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Scientific & technological obstacles to achieve the autonomy

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What are we going to cover today ?

- What is the impact of new technologies and organizational innovation on Railways ?
- Walk through a real case : The SNCF Freight Autonomous Train Project
- How can the combination of innovation and cooperation enable us to overcome scientific & technological challenges ?

Innovation & Cooperation

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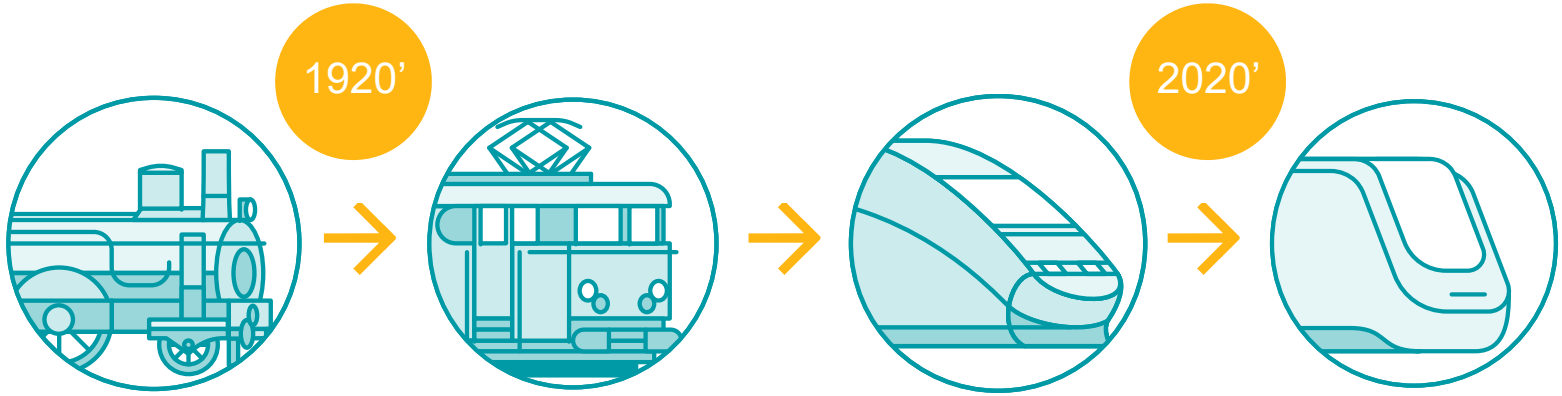
A breakthrough innovation disrupting the production model



Birth of the Steam engine — **Electrification** — **High Speed** — **Autonomy**

Short trains more frequently

Faster yard assignment operations

Immediate recovery on hazards

Trains without stopping from end to end

Flexibility of adaptation

More varied stations service

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The Grade of Automation = GOA

