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Our teams are driven everyday by our ambition: to imagine and to design the digital world of tomorrow.



Michel Morvan President, IRT SystemX @MichelMorvan

t is with great pride and joy that I present to you the first edition of the Notebooks of Digital Transformation by the IRT. You will discover a selection of our significant results and impacts, obtained in collaboration with our industrial and academic partners, all contributing to a safer, more sustainable and more efficient digital world.

This collection of write-ups seemed to be essential to me, especially in the light of many new challenges that lie ahead of us. Indeed, more than ever, the digital transformation of our societies and businesses is and will have to accelerate. Massive digitalization is essential for French industry if it is to hold its own at the European and global level. It is a real lever for growth and competitiveness and goes closely together with a considerable need for high value-added digital technologies.

I am convinced that France can become

the 'world champion' in the digital transformation of the industry, and that SystemX will spearhead it. Our teams are driven everyday by our ambition: to imagine and design the digital world of tomorrow. Thanks to the pooling together of their talents and those of our partners (major groups, SMEs, startups, research laboratories), our institute has consolidated a critical mass of skills in the fields of analysis, modelling, simulation and decision support applied to complex systems, while building up an unprecedent technological base, which combine various high-level technologies.

Digital technology is at the crossroads of many fields, such that our expertise, which has proven its worth in the fields of mobility and autonomous transport, industry of the future, defence and security, environment and sustainable development, can in fact benefit many sectors more widely. We will therefore be led to broaden our fields of application according to the extent of this digital transition for the society. I am thinking, for example, of health, education, agriculture and the food chains. There is no doubt in my mind that, in the years to come, SystemX will play an essential role in accompanying the industries in the movement by facilitating and accelerating the transfer from science to technology.

Throughout the pages that follow, you will discover the impacts we have chosen to present to you, through testimonials from our teams and our academic and industrial partners. I would also like to personally pay tribute to the work carried out by the men and women who make SystemX what it is, and are the main driving forces that led us to the numerous successes.

Paul Labrogère CEO, IRT SystemX

am pleased to share with you the Digital Transformation Notebooks, which highlights some of our finest achievements since 2012, concrete illustrations of our impact on industry, services and territories.

SystemX finds its strength in its model: our R&D projects involve multiple fields and bring together many different scientific and technological disciplines. In this way, we encourage the crossfertilisation of know-how and we address the use cases of the industry by providing a "system" vision. This positioning is a guarantee of our ability to support major industries, such as aeronautics, automotive and defence, in their digital transformation. We are attentive to the market and the needs of the industry and rely on our skills in eight cutting-edge scientific and technological fields to provide solutions adapted to the problems encountered by our partners. This is how our institute advances research and innovation, by ensuring a permanent increase in the skills of its teams and partners, and by supporting the emergence of new use cases.

Our model has recently been reinforced by the government with an allocation of 35 million euros in two tranches, the first of 25 million euros extending until 2023. This funding is part of the €450 million allocation over five years to the Institutes for Technological Research (IRT) and the Institutes for Energy Transition (ITE), to support industrial innovation and research.

Since 2012, we have been working to make SystemX a reference, both nationally and internationally, in the field of digital systems engineering. We have proved our worth on a European scale with our involvement in several major H2020 projects, including SeColla, which aims at ensuring the digital transition of the manufacturing industry, and LEAD, which is working to create the digital twins of the urban logistics networks of six major cities (Madrid, The Hague, Budapest, Lyon, Oslo and Porto). At the international level, we opened an office in Singapore in 2017, where we are collaborating with Nanyang Technological University (NTU) and major French industrials on themes related to autonomous transport, cybersecurity, artificial intelligence, IoT and blockchain.

IRT SystemX finds its strength in its model: our R&D projects involve multiple fields and bring together many different scientific and technological disciplines.

> Our research is also deeply rooted in the French territories. The vast majority of our R&D activities are carried out at the heart of the Paris-Saclay cluster, which brings together 20% of French research. Finally, in Lyon, we have expanded our R&D activities in the fields of new mobility, energy and digital security, in collaboration with the Lyon Metropolitan Area, renowned scientific centers, industrial players and the region's competitiveness clusters.

> Our ambition by 2025 is clear: to help our partners to master the key technologies for a successful digital transformation. To achieve this, we will continue to build on what makes us original and there is no doubt that our research projects will be very impactful for the industry in the months and years to come.

You will discover, through tangible results presented in this document, our ability to imagine and design the digital world of tomorrow, in close collaboration with the academic and industrial worlds. I hope you will enjoy reading it!



IRT System ma and



Abdelkrim Doufene Strategy and Programs Director, IRT SystemX

How does SystemX meet the needs of the digital society?

In collaboration with its partners, our institute prescribes innovative solutions with regard to industrial constraints, while relying on a unique multi-skilled and multi-disciplinary skills map. The IRT plays a value-creating role by pooling together "know-how" and anticipating future changes, in the service of the digital society.

What will be the priority issues addressed by the institute in the years to come?

We rely on four driving forces to identify the priority issues to be addressed within our project:

- societal needs and environmental and regulatory guidelines,
- roadmaps of the industrial partners of the institute and technological developments,
- recommendations from the academic world and scientific challenges prioritised,
- and lastly, the internal skills and platforms developed within SystemX.

What indicators do you use to arbitrate the projects to be carried out?

We prioritize issues with the greatest potential for economic, technological and societal impact. Our projects must also have at least one of the following three dimensions: resilience (remaining operational despite environmental changes), sustainability (producing sustainable developments favoring short energy cycles at low cost) and sovereignty (ensuring the geographical and/or economic subsidiarity of new developments and their technological independence).

The Digital Transformation Notebooks #1



IRT SystemX offers a distinctive model for the industry to accelerate the impact and transfer of technology.



Bruno Foyer Research and Technologies Director, IRT SystemX ©@BrunoFoyer

What is an impact for SystemX?

We respond to the scientific challenges of our partners to help them innovate and optimize their operational use cases. Our objective is to create impact by transferring to them, at the end of an R&D project, the digital assets produced. These results can take several forms: proofs of concept or specifying prototypes, scientific studies, innovative data sets and algorithms, and operable and valuable technological platforms.

How is the institute structured to generate the most impact on its partners?

We have established a matrix organization to facilitate the synergy of skills. Our teams are structured around eight areas of expertise assigned to one or more R&D projects. This 360° vision enables them to direct their work in a shared manner. One of the institute's assets is its "Software & DevOps" engineering team, which assists teams in producing proofs of concept or technological platforms to turn them into operational and transferable products.

How are the impacts exploited and valued by the institute's teams and partners?

The impact production process is supervised by a methodology that is at the heart of the institute's digital governance. This follows a process of increasing maturity, from the creation and evaluation of scientific or technological solutions to the development of operational proofs of concept, which in some cases give rise to reusable platforms. These platforms can be further engineered, either by our partners or via a dedicated structure. Since 2014, SystemX has developed more than 200 assets, almost half of which have been assessed as relevant or high potential!





Meeting the challenge of validating the autonomous vehicle

The MOSAR platform (Methods and Tools for Operational Safety Assessment and Robustness Analysis of Autonomous Vehicles) offers a methodology and a suite of tools for designing and validating the safety of autonomous vehicles through the use of a database of scenarios.



utomobile manufacturers and equipment **H**suppliers are faced with a major scientific challenge: to demonstrate the safety of the autonomous vehicle in a complex environment, generating a very large number of driving situations in which it must react safely. The MOSAR platform is the result of the IRT SystemX collaboration with leading French automotive players such as Renault Group, Stellantis, Valeo, AVSimulation and Expleo. This platform provides unique expertise for evaluating the behavior of an autonomous decision-making system based on scenarios derived from driving, accident statistics or expert assessments.

MOSAR is available in three modules:

- 1- The management of scenarios representative of the situations encountered by the autonomous vehicle: the platform provides its users with capabilities enabling the management of a library of reference scenarios and the statistical analysis of situations for the design, validation and approval phases.
- 2- The combinatorial generation of test cases, the objective of which is to assist in the creation of a validation plan and to generate simulable test cases by exploiting the variability of the scenario parameters to represent the diversity of situations encountered by the vehicles.
- 3- The execution of tests in simulation and the analysis of the results and the behaviour of the autonomous system under test

FOCUS

mosar

The international influence of the MOSAR platform

• Renault Group and Stellantis now wish to exploit R&D work developed around the MOSAR platform for their operational needs and federate European or international players via their alliances around a common reference method. It is with this objective in mind that the creation of a dedicated legal entity is being studied.

