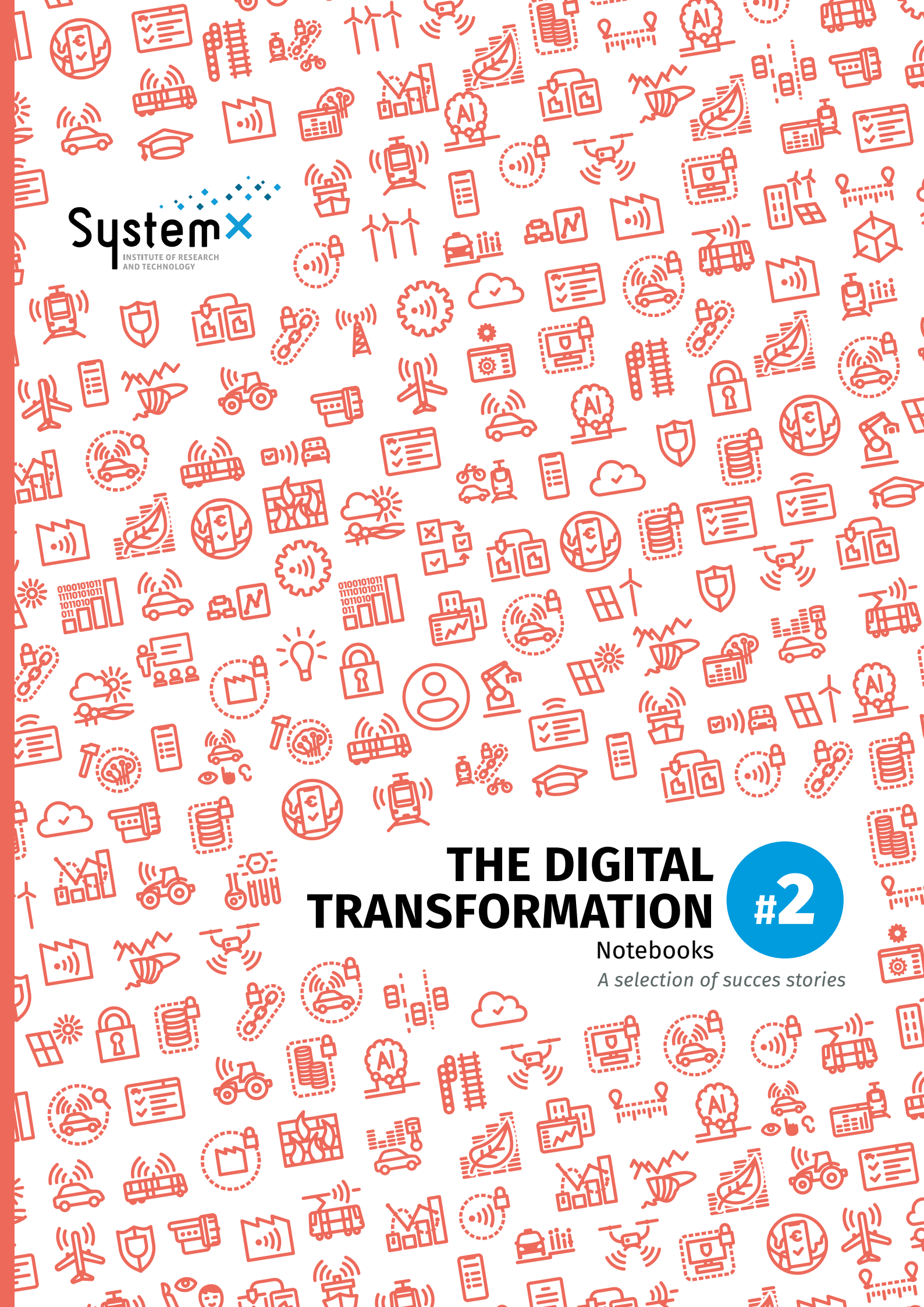


THE DIGITAL TRANSFORMATION #2

Notebooks

A selection of succes stories

Contents

Michel Morvan
President, IRT SystemX

Paul Labrogère
CEO, IRT SystemX

The second edition of the Digital transformation notebooks shows once again the vitality of the RTO SystemX (Research Technology Institute or *IRT - Institut de Recherche Technologique*), through the number and the quality of results presented here. These are the fruit of the labour of women and men of talent, collaborators of the institute but also academic, industrial and institutional partners.
Together, they are creating a safer, higher-performing and more sustainable world.

The world is constantly changing, and the change is accelerating. We must take into account the great transitions, stay on top of complexity and face uncertainty, as we did during the recent pandemic crisis. Within this context, the transformation of our organisations is both necessary and urgent. Their competitiveness and durability are at stake. Digital transformation is key here. And I am convinced that we have the means to make France the champion of this transformation to the benefit of industry, services and regions.

Today, IRT SystemX is tackling topics such as mobilities of the future, connected autonomous transportation, circular economy and ecological transition, extended enterprise, additive fabrication, industrial systems of the future or even digital safety. The Confiance.ai programme, initiated in 2021 within the framework of the *Grand Défi* “Securing, certifying and enhancing the reliability of systems based on artificial intelligence” and the France 2030 plan, is already showing great results.

You will discover illustrations of these achievements in the following pages. Today, our research engineers are collaborating with our partners to produce impact to the benefit of health and the patient journey, agriculture and food production, the circular economy, education... which we will be able to present to you, I hope, in a subsequent edition of the notebooks.

I am proud to share with you this new edition of the Digital transformation notebook. You will learn here about our most emblematic impacts. They materialize our asserted strategy in particular in the areas of cybersecurity, digital twins and trustworthy AI.

Among the first results of the Confiance.ai programme, is the delivery of the first version of an environment of trust, currenlty under deployment in the engineering departments of our industrial partners, as well as the development of DebiAI, an optimisation plaform for data to be used in learning models. Today, digital twins are everywhere, accessible to the general public in the metaverse or simplifying collaboration in the extended enterprise. They also constitute a powerful decision-making tool for both industries and regional planning. They can support public decision-makers, as illustrated by the Decarbonized City demonstrator, or even help consolidate urban logistical flows as tested within the LEAD project. As for cybersecurity, common to many of our projects, it is key to securing industrial systems. Our CHESS4Industries platforms offers a catalogue of attacks which is namely used within the framework of the H2020 European project SeCoIIA (Secure Collaborative Intelligent Industrial Assets).

All these new impacts, platforms and demonstrators, improve our technological environments, and offer real laboratories open to our partners. If we are today involved in several European projects on a large scale, it is because those projects can benefit from the potential of these environments. This document illustrates perfectly the efficiency of our “simultaneous dual impact research model”, as characterized by the study we carried out in partnership with the Centre for Management Science (Mines Paris – PSL) which is presented in the notebooks.
I trust you will enjoy reading what follows!

IRT SystemX offers a unique model to help industry accelerate technology impact and transfer in many areas, namely artificial intelligence, the circular economy and energy transition. Focus on the institute's activities in these areas with Loïc Cantat and Amira Ben Hamida.

Designing

the digital world of tomorrow

Loïc Cantat
R&D Manager AI and Data Science, IRT SystemX

Amira Ben Hamida
Project Manager and Circular Economy and Ecological Transition Domain Leader, IRT SystemX

What are the biggest challenges that the field of AI is facing today?

Historically driven by the creation of demonstrators, the field is now entering a new era – that of process industrialisation with the aim of building AI components for industrial products. The methods and tools that are currently in use are not adapted. In order to address this issue, we are face with two main challenges. We must create an environment of trust within the systems and accelerate their acceptability by both industry and society as a whole.
The scientific challenges that need to be overcome to provide tangible solutions that can be applied on a very broad scale, mainly concern the fields of systems engineering, data science and interaction. The Confiance.ai programme, led by the IRT SystemX, is working to establish this environment of trust by focusing on a range of topics such as human-machine interactions, explainability, robustness and safety as well as standards and norms.

How does IRT SystemX contribute to the issue of AI?

Set at the crossroads of industry and academia, the institute uses real data and invests in specific industrial use cases to adapt and implement the scientific work from the field.
Our RTO is multidisciplinary. As such, this enables us to explore all fields related to hybridisation of AI by pooling together our skills in the areas of physical simulation, human-machine interaction, functional safety and systems engineering. We have the necessary know-how to connect AI with other scientific fields in order to integrate it within complex industrial systems.
Some of our most important contributions in this field are:

- The hybridisation of industrial physical simulation processes combined with learning methods based on observation or simulation data. This was carried out within the HSA project (Hybridisation Augmented Simulation) led by SystemX, launched within the framework of IA2 programme (Artificial Intelligence and Augmented Engineering - *Intelligence Artificielle et Ingénierie Augmentée*). It has already received recognition from the scientific computing community, with the award of the Trophy of Simulation and Digital Technologies for Co-design at the Teratec 2022 Forum..
- Providing the first version of a trustworthy environment we are rolling out across our industrial partners' engineering departments. We are also contributing to the establishment of standards to respond to the European AI Act that is being drafted.

How is IRT SystemX committed to the circular economy and the ecological transition?

We have launched several R&D projects on issues relating to energy efficiency, prediction and the use of artificial intelligence. These aim to make all practices more environmentally-friendly. These projects are based on the platforms and expertise that are the driving force of IRT SystemX in the fields of systems engineering, AI, optimisation and operational research, blockchain and operational safety. We wanted to push boundaries to consistently work on these topics all the while taking into account several visions driven by all our partners. In order to do this, we established an observatory on systems in partnership with both national and European players to identify the scientific and technical challenges faced by industry and academia.

Could you tell us more on the observatory on systems that you established?

Launched in June 2021, it has enabled us to define the state-of-the-art by interviewing a range of key players in the field. We have identified a number of subjects that are priorities, such as energy optimisation, change management, hydrogenics, digital sobriety, the circular economy and recycling, integrated approaches (smart city, supply chain, etc.) and water management. The state-of-the-art revealed synergies between different players involved in the value chains of these topics. Building on this, we have launched several collaborative R&D projects to help them find sustainable and resilient solutions.

What is one of the institute's key achievements in this area?

The creation of Decarbonized City, a regional planning demonstrator based on data management and on digital twins that can be emulated. More specifically, it enables elected representatives to make environmentally-friendly decisions while striking a balance between economic factors and citizen satisfaction. It is also a great example of collaboration between SystemX, an SME (Cosmo Tech) and a regional authority (the Paris-Saclay urban area – Agglomération Paris-Saclay).

Linking ride-share providers using blockchain technology

In collaboration with Ridygo and the City of Lyon, IRT SystemX has designed an interoperability technology that connects different ride-share providers. It aims to help providers to coordinate their offering with demands of their user communities.

The platform is based on a blockchain technology dedicated to the consortium of providers. It is the outcome of substantial work: the data models have been unified, advanced cryptography tools have been implemented to guarantee a high-level of privacy, and experiments have been carried out under real operating conditions. The technology has been implemented in open source with the aim of generating strong momentum to federate ride-share providers.

"This new technology improves both the ride-share offering as well as the credibility of the service among citizens by increasing its value at a regional scale."

Yann Briand,
Project Manager and Head of Mobilities of the Future, IRT SystemX

INTERVIEW

Arnaud Delcasse
Founder and CEO, COOPGO (Ridygo)

What are the inherent obstacles to the development of a ride-share service offering?

The development of a ride-share service is complex. It involves raising user awareness, changing user behaviour and connecting users. At the moment, daily ride-share journeys such as the commute from home to the office are spread across several providers and services. We believe that one solution is to remove the obstacles to interoperability between ride-sharing platforms, or between a MaaS system (Mobility as a Service) and ride-share providers, in order to facilitate discussions among users, enhance the service offering and increase resources to boost changes in behaviour.

How can blockchain technology sustain collaboration between different ride-share providers?

The aim of our collaboration with IRT SystemX was to facilitate cross-platform ride-sharing in order to offer a seamless user experience without having to install several apps. This also means that each provider can focus on their own user experience while benefitting from a range of routes that meet their users' needs. Blockchain removes technical obstacles to payment between providers and acts as a trusted third-party between the different stakeholders.

How have you benefitted from working with IRT SystemX?