➔ **Autonomy = different levels of automation from GOA1 to GOA4**

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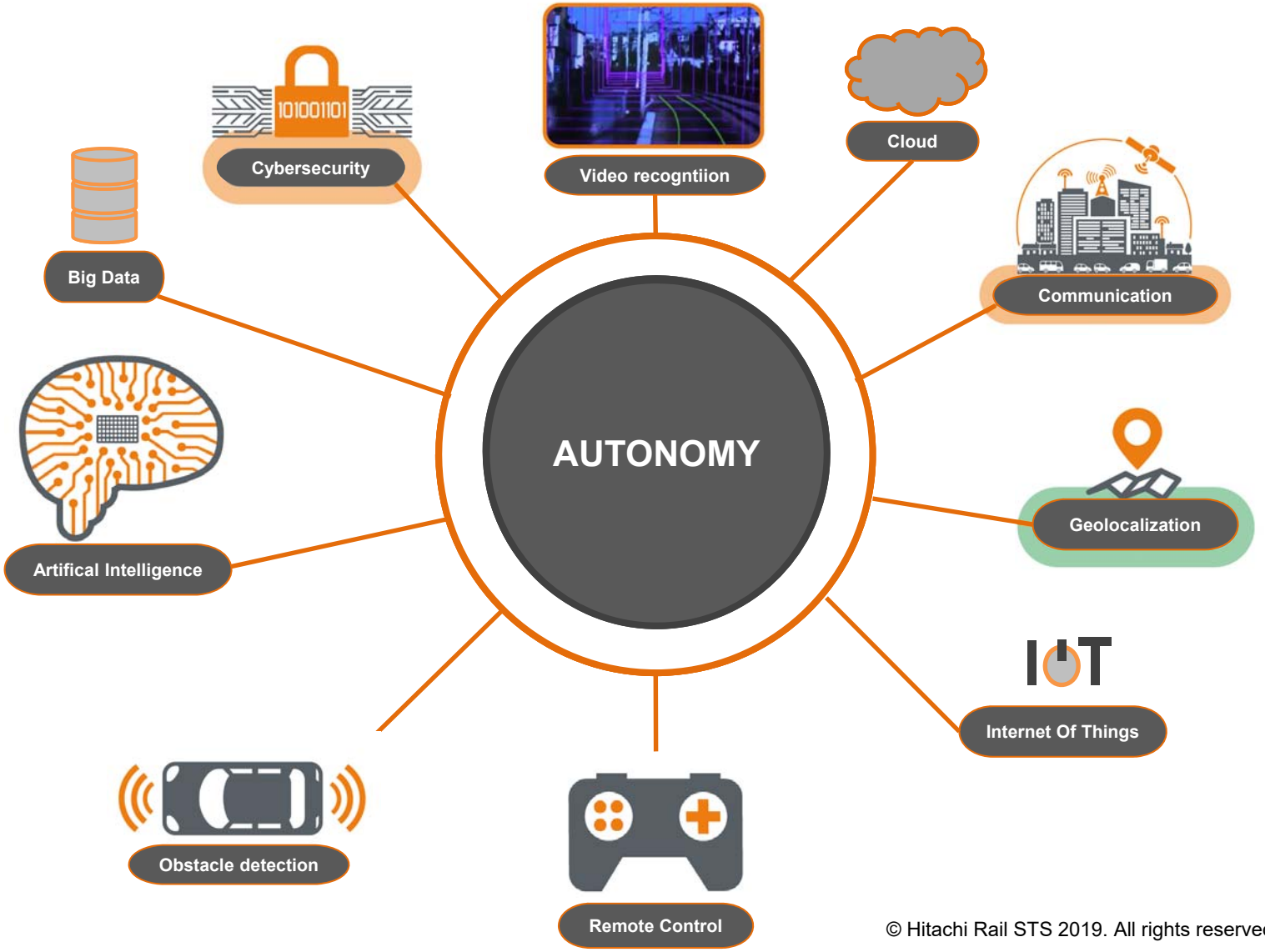
New technologies open up perspectives for Railways



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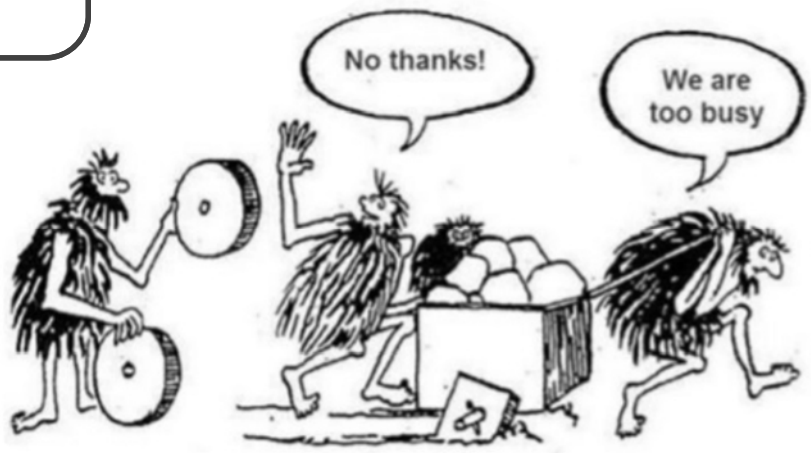
Cooperation is no longer an option for Innovation:

Breakthrough innovation often comes where it is not expected

There are important sources of knowledge and skills outside the firm's boundaries

No company has all the knowledge required to practice its profession



The company has to be able to take advantage of technologies at the right time

Unfortunately, the best resources do not always work for us.

