

ON-INO OUT

CEA LIST 2019 ACTIVITY REPORT



THE CHALLENGES OF OUR FUTURE

ON LIST

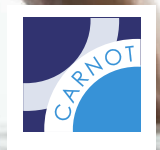
MISSIONS

INSIDE

TECHNOLOGICAL
ADVANCES

OUTSIDE

INTERNATIONAL
ACTIVITIES





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DIRECTOR'S FOREWORD

**" OF THE 200 COMPANIES THAT WORK WITH CEA LIST ON R&D,
46% ARE SMBs, MID-CAPS, AND STARTUPS."**



In 2019, CEA List continued on its trajectory of strong growth, in terms of both multi-partner R&D projects and exclusive R&D partnerships with some of the top companies in their industries. We brought our unique technology-transfer model to nearly 200 R&D partnerships with companies

that placed their trust in our 900 scientists and engineers for support developing enabling digital technologies with the capacity to drive business competitiveness. Our partnerships are remarkably long-lasting, and our partners often choose to set up joint labs with us. The Thales VisionLab, whose tenth anniversary we just celebrated, is a prime example.

The year 2019 was also particularly successful in terms of European projects. We submitted nearly 170 collaborative R&D proposals with our many European partners. Our success rate obtaining funding was 30%—twice the European average. European research programs are also helping sustain the development of our tech ecosystem. DigiHall, the Paris-Saclay digital technology hub, is one of the main beneficiaries of this support. DigiHall was appointed to lead the AI (artificial intelligence) Digital Innovation Hubs Network and, with the support of the Ile-de-France regional government, will submit a proposal for the E-DIH (European Digital Innovation Hub) for the region. The overriding objective is to create a powerful research and open innovation ecosystem with a capacity to drive the digital transformation of industry.

Artificial intelligence, of course, is playing a major role in this transformation. Over the past two decades, List researchers have risen to the top in AI, honing their expertise in data

processing, AI chip architectures, algorithms, design, and applications. List is poised to respond to a wide range of needs on a vast array of markets. We master all of the technologies that go into AI, plus know-how integrating these technologies into smart digital systems that are reliable, safe, and secure. One of the pillars of our research is trusted AI. Specifically, we believe that there is an underlying need for certification to ensure public acceptance of AI. We also know that trust is a roadblock to widespread adoption. Our trusted AI research is part of our broader strategy of incorporating explainable AI (XAI), ethics, and social and environmental responsibility into our work. We are uniquely positioned to address the challenges of AI from a strong foundation of critical systems safety and security. This is due to our early history developing critical systems for the nuclear industry and to our more recent collaborations with industrial partners who provide us with real-world data to train our algorithms. Therefore, we are able to guarantee the robustness of our solutions to data variability in the field and can scale up the solutions we develop.

Last, but not least, our priority research topics got an additional boost from national and EU initiatives. The strategy outlined by France's Secretariat General for Investment contains two pillars that align with List's research (Trusted AI and Cybersecurity) with more forthcoming (Additive Manufacturing, Blockchain, and Quantum Computing.) List's roadmap aligns closely with these national priorities. We are staying ahead of the digital technology curve and investing in pump-priming research to guarantee that we have the technologies needed to very rapidly develop solutions to support our industrial economy through current and future transformations.

Alexandre Bounouh, Director, CEA List

CEA LIST IN BRIEF

CEA List draws on international-caliber scientific research and technology expertise to develop breakthrough digital solutions. Our approach to research and development is collaborative, and our goal is to transfer new technologies to industrial companies. Every year, the innovations developed at CEA List help our more than 200 industrial R&D partners of all sizes and from all markets become more competitive by positioning them to address major societal and economic challenges, from AI, advanced manufacturing, and cyberphysical systems to e-healthcare. CEA List is a member of the Carnot Network and is located in Saclay, near Paris, France.

2019 KEY FIGURES

PROJECTS AND PARTNERSHIPS



500
projects
per year



200+
industrial
R&D partners



€ 31 M+
in contract
R&D revenue



20
technology
platforms

HEADCOUNT



900
employees



105
PhD students



64
Research directors,
senior experts and
international experts



32
State-sanctioned
PhD supervisors

TECH TRANSFER



560
Patents, including
67 new in 2019



€ 86 M
Annual operating
budget (75% from external
sources)



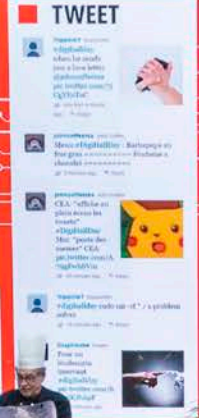
22
Startups created
since 2003



172
Active IP
licenses

COME INSIDE

SPEND A DAY AT CEA
LIST AND EXPERIENCE
INNOVATION



étente ?
espace Zen (rdj du 861) pour découvrir notre exposition photos - en...
sensorielle et musicale avec notre fauteuil haptique.





ONTOLOGY
ONAIR
ONBOARDING
ONLINE

ONLIST



CEA List is known for its excellence and leadership in high-tech innovation.

Our people are proud to belong to List, and have the knowledge and skills to address the challenges of tomorrow's digital world with confidence.

MISSIONS AND AMBITIONS

CEA LIST, WHERE SCIENTIFIC RESEARCH MEETS INDUSTRIAL R&D

CEA List is the Institute for the Integration of Systems and Technology of the French Alternative Energies and Atomic Energy Commission (CEA). The institute's mission is to innovate new technologies and transfer them to businesses to support their economic competitiveness. Smart digital systems is our area of excellence.

