



# S·M·A·R·T INNOVATION

2017 Activity Report



**LIST (Laboratory for the Integration of Systems and Technologies) conducts cutting-edge scientific and technological research to fuel the development of innovative solutions that meet the needs of industrial companies. LIST research is backed by proven technology-transfer services to get the technologies developed to the businesses that need them.**

At the forefront of innovation, LIST helps companies of all sizes and from all industries stay competitive. Each year, the 800 scientists, engineers, and technicians at LIST work with 200 industrial companies from France and around the globe on projects that address major economic and societal challenges, from advanced manufacturing technologies and cyber physical systems to data intelligence and technologies for the digital patient. LIST is a CEA Tech institute and a member of the Instituts Carnot network under the name Institut Carnot Technologies Numériques@UPSaclay (TN@UPSaclay).

LIST is based in Saclay, west of Paris, France.



[www-list.cea.fr](http://www-list.cea.fr)

# D·i·r·e·c·t·o·r·s'·f·o·r·w·o·r·d

**Jean-Noël Patillon, Director, CEA LIST**

**I**n 2017 CEA LIST consolidated its position as a top-tier digital innovation partner for industrial companies, with 10% revenue growth over the previous year. We are signing increasing numbers of major, long-term R&D partnerships with industrial companies each year, evidence of business' mounting interest in digital technology as a driver of growth in all markets. These partnerships enable a substantial volume of scientific and technical research. Each project we complete brings our current and future partners concrete examples of how CEA LIST technologies can benefit them. Whether it is our work on the Factory of the Future with Technip and Safran or on artificial intelligence for transportation and mobility with Renault and Valeo, our partnerships investigate topics of interest to industrial companies.

**At LIST we strive to maintain our core scientific research activities as we continue to deepen our technological know-how. Our overriding objective is to fulfill our mission as a provider of innovations to France's industrial economy.**

Our 800-strong research staff, which includes more than 120 post-docs, is committed to reaching these objectives each day. In 2017 we made notable advances in artificial intelligence, carving out a position as a source of safe, reliable AI technologies. This strong position on AI technologies could ultimately become a key differentiator for France's industrial companies. We also leveraged our long-standing and internationally-recognized know-how in software security to successfully secure our leadership on a topic that is crucial to industry. We now have the capacity to offer our partners the opportunity to move from software certification to the certification of artificial intelligence algorithms.



The year 2017 was also the year we saw the DigiHall digital innovation hub become a reality on the Paris-Saclay campus with the support of the Ile-de-France regional government. We are proud to have mobilized our partners Systematic Paris-Région, IRT SystemX, Télécom ParisTech, Télécom SudParis, and Inria and to have earned the backing of industrial companies and government for this project. Today, DigiHall is home to more than 1,500 researchers investigating artificial intelligence, cyber physical systems, cybersecurity, and the Factory of the Future.

**We also continued to nurture our culture of excellence in 2017 and our staff was more engaged than ever in transforming their research into innovations.** We strengthened our ties to industry to achieve our objective of impacting the industrial economy and, more broadly, society. Our goal is to effect immediate and lasting change that is sustainable and respectful of all people. Last but not least, we are actively pursuing our open innovation strategy by enabling collaboration, communication, and cross-disciplinary investigations to broaden the scope of both our research and its applications. Our 2017 Activity Report reflects our open innovation approach and showcases the diversity of our research. We hope you will find compelling reasons to work with us inside!



**LIST IS PREPARED TO LEAD ADVANCES IN ARTIFICIAL INTELLIGENCE.**



Read the Director's foreword online at <http://www-list.cea.fr/en/>



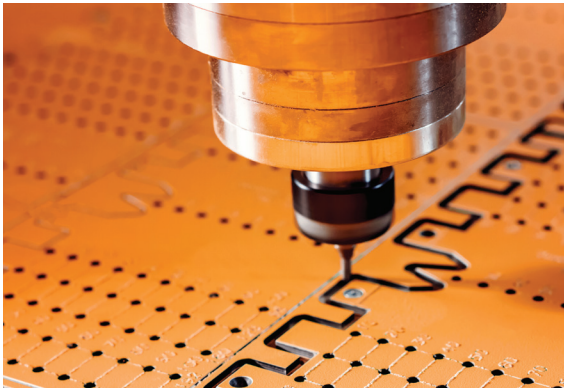
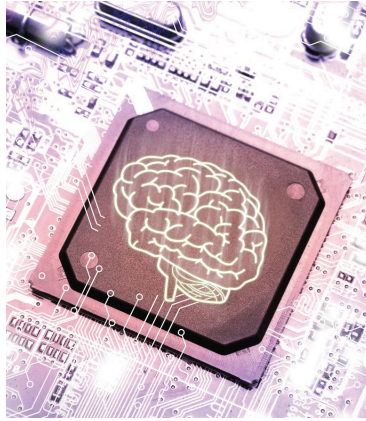
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- ◆ Manufacturing rejects: prediction and diagnostics



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- ◆ Augmented reality on a larger scale



**START-UPS,**  
facilitating the transfer  
of technology from lab to market

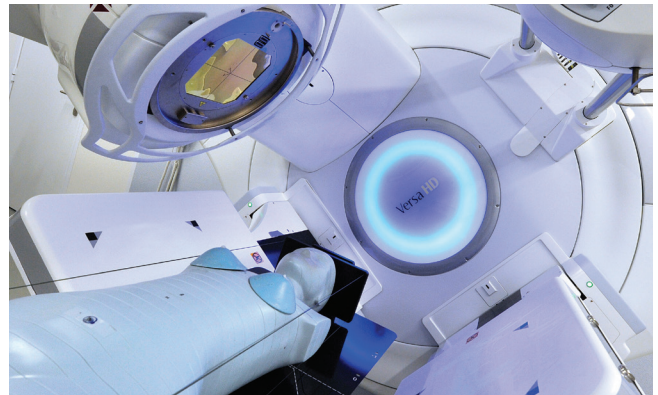
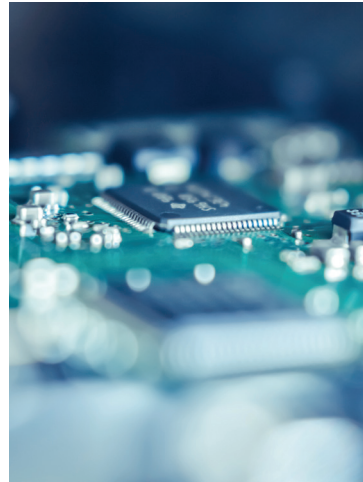
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# LIST, an active member of the Carnot network

**LIST is one of the pillars of the CEA's technology research activities. Since its inception in 2003, the institute has been committed to developing its technology transfer programs to contribute to making the French economy more competitive. The institute earned its first Instituts Carnot seal in 2006; the seal was renewed in 2011 and 2016.**

**D**uring its first mandate as a member of the Carnot network (2006–2011), LIST sharpened its focus on technology transfer, increasing R&D partnership revenue by 48% during that period. The institute also strengthened its organization through proactive human resources policies that included training and recruitment, and by initiating pump-priming research programs to support LIST's innovation capabilities. All of these policies have had a significant impact on R&D programs run with partners. However, they have also supported the emergence of a powerful academic and industrial ecosystem. LIST's membership in the Carnot network was renewed in 2011, and again in 2016, this time as Institut Carnot Technologies Numériques @ Université Paris-Saclay (TN@UPSaclay).

## **A COMMITMENT TO QUALITY, INNOVATION, AND KNOW-HOW**

As a member of the Carnot network, LIST has made a commitment to adhere to the Carnot charter. This commitment includes taking steps to ensure the continuous improvement of the institute's relationships with companies and other socioeconomic stakeholders. LIST also engages in pump-priming research to maintain its capacity for innovation and actively promotes its membership in the Carnot network, in terms of both visibility and access to the other Carnot network members. Membership in the Carnot network solidly positions LIST to offer know-how in a broad range of fields to effectively respond to the R&D needs of companies from all industries.



## **A COMMITMENT TO SUPPORTING BUSINESSES' INNOVATION STRATEGIES**

- **One core mission:**  
Carnot network members are government research organizations operating under the aegis of the French Ministry of Research. As Carnot members, they commit to engaging in and developing contract research with companies of all sizes and with other socioeconomic stakeholders.
- **A clear objective:**  
The purpose of the Carnot network is to boost the economic impact of member institutes' contract R&D activities in terms of job creation and domestic and export sales revenue, and, therefore, economic competitiveness.
- **The most advanced and comprehensive R&D services to support innovation:**  
With a combined staff of 30,000 research professionals—18% of France's government research employees—the members of the Carnot network are responsible for 50% of all R&D projects outsourced to government research organizations by companies.

# LIST: I·N·N·O·V·A·T·I·O·N

## the foundation of our partnerships

### AN OPEN INNOVATION MODEL

The R&D programs at LIST, a CEA Tech institute, create innovations for tomorrow's digital society.

As a member of the Carnot network and a center for advanced R&D in digital technology (Carnot TN@UPSaclay), LIST works with industrial companies of all sizes every day, helping them leverage technological innovation to boost competitiveness while keeping people at the center of their approach. LIST also helps further this mission through involvement in high-tech clusters like Systematic Paris-Région.

The institute is at the international state of the art in smart digital systems. LIST's activities cover the entire value chain from the development of enabling technologies to their integration. Our R&D focuses on five strategic topics:

- Artificial intelligence
- Factory of the Future (FoF)
- Innovative instrumentation
- Cyber physical systems
- E-healthcare

### Valorisation

139

active licenses

480

active patents

68

patents filed in 2017

LIST's partnerships with major digital technology research organizations on the Paris-Saclay campus, including Inria as part of the DATAIA institute, have expanded the scope of our research. Thanks to these partnerships, we are solidly positioned to take a people-centered approach to research on big data and artificial intelligence, leveraging insights from the social sciences and humanities. **In addition, we now offer new open innovation tools based on our broad, deep knowledge of industrial environments and our capacity to build powerful innovation ecosystems.**

In 2016, for example, we partnered with fellow Carnot network members CETIM and ARTS to create the **FactoryLab** platform for the integration of solutions for innovative industrial systems. FactoryLab unites a consortium of industrial companies that either provide innovative technologies or use them. We joined forces with CETIM and ARTS again in 2017 to form the **Additive Factory Hub**, a far-reaching initiative to support the development of additive manufacturing involving major research



### LIST enjoys a strategic position in Europe and internationally.

organizations in the Greater Paris area. The purpose of the Additive Factory Hub is to respond to the needs of industrial companies and to develop new product manufacturing techniques. In 2017 we also partnered with Carnot members Inria and Télécom & société numérique, IRT SystemX, Paris-Saclay University IDEX, and the Systematic Paris-Région cluster to create the **DigiHall** digital technology center with the support of the Ile-de-France regional government

**LIST enjoys a strategic position in Europe and internationally** as part of the European Institute of Innovation & Technology (EIT) through three EIT innovation communities: Digital Technology, Energy, and Healthcare. LIST is also part of the public-private partnership on European Cyber Security Organization (ECSO). In the field of cybersecurity, LIST has also formed a major partnership on static code analysis with the US National Institute of Standards and Technology.