- The MOSAR platform, referenced by the OICA (International Organisation of Automobile Manufacturers), has already aroused the interest of renowned players such as BMW, Toyota Europe or the JAMA (Japanese Automobile Manufacturers Association). Usage tests are currently underway.
- Joint work is being undertaken via the ASAM (Association for Standardisation of Automation and Measuring) and the ASC(S (Automotive Solution Center for Simulation) association, which includes BMW, Daimler Chrysler, Porsche and Audi, to converge on the simulation method and the use of the Open Scenario standard resulting from the German Pegasus project.



How does the French automotive industry approach the challenge of the safety of autonomous systems?

Since the launch of the "France Véhicules Autonomes" programme, coordinated by the Automobile and Mobility sector (PFA), SystemX has played a central role in the field of system security.

Securing an autonomous transport system encompasses several aspects requiring specific approaches depending on the type of system, its environment, operational conditions and the safety levels to be achieved. In particular, it is necessary to:

- secure the system against internal malfunctions ("safety"),
- protect the system from external attacks (cyber security or "security"),

 avoid erroneous decision making by the system, due for example to a misinterpretation of its environment by the system through its sensors ("Safe Functionality" or "Safety Of The Intended Functionality"),

 Prevent the driver or operator from misusing the system (potentially foreseeable misuses).

What role could the MOSAR platform play and what are its main assets to meet this challenge?

For the demonstration of the security of such a system, it is essential to have common methodologies and shared repositories, in particular a catalogue of relevant scenarios. With



The MOSAR platform offers its users a management of relevant scenarios for demonstrating the safety of autonomous vehicles. Its development was made possible by the successful pooling of scientific and technical skills between IRT SystemX teams and its partners.

Erwan Revert, Software & DevOps Architect, IRT SystemX

INTERVIEW

Jean-François Sencerin,

Director of the NFI/PFA Autonomous Driving Programme

the introduction of the ISO SOTIF 21448 standard, relating to the implementation of security standards for driver assistance systems, the capitalisation of existing relevant scenarios in a common database has become essential. In this context, SystemX has built a library of scenarios, following a standard data format, and by developing the MOSAR platform. This platform supports a software application called "Scenario Manager" which, in Software As A Service (SaaS). offers features to manage these scenarios. Based on a common data model, MOSAR allows SystemX partners to describe their scenarios via a web interface, within a secure and shared library. These scenarios will then be used for design and simulation activities, validation or approval.

How do you plan its international development?

The results have already been submitted to the various standardisation bodies which are in the process of defining the first standards in the field, to the national and international working groups in charge of future regulations, to the PFA, JAMA (Japanese Manufacturers Association) or the European Commission and the VDA (German Association of the Automotive Industry). The aim is to place French players at the heart of the construction of the new vehicle ecosystem and autonomous mobility.





Contributing to developments in the field of mechanical systems design

SystemX innovates in the field of mechanical systems design through model reduction and multi-physics optimisation with the DCIDE (Dashboard for Collaborative Innovative DEcision) software platform and the ReCUR (CUR Regression) calculation module, developed with the support of Renault and ESI.

hese complementary technological bricks support design teams of mechanical systems. It gives them access to an interactive, system design teams by collaborative and decentralised Man-Machine Interface for the visualisation of results and the piloting of calculation infrastructures (DCIDE), and by offering them innovative model reduction methods (ReCUR). The combination of DCIDE and ReCUR makes it possible to drastically reduce calculation times, while maintaining exhaustive representativeness of simulation results.

Sector.	176.2

This solution was used by Renault Group to find, in just a few computation iterations, the optimization of the body model of the Renault Talisman, instead of months to do so.

Jean-Patrick Brunet, Software & DevOps Architect, IRT SystemX

FOCUS

An extension of DCIDE's work within the AMC and ISC projects

The IRT SystemX Agile Margin of Design (AMC) project used DCIDE to accelerate the development of its SimArt platform (Simulation Architect Tool). Its ambition: to strengthen collaboration between all the players in the design chain of complex systems by means of a tool connected to the infrastructure and thus guarantee an optimal search for efficient solutions. The Collaborative System Engineering of Complex Systems (I(SC)²) project completes this collaborative platform by proposing new decision support functionalities for system architecture choice: visualisation of preference models for architecture evaluation and choice, functionality for comparing architecture scores, visualisation of the uncertainty of the parameters involved and the impact of its propagation.

Eric Landel,

Senior Consultant in the field of numerical simulation, leading expert in modelling and numerical simulation from 2011 to 2020

What does the DCIDE platform bring to the field of mechanical systems design?

The DCIDE platform enables fast and efficient parametric vehicle optimisation studies to be carried out, while integrating numerous variations (thickness of structures, nature of materials, etc.) and obtaining the best possible solution. At present, this objective is achievable, but within significant and binding deadlines. Thanks to the model reduction methods integrated in DCIDE. calculation times are reduced and combined with powerful visualisation tools.

What role did Renault Group play in its development?

As a partner of SystemX, Renault Group has invested in the development of the DCIDE platform by providing its industrial point of view on the problems and use cases to be resolved, and by contributing to the methodological development of the ReCUR model reduction method

How do you project the evolution of this platform in the coming years?

The DCIDE platform is currently a demonstrator that allows the potential of model visualisation and reduction methods to be exploited in order to converge towards optimal solutions. Renault Group is pursuing methodological research work on the ReCUR platform in order to equip itself with an efficient industrial tool, at the same time as the design of the mechanical systems of its vehicles.



Accelerating risk analysis through models

It is based on model-driven design and offers dynamic modelling of failures.



The OpenAltaRica platform is the result of a very rewarding collaboration with the academic sector, and more particularly with the AltaRica association. dedicated to the development of model science and modelling for systems engineering. The work carried out reflects the institute's ability to ensure the transfer of academic work to the industrial sector.

INTERVIEW



Antoine Rauzy

President of the AltaRica Association, Professor at the Norweaian University of Science and Technology (NTNU)

What did OpenAltaRica bring to the operational safety teams?

The advances are considerable. The OpenAltaRica platform has created a real pool of scientific and technical knowledge in the field of model-based risk analysis. Our work has led to significant progress in the area of operational safety and has made France a world leader in this field. Our research has also led to the development of effective solutions for carrying out dependability studies of complex systems. The platform has positioned itself as a reference on the subject and as a tool that can be directly industrialised. Finally, we have, on our own scale, supported the increase in skills of the operational safety community thanks to the numerous dissemination activities we have carried out.

SystemX has developed OpenAltarica, a reference software platform to implement tools and methods for risk analysis of critical complex systems (aeronautics, railways, nuclear, etc.).

Systems are becoming more and more complex and their safety is becoming a major concern for industries. IRT SystemX has developed the OpenAltaRica platform to support engineering teams in the design of the future systems, integrating the safety constraint. This reference platform provides access to a high-level modelling language - AltaRica 3.0 - dedicated to risk analysis and based on the Model Based Safety Assessment (MBSA) method.

OpenAltaRica is thus positioned as close as possible to system descriptions and could ultimately lead to a reduction in costs related, for example, to design or maintenance activities, which are frequently impacted by the risk of errors. Integration with other fields of engineering is also simplified for better information sharing between all stakeholders. Since its availability, the OpenAltaRica platform has been downloaded more than 400 times by the community of its users. It is operated by renowned manufacturers such as Apsys, Thales and Safran.

Michel Batteux, OpenAltaRica Project Manager, IRT SystemX

How did you contribute to the development of this platform?

Behind OpenAltaRica, there is a team on a human scale. The exchanges were very rich, we all brought theoretical solutions and participated in the development of the platform and in the conduct of experiments. For my part, I brought my scientific culture and my general knowledge in fields related to mathematics, systems engineering and operational safety. I also contributed to the platform's development activities.

What do you take away from your collaboration with IRT SystemX?

I am convinced that an intermediary between the academic world and industry is essential to disseminate the results of scientific research to the industrial world on the one hand, and to convey the needs and expectations of industrialists to researchers on the other. IRT SystemX has played this role throughout the development of the OpenAltaRica platform.



Optimizing the cybersecurity of system architectures with the CHESS platforms

As the result of five years of collaboration with nine industrial and academic partners. CHESS is a platform dedicated to the development, evaluation and integration of cyber security solutions for hyper connected computer and cyber-physical systems.



CHESS is one of the few platforms, at national and European level, entirely dedicated to cybersecurity, which is secure, trustworthy, comprehensive, neutral and open to all. It offers a wide range of hardware and software capabilities, together with a range of security services based on cutting-edge human expertise, in order to respond rapidly to the needs of cybersecurity research, innovation and training. We invite French manufacturers wishing to assess the vulnerabilities of their systems, their protection strategies and/or their innovative solutions to test it.