"ON" LIST: BRINGING INNOVATION TO INDUSTRIAL COMPANIES

A GLOBAL LEADER

CEA List's advanced knowledge and world-leading expertise has earned the institute an international reputation. In France, List's consistently high level of excellence has earned it the prestigious Carnot seal. Our industrial R&D partners turn to us to help them overcome the technology-related hurdles to remaining competitive in a wide range of industries:

- transportation and mobility
- security and defense and the associated cybersecurity concerns
- energy, through smart energy and grid management
- smart manufacturing, emerging as a major driver for Industry 4.0
- e-healthcare, from practitioner assistance to personalized medicine
- information technology, with its demand for ever-increasing performance and productivity

BREAKTHROUGH INNOVATIONS

The breakthrough technologies developed at List and, especially, technologies leveraging artificial intelligence, have the capacity to help companies of all sizes, from SMBs to multinational corporations, penetrate new markets. List brings an open innovation model to its partnerships and is committed to transferring high-value-added technologies to its partners. Each year, we work with more than 200 industrial R&D partners.

THE CARNOT SEAL, A MARK OF EXCELLENCE

List's activities cover the entire innovation value chain, from proof-of-concept through to pre-production functional prototypes. The institute's R&D follows joint technology roadmaps developed with our partners. Our shared vision of technology comes to life in 40 joint R&D programs and labs CEA List has set up with partners. The quality of our research partnerships was recognized by the French Ministry of Higher Education and Research in 2006 in the form of the Carnot seal, which CEA List still holds today.

“INSIDE” LIST: EXCELLENCE IN SCIENCE AND TECHNOLOGY

ADVANCED RESEARCH IN FOUR AREAS

CEA List employs 900 scientists and technicians working to address major societal and economic challenges through advanced research in four areas: artificial intelligence, advanced manufacturing, cyberphysical systems, and e-healthcare. The year 2019 was filled with high points. However, we would like to focus on four scientific advances in particular: We completed the formal validation of embedded symbolic AI, scaled up a SHM (Structural Health Monitoring) modeling tool for transfer to an industrial partner, validated a blockchain consensus process, and developed new tools for controlling X-ray doses in interventional cardiology.

CULTIVATING SCIENTIFIC EXCELLENCE

Our scientists’ work is published regularly in top-tier international journals and conference proceedings. List is a technology research organization. However, our close relationships with academic research labs help us maintain our knowledge at the international state of the art. Our scientists have a unique ability to see what is just over the digital innovation horizon, and they have patented a staggering range of breakthrough technologies. List owns 560 international patents and currently has 172 active licenses to its technologies.

“OUTSIDE” LIST: AN OPEN INNOVATION STRATEGY

A CREATIVE AND INTERACTIVE ECOSYSTEM

CEA List is part of a particularly dynamic regional and national ecosystem, and has built strategic academic, collaborative, and industrial research partnerships. List has been the driving force behind a large number of projects, such as DigiHall and FactoryLab, that involve a wide variety of partners. Since 2001, we have also created more than 20 tech startups, which play a vital role in our technology transfer strategy.