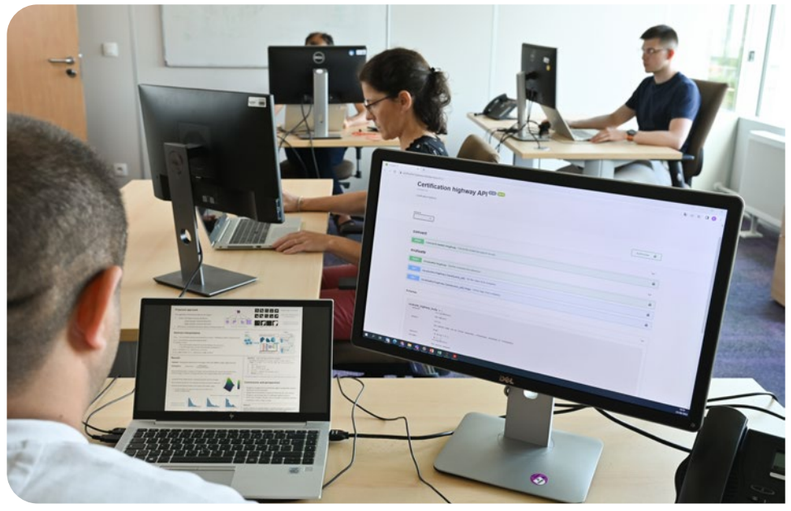
Thanks to our work with the institute, we were able to conduct specific experiments on this mode of operation which we are now bringing to other players as part of a standardisation process. We are proud of the work we have done together, and to see it released in open source, in order to develop and integrate it within our MaaS ride-share offering.

Evaluating the robustness of driving models for the autonomous vehicle

In collaboration with APSYS (Airbus), Expleo, Naval Group and its subsidiary SIREHNA, and Stellantis, IRT SystemX has developed an unique demonstrator: Robust AI (ROBUSTness toolkit in AI). This tool combines simulation-based approaches with mathematical theories based on formal methods to evaluate the performance and safety of autonomous driving pilots.

Decisional functions based on artificial intelligence, and more specifically on deep learning, must meet operational safety requirements and then demonstrate their reliability in a given area of operation. The solution that has been developed is made of technological blocks that have enabled significant advances for this evaluation.

With this work, the institute has been able to provide the industrial world and the scientific community a unique approach in this field, combining operational safety[1] and formal proofs in the context of autonomous driving resulting from a model trained by reinforcement learning.



"Our demonstrator integrates the first building blocks of a methodology to evaluate the robust properties of an autonomous pilot reinforcement learning model, while meeting safety requirements inherent to autonomous vehicles. It is currently being transferred to our partners and its prospects for use and development are very promising."

Hatem Hajri,
Research Engineer, AI Architect, IRT SystemX

INTERVIEW

Patrick Boutard
AI Trust, Safety and Compliance Lead, Stellantis

What was the aim of your work with IRT SystemX?

Back in 2017, Stellantis identified that the robustness of its algorithms needed more work and optimisation to enhance both performance quality and operational safety in the context of using AI and statistical learning for Advanced Driver Assistance Systems (ADAS) and autonomous vehicles.
We have broken down the issue in two parts: a theoretical axis based on formal validation with the analysis of operational coverage, and a practical methodology axis to increase the robustness of learning and performance evaluation, taking into account unlikely scenarios. These *corner cases* because the design field is a long way from covering the typical sphere of operation – the most unexpected events can happen on the road!

What were the main results of your collaboration? How do you plan to reuse them within the Stellantis group?

As expected from the beginning, the theoretical axis was challenging, and, in spite of our progress, formal verification is still an open question. In the practical part, we have managed to make significant progress on the robustification of learning by coupling adverse attacks and reinforcement learning. A set of performance and safety indicators and a simulation environment round off the deliverables and allow for operational implementation in our development studies.

1. ISO/PAS 21448:2019 SOTIF Safety Standard

Supporting regions towards a green transition

In partnership with Cosmo Tech, IRT SystemX has developed a regional planning demonstrator called Decarbonized City based on data management and digital twins. It aims to help regions make enlightened decisions by evaluating the impact of their projects on the region and monitoring key performance indicators.

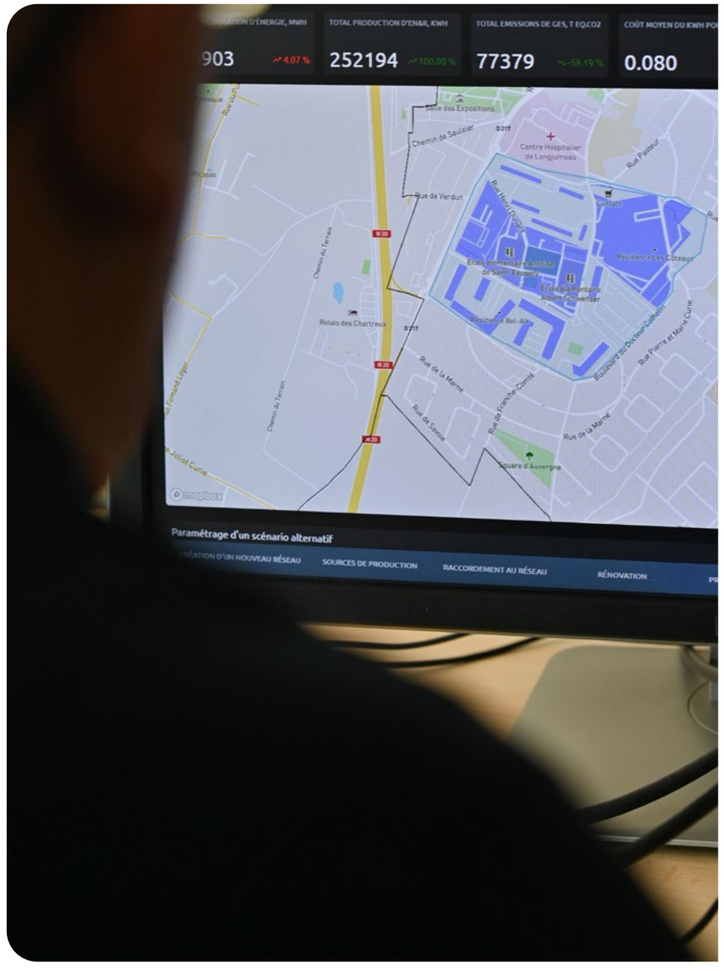
This innovative demonstrator is based on the modelling and simulation of digital twins to generate what-if scenarios dedicated to the rolling out of energy infrastructures, in order to extract indicators on the pertinence of new land developments and the impact of strategies. It is one of the first applications in the world to use Microsoft's "Azure Digital Twin" platform.

With Decarbonized City, IRT SystemX namely supported the Paris-Saclay urban area in its green transition by creating a digital twin, a virtual replica of the 27 towns that make up the area, built from a variety of data (regional configuration, municipal registry data, buildings, energy networks, etc.). In this way, elected officials can measure the precise energy impact of future land development projects and make the best choices.

Almost any land development scenario can be tested with the digital twin that can be emulated, such as building new facilities, renovating buildings or even setting up a heating network for a new urban district. For instance, one of the tested simulations determined that a town could reduce the CO2 emissions of a district by 75% over 20 years by choosing geothermics over fossil fuels while maintaining an attractive energy rate.

> *A use case for the town of Longjumeau was demonstrated thanks to our platform. The data consolidation made it possible to identify the crossroads between an area with a high potential for geothermal energy and a new concerted development zone (ZAC) in the city. Notably, we simulated the installation of a district heating network in the area to measure the impact of such a project.*

Amira Ben Hamida,
Project Manager and Circular Economy and Ecological Transition Domain Leader, IRT SystemX



> *In France, public sector officials turned to our partners, Cosmo Tech and SystemX, to model and simulate a region's growth. They used Azure Digital Twin along with our data and analysis services to determine where new energy sources should be located and their impact on the region's electrical grid.*

explains
Satya Nadella, *Chairman and CEO of Microsoft, on the occasion of his keynote in July 2021 for "Microsoft Inspire"*

INTERVIEW

Grégoire de Lasteyrie
President of the Paris-Saclay urban area

Why did Paris-Saclay join the Decarbonized City project?

The Paris-Saclay urban area has a special culture of innovation and creativity demonstrated by a "Technological Innovation Hub," which brings together 20% of French researchers!
Quite logically, the region is at the cutting edge of green and environmental transition, with a finely-tuned roadmap defined in our Regional Climate, Air and Energy Plan (*Plan Climat Energie Territorial*). In order to respect the plan, we decided to take into account the issue of energy in the very first stages of our projects. That is why we immediately saw the value of the Decarbonized City demonstrator project, led jointly by IRT SystemX and Cosmo Tech. This operational tool can be applied to a range of issues, promoting a healthy dynamic of cooperation and partnership between very different players, which is key for a successful green transition!

How is the Decarbonized City demonstrator going to help the Paris-Saclay region with its green transition?

Decarbonized City provides local officials with a tool that enables them to test different scenarios for energy policies at the district level. It is possible to view the different energy networks throughout the region, with the actual rate of consumption, to know what the options are in terms of renewable energy, to finely analyse the situation by geographical areas, and work on impact studies and in particular on scenarios for energy policies. The tool is unique because it enables us to measure the energy impact of future land development projects, to work on alternative energy scenarios and, above all, to better involve all stakeholders in the operational and technical challenges of the green transition.
In the short and medium run, thanks to the demonstrator, we will be able to finalise our renewable energy blueprint and open up new fields of study on topics as diverse as energy management for buildings, setting up data centres, rolling out district heating networks, and establishing environmental and carbon compensation areas.

Ensuring the cybersecurity of industrial production systems

In collaboration with Naval Group, Atos, Airbus, SPIE and BeijaFlore, IRT SystemX is developing a dedicated cyber-physical platform for cybersecurity research. Named CHESS4Industries (Cybersecurity Hardening Environment for Systems of Systems for Industries), the platform enables the modelling, simulation and emulation of complex infrastructures or industrial systems (energy, water treatment, crane work, production lines, etc.) to evaluate their safety levels and test adapted defence strategies or solutions.

CHESS
Cybersecurity Hardening Environment for Systems of Systems

The platform comprises several innovative technological blocks:

- Cyber-physical equipment representing the material components of the industrial system,
- Digital twins to simulate complex industrial processes,
- And a library of attacks to evaluate safety solutions.

"The CHESS4Industries platform is currently being used in two broad projects: the European H2020 SeCoIIA project, which focuses on securing aeronautical, naval and automotive production lines. It is also deployed within the R&D project Secure Ports of the Future (PFS) led by IRT SystemX, which aims to secure critical maritime infrastructures. A service offering is currently under study to open up the platform to other players, namely within the framework of training courses and awareness-raising campaigns on digital security."

Reda Yaich,
Head of Cybersecurity and Networks, IRT SystemX

FOCUS

IRT SystemX, stakeholder in the H2020 SeCoIIA project, *Secure Collaborative Intelligent Industrial Assets*

DWithin the framework of the SeCoIIA project, IRT SystemX has developed and validated a prototype for the decentralised and resilient management of access control to cryptographic resources used within an manufacturing supply chain of electronic components.
The demonstrator is the result of the integration of three technologies:

- *An innovative attribute-based encryption protocol that enables revocation of rights in a distributed environment,*
- *An attribute-based access control model,*
- *Blockchain to ensure tracing of operations and platform resilience.*

The demonstrator has been validated in an automotive use case driven by the Continental Group. The proof of concept demonstrated the benefit of attribute-based encryption to ensure the end-to-end security of the cryptographic elements used for manufacturing electronic control units (ECUs). Attribute-based encryption makes it possible to access the subset of cryptographic elements (metadata) necessary to process them while ensuring the other information (keys, random numbers, etc.) remains secure. Disclosing them would compromise vehicle digital integrity and endanger passengers. Together with Airbus, a study is under way to investigate whether the approach can be applied to an aeronautical use case. The aim is to apply the same technology to data sharing from several factories in order to optimise the manufacturing process without compromising confidential shared data.

INTERVIEW

Adrien Becue

Head of Innovation, Airbus Cybersecurity

What is the aim of the SeCoIIA project?

The SeCoIIA project (*Secure Collaborative Intelligent Industrial Assets*) aims to design the security of the collaborative industrial production systems of tomorrow. It mainly aims to:

- **Develop and validate systems for simulation, testing and immersive training based on digital twins of the industrial tool,**
- **Develop and validate authentication and encryption technologies applicable to distributed industrial clouds (*Cloud Manufacturing*),**
- **Create and validate collaborative systems to detect, decide on and respond to industrial security incidents,**
- **Define methods to develop a robust AI, legal liability principles, and digital evidence collection techniques, applicable to the factory of tomorrow,**
- **Demonstrate these key capabilities as applied to the security of several industrial sectors such as aerospace, automotive, naval and robotics.**

What has IRT SystemX brought to this European project?

IRT SystemX has made a range of contributions with a focus on the technological advances of the project. Firstly, the institute developed digital twins integrated into the Airbus CyberRange tool for testing, training and demonstrating automotive and naval use cases. Secondly, the teams developed attribute-based encryption techniques for use in distributed cloud environments. Finally, SystemX integrated, tested and demonstrated risk scenarios applied to automotive and naval pilot systems.

How do you assess the innovation potential of the attribute-based encryption solution? How could it affect collaborative manufacturing?