## 2017 headcount

820

people

31

state-sanctioned  
research supervisors

167

subject-matter experts

127

PhD and post-doctoral  
candidates



## Annual operating budget

52%

incentive funds

48%

R&D contracts with  
industrial partners

500

projects

210

single-partner  
R&D contracts

## A STRATEGY BUILT ON PARTNERSHIPS

LIST's strategy is closely interrelated with its business model—one that is based on partnerships with **systems manufacturers** and integrators and technology providers, including startups spun off from LIST research programs.

Close relationships with systems manufacturers and integrators—mainly large corporations—give LIST unique insights into industrial companies' current and future needs and position LIST to shape the **tech roadmaps** that underpin the institute's research. Basic and pump-priming research programs at LIST provide a pipeline of enabling technologies that inform development roadmaps.

Enabling technologies developed in response to the needs of systems manufacturers and integrators are adapted for variety of applications by **technology providers**, who in return gain valuable insights from integrators so that they can more closely align their solutions with actual needs.

# THE ORGANISATION

## DIRECTOR

♦ Jean-Noël PATILLON

## DEPUTY DIRECTOR

♦ Étienne GARDERET

### Communications Manager

♦ Élisabeth LEFÈVRE-RÉMY

### Associate Director, Major Projects

♦ Sonia FALOURD

### Associate Director, Strategy and Programs

♦ Julien CHIARONI

### Project Manager, FactoryLab

♦ Frédéric AMBLARD

### Associate Director, Industrial Partnerships

♦ Laurent DISDIER

### Project Manager, FACE

♦ Raphaël DAVID

### Associate Director, Scientific Research

♦ Jean-Noël PATILLON

### Head of the Administration and Finance Department

♦ Philippe LECESTRE

### Associate Director, Europe

♦ Gregorio AMEYUGO

### Manager, Human Resources

♦ Christine YVRAY-PETIT

### Associate Director, Institutional Relations

♦ Éric LEMAÎTRE

### Associate Director, Strategic Marketing

♦ Yannick BONHOMME

## DACLE

### Embedded Software and Architecture Development Department

♦ Jean-René Lequepeys

## DISC

### Imaging and Simulation for Testing and Inspection Department

♦ Clarisse POIDEVIN

## DILS

### Software and Systems Engineering Department

♦ François TERRIER

## DM2I

### Metrology, Instrumentation, and Information Department

♦ Alexandre BOUNOUH

## DIASI

### Ambient Intelligence and Interactive Systems Department

♦ François GASPARD

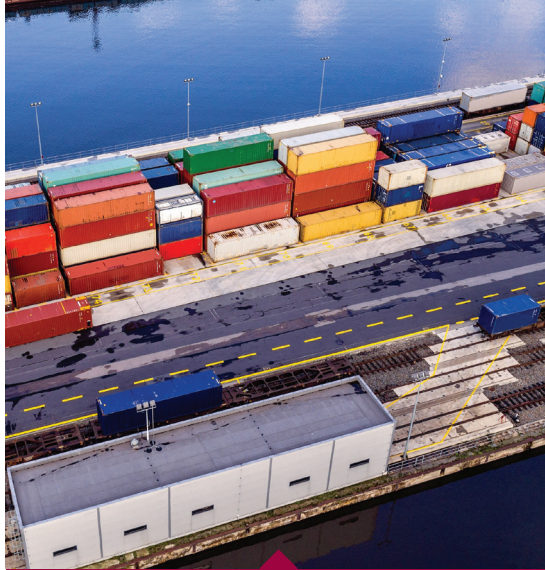


# 2.0.1.7 YEAR IN REVIEW

**JANUARY 30, 2017**

## Designing the Factory of the Future: Grand opening of the FFLOR platform

CEA Tech opened the FFLOR (Future Factory @ Lorraine) platform at the PSA automotive plant in Trémercy-Metz. This new technology platform will help make France's Grand Est region a center for excellence in technologies for the Factory of the Future.



**MARCH 31, 2017**

## CEA-BIPM agreement: Toward ultra-precise metrology for radiotherapy

CEA Tech and international measurement science and measurement standards organization BIPM signed an agreement for BIPM to use the medical radiotherapy accelerators at the DOSEO platform. BIPM will use the accelerators to compare reference dosimeters and calibrations to comply with stringent international traceability standards for external radiotherapy.

**SEPTEMBER 27, 2017**

## Artificial intelligence for the "port of the future"

Channel 5, a decision-assistance service for ports developed by CEA Tech in partnership with MGI, won the Trophée Port du Futur in the logistics category at the Assises du Port du Futur, a port-industry event held on September 26 and 27, 2017.

**OCTOBER 10, 2017**

## Tridimeo is the CEA's 200th startup

Tridimeo, a LIST startup specializing in a new-generation 3D vision technology, won the CEA's 200th startup award at the CEA's annual startup day.





**MARCH 14, 2017**

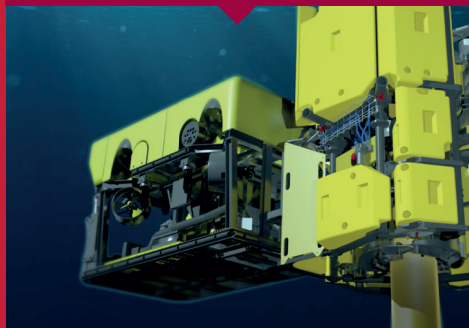
**N2D2, Europe's first open-source deep learning platform**

N2D2 will provide developers with a design environment for deep learning applications. It will also support the creation of an ecosystem of users that will help broaden the use of neural networks to new applications.

**SEPTEMBER 27, 2017**

**IRIS: An embedded solution for inspecting complex materials**

IRIS, developed by LIST and TechnipFMC, was integrated into a robotic undersea inspection system to detect defects in oil and gas pipelines. The system has been implemented at several offshore platforms.



**MARCH 9, 2017**

**Breakthrough innovation in cybersecurity**

One of the major challenges faced by the digital society is IT security, from design to verification to certification. Formallab, a joint initiative of Thales and LIST, presented a novel security solution at LIST's Techdays. The solution, based on the FRAMA-C code analysis platform, is designed to guarantee the security of cryptographic code. The solution represents a real technological breakthrough. Its main innovation is the formal verification of components from secure libraries for the encryption of sensitive communications.

**NOVEMBER 28, 2017**

**For a more transparent food industry**

CEA Tech unveiled its blockchain-based real-time manufacturing audit system, which will be sold by Connecting Food to food-industry stakeholders seeking proof of compliance with product specifications at all stages of manufacturing.



**DECEMBER 5, 2017**

**Ribbon cut on the Additive Factory Hub**

The ribbon was cut on the Additive Factory Hub (AFH) by Valérie Péresse, President of the Ile-de-France Regional Council. The AFH, located on the Paris-Saclay campus, will develop additive manufacturing techniques and unite research stakeholders from Paris-Saclay and all of Ile-de-France to respond to major industrial and economic challenges.

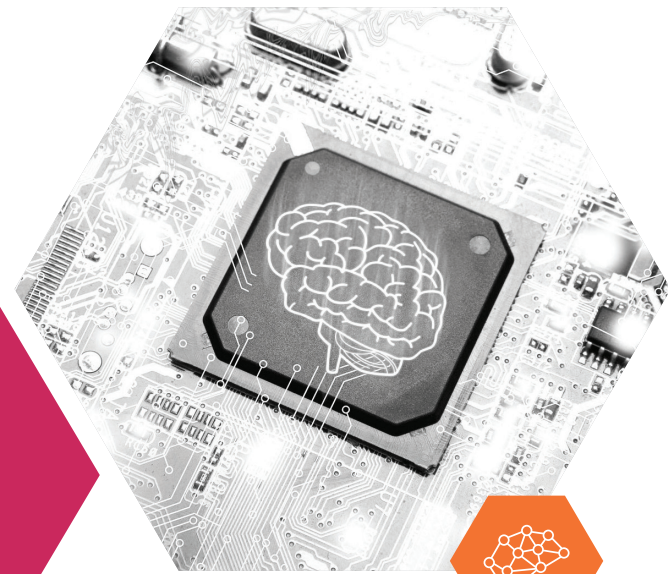


# 5 TECHNOLOGY RESEARCH programs

LIST's strategy is built on a scientific and technical roadmap that will lead to the development of technology bricks that can be transferred to industrial companies through R&D partnerships. The institute's roadmap is built on five areas of expertise:

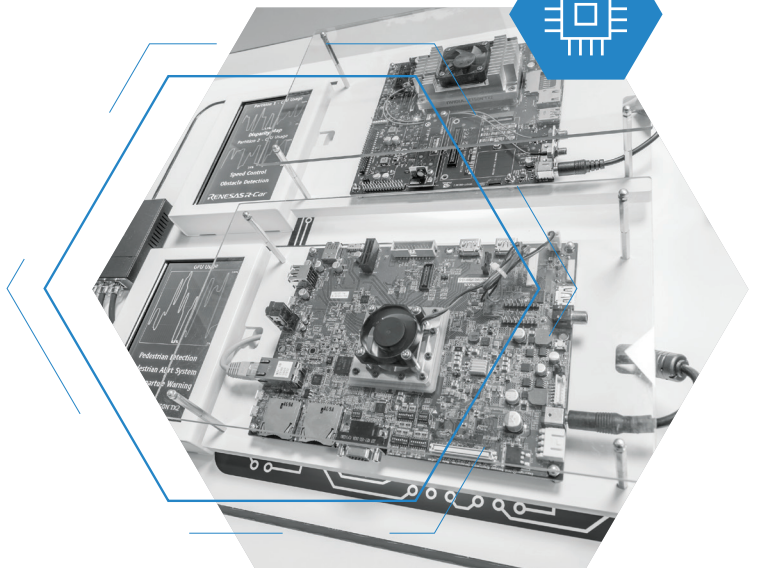
## CYBER PHYSICAL SYSTEMS

Mastering cyber physical systems, whether it is integrating digital technology into factories or improving product performance, is a major challenge for industrial companies in markets like transportation (the autonomous vehicle) and energy (smart grids). These systems are characterized by massive data flows (big data), intelligence distributed across the system, and levels of connectivity never before seen, both within the systems themselves and between the systems and other systems. In other words, cyber physical systems are distributed and communicating. The speed of the applications used and the volume of data transmitted require constant advances in technology, which must also address data security and strategic economic challenges.