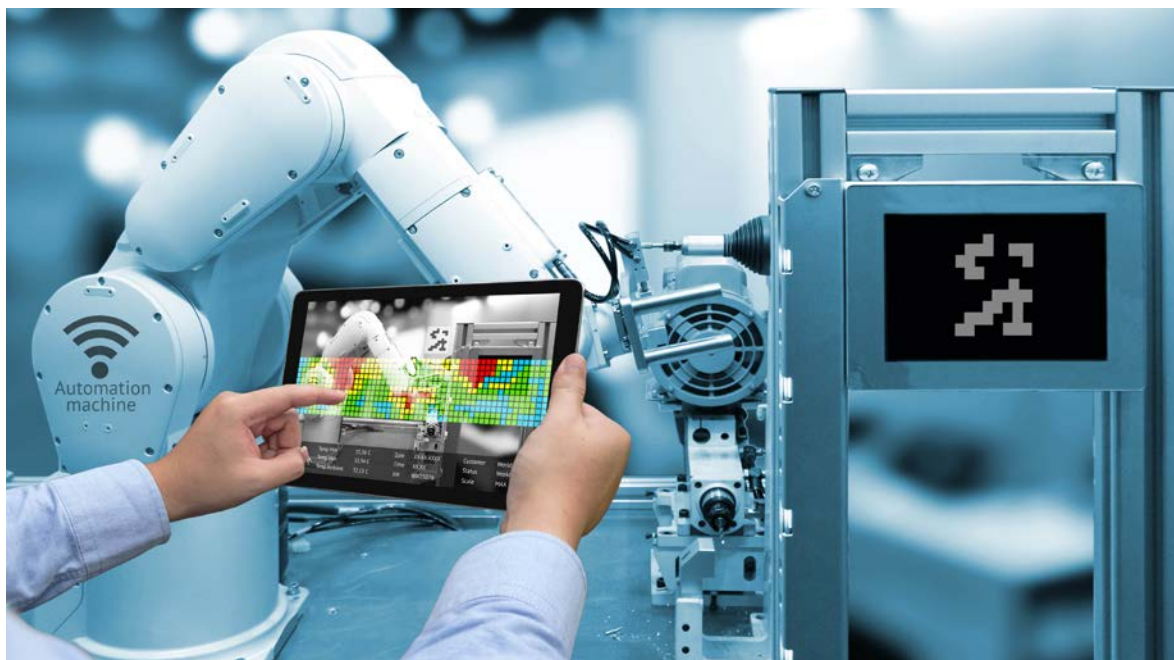
EUROPE AND THE WORLD

We are engaged in more than 100 EU R&D projects and initiatives, including Sparta, EIT Manufacturing, CPS4EU, Heliaus, and Robmosys. These multi-partner projects help us to maintain our know-how at the international state of the art. We also have joint programs with some of the world’s top academic research labs, including UC Berkeley and Stanford University in the US. List is also a regular participant in leading international tech industry trade shows and events, including CES in Las Vegas, the International Cybersecurity Forum (FIC), 3DPrint, FormNext, Vivatechnology, and more.



FRENCH NATIONAL RAIL SIGNALING PROGRAM

In 2019 List and Systerel won a French National Rail (SNCF) contract to contribute to the development of new-generation computer-based interlocking systems. The goal is to develop the specifications for new-generation computerized signaling control panels and complete the formal validation process. List’s Papyrus open source software engineering platform is playing a key role in the project.



FACTORYLAB

AN INDUSTRY 4.0 COMMUNITY



FactoryLab
La communauté pour
l'industrie du futur

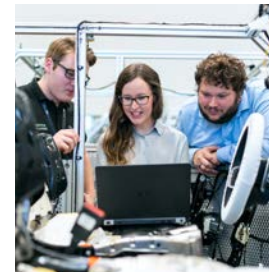
FactoryLab is a consortium of industrial and academic partners led by List. It was set up to deliver a practical, collaborative approach to innovation. The focus is on short projects capable of creating solutions that can be rapidly transferred to Industry 4.0 applications.

PROJECT FACTORY

FactoryLab, located on the Paris-Saclay innovation campus, leverages an innovative shared resource model to ensure that companies of all sizes can effectively create value. The unique “project factory” setup ensures that end users and the R&D ecosystem (represented by technology providers and academic research scientists) talk to each other.

CO-INNOVATION

Projects at FactoryLab are short (maximum 18 months), and the solutions developed have to be ready or almost ready to commercialize at the end of that timeframe. So, projects must address a specific challenge shared by more than one company. For a project to be eligible for FactoryLab support, at least three user companies from different industries must be interested in it. This mitigates risk for technology providers, providing



them with a high degree of assurance that there will be a market for the solution before they invest in developing it and scaling it up. Everyone wins in this collaborative approach to innovation.

THREE MAIN TOPICS

FactoryLab focuses on three Industry 4.0 topics: the flexible digital factory, physical and cognitive operator assistance, and manufacturing and control process automation.

A SELECTION OF PROJECTS COMPLETED IN 2019

- GECCO: managing multiple activities on an assembly line
- CYBOC: cybersecurity of IIoT devices
- COBOBENCH: collaborative robot selector
- LUTAC: augmented remote assistance goggles with a reliable and secure connection

FACTORY LAB KEY FIGURES



33
active
members



12,5
million allocated
to projects



26
innovation
projects



15
feasibility
studies



CEA LIST STARTUPS

22 startups have been created to develop and commercialize the results of List R&D. Most of the founders are List scientists, and their companies have created more than 300 jobs. These startups are vital to transferring the institute's technologies to markets around the globe. Read on to learn more about eight List startups.



Sport Quantum manufactures interactive electronic targets for shooting sports. In 2019, the company set up a large network of distributors in Europe, Asia, and the United States. As Sport Quantum's sales continued to increase in France, the company launched its SQ10 product, an electronic target for air pistol and rifle shooting at ten meters. A total of 200 units were sold, including 85 internationally in 21 countries. www.sportquantum.com



WiseBIM offers AI-based solutions that can automatically generate a 3D BIM (Building Information Model) from 2D architectural drawings. The company, founded in 2017, is growing rapidly and counts among its 40 customers subsidized housing authorities, construction professionals, engineering firms, government agencies, and corporations (EDF, Orange, etc.). WiseBIM will soon release the 100% online PLANS2BIM. www.wisebim.fr



Smart processor pioneer Kalray successfully launched its latest MPPA® processor, Coolidge™. The company then signed a strategic partnership with NXP, a leader in automotive semiconductors, in April. Kalray also started working with data center leaders like Wistron and 2CRSi to develop future generations of smart storage servers. Kalray's MPPA® addresses the booming edge computing and AI markets. www.kalrayinc.com



Tridimeo designs and manufactures new-generation multispectral 3D cameras and develops vision software solutions for industrial customers. In 2019, the startup began scaling up the hardware component of its solution and developed its industrial vision software for robotized depalletizing applications. Tridimeo announced the sale of its first systems at the end of the year. www.tridimeo.com



Isybot, which designs and manufactures collaborative robotic arms, saw its sales increase in 2019. The company manufactured 24 robots and made its first international sale, a sanding cobot shipped to Airbus in Germany. Isybot also signed a partnership with Gebe2 (a subsidiary of Europe Technologies Group) for the robotic sanding of industrial parts. With annual revenue of €1.1 million, Isybot, which is just three years old, has already started turning a profit, reporting positive net income for the first time in 2019. www.isybot.com

