certified SIL2 to SIL4
- Prototype of safety critical systems and proof of concept

Safety critical software design

- Usage of **the B formal method to develop safety critical software** and to **prove system specifications**: formal specification and code verification
- Support for the software development toolkit: Atelier B, used by Alstom and Siemens to develop ATP safety critical systems
- Design of supervision and simulation systems
- Safety critical data validation

ERTMS/ETCS
CLEARSY Offer

We have an in-depth knowledge of ERTMS/ETCS:

- SUBSET 026, ERA DMI specification
- DMI development (SIL0, SIL2)
- Track plan editor
- EVC development

And in-depth expertise in Simulation and Testing:

- Training
- Testing (SUBSET 094, SUBSET 110/111/112)
- Train behavior simulation
- Trackside simulation (IXL, RBC, …)

Available tools developed by CLEARSY:

- **ETCS operational simulator**
- **ETCS traffic simulator – Track plan editor**
- **ETCS RBC test bench**
- **ETCS on-board unit test bench (EVC)**
- **Multi-platform DMI software**
- **Safety critical data validation software**

Available product developed with CENTRALP:

- **A SIL2 DMI**

ERTMS/ETCS
20 years of experience

More than 20 years of Experience – since the very beginning of ERTMS

- Founded as part of the former **ERRI** (European Railway Research Institute – financed by the UIC – International Union of Railways) to develop the first ETCS simulator for the **project A200.**
- Our first mission: **translate complex details of Technical Specifications for interoperability (TSI) into a suit of tools for training and testing equipment**

Reference in ERTMS

- Developed the **first ETCS simulator**
- **UNISIG** asked us to develop the first test bench for on-board systems
- The test bench was delivered to **CEDEX**, then **DLR** and **MULTITEL**, **3 well-known ERTMS laboratories in Europe that certify systems are compliant with TSIs**
- Helps the **ERA** (European Railway Agency) and the **ERTMS Users Group** in the consolidation of the specifications of Baseline 3
- Today, our set of tools is still helping companies **to develop and test their new ERTMS systems and train their collaborators**

UNISIG

EUROPEAN UNION AGENCY FOR RAILWAYS

ERTMS USERS GROUP

Our Expertise

Standards for railway safety critical systems

- **CENELEC** standards: EN 50126, EN 50128 and EN 50129
- **AREMA**

Urban line – Metro and Light Rail

- **CBTC** (Communication Based Train Control): worked with the main suppliers on their Automatic Train Operation (ATO), Automatic Train Protection (ATP) and Automatic Train Supervision (ATS). Experienced with GoA2 to 4 operation
- **Signaling:** Realized several interlocking systems based on PLC and relays

Main line – Regional trains and commuters

- **ERTMS** (European Rail Traffic Management System): CLEARSY has a dedicated department (ERSA)
- **Signaling**

Railway clients and partners

MÉTROPOLE NICE COTE AZUR
New York City Transit
SIEMENS
engie
TÜBİTAK
vossloh
THALES
INFRABEL Right On Track
CAF
RATP
keolis
Atos
MITSUBISHI
NetworkRail
SNCF
AREVA
BOMBARDIER TRANSPORT
Eisenbahn-Bundesamt
transdev
ST Electronics A company of ST Engineering
epsf
Transurb
TRAFIKVERKET
RTM
RSSB
ALSTOM
Faiveley Transport A Wabtec Company
ProRail
mobility. cegelecmobility.com
SYTRAL
COLAS RAIL
SBB CFF FFS
CEDEX CENTRO DE ESTUDIOS Y EXPERIMENTACIÓN DE OBRAS PÚBLICAS
Ansaldo STS A Hitachi Group Company
HITACHI Inspire the Next
indra
METRÔ
EIFFAGE
CROSSRIVERRAIL
Talgo
ST Engineering
GILGEN DOOR SYSTEMS
BÄR BAHNSICHERUNG
ATKINS Member of the SNC-Lavalin Group
ANGELSTAR

Design and implementation of certified safety critical systems and software

CERTIFER

Reference : 9111/1000 édition 1

CERTIFER certifie que le système de management mis en place par:
CERTIFER certifies that the management system implemented by:

CLEARSY System Engineering
320, avenue Archimède, Les Pléiades 3 – Bâtiment A
13857 AIX-EN-PROVENCE Cedex 3, France

Pour les activités suivantes :
For the following activities:

Conception et développement de systèmes de contrôle-commande, de logiciels sécuritaires et de produits - activités de conseil

Design and Implementation of safety critical control-command systems and software – Consulting

a été évalué et jugé conforme aux exigences requises par :
has been assessed and found to meet the requirements of:

ISO 9001 : 2015

et est déployé sur les sites suivants :
and is developed on the following locations:

320, avenue Archimède, Les Pléiades 3 – Bâtiment A
13857 AIX-EN-PROVENCE Cedex 3, France

62, rue de la Chaussée d'Antin
75002 PARIS, France

10 rue des Emeraudes, 69006 LYON, France

1 rue des cigognes, 67100 STRASBOURG, France

Date de délivrance initiale : 10/03/2021
Date of certification

Date de fin de validité : 09/03/2024
Date of end of validity

Délivré à Valenciennes le 10/03/2021
Issued in Valenciennes on

La Directeur Général
The Chief Executive Officer

Marie IACOVOLA

Usage of B formal method

Formal software development of ATP (CBTC)

- Teams expert in safety software design and development, Verification & Validation
- Alstom (URBALIS), Siemens (TRAINGUARD)

Property-based formal system verification

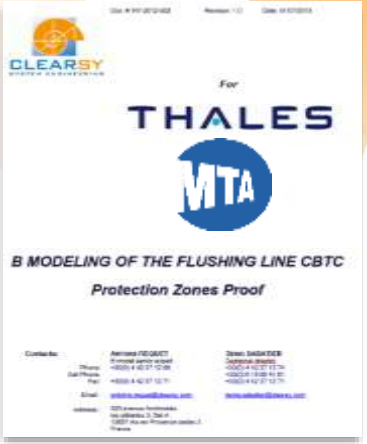
- New York City Subway / THALES (Flushing line finished in 2015, in progress for other)
- SNCF: NEXTRégio (ERTMS)
- RATP: Octys (CBTC)

Property-based formal software verification

- ALSTOM (Urbalis 400), RATP / SIEMENS (Octys, TRAINGUARD)