## ARTIFICIAL INTELLIGENCE

LIST's artificial intelligence program was primarily founded on the current definition of learning techniques, spanning technologies from innovative sensors to gather information (data) to human-machine interaction, and including the transmission and processing of increasingly massive volumes of data. Multi-mode interactions, which enable a "natural affinity" between humans and systems, are at the center of the human-information-environment triad and of major societal challenges at the global level.

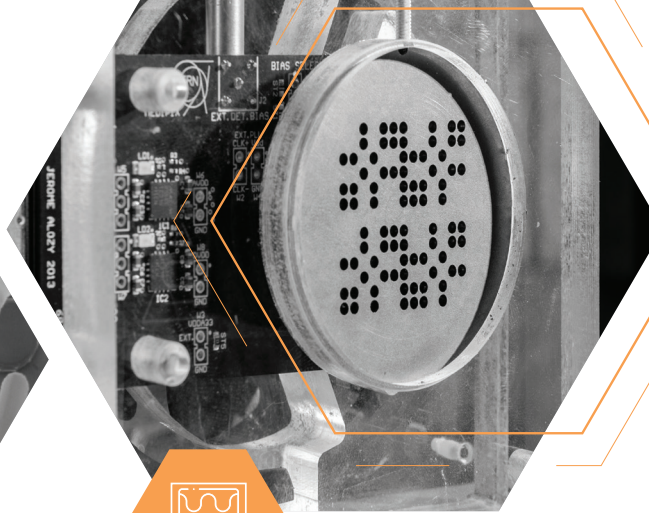






## FACTORY OF THE FUTURE

Tomorrow's manufacturing facilities will be proactive and adaptive. They will respond to industrial companies' needs, from competitiveness to product personalization. LIST addresses the factory holistically, with technologies to support product design and manufacturing. LIST research also takes into account topics that have become high priorities for society. These include the safety of work environments (and, especially, preventing repetitive-strain injuries and human-robot cohabitation and cooperation) and environmental protection and eco-design.



## INNOVATIVE INSTRUMENTATION

LIST is building on its substantial experience with nuclear reactors and the large scientific instruments used in basic physics research to drive advances in instrumentation and meet industrial companies' need for qualification and testing of sensors and other instruments. The scope of applications for instrumentation is gradually widening to meet new objectives like security and sovereignty.

## E-HEALTHCARE

LIST brings its know-how in artificial intelligence and cyber physical systems to e-healthcare. However, the institute also possesses extensive experience in ionizing radiation metrology and in simulation and modelling in areas related to healthcare and radiation such as radiotherapy, medical imaging, and radioprotection. Medical applications require a particularly high degree of precision. Innovations in radiotherapy in recent years have created an even greater need for R&D to improve control of the doses delivered to patients. LIST responded by creating DOSEO, a platform dedicated to these challenges.



# 20 TECHNOLOGY PLATFORMS

To meet the needs of companies, LIST has created a strategy of offering technology platforms backed by dedicated infrastructure and technical know-how. The three pillars of LIST's technology platforms are a powerful, state-of-the-art infrastructure to enable development work from proof-of-concept testing through to prototypes or industrial scale-up; scientific and technical know-how; and knowledge of markets and applications. The technology platforms can handle the different types of R&D projects run at LIST, from pump-priming to technology transfer. ■



ARTIFICIAL INTELLIGENCE

## SCIENTIFIC ADVANCE

# AUTOMATED DIAGNOSTICS FOR NDT

Because non-destructive testing (NDT) processes are affected by so many uncertainties, the CEA's model-based learning approach results in effective signal sorting, thereby facilitating and improving diagnostics.

**P**ost-testing diagnostics, whether categorical or quantitative, remain an industrial problem that has not yet been truly solved. "Parameters related to a part's geometry or to how the controls are implemented can interfere with the signals emitted by defects, making NDT inconsistent. This is compounded by environmental disturbances, which are not necessarily taken into account by modelling equations and are often case-dependent," said LIST engineer Christophe Reboud. "Being able to estimate the quantitative influence of these uncertainties so that a confidence rating can be given to a diagnosis taking into account any disturbances is vital."

### PRE-PROCESSING TESTING DATA TO ASSIST OPERATORS

LIST is currently leveraging a generic "pre-sorting" method to drive advances in automated diagnostics for NDT. "Isolating areas where expert insights are needed from within a large amount of control signals can vastly increase the expert's effectiveness. The amount of data to analyze is reduced without negatively impacting the quality of the diagnosis."

The method developed by LIST uses a model-based approach and learning. "The system learns effectively because it 'trains' on signals modelled with different physics—electromagnetic, ultrasound, X-ray—so that indicators of interest can be extracted. The system is also effective because disturbances are introduced into the data used, whether that data is from the lab or produced by simulators." The multi-dimensional learning and interpolation tools developed have been implemented in ultrasonic inspection for integrated structural health monitoring for the aeronautics industry.



### LIMA SEMANTIC ENGINE TECHNOLOGY TRANSFERRED

LIST transferred its LIST Multilingual Analyzer (LIMA) and LIMA Configuration Wizard (CLIMA) to KBCrawl. The company will use the technology to develop an automated update and access service for Bureau Veritas for its regulatory database. The first version of the service, Diregt.com, which centralizes and monitors regulations concerning 4,000 pieces of equipment for 50 countries, is already online. It includes a multilingual back office that Bureau Veritas can use to determine countries, pieces of equipment, and topics and sources of interest, and collect regulatory documents and extract information for inspections. It also includes a customer-facing front office where the information produced by the back office is available. ■





**EXPERT INSIGHTS**



**We are positioning our solution as an artificial intelligence technology for BIM.**

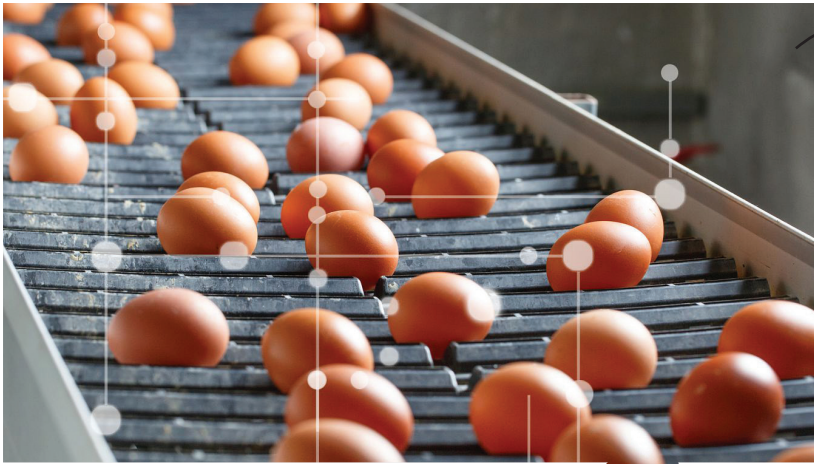
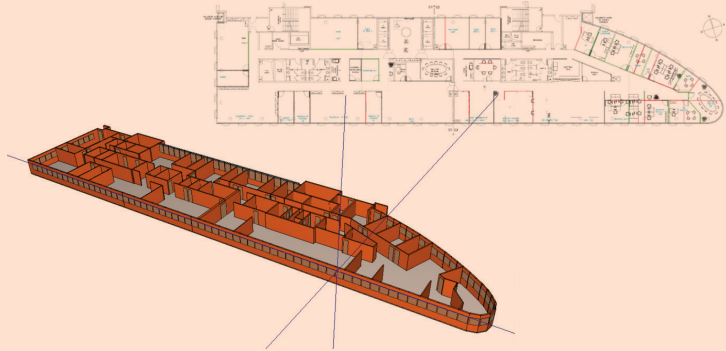
WiseBIM will help our customers make the transition to BIM faster by generating models that are interoperable with automated solutions. Our customers have told us that they find WiseBIM useful and that the high-quality models generated meet their needs. We are pursuing further development of the software in-house and in partnership with LIST through continuous innovation and by positioning our solution as an artificial intelligence technology for BIM.

**TRISTAN GARCIA**

CEO and co-founder  
@WiseBIM

**STARTUP WISEBIM CREATED**

WiseBIM is commercializing and pursuing the development of a LIST technology that can automatically generate a digital BIM (Building Information Model) from 2D architectural drawings. The company's solution makes the transition from paper to digital information faster and easier. It is powered by innovative algorithms that use artificial intelligence and image recognition. It generates a BIM file in IFC format compatible with most building-specific software. WiseBIM targets property management professionals and is designed to support them with their digital transformation projects. ■



**EXPERT INSIGHTS**



**LIST successfully leveraged a breakthrough innovation.**

Blockchain is an unfalsifiable record, making it an important technology for ensuring the transparency of food manufacturing. Specifically, blockchain lets stakeholders share information with confidence. We turned to LIST for help developing a system to audit and validate information to ensure that brand promises are being kept. We were impressed with LIST's ability to successfully leverage a breakthrough innovation. LIST's people are highly knowledgeable and demonstrated a strong capacity to work closely with our team. The project was beneficial to both partners. LIST contributed scientific and technical know-how, and we brought our knowledge of the food industry and an agile and pragmatic approach.

**STEFANO VOLPI**

Co-founder, Connecting Food

**BLOCKCHAIN FOR THE FOOD INDUSTRY: FOR GREATER CONSUMER TRUST**

Food manufacturers only have a partial view of what goes into their products. However, they can be held liable if a product does not comply with specifications—even if the underlying problem did not occur at their plant. Blockchain can be used to gather product quality and traceability data throughout the manufacturing process for all stakeholders involved, from farmers and processors through distributors. Real-time audit capabilities make it possible to issue an alert in the event of non-compliance with specifications. In research conducted by a joint

lab between LIST and Connecting Food, LIST developed a real-time auditing prototype on a blockchain platform. Information is gathered from the processes involved in food manufacturing and the software used is certified. The solution verifies the information at each step and issues a "verdict" that can be validated by all stakeholders. The solution was tested for two months by a food manufacturing company using their data, where it effectively detected all errors known to the customer. ■





ARTIFICIAL INTELLIGENCE

## SCIENTIFIC ADVANCE

# MANUFACTURING REJECTS: prediction and diagnostics

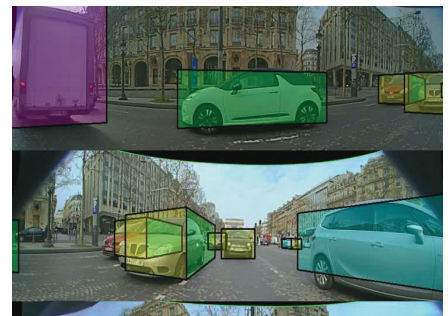
Thanks to an algorithm developed by LIST, the signals gathered by tracking sensors implemented on objects manufactured at certain modern factories were used to identify manufacturing rejects and troubleshoot manufacturing errors.