Reda Yaich, Digital Security and Networks Team Leader, IRT SystemX

he Institute and its partners (CEA, Télécom SudParis/Institut Mines-Télécom, Airbus, Airbus Defence & Space, Bertin IT, Engie, Gemalto, Prove&Run, Thales) have developed, in collaboration with ANSSI¹, a "secure and trusted" environment dedicated to the integration, evaluation and reinforcement of the cybersecurity of the systems of the future (connected vehicles, industrial IoTs, smart grids, etc.), during advanced scenarios. Named CHESS², this platform offers a complete hardware and software environment for analysing the future systems, identifying security flaws, modelling and simulating attacks and testing protection strategies and innovative defence technologies (moving target defence, segmentation, isolation, authentication, homomorphic encryption, etc).

Certified by the CoFIS³, it also offers a rich catalogue of cyber attacks on IT (Information Technology) and OT (Operational Technology) networks, as well as an environment dedicated to cyber awareness and training. The CHESS platform is also the venue for the ANSSI's national selection to represent France in the European Cyber Security Challenge, organised each year by the European Cybersecurity Agency (ENISA). The platform is also made available to companies as part of their

mission to raise awareness and train their emplovees in cyber risks.

CHESS aims at becoming a French reference platform in industrial cybersecurity. Constantly enriched by new building blocks, which may take the form of software, attack scenarios, life generators or detection tools, and fed by SystemX projects, the platform aims at building a range of services dedicated to cybersecurity and open to all in order to encourage the sharing of expertise and knowledge between industrialists and academics.

Applications of the CHESS platform for the transport sector

The CHESS platform enables, among other things, the modelling, simulation and emulation of complex cyber-physical infrastructures for the purpose of evaluating and enhancing digital security. This platform has aroused the interest of several industrial and institutional partners, including Naval Group.

............... FOCUS

As part of the work on the CHESS platform, a thesis on "Simulation of activity and attacks: application to cyber defence" (Pierre-Marie Bajan - IRT SystemX, Télécom SudParis) was devoted to the development of a new networked simulation method to create an environment for evaluating security products and services. This thesis was awarded a "Best Paper Award" at the 2018 edition of the ICIMP conference (International Conference on Information Communication and Processing).

Why and how does Naval Group position itself in the field of industrial infrastructure security?

Industrial infrastructures are an integral part of the areas concerned by cybersecurity for Naval Group. It is at the very heart of our strategy: we integrate cybersecurity into the entire life cycle of the ship, from design to maintenance, and this includes the entire ecosystem, of which industrial infrastructures and the supply chain are part. Naval Group also ensures the security of its own infrastructures and information systems, at its sites in France and abroad.

What are the prospects for the use of the CHESS platform by Naval Group?

We discovered CHESS as part of the Secure Future Port and Ship of the Future (PFS) project, which we are carrying out with SystemX and which deals with cybersecurity in the maritime domain. It opens up a new playground for the CHESS platform, which already feeds on various use cases in the fields of smart grids,

FOCUS Ground-breaking field survey by the IRT SystemX among French SMEs and VSEs that were cyber-attacks' victims

For almost three years, SystemX surveyed around 60 companies, mainly French VSEs and SMEs, which were victims of successful cyber attacks. Objective: The objectives were to quantify the real impact of cyber-attacks in France, to develop models for calculating the costs as well as a company's exposure to risk.

From this unpublished study, particularly interesting figures emerge which shatter two commonly accepted beliefs: the number of successful cyber



Patrick Hebrard

Cyber Research and Innovation manager, Naval Group

smart cars or Industry 4.0 - subjects on which we are also working with SystemX through the H2020 SeCoIIA (Secure Cooperative Intelligent Industrial Assets) project.

Naval Group has invested heavily in cybersecurity in recent years. We are now bringing all our expertise. and experience for the benefit of the PFS project. The collaboration will accelerate our cyber innovations on both sides and in particular around CHESS. The project is only just starting and we will study the functionalities that can be possibly reused (catalogue of attacks, knowledge about security probes, etc.). Several other partners have joined

the project to develop new use cases, in the SystemX premises in Saclay. This will be an opportunity for us to enrich each other with all our know-how and to capitalise on our different platforms.

attacks, of the order of 2 to 5%, proves to be much higher than the estimates made public, while the average cost of cyber attacks proves to be much lower than assumed and is evaluated in thousands of euros. This study has made it possible to make small French structures widely aware of the cyberrisks and basic measures to be implemented. A study was also conducted with insurers to better control cyber risk throughout the value chain and its transfer to the insurance industry.

^{1.} National Agency for the Security of Information Systems.

^{2.} Cybersecurity Hardening Environment for Systems of Systems - Simulation and Analysis for Cybersecurity Assessment of Systems Architectures.

^{3.} Comité de la Filière Industrielle de la Sécurité.



Responding to the security and "privacy" issues of the connected vehicle

The safety of the connected vehicle is one of the major technological challenges of tomorrow's mobility. With its partners, the institute has developed a Public Key Infrastructure (PKI) adapted to the complexity of cooperative ITS (intelligent transport systems) to secure V2X communications, i.e. communications between vehicles and between vehicles and their environment, while auaranteeing user privacy.

This PKI is a trusted third party that issues digital certificates to the various entities in the road network (vehicles, roadside infrastructures, etc.) to guarantee integrity and authenticity of the messages exchanged between them and thus protect the system from external attackers. The solution implemented handles the entire chain for ensuring V2X communications, from the management of pseudonymised certificates to their implementation in a software stack embedded in the vehicle or roadside infrastructure. The PKI developed has been further standardised by SystemX and its partners in Europe at ETSI. It has been deployed in the framework of two ambitious national projects:

- The SCOOP project for the pilot deployment of cooperative intelligent transport systems, including a fleet of 3,000 vehicles in France integrating the PKI protocol. The Paris-Saclay Autonomous Lab experiment with several on-board equipment that integrates the PKI protocol.
- The Paris-Saclay Autonomous Lab experiment with several on-board equipment that integrates the PKI protocol.



The PKI technology developed by Atos with the support of SystemX IRT is particularly mature. It secures V2X communications, to protect cooperative ITS against cyberattacks and at the same time meet the associated privacy and interoperability challenges. Our work will continue with the development of a technology to detect malicious behaviour among PKI-certified entities.

Arnaud Kaiser, Project Manager, IRT SystemX.

INTERVIEW



Coralie Héritier, Managing Director, IDnomic (Atos Group)

Why work with SystemX to improve the security of connected vehicle communications?

Our cooperation with SystemX started in 2014 with the ISE (ITS Safety) project. We immediately perceived the adequacy of our technological expertise with the needs of the project, but also identified the technical obstacles that would enable us to enrich our expertise and, above all, to participate in the development of a platform with very concrete applications in a future field, prefiguring the work on the safety of future autonomous vehicles. Another major interest of the ISE project was the fact that it was part of the search for conformity with the European C-ITS standard.

What results has this collaboration brought you?

- The first project resulted in a demonstrator which
- was then used in the framework of a major European
- project SCOOP, aimed at deploying real-time ITS safety

- on roads. It has spun off others, enabling further
- explorations and demonstrations in terms

of scaling up, hybrid connectivity, continuity of service across geographies, and detection of malfunctions. Another major result for our company: great commercial achievements. In particular, the know-how we have acquired has enabled us to win the contract awarded by the JRC (the European Commission's science and technology department) for its ITS security platform. Finally, this cooperation has been very rich on a human level. The emulation within SystemX has allowed our innovation teams to flourish by participating in inspiring and visible projects. More generally, this development has contributed to the company's influence and the confidence of all our employees.



Validating the perception systems of the autonomous train

SystemX and its partners have provided access to a unique open source dataset of more than 100,000 real images illustrating the different classes of French railway traffic lights, their colour combinations, and the associated manual qualifications.

This is a groundbreaking initiative in the field of autonomous train: SystemX and its partners SNCF, Alstom and Systra have shared, at the end of their work on automating the observation functions of the Autonomous Train, the largest open source data set on French railway traffic lights, called FRSign. More than 100,000 real high-definition images extracted from a dataset of several million images have been made available to the scientific community. This new source of field data can be used to test deep learning algorithms, particularly those dedicated to image classification or the detection of objects in images.

These images are the result of driving sessions carried out on the same lane for two years and have all been manually annotated. They illustrate six types of French rail traffic lights and their possible colour combinations (thirteen states), as well as information concerning their acquisition (date, time, sensor parameters and delimitation frames, etc.).

This massive dataset was built up as part of a SystemX R&D project, the main objective of which was to define the state of the art for automating the observation functions of a rolling stock driver. This two-year project was part of the SNCF's Automatic Train project.