ARCURE

IPO FOR ARCURE, SMART VISION FOR INDUSTRIAL VEHICLES

Arcure founded in 2009, went public in 2019. The start-up develops 3D vision solutions to improve safety around industrial vehicles. Inside Arcure's Blaxtair system is a List pedestrian detection technology that leverages image analysis. Blaxtair is a stereoscopic embedded vision system that consists of a smart head, two cameras, and real-time image-analysis software that reconstructs the environment around the vehicle in 3D. It detects the presence of pedestrians and alerts the driver if necessary. Arcure has expanded its product lineup with Omega, a smart 3D vision sensor for systems integrators. It can reconstruct the environment around the sensor in 3D and in real time. The successful IPO will position the company to penetrate key markets (Germany, United States, etc.) and to sign partnerships with the world's leading industrial vehicle manufacturers. Arcure is now setting its sights on a next-generation AI. www.arcure.net

CONNECTING FOOD

BLOCKCHAIN TO SECURE FOOD PRODUCT TRACEABILITY

Connecting Food restores consumers' trust in food manufacturing thanks to blockchain technology. LiveAudit®, developed in partnership with CEA List, can authenticate every transaction from farm to supermarket shelves and certify in real time that a product is compliant with its specifications. For consumers, this means simply scanning a QR code on the product to find out where it comes from and ensure that it delivers what is promised on the label. Connecting Food was invented by food-industry experts, and has won over more than 20 farmers, food manufacturers, and distributors to date. Globally, Connecting Food ranked first in the FoodTech 500 Food Safety and Traceability category and was the first blockchain startup in the overall ranking. Founded in 2016, the company has already raised €5 million in capital. www.connecting-food.com



Extende is the exclusive distributor of CIVA, the NDT modeling software platform developed by CEA List and world leader in Non Destructive Testing (NDT) simulation. The company released CIVA 2020, which integrates the latest advances in simulation and analysis for enhanced performance, and launched TrainDE UT, its first ultrasonic NDT training assistance solution, in 2019. www.extende.com

DIGIHALL

DIGIHALL

SCIENTIFIC EXCELLENCE TO DRIVE ECONOMIC PERFORMANCE

The DigiHall magnet center for digital technology at Paris-Saclay was hatched in 2017 at Nano-INNOV. At the center of a vibrant, fast-paced ecosystem, DigiHall and its founding members bring together stakeholders from research with industrial companies of all sizes, from startups to major corporations, and from all markets.



EUROPE'S LARGEST COMMUNITY OF RESEARCHERS

DigiHall is home to more digital technology research scientists and R&D engineers than any other facility in Europe. The more than 1,500 experts at DigiHall are working on some of today's most exciting topics, from artificial intelligence, digital infrastructures, and cyber security, to quantum computing and Industry 4.0. DigiHall is where scientific excellence supports economic performance. New open innovation labs will open at DigiHall in 2020 (at Nano-INNOV); additional facilities will open by 2025 (in a new set of buildings). Ultimately, DigiHall will be able to house an even larger community of researchers united in their desire to create value.

ARTIFICIAL INTELLIGENCE DIGITAL INNOVATION HUB

As Europe's leading innovator in artificial intelligence, DigiHall earned the backing of the Ile-de-France regional government and was subsequently selected to be the E-DIH (European Digital Innovation Hub) for artificial intelligence. DigiHall is now one of the 30 DIHs that will create Europe's AI-DIH network. The ultimate goal is to move the industrial economy and society at large toward the adoption of AI technologies and expand the range of uses for these technologies.

IA A PILLAR OF INNOVATION AT DIGIHALL

Artificial intelligence will enable new services that leverage the information contained in data. There are still some major hurdles to the widespread development of new AI technologies. The systems are complex and difficult to integrate, the technologies are evolving rapidly, and issues like security and cybersecurity of data and systems, connectivity (IoT), and certification are concerns. The DigiHall DIH possesses the know-how and resources to overcome these challenges.



“ OUR AMBITION IS TO MAKE DIGIHALL AN INTERNATIONALLY-RECOGNIZED CENTER FOR AI AND DIGITAL TRUST RESEARCH. ”

ALEXANDRE BOUNOUH - DIRECTOR, CEA LIST

DIGIHALL, INNOVATIVE SERVICES FOR COMPANIES

DigiHall works with companies from all industries: manufacturing, transportation and mobility, healthcare, security and defense, environmental technologies, energy, food manufacturing, construction, education, information technology, and more. DigiHall will soon offer a wide range of services to meet the needs of manufacturing companies of all sizes and, especially, SMBs:

- Testing facilities for new technologies
- Prototyping for new solutions from software to robotics, smart sensors, and autonomous vehicles
- Digital maturity audits
- Business creation services for innovative companies
- Network-building to help users form partnerships so that they can share R&D and innovation investments

DIGIHALL KEY FIGURES



7

founding members :
CEA, CNRS, INRIA, SystemX,
Systematic Paris-Region,
Université Paris-Saclay,
Institut Polytechnique de Paris



5

research programs :
artificial intelligence, digital
infrastructure, cybersecurity,
quantum computing,
Industry 4.0



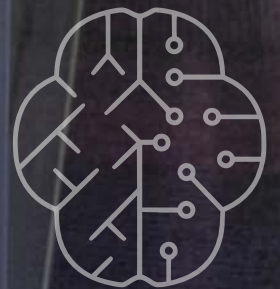
1500
researchers



30 000 SQ. M
now with more new buildings
planned (DigiHall Next)

HUMAN INTELLIGENCE

900 EMPLOYEES,
INCLUDING MORE THAN
100 PHD CANDIDATES:
CEA LIST IS HOME TO
SOME OF THE BEST
MINDS IN SCIENCE





INTERFACE INNOVATION INDUSTRY INTERNATIONAL INSIDE



CEA List's four core research programs are in artificial intelligence, advanced manufacturing, cyberphysical systems, and e-healthcare.