**L**IST developed a monitoring and troubleshooting algorithm capable of meeting industrial companies' growing need for automated assistance analyzing and interpreting large volumes of signals recorded by sensors. *"The ability to track data and pinpoint manufacturing rejects reduces post-manufacturing product failure rates and makes quality control more efficient. It also enables operators to rapidly take the necessary steps to improve operations identified as frequent sources of defects,"* said Cédric Gouy-Pailler, a researcher at LIST.

### TREES SORT, NEURONS UNDERSTAND

LIST developed a processing chain for a data science competition on data from a Bosch manufacturing plant. The step-by-step chain involved using visualization and statistical tools to explore the data. Characteristics of interest were then constructed so that items could then be classified as "defective" or "healthy."

Finally, the classification of an item as defective was analyzed using aggregated classification trees and neural networks. *"The aggregated classification trees were able to pick out new items on the continuum between 'defective' and 'healthy.' The neural network served as a bridge between the decision, which, due to the hundreds of trees used, was robust, and the cause that led to the decision. This provided an explanation for the defect."* The algorithm, ranked among the best in the competition, makes it possible to set a decision-making threshold according to operational needs in order to predict the reject rate at the end of the manufacturing line. A "defective item by defective item" diagnosis was made to determine the origin of the defects. The algorithm is currently being used for collaborative R&D projects, for semiconductor manufacturing, and for contract research for industrial partners.



### EMBEDDED REAL-TIME DETECTION OF ROAD OBJECTS DEMONSTRATED

LIST developed a perception system based on a deep learning algorithm in partnership with Valeo. The system can detect and locate road objects in real time and in 3D from images from four fish-eye cameras installed on a vehicle covering a 360° view of the environment. A modified and enhanced version of the DeepManta algorithm was used for detection. This multi-task neural network stood out for its remarkable performance in the KITTI world computer vision benchmark. A successful demonstration of the system was completed at Valeo's Bobigny plant and in an urban environment, and the algorithm proved effective on the open road. ■



### HUMAN ACTIVITIES RECOGNIZED IN REAL-TIME AT THE MOBILE MII SMART HOME

The ability to recognize human activities represents a crucial technological and functional breakthrough for tomorrow's video-vigilance and video-assistance systems for assisted living and other home services. LIST leveraged a novel database, a patented innovative algorithm, and real-time optimization to develop

the world's only system capable of recognizing day-to-day human activities in real time. A prototype was tested at a smart home at LIST's Mobile Mii platform, achieving a recognition rate of 75% based on the analysis of data from a single camera. ■



### N2D2 AVAILABLE TO ALL!

The N2D2 (Neural Network Design and Deployment) platform is now available on an open-source basis on the LIST website. N2D2 is the first-ever European platform that can generate neural networks optimized for a wide variety of hardware. Opening up N2D2 will give developers access to a design environment for deep learning applications and will promote the creation of an ecosystem of users that will expand the potential uses for neural networks. ■



EXPERT INSIGHTS



### Making N2D2 open source is a key step forward toward securing LIST's partnerships with industrial companies over the long term.

We decided to work with LIST's N2D2 platform because of its main advantage: the flexibility to port applications to different platforms. During previous projects, we were able to take the executable C files and run them on our machines. We would now like to run them on GPUs and FPGA-DSP type platforms. We are currently finalizing a partnership to use N2D2 to improve our surface inspection systems with the goal of enabling real-time capabilities. The partnership will also enable us to integrate N2D2 into our processes and broaden its use. Moving the core of N2D2 to open source is a good way to get the software out there and to create a community of users to keep it alive. Some of the value-added modules, which we will undoubtedly need in the future, will remain under license. This is completely understandable given that LIST put its industry-leading know-how into developing these modules.

### GABRIEL FRICOUT

Head of Measurement and Control R&D, Arcelor-Mittal





CYBER PHYSICAL SYSTEMS



## SCIENTIFIC ADVANCE

# LIFE·LONG·EXPLORATORY NAVIGATION (LEN):

robots are not infallible, but they can be better explorers!

**Robot navigation must be robust and efficient—but not at the cost of overtaxing computing resources. LIST came up with a solution to this challenge in the form of a simple, economical, and intuitive navigation system based on human experiences of movement.**

**A** ccording to LIST researchers, topological maps are sufficient for robot movements: *“Like us, robots do not generally need to know their position down to the millimeter—which would be very memory-intensive. They just need to get to their destination quickly enough and without any collisions,”* said LIST’s Laurent Soulier. To do this, robots can also use incomplete or partially-invalid maps. However, in the event of an anomaly, the system must be able to continue to operate and take shortcuts in unfamiliar environments. LIST developed an algorithm called EDNA (Exploratory Digraph Navigation Using A\*) that chooses between safe trajectories and risk-taking for exploration. To build the graph, distance sensors are integrated into the LEN system, and the topology is analyzed, selecting notable features like intersections as nodes: *“It isn’t necessary to map everything. You can keep very few nodes and keep the system operating well enough throughout its lifetime and save memory.”*

A loop-detection feature recognizes places that have already been visited, improving the quality of the map stored: *“When the robot encounters a new node, it figures out whether it can close the loop or explore its surroundings to confirm its location.”*

### APPLICATIONS FOR BUILDING AND AUTOMOTIVE ROBOTICS

The method developed by LIST can be used to build topological maps of arbitrarily-large environments whose complexity does not depend on their size. And it works! *“The solution was tested successfully on a real robot equipped with a Kinect sensor and an accelerometer navigating through a building. The system can now be applied to the autonomous vehicle, where it could replace the GPS card, and to indoor robotics for immediate rollout without the need to first create a map of the building.”*

*\* Fabrice Mayran De Chamisso, Laurent Soulier, Michael Aupetit: Robust topological skeleton extraction from occupancy grids for mobile robot navigation, RFIA 2016.*



## REQUIREMENTS-BASED ENGINEERING AT AUTOMOTIVE EQUIPMENT MANUFACTURER PLASTIC OMNIUM

Requirements-based engineering is the cornerstone of complex systems. Plastic Omnium has to be able to guarantee the compliance of its products with automotive-industry and software-engineering standards and ensure consistency across all of its documentation. LIST developed a process based on the SysML systems modelling standard and the Papyrus platform that was validated on several diesel depollution system test projects. The validation testing revealed a sharp increase in productivity and product quality and could create opportunities to lower development costs. Plastic Omnium is now rolling the tools out at its R&D center. ■





## POLYMORPHIC CODE FOR MORE SECURE EMBEDDED SYSTEMS

In research conducted under the COGITO project on embedded systems security, LIST developed measures to protect systems against physical attacks that have turned out to be particularly effective against cryptographic code implementations. LIST used LLVM deGoal technology to design a new embedded systems security toolchain. Polymorphism is one of the security principles that proved to be effective against these attacks. It consists of causing dynamic variations to the behavior of a secure component without modifying its functional properties. When used in addition to state-of-the-art countermeasures, polymorphism can be implemented on embedded components, even if their computing resources are limited. The COGITO project resulted in several patent applications and international conference papers. ■



## FRAMA-C: SOFTWARE-TRANSFER SERVICES FOR THE IMPLEMENTATION OF FORMAL METHODS IN INDUSTRIAL ENVIRONMENTS

LIST is building on its advances in R&D with new software-transfer services for the formal validation of critical code. LIST has already signed support contracts for its Frama-C platform and to implement its functional modules for two major industrial corporations. Interactive proof module WP is helping Airbus support the validation of functions in the specifications with reasoning based on formal mathematical properties. EVA, an automated analyzer of intrinsic code quality, is bringing electric utility EDF a guarantee of no table overflow or division by zero errors. ■



## ANALYZING IoT SYSTEM RISKS AND SECURITY

Internet of Things (IoT) connectivity can effectively link and control a variety of remote devices. However, it also leaves a number of doors open to cyberattacks. LIST is exploring ways to make IoT systems more secure through investments in collaborative R&D with industrial companies. LIST has already set up a two-phased method and the associated tools. The first phase involves assessing risks like system vulnerabilities, the relationship between likelihood and the seriousness of impact, and deployment of countermeasures. The second step entails analyzing the robustness of countermeasures by comparing a model of the detection mechanisms with attack scenarios. The approach was validated on a test case on Engie's smart grid in Toulouse. ■



CYBER PHYSICAL  
SYSTEMS

## SCIENTIFIC ADVANCE

# GETTING CLOSER TO TACTILE TEXTURE DISPLAYS: CEA LIST wins award

LIST research on using non-radiating ultrasonic vibrations to create tactile texture won the Best Paper Award at IEEE WorldHaptics 2017.

**L**ocal friction modulation applied to a surface effectively mimics texture through vibrations that occur upon the contact of a finger. However, current implementations of the technique make the entire surface vibrate with the same amplitude, which is modulated over time depending on the position of the finger. If several fingers come into contact with the surface, which is subject to the same friction coefficient, the illusion of texture is broken.

### LOCAL VIBRATION IN THE AREA COVERED BY THE SWITCH

The habitual technique uses a piezoelectric switch bonded to a glass plate, which, when subjected to an electrical signal at a surface resonance frequency, produces waves that are of a large amplitude but uniform. LIST made a major change to the technique by switching wavelengths: *“We thought it would be possible to excite a switch at a very specific type of frequency: a non-radiating frequency,”* said LIST researcher Charles Hudin. *“Due to interference effects, the vibrations generated by the switch remain confined locally. The vibrations outside of the area covered cancel each other out.”*

The research positions LIST’s know-how in wave physics alongside the mainly robotics-oriented approaches used by the haptics community. A paper on the research entitled *“Local friction modulation using non-radiating ultrasonic vibrations,”* won the Best Paper Award at IEEE WorldHaptics 2017 and the method was patented. LIST can now look ahead to implementing the method on several transparent switches placed under a surface to enable multi-touch capabilities.



## LIST PLACES FIRST IN INFORMS RAILWAY APPLICATIONS SECTION COMPETITION

A team of LIST researchers (Sergiu Carpov, Loïc Cudenneq, and François Galea) came in first out of 40 entrants in the INFORMS (INstitute For Operations Research and the Management Science) Railway Applications Section competition. The winning entry was a two-stage heuristic algorithm designed to solve a train traffic and maintenance scheduling problem. The achievement is evidence of LIST’s ability to effectively optimize systems for a truly diverse range of applications. ■





## BETTER CONTROL OF MIXED-CRITICALITY ON MANYCORE PROCESSORS FOR AVIONICS

LIST and Safran have been working together since 2014 to assess whether or not the capacities offered by manycore architectures can meet the needs of avionics applications and, in particular, maintaining the safety of critical applications and boosting the performance of intensive computation processing. In 2016 Kalray's MPPA Bostan network-on-chip was evaluated in the lab. A prototype demonstrated that the mechanisms for regulating application communication can be leveraged to control the sharing of pathways on the network-on-chip by applications of the same criticality; routers can be locked to isolate applications with different



criticalities. LIST's research will pave the way toward the use of manycore processors in future Safran products for the aeronautics industry. ■



## RENAULT TURNS TO LIST TO REVOLUTIONIZE VEHICLE E/E ARCHITECTURES

The automotive industry is changing rapidly as manufacturers develop increasingly connected and autonomous vehicles. These transformations will require growing processing power, greater safety, and additional software flexibility

—all of which call for a thorough overhaul of Electrical/Electronic (E/E) architectures. Renault turned to LIST to develop new centralized, modular computing solutions that could help simplify the E/E structure and prepare for future needs. ■





**FACTORY  
OF THE FUTURE**

## SCIENTIFIC ADVANCE

# A DIGITAL TWIN FOR PSA AUTOMOTIVE PLANTS

LIST provided automotive manufacturer PSA with a method combining modelling, optimization, and simulation to keep production line downtime to a minimum.

