IRSC 2019 – Frédéric Delorme (Chief Safety Officer SNCF)

SNCF Rail Safety and the Fourth Industrial Revolution

SUMMARY

The fourth industrial revolution is having an impact on three different areas: global mobility systems, long-term disruptive railway technologies and safety demonstration challenges, but also intermediate digital solutions for new safety loops in the short term. These new opportunities for our business are bringing new safety challenges with them, which will be presented in this paper.

INTRODUCTION

As a world leader in logistics and the mobility of people and goods, SNCF operates 15,000 trains every day. Its **main research priorities for the future of rail** are as follows:

- **New technologies** with a major potential impact on its business: artificial intelligence, energy storage, robotics, automation, materials, electronics, geolocation, etc.
- **Mass transit systems** to improve passenger mobility in high-density areas
- **Digital transformation** to facilitate the transformation of our industrial and business activities
- **Improvements to the safety of rail systems**, taking into account new challenges with regard to new IT and digital technologies.

SNCF's innovation clusters are implementing 300 innovative projects in these areas, with 1,000 experts involved in such projects. One of the clusters is specifically dedicated to system safety. The innovative projects are being implemented within the context of new, disruptive transport solutions that have recently emerged, particularly in the road transport sector, which is both a competitor and partner to rail transport.

The innovation fields of the clusters are as follows: Maintenance, Optimisation of Resources and Operations, Services and Passenger Experience, Energy, Data and Mobility, Sustainable Development, and of course System Safety.

Our priorities for new technologies are accordingly: Artificial Intelligence, Energy Storage, 3D Printing, Robotics, Automation, Materials, Electronics, Geolocation.

At the same time, new disruptive transport solutions are appearing on roads, such as autonomous cars of course, but also in relation to freight transport: Sweden builds its first electrified road for charging vehicles, Scania launches the first full-scale autonomous truck platooning operation and Uber's self-driving trucks make their first delivery (50,000 beers).

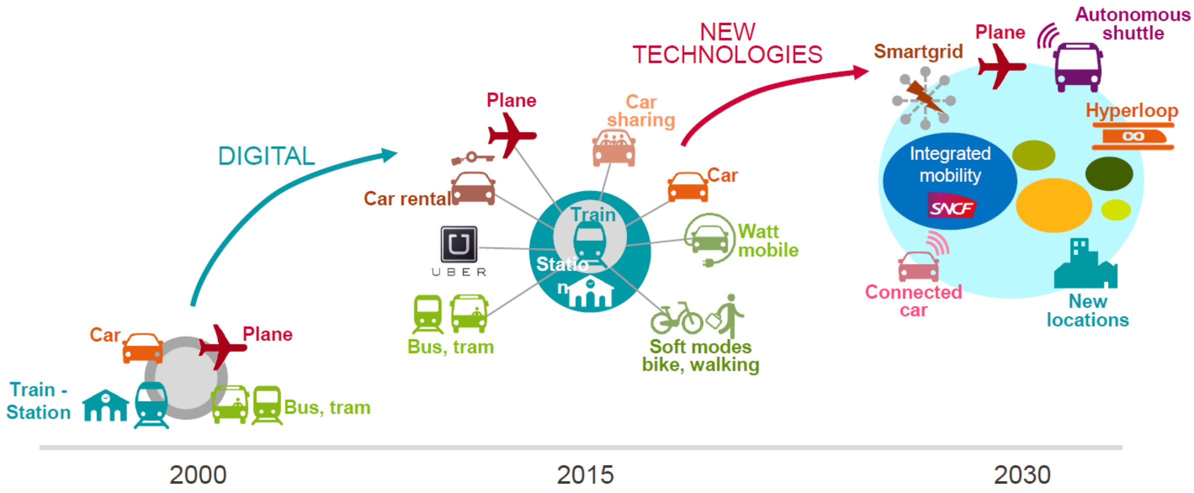
Global Mobility is a challenge, connecting different transport solutions and combining various disruptive transport solutions which are removing the limitations of individual and public transport modes. The technologies deployed to develop autonomous cars are serving as inspiration for railway engineers.

Digital innovative solutions will be disruptive for safety improvement in the future: in the long term with autonomous trains of course, but also for intermediate solutions which can improve safety in the short term. Some short-term solutions are driven by research on autonomous trains, such as lateral signal recognition. This is a new paradigm for railway engineers.