Subeer Rangra received the "Methods and Industry" $\lambda\mu$ Gold Award (best interactive paper) at the 21st Lambda Mu Symposium in 2018. This prize rewarded his work, carried out as part of the TAS (Safe Autonomous Land Transport) project of IRT SystemX, and dedicated to risk analysis and safety in the autonomous operation of trains on main lines.



Why did you decide to join forces with IRT SystemX as part of the SNCF's Automatic Train project?

SNCF has teamed up with IRT SystemX to meet the challenge of the autonomous train. Autonomy will bring additional advantages to the railways: increased infrastructure capacity, better regularity, quality of service, control of energy consumption, etc. To strengthen the competitiveness of the railways, we must lift important technological barriers in many fields, some of which are at the heart of the institute's competences: digital technology, artificial intelligence and detection. Since the launch of the project, in 2017, to automate the reading of lateral signalling and obstacle detection, a great deal of work has been done. The SystemX teams have, in particular, contributed to the writing of software and the design of a signal detection system with deep learning algorithms.





Luc Laroche Automatic Train Project Director,

What benefits do you derive from this collaboration?

At the end of the first phase of the project, dealing with signal detection, a prototype equipment worked in real-life situations on a test train in the Paris region. The project has entered a second test phase, with the detection of obstacles. The aim is to integrate this system on a freight locomotive in mid-2021. The partnership with SystemX, allows us to take major steps towards the successful operation of a standalone train. In order to train algorithms to read the signalling, SystemX and SNCF have built a large database of railway signals, which is now open source. This database has been annotated.



Developing new uses and service offerings thanks to blockchain technology

Since 2016, SystemX has been multiplying projects aimed at enhancing the potential of the blockchain in its ability to transform economic models and uses. The institute is particularly interested in new applications and services using this secure, tamper-proof information storage and sharing technology, which is free from trusted third parties.

It has developed the BEST (Blockchain Environment for Smart Trust) technology platform to instantiate and test use cases in the fields of mobility, energy and finance, to lift the associated technological locks and validate their technological, economic and legal feasibility.

IMPACT #1

Car maintenance booklet: **Experimenting with decentralised and traced management** of vehicle maintenance monitoring by the blockchain.

Can the blockchain improve the recovery of used vehicles? This is one of the use cases studied by the SystemX teams and its partners, which has resulted in a demonstrator enabling the automation, security and sharing of information relating to a vehicle through a decentralised and secure virtual service book, between all the key players in the automotive value chain (car manufacturers, garages, insurance companies, document archiving services, users etc). It enables the traceability of a vehicle's life cycle and mileage to be certified, from its purchase to its destruction, through the maintenance and resale stages. The creation of a demonstrator on the BEST platform made it possible to validate the relevance of this use case.



INTERVIEW



Aldric Loyer Pilot of technological roadmaps for electronic architectures, Stellantis

What benefits do you derive from working with SystemX?

With SystemX, we appreciate the opportunity to explore technologies that do not come from the automotive world. The institute allows us to teach technologies, such as the blockchain, which come from traditional computer science and which are very little known to our on-board teams. Moreover, the multi-wire and multi-partner nature of the projects is of particular interest to us in this type of upstream work. It allows us to reach a critical mass by building an ecosystem of companies competent in a specific field, to share our visions and to be able to analyse the potential of a technology, by pooling both costs and skills.

What concrete results has this work brought to Stellantis?

From the outset, the ambition was to fully understand and assess the maturity of blockchain technology, by

- applying Proof-of-Concept (PoC) techniques applied
- to sector-specific use cases in our case, testing

the blockchain for the benefit of implementing a secure vehicle maintenance logbook. The inclusion of legal experts was interesting in order to have an operational vision of the use and contribution of the blockchain in relation to the legal constraints of data manipulation. The blockchain is indeed a break with our traditional data management methods. Finally, after explaining the results of the PoC to our technical teams, we decided to go further and develop a "Proof of Value". This is the ambition of a new collaboration with SystemX which focuses solely on automotive use cases. It involves a consortium of players from the automotive world (manufacturers, independent repairers) and the insurance industry, and aims to develop and test a "Minimum Viable Product", which will notably aim to evaluate what the vehicle's maintenance book based on the blockchain brings from the end user's point of view.



IMPACT #2

Energy marketplace: Proposing a market place for collective self-consumption governed by the blockchain

The institute has developed a demonstrator to deploy an energy market place, based on a local blockchain with Vehicle to Grid capabilities based on private charging stations. It enables households to purchase energy produced locally (for example from photovoltaic panels) or stored in batteries, without the intervention of third parties. Energy exchanges are accounted for in a secure and automated manner using Smart Contracts, on a dedicated blockchain that implements a token representing a monetary value. The governance and economic model aspects have also been extensively explored in this case study.

INTERVIEW



Gilles Deleuze Blockchain coordinator, Systems Risks & Safety Analyst, EDF Group

What were the EDF Group's expectations through the study of the market place use case of self-production / collective consumption based on blockchain technology?

In 2017, the blockchain was a very upstream and relatively new subject for us. By joining the BST (Blockchain for Smart Transactions) project of IRT SystemX, we were in a process of exploration and learning. EDF was involved in the second PoC of the project, which was about the self-consumption of a collective market place, because this was the subject through which the blockchain entered the energy field. We had already started to think about this subject through a thesis conducted with Télécom Paris; it was an opportunity for us to go further and to rely on SystemX to develop a solution. We had set ourselves two objectives: to prove that the blockchain could consume little energy, and to demonstrate. its ability to quickly process information relating to a neighbourhood of 200 homes. We tested the platform in our EDF Lab laboratory of "Les Renardières": the tests were conclusive, in terms of low energy consumption, cost and technical feasibility.

Within the framework of this work, three outstanding publications have stood out:

• "Blockchain Energy Market Place Evaluation: an Agent-Based Approach", by Kei-Leo Brousmiche, Tesnim Abdellatif, Omar Dib and Andra Anoaica, on the occasion of the 9th Annual Conference on "Information Technology, Electronics and Mobile Communication", Vancouver, Canada (IEEE IEMCON 2018)

FOCUS

- "Named Data Networkina: A Promisina Architecture for the Internet of Things (IoT)", by Maroua Meddeb, during the IGI Global's 11th Annual Excellence in Research Journal Awards (Computer Sciences, 2019).
- "Bitcoin transaction visualisations", by Natkamon Tovanich, on the occasion of EUROVIS'19 (poster prize).

Following your investment in the BST project, what actions have you or will you implement?

Numerous technical publications have been written and demonstrations have been carried out with our teams to show them how concrete the applications of this platform are. We then continued to bring it to life in two ways: firstly, we modelled the system to study its availability, then we carried out a second PoC as part of a BOOST project conducted with SystemX. In this use case, we went one step further by modelling a collective self-consumption market place with electric vehicles that are recharged by moving from one neighbourhood to another. We also studied the counting of energy transport between these groups. These projects have enabled us to see the true potential of blockchain technology, while continuing to develop our simulators.

This is a particularly complex socio-cyberphysical system, capable of linking blockchain and different physical layers (solar production and energy consumption).



Encouraging the creation and development of innovative companies

In 2019, IRT SystemX created its recovery subsidiary, SystemX Transfert. Its ambition: to create a new model for technology transfer to industry and services.

flexibility in its governance and decision- ma-

king processes, SystemX Transfert enables it

to accelerate technology transfer. Through the

creation of this valuation subsidiary, SystemX

n order to provide clarity between its profit and non-profit activities, SystemX created its own valuation subsidiary. This subsidiary helps it in its socio-economic mission of valuating its results. By providing a legal basis with a certain



The Blockchain Xdev: a hub for the industrialization of the technological bricks of SystemX's R&D projects in the field of blockchain.

Blockchain Xdev

The Blockchain Xdev, a subsidiary of The Blockchain Group, was born in 2019 from the first SystemX Transfert spin-off. The entity has a licence to use the institute's blockchain oriented assets to support the design, integration and supervision of blockchain solutions within the IT infrastructures of its customers. Through this collaboration, IRT SystemX and The Blockchain Group have completed the blockchain landscape by creating a reference player in charge of supporting manufacturers in the adoption and use of this technology in their business lines.

In one year of existence, The Blockchain Xdev has created five jobs and generated a turnover of €1 million euros.



How did the idea of the creation of this valuation subsidiary emerge?

The primary objective was to deepen the mechanism for valuating the technologies and innovations resulting from our R&D projects. The creation of this "subsidiary" notably allows us to enter into the capital of startups exploiting these assets. In concrete terms, it is the outcome of a spin-off project in the field of blockchain technology that has led us to accelerate our thinking. In creating SystemX Transfert, we wanted to be able to support the project leader by creating a new model for technology transfer to industry. Our valuation subsidiary provides us with a real legal and commercial structure adapted to valuate the assets of our IRT.