External R&D represents a significant potential source of value

The company does not need to be at the origin of an innovation to benefit from it

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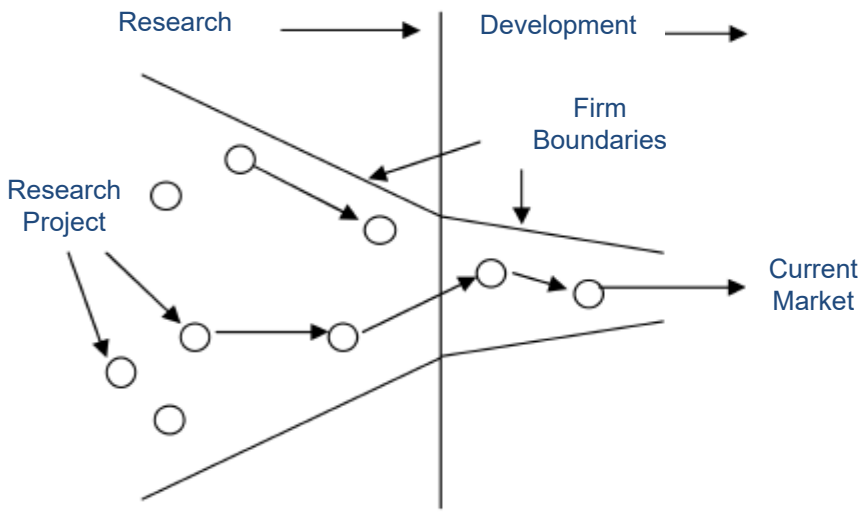
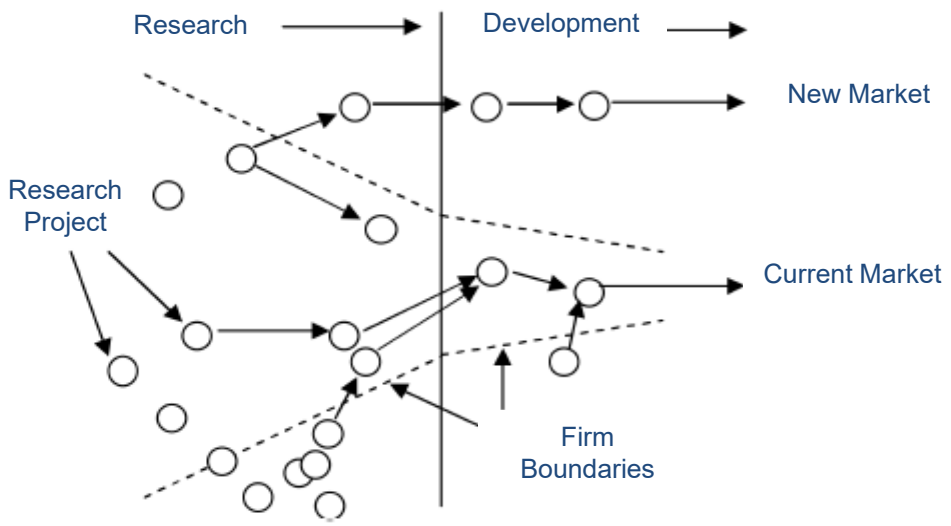
From Closed innovation to Open Innovation



Closed Innovation



Open Innovation

Source : Chesbrough (2003)

➔What is open innovation?

- Open innovation is the act of associating internal and external ideas and skills to a structure (company, organization...)

➔Why?

- By collaborating with other actors, an organization will multiply the sources of innovation to which it has access and broaden its scope of possibilities: new products, new markets, new working methods

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Why shall we Innovate & Cooperate for Autonomy ?

Capacity

- Improved coordination of train operations,
- Increased train rotation towards theoretical capacity,
- More intensive use of Infrastructure,

Quality of Service

- Driving algorithms optimize speed,
- Early conflict detection enhancing capacity,
- Trains orchestration according to the global situation (weight, weather conditions, …)

Cost Reduction

- Operational costs reduction (drivers)
- Reduction in consumption of wearable parts in maintenance
- Equipment acquisition costs reduction (Less trains required thanks to the capacity optimization),

Energy Savings

- Optimized driving algorithms adapt perfectly to line profiles reducing energy consumption,

➔ Reduce investment & operational costs, Increase infrastructure capacity, improve performances and reduce carbon emissions