With each R&D partnership, our researchers push the frontiers of the digital sciences further and drive the technological advances that will shape industry and society.

ARTIFICIAL INTELLIGENCE

Trust, reasoning, expertise, collaboration: At CEA List, artificial intelligence is designed to support people and organizations. Read on for a look back at some of the major advances that marked 2019.



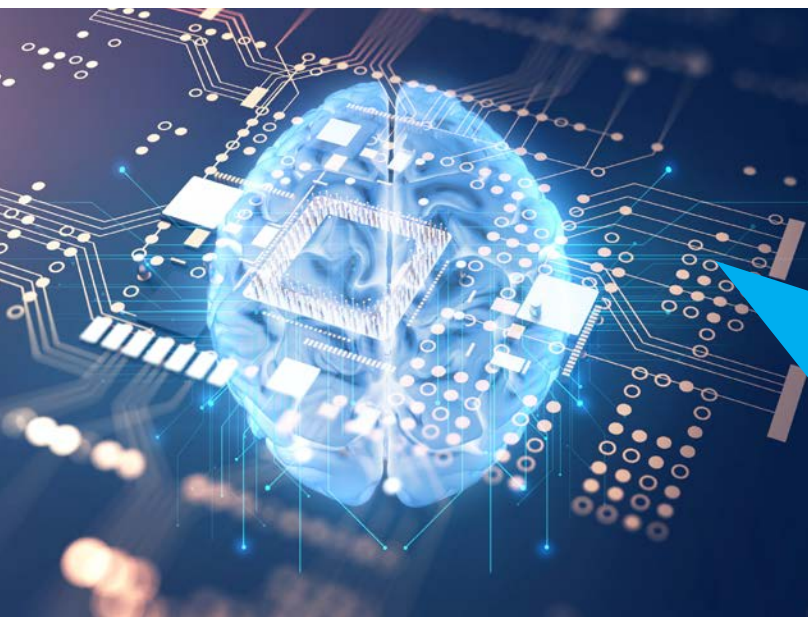
SCIENTIFIC ADVANCE

DIGITAL TRUST: FORMAL VALIDATION OF EMBEDDED SYMBOLIC AI



Digital trust is a pillar of all research at List, which has earned recognition for its expertise in formal software validation. List and Thales joined forces to create Formal Lab, which achieved a scientific world-first: the formal certification of a symbolic AI system developed to be embedded in a device.

This is a major advance in that, despite the attention learning-based AIs are getting, symbolic AIs are still crucial. Constraint solvers, for example, are particularly effective for planning and decision-making applications. And, sometimes, the critical aspects of the functions performed necessitate more stringent safety requirements. List researchers, working from specifications developed by the people at Thales, utilized Inria's Why3 platform to validate both the solver and the properties it is supposed to guarantee. Why3 was also used to extract a code into embeddable languages like C. This code was also formally validated using List's Frama-C. The approach developed by the partners will be of use in critical applications with extremely high safety requirements. List will also use it in-house, integrating it into formal program analysis technologies to enable the analysis of floating-point numbers, for instance.



EXPRESSIF™ NOW HAS A NEW CONSTRAINT SATISFACTION MODULE.

EXPRESSIF™: AI CLOSER THAN EVER TO HUMAN REASONING

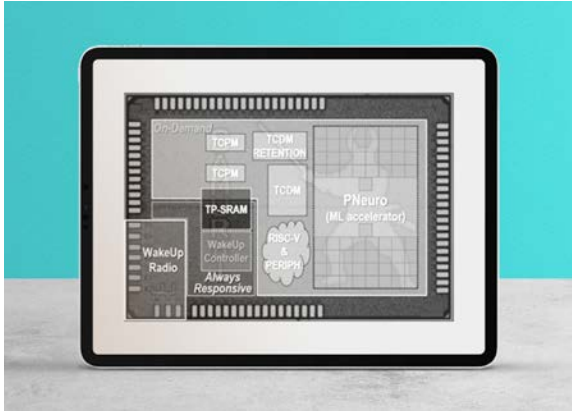
Planning, assigning tasks, and annotating objects in an image are all examples of combinatorial problems that algorithms have a hard time handling. List's ExpressIF™ software now has a new "constraint satisfaction" module that addresses this challenge. The module is built on an artificial intelligence algorithm that simulates human reasoning to explore and find more elaborate solutions. Even better, the problem can be stated in natural language. The EU Micado (mass spectrometry) and DeepHealth (annotation of medical images) projects will also take advantage of this smart new tool.

CBRNE THREATS: NEW ALGORITHM HELPS EXPERTS

In research conducted for the French government's CBRNE (chemical, biological, radioactive, nuclear, and explosive) counterterrorism program, List researchers came up with a new SVM (support



vector machine) algorithm. It utilizes the PCC (peak correlation classification) method patented by List. The tool signals the presence, even in very small quantities, of toxic chemicals and explosives



in complex mixtures and in real time. It will be especially useful for the law enforcement lab technicians responsible for interpreting the results of spectral analyses of suspicious substances.