What are the ambitions of the institute through its valuation subsidiary?

With SystemX Transfert, we seek to create impact and value for our partners. Our ambition is to process one to three equity investment or

licensing deals per year, based on promising assets developed within the institute. In the longer term, this structure is intended to strengthen the IRT's attractiveness to talent and contribute to job creation in France.

an entrepreneurial spirit by giving them the

opportunity to benefit from the institute's sup-

port in the realisation of their projects.

What assets are likely to be valuated by SystemX Transfert?

Our R&D projects produce digital assets that can take the form of of methodologies, data sets, algorithms, software, or functional proofof-concept demonstrators. These assets are as many elements to perpetuate, enhance and capitalise in order to ensure quality transfers and controlled reuse. They can give rise to a technological platform as soon as a potential for reuse has been detected. SystemX Transfert's vocation is to accompany the valorisation of all these digital assets towards our partners.

The creation of The Blockchain Xdev in 2019 gave concrete form to the spin-off project that I led within IRT SystemX, with the aim of creating a reference player in charge of supporting manufacturers in the adoption and use of this technology in their business lines. Today, we work closely with SystemX by positioning ourselves as a relay for the industrialisation of the technological building blocks resulting from its R&D projects in order to promote the design, integration and supervision of blockchain solutions within our clients' IT infrastructures.

Charles Kremer, Managing Director, The Blockchain Xdev



Prototyping tomorrow's mobility solutions

SystemX collaborates with stakeholders in the world of research and territories to support the digital transformation of the mobility sector. Work includes the definition, prototyping and qualification of innovative technological bricks: forecasting, optimisation, supervision, simulation, safety, etc. Through this work, the institute places the user at the heart of the design process, and is particularly interested in the issues raised by mobility as a service, urban and interurban transport, logistics, on-demand services and territorial planning.

s part of a project focused on optimising metro subway networks, RT SystemX and the RATP Group have co-developed a multimodal supervision portal offering a 360° view of the state of the networks and the systemic impact of an incident. This tool hybridizes several real-time data sources with traffic forecasting and vehicle and passenger reassignment modelling functionalities. The user interface provides operators with synthetic and contextualised information for sup-

FOCUS

The expertise of IRT SystemX is recognised by two leading Mobility Organising Authorities: Île-de-France Mobilités and the Lyon Metropolitan Area. The institute assists them in exploring new mobility solutions, upstream from simulation and exploration of prospective scenarios to prototyping and in situ experimentation of operational solutions. This is notably the case in the Paris-Saclay Autonomous Lab experiment, in which SystemX piloted the operational reliability and the securing of the system infrastructure but also through the LCE project (Lyon Carsharing Experimentation), which has enabled the development of a solution for the interoperability of carpooling services based on a blockchain technology.

INTERVIEW

Yann Briand IRT SystemX

What are the main areas addressed by IRT SystemX in the field of mobility?

Our activities are centred around:

- 1. The valorisation of massive data: our objective is to enable territories, operators and users to understand and anticipate practices and the availability of vectors in order to adjust transport offers as well as possible.
- 2. Modelling: we simulate operations and uses in order to analyse existing mobility offers and anticipate the deployment of new services, for example autonomous or digital services.
- 3. Optimisation: at the scale of a territory, mobility aggregates a combination of interdependent but often poorly interconnected players and operators. This combination can be complex in highly networked territories such as Île-de-France. Our work focuses on optimising these multimodal systems in order to improve their availability and performance.
- 4. Human-Machine interfaces: the multiplication of information and interactions requires an improvement in user routes, to the benefit of operators and passengers.

Can you share with us some examples of assets developed as part of the institute's **R&D projects?**

- I will mention two exemplary results. Firstly, the development of a decision support tool for the
- operation of dynamic carpooling lanes, parameterized

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port in decision-making. This portal integrates several technological building blocks developed within an R&D project of the institute dedicated to the modelling of mobility solutions: traffic forecasts at bus stops, modelling of the multimodal network, definition of new routes in the event of disruption, etc.

Project Manager and Referent for the "Mobility of the Future" thematic,

on the basis of a set of modelling works. Intended

for a "traffic" operator, this console, based on a traffic forecasting engine, issues instructions aimed at optimising the operation of transport infrastructures. Another major asset is our crowd simulator, which replays disturbances within a rail network by modulating the information delivered to users. Calibrated with the help of behavioural studies, this tool makes it possible to evaluate passenger information scenarios in order to improve incident management and anticipate load transfers.

How do you plan to support the evolution of the increasingly connected mobility sector in the coming years?

One of the main challenges is to support the decarbonation of the sector through digital technology. All of our work is contributing to this, but we want to go even further with our partners by combining performance improvement and reduction of the environmental footprint.

We will also strengthen our activities around change management by prototyping operational solutions, largely based on blockchain technology. The mechanisms that will allow us to effectively support changes in mobility practices will be a decisive lever for territories and citizens.



Improving the detection of biometric parameters of vehicle occupants through deep learning

SystemX provided support to Faurecia, a global player in the automotive industry. to improve its method of detecting biometric parameters of vehicle occupants using innovative artificial intelligence (AI) technologies.

raditional biometric parameter detection solutions based on their worth in controlled environments (static, such as medical environments, for example) but are less effective when used in a disturbed and noisy environment, especially one that is in motion. The number of sources and the diversity of the types of disturbances present in a car interior make the search for solutions by signal processing complex.

IRT SystemX therefore exploited AI technologies to offer an innovative alternative solution to Faurecia. Based on a principle of learning and adaptation, AI makes it possible to search for cases at the margin that cannot be dealt with by conventional deterministic solutions. The institute has developed a dual approach to analysing the performance and causes of malfunctioning of the classic solution operated by Faurecia, with a parallel exploration of machine learning-based solutions. This solution can currently be industrialised and integrated in real conditions on vehicles.



FOCUS

EngageAl

In order to accelerate the transfer of skills between academic research and industry around AI, the eight IRTs launched in 2018, within the framework of the FIT Association (French Institutes of Technology), the joint initiative EngageAI. Its ambition: to accelerate the use of artificial intelligence in industrial products and services for the benefit of business performance. The IRTs, by their respective positioning and their collective strike force, are able to address the development of AI and its multiple technologies to support the performance of each future sector of the French economy. At the FIT level, EngageAI represents five BoostAI-type support projects, 25 ImproveAI collaborative projects, and seven AdvanceAl initiatives.



What was the purpose of your collaboration with SystemX?

We called on the institute to help us improve our method of detecting biometric parameters of vehicle occupants using artificial intelligence technologies. Outsourcing an activity with such strong technological potential is not easy for an industrialist. This first step enabled us to better target the orientation of the solution to be deployed and the skills required for its implementation.

What benefits did you derive from it?

SystemX provided us with end-to-end support: from the characterisation of our problem to the development of an industrialisable solution. The institute has the appropriate scientific and technological skills and the necessary capacities

to conduct a multidisciplinary technological project and meet expectations of the industrial world. This know-how is rare! The institute has responded to our need by providing us with a prediction in particular by real time on the data while integrating embarkation constraints. Our collaboration has had two very strong impacts for Faurecia: the development of a solution that can be industrialised and the acquisition of enormous technological visibility on AI for embedded systems, thanks to the knowledge transfer we have received from the institute.



Encapsulating human knowledge in industrial AI systems

SystemX has established itself as one of the key R&D players in France in the field of artificial intelligence (AI). Not only do the scientific and technological issues related to AI and data sciences underpin a dozen research projects carried out by the institute, but SystemX is also at the initiative of a particularly ambitious prospective R&D programme: "Artificial Intelligence and Augmented Engineering" (IA²), launched at the beginning of 2020 and bringing together some twenty industrial and academic partners for five years on the theme of AI hybridisation. SystemX is also the operator of the technological part of the Grand Défi du Conseil de l'Innovation (Innovation Council's Grand Challenge) on the theme of "Securing, certifying and making reliable systems based on artificial intelligence".

Phrough six collaborative R&D projects for industrial purposes and an upstream project to pool scientific results, the IA² programme aims to provide engineering teams designing complex systems with new tools that take advantage of new approaches resulting from IA. By developing solutions that hybridise the three existing approaches to modelling and simulation (physical modelling of systems, knowledge models expressed by business experts, data-based learning models), it aims to optimise their operational performance and contribute to the necessary transformation of expertise.



INTERVIEW

Marc Schoenauer

Research Director, Inria Saclay - Île-de-France Centre, coordinator of the IA² programme

What are the technological and scientific challenges facing the Al² programme?