SNCF INNOVATION PROGRAMME: TECH4RAIL

Our TECH4RAIL programme focuses on disruptive mobility systems: our focus has evolved from rail transportation to digital mobility and, most recently, to integrated mobility.

From digitalized mobility to integrated mobility



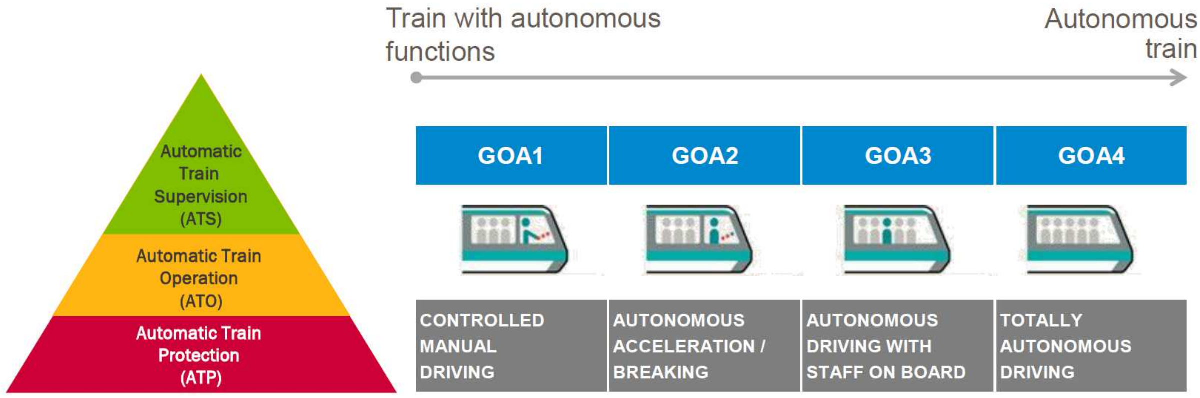
Automatic and autonomous trains are part of the TECH4RAIL programme.

AUTONOMOUS TRAINS AS A CHALLENGE FOR DISRUPTIVE RAILWAY TECHNOLOGIES

Automatic and autonomous trains are part of the TECH4RAIL programme, from grade of automation (GoA) 1 to GoA4 (autonomous functions), including automatic train protection (ATP), automatic train operation (ATO) and automatic train supervision (ATS). The first use cases at SNCF (from prototype to industrialisation to deployment) are as follows:

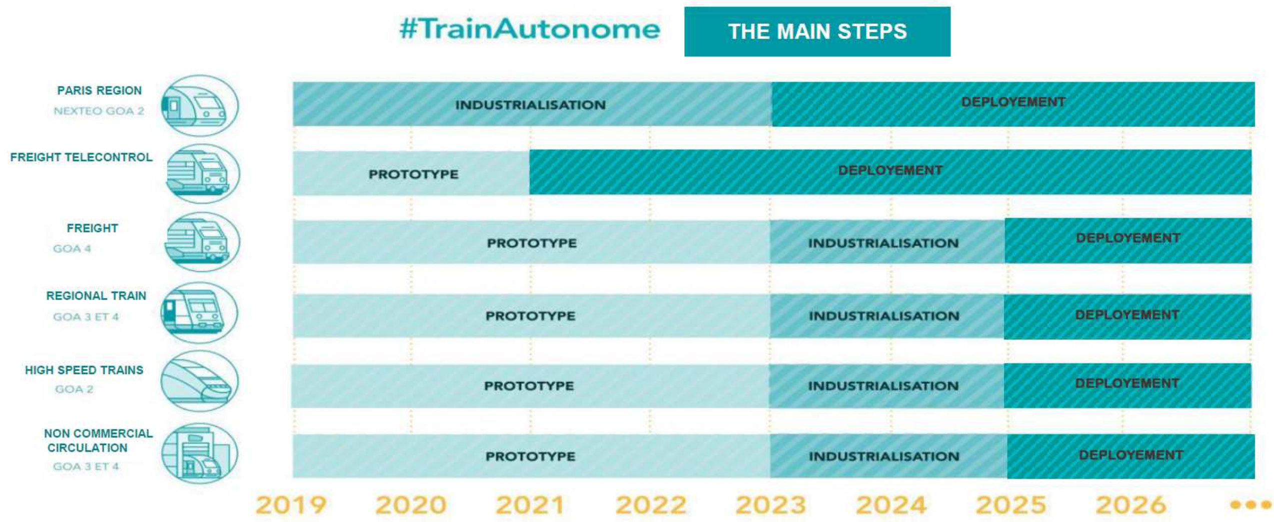
- Cargo (GoA2/4 for long-distance routes),
- TGV 2020 (high-speed trains) (GoA2 for commercial high-speed trains, GoA4 while running for maintenance),
- Regional trains (GoA3 on shuttles),
- Paris regional commuter trains (GoA4 – remote control on technical trains).