A NEURAL ACCELERATOR FOR LOW-POWER ARTIFICIAL INTELLIGENCE

Making IoT devices more energy efficient is a key challenge for manufacturing companies across all industries. Unfortunately, integrating AI into IoT devices makes them less energy-efficient, not more. List researchers designed an integrated circuit that combines a very-low-power wakeup system with an on-demand processing system built on a low-power neural accelerator developed at List. The SamurAI circuit, currently at the prototype stage, can perform local neural processing to detect human presence and count the number of people in a room (using an infrared camera). The prototype was built to show how low the power consumption is in sleep mode and how flexible and responsive the chip is when full processing power needs to be activated.

PROGRESS TOWARD A SAFER, MORE PERSONAL HUMAN-COBOT EXPERIENCE

Cobotics, or collaborative robotics, gets robots and operators to work together to perform difficult or

repetitive manual tasks. But any time humans work closely with machines, safety is a concern. CEA List researchers developed an AI tool for detecting and analyzing impacts with the robotic arm. Learning algorithms and feedforward neural networks determine whether the contact is intentional or accidental. They then trigger the most appropriate robot reaction. The researchers also analyzed operators' proprioceptive signals and used the data to feed algorithms to optimize human-cobot interaction depending on individual operator profiles. The result is a more personalized human-cobot experience for each operator.

DIABOLO, «BOTTOM-UP» AI INNOVATION FOR VIDEOSURVEILLANCE

AI-based scene analysis technologies are particularly useful for video surveillance. CEA List partnered with Thales to develop a new method based on a





deep neural network called DIABOLO (Detecting InterActions By Only Looking Once). It can simultaneously detect all interactions between all humans and all objects with a single “look” at the image. This innovative «bottom-up» approach (as opposed to the state-of-the-art methods, which are “top-down”) achieved top rankings in international benchmark surveys. The method is still being improved to handle people-to-people interactions more effectively. It could be transferred to an industrial partner for threat detection in crowd surveillance applications.



SHM ENHANCED WITH NEURAL NETWORKS

Structural Health Monitoring (SHM) consists of instrumenting a structure to detect the appearance of defects over time. List partnered with Safran to develop a complete SHM system specifically for aeronautic structures. The system utilizes elastic waves, excellent for the systematic detection of defects. The only problem left was to dimension the system. A Convolutional Neural Network (CNN) was trained from a simulated database using List’s CIVA software. It was then tested twice: first using numerical modelling, and then in laboratory tests. The research shows that it is possible to use Deep Learning trained with simulated data for the interpretation of lab data.

ADVANCED MANUFACTURING

Industry 4.0 is here. List's ecosystem includes industrial companies of all sizes, from SMBs to large corporations. We are uniquely positioned to support our R&D partners with everything from custom innovation services through to support implementing our technologies in industrial environments.



SCIENTIFIC ADVANCE

SHM SCALING UP FOR INDUSTRIAL ROLLOUT



Structural Health Monitoring (SHM) is all about equipping engineering structures with devices that can identify and characterize damage or degradation. Guided elastic waves can be used to monitor structures in a way that is completely

non-destructive. This emerging technology can help ensure that structures remain safe over time and streamline maintenance operations. The industrial applications for this type of SHM are still limited, due to the high cost of testing campaigns. List researchers developed an innovative simulation tool for evaluating and certifying SHM performance in a wide range of configurations, effectively overcoming cost issues. The new module has been integrated into List's CIVA software platform. In a NASA benchmark study, CIVA was much faster than competing solutions. CIVA SHM can also be used with decision-assistance software. A commercial version of CIVA SHM will be released in 2020. It will then be modified for the control of structures with complex geometries, such as critical pipework in nuclear power and petrochemical plants.



AUTOMATED BIN PICKING GETS 3D VISION AND ROBOTIC ARMS

Bin picking refers to the task of removing known but randomly-positioned objects from a bin. For humans, bin picking is intellectually simple yet physically demanding, precisely the kind of task to assign to a robot. And yet, automating bin picking is harder than it sounds. The process has to be accurate and repeatable, of course. But it must also be generic (the robot has to be able to apply the process to different use cases). Car maker Renault turned to List to develop a solution that combines a 3D vision system commercialized by List startup TRIDIMEO and a robotic arm. The sensor (via a software interface) sends a 3D point cloud to an image registration algorithm. A demonstrator system was implemented at Renault's plant in Le Mans, France, marking a major step toward scaling up the technology for TRIDIMEO. List is now working on extending the algorithms for even more complex use cases.



IMMERSIVE SIMULATION FOR MORE SEAMLESS COBOT INTEGRATION

Integrating a cobot, or collaborative robot, into a production line can make the line more flexible and agile. However, cobots do create some challenges. First, the risk of collision (and injury) must be minimized by securing the workspace. Task sharing must be managed, and the workstation has to be ergonomic for operators with different body types. CEA List, through its FactoryLab, designed the SEEROB ergonomics simulation application for work environments with cobots. This simulation tool leverages Virtual Reality (VR) and Mixed Reality (MR) to deliver an immersive experience. PSA and Safran, both members of FactoryLab, have already signed up to purchase the software, which will be sold by List startup Light & Shadows.