The ambition of the IA² programme is twofold: from a technological point of view, it aims to bring the most recent advances in terms of artificial intelligence to industrialists who design, develop and validate systems. so that they can be applied to their professions. From a scientific point of view, it aims to hybridise scientific fields such as simulation, multi-agent systems, semantics and ontologies or even man-machine interfaces and to make them benefit from the latest advances in AI. AI is in the process of becoming a universal tool and I am convinced that the future of AI is multidisciplinary.

What were your motivations to join this project?

What particularly interested me is that this programme tackles real cases of industrial use, through six projects. The industrial partners have, in each of the projects, identified the

scientific locks to be lifted and are aware that this requires significant fundamental research work. It is therefore a question of hybridising AI with other disciplines, both fundamental and applicative. In my opinion, this will also involve crossing different AI techniques with each other (deep networks, logical reasoning, semantic approaches, etc.). My role, as scientific coordinator of the IA² programme, is to match these different techniques, to act as a kind of conductor.

What actions do you plan to implement in Advance IA² for which you are in charge of scientific coordination?

In particular, we plan to organise a major conference to which other comparable initiatives in France and Europe will be invited. But also, the drafting of white papers and state of the art papers, as well as the animation of the whole IA² doctoral programme.



Artificial Intelligence and Augmented Engineering

Grand Défi "Securing, certifying and makina reliable systems based on artificial intelligence".

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One of the five Grand Défis chosen by the Innovation Council in 2019 is the transparency and auditability of autonomous AI-based systems. Named "Securing, certifying and making reliable systems based on artificial intelligence", this programme aims to develop the necessary capacities to observe, understand and audit the functioning of these systems while developing approaches that demonstrate the explicable nature of their operation. SystemX is in charge of the technological component of this Grand Défi, which is being developed through a four-year programme, currently hosting six projects and involving some ten partners.





Patrice Aknin Scientific Director, IRT SystemX 🕑 @AkninP

he structuring and coordination of scientific activity is a central point of SystemX's strategy, which is seen as being at the crossroad that links the academic and industrial worlds. This structuring is a guarantee that the work will be carried out according to the state of the art. It also facilitates interaction with academics, while demonstrating to industrialists our ability to dialogue with the best researchers.

In order to carry out our research activities in the best possible way, we have built up a critical mass of skills in eight scientific and technological fields advanced: data science and Al, interaction and usage, scientific calculation and optimisation, system engineering, functional safety, digital security and blockchain, loT and networks. These skills enable us to respond to numerous challenges, the most recent of which concern, for example, the hybridisation of statistical learning with physical models, the digital additive manufacturing chain,

conditions for the development of trustworthy AI, predictive maintenance, multi-agent simulation for more sustainable mobility, cybersecurity of inter-vehicle communications, postquantum cryptography and validation of the autonomous vehicle. These topics feed our scientific and technological roadmap and guide our activities.

All of these skills carried by our engineer-researchers, become involved with the academic fabric in order to understand the subjects of tomorrow. Today, we are proud to count 35 laboratories among our academic partners, with leading institutions such as the Université Paris-Saclay, Inria Saclay - Île-de-France, CentraleSupélec, CNRS, ENS Paris-Saclay and Télécom Paris. This academic core participates in the success of our R&D projects, providing us with cutting-edge knowledge and know-how to meet the major societal and technological challenges of our time.

The collaboration of these academics with our engineer-researchers, PhD students and industrial partners is the guarantee of a real transfer of expertise within the institute and its ecosystem.

In 2019, our institute was recognised as a host team at the STIC (Information and Communication Sciences and Technologies) doctoral school and as an invited member of the Graduate School Computer Science at the Université Paris-Saclay. We are

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The structuring and coordination of scientific activity is a central point of IRT SystemX's strategy, which is seen as being the crossroad that links the academic and industrial worlds.

> also referenced in Plug-in-Labs, the database of the Université Paris- Saclay, which brings together more than 500 laboratories and technological platforms on the Saclay Plateau working on tomorrow's innovations. This recognition from the actors of academic research reinforces our anchoring within the French research landscape.

In order to broaden the scientific scope of our research work, we launched the "Exploratory Research" facility in 2020. with our own funding. On the initiative of the institute's research engineers, it offers the possibility of carrying out upstream research on future subjects in collaboration with excellent academic partners. This exploratory research will feed into the institute's roadmap and help to build new R&D projects. It is also an excellent vehicle for building new alliances, such as joint laboratories, joint research initiatives and co-operative chairs. Already, some emblematic actions carried out in collaboration with our academic partners make us very proud, such as the creation of a chair dedicated to tomorrow's urban mobility (Anthropolis chair) with CentraleSupélec, the creation of a major academic research collective on the challenges of the blockchain (BART) with Télécom Paris, Télécom SudParis and Inria, and the conduct of training engineering activities to support the development of the skills of our employees and the French industrial fabric. They are to discover in the following pages.



Imagining tomorrow's urban mobility: the Anthropolis Chair

A first of its kind in France, supported by SystemX and CentraleSupélec and financed by five industrial partners (Alstom, ENGIE, RATP, Renault Group, SNCF), the Anthropolis Chair has for four years brought together a multidisciplinary team dedicated to placing the human at the centre of innovations for urban mobility systems.



he research activities of the Anthropolis Chair have focused on eco-innovations for sustainable urban and peri-urban development at the service of citizens and communities, taking into account the interactions between mobility (of individuals and goods) and other systems. The design, modelling and optimisation of shared mobility services, which can integrate autonomous vehicles, were thus explored.

Four doctoral theses, ambitious innovation projects and national and international collaborations

The work carried out by the Anthropolis Chair team has contributed to advancing the state of the art in the field of urban mobility:

- Two theses have been carried out on the modelling of the passenger experience and the synchronisation of passenger and freight flows in urban mobility systems. The results of this work have made a major contribution to advancing the Chair's research work. By combining the viewpoints of user experience design and transport, the first thesis contributed to a deeper understanding of how travellers experience their journeys and the problems they encounter. The second thesis proposed algorithmic models to analyse the impact of shared mobility systems and to assist in their operational implementation.
- The chair has also been involved in the direction of two complementary theses on the design, modelling and simulation of robotic taxi services and on the optimisation of op-

erations for delivery robots in urban environments. These theses have extended the Chair's vision and added a thorough understanding of the design of transport services based on autonomous vehicles.

- The supervision of two innovation projects carried out with CentraleSupélec students consisting of a systematic exploration of unsatisfactory uses and situations have led to the emergence of "pockets of value".
- Numerous national and international collaborations have been set up, including those with the Square Paris team, the MADP (Mutations de l'Action publique et du Droit public) chair at Sciences Po, the Technical University of Eindhoven (Netherlands), the Austrian Institute of Technology (AIT in Vienna), the TUMCREATE autonomous mobility research platform (Singapore), and the prospective workshop "la vie robomobile" led by the Ministry of Transport. These collaborations have enriched the reflections that have taken place, by adding multidisciplinary and international points of view, leading to joint publications with researchers from other institutions.
- Finally, a total of 35 publications were published in scientific journals or presented at conferences.



Bernard Yannou Director of the Industrial Engineering Laboratory, CentraleSupélec

The Industrial Engineering Laboratory (LGI) of CentraleSupélec is an early partner of IRT SystemX. Through multi-partner projects in the automotive and aeronautics fields, but also through the Anthropolis chair on new uses of urban mobility. This partnership has resulted in seven theses being defended and five in progress. The open innovation practiced by the institute enables researchers of the LGI to take advantage of quality scientific leadership on themes such as system engineering, blockchain or mobility of the future. In return, SystemX benefits from the expertise of the LGI researchers, openings at Centrale Beijing and Centrale Casablanca. and opportunities to submit projects on behalf of CentraleSupélec.

INTERVIEW

Imagining the digital world of tomorrow



Jakob Puchinger Anthropolis Chairholder, IRT SystemX · CentraleSupélec

What was the context for the creation of the Anthropolis Chair?

The landscape of urban mobility is changing. In recent years, we have seen a general awareness of the negative environmental impact of mobility and a shared desire to make daily life in our cities more humane and pleasant. Technological upheavals related to automation and electrification of cars, as well as new micromobility offers will induce changes in our mobility system.

We therefore identified, together with our industrial partners, the need to explore this field within the framework of the Anthropolis Chair.

What were its priority areas of research?