Formal data validation

- ALSTOM, RATP, SNCF, THALES, ATKINS, ATOS, SIEMENS, MHI

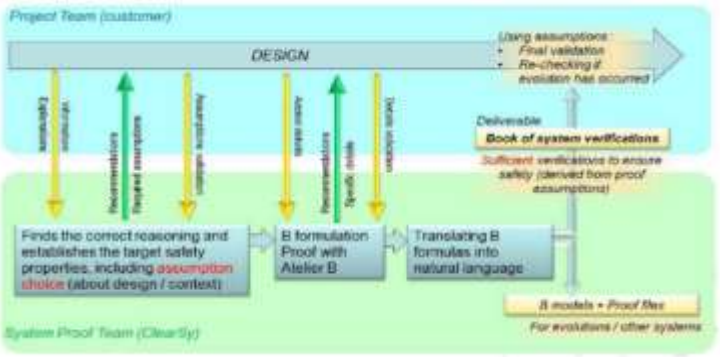


Property-based formal system verification

Safety verification of the CBTC of NYCT

NYCT entrusted us to demonstrate system properties are compliant with specifications and which assumptions need to be verified to ensure safety of daily operation

- **Save time**
  - Address every design detail in the early phase
- **Enhance Safety**
  - Define sufficient tests which need to be passed before daily operation
  - Define tests for acceptance of subcomponents
- **Less dependent**
  - Ease subcomponents integration thanks to a model of the system.
  - Less dependent to one supplier



This organisation was used for the NYCT project

System : Method for **verifying the CBTC of the line 7 in New York**, for **CBTCs for Paris metro (RATP),** for **ERTMS** for **SNCF (Marseille Vintimille ETCS HL3**
Software : ALSTOM, RATP

Formal data validation

Ensure safety critical data/system parameters are correct

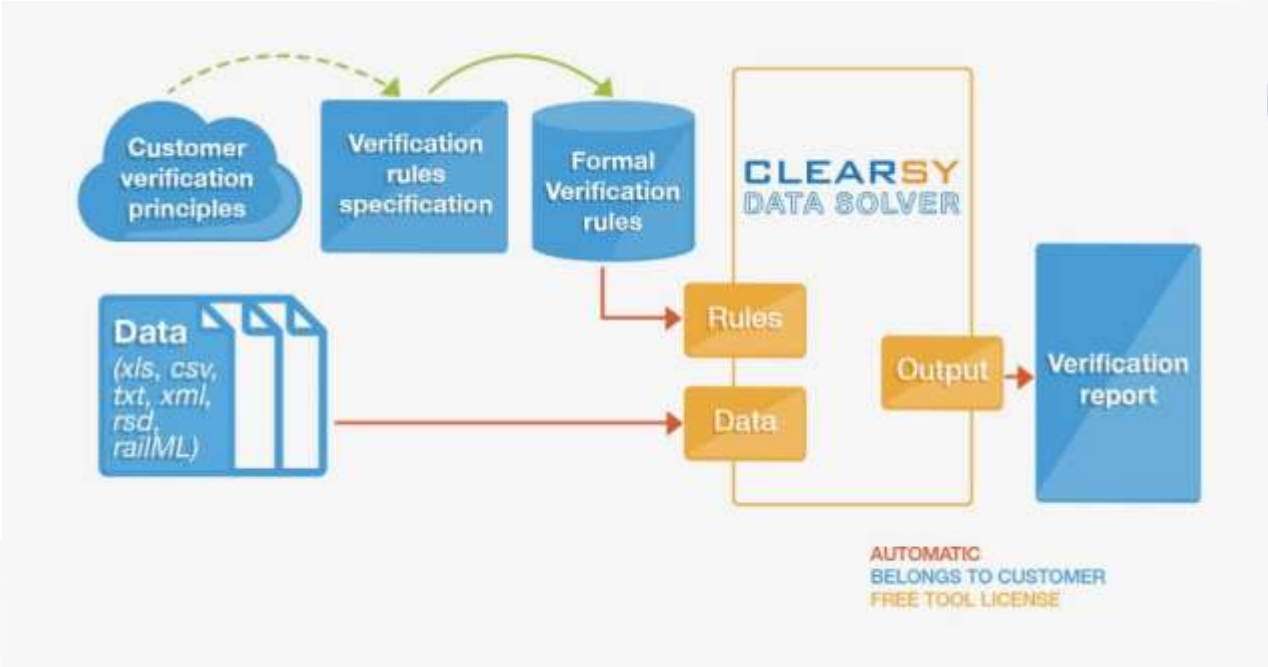
Safety critical software applications are developed and validated independently and each part must be safe at the same level: SIL4

CLEARSY proposes a **data validation tool** and its associated services.

Advantages:

- It is **fast**: a couple of hours is enough for validating a complete railway project. This speed can never be matched by human verification.
- It is **automatic**, **exhaustive**, push-button and **repeatable at will** (it avoids fastidious non-regression phase, easy iteration phases).
- It removes human errors, as it makes use of **certified formal techniques**.
- It allows a **strong reuse** from one project to another (capitalization of the knowledge and the generic rules database).
- It is **T2 certified** (including ProB engine) for SIL4 project regarding Cenelec EN 50128.
- Targets = CBTC, Mainline, Interlocking, …