**T**he inter-process inventory storage areas in car manufacturing plants are where parts are kept between robot-staffed assembly lines. Buffer inventory absorbs the impact of unforeseen events and makes the production line run smoother. However, until they are needed, the parts just sit there taking up floor space. To reduce costs, buffer inventory must be kept to the strict minimum required to keep the line running. PSA had been sizing the buffer inventory for its Body in White (BIW) lines by trial and error, before entering the best size found "by hand" into flow simulation software. LIST came up with a solution to automate and optimize the process.

### A THREE-STAGE INNOVATION FOR MORE EFFICIENT PRODUCTION

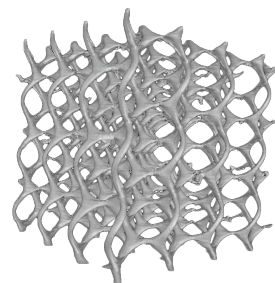
The method developed by LIST starts with a model that brings all of the data together in a functional digital twin for a comprehensive overview of the system and processes.

*"The model was created using LIST's Papyrus software in a language based on the ISA-95 standard, including management functions and business processes,"* said LIST researcher Ariane Piel. The model is then sent to an optimization tool developed by LIST where the number of configurations to explore is reduced. *"The tool factors in unforeseen events and calculates the possible dimensions of the inventory storage area to achieve production targets."* Finally, a simulation provides support selecting the smallest configuration that will keep the production line running smoothly. *"The library in Sherpa Engineering's tool can be used to simulate discrete, or one-off, events and extends an existing library designed for continuous simulation. Ultimately, it will be possible to use both types of simulation simultaneously."*



## X-RAY TOMOGRAPHY FOR ADDITIVE MANUFACTURING

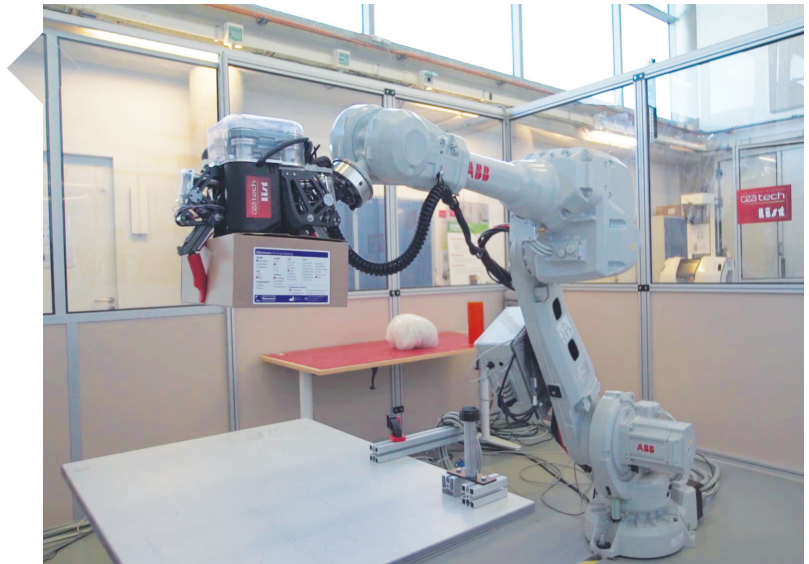
X-ray tomography is considered the number-one quality-control method for parts made using additive manufacturing processes. It is very good at checking part dimensions and at finding defects within the material. In research conducted for the French Single Interministerial Fund IMASURE project, tomographic image acquisition, reconstruction, and analysis tools developed by LIST were used to characterize the specimens used in traction tests. High-resolution tomographic imaging was used to assess pore and inclusion granulometry and position, for concentrations that fluctuated between 10-4 and 10-3 depending on the manufacturing parameters. For the kind of complex components that can be made using additive manufacturing, the inversion methods developed by LIST for tomographic reconstruction were tested on lattice structures, where they were used to check geometry. The methods are based on the hypothesis that the component is made from a single material, reducing tomographic acquisition times by a factor of 10 to 20 while maintaining spatial resolution of 0.1 mm, for example, for an object whose characteristic dimensions are 80.0 mm. In addition, the method used is compatible with images obtained using robotic systems. Finally, a robotic tomography system that allows around 100 samples to be analyzed simultaneously was developed to provide statistical analyses of reproducibility and of the influence of manufacturing parameters. ■



◀ A metal lattice structure analyzed using X-ray tomography; reconstruction obtained from 30 projections acquired over 150 degrees.

## ROBOTS FOR REMOTE HANDLING OF CONTAMINATED WASTE

In research conducted in partnership with ITER, LIST developed a remote handling system to equip the walls of hot cells. The system meets the needs of companies that sort and decontaminate radioactive waste. A “slave” robot reproduces the movements of a “master” unit run by an operator, keeping the operator away from radiation hazards. The quality of the solution was demonstrated in a representative environment. LIST is also designing new grabbers with several fingers that will be coupled with haptic feedback gloves on the “master” side of the system to enable dexterous manipulation. ■



## CIVA ANALYSIS, A SOLUTION FOR OPTIMIZING AND AUTOMATING NDT DATA ANALYSIS

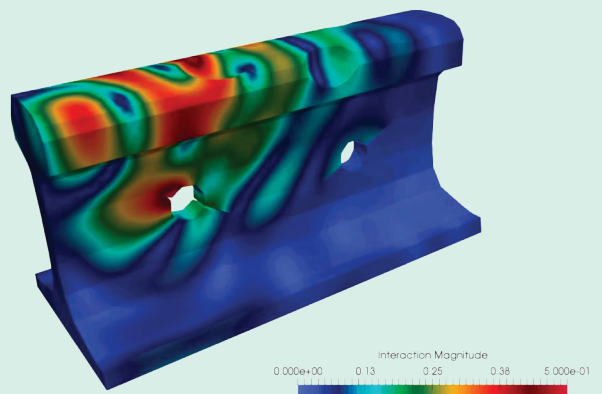
The CIVA Analysis module, part of LIST’s CIVA simulation platform, includes a set of imaging and processing tools for the analysis of ultrasonic tests. The diagnosis is a crucial factor in the performance of non-destructive testing (NDT); automating the diagnosis could generate major improvements in both productivity and safety. This year, several industrial companies turned to LIST to take advantage of the institute’s innovative automated diagnostics. Ocean Breeze Energy, one of LIST’s partners, was seeking maintenance and operations solutions for an offshore windfarm. LIST provided a personalized CIVA solution that helped Ocean Breeze Energy reduce the time spent on annual maintenance inspections from several months down to just days. ■



## PASSIVE TOMOGRAPHY, AN INNOVATIVE APPROACH TO STRUCTURAL HEALTH MONITORING

Structural Health Monitoring (SHM) systems use integrated sensors to detect the appearance of defects before a failure occurs. LIST is developing passive tomography, an original approach to SHM that uses ultrasound waves to monitor damage (like loss of thickness due to corrosion) to thin structures like plates or tubes. Sensors are integrated around the

concerned areas. The sensors “listen” to the low-amplitude waves propagated through the structure, without the need to inject energy into the structure. The time it takes for the waves measured to travel between the sensors is used to reconstruct an accurate map of the thickness of the area. ■





**FACTORY  
OF THE FUTURE**

## SCIENTIFIC ADVANCE

# AUGMENTED REALITY

on a larger scale

LIST is building on its success with augmented reality for small objects to apply the technology on a larger scale. The institute is currently developing an augmented reality system for the construction, maintenance, and inspection of large structures.

**T**he augmented reality technologies developed by LIST can effectively estimate in real time the exact position and orientation of an object in relation to a mobile camera using a CAD model. Diota has been commercializing the technologies for industrial applications since 2010: *“These technologies can be used to tell an operator where and in which order drilling or screwing tasks should be completed,”* said LIST researcher Régis Vinciguerra.

**MEASURING MOVEMENT, ONE OF THE KEYS TO AUGMENTED REALITY FOR LARGE OBJECTS**  
LIST’s recent developments in algorithms now make it possible to implement augmented reality in large environments or on large objects offering only partial visibility with the same degree of robustness as for small objects. *“We are now using more complex algorithms to create a smooth 3D reconstruction from a moving camera,”* said Vinciguerra.

LIST’s algorithms are used with a method to fuse the data from several cameras with a motion sensor capable of measuring the orientation and speed of rapid movements. *“For objects like an airliner or ship, cameras alone are not sufficient, especially in areas that are too dark or on surfaces that are too smooth. The information from the motion sensor lets us compensate for the cameras’ temporary or local weaknesses in certain conditions.”* LIST also made advances on location processes in the absence of a model to develop real-time navigation tools, such as for an entire industrial facility. The tools will be able to generate geolocated information that can be displayed using augmented reality interfaces like a tablet or glasses.