- There were three strands of research that we studied:
- The strand on "Understanding uses" focused on user-centred approaches to the daily mobility of people in a given area (e.g. the Plateau de Saclay or La Défense). This mobility is characterised by constrained or unconstrained, daily or occasional movements. Our research led to the characterisation of the quality and problems of commuting in a "door-to-door" vision of traveller profiles and to the modelling of traveller experiences.
- The strand on "Foresight and Innovation" was dedicated to breakthrough objects that could bring about radical changes in urban mobility. In



An extension of the work of the chair

The Anthropolis Chair has initiated the extension of its exploratory work on the challenges of tomorrow's urban mobility for a period of four years. This "2nd edition" identifies the fundamental methods and tools to take into account the needs of the citizenuser, the city and the community in the process of designing mobility systems and services. It will give an important place to the reduction of greenhouse gas emissions produced by the movement of goods and people, as well as to the improvement of air quality.

Identity card of the 2nd edition of the Chair

- Co-holding with the LGI laboratory of CentraleSupélec, University of Paris-Saclay
- Duration: 4 years, starting in 2019
- Team: 2 senior researchers, 4 PhD students
- 3 lines of research: Future mobility and urban life, MaaS (Mobility as a Service). Infrastructures of the future
- 4 industrial partners: EDF, Engie, Nokia Bell Labs, Renault Group
- 1 institutional partner: Paris-Saclay Agglomeration Community





particular we were interested in how to conceive prospective mobility scenarios up to to 2030, and we have introduced an original vision of this, based on the construction of the personae.

• The strand on "Impact analysis", within which we have developed models and methods for optimisation and simulation that take into account the objectives of the users and operators of these systems. Different hypotheses of mobility transformation have been examined, be it the evolution of mobility ecosystems, the transformation of business models, or the sustainability of mobility services and systems.

What is the most compelling result you have achieved?

This is our analysis of shared mobility systems with a focus on shared autonomous electric vehicles: we have succeeded in approaching this topic from a systemic point of view by taking into account and combining qualitative aspects (user perception and integration into the mobility system) and quantitative aspects (optimisation, simulation and impact on urban traffic). A number of important publications have resulted from this analysis, including a publication cosigned by three doctoral students of the chair.



Creating talent pools and breaking the technological locks of blockchains: the BART collective

With around thirty researchers from SystemX, Inria, Télécom Paris and Télécom SudParis, BART (Blockchain Advanced Research & Technologies) is the largest academic research collective dedicated to blockchains in France.

he BART initiative was born out of shared desire of SystemX. Inria. Télécom Paris and Télécom Sud-Paris to federate the Ile-de-France research ecosystem around the technology of blockchains. Since 2018, this Paris Region academic research collective has been coordinating its actions around a single roadmap aimed at breaking the scientific and technological locks of the blockchain, in line with the needs of society and industry. Its research work focuses on six areas: theoretical models, scaling and monitoring tools, security, architectures, data confiden-tiality and economic models, and regulations. BART is also involved in joint scientific coordination activities within its vast ecosystem.



INTERVIEW



Gérard Memmi Head of the IT and Networks Department, Télécom Paris, Professor

What strengths does the BART collective have?

This is a much more original initiative than a classic research project or the creation of a joint laboratory. We have built up a true scientific community by bringing together a hundred or so specialists mainly located in the Ile-de-France region (partners of BART, Sorbonne University, École polytechnique, Mines ParisTech, CEA, etc), via the organisation of bimonthly working seminars open to the general public as well as an annual workshop where industrialists and scientists can exchange ideas. I think that one of our strengths really lies in the quality of the research topics that we have identified and which today have stood the test of time.

What makes the BART collective unique?

Our four establishments were among the very first to want to move the lines in the blockchain sector. Our collective is unique in scope and format. It has guickly gained notoriety, and we are proud to have had BART named in a Senate report on the blockchain. following the workshop organised in 2018 and numerous exchanges with a number of elected representatives. We also co-signed a report on the technological barriers of blockchains, which is currently on the working table of three Ministries.

Can you share with us some of the best achievements?

Let me give just two short examples. One such example is a blockchain protocol that one of our PhD students recently developed and perfected at a low communication cost ("scalable" in number of nodes), thanks to a partitioning method known as sharding. This protocol is currently being studied for transfer to a SystemX partner. Another important area of work involves the use of visualisation techniques to explore the dynamic operation of blockchain applications.

What prospects are there for the coming years?

We are already in the process of envisioning a second edition of BART for the years to come, which shall include industrialists who reflect on issues such as the interoperability of blockchains. New theses are also envisaged and BART will remain a valuable initiative for our researchers.



A one-of-a-kind offer in training development

SystemX has developed its training engineering activities in order to promote the dissemination of the knowledge and skills developed within its R&D projects to its employees and industrial partners.

The institute is strengthening its role as an accelerator of the digital transformation by offering a unique training engineering programme based on its eight scientific and technological fields (Data Sciences and AI, Scientific Computing Interaction and Use, Optimisation, Systems Engineering, Operating Safety, Digital Security and Blockchain, IoT and Networks) and their inter-faces. The continuing education modules are built in association with excellent academic and industrial partners.

Passport@SystemX: supporting the development of SystemX employees

The institute supports the continuous learning of its engineer-researchers through the implementation of a common set of skills. Passport@SystemX, launched in 2019, enables all employees to receive general training in its eight scientific and technological fields, thus diversifying their skills. Its objective is to facilitate career development within the institute while consolidating a common DNA of expertise. More than fifty of the institute's employees have already been trained as part of this offer.



At IRT SystemX, we offer a training programme adapted to the challenges of digital transformation, responding to the current problems of the industrial world. Our ambition: to provide the industrial world with the results developed in our R&D projects in the form of training modules covering all of the institute's scientific and technological fields and their interfaces.

Alexandre Bekhradi, Training Development Manager, IRT SystemX

Campus@SystemX: supporting the skills development of industrial players

This continuing education and certification offer is co-constructed with academic partners or with certain industrial partners of the institute already operating training. It aims to accelerate the development of the skills of industrial players by offering them privileged access to certain results of the institute's R&D projects transformed into educational bricks. The first training courses have already been given in the fields of blockchain and cybersecurity, in partnership with Télécom Évolution.

FOCUS

Since 2020, SystemX has been carrying out the IFI (Innovative Training Engineering) research project which structures its training engineering methodology. Its main objective is to identify the building blocks of knowledge and the technologies that can be exploited from its R&D projects, as well as the pedagogical approaches best adapted to the changes in expertise expected by many industrial sectors.

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Supporting

remarkable journeys

A conducive framework to doctoral training

PhD education is an essential driving force for IRT SystemX which develops doctoral work within its R&D projects. The institute aldoctoral schools from which SystemX has obtained the status of hosting unit. Read on to see what two PhD students have had to say about low its doctoral students to specialize in a promising field after obtheir experience with SystemX. taining a Master's or engineering degree. Supervised by researchers and teacher-researchers from our partner laboratories, by an IRT en-INTERVIEW gineer-researcher and in contact with industrial players involved in themes such as Mobility and Autonomous Transport, Future Industry, Manon Césaire Security and Defence, Environment and Sustainable Development, **Project:** EPI (Evaluation and Performance our PhD candidates are nurtured in an innovative and dynamic enof AI-based decision systems) vironment, where they build up a solid network and develop unique expertise. Since its creation, the institute has supported more than Partner Research Lab: LIP6, Sorbonne Université 70 PhD students and has forged structural partnerships with several

INTERVIEW

Reza Vosooghi



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Project: MSM (Mobility Solutions Modelling) Partner Research Lab LGI (Laboratoire Génie Industriel), **CentraleSupélec** PhD research topic: Design, modelling and simulation of Robot-Taxi services PhD worked on between 2016 and 2019

What did you learn from your PhD at IRT SystemX?

The institute gave me the opportunity to work on a multidisciplinary R&D project with industrial players and academic experts in mobility and automobile construction. Their knowhow and experience have enabled me to acquire a great deal of theoretical and practical knowledge in the fields of modelling new travel services, data analysis, transport user behavioural studies, optimisation, machine learning and programming.

What role did the institute play in your subsequent career?

The IRT is known for its expertise in emerging fields. It is thanks to this reputation and also with the help of the Institute's Scientific Department that I was able to join Systra, a reference company in the transport sector and a SystemX partner. I currently hold the position of Business Manager, which consists of managing and ensuring the smooth running of transport planning study missions. I also work in the field of travel and transport system modelling.

Can you describe SystemX in 3 words? Digital, Innovation, Collaboration.



PhD research topic: Generation of scenarios for the learning and validation of a decision function for piloting autonomous vehicles or assisting in the piloting of ship Her PhD research began in 2019

What is the topic of your PhD research?