Formal data validation principles
T2 for SIL4 tool

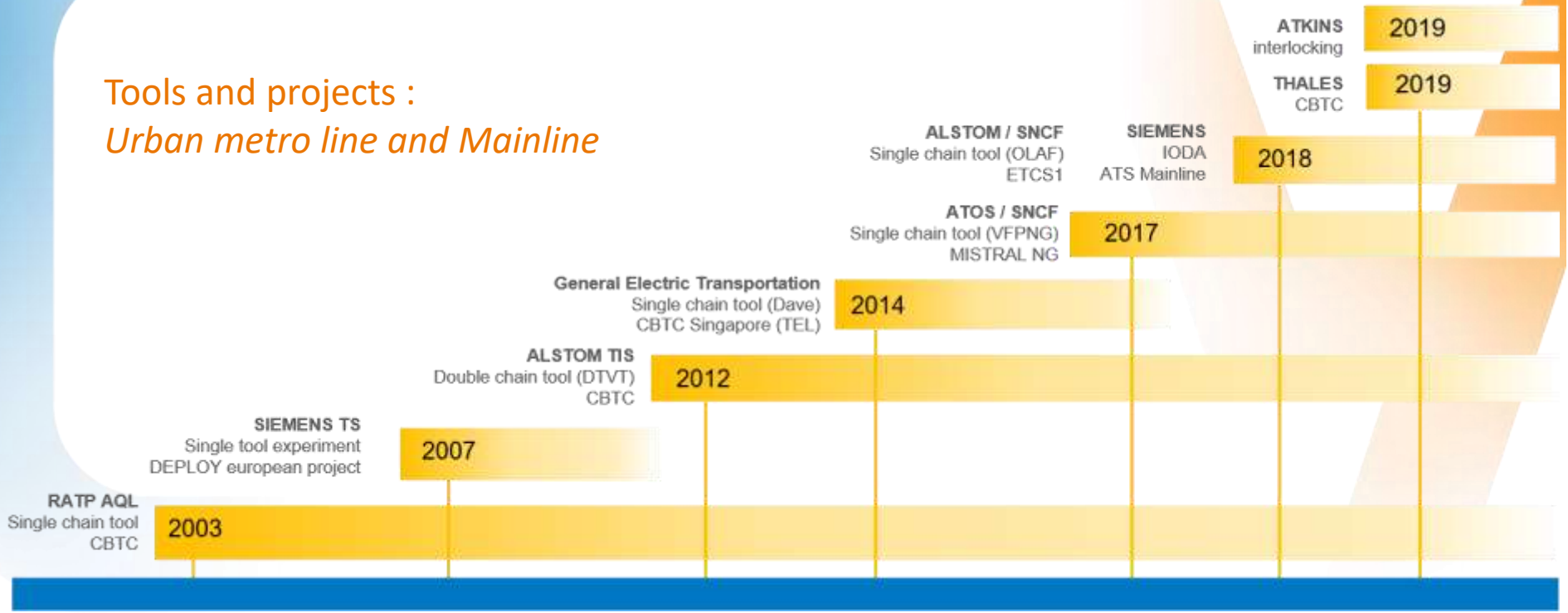


T2 certified by CERTIFER EN50128:2011

References : almost 20 years of formal data validation

Tools and projects :

Urban metro line and Mainline



CLEARSY has deployed its systems worlwide

Automatic train stop

Deployed in Valenciennes, Nice, Lyon (France) and Baku in Azerbaijan

Overspeed control system

Deployed in Paris (France)

Axle counter

Deployed in Bordeaux, Marseille (France), Luxembourg, Macao (China), …

PSD Control systems

Deployed in Paris (France), Stockholm (Sweden), Sao Paulo (Brazil), Caracas (Venezuela), Kuala Lumpur (Malaysia)

Track intrusion detection system

Deployed in New York (USA)

Safety remote I/O network (SIL0, SIL2 and SIL4)

In deployment in North America

RS4 safety critical relays (SIL4)

Deployed in France, Luxembourg, Singapore, Greece, Turkey, Egypt, in USA …

Autonomous Platform Screen Door opening and closing systems

- Independent from any train control systems (ATC or only ATP) and signaling
- Can be installed on existing and new line, existing and new trains with existing or new train control system
- Connected to PSD controller

COPPILOT & DOF Systems

SOLUTIONS FOR

Metro authorities

- ▷ Driverless turnback project
- ▷ PSD tests
- ▷ PSD operation before commissioning of a new ATC*
- ▷ Mixed operation during ATC deployment (new and old train mixed)
- ▷ Backup system to control PSD

PSD supplier

- ▷ Turnkey PSD project:
  - ➔ Including safety critical control system on existing and new line
  - ➔ Compatible with any types of PSD and interfaces (half, semi-full, full height)

ATC supplier

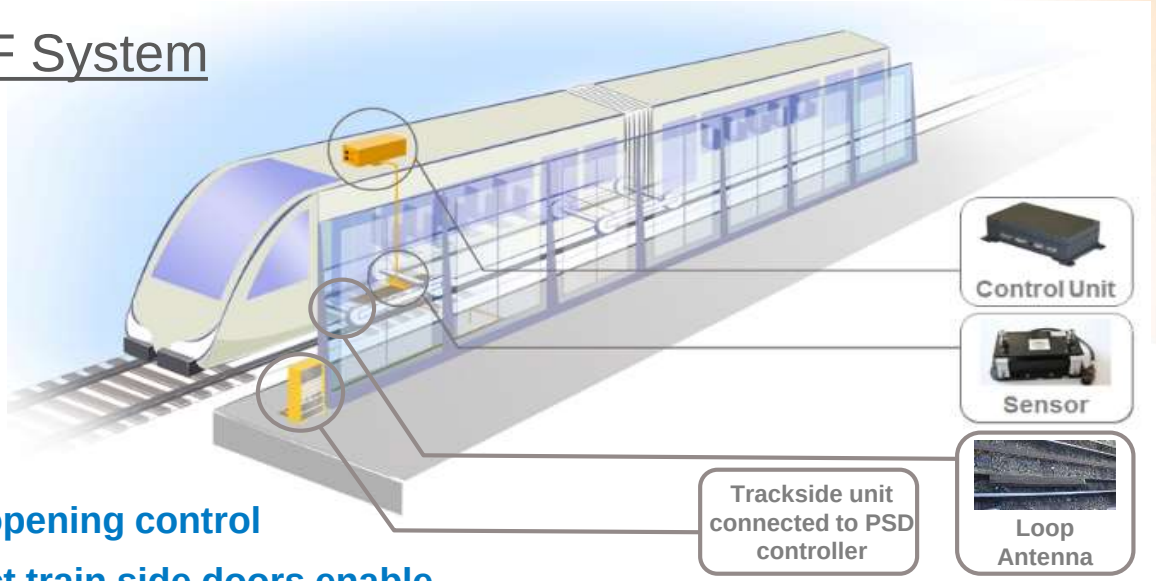
- ▷ PSD control managed independently of the ATC

*ATC: Automatic Train Control like CBTC, ETCS,…

SIL3 platform screen doors control system
with onboard equipment

PSD opening authorization when the train stops in the tolerance zone, and train doors are opening

DOF System



SIL3: Door opening control

SIL4: Correct train side doors enable

Proven product already in use

- Paris Metro Line 1 (four years of operation), in operation on lines 13 and 4
  - DOF CLEARSY's product is independent from the CBTC system
  - CBTC doesn't manage the PSD