FACTORIES: DIGITAL TWIN FOR ENHANCED TASK SCHEDULING

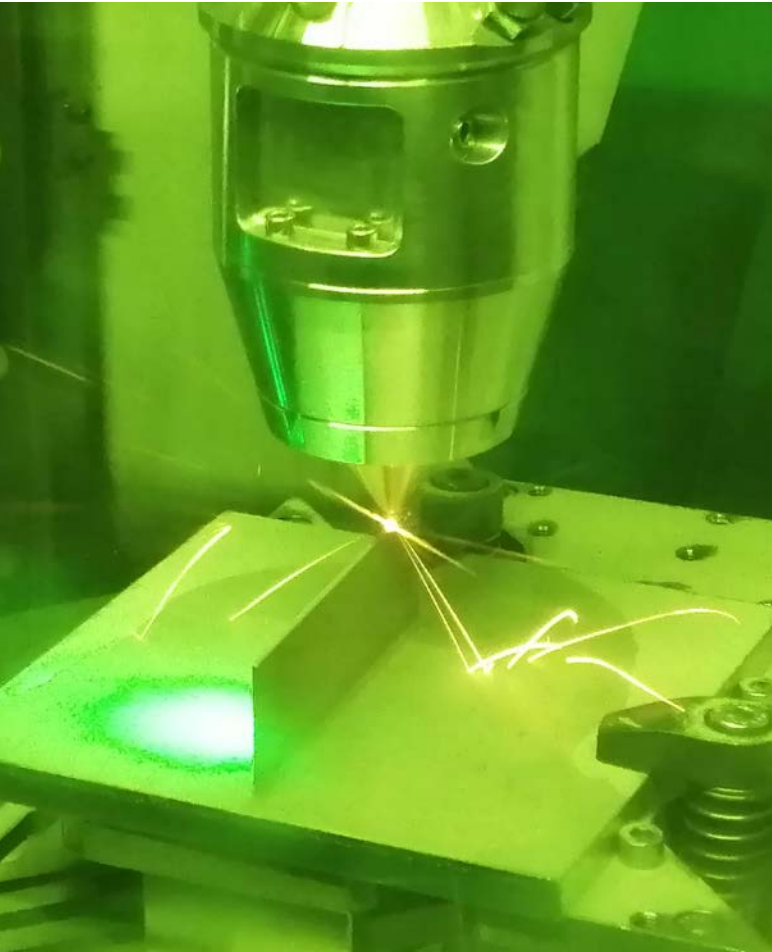
Task scheduling is vital to the productivity of any industrial facility. It is, however, a complex process that has to be able to factor in constraints inherent to the product, the availability of human and material resources, and safety issues that prevent two given tasks from being performed at the same time. In research conducted for the FactoryLab GECCO project, CEA List built a digital twin software suite on its Papyrus platform. The software can effectively model a smart digital twin of the entire production chain. This AI-based solution can simulate and optimize task scheduling by testing, according to relevant

heuristics, “virtual” variations of all production line parameters and constraints before implementing a schedule in the actual plant. Initial tests at Safran and PSA were encouraging.

DED ADDITIVE MANUFACTURING ULTRASONIC LASER TECHNOLOGY FOR REAL-TIME PART INSPECTION

DED (Direct Energy Deposition) is an additive manufacturing technique that utilizes the laser fusion of metal powder. It is the only method that can be used to 3D print certain particularly-complex parts. The DED process itself is complex, with thermal, fluid, and chemical mechanisms that are





governed by many parameters. To ensure that parts produced using DED are flawless, CEA List designed an innovative in-line ultrasonic laser (UL) inspection process. Elastic waves are generated and detected by lasers, providing information about the quality of the parts during the actual manufacturing process. In research conducted for the I AM SURE project, a series of tests were completed at project partner BeAM's facility in conjunction with VLM Robotics. The tests confirmed the feasibility of integrating robotic UL inspection into a DED machine. This type of integration would allow real-time inspection during manufacturing.



PORTABLE NEUTRON IMAGER PROTOTYPE BUILT ON TIMEPIX DETECTOR

In the nuclear industry, being able to detect radioactive sources or objects is vital to safety. Gamma imaging is often used to detect radioactivity. In some cases, however, its effectiveness is limited. Neutron emission detection is the alternative in these situations. CEA List designed and tested portable neutron imager prototype. Based on the GAMPIX gamma camera concept, it combines a MURA coded polyethylene mask with a modified Timepix detector. Tests carried out in actual operating conditions on the Atalante C10 armored chain and on the CEA Cadarache Danaïdes facility were conclusive. Ultimately, the imager could be used in nuclear research or national security applications.

CYBERPHYSICAL SYSTEMS

From mobility to food manufacturing, industrial companies need to capture and process data and integrate smart capabilities into high-performance embedded systems, all while controlling costs.