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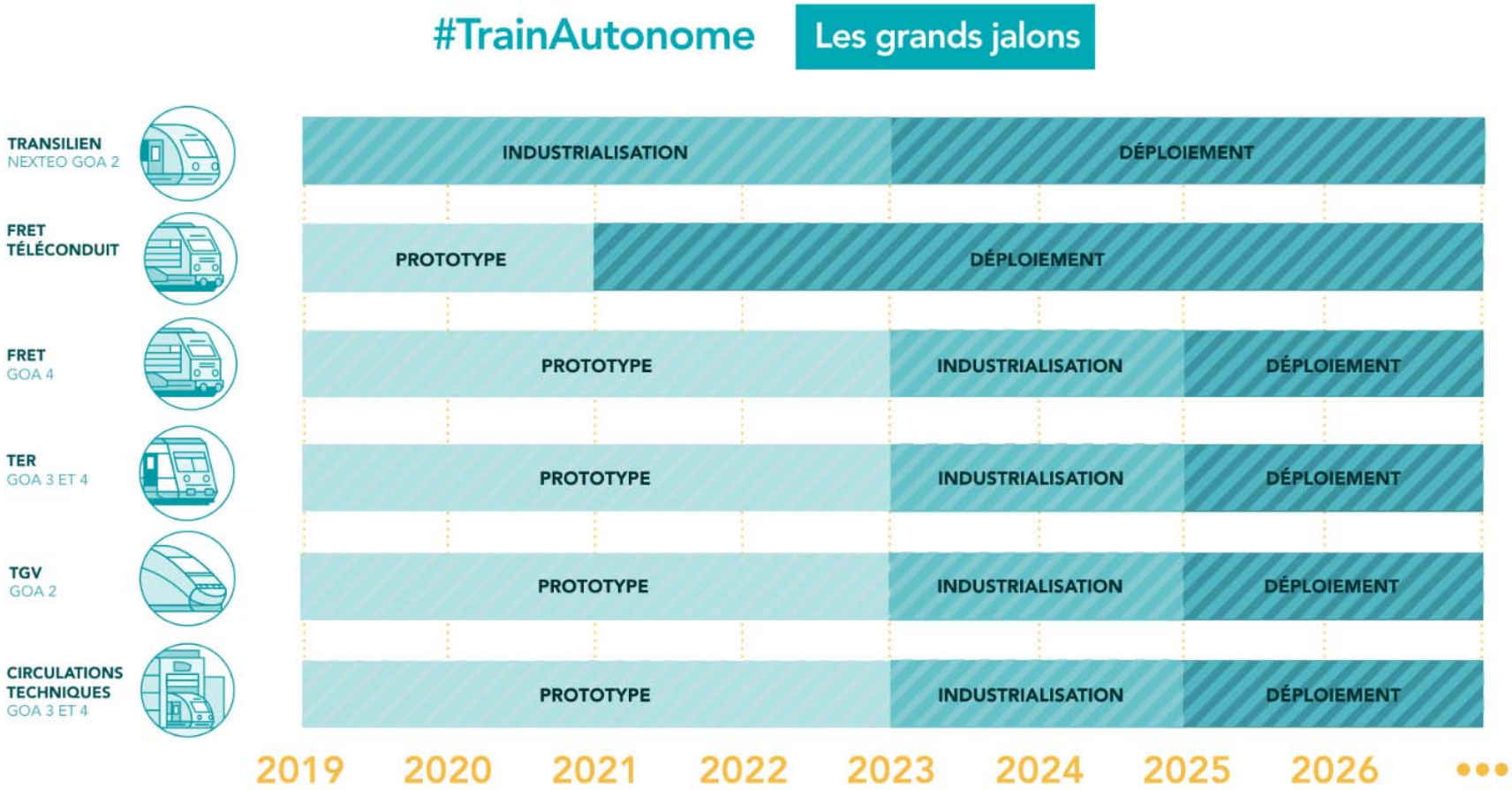
THE SNCF AUTONOMOUS TRAIN INITIATIVES

SNCF has launched several autonomous trains initiatives :