The attribute-based encryption solution developed by IRT SystemX meets the need to share sensitive information with industrial partners along an extended supply chain. This solution offers considerable advantages:

- **Encryption and access control at the data point, refined authorisation management in the context of industrial collaboration between players at different privilege levels,**
- **Applicability to distributed cloud environments, no single point of failure, resilience to denial of service attacks and Byzantine fault scenarios,**
- **Security apparatus is scaled and reinforced by user community growth, traceability and auditability of transactions, and compatibility with privacy protection measures.**

Testing human-machine interfaces to support drivers of automated vehicles

In order to support vehicle automation, IRT SystemX collaborated with its partners Arkamys, Renault Group, Saint-Gobain Sekurit and Valeo to create, integrate and develop an innovative driving cab integrated into a non-driven production vehicle, equipped with several interaction modes and driving simulation. This experimental platform helps evaluate the relevance of several interaction modes and ergonomics of between the autonomous system and the driver in a simulated driving environment, by confronting it with unique scenarios.

The cockpit is made up of different technological blocks: a generic on-board architecture which integrates an automated management system for four levels of automated driving, a set of rules with context recognition, and various assistance features (sounds, vibrations, LED lighting integrated in the windscreen and steering wheel, holographic assistant). These blocks have made it possible to offer multimodal and synchronous human-machine interfaces (HMI), while varying the methods used, in order to adapt the interactions between the vehicle and the drivers according to the driving situation, and thus facilitate its use.

More than 150 people, representing a heterogeneous sample of drivers, experimented with the different scenarios developed by the institute's teams in order to validate the HMI configurations in different use cases (regaining control of the vehicle, degraded driving conditions, etc.).

INTERVIEW

Bruno Albesa

Head of R&D and Innovation, Valeo

What issues did you want to address in the Interactive Multimodal Cockpit (CMI) R&D project?

Valeo joined the CMI project at its onset in 2018. We wanted to evaluate the performance of human-machine interfaces in self-driving cars by collaborating with several renowned academic and industrial partners. More specifically, we wanted to help drivers understand the status of their vehicle (e.g. by activating the manual or autonomous mode) and the transmitted information (upcoming traffic jams on the road, deteriorating weather conditions, etc.).
We have established personas with very different attitudes towards self-driving technology, some who are very comfortable in using them, and others who are less enthusiastic about these innovations. We have studied the implementation of solutions adapted to each of these profiles through different sensory methods.

What will you do with the results from the experiments that were carried out?

As technologies evolve and are adopted, Valeo adapts the technological roadmaps of its products for car manufacturers and new mobility players. The experiments with IRT SystemX will enable us to refine or strengthen these roadmaps in answer to the different needs of autonomous vehicle drivers.

"The results were used in the roadmaps of the institute's partners. Renault Group is currently improving haptic feedback (vibrations or forces transmitted to the operator via the steering wheel) to industrialise it for future vehicles. In partnership with Renault Group, Valeo has filed a patent for using LEDs on the steering wheel. Finally, Saint-Gobain Sekurit plans to reuse the roadmap definition method and tool for product innovation based on a process to predict user experience trends."

Kahina Amokrane,
Research Engineer and Architect for Interaction, Uses and Knowledge, IRT SystemX

FOCUS

Reusing results in the Confiance.ai programme

The Confiance.ai programme has continued the work carried out within the CMI project, based on the method used to evaluate user trust when interacting with a system. The challenge will now be to extend this method to systems made of blocks of artificial intelligence and to improve awareness of the different aspects to evaluate this trust.

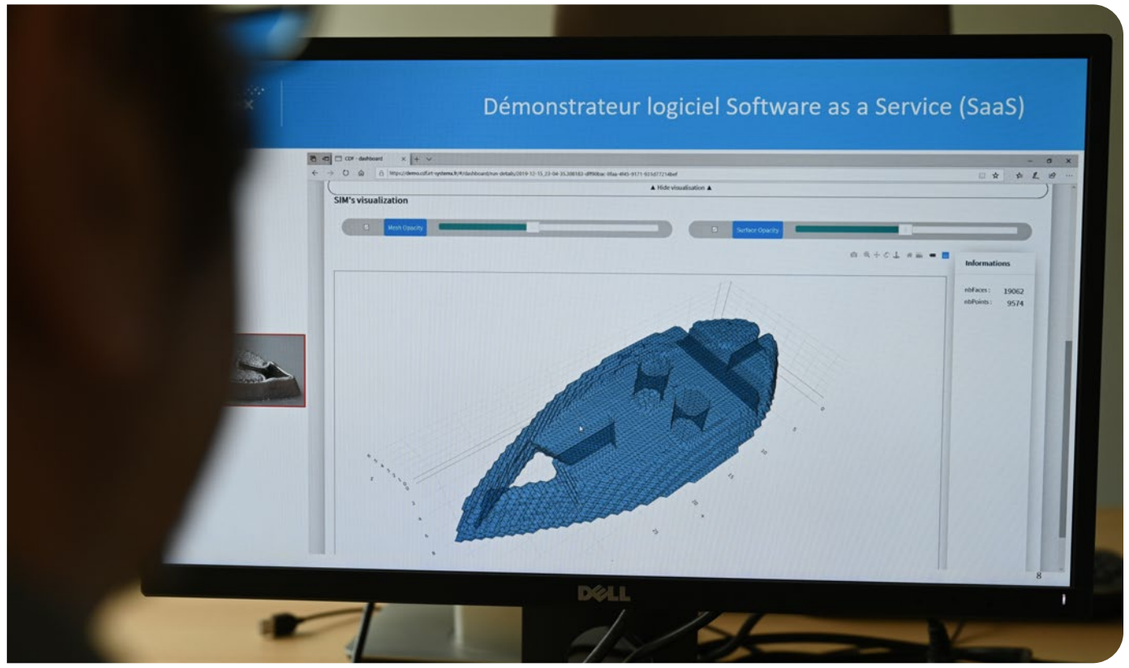
Simulating the additive manufacturing process to optimise performance

IRT SystemX has developed a digital chain of innovative tools and methods capable of simulating a Laser Metal Deposition (LMD) additive manufacturing process. The aim of the simulation is to evaluate different creation strategies based on the geometry of the part, in order to optimise the production process in terms both of time and quality.

Developed in collaboration with DP Research Institute (DPRI), ENS Paris-Saclay, ENISE (Engineering school of the École Centrale de Lyon), Safran and SPRING Technologies, this software solution provides a topological simulation of the part that integrates simulated kinematic data, i.e. the speed and position of the nozzle according to time. It relies on four software blocks:

- a simulation block for material deposition,
- a kinematic simulation block for the behaviour of the machine,
- a block for collision management,
- and a brick for the optimisation of flow paths.

Safran has used the demonstrator in a use case for manufacturing a part. Thanks to the results, they were able to validate the evaluation criteria of different manufacturing strategies.



INTERVIEW

Christophe Tournier

University Professor, ENS Paris-Saclay

What can you tell us about your collaboration with IRT SystemX?

Over the three years I spent at IRT SystemX, I launched three additive manufacturing R&D projects. The model of the institute enables us to move forward in the creation of digital prototypes. The cross-disciplinary Software & DevOps team supports us in the development of our demonstrators and helps us share our results, which would not be feasible in a research lab.

What did you gain from this experience?

My time at SystemX was very fruitful. I learned a lot about project management and about other scientific and technical issues, such as the internet of trust, which also applies to additive manufacturing. I was able to share my skills in additive manufacturing and in the digital definition of manufacturing processes. Added to the expertise of industrial and academic partners, IRT SystemX was able to leverage on these skills, as it excels in supporting the digital transformation of industry. We have been able to make significant progress in the field, as seen with our CDF demonstrator (Conception des Directives de Fabrication – Design Manufacturing Guidelines) and both our DSL (Durability of Lattice Structures) and WAS (Wire Additive manufacturing process Simulation) projects.

"This demonstrator provides significant advances in the field of additive manufacturing. Thanks to the simulator, we can simulate the geometry resulting from deposition, realistically predict the feed rate of the nozzle (and thus manufacturing times), and manage collisions to optimise the flow path. The aim is to define and validate a manufacturing strategy during production."

Xavier Lorang,
Project Manager and Head of Additive Manufacturing, IRT SystemX

FOCUS

In the field of engineering for the industry of the future, IRT SystemX is also studying, in collaboration with Safran, how variability in the manufacturing process impacts the state of matter, mechanical resistance and the service life of manufactured structures.

INTERVIEW

Oana Ciobanu

Engineer, Advanced Digital Methods for Additive Manufacturing, Safran

What is the role of additive manufacturing within the Safran group?

At Safran, additive manufacturing helps to develop and deliver competitive, innovative products. The aim is to create value for the group's customers.

What can you tell us about your collaboration with IRT SystemX?

IRT SystemX supported Safran in our first collaborative project around additive manufacturing that also included IRT Saint Exupéry along with other industrial and academic players. We established a smooth collaboration from our very first meetings. The Institute showed great interest in the subject and demonstrated a deep understanding of the resulting industrial need. SystemX was in charge of piloting the project. The aim was to develop digital tools and methodologies to design parts for additive manufacturing using powder bed fusion and study their behaviour. Thanks to the knowledge of the IRT SystemX on the state-of-the-art, we were able to study the impact of manufacturing dispersions on the service life of parts. Knowledge transfer has been at the heart of all digital developments, brought together in a fast and easy to use high-performance platform available in Safran's infrastructure.

Supporting the collaborative engineering of large and complex systems

In collaboration with ArianeGroup, Dassault Aviation, the French Government Armaments Agency (DGA - Direction Générale de l'Armement) , Naval Group and Thales, SystemX has proposed a coolaborative tool-based process dedicated to the review of heterogeneous models in the context of the extended enterprise, as well as a process to evaluate architectural alternatives aimed at classifying different possible architectural solutions.

Engineering large, complex systems involves a multitude of partners with a range of different needs, points of view, processes and tools. In this context, it is essential to manage the chain of design and overall consistency of specifications to ensure end customer needs and costs are met. In order to meet this design challenge, innovative collaborative engineering processes must be implemented, involving project management, industrial project management and other industrial partners.

Within the context of model-based systems engineering (MBSE), IRT SystemX studied solutions to share and manage the complexity of these large systems through managing the consistency between systems engineering data and by finding and comparing architecture solutions offering the best compromise.

The review process was implemented within the framework of a defence "fighter aircraft and facilities" programme on the Dassault Systèmes 3DExperience platform and highlighted the key elements of a model review:

- A reading path to guide the reviewer through the model review by suggesting an order of display,
- Graphic and textual annotation of the model,
- A thread of discussions,
- Data sharing security management depending on stakeholders.

The evaluation process of the architecture was tested using a complex systems engineering case study. Combined with the previous collaborative review process, the test consisted in sharing and validating, via a review, the architectural alternatives to be evaluated, then measuring these alternatives according to the architectural evaluation process, based on the 3DExperience platform and the implementation of an innovative collaboration platform (DCIDE – Dashboard for Innovative Collaborative Decision).

The various industrial players collaborating on major programmes will be able to use these processes, particularly in the defence, aeronautics and naval sectors.

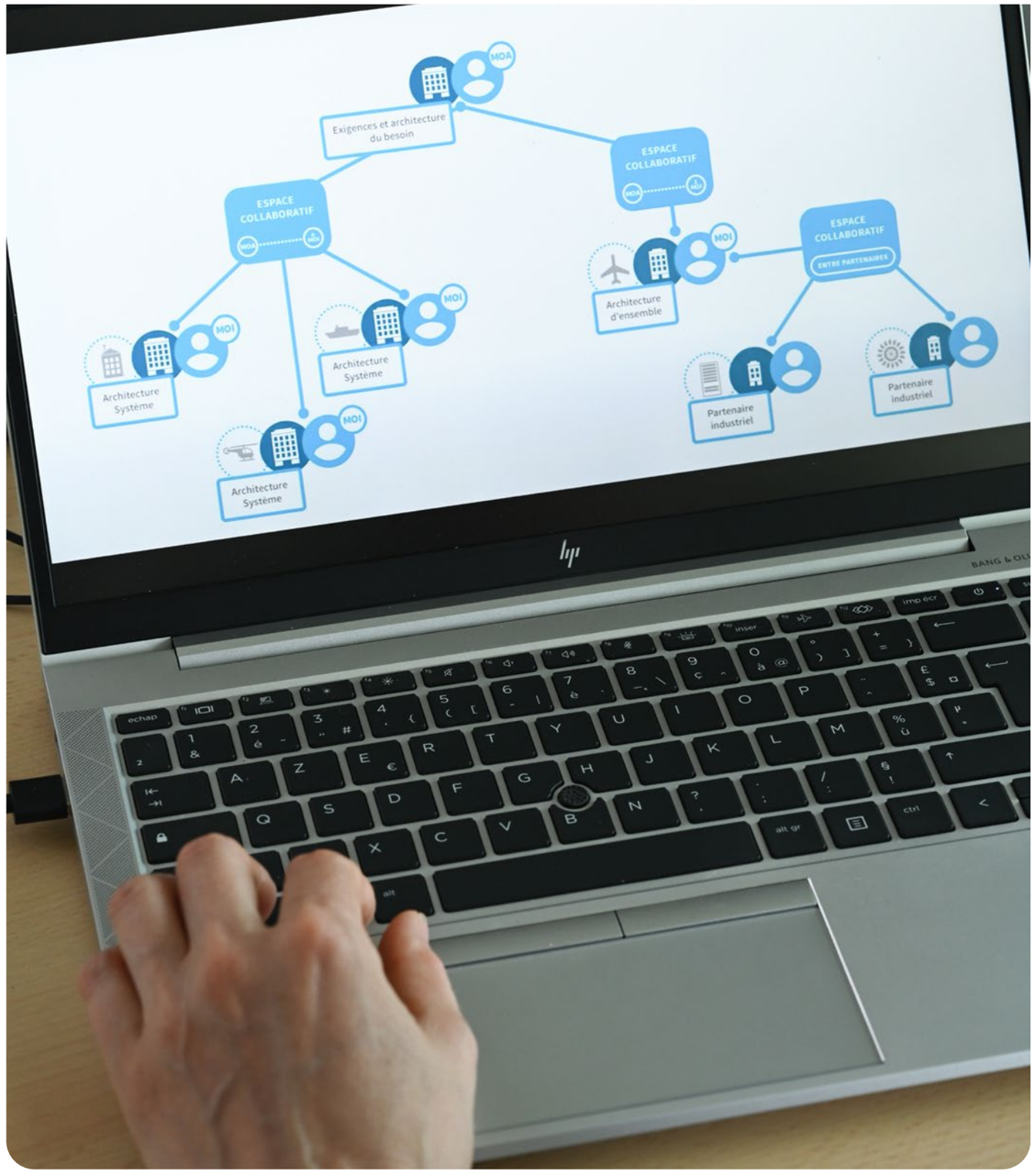
> *"There is still so much to explore: consistency management, digital continuity, model coevolution or co-simulation. We hope to pursuve our work with our partners to create the collaboration processes of tomorrow."*
>
> **Anouk Dubois**,
> *Project Manager and Head of Extended Enterprise, IRT SystemX*