## COBOTS ASSIST FOOD MANUFACTURING OPERATORS WITH DIFFICULT TASKS

LDC’s manufacturing plants use crates that are regularly piled up and taken down and put on and taken off of pallets—all by hand. LIST offered to develop a new cobot to help LDC operators move the crates, reducing the strain associated with the task. To show that the technology bricks LIST planned to use were relevant, the institute built a representative model of LDC’s needs based on several use cases and carried out a well-received demo at an LDC plant. ■

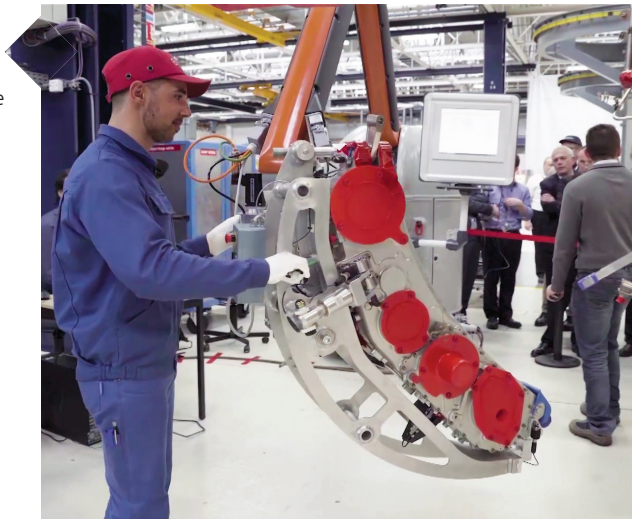






## COBOMANIP HANDLES MISSILE TURBO ENGINES!

LIST built on its extensive experience with collaborative robotics to develop Cobomanip, a new-generation assisted handling system, in partnership with SMB Sarrazin Technologies. A prototype of the system was tested on industrial use cases; improvements were made to boost reliability and experiments with new functions were completed. Specifically, the system was used with a special grabber to remove and reinsert the turbo engine of the MBDA Scalp missile for maintenance. Cobomanip handled the heavy, cantilevered load with ease, confirming that the technology bricks used to build the system are relevant. ■



## AFFORDABLE DEXTEROUS MANIPULATION OF 3D OBJECTS IN VIRTUAL REALITY

LIST transferred a low-cost virtual reality software application that simulates dexterous manipulation tasks to company Light & Shadows. The solution combines real-time simulation of the dynamics and interactions of multi-body systems (LIST's XDE engine), a contact model for grabbing, and a measurement of the quality of the "grab" so that the command rules can be adjusted accordingly. Light & Shadows released INTERACT, its first product based on the solution, to meet the needs of advanced manufacturing. ■

## VIRTUAL REALITY PAINTING TRAINING

Alstom turned to LIST to make some changes to its virtual reality painting training tool to better align the tool with the company's needs. LIST's solution consists of a real, instrumented, and tracked paint sprayer gun that "paints" a 3D model of a train. The bucket lift is controlled using a pedal. The paint spray simulated on the part being painted is based on a ray tracer technology at the state of the art for Alstom's unique environment (sprayer nozzle, paint level, etc.). The tool was transferred to startup Light & Shadows. Alstom purchased the first system sold for its Katowice, Poland plant. ■

### EXPERT INSIGHTS

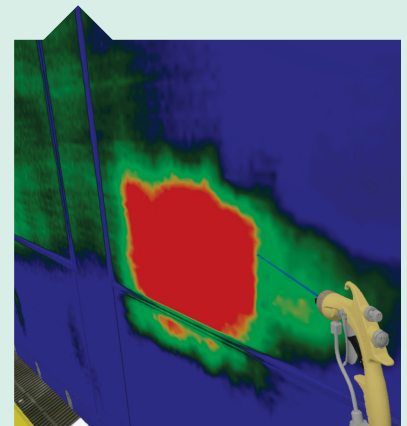
LIST took the solution as far as it could go within the physical constraints of the project.

Our partnership with LIST continued in 2017 with the development of a technology brick to enable dexterous manipulation. LIST researchers are experts in their field. We come from a more operational angle with high demands in terms of time to market. In other words, we speak different languages. The project framework was effectively established at the start, which got everyone on the same page in terms

of deliverables and other expectations. LIST took the solution as far as it could go within the constraints of the project, especially when it came to capturing manual gestures. We are satisfied with the results. We are already selling the software to companies in the transportation industry, and plan to make further improvements like integrating new peripherals for enhanced interaction with the system.

### ANTOINE LASNIER

Industrial Project Manager, Light & Shadows





**INNOVATIVE  
INSTRUMENTATION**

## SCIENTIFIC ADVANCE

# HIGH-PERFORMANCE SURFACE-FLATNESS CONTROL

for cold rolling mills

LIST completed proof-of-concept testing on a prototype system to improve in-line quality control of cold rolling mills. The prototype flatness-measurement roller leverages a sensitive, high-spatial-resolution distributed Bragg reflector (DBR). It was tested on a pilot cold rolling mill.

**T**he automotive, aeronautics, packaging, and other industries are demanding increasingly thin, hard sheet metal, creating challenges for steel companies like Arcelor-Mittal. "Quality control on very thin steel is complex, in terms of acquisition rates, spatial resolution, and effort," said LIST researcher Sylvain Magne. "Current inspection systems do not perform well enough to support incremental upgrades to existing cold rolling mills in France and other European countries. For example, today's systems cannot reliably detect and measure local defects on the edges of products like panels or excessive tensile stress on the extreme edges leading to premature breakage of the product."

### A FASTER, MORE SENSITIVE, AND MORE PRACTICAL SOLUTION

LIST and Arcelor-Mittal cooperated on the design of a new type of high-performance flatness measurement roller built on distributed Bragg reflectors (DBR) "light inscribed" inside of optical fibers.

*"The roller can measure the distribution of force synchronously over the entire generator. This eliminates errors like those due to unbalanced force. Distributed Bragg reflectors are excellent at measuring deformation. Wavelength multiplexing makes the method very easy to implement."*

The system's detection limit is 1 kPa, and it offers dynamics of more than 1,000 measurement points across the range and spatial resolution of 5 mm. The acquisition rate of 1 kHz is compatible with industrial rolling mills.

Finite element simulations were completed, and then a prototype of the roller was developed and calibrated by LIST and tested in static and dynamic modes on a test mill at Arcelor-Mittal.



### EXPERT INSIGHTS



## NICOLAS LEGRAND

R&D Engineer,  
Arcelor-Mittal USA

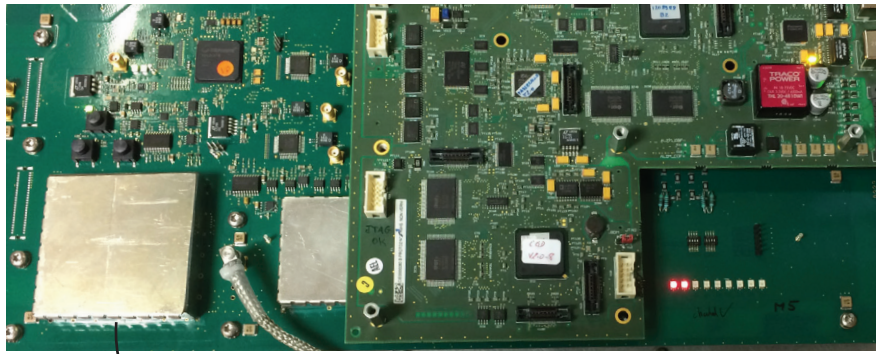
### Our partnership with LIST improved our knowledge of fiber optics.

LIST contributed knowledge of fiber optics and the ability to build laboratory prototypes of several technical solutions to our joint project. Arcelor-Mittal brought skills in finite-element calculations, useful in verifying, dimensioning, and testing the solutions on pilot production lines. Our complementary know-how led to a patent. However, constant communication with LIST scientists throughout the project really helped us improve our knowledge of fiber optics. This new knowledge positioned us to use fiber optics for other measurement needs in our manufacturing processes, such as measuring friction on rolling mills and measuring temperatures in industrial environments.



## NEUTRON CHAIN PROTOTYPE FOR FOURTH-GENERATION REACTORS VALIDATED

Neutron chains are a key component in the operation of nuclear reactors. They are used to measure the flow of neutrons, detecting speed and variations in all nuclear boiler room situations, from start-up and heat-up to full power. In LIST research and development for fourth-generation nuclear reactors, an innovative high-dynamic-range neutron chain was developed to monitor reactor power. The neutron chain's new electronics and simplified signal processing system enhance safety, even in the event of an accident. Rolls-Royce expressed an interest in using the technology to meet the needs of the Chinese and US markets. LIST's demonstrator system and a prototype developed by Rolls-Royce were validated on the ISIS reactor in Saclay. ■



### EXPERT INSIGHTS

#### NICOLAS CAMPET

Nuclear, Instrumentation, and Control Project Manager, Rolls-Royce CN

### Working with LIST gives our products a major advantage in terms of perceived quality.

We turned to LIST for support developing and validating the performance of an innovative neutron chain. LIST provided advanced technical know-how and the infrastructure we needed to test and validate our product. The functional testing completed on the ISIS reactor confirmed that the product met the targets we had set. We are now seeing

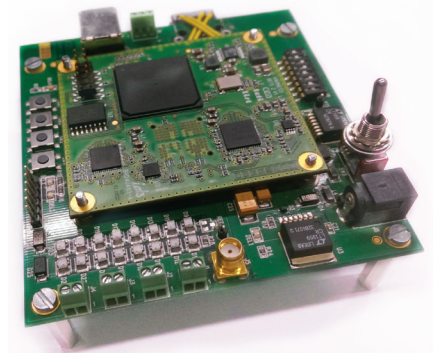
the potential business benefits of the technology developed through our partnership with LIST. Beyond just developing and transferring technology, LIST is a key partner for industrial companies like ours, bringing our products greater credibility with our customers as well as with the nuclear safety authorities.



## X-RAY IMAGING DETECTS OBSTACLES IN RAILWAY TRACK BALLAST

SNCF, France's national railway operator, is currently using special trains to rebuild its network of tracks. One such train is equipped with a chain that releases and screens the ballast. Obstacles like pieces of wood, concrete, or metal under the ballast can bring work to a halt, causing costly delays. SNCF turned to LIST to develop a robust obstacle detection system that could ultimately be installed on board a train. LIST carried out a feasibility study of a backscatter

X-ray system with a beam limiter and two detectors. Tests were done using LIST's SAPHIR linear accelerator on a model track equipped with obstacles. The initial results showed that the system is capable of identifying obstacles both at a standstill and in motion (at speeds of at least 35 kph) with reliability rates of 80% to 95% depending on the obstacle type and location. These results met the SNCF requirements for the project. ■



## CABLE DIAGNOSTIC INTEGRATION DEMONSTRATED ON AN AIRBUS A350

A reflectometry sensor technology for cable diagnostics developed by LIST was integrated into three aeronautics systems on an Airbus A350 to provide real-time monitoring of cable status and diagnostics. The research was part of LIST's @MOST Motivation project, which aims to simplify the maintenance of aeronautics system cables. Demonstrations were completed at Airbus for the aeronautics-industry partners involved in the project and provided insights into what future aircraft cable maintenance technologies could look like. ■





SCIENTIFIC ADVANCE

# SECURE GENOMIC DATA

for mass sequencing

LIST is running a project to develop a personalized genomics platform that includes securing the data generated by mass sequencing so that it can be used in personalized medicine.