DOF System

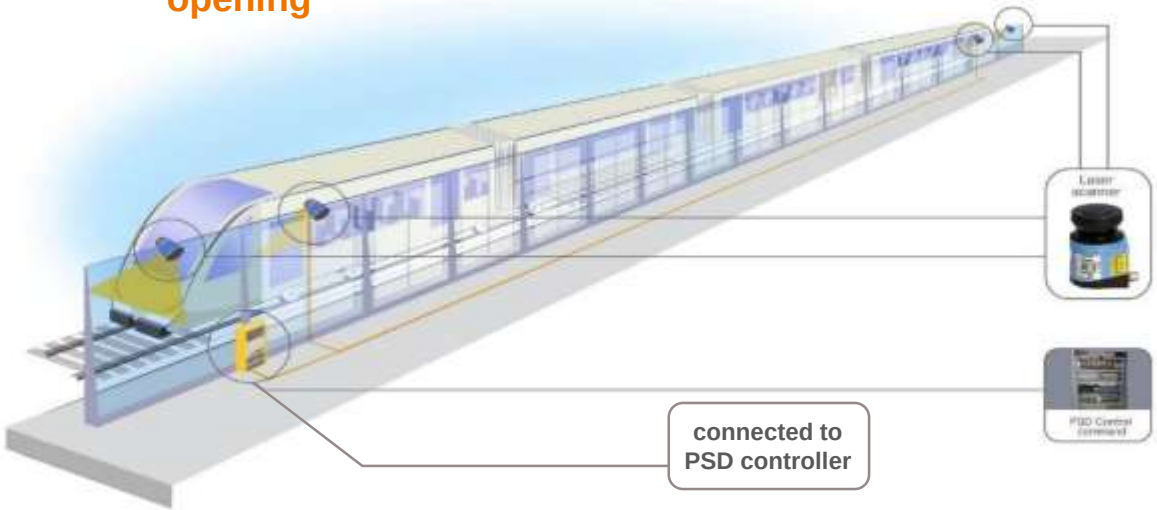
BOMBARDIER TRANSPORT

- Upgraded version of DOF
  - SIL4
  - Doors selectivity: each opposite PSD and train doors are synchronized
  - Opening adapted to different train lengths
  - If obstructed, automatic re-opening of only concerned train doors and their related PSD
  - LAN connectivity or relays interface: interfaced with PSD controller and train network

SIL3 PSD control system
with only wayside equipment

PSD opening authorization as: the train stops in the tolerance zone and the train doors are opening

COPPILOT System



- **No equipment on-board**
  only on the wayside
- 2 doors lasers detect: opening and closing of train doors managed by train operator
- Head and tail lasers ensure correct positioning of the train and the train is stopped
- **SIL3 or SIL4 door opening control**

Easy-to-install on new and existing stations

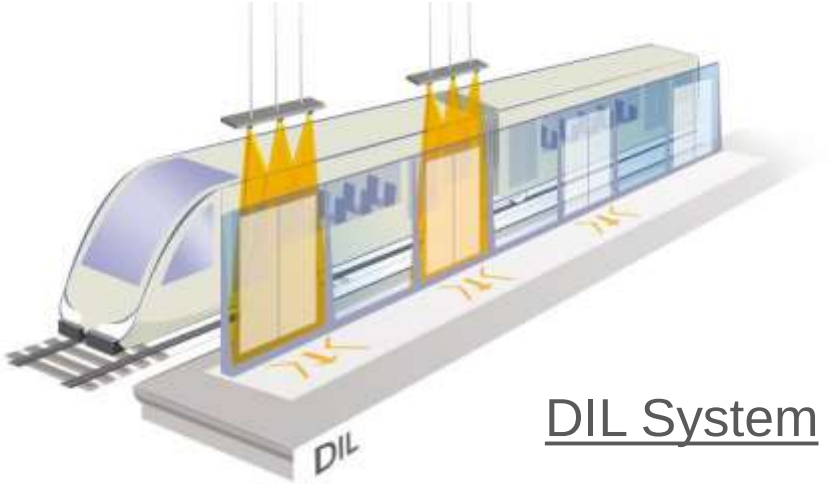
COPPILOT System

- In service for 9 months in **Paris** during the **PSD test period**
  - COPPILOT was chosen to manage 3 PSD from 3 different manufacturers of mechanical PSD on 3 platforms. RATP didn't want any installation on the 65 trains during the test.
- In service in Sao Paulo Metro : **Tamanduatei, Vila Matilde, Sacoma, Vila prudente** (1st project in South America), deployment on line 1, 2, 3
  - 143 trains shared on 3 lines, 7 train types : impossible to install equipment on-board
  - Metro wanted an **auxiliary SIL3 system** to control PSD. COPPILOT was selected and became the main system to compensate late CBTC delivery..
  - 2018: 5 more platforms to be equipped, **driverless turnback project**
- A monorail version in test for **Sao Paulo Monorail** line 15. It was upgraded for monorail application (SIL4 certification). 13 stations will be equipped
- In service in **Stockholm**: 6 platforms in operation (2 stations)
  - Additional functions: PSD individual opening, 2 trains lengths, platform berthing guidance, two way trains, and can handle 2 berthing positions
- Current project in **Los Teques Line** (Caracas)
  - Additional functions: 2 trains lengths and 2 train types, 2 berthing positions …

SIL3 platform gap safety monitoring system

GAP SAFETY MONITORING

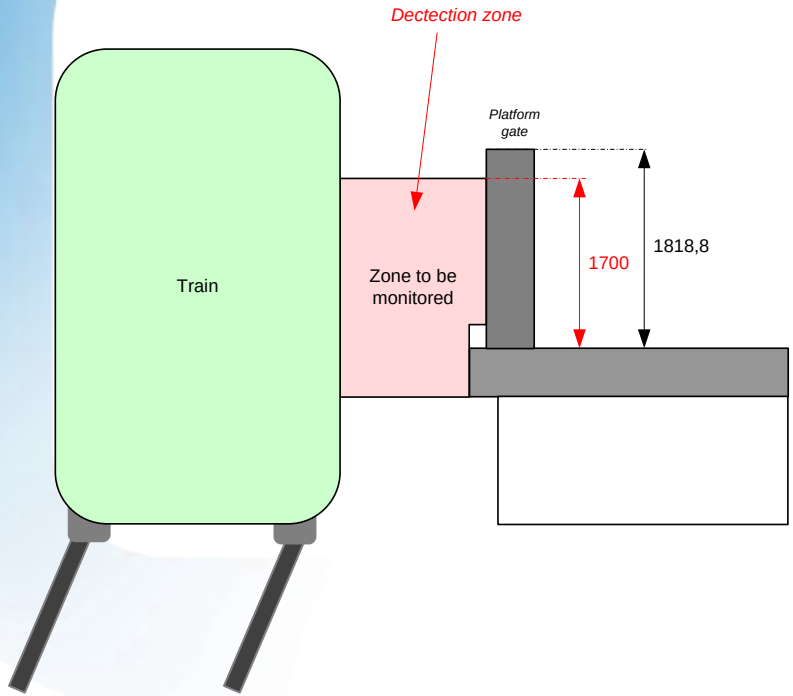
- In operation in PARIS line 1, deployment in PARIS on Line 4, safety critical system
- System to detect a person in the gap zone between platform door and train door

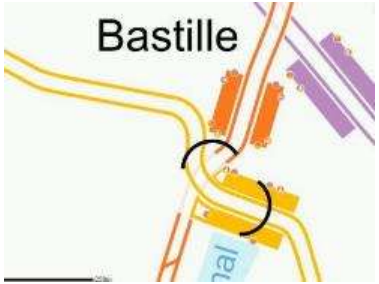


DIL System

Laser sensors monitoring gaps

Monitoring these spaces
(DIL system)