Autonomous Freight Train

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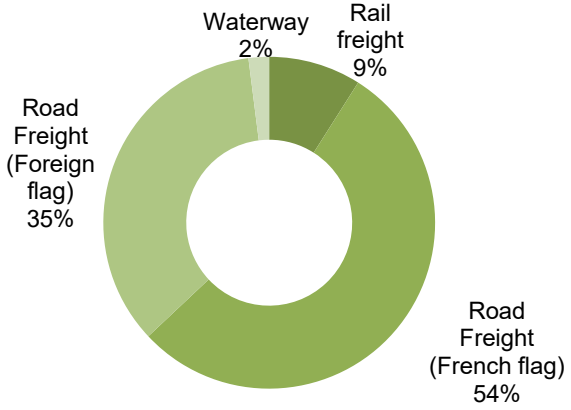
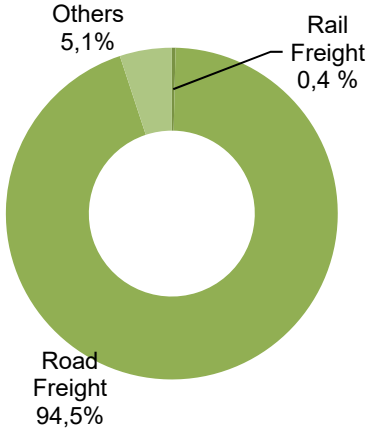
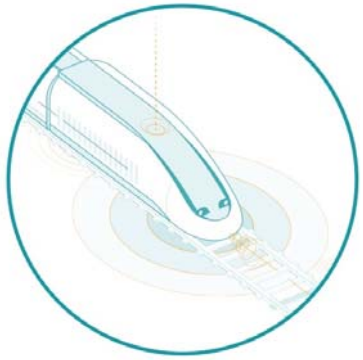
Autonomy: a vector for rail's competitiveness versus road transport



Modal share of land freight transport in T.km (transport accounts 2017)



GHG emission level in T CO2 eq (transport accounts 2017)



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The Autonomous Freight Train Project

Autonomy opens the 4th era of railways (after steam, electrification and high speed), improving thanks to new technologies, quality of service and competitiveness in relation to road freight transport.

The Autonomous Freight Train project will design what the autonomous freight train will be and demonstrate its feasibility on prototypes, without modifying the infrastructure.

This collaborative project of 27M€ over 5 years is a partnership led by the IRT Railenium, bringing together SNCF, major industrial and engineering companies, academic research centers and security authorities.

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➔ The SNCF objective is to run a prototype of autonomous driving system in GoA4 by 2023 without infrastructure adaptation

Autonomous Freight Train

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Aim of the Autonomous Freight Train initiative

Specifications

Specification of the target system after having demonstrated its feasibility from GOA1 to GOA4

Prototype

A BB27000 SNCF FRET locomotive equipped with innovative sensors, additional computers and a Bi-Standard “ERTMS Shadow”

Autonomous Freight Train

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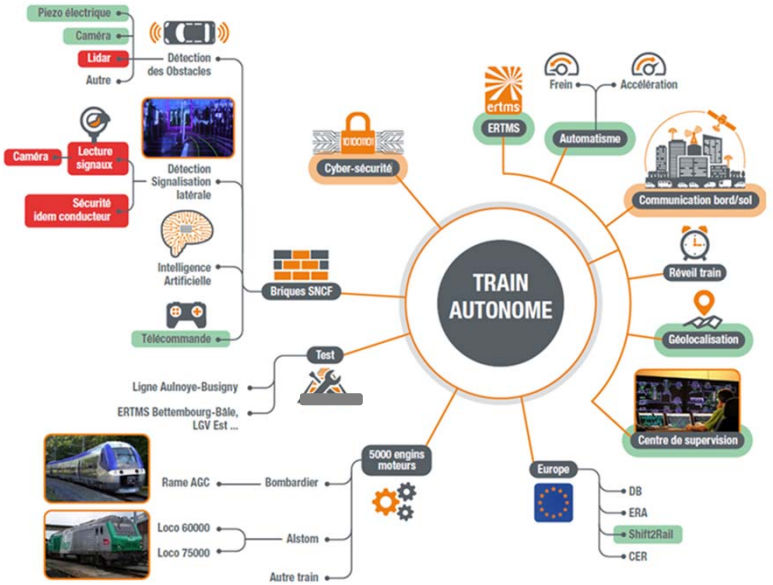
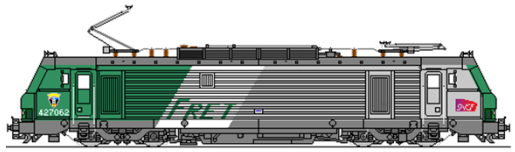
A project based on cooperation

- **Partners :**
  - Industrials :
    - SNCF
    - Hitachi Rail STS
    - ALSTOM
  - Engineering companies :
    - ALTRAN
    - APSYS
  - Academics & Research centers :
    - IRT RAILENIUM
    - Valenciennes University (LAMIH)
    - UTC – HEUDIASYS
    - Ifsttar – ESTAS
    - Lille 1 - CRISTAL
  - Safety authorities
    - EPSF
    - ANSSI