ATP + ATO + ATS = best way to create automatic and autonomous trains



ATO: A significant leap for our customers

SNCF vision of an autonomous train



The safety challenges of autonomous train are as follows:

1. Autonomous trains will increase the safety level of the railway system as a whole.

2. Nevertheless, automation could also bring some new risks, according to the grade of automation (GoA) and the automatic train protection (ATP).

3. These risks must be taken into account to define the process for gradually introducing automated driving.

4. Other challenges for safety could also be identified concerning social aspects, cyber security and the migration time between the current and future systems.

SAFETY DEMONSTRATION PROCESS FOR NEW SYSTEMS

The safety demonstration of the new systems impacted by the 4th industrial revolution is a challenge. It will be complex and innovative, especially for autonomous trains, for instance. The authorisation process for the future systems might be modified considerably as the regulation of the railway system will certainly change.

The new issues that have been identified relate particularly to the risk assessment and the definition of the safety requirements.

If, in the context of the risk assessment, it is decided to opt for the GAME measure for a particular feared negative event, it will be necessary to compare this with the safety level of the current system. Ideally, it will be appropriate to evaluate the number of cases of this particular feared negative event per hour of operations in the current system, which will make it possible to define a safety integrity level (SIL) for the system to be designed. However, such evaluation data about the current situation are often only partially available. It will therefore certainly be necessary to conduct various research studies, which aim to assign an SIL to various feared negative events by combining statistical components with other elements: the sensory and cognitive capacities of the driver, working conditions, etc.

The evaluation of the safety performance of the reference system therefore represents an initial problem that we shall have to confront.

If, on the other hand, it is decided to use a measure involving the estimation of the explicit risk for a particular feared negative event, it will be necessary to assign a level of severity and frequency to this event. It is customary to do so in a relatively imprecise manner by placing the event, according to expert opinion, in a matrix of acceptability of risks that occur rarely. However, it is probable that the frequency levels of certain serious events are not self-evident, so the choice that is made may lead to either an unacceptable risk or an exaggerated requirement that would be difficult to comply with.

There is also a significant challenge involved in finding the correct balance for the safety requirements between the minimum required and the ideal possible level, based on the ratio between cost and the safety benefit.

Once the requirements for the system have been formulated, our industrial partners will need to design and then implement the various integrated sub-systems while complying with the requirements.

Once the safety requirements have been defined and the design has been implemented, it will be advisable to demonstrate that the requirements have been observed effectively. Of course, our industrial partners will grant a number of guarantees (certificates, test results, formal demonstrations, etc.) to confirm the compliant functioning of the system within a defined scope. However, given that the future scope of use involves a range of unquantifiable different situations (different lines, operational situations, etc.), it is probable that these guarantees will be insufficient. The answer may be a combination of several elements of proof for the new systems:

- A formal demonstration of the software involved in the safety functions
- Tests on the operational network or in rail test centres
- Digital simulations in conjunction with physical tests to guarantee that the implemented tests are representative

The new, innovative systems, especially the ones using artificial intelligence or complex digital systems, will therefore increasingly need extremely intensive collaborations between the proposers of the new solutions and the supervisory authorities responsible for validating them.

OPPORTUNITIES: INTERMEDIATE DIGITAL SOLUTIONS FOR NEW SAFETY LOOPS

In the short term, SNCF is implementing elementary components of autonomous trains and IoT in conventional trains. These components include signal detection to reduce incidents of signals passed at danger (SPADs) and new digital solutions: digital systems for rear-end and single-track collisions, and for speed limit supervision.