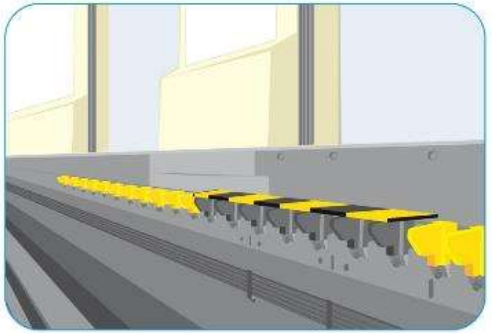
Bastille station in Paris

- Lasers are also used to detect people who try to escape into the tunnel
- System is in revenue service in 3 stations in Parisian network: Charles de Gaulle Etoile, Nation and Bastille
- In deployment on Paris line 4

Flexible gap filler

between platform and door edge on Paris metro line 1 and Lyon

- Gap filler prevents accidental fall if a person steps between platform and train
  - Fixed on the platform
  - Rubber material - Flexible



Already in Service

- Paris metro lines 1&4
- Lyon lines A&B

Track intrusion detection system,

Tested in New York City (MTA)

Detects falling passenger onto the tracks

- **Laser**

Pictures are analysed to discern an object as a rodent or a human

Accuracy is crucial:
To avoid false positive alarms

- **Alarm and Stroboscope**

They are activated to warn the train officer in the case of a person falling onto the tracks

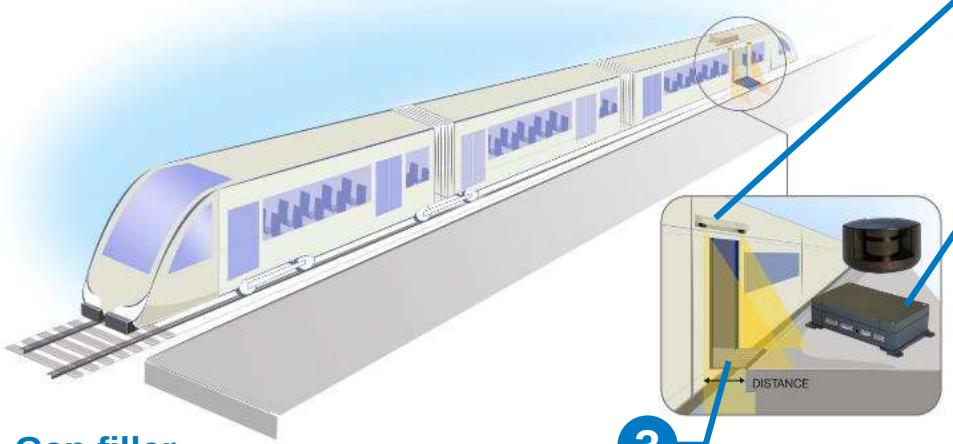
Similar systems already in service in:

- **Lyon**: based on Infrared
- **Nuremberg**: based on radar
- **Budapest**: based on radar

To detect platform and measure gap between train and platform (SIL2)

All system components are mounted on board

ALSTOM



1 **Laser scanners**
Measure gap between train and platform

2 **Controller**
Will authorise the car doors to open or/and the gap filler to move if platform is present in front of doors

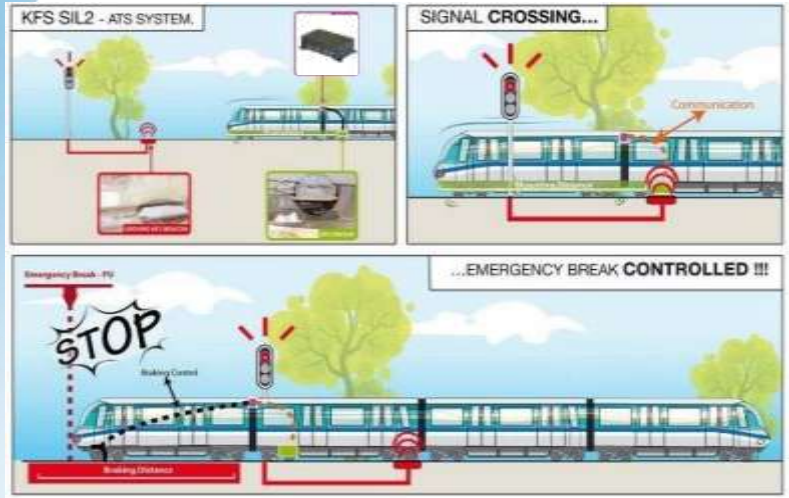
3 **Gap filler**
Is deployed to just fill the gap which is measured by the laser scanners

SSIL2 certified by CERTIFER EN50128:2001

SIL2 certified by CERTIFER EN50129:2001

operating on ALSTOM Train STI PMR

Automatic Train Stop (ATS) – *SIL2*



RATP

KFS & KPVA System

1. Train operator is in charge of stopping the train when there is a restrictive signal and is responsible of the speed of the train.

2. Emergency brake is applied if train overruns a restrictive signal

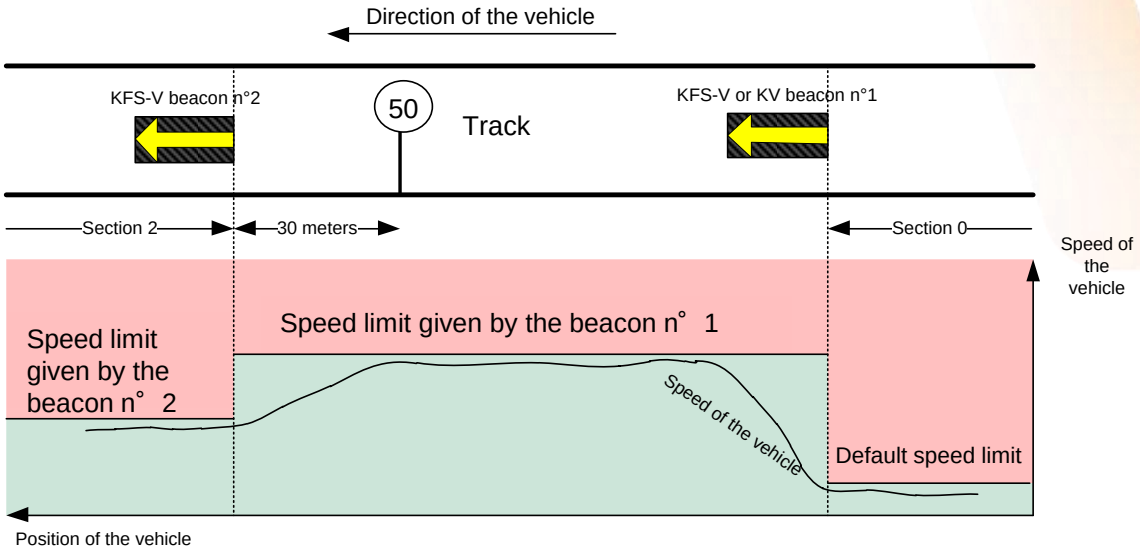
KFS musts be **HIGHLY AVAILABLE** and that's why SIL2 is enough.