- **Academics :** 3 PHD thesis initiated by Railenium
  - Environment detection supervision & IA Safetybag approach,
  - ATO Multiagent dynamic modelisation,
  - Formal method assessment of high level specification and architecture

Autonomous Freight Train

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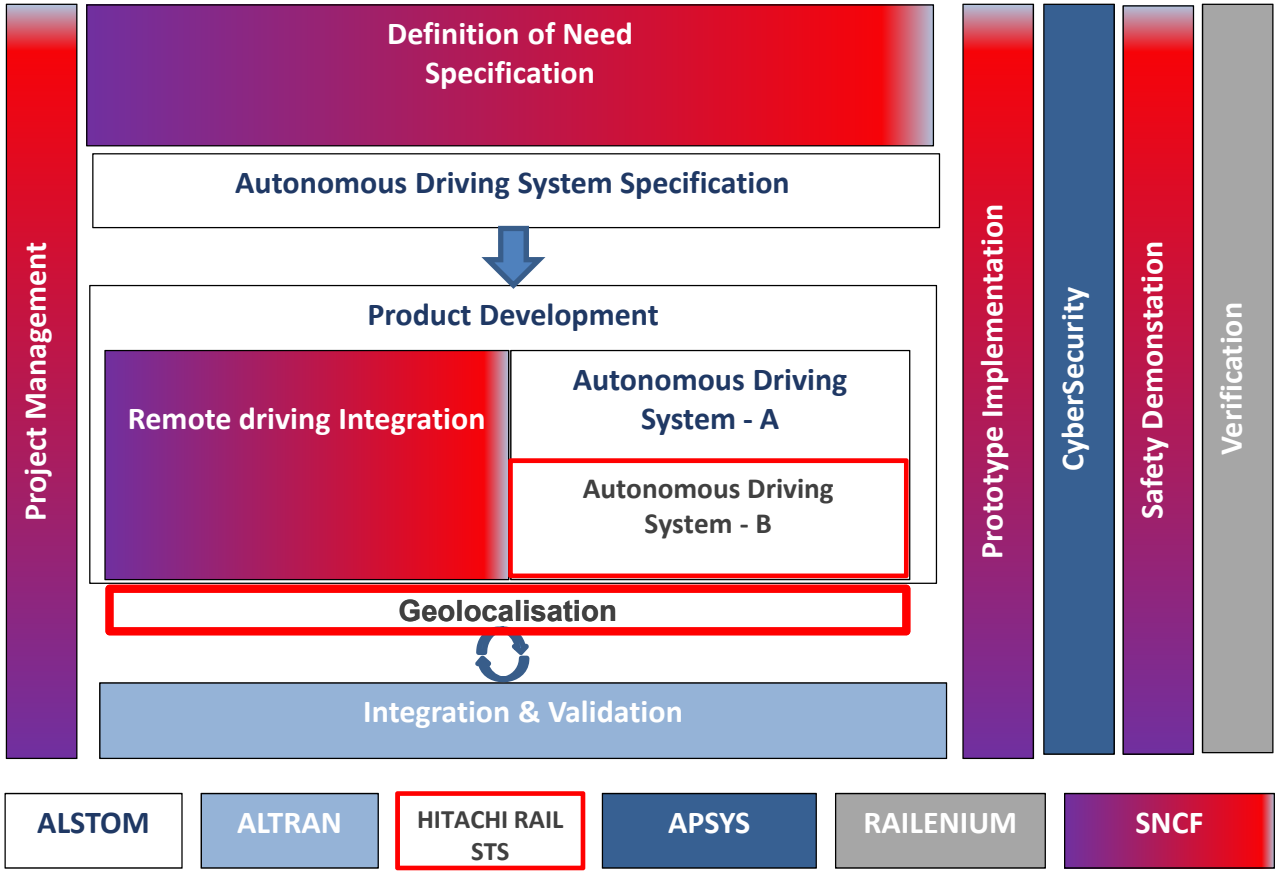
What is the work package allocation on the Project?



The EPSF and ANSSI will accompany the project on security issues and will carry out any possible regulatory changes in order to provide appropriate responses to blocked points prior to a request for product authorization.