> *"IRT SystemX has supported defence players in experimenting with new methods for major R&D programmes. By facilitating technical reviews, consistency management and the exploration of system architectures, we have improved the operational efficiency of systems under economic constraints. Working with IRT SystemX has been a great opportunity for the DGA to facilitate collaboration with its partners, while benefitting from a neutral space."*
>
> **Jean-Philippe Masson***,
> *Assistant Director of Engineering, Systems Engineering Project Manager, DGA*

* Testimony received in 2019

Designing the digital world of tomorrow

> *"We decided to join an R&D project led by IRT SystemX in order to collaborate with other industrial players on the development of innovative processes in a non-competitive mode. We used the Dassault Systèmes 3DExperience platform to implement the tools developed by the different industrial partners and to produce prototypes. We were particularly interested in the review process, which is fundamental because it enables us to compare the digital model of the user's needs with the digital model of the solution offered by manufacturers."*
>
> **Jean Sass**,
> *Managing Director of Digital Transformation, Dassault Aviation*



Identifying uses to make change management a reality

In partnership with Mappy and the City of Lyon, IRT SystemX has developed a wallet to centralise all user mobility information based on blockchain technology. The aim is to accelerate the adoption of new policies by deploying targeted practical incentives.

How can we encourage and oversee the practical use of healthy mobility within a region and incite users to adopt positive behaviour? To respond to this issue, IRT SystemX and its partners have created a prototype mobile app ("Mobility Wallet") for users, that synchronises several service providers, consolidates transport tickets and manages local tokens (i.e. digital credits in blockchain) which can be used to pay for services within a mobility marketplace. This is all driven and supervised by the Region, which defines its incentive strategy.

Change management is a considerable challenge to make practices evolve, on top of regulatory measures. These methods are based on certifying usage and targeting measures based on practice. Communities can use the portal to set up incentive campaigns or dynamic pricing.

For example, with this wallet, certain practices can be rewarded (frequent ride-sharing, travelling outside peak times, etc.) with tokens that can be reused for mobility services according to pre-established terms. Thanks to the flexibility offered by the tool and its configuration options, sponsors of the solution can take in-depth actions.

> ***"This solution has the potential to drive the operational implementation of change management by combining financial incentives and proof of use. We are studying opportunities to extend case studies beyond the field of mobility."***
>
> **Yann Briand**,
> *Project Manager and Head of Future Mobilities, IRT SystemX*

FOCUS

Digitising the nudge towards decarbonisation

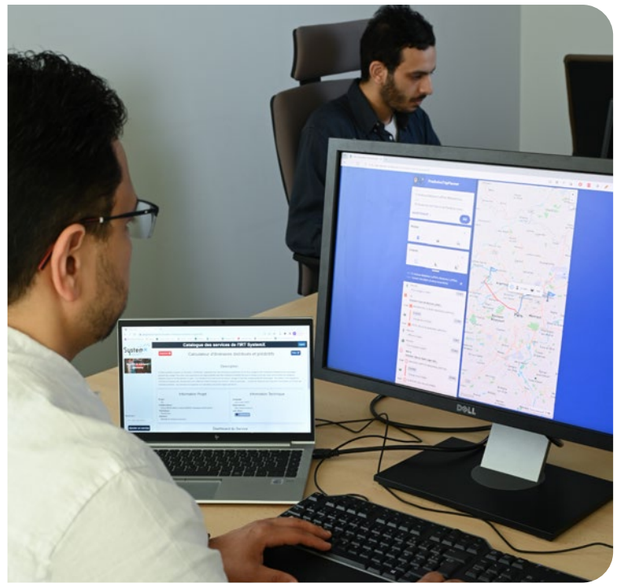
Certification-incentive devices such as these are under study to meet other societal challenges. IRT SystemX teams have explored overriding principles such as social pricing that could be applied in low emission zones, for example. This approach would make it possible to include equity principles based on personal attributes (for example, recipients of the minimum wage) and to implement dynamic exemption systems.
The challenges of decarbonisation are multi-sectoral and unite institutional and economic players around common goals. The institute is studying ways of bringing together user communities and operators around common incentive programmes.

Customising the mobility experience of passengers

Alongside Hove and Île-de-France Mobilités, IRT SystemX has developed a distributed architecture to calculate innovative, multimodal itineraries that take traffic forecasts into account to improve travel information and expand the interoperability of existing systems.

R&D work by the Institute has contributed to increasing the multimodal capacity of the Navitia[1] journey planner that was previously focused on public transportation. It now includes other methods of travel such as road transport and soft mobility.

The IRT SystemX teams also redesigned Navitia's architecture by adding new features based on advanced AI models. Thanks to these new features, travellers are provided with predictive information based on qualitative indicators connected to travel comfort. Data on station and train occupancy have been integrated into the tool to improve both the information offered as well as the travel experience.



INTERVIEW

Malik Chebragui
Operations Director, Hove

What have you gained from your collaboration with IRT SystemX?

Hove must stay in the MaaS (Mobility as a Service) race. Working with IRT SystemX has enabled us to open up the architecture of our Navitia calculator to other mobility methods and services, and also to innovatively integrate new data on passenger and traffic flow. We have been able to remain pioneers in the development of passenger information platforms that can bring together all forms of mobility. The results were industrialised in 2020, enabling us to provide innovative mobility solutions to all our customers.

How do you expect your Navitia calculator to be used in the coming years?

Hove is positioned as a French leader for multimodal passenger information, and we want to accelerate our development both in France and abroad. Firstly, by enriching travel information and adapting it to meet new expectations by providing information on disruptions, comfort, etc. Secondly, by offering dynamic information in real time to respond to the flexibility needs of transport organisation authorities. Finally, we are striving to break down geographical barriers to offer local, regional, national and even international mobility solutions with Navitia by making cross-border use possible. We already have considerable reach, and wish to remove mobility limitations using the wealth of information and intermodality available to us.

> ***"This new architecture has been tested and evaluated on the Transilien H line with actual data provided by our partners. The solution developed was industrialised by Hove (formerly known as Kisio Digital) in 2020 while the multi-criteria planning component is expected to be deployed in 2022. The work will also benefit the ViaNavigo route planner which is based on Navitia and offered by Île-de-France Mobilités."***
>
> **Mostepha Khouadjia**,
> *Project Manager, IRT SystemX*

1. Open reference API for mobility, developed by Hove

Optimising the use of ride-share lanes

In collaboration with SPIE CityNetworks, IRT SystemX has developed a decision-making tool for the use of dynamic lanes reserved for ride-sharing - OAD VR (Outil d'Aide à la Décision pour l'exploitation des Voies dynamiques Réservées au covoiturage). The solution has been the tested in partnership with the City of Lyon and is ready to be industrialised.

OAD VR is a console dedicated for road operators. The tool anticipates traffic conditions within a network and provides instructions to maximise the availability of dynamic lanes without having a negative impact on traffic on connected roads. Developments combine predictive traffic algorithms according to different time frames, a decision engine and an intuitive human-machine interface that provides real-time operating instructions. The operating modes of these innovative infrastructures were identified via modelling work.

In an effort to increase road traffic analysis capabilities, the institute tested an in-vehicle passenger counting solution on all lanes of a network. In partnership with the City of Lyon and Vinci Autoroutes, a system that integrates video cameras, an image processing protocol and an exploration portal was tested. The user flow generated offers unprecedented data. The scaling up this type of solution opens up promising avenues for dynamic and predictive network operation.

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INTERVIEW

Guillaume Georgin

Service Manager - Mobility Information Systems, SPIE CityNetworks

To what extent is OAD VR a new response to the issues of using and regulating dynamic lanes reserved for ride-sharing?

OAD VR has led to two major innovations in the field. The first is concerns dynamic ride-sharing lane management which is currently under full development in France. Until now, this type of management has been very static. It is essentially based on the typology of trips in these lanes and especially on home to work travel. Thanks to OAD VR, these lanes can be dynamically assigned to ride-sharing use based not only on traffic but also on the events on the network. The second innovation concerns the anticipation and prediction that dynamic management brings. By relying on decision-support tools based on deep learning technologies linked to both historical and real-time traffic data, the use of these lanes is easier to optimise.

What did you gain from the experiments in Lyon?

At a technical level, we were able to validate the predictive traffic models up to a 95% degree of accuracy. This result reinforces the experiments we conducted and will help facilitate the industrialisation of solutions to respond to the current needs of the mobility market. IRT SystemX has the ability to mobilise an entire ecosystem of players, both private and public, and to unify their efforts around a common goal. As a stakeholder in this project, we were able to compare and evaluate the results of these experiments.

What is the outlook for this solution?

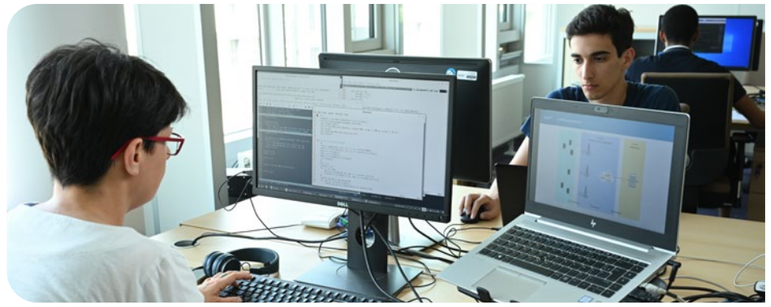
There are so many! In particular, I would mention the selection of our project as part of the call for innovations launched in 2021 by the France Mobilités association alongside Cyclope.ai, HERE, Lacroix and SystemX. It consists in implementing a dedicated system to optimise reserved lanes and intelligent intersections for the 2024 Olympic and Paralympic Games.
Beyond these experiments, SPIE CityNetworks aims to industrialise these innovations within the context of solutions that are currently used to support mobility players.

"The experiments were conducted on the urban M6 and M7 highways in the City of Lyon. Together with the institute's partners, we are examining ways to replicate these in other regions."

Yann Briand,
Project Manager and Head of Future Mobilities, IRT SystemX

Developing increasingly efficient mobile telecommunication networks

Responding to the need to roll out a large-scale 5G network, IRT SystemX has carried out a proof-of-concept based on the open source radio software solution OpenAirInterface (OAI). In this context, the institute considered the Cloud-RAN (Radio Access Network) architecture of the radio access network, which allows the complexity of data processing to be deferred to a centralised cloud computing platform, in order to control its performance.



The fifth generation of mobile telecommunication networks is responding to the growing need for frequency bands and connectivity in increasingly densily-populated areas. Telecommunication OEMs and operators are faced with three challenges: ensuring the connectivity can be scaled up all the while improving latency and energy efficiency of the underlying infrastructure. In collaboration with Nokia, Open-Cells and Orange, the institute worked on proposing a split of the radio access network functions, some of which are kept as close to the antenna as possible and others that are offloaded to the cloud. This split resulted in a Cloud-RAN architecture that complies with the "5G New Radio" specifications established by the 3GPP (3rd Generation Partnership, a cooperation between telecommunication standardisation bodies).