**T**he emergence of mass sequencing is creating new possibilities for the personalized use of genomics in healthcare: *"The use of genomics could go beyond just studying populations. Genomics could now focus on individual patients,"* said LIST Research Director Renaud Sirdey. Personalized genomics will require data storage and processing infrastructures that are both open and secure. *"Remote access to the data will be a must. However, due to the sensitive nature of genomic data, confidentiality is also crucial."*

### ENCRYPTED DATA PROCESSING FOR OPTIMAL SECURITY

To respond to these needs, LIST developed homomorphic encryption methods suitable for genomics. *"Our encryption method does not diminish the capacity to process 'hidden' data. Only authorized users can access the results. This protects against threats originating from the server where the data is processed."*

An initial genomic diagnostic demonstrator system using encrypted data was successfully used to run several variants of an ABO blood type test in just minutes. A multicore architecture will be implemented and further optimizations made to improve the demonstrator system's performance. Specifications for a systems architecture for the secure processing of genomic data were also completed. The scope of the research was recently expanded to HLA immunocompatibility tests, which were also successful. *"Our algorithm securely extracts the phenotypes from an encrypted portion of a genome, rather than from the entire genome. This enhances the system's performance."*



### EXPERT INSIGHTS



### LIST's solution meets the needs of tomorrow's genomics.

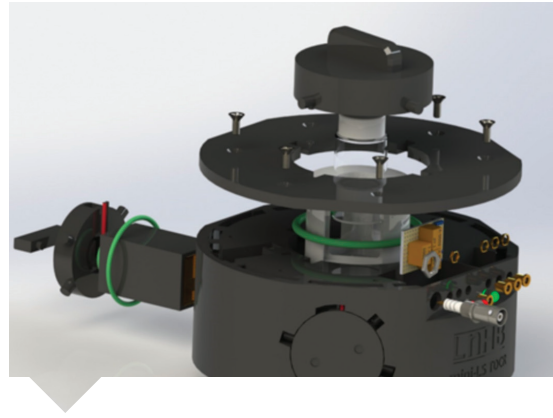
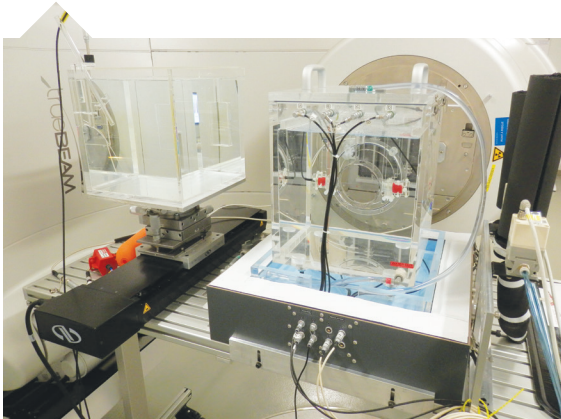
Genomic data is encrypted in such a way that it can not be hacked at any time on any machine. Regulations are becoming more stringent and our market is very competitive, so being able to guarantee the security of patient data—and, especially, genetic data—will give our product a major market advantage. In addition, it will be possible to query a genome for a specific biological question. These highly-desirable capabilities will meet the needs of both researchers and clinical practitioners, especially in fields like cancer and rare diseases. More broadly, they will comply with new requirements that are emerging amid the global genome sequencing revolution.

### FRANÇOIS ARTIGUENAVE

CEO, Traaser, a startup that is developing sequencing data analysis software for clinical practice

## NEW METROLOGICAL REFERENCES FOR RADIOTHERAPY AT DOSEO

A Varian TrueBeam® medical linear accelerator was installed at the DOSEO platform. LNHB (the Henri Becquerel National Laboratory) will now create new metrological references for radiotherapy based on the new beams using a water calorimeter developed in-house. This primary instrument measures temperature increases to determine the doses of high-energy photons and electrons absorbed in water, the reference environment for radiotherapy. As a result of measurements taken on the Varian TrueBeam®, the uncertainty rate for the absorbed dose to water for photons was reduced by a factor of 2. ■

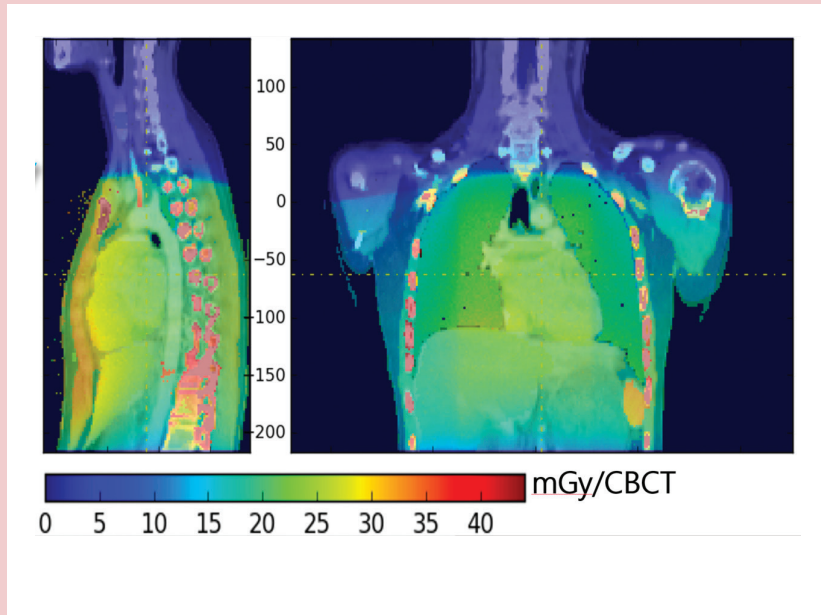


## NEW PORTABLE MEASUREMENT DEVICE FOR CALIBRATION IN NUCLEAR MEDICINE

The devices used to measure the activity of radiopharmaceuticals have to be calibrated by a metrology lab before they can be used. However, certain radionuclides produced in hospitals have short half-lives and must be calibrated on site. LNHB (the Henri Becquerel National Laboratory) designed a primary activity measurement device for on-site calibration where radiopharmaceuticals are manufactured or used. The portable liquid scintillation counting device (the technique commonly employed by national metrology labs) was designed using additive synthesis. It features compact photomultipliers and miniature acquisition electronics. In validation testing completed at LNHB the device performed similarly to lab equipment. ■

## LOWER DOSES FOR EMBEDDED IMAGING IN RADIOTHERAPY

Better estimations of the doses received by patients when images are taken during the necessary patient positioning prior to radiotherapy will lead to more accurate dose control and, ultimately, fewer cases or radiation-induced cancer. LIST is also engaged in a project with Dosisoft and four treatment centers in France to develop a prototype software application to complete 3D delivered dose assessments on embedded imaging systems. The software can tailor the assessments for individual patients and procedures. It was used in an initial clinical trial to calculate the dose received by a pediatric cohort and by ten adult cancer patients. The results indicated that it is possible to estimate the dose delivered to organs and to improve protocols, potentially reducing uncertainty by a factor of 2 to 10. ■





E-HEALTHCARE

## SCIENTIFIC ADVANCE

# A D·E·C·I·S·I·O·N A·S·S·I·S·T·A·N·C·E T·O·O·L for new radiotherapy techniques

LIST developed software that will help medical physicists better assess the complexity of radiotherapy treatment plans, freeing up additional time that they can spend caring for patients.

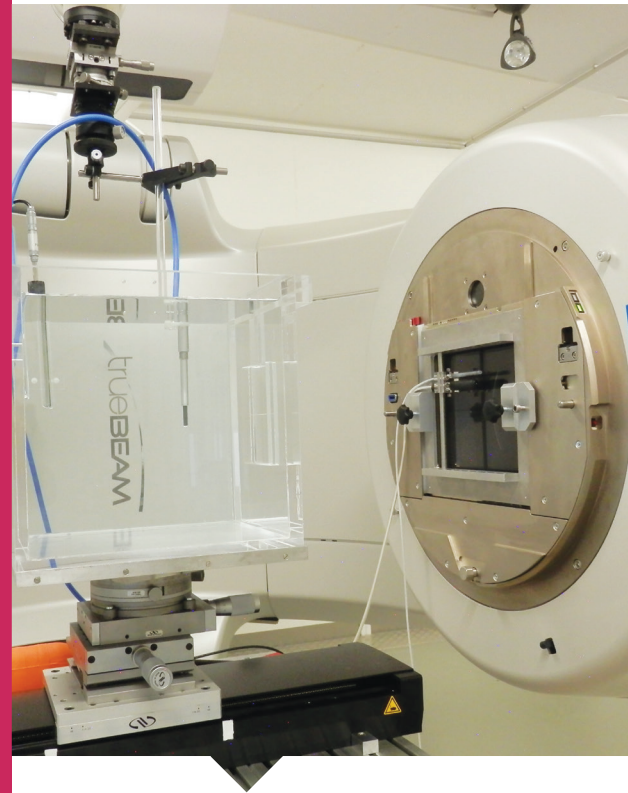
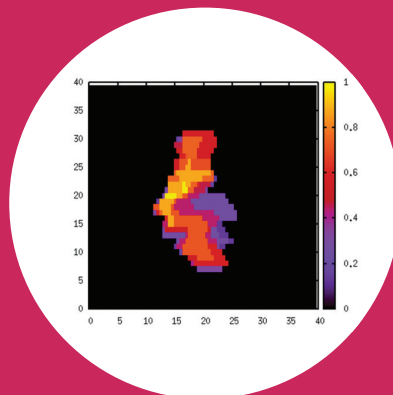
**N**ew radiotherapy methods like intensity-modulated radiation therapy (IMRT) are complex, which creates additional demands in terms of quality assurance and preparation time. Systematic dose controls must be completed on treatment plans before treatment can begin. The ability to assess treatment-plan complexity could save on valuable resources like time, labor, and machines.

**A BETTER ASSESSMENT OF TREATMENT-PLAN COMPLEXITY FOR IMPROVED QUALITY CONTROL** Radiation Therapy Consulting turned to LIST to develop software that generates a list of complexity metrics for each treatment plan.

*"We took eight indicators of complexity in terms of geometry and particle flows and combined them. We looked at factors like the irregularity of the shape of the treatment field, the differences in the blade openings, and the variations in fluence,"* said LIST researcher Mathieu Agelou.

The software takes information from the treatment planning software associated with the machine, regardless of who manufactured the machine or the software.

*"Our algorithm predicts the results of quality controls based on previous treatment plans and controls via a learning algorithm."* The partner treatment centers will complete an initial data-acquisition phase to validate the prototype software delivered to Radiation Therapy Consulting. Improvements will then be made to the prototype before the software is released on the market. Medical physicists will be able to use the software to set thresholds to determine which treatment plans can be used without an additional analysis, which plans to reject, and which plans to analyze further.



## LIST CONTRIBUTES TO IAEA TRS-398 RADIOTHERAPY PROTOCOL UPDATE

The new radiotherapy techniques are very precise, which also makes them safer and more effective at treating cancer. To support the update of the IAEA TRS-398 code of practice for dosimetry in radiation therapy of cancer published in 2000, LNHB (the Henri Becquerel National Laboratory) offered to develop a coordinated response for the European ionizing radiation metrology community at the request of IAEA. As part of the European RT-NORM project, LNHB will determine the quality conversion factors (between the cobalt-60 photon beam and the medical accelerator) for the calibration coefficient of dosimeters released on the market since 2000. The conversion factors will support the publication of a set of values for the IAEA TRS-398 update. This new data will be made available to all medical physicists. ■



# C·O·N·N·E·C·T·W·I·T·H·L·I·S·T

## on social media!

Stay in touch with LIST and its people with the latest news, events, educational videos, interviews, and more!