Autonomous Freight Train

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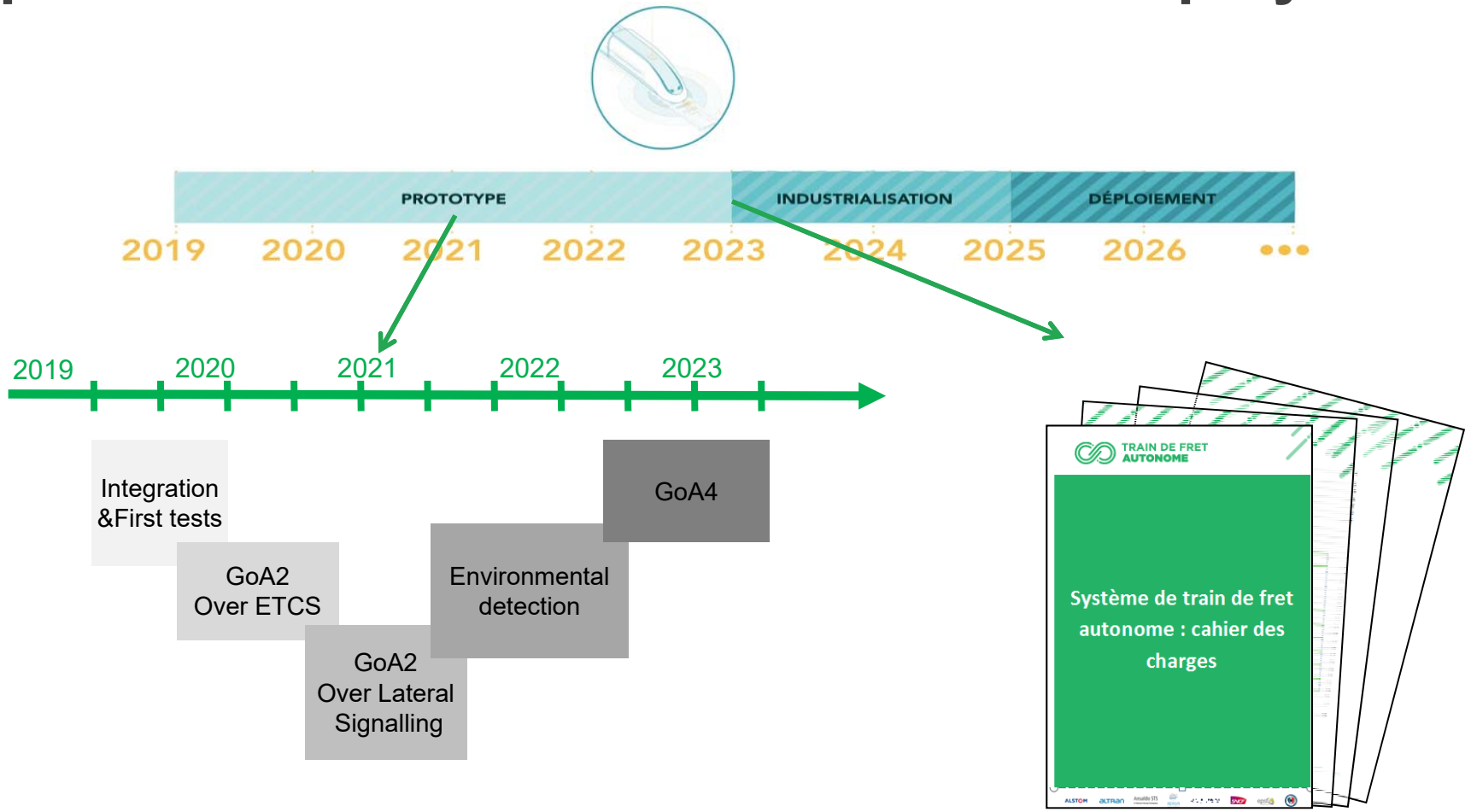
A phase towards industrialization and deployment



➔ These technological challenges have become strategic and will have to be answered to demonstrate the autonomous trains feasibility

Main Challenges

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The main scientific & technological challenges :

Cybersecurity

How to ensure the integrity and confidentiality of information ?

Environment detection

Can an autonomous train understand its environment?

Decision Making

Can an autopilot be smart?

Geolocalization

How to ensure an accurate geolocalization of the train ?

Validation

How to validate such complex systems before letting them run?

Safety

How to ensure the Safety of the system ?

➔ **These scientific & technological challenges have become strategic and will have to be answered to demonstrate the autonomous trains feasibility**

Main Challenges

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How to ensure the integrity and confidentiality of information ?

One of the critical issues of telecommunications concerns vulnerability to external attacks.