Ex: ATS system of Paris commuter trains is SIL0

KPVA measures **instantaneous speed of trains** at defined point of the line and apply **emergency break in case of overspeed**.

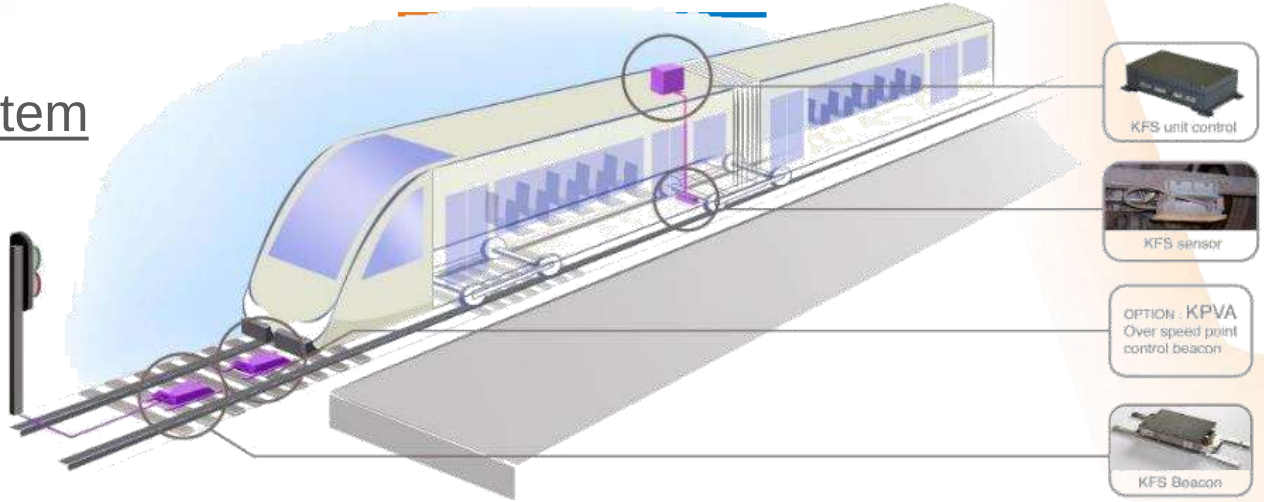
Speed control by section
KFSV

- Beacons installed on the track communicate the speed limits to the controller on board.
- Controller compares the speed limit to the train speed. In case of overspeed: **it applies emergency brake**



Automatic Train Stop (ATS) – *SIL2*

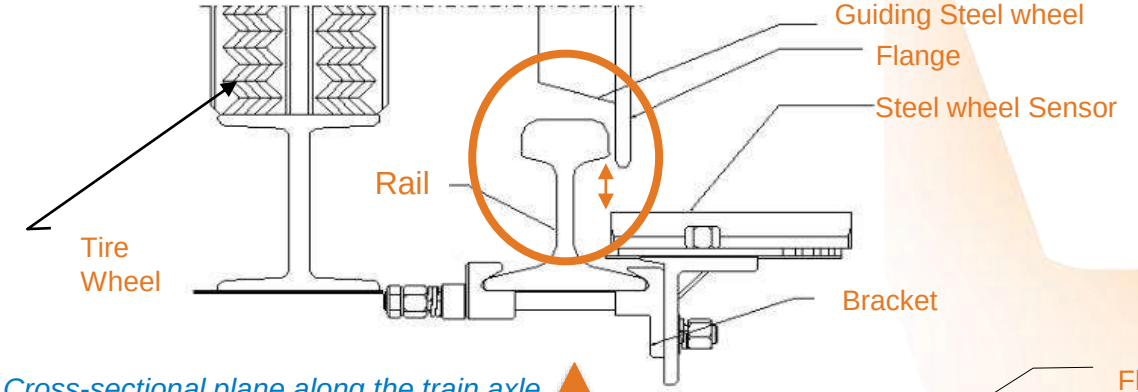
KFS System



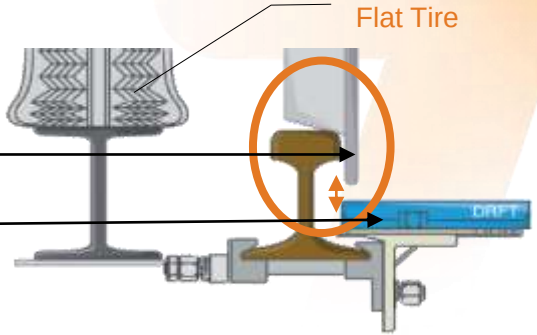
KFS installed for:
Valenciennes, Nice, Lyon Tramway – France – and Baku Metro – Azerbaijan

KPVA is installed on all Paris metro lines (Parisian metro authority RATP patent)

Flat tire and steel wheel detection
for rubber-tired metro with steel guide wheel



Cross-sectional plane along the train axle
Normal operation



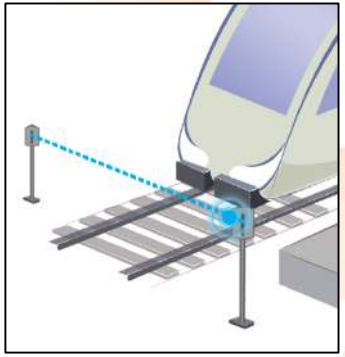
Cross-sectional plane along the train axle
Flat Tire

Track vacancy detection - hyper frequency barrier

In Research & Development

Alternative to steel wheel sensor: when a train crosses the barrier, it is detected.

- SIL4 system
- Hyper frequency technology
- Less maintenance than infrared sensor:
  better availability
- Fit for outdoor and indoor applications
- Plug and play system: system is very compact



tested in Lyon

SIL4 certified vital relays
RS4

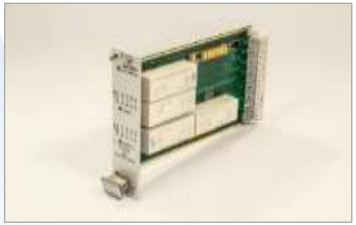
RS4 vital relay features:

- Normally Open contacts guaranteed to open with a **Safety Integrity Level 4***
- **Weld no transfer contacts**
- Fit **onboard and trackside application** (vibration, shock, environment,…)
- Sealed contacts to assure **making contact at low current** (4mA at 1 VAC and 1VDC)
- **DIN mounted or 3U**
- **Small size** and **light weight**

REFERENCES	SIL4 NO CONTACTS	NC CONTACTS
RS4.DIN.202.24V	2	2
RS4.3U.202.24V	2*2 (2 relays 202)	2*2
RS4.DIN.304.24V	3	4
RS4.DIN.402.24V	4	2
RS4.DIN.406.24V	4	6
RS4.DIN.202.110V	2	2
RS4.B.24.0.24	24 contacts right and left	