"IRT SystemX emulated a 5G network with several antennas and the successful rollout of OpenAirInterface software to offer split architecture. Telecommunications OEMs and operators can use this solution to study rollout performance on a large scale in their networks."

Makhlouf Hadji,
Research Engineer Expert, IRT SystemX

INTERVIEWS

Laurent Thomas

Director, Open Cells project

What are the main obstacles to rolling out a 5G network from a technical point of view?

5G uses higher frequencies than 4G and a completely new frequency band for mobile communications - the millimetre band (24-27GHz). The radio will increasingly use the physical configuration between transmitters and receivers with more antennas per item with MIMO (multiple input and output) and beamforming technologies. These innovations will offer subscribers much higher speeds as well as a much lower latency than 4G. In addition to rolling out 5G relays, the entire wireline network will have to adapt to these new radio capacities.

Francesca Bassi

Senior Research Engineer, IRT SystemX

To what extent does the work on 5G by IRT SystemX represent an innovation for the future?

Our work is based on Cloud-RAN architecture, a new paradigm in which the antennas that provide user connectivity use cloud computing resources. To make this architecture a reality, enormous volumes of data must be processed and sent to the cloud. IRT SystemX has provided several strategies that have made this possible. Cloud-RAN will enable the development of dense and easy-to-scale mobile networks. Furthermor, the proximity of antennas to users will optimise connectivity and improve energy consumption.

Improving the agility of design processes for complex systems

In collaboration with Renault Group, Sherpa Engineering, Stellantis and Valeo, IRT SystemX has developed a prototype of connected tools made of software blocks offering digital continuity between system modelling tools and digital simulation tools, in order to improve the agility of design for complex systems.

This innovative prototype aims to strengthen the link between system architecture and digital simulation to improve decision-making in the design of complex systems. The set of tools includes three main modules:

- SimReq: A tool for the formalisation of a simulation request from SySML modelling,
- SimArT: A tool to build executable simulation architecture,
- A cockpit offering customised visualisation of simulation results to help with decision-making.

The efficiency of the tools developed has been demonstrated in an industrial use case for the design of an autonomous car. To create the simulation architecture in SimArT, the institute initiated a standardisation approach for the description formalism of MIC simulation models (Model Identity Card). This was carried out on an international scale in collaboration with the German industry consortium ProSTEP.

INTERVIEWS

Laurent Di Valentin

CAE senior expert, Stellantis

What is Stellantis striving to do in the area of complex system design?

Stellantis aims to develop agile tool-based processes ranging from functional specifications to the validation of cyber-physical systems, in order to respond to the increasing complexity of cross-system links, driven by the needs of electrification, the autonomous cars and connectivity, in an industrial context whichh imposes optimising project development costs. These developments involve several areas: the systematic modelling of systems using SysMl methods, the continuity between SysMl tools and collaborative simulation platforms, and the efficient harmonisation between digital and physical.

What have you gained from your collaboration with IRT SystemX?

Our work with the institute has enabled us to work on standardisation methods within the automotive community. Namely, we have been able to describe the content and context of use of simulation models and event scenarios for the development of ADAS functions. We are currently implementing this work in our internal model management tools and in the development of autonomous vehicles.
We are also investing in future IRT SystemX R&D projects to study, more specifically, the fidelity of system simulation models and to define operational processes for exchanges between manufacturers and equipment suppliers.

Olivia Penas

Deputy Director of Research, ISAE-Supméca

What role did you play in the development of the prototype of connected tools?

We offered scientific approaches to ensure data consistency between systems engineering and simulation models. Three research areas were launched:

- Making tools developd independent from the companies' own engineering methodologies,
- Identifying semantic consistency between the systems engineering models and simulation models, based on ontologies,
- Generate a coherence metric in a MBSE (model-based systems engineering) approach to facilitate collaboration between systems architects and simulation experts based on semantic and structural similarities between functional, product and simulation architectures.

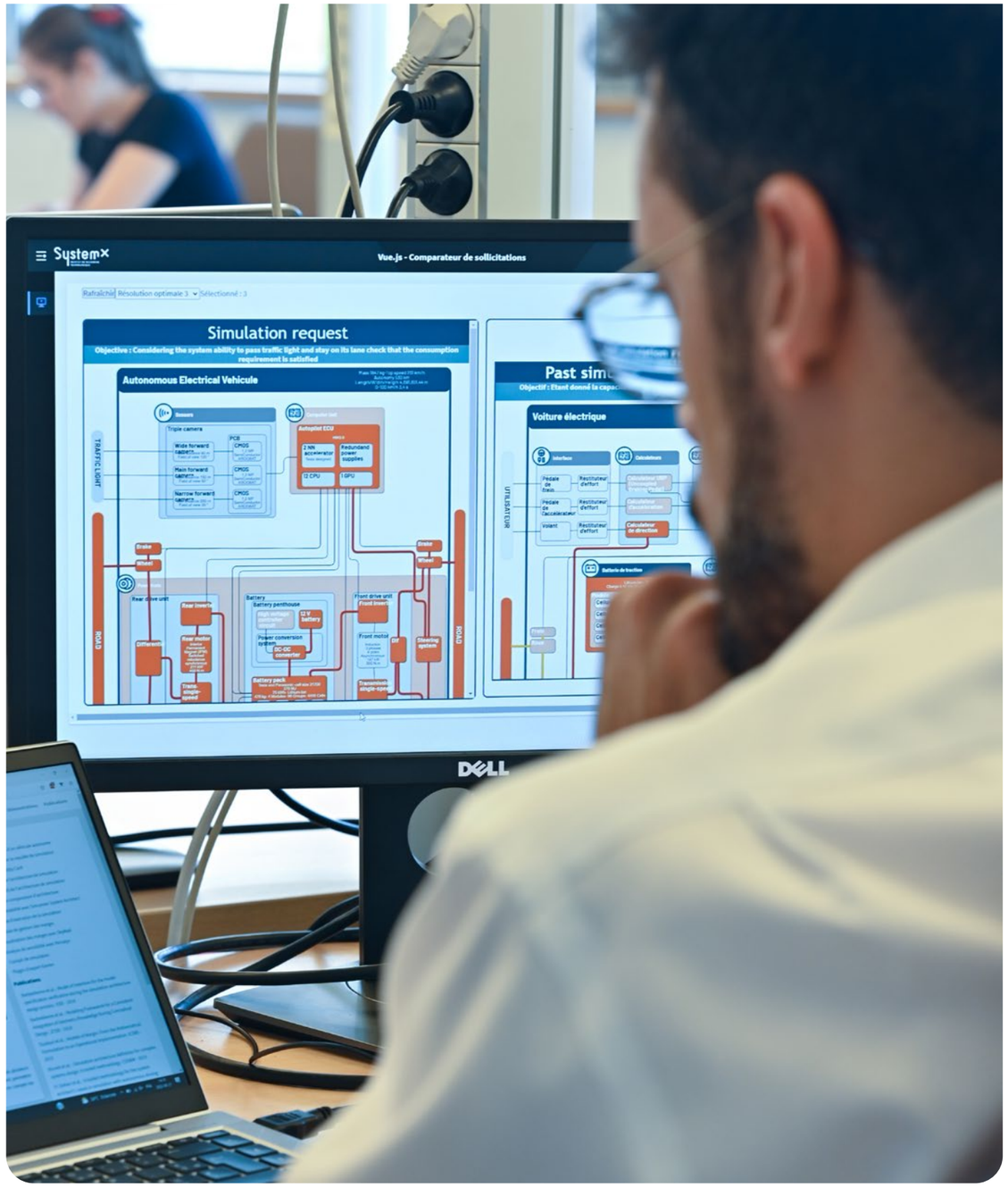
Thanks to the expertise of SystemX research engineers, we were able to prototype and validate the finalised approaches on the autonomous vehicle use case provided by our industrial partners.

What could you say about your collaboration with the institute?

IRT SystemX offers a great working environment to foster collaborative R&D projects. Participating in the AMC project (Agility and Design Margins) project was a fruitful experience from an academic point of view because it helped us to identify precisely the scientific and technological obstacles associated with the project. The results of this collaborative work have been shared with the international scientific community in conferences and scientific articles.

"This work has enabled us to develop, collaboratively, new solutions that strengthen the link between systems architecture and digital simulation, improving traceability between complex systems and digital simulation. The automotive use case on the design of autonomous vehicles has brought to light several obstacles related to the issues studied, demonstrating the feasibility of the tools that were developed."

Mouadh Yagoubi,
Project Manager and Head of Industrial Systems,, IRT SystemX



Designing trustworthy AI-based systems

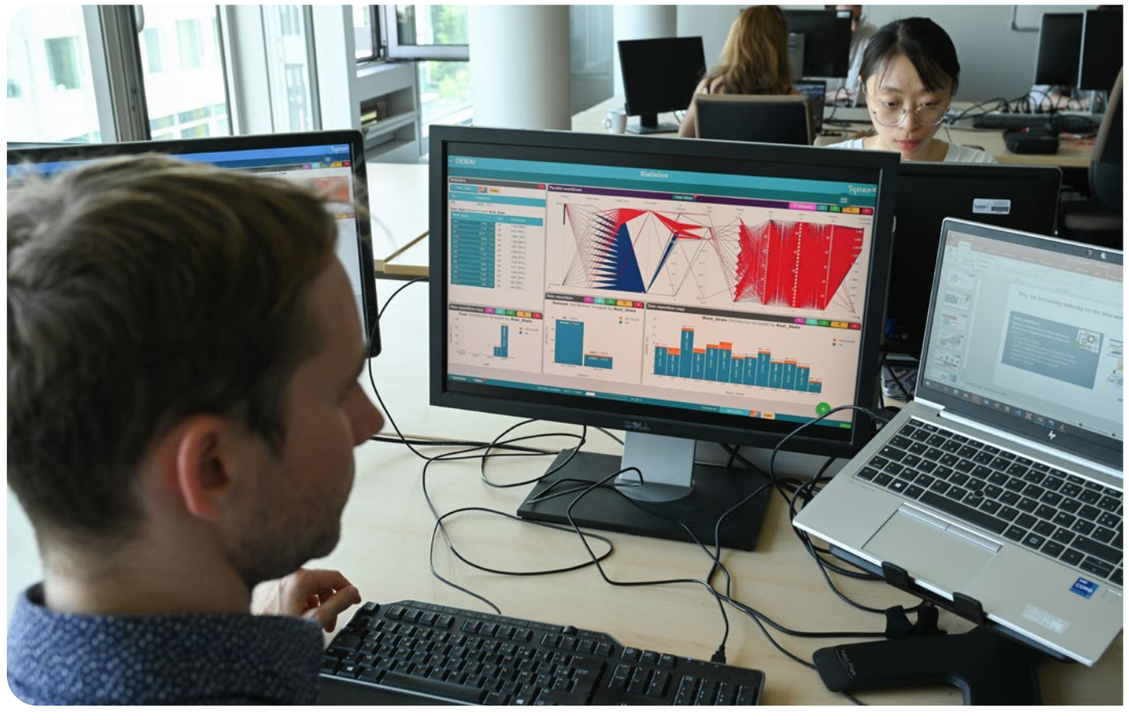
The French collective Confiance.ai has produced an initial version of a methodological guidebook for industrial engineering. The ambition is to design systems that integrate components based on trustworthy artificial intelligence (AI).

The methodological guidebook focuses on embedding the notion of trust (*confiance* in French) in relation to deep learning. In particular, the work carried out has brought to light different tools that can generate, annotate and label data. These tools come with a guide explaining how to control the quality and life cycle of data generated (quality of annotations, management of use contexts, etc.)

Within this framework, Confiance.ai relied on two turnkey tools: DebiAI and Pixano. Together, these tools make it possible to identify data of interest, which is then visualised, corrected or annotated, as well as improve data flow

About DebiAI:
DebiAI is an open source app developed by IRT SystemX which aims to facilitate the development process of automatic learning models, in particular during the project data analysis phase and model performance comparison phase. It has three aims: identifying the biases in the data, comparing the machine-learning model performance, and creating static visual representations of the data.

About Pixano:
Pixano is an open source tool developed by CEA List which provides users with a collection of smart and reusable components to build an image and video annotation tool that is highly customisable. It aims to explore and generate data annotations. This tool includes pre-trained models to facilitate and accelerate annotation at a low cost.



These two tools have been used in an industrial use case led by the Renault Group focusing on the visual inspection of welding joints based on a critical artificial intelligence system. This system had to meet a high level of efficiency and reliability to ensure it would not miss any anomalies and guarantee its robustness under several visual conditions (such as brightness, viewing angle or clearness).