The worst-case scenario that could be considered would be the remote control takeover of an autonomous train which is connected to the telecom network.

Cybersecurity is a priority for manufacturers, it is now necessary to integrate existing means of protection into system development.

Research axes :

- Firewall functions,
- The security of internal communications by encryption & signature,
- The "hardening" of embedded computers,
- The security of the information systems involved in the circulation of autonomous and connected trains.

➔ **The cooperation on the project with an engineering company specialized in Cybersecurity in aeronautics will allow to implement cybersecurity from design**

➔ **The implication of the National Agency for Information System security will allow to benefit from their recommendations to prepare future certification.**

Main Challenges

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Can an autonomous train understand its environment?

To achieve autonomy, the train must be able to detect and perceive fixed or moving objects in its environment.

Two research axes are explored :

First

Fusion of inaccurate, uncertain, biased, delayed (latencies) and asynchronous data (on-board camera and multi ranging sensors to reduce detection errors)

Second

The development of models allowing a semantic analysis of the scene including the detection and analysis of dynamic behaviours.

➔ The cooperation on the project with an engineering company specialized in autonomous cars will allow to benefit from cross-fertilization coming from the automotive industry

Main Challenges

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Can an autopilot be smart?

The train's autonomy is also its ability to make decisions.

When a train is in autonomous mode, it is the train's software that must make the right driving and safety decisions. It must analyze what it perceives in order to dynamically adapt his speed. The advanced decision systems that will equip autonomous train will therefore be complex

Research axes :

- **Decision-making algorithm,** including fuzzy logic that is often used to develop decision trees on established or learned rules.
- **Decision-making diagrams** can also be developed using multi-criteria optimization techniques.

➔ The cooperation on the project will allow to benefit from the result of works performed by university researchers specialized in artificial intelligence

Main Challenges

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How to ensure an accurate geolocalization of the train ?

- To achieve autonomy, the train must be able to have a precise, available and reliable localization in all conditions.

Target

The challenge is to provide an accurate location solution at the meter scale in all kind of environments

Research axes :

The global positioning techniques that will achieve this objective are based on the fusion of GNSS data (satellite positioning) with the other available sources of information to achieve the required accuracy.

➔ **The cooperation on the project with a company specialized in Geolocalization for autonomous trains will allow to benefit from an accurate geolocalization experienced in the railways environment.**

Main Challenges

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How to validate such complex systems before letting them run?

An autonomous train, like any automated system, has to be validated. Nevertheless, since it is impossible to cover the millions of kilometers that would be required to assess its failure rate under multiple conditions, the solution lies in the simulation.

Research axes :

- A virtual and representative simulation bench has to be developed to allow massive laboratory tests.
- Reuse existing railways simulation tools,
- Develop tools able of simultaneously simulating technological blocks such as trains dynamic behavior model, sensor models (including inaccuracies and measurement uncertainties), realistic environmental models, meteorological models and communication models.

➔ **The cooperation on the project will allow to benefit from cross fertilization between deterministic system validation tools used in the Railway industry with virtual validation benches used for autonomous cars**

Main Challenges

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How to ensure the safety of the system ?

Autonomous train will increase the safety level of the railway

- The autonomous train system is an assembly of systems comprising many software components → It will be necessary to demonstrate the operational safety of the system, which must operate with the required level of safety, even in degraded mode.
- The Safety demonstration of the autonomous train will be complex
- The authorization process of the autonomous train might change a lot as the regulation of the railway will certainly change

Research axes :

- optimization of software, test verification and validation methods
- Definitions of rules and regulatory standards adapted to autonomy

→ **The cooperation on the project with SNCF safety experts and with the national safety authority will allow to accompany the project on security issues and to carry out any possible regulatory changes in order to provide appropriate responses to blocked points prior to a request for product authorization.**

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Conclusion

Innovate & cooperate.

Through the real case of the SNCF autonomous freight train project, we have seen how the combination of innovation and cooperation can enable us to overcome the scientific and technological challenges of autonomy.

Capitalize.

Autonomy as a technological evolution of railways will improve the safety and reliability of railways, increase the capacity of the system while reducing production costs and carbon emissions. This will benefit to all

Improve design.

For this reason, it is important that the researchers and developers of the railway sector can cooperate & share their visions.
This will ensure that research is guided by railways real needs and contribute to the development of usable, scalable and deployable technologies that will improve the design of tomorrow's railways system.

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Thank you for your attention

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