DIN packaging, Relays

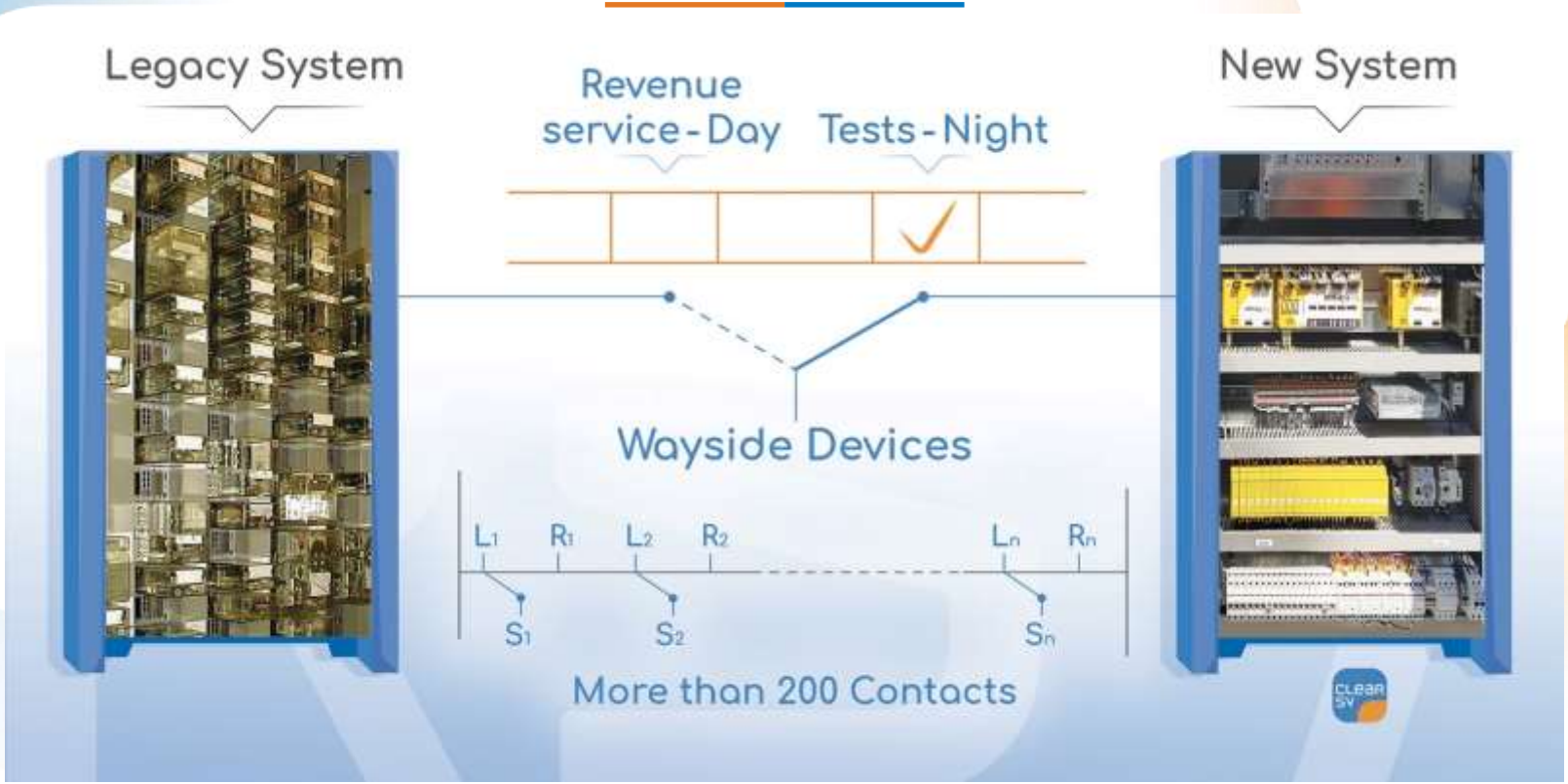
Latching interface system
24 NC and 24 NO contacts
6U card packaging



Relay 3U card packaging

*SIL4: Probability of the NO contacts not opening is of 10-8 per hour

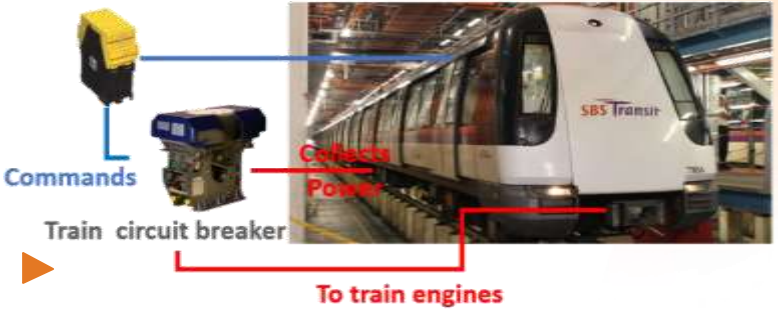
Vital Latching Interface System



RS4 vital relay applications

- Safety interface relay for SIL4 PLC
  - Inputs and outputs
  - Galvanic isolation of 2kV (AC)
- Closed and locked signal contacts commanded by door control unit of platform screen doors
- Safety relay for onboard applications
  - Control train traction circuit breaker

LUXTRAM - Luxembourg tramway



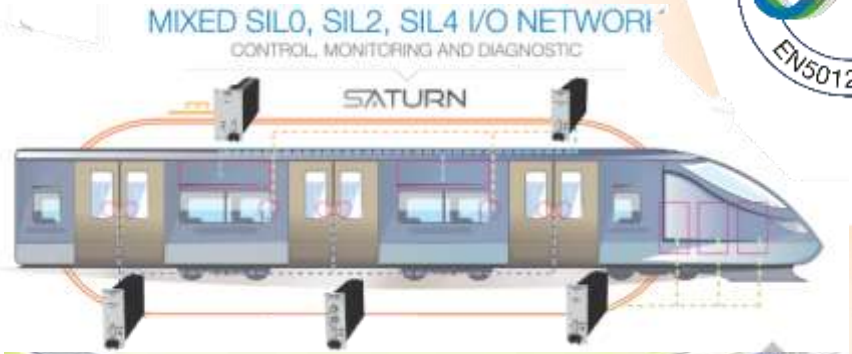
RS4 controls circuit breakers

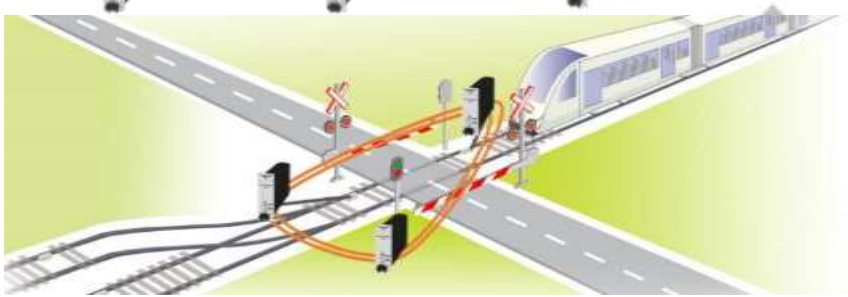
Safety remote I/O network (SIL0, SIL2, SIL4)
SATURN