Raphaël Braud,
Research Engineer,
AI Architect,
IRT SystemX

About Confiance.ai
Driven by a group of 13 French companies and research organizations, Confiance.ai is the technological pillar of the Grand Défi "Securing, certifying and enhancing the reliability of systems based on artificial intelligence". Launched in January 2021, the ambition of this 4-year project is to design a platform of sovereign, open, interoperable and sustainable methods and tools that will enable AI of trust to be integrated into critical products and services. It brings together some forty industrial and academic partners.*

INTERVIEW

Antoine Leblanc

Industry 4.0 Expert,
Renault Group

How have you benefitted from your involvement in the Confiance.ai programme?

For artificial intelligence to be trustworthy, it must be possible to qualify it and it must demonstrate optimal operation well over time. There are already several "vertical" AI solutions available to industrial players. These solutions are based on services that are not durable and on approaches that are either not iterative or are very far removed from the actual knowledge of the industrial field. The Confiance.ai programme, of which Renault Group is a member, aims to provide its end users in industry with the tools they need to qualify the data used for learning or the robustness of their algorithms.
There are numerous use cases for a trustworthy AI in an industrial context. AI adapted to operators is imagined as a virtual assistant that can relieve the cognitive load. We believe that a trustworthy AI could lead to a completely new way of looking at the relationship between people and machines by developing new workspaces and by involving industrial players.
Despite advances in the data capture process, the current state of affairs is that not enough data is being used and not enough data operation drivers are being converted into actual industrial systems. Confiance.ai provides a full data management methodology and tools aiming to integrate AI into critical production systems, in order to accelerate their adoption in our industrial environment.

What are the advantaged of using DebiAI and Pixano, and what is the outlook for using these tools within the framework of Renault Group activities?

I have been following the work around data structuring in particular and it has confirmed our belief in the value of data. Well before using machine learning solutions, it is essential for engineering companies to adapt their organisation around data culture: data identification, value definition, data ownership and management.
The primary technological blocks offered by DebiAI and Pixano are very useful because they are accessible and can be integrated into several different work environments to identify data of interest, visualise it and optimise its use.
In the field of data use, we have launched an ambitious plan within the Renault Group's manufacturing department to visualise industrial data in open access at group level. With the Confiance.ai platform, we hope to push this autonomy to more complex levels of data use.


CHESS

Imagining

the digital world of tomorrow

Georges Hébrail
Head of Data Science and Interactions, IRT SystemX

How would you describe the role of the academic world in IRT SystemX R&D projects, particularly in the area of "Data Science and Interaction"?

One of the main missions of IRT SystemX is to build bridges between the academic and industrial worlds to accelerate the creation of value and rollout of digital technologies. Academic laboratories play a central part in our R&D projects. They enable us to work on upstream research topics and overcome scientific obstacles, in order to respond to the use cases brought by our industrial partners. The laboratories are involved in project building workshops to help define the list of scientific challenges to be met. Their support often involves establishing and co-supervising a thesis or post-doctoral work.
As the head of Data Science and Interactions, my role is to fine-tune the degree of involvement of the academic world in this initial stage. The aim is to establish partnerships with top laboratories in their field to achieve the best state-of-the-art for the areas concerned.
The "Data science and interaction" division has been in high demand over recent years. The IA2 programme (Artificial Intelligence and Augmented Engineering - *Intelligence Artificielle et Ingénierie Augmentée*), which hybridises AI models, physical models and knowledge models, together with the Confiance.ai programme, which supports the major national challenge of “securing, certifying and enhancing the reliability of systems based on artificial intelligence”, have alone paved the way for 79 academic collaborations and the funding of 18 theses or post-doctoral research projects.

What scientific structuring measures have been set up within the institute?

The actions of the institute's scientific department are implemented through several measures:

- **Doctoral training**, which is essential to generate knowledge in the areas addressed by our projects. The head of the area of research follows doctoral researchers in their related fields on a quarterly basis. In the areas of "Data science and AI" and "Interaction, uses and knowledge" that I manage, there are about 15 doctoral researchers.
- Aiming to expand the scientific field of our research work, we launched in 2020 a new measure entitled **"Exploratory research"**. Led every year by the research engineers of the institute and on its own equity, this programme enables researchers to carry out upstream research on future topics in collaboration with top-tier academic partners.
- This exploratory research also drives the **roadmaps of the institute's eight scientific and technical fields** (Data science and AI; Interaction, uses and knowledge; Scientific computing; Optimisation, Systems Engineering; Operation Safety; Digital Security and Blockchain; and IoT and Networks). These roadmaps aim to identify our know-how and drive the scientific skills of tomorrow within the institute, making it easier to overcome the priority challenges of our R&D projects.
- Another important action is **publication**. We already have over 640 publications on HAL, the open university archive for high-level scientific articles.
- Finally, we lead **scientific leadership projects** such as the monthly Seminar@SystemX which involves outside researchers, or by leading large-scale scientific networks such as that of the Confiance.ai programme.

The institute has established several engineering training programmes in recent years. What do these involve?

IRT SystemX has developed a new training programme with the support of its top academic partners: **SystemX Academy**. Its guiding principle is learning by doing. This training initiative offers modules that link technological components in line with the institute's scientific and technological fields and their hybridisations, with a theoretical component led by our academic partners.
This offer is available internally through the Passport@SystemX initiative, which aims to extend and develop the skills of our research engineers. Outside SystemX, our offer is aimed at the industrial world by reinforcing skills in cutting-edge sectors. For example, we have launched a continuing education programme in the area of the industry of the future together with the University of Paris Dauphine-PSL.

Addressing the cybersecurity challenges of connected and intelligent transport systems

In collaboration with Airbus, Prove&Run, Renault Group, Stellantis and Valeo, IRT SystemX has designed a new platform: CHESS (Cybersecurity Hardening Environment for Systems of Systems) for Automotive. It aims to validate the cyber defence mechanisms of modern car architectures. Through this platform, the institute has developed an intrusion detection and prevention system: IDPS.

The system is made of software blocks:

- Placed on-board the vehicle, these blocks log events to detect any indications of intrusion, decide on preventive measures and warn the manufacturer's information system. Detection algorithms obtained via machine-learning are supplemented by model-driven design rules. They respect response time constraints while minimising on-board computing resource consumption.
- When integrated into the manufacturer's information system, these software blocks collect warnings reported by the vehicle to help find the cause of incidents by using historical data (big data).

The efficiency of this software chain has been validated by a dedicated library of attacks.

The institute's work has demonstrated the importance of IDPS to ensure the security and operational safety of vehicle functions. The results are currently in the industrialisation phase.

"The CHESS for Automotive platform provides advance access and isolation control functionalities and a powerful attack detection engine connected to a security operation centre (SOC) to offer concrete answers to security incidents."

Witold Klaudel,
Project Manager, IRT SystemX

INTERVIEW

Blaise Hanczar
Professor, IBISC laboratory – University of Evry Paris-Saclay

Why did you decide to partner with IRT SystemX on the detection of anomalies in automobile systems?

The University of Évry has been working with IRT SystemX for several years. The institute provides a unique collaborative environment that brings together the academic and industrial worlds and covers a wide range of research areas. In this environment, we wanted to put our machine-learning expertise to use in detecting anomalies in the automotive sector.

What were the results of your collaboration?

Involving SystemX enabled us to work with experts offering very different skills and backgrounds and, thus, to enrich our methodologies. The approaches to detecting anomalies that were developed have been applied in a very concrete way in the field of cyber security. Looking further ahead, we will also be able to apply them to other sectors.

Having a dual impact on both science and industry

Together with the Centre for Scientific Management (Mines Paris - PSL), the institute has conducted a new study that seeks to qualify the nature of the relationship between science and industry as organised and led by IRT SystemX within its ecosystem.

The results of this study have made it possible to define the IRT SystemX business model as a "simultaneous dual impact research model". Its R&D projects generate impacts simultaneously for its industrial and academic partners. The work has shed light on original types of activity at the crossroads between science and industry, progressively developed by the institute and central to the dual impact process. For example, SystemX has developed the ability to identify common challenges faced by several partners or even to highlight new disciplinary corpus to be explored and structured.

"IRT SystemX activities concern multidisciplinary fields and cross-sector topics. The institute has developed the unique ability to articulate these two dimensions for the benefit of the academic and industrial worlds."

Patrice Aknin, *Scientific Director, IRT SystemX*

INTERVIEW

Agathe Gilain
Research Pofessor, Centre for Scientific Management, Mines Paris - PSL

Why have you placed IRT SystemX at the heart of a study on dual impact?

When we started, IRT SystemX hypothesised that its R&D projects would enable interactions between scientific and industrial partners, generating scientific and industrial advances for modern topics of transformation. However, according to the literature, such "dual impact RTOs" are rare. Most of them are confronted with the double constraint that science and industry can have on each other. Studying SystemX, its internal workings and its projects gave both our team at Mines Paris - PSL and the institute's team the opportunity to model the way an RTO (Research and Technology Organisation) can have a dual impact across both industrial areas and academic disciplines using C-K theory.

What are the main strengths of the institute's research model?

IRT SystemX has developed measures to enables various forms of science-industry relations to have this dual impact. In addition to its exemplary knowledge of scientific disciplines and industrial situations, these measures help to clarify the unknown of each partner (technologies not yet imagined, markets not yet considered, technological and scientific knowledge, unavailable markets, etc.) to progressively build common unknowns to be explored, with the potential to even create new scientific disciplines.
These are rolled out into projects that are adapted to the nature and intensity of the unknowns to be managed.

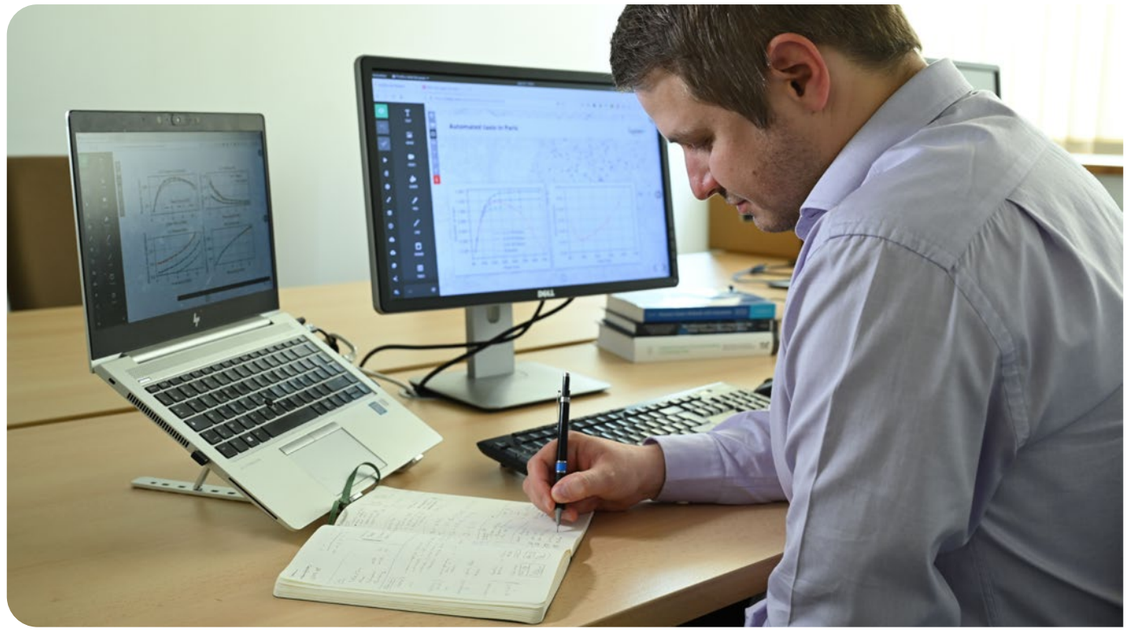
In your opinion, how will this dual impact research model evolve in the coming years?

Faced with the many scientific and industrial unknowns of modern transitions, dual impact research is a major challenge that calls for the development and expansion of RTO models such as that of SystemX. This could be achieved by sharing management tools or with new solutions to increase the value of the knowledge that is generated by projects.

Planning mobility and logistical infrastructures and services

In collaboration with MOIA (the Volkswagen Group brand for new mobilities), Renault Group and SNCF, SystemX has rolled out simulation chains aimed at sizing and evaluating new mobility and logistical services. The work carried out has made it possible to offer new algorithms for the management of shared taxi fleets and to consolidate urban logistics flows.

With the help of the MATSim open source framework, the institute's teams have standardised the implementation of large-scale multi-agent transport simulations dedicated to the planning of transport systems. A synthetic population model for France, i.e. a digital representation of the population, has been created. Several use cases for different regions (Île-de-France, the cities of Lyon, Nantes and Rouen) have been instantiated to optimise the management of a shared taxi fleet and implement an infrastructure for a taxi robot service.



INTERVIEW

Lóránt Tavasszy

Professor,
TU Delft

What are the scientific challenges that last mile delivery services face today?