Safety loops are frequently categorised as Safety Integrity Level (SIL) 0, but often reduce a risk by at least 100. They are very useful for safety purposes, but their safety cannot be demonstrated in the same way as for automation or signalling systems. The status of safety loops must be clearly defined, including on a legal basis.

First example: System for rear-end collision on single tracks (SRVU)

Functional requirements:

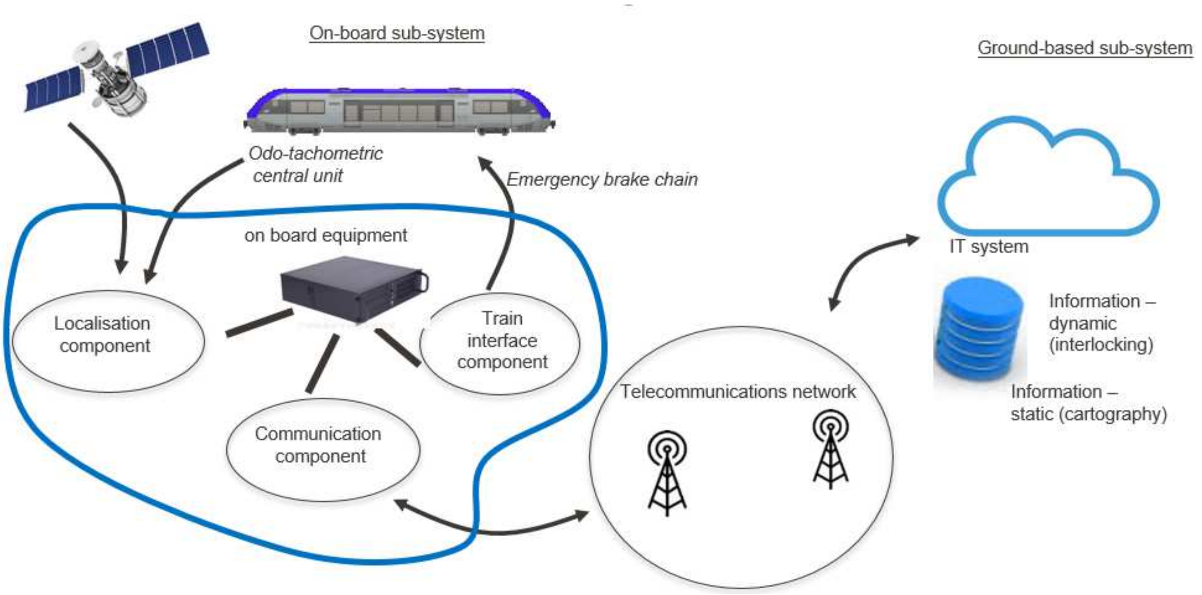
Requirement 1:

"...to implement a procedure or a tool, able to raise an alarm when detecting inconsistencies that could lead to a train collision on a single track"

Requirement 2:

"...to raise an alarm: as a first step, it is a question of having a "parachute" system on single tracks."

SRVU Needs analysis

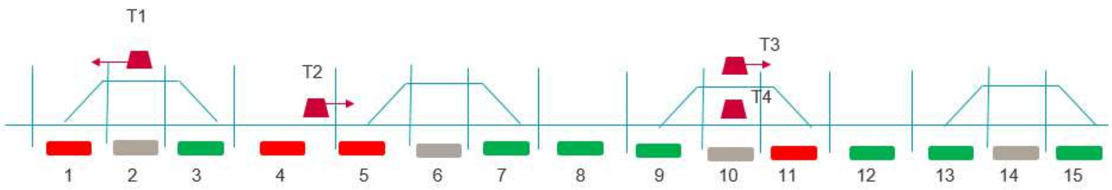


SRVU Advantages:

- Re-use of the already tested functions (localisation and speed supervision on train test runs over new infrastructures)
- Reduced development costs
- About 90% of the distance covered (open track outside stations)
- Low impact on actual operations on single tracks