Reducing wiring for onboard or trackside application

- Replace wiring by a safety network
- Non standard open source communication protocol

  Protocole compatible EN50159
- Different safety level modules on the same network
- Industrial network response time: 10 to 15 ms
- Data rates: 12 Mbits/s over 100 m
- 3U packaging
- Up to 512 Inputs/Outputs
- Partnership with: Leroy Automation





CLEARSY Safety Platform

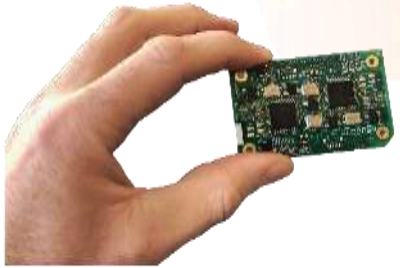
Low-Cost safety execution platform for SIL4 application

CLEARSY Safety platform combines:

- A **complete software development environment** based on **formal language** (B mathematical language) and using a double compilation chain (certified T3)
- A **computing platform** that **natively integrates safety principles** (5cm x 8cm)

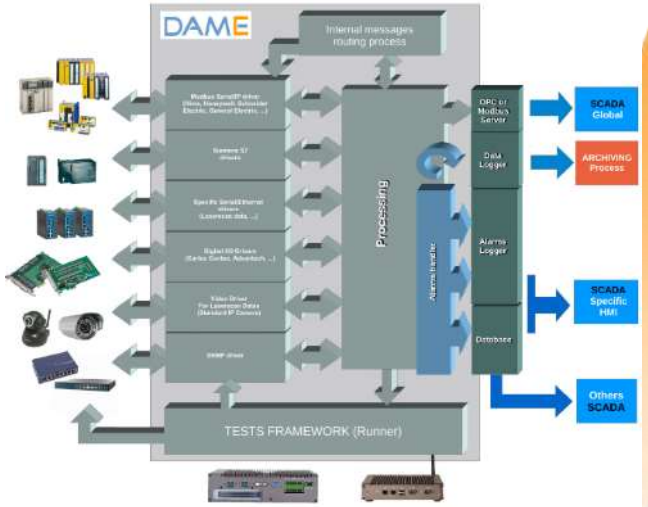
Purposes of the platform are:

- **Ease development of SIL4 certified systems and software**
- **Drastically reduce the time and effort to certify (80%),** SIL4 generic certificate supplied
- **Drastically reduce costs** associated with their development



DAME
Railway custom SCADA

- **Custom SCADA for small and large applications or systems: flexible architecture**
- **Extend on demand the range of supported devices and protocols**
- **Interface with SCADA available on the market:** *data preparation, component status*
- **Real-time supervision of large complex systems (PLC, digital I/O devices, …)**
- Real-time calculation and alarms triggering
- Collecting and archiving of input data
- Archiving of **alarms**
- Provides data and alarms in HMI, Modbus, OPC



RATP line 1 on 3 stations (DIL): PLC and laserscan data
Sao Paulo Monorail line 15 (COPPILOT): Modbus IP, Laser sensors data, video (13 stations)
Caracas Los Teques line (6 stations) (COPPILOT): PLC, Modbus IP server (export to SCADA)
Honolulu Line (21 stations): I/O board, RS485 (ATC), Modbus RTU (Doors Control Unit)

SIL2 centralized supervision system of fire safety systems

- Forwards fire safety data (alarms and equipment statuses) **from stations to the command centre**
- Examines fire safety equipment and its own system status
- Informs officers in charge of fire safety, on a real-time basis about any events occurring on the supervised network.
- Supplies the operating system with all the **data necessary for the first inspection prior emergency procedure**
- **Remotely controls in SIL2 (IEC 61508 (edition 2) – Parts 1 to 4), the safety devices on site**
- Continuously controls data validity (alarms, command execution)

Supervision system certified, approved and interoperable

- Suitable to supervise fire systems of **public-access buildings**
- Approved by **the CNPP**, the French association for risk prevention and control (article GA44.2) and Certified **SIL2**
- **Interoperable:** work on hardware from any manufacturer
- **Flexible:** can be interfaced with many different fire safety systems
- In deployment in: **Paris Metro (RATP):** it centralizes supervision of all fire safety systems of the Paris metro network, and **in "Grand Paris",** the extended commuter and metro network of Paris area

Complete SIL2 DMI and SIL2 associated generic platform

- ETCS baseline 3 DMI Based on a **generic SIL2 platform**
- The specific customer HMI application can be added and doesn't change the certificate
- DMI manages safety features according CENELEC SIL2
- EN 50126 (RAMS), EN 50128 (Software), EN 50129 (Hardware)
- SUBSET 026 v 3.6.0 chapter 4.7 / ERA specification v 3.6.0 / SUBSET 091 v 3.6.0

Certification

SIL2 certified by CERTIFER EN50126:2000

SIL2 certified by CERT FER EN50129:2003

SIL2 certified by CERT FER EN50126:2011

Software developed by CLEARSY

CENTRALP

Hardware developed by CENTRALP

ETCS operational and traffic simulator

Operational simulator

Build a real-time visualization of a train running under ERTMS supervision

- Predefined track side messages
- Simulated RBC messages
- Standalone
- Baseline 2 or Baseline 3
- First version in 2005
- Running on Linux

Traffic simulator

Build a detailed engineering model of a complete railway running under ERTMS

- First version released in 2002
- Simulators for all parts of ERTMS:
  - IXL
  - RBC
  - Automatic route setting
  - Trains
- Can include multiple OPSIMUs w/o 3D

Traffic Simulator

ETCS On-board unit test bench

- First version in 2001 (EMSET EU project)
- Testing of industrial on-board units
- Interfacing via SUBSET-094

ETCS RBC* test bench

- First version in 2009
- Based on Traffic Simulator
- Trackside simulators replaced by industrial equipment
- Simulated trains
- Enables connection with OBU Test Bench
- Enables integration of SUBSET-111-2 to perform IOP tests (TVS)

RBC Test Bench hardware installed in a cabinet together with tested equipment

*RBC: Radio Block Centre

Contact

- www.clearsy.com
- contact@clearsy.com
- Parc de la Duranne
  320 Av. Archimède – Les Pléïades III
  13100 Aix-en-Provence
  FRANCE