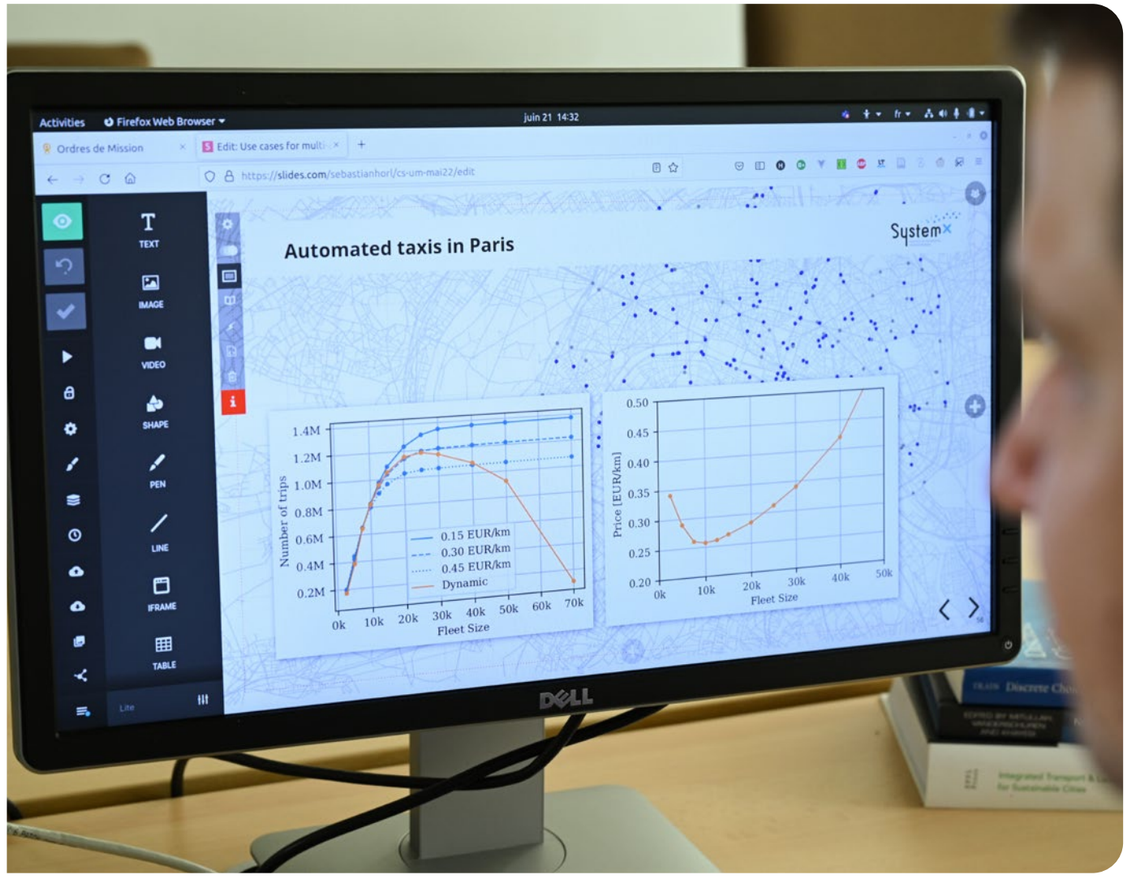
The practical challenges of city logistics in sustainability terms are obvious for all stakeholders. There are many concerns about traffic congestion, delivery drivers without social security, the lack of safety for cycle couriers, deliveries taking up street space and causing air pollution. Following the pandemic, e-commerce has accelerated, giving rise to new services like instant fulfilment, crowd-shipping, product pick-up and return, and omni-channel delivery. Curbing the negative effects of logistics is very difficult. Problems are all intertwined, there is no single solution, and policy instruments are obsolete or inadequate. The only way forward is to make incremental improvements based on transparent evaluations and an agreement between all stakeholders on innovations.

How did the work carried out in collaboration with IRT SystemX enable you to meet these challenges?

In order to solve these issues, SystemX and TU Delft are collaborating to create digital twins of city logistics: decision-support systems that measure problems, interpret them with models and offer community-based management approaches. Together with the LEAD consortium partners, we have developed a flexible digital twin, based on a library of models which can be applied to different types of cities. We are now halfway into the project and will be validating and testing the digital twin on living labs in different cities in Europe, including our local partners The Hague and Lyon.

Imagining the digital world of tomorrow

> *We have defined mobility scenarios in line with actual demand and future policies to design mobility services that are able to meet energy needs and challenges.*
>
> **Sebastian Hörl,**
> *Research engineer, IRT SystemX*



INTERVIEW

Eike Bethmann

Head of Strategy,
MOIA GmbH

What are the major challenges facing mobility operators and services today?

The biggest challenge for ride-share operators like MOIA is to identify the underlying mechanics of its constantly evolving mobility system and match them with the requirements of a fast-changing and very young, regulated market. With autonomous vehicles still undergoing testing, we rely heavily on simulation and its analytics to support our decision making.

What benefits do you derive from your collaboration with IRT SystemX?

The collaboration with IRT SystemX enabled our Mobility Simulation team to implement and evaluate cutting-edge optimization algorithms for the simulation of our on-demand ride-sharing fleet. We were able to create a digital twin of our real-world service and assess different service designs, vehicle specifications, or policy implications. Not only did we benefit from the experience of the institute in terms of on-demand dispatching algorithms, but also from their extensive experience in the mobility sector. The specification and implementation of realistic behavioral models in our traffic modeling framework has been a tremendous help to better understand our existing and future service.

Supporting the design of mechanical parts and systems through topological optimisation

In collaboration with the Safran group, IRT SystemX has developed PISCO, a topological optimisation platform driven by the level set method. Thanks to this innovative tooling process, the shape of a mechanical part can be optimized based on previously defined requirement specifications (fracture resistance, vibration levels, etc.).

PISCO draws on a robust tooling process to advance the level set of a mechanical part during the optimisation process. It uses remeshing that fits the part during each iteration with a significant potential for enrichment, making it possible to integrate new optimisation and manufacturing criteria as well as new physical constraints on mechanical performance, for example.

This platform has been applied in academic and industrial use cases. It integrates several functions that consider manufacturing limitations for foundry processes and the ability to manage uncertainties related to industrial requirement specifications. It is currently being deployed in open source and will include a maturity plan for use by the scientific community and to support industry in embedding its use cases.

> *"Different algorithms and design methods have been embedded in the PISCO platform to provide a robust tooling process. Our users have identified the best compromises for optimising the design of mechanical parts."*
>
> **Chiara Nardoni**,
> *Senior Research Engineer, Scientific Computing Architect, IRT SystemX*

INTERVIEW

Grégoire Allaire
Professor, École polytechnique

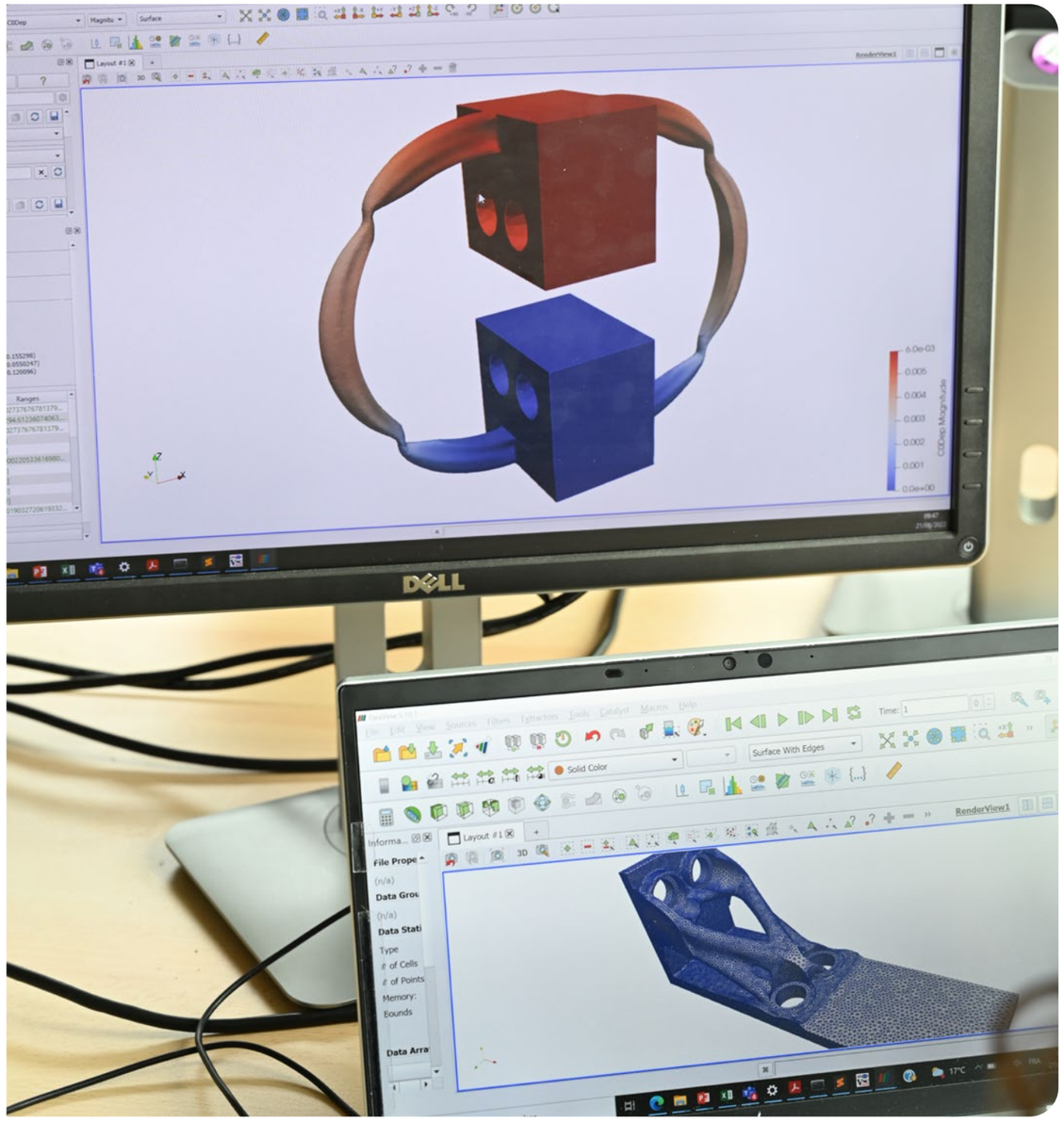
How was the academic community involved in the creation of the PISCO platform?

During the TOP (Topology Optimization Platform) project, led by IRT SystemX, for the development of topological optimisation tools for mechanical structures, industrial partners relied on two academic laboratories: the Centre for Applied Mathematics (CMAP) at the École Polytechnique and the Jacques-Louis Lions laboratory of Sorbonne University and Paris Cité University. Both laboratories had extended experience collaborating with the main partners of the project: Airbus, ESI Group, Renault Group and Safran.

What will its open source release contribute to the field of topological optimisation?

Beyond the prospect of new research and applications, the two academic laboratories involved in the TOP project were striving to develop an open source software platform to unify a large community of users and developers. Joint digital developments are too often restricted to a few industrial users, software blocks usually cannot be reused for other applications. The PISCO platform will help reverse the current trend by offering a durable and stable maintenance for the computerized implementation of shape optimisation algorithms.

Imagining the digital world of tomorrow



INTERVIEW

Christian Rey
Emeritus Expert, Safran

What design issues does the PISCO platform solve?

In the upstream design phase, the PISCO platform makes it possible to optimise the shape of various mechanical parts by considering complex requirement specifications that include numerous manufacturing constraints and requirements to control the uncertainties of operational conditions. It aims to respond to a strategic challenge faced by industry: reducing the weight of mechanical parts. To achieve this, we are optimising the shapes of mechanical parts, using as little material as possible, tailored to need, all the while guaranteeing performance.

What have you gained from your collaboration with IRT SystemX?

Collaborating on the TOP project had a strong leverage impact on the development of the PISCO platform. We share the common ambition to capitalise and enhance state-of-the-art academic work thanks to interactions with our renowned academic partners in the field of shape optimisation to enrich the platform. Thanks to our collaboration, we developed tools that will enable us to offer faster and enhanced design in the future, by integrating multi-physics optimisation and additive manufacturing constraints.

Guiding

extraordinary career paths

A framework conducive to doctoral training

Doctoral training is a pivotal mission for IRT SystemX which offers PhD work within its R&D projects. Students with a Master's degree and/or an engineering degree are able to specialise in a promising field through a first research experience and can help solve one or even several scientific obstacles. Supervised by researchers or professor-researchers from our partner laboratories and by a SystemX research engineer, our PhD students grow in an innovative and dynamic environment where they develop expertise in one of our scientific and technical fields. They develop a strong network including industrial players working on topics such as mobility and autonomous transport, the industry of the future, security and defence, the environment and sustainable development, health and digital technologies.
Since its creation, the institute has supported 53 doctoral students and has established structural partnerships with several doctoral schools, such as STIC (Sciences and Technology of Information and Communication) and Interfaces at the University of Paris-Saclay, where SystemX has received “hosting unit” status.