TWITTER



CEA LIST @CEA\_LIST 7 sept. 2017

@CEA\_LIST and @thalesgroup innovate in #cybersecurity



YOUTUBE



Best of techday 2017  
CEA LIST • May 10, 2017



CEA LIST @CEA\_LIST Dec. 15, 2017

Valérie Péresse, President of the Ile-de-France Region, cut the ribbon on the Additive Factory Hub (AFH) on the CEA's Saclay campus



Career paths | Create a startup  
CEA LIST • July 7, 2017



LINKEDIN



CEA LIST @CEA\_LIST 15 déc. 2017

With LIST's Frama-C software @Dassault\_OnAir is innovating in #cybersecurity #ProofOfConcept



CEA LIST  
"Virtual reality: Gateway to a new world?"



CEA LIST  
January 25, 2018 | Touch screens: Local electromagnetic pulses for more precise haptic feedback

# START-UP,

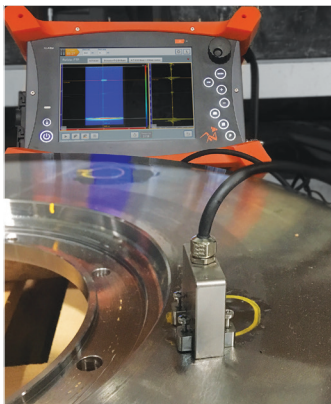
## facilitating the transfer of technology from lab to market

Since 2001, research at CEA List has resulted in the creation of 21 startups, most of which were founded by our researchers. These startups have created 300 jobs. They also play a key role facilitating the transfer of know-how and tools developed at LIST to businesses. LIST startups scale-up and commercialize new technologies and develop associated services.



### SPORT QUANTUM

Sport Quantum was founded in April 2017 to develop athletic performance measurement technologies. The company's core technology leverages mathematical models of the physics of impacts to accurately locate impacts on a connected plate in real time. Sport Quantum will initially address the shooting sports market.



M 2 M

### M2M

M2M is expanding its lineup of in-the-field ultrasonic non-destructive testing (NDT) equipment with the release of MANTIS, a new 16:64 multi-element probe that is compact, powerful, and affordably-priced.



### TRIDIMEO

Tridimeo, which was founded in early 2017, brings industrial customers fast, accurate 3D vision solutions that leverage a technology developed by the CEA for high-throughput quality control and robot operation. The company won the ILAB 2017 competition in the digital technology category and the EIT Health "HeadStart/Proof of Concept" award. The CEA also gave Tridimeo its "200th Startup" award for CEA spinoffs.



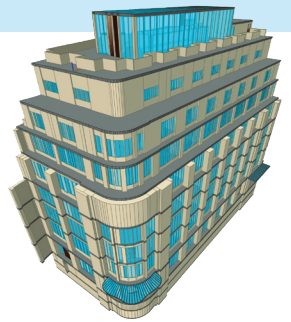
### KALRAY

This year Kalray introduced solutions for the datacenter market, with its Kalray Target Controller (KTC), and for the automotive network, with the Kalray Neural Network (KaNN), based on the second generation of its smart MPPA® processor. Renault selected the processor for its SYMBIOZ concept car. Finally, Safran, MBDA, and Pengpai Capital acquired stakes in Kalray in 2017.



### KRONO-SAFE

Krono-Safe's sales continued to rise, with new business from leaders in the military, aeronautics, automotive, rail, energy, and industrial IoT markets. The company is currently developing a DAL-A DO-178C avionics certification kit for Asterios.



### WISEBIM

LIST startup WiseBIM offers an innovative and virtually completely automated solution for generating BIM files of existing buildings from 2D drawings (PDF, jpeg, dwg, etc.). Founded in April 2017, WiseBIM has completed several test cases with subsidized housing operators and large construction companies. The company, which currently has four employees, has won multiple awards, including the BIM World 2017 award for digital technology startups in the construction, real estate, and urban planning sectors and the Veolia Open Innovation Day award.



### ISYBOT



Isybot is reinventing sanding, polishing, painting, and other factory workstations with lightweight, safe, easy-to-program robots that either do the job on their own or help human operators. Customers like SNCF and Dassault Aviation have chosen Isybot for its solutions for industrial sanding—the company's main focus when it was founded in 2016. Today Isybot is setting its sights on other applications like polishing, painting, and welding. The CEA spinoff holds exclusive licenses to nine LIST patents and, in 2017, completed its first round of fundraising, bringing in nearly €1 million in fresh capital from Calao Finance, CEA Investissement, and Scientipole Capital. The company is pursuing its partnership with the CEA through a joint lab.



### LIGHT AND SHADOWS

Light & Shadows officially released its INTERACT software, the fruit of joint R&D with the CEA. INTERACT is used to create virtual-reality experiences that let industrial customers bring their simulations to life for training, design, maintenance, and ergonomics purposes.



### ARCURE



Blaxtair, Arcure's smart stereoscopic camera, can identify pedestrians moving in the "danger zone" around industrial vehicles and equipment and alert the driver or operator. Major corporations like Vinci, Bouygues, and Eiffage have purchased the product, which is used on large construction sites, in mines, at waste recycling plants, and at logistics facilities. Arcure has already sold 2,500 Blaxtair systems, which now come standard on vehicles from manufacturers like Jungheinrich. The company reported sales of €5 million in 2017, an increase of more than 70% over the previous year. A total of 75% of Arcure's sales are exports and the company employs 25 people.





FactoryLab

# FACTORY LAB

## Sharing resources across industries

**F**actoryLab is a consortium of industrial companies and academic research labs. It was set up to develop and integrate mature technologies very rapidly (one year on average) and create prototypes for industrial scale-up that respond to the transformation demands of its members.

The idea behind FactoryLab is to facilitate exchanges and resource sharing between industries. FactoryLab members, whether they are industrial “end users,” integrators, or technology providers, are boosting value creation thanks to this ingenious new model. As a founding member of FactoryLab, LIST serves as both an academic research partner providing human resources and as project lead, coordinating the consortium on a day-to-day basis.

And, to respond to the challenges of the Factory of the Future, FactoryLab is focusing on three main topics: the digitization of manufacturing, operator assistance, and automation and control.

## FactoryLab’s mission is to develop innovation projects and scale the solutions up for industrial rollout.

### Based on feedback from its initial experiences, FactoryLab moved its processes forward in 2017.

The changes positioned the consortium to more effectively identify challenges shared by multiple members and to create a shared vision of the Factory of the Future.

The year also saw two new end users (Bureau Veritas and TechnipFMC) and seven new technology providers (TDR Groupe, Singularity Insight, Sensewaves, Predict, Monixo, KBCrawl, and Ant’INNO) join FactoryLab based on the firm belief that working together is an excellent way to gain traction.

Finally, of the four projects initiated in 2016 and completed in 2017, two created direct value for their end users and for the technology providers involved. The two other projects generated new knowledge that will be reused for other projects.

The consortium also identified several other key topics during the year, including IoT integration into information systems and the need to benchmark certain technologies to enable functions like the traceability of tools and equipment on industrial and construction sites, for example.

### 2017: A WINNING YEAR...

**23**

members



**3 M€**

million in projects started



**9**

new members



**5**

feasibility studies started



**5**

innovation projects started

...AND A COLLECTIVE MOVEMENT DRIVEN BY THE MEMBERS OF FACTORYLAB!



# DIGIHALL

## DIGITAL TECHNOLOGY HUB on the Paris-Saclay Campus

**DigiHall, a major center for digital technology research, will reshape the Nano-INNOV center at Paris-Saclay. DigiHall brings together partners LIST, cluster Systematic Paris-Region, IRT SystemX, Télécom ParisTech, Télécom Sud Paris, and agencies that administer the French government's technology-transfer support instruments on the Paris-Saclay Campus. DigiHall functions as a coherent entity designed to deliver the best in technology transfer and bring digital technology into the spotlight at Paris-Saclay University.**

**T**he members of DigiHall possess know-how covering the entire digital technology spectrum, from the most advanced basic research to industrial applications. DigiHall is also home to partnerships of all kinds. These capabilities have earned recognition from corporations like Safran, Renault, PSA, Valeo, Faurecia, Dassault Systèmes, Air Liquide, and Thales, positioning DigiHall to deliver relevant responses to industrial companies' needs. DigiHall brings these companies unrivalled insights and world-class innovation capabilities on key digital challenges like cybersecurity, artificial intelligence, connected devices, and embedded systems. Paris-Saclay University will also be ramping up its research on these topics, creating even stronger ties between academic research and industrial R&D on the technologies driving digital transformation.

### POWERFUL TECHNOLOGY-TRANSFER ORGANIZATIONS

DigiHall has close ties to the IPHE business incubator and, specifically, Incuballiance. Incuballiance counts among its members technology research stakeholders on the Paris-Saclay campus like Carnot network members LIST, Mines-Télécom, and Inria, and tech-transfer support organizations like SATT Paris-Saclay. Together, these organizations will build

bridges between industrial companies and academic research organizations (and, specifically the Technological Research Institutes), support technology maturation projects and relationships with the industrial community, and enable the growth of businesses, especially through the Systematic Paris-Région cluster. The project has strong backing from the Ile-de-France regional government and has garnered interest from the French Commissioner General for Investment as well as from several investors, including French government financial institution.



**3** approaches: research and technology, design and user experience, SMBs and corporations

**1,500** research scientists and engineers working together to develop tomorrow's digital tools

**60,000** sq. m planned on the Nano-INNOV campus



### DIGIHALL'S MISSION:

- Host new research partners, especially Inria
- Provide space to house industrial innovation projects
- Create a showroom that illustrates how the technological innovations developed by Paris-Saclay University can be used
- Cooperate with the new innovation organizations on the Paris-Saclay University campus
- Support the development of LIST R&D services for businesses, including SMBs



### FOCUS AREAS

- Artificial intelligence
- Cybersecurity
- Cyber physical systems
- Factory of the Future (FoF)

### APPLICATIONS

- Healthcare
- Transportation & mobility
- Energy & the environment
- Defense
- A world-class innovation ecosystem

**R·E·A·D**

The 2017 activity report online at

**[HTTP://WWW-LIST.CEA.FR/EN/DISCOVER-CEA-LIST  
/WHO-ARE-WE/ACTIVITY-REPORT](http://www-list.cea.fr/en/discover-cea-list/who-are-we/activity-report)**









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