I am interested in the generation of scenarios for the learning and validation of a decision-making function for steering of autonomous vehicles. Scenario data collection driving in real-life situations (e.g. with regard to the number of lanes, surrounding vehicles or weather conditions) is very expensive. One solution is to automatically generate realistic scenarios, respecting the physical constraints of the environment and nearby vehicles, to meet the expectations of autonomous driving and cover as many situations as possible in order to anticipate potential hazards. To do this, I use adverse attack methods thanks to reinforcement learning algorithms. These methods refer to machine learning algorithms that attempt to "deceive" models (for example neural networks) by providing erroneous information. I am thus able, on the basis of existing scenarios, to generate new ones that can mislead the autonomous driver thanks to the various adverse attacks set up, while maximizing the loss function of the decision system taken between the two scenarios.

Why did you decide to do your PhD at IRT SystemX?

I did my Master 2 Data Science internship at the institute. It was therefore quite natural for me to want to continue my studies within the Data Science and AI team and to make the most of my skills in mathematics and computer science. The collaborations between the academic and industrial worlds within the institute are also very instructive. Moreover, autonomous driving is a cutting-edge area that I find particularly exciting because it is about to radically change the relationship between users and their vehicles. It is therefore essential to have enhanced safety and to avoid any failure of this type of vehicle. I wanted to make my contribution in this field by completing my doctorate at the institute.

Can you describe SystemX in 3 words?

Collaboration, Competence, Conviviality.



Remarkable journeys

To work at SystemX is to be an integral part of an innovative technological research institute, driven by a bold ambition: to accelerate the digital transformation of industries, services and territories. Everyday, our employees imagine and design the digital world of tomorrow, alongside renowned academic and industrial partners. Together, they address new uses that respond to the major societal and technological challenges of our time. Discover the testimonials of six employees and alumni who talk about their jobs and their careers within the institute:



Pierpaolo Cincilla Cybersecurity Expert, Renault Group

I joined SystemX in October 2014 as a research engineer, before moving on to a project manager position. This was my first professional experience after my PhD. The institute enabled me to keep one foot in the world of research, while working with industrialists on exciting projects.

When I arrived, I was lucky enough to be integrated into a project involving open and passionate partners. I very quickly had the opportunity to develop my skills, to participate in the launch of two projects in areas related to the safety of connected and autonomous vehicles and to take the lead in one of them. The dynamic environment of the institute, which almost tripled in size between the day I arrived and the day I left, also allowed me to push my ideas and take on many initiatives.

In 2018, I left the institute to seize a great professional opportunity at Renault. The project I invested in, the energy I put into it, and the stimulating environment of the institute played a very important role in my professional development. For me, the IRT was a privileged place of observation to come into contact with academic and industrial realities.



Théo Chelim Engineer-Researcher, IRT SystemX

I joined SystemX in 2017 at the end of my Master's degree, in order to contribute to an innovative project in the field of cybersecurity, combining research and development. This project enabled me to understand the technological issues affecting the autonomous transport sector.



Gwenaëlle Berthier Project manager, IRT SystemX

After several professional experiences in the private and public sectors, particularly in the field of climate risks, I joined SystemX, the cradle of digital transformation in the heart of Paris-Saclay. In line with my crossfunctional vision of innovation, it is an organisation in which I was sure to enrich myself, as it deals with very diverse, and often pioneering, R&D projects. Within my project, we are working on the evaluation of the contribution of artificial intelligence (AI) within the framework of autonomous automobile and maritime vehicles.

I am aware today that it is partly

thanks to the confidence that the in-

stitute has given me that I was able

to build up my skills on various in-

novative subjects such as on-board

systems, cybersecurity issues and

the problems of vehicle autonomy.

The setting is ideal for learning from

people who are very competent in

many fields, both SystemX research

engineers and partners. It is this

synergy between the academic and

industrial worlds that has attracted

me and continues to stimulate me

everyday.

As project leader, my main mission is to bring to life the developments of these different activities in the most harmonious way possible. Within our highly committed project team, we combine the skills of our experts from all walks of life. Synergies are essential for these types of projects to really work and for the success that will be felt by IRT SystemX and all our partners.

The Digital Transformation Notebooks #1



Rim Kaddah Scientific Computing and Optimisation Team Leader, IRT SystemX

I discovered IRT SystemX during my PhD years. The institute was then a partner of the laboratory in which I was doing my thesis, but I was not necessarily familiar with how it worked. I decided to join it in 2017 as an engineer-researcher in order to continue my work in the field of energy network optimisation within a project that brings together large groups, SMEs and high-level academic players. The projects in which I subsequently participated in and in which I am still involved do not fail to arouse my interest.



Sandra Dausend Process Owner, Renault Group

I spent four years working on several SystemX IRT projects in the field of user experience for autonomous driving as a research-engineer and then project architect. I was fortunate enough to take up a very cross-disciplinary role and to coordinate a working group dealing with various topics (user experience, data visualisation, design and ergonomics of man-machine interfaces). What I retain from the institute is the important support I received: my ideas were encouraged, implemented and valued. Everyone can contribute at his or her own level to the development and influence of the IRT and share his or her vision. I also greatly appreciated being immersed in a very rich academic and industrial environment, which enabled me to develop my skills in the field of research.

SystemX has played a key role in my career. Indeed, the knowledge of the onboard automobile and user experience that I acquired enabled me to join Renault Group as a process pilot in the field of connected services. I am delighted with my experience here. The IRT has given me the opportunity to evolve professionally from a research engineer to the position of Head of the "Scientific Computing and Optimisation" team, and to collaborate alongside research-engineers working on cutting-edge subjects with strong industrial and scientific potential.



Makhlouf Hadji Senior Researcher, Scientific Director of the digital infrastructures, IRT SystemX

Relying on the diversity of research activities is the key to confronting divergent opinions and bringing them together on a common basis to help formulate scientific subjects. I joined SystemX in 2013 with the ambition of working on collaborative projects around the themes of the cloud, networks, edge computing and optimisation. Collaborations with researchers from various backgrounds, both internally and externally, have enabled me to enrich my knowledge of the industrial and academic worlds between which the institute positions its offers and collaborations.

I completed my Habilitation to Direct Research (HdR) in 2017. This is the result of several years of confrontation, sharing ideas and research subjects in the abovementioned themes, made possible in large part thanks to the efforts made and scientific missions accomplished within SystemX.

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SystemX, a reference institute for analysis, modelling, simulation and decision management



Accelerating the digital transformation

Based on the Saclay plateau, in Lyon and Singapore, SystemX is a Technological Research Institute (IRT) expert in analysis, modelling, simulation and decision support applied to complex systems. Dedicated to the digital engineering of the systems of the future, it coordinates partnership research projects, bringing together academics and industrialists in a multi-field perspective. Together, they work to remove major scientific and technological obstacles in 4 priority application sectors: Mobility and Autonomous Transport, Industry of the Future, Security and Defence, Environment and Sustainable Development.

Through use-case oriented projects, SystemX's engineer-researchers respond to the major societal and technological challenges of our time, and thus contribute to accelerating the digital transformation of industries, services and territories.

The Digital Transformation Notebooks #1

Towards a more sustainable. resilient and sovereign society

The institute has set up three indicators that serve as a guideline for prioritizing the issues to be addressed with its partners: residency, sovereignty and sustainability. These labels of quality guarantee that it is addressing the current issues that contribute to imagining and designing a new digital world that is safer, more sustainable and more efficient.

A melting pot of interactions between the academic and the industrial worlds

Digital technology is essential to the transformation of the industry and more broadly our society. In order to support and accelerate its deployment, the institute offers its partners a unique research environment. Within its R&D projects, its engineer-researchers create the link between fundamental and applied research to meet a triple objective: stimulate knowledge production, strengthen collaborative R&D capacities and accelerate the use of technologies. Their research work, consolidated by high-level digital assets, enables IRT SystemX to provide concrete responses to the use cases of its industrial partners (startups, SMEs, large groups) by drawing on cutting-edge academic research.

A unique value proposition

The IRT SystemX offer is divided into three parts:





The offer to BOOST

Objective

Support an industrial partner wishing to test technological solutions on a specific use case and understand the interest for its business lines.

Duration

3 to 6 months.

Result

Realization of a Proof of Concept (POC) from the bricks "on the shelf" or pre-existing within the institute.

The offer to IMPROVE

Objective

Consolidate innovation ecosystems through the conduct of collaborative R&D projects with the aim of removing scientific and technological obstacles. These projects bring together collaborators from large groups, SMEs, research engineers from SystemX and academic players to place scientific excellence at the service of industrial challenges.

Duration

2 to 5 years.

Result

Major technological and scientific advances, production of patents, software and technology transfers.

The offer to ADVANCE

Objective

Federate the skills and excellence of the academic partners around major scientific challenges.

Duration At least 3 years.

Result

Deployment of research initiatives and industrial chairs or doctoral programmes (e.g. the academic research community BART dedicated to the blockchain launched in 2018).

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