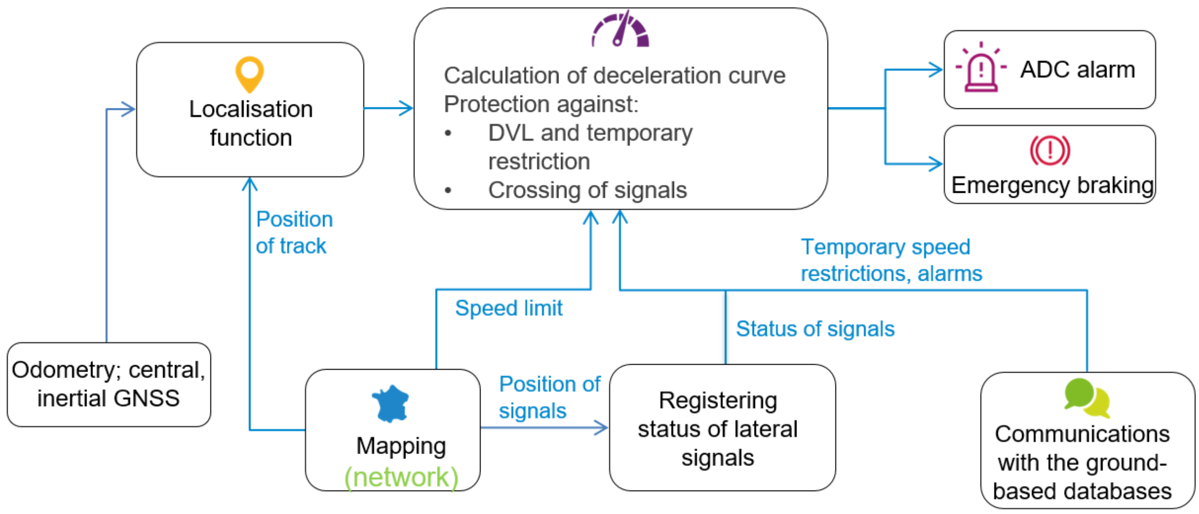
SRVU Functional principles

Central management of the occupation of the zones by the ground-based sub-system



Block	Occupied / Free	Block	Occupied / Free
1	Occupied T1	9	Free
2	Not covered	10	Not covered
3	Free	11	Occupied T3
4	Occupied T2	12	Free
5	Occupied T2	13	Free
6	Not covered	14	Not covered
7	Free	15	Free
8	Free		

Second example: Speed limit supervision (ESVE+)



The ESVE+ system, which is currently in the prototype phase, will make it possible to monitor the risks of trains exceeding the speed limit of the particular line (at a lower cost than ERTMS while waiting for its deployment), thanks particularly to the following functions:

– precise geolocalisation to identify the track and to determine the actual speed

– mapping of the tracks with their speed limits

– display of the speed on the driver's MMI (man-machine interface), with a signal/alarm issued to the driver if the authorised speed limit is exceeded

The risk of crossing lateral signals is also covered thanks to the following functions:

– reading of lateral signals (sub-system of the autonomous trains of the future)

– geolocalisation

– calculation of the speed curve

In this case, again, a warning is output to the driver.

SNCF has developed the ESVE sub-system which uses geolocalisation and mapping to calculate the expected braking curves, based on the speed limits of the line, the gradients and the braking capacities of the vehicle. The system also issues an alarm or triggers emergency braking if the speed of the vehicle exceeds the braking curve. At present, these applications still lack a localisation function that makes it possible to identify the track and also signalling information, but this will be viable by 2022.

We intend to test these developments in the short term in passive mode ("shadow mode", without any impact on the train or interaction with the driver) on a commercial service train. It is indispensable to characterise the performance of the localisation solutions and to acquire the necessary data for developing the recognition of lateral signalling.

It is important to note that the European directives prohibit the introduction of any new signalling systems in class B. The ESVE+ project is not a new system in class B. It is a driving aid that could help to significantly reduce risks pending the introduction of ERTMS, given that its deployment on low-density lines will take several years.

The planned due date for the deployment of SRVU and ESVE+ could be 2022.

Conclusion: For several years, we have been observing the emergence of disruptive technologies in other sectors (localisation, telecommunications, digitalisation, artificial intelligence) which aim to improve the safety of operations and make it possible to visualise alternative solutions that do not modify the infrastructure – a factor that makes them viable in terms of both cost and scheduling. Some of these solutions will use intermediate sub-systems that are indispensable for the development of the systems of the future, especially the autonomous train. As a result, they do not represent a "wrong move" with regard to the long-term developments of systems.