INTERVIEW

Jeet Desai

R&D project: *Topology Optimization Platform (TOP)*

Partner laboratories: *Jacques-Louis Lions laboratory (Sorbonne University), Centre for Applied Mathematics (École polytechnique)*

Dissertation topic: *Topological optimisation in the mechanics of contact, plasticity and damage using a level set method*

Dissertation completed between 2018 and 2021

What are some of the highlights from your experience as a PhD student at IRT SystemX?

I got to be part of an excellent team, and had exceptional pedagogical and scientific leadership from the institute's teams and its industrial and academic partners. This wide range of skills and backgrounds was really enriching, and I learned a lot.

What impact did the institute have on your career?

After completing my PhD, I went back to my home country, India. I want to found a start-up that captures CO2 from the atmosphere. I was able to learn the key skills to do this during my time at IRT, both on a scientific and technical level.

What are you most proud of?

I am most proud of having been able to demonstrate a new mathematical theorem. The environment at IRT is ideal for this kind of research and played an important part in this achievement.

INTERVIEW

Laura Mariana Reyes Madrigal

R&D project: *Human Centered Mobility (HCM) – Anthropolis Chair*

Partner laboratories: *CentraleSupélec industrial engineering laboratory - University of Paris-Saclay*

Dissertation topic: *Leveraging pedestrian mobility in Mobility as a Service (MaaS) solutions: approach to governance and public policy implications*

Dissertation started in 2020

What is your dissertation about?

My thesis studies how to identify mechanisms to create value sustainably with Mobility-as-a-Service solutions. This innovation aims to integrate information and data from multiple mobility services and different infrastructures available in a region onto a single digital platform. This enables users to receive travel information in real time and to pay for and access services that are part of the mobility ecosystem.

Why did you decide to carry out your doctoral studies at IRT SystemX?

I discovered the Anthropolis chair through a researcher at my former research lab where I did my Master's internship in transport and mobility. For me, doing my dissertation with IRT SystemX is a unique opportunity to be involved in both innovation and industry while remaining at the heart of an academic context with the goal of researching MaaS, which I am passionate about.

What do you like best at SystemX?

I like the work environment at the institute, it is so friendly and dynamic. I also like being surrounded by colleagues with different experiences and backgrounds who encourage me to think differently.

Extraordinary career paths

Working at SystemX means being part of a melting pot of innovation located in the heart of the Paris-Saclay cluster, a driving force in the renewal of French and European industry. We build bridges between industry, academia and institutions, and conduct collaborative technological research projects to accelerate the digital transformation of these organisations and to respond to the major challenges of our time. The institute has a bold ambition: increasing the competitiveness of France and French business. Every day, we develop and roll out digital technologies to create a safer, more efficient and more sustainable world for tomorrow. Learn more from the testimonies of six employees and alumni discussing their roles and career paths at the institute:

Loïc Cantat
Head of the Data Science and AI Team, IRT SystemX

I had been working in the industrial field for fifteen years before changing to research. I joined IRT SystemX in 2016 as a technical management coordinator. I have been an R&D manager and head of the Data Science and AI team for three years. I also coordinate the technical and scientific side of the Confiance.ai programme. This is a very important European-level programme. Thanks to the institute, I can be at the centre of scientific and technical developments, where industry and research come together and where topics such as AI can be approached in an innovative way.

Arnaud Kaiser
Project manager, IRT SystemX

I joined IRT SystemX in 2014 as a research engineer with expertise in wireless mobile networks. Working at the institute, I have developed my skills in the area of cyber security for inter-vehicular communication networks and reinforced my knowledge of vehicular networks. In 2018, I was offered the opportunity to take up a project management position. IRT supported me along this path by giving me project management and cross-functional management training, key skills that I did not have before.

Flore Vallet
Researcher, IRT SystemX

During my time working in the Anthropolis chair and on the IVA project (Enhanced Traveler Information), I worked with academia and industry on complementary fields such as optimisation, usability and sociology. I have also co-supervised three dissertations on mobility since 2016. These tasks have been a great step towards getting an accreditation to direct research HDR (*Habilitation à Diriger des Recherches*). The framework of the institute also enables me to work on research topics in sustainable design and the service user, connected to data science methods.

Jeanine Harb
Research Engineer at IRT SystemX from 2017 to 2020, currently Senior Data Engineer at Ubisoft

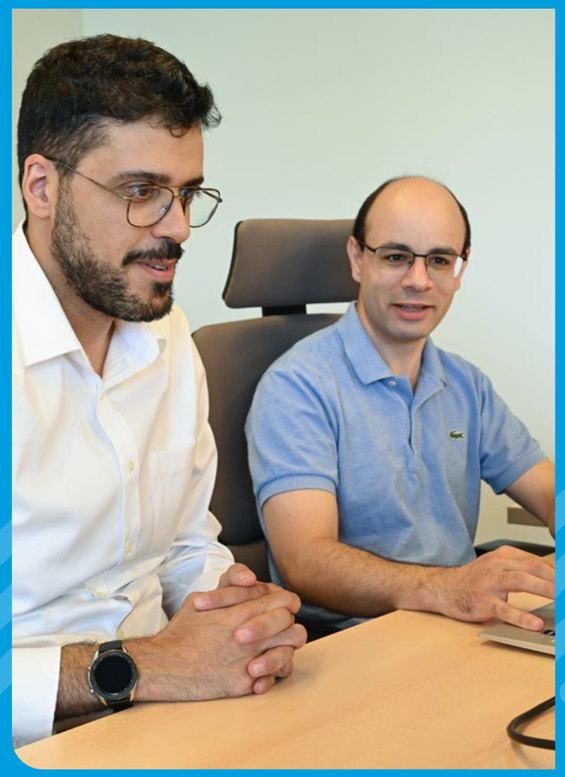
I joined IRT SystemX in 2017 to work on an autonomous train project in partnership with SNCF and Alstom. I am only just now realising the scope of the project, which aimed at reproducing a train driver's point of view using intelligent algorithms. When the project was launched, it was missing its raw material: data! We set up a test train with sensors, built a substantial image database, developed and optimised algorithms, and finally produced our proof of concept. I was also lucky to be able to open up some of the annotated images to the general public to contribute to the worldwide open data effort around applied research. It was very exciting! Thanks to the project, I got to apply AI to a field I was not familiar with. SystemX offers this kind of synergy to everyone who spend time at the institute.

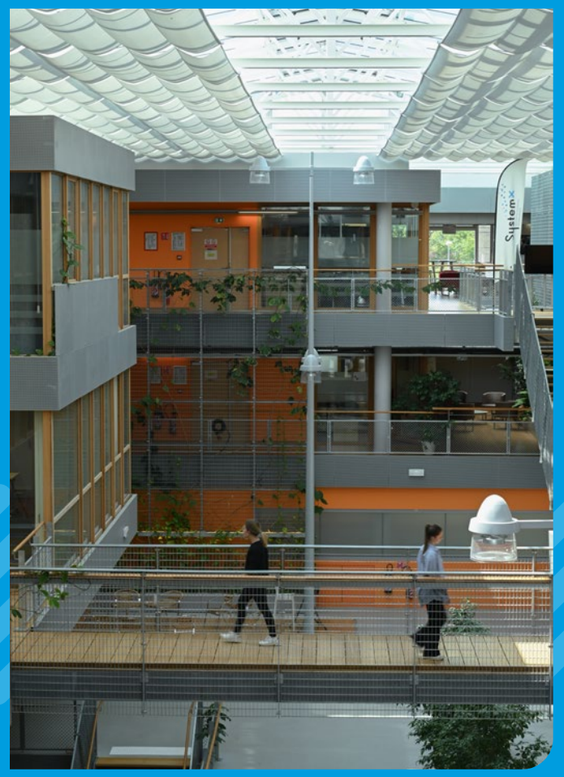
Karla Quintero
Systems Engineering Architect, IRT SystemX

I joined IRT SystemX in 2020 after five years of experience in automotive research. For me, the institute strikes a perfect balance between academia and industry in applied research. SystemX offers a wide range of collaboration options and development into different fields of application, which is so motivating and enriching. Since joining, I have been involved in five R&D projects. I am grateful and proud of the culture of coordination, coaching and collaboration that I have experienced and that I get to share with my colleagues today: we produce quality work while respecting and valuing our resources and human values.

Andreas Hein
Systems Architect and Confirmed Research Engineer at IRT SystemX from 2020 to 2021, currently Professor and Head of the Systems Engineering team at the University of Luxembourg

Working at IRT SystemX, I was able to combine research with more applicative tasks in the fields of systems engineering and systems architecture. I was part of an industrial partner's team as a systems architect. This experience offered me thorough understanding of the challenges linked to systems engineering, enabling me to then identify high-impact research topics. The institute offered me great support in enabling me to lead an exploratory research project in the field of reference architecture instantiation. I learned a lot from this experience which offered me a huge leap forward towards my career at the University of Luxembourg, which I joined in 2021 as a professor and Head of the Systems Engineering team.





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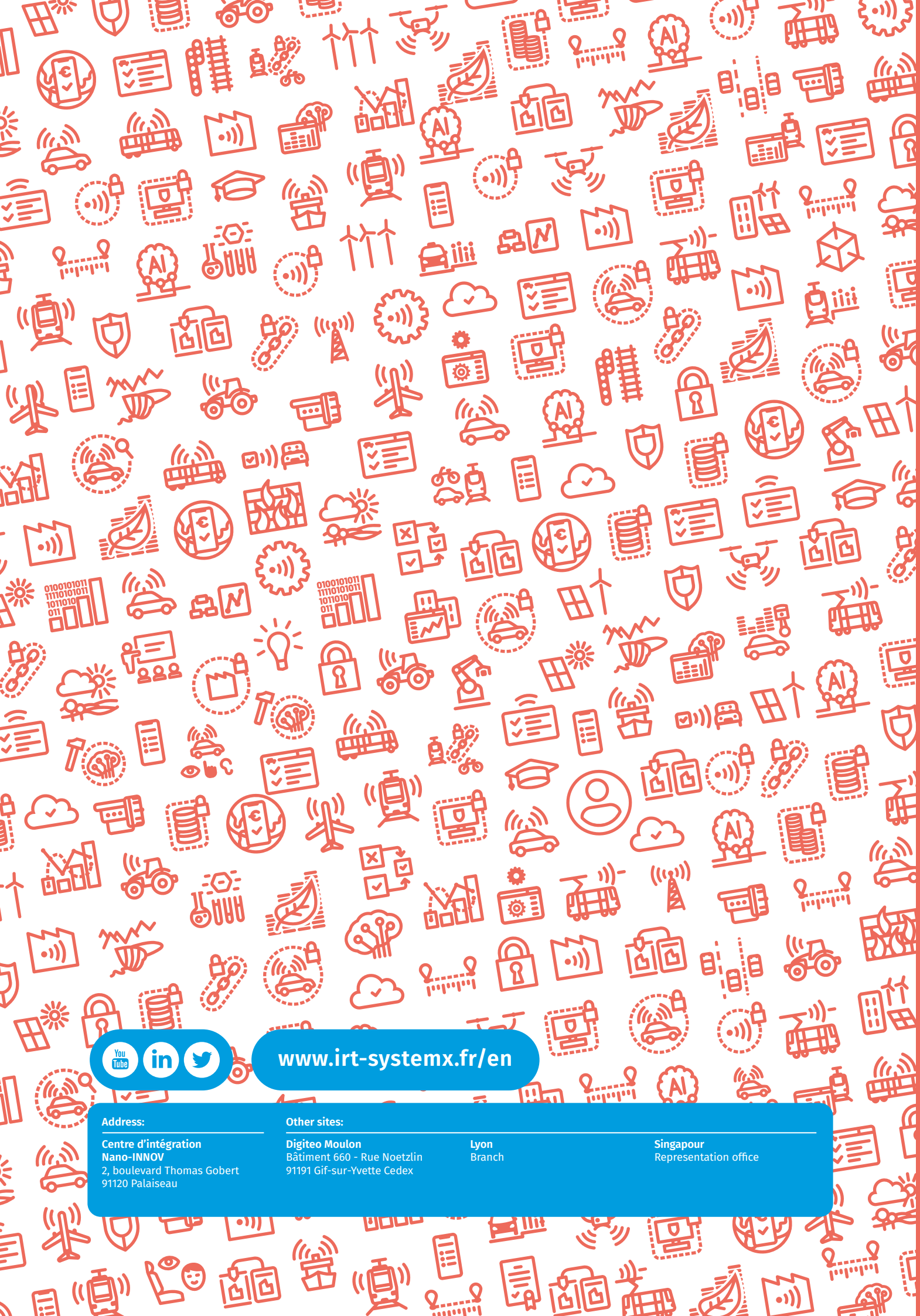

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