SCIENTIFIC ADVANCE

BLOCKCHAIN: RELIABILITY OF TENDERMINT CONSENSUS PROTOCOL CONFIRMED



Blockchain is widely used in many applications. There are new consensus-based protocols for recording data in the blockchain, but their reliability had not been proven until recently. In a world-first, CEA List researchers characterized a well-known energy-

efficient consensus protocol. They analyzed one of the most complex blockchains, Tendermint, and recommended corrections to obtain a strong, fault-tolerant consensus and a fair reward mechanism for participants. A team from Nomadic Labs, which is behind Tezos, France's first blockchain, is now working with List to implement Tendermint within Tezos. Since the research was completed, several international companies have turned to CEA List for its blockchain expertise. In other blockchain news, CEA List is also one of the French government's partners of choice. In 2019, List, INRIA, and IMT were tasked with developing a national blockchain strategy. France's Economy and Finance Minister Bruno Lemaire and Digital Technology Secretary Cédric O unveiled the nation's strategy to bring blockchain to France's industrial economy.



FACE: A NEW TAKE ON IN-VEHICLE SYSTEMS

As cars and other vehicles become more connected and autonomous, the amount of technology inside them (from sensors to computers) is growing exponentially, creating some unique integration challenges. CEA List, in partnership with the Renault-Nissan-Mitsubishi Alliance, presented the FACE* platform and its companion software FACE Tool Suite at CES in Las Vegas in January 2019. The suite leverages model-driven engineering and formal methods integrated with the Papyrus platform to automatically verify system runtime configuration and compliance after new functions are added. Artificial-intelligence-type technologies could also be integrated to further improve upon the software. Other companies in the transportation, defense, and autonomous systems industries have expressed interest in the software.

* New safe, modular, and flexible electrical and electronic architecture

COMPLEX CALCULATIONS ON ENCRYPTED DATA NOW POSSIBLE

Data privacy is a top-line issue in fields like e-healthcare. To keep hackers at bay, personal medical data has to be encrypted before it can be displayed or sent over the internet. Cingulata, a technology developed by List, now has its own cryptosystem: TFHE (Fast Fully Homomorphic Encryption over the Torus). The system utilizes homomorphic encryption to enable complex calculations on encrypted data. The tool is being put to good use on EU H2020 project KONFIDO on



e-healthcare data, and companies like Orange and Technip have expressed interest. Ultimately, additional cryptosystems will be integrated into Cingulata.

ENHANCED FAULT DETECTION ON MEDIUM VOLTAGE NETWORKS

Cable manufacturer Nexans turned to CEA List to design a system for detecting transient faults in near-real-time on medium-voltage networks. This sensor-based technique uses a List-patented variant of the Time Reversal (TR) technique to “listen” to the network. In under a minute, the system was able to pinpoint sudden current variations lasting around 1 ms, accurate to within two meters on a network of several kilometers. List also developed comprehensive software application for adapting the solution to different use cases. Nexans will now be able to offer a new network monitoring service to a wide range of customers.



THE INVISIBLE MACHINE: CYBERPHYSICAL SYSTEMS KEEP FARMERS ON SOLID GROUND

List researchers investigated ways to make operating complex farm machinery easier without removing the tactile sensation of force. The research was carried out for AGCO, a leading global agricultural machinery manufacturer. The researchers came up with an intuitive, fast, programmable haptic interface in the form of a rotating knob connected to a motor and magnetorheological fluid for a very realistic touch sensation. Operators can also see all functions via menus on a display screen. The operator can configure hard stops, increasing resistance, and vibrating alerts. A prototype for controlling a tractor gearbox and draft was tested. List presented a joystick version of the control system at CES in Las Vegas in January 2020.



FEDERATED LEARNING FOR CONFIDENTIAL AND ECONOMICAL AI-BASED VEHICLE MONITORING

Steering wheel vibrations are a valuable source of information. To make the information actionable, List designed an algorithm for analyzing the vibration data to estimate the speed of the car and, ultimately, calculate the distance travelled. The system leverages an approach called federated learning. The training of the model is distributed, and the data is not sent to a server.

Once implemented on a vehicle, the model continues to be improved locally by the data picked up by the vehicle's sensors. Only optimized updates go through a server. Federated learning offers some very real advantages in terms of confidentiality and data transmission costs, making it ideal for a wide range of mobility and IoT scenarios.





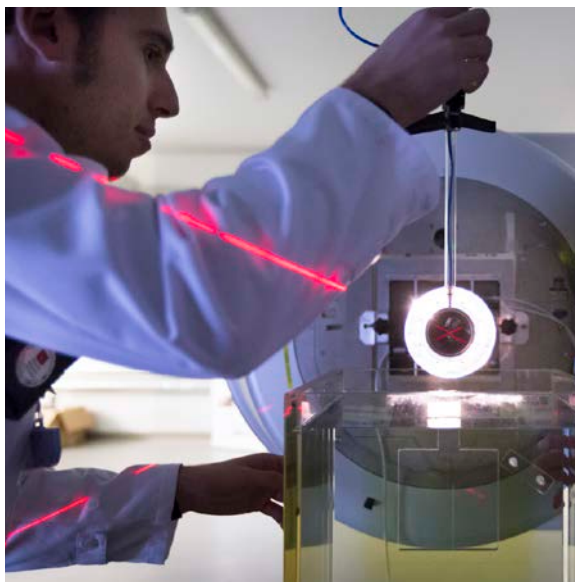
E-HEALTHCARE

CEA List e-healthcare research is designed to support doctors. We design systems to optimize the use of medical data without compromising the privacy and safety of patients and practitioners.



SCIENTIFIC ADVANCE

INTERVENTIONAL CARDIOLOGY: CONTROLLING X-RAY DOSES



In research conducted for the EU VERIDIC project (an alliance of research labs, hospitals, and equipment manufacturers) CEA List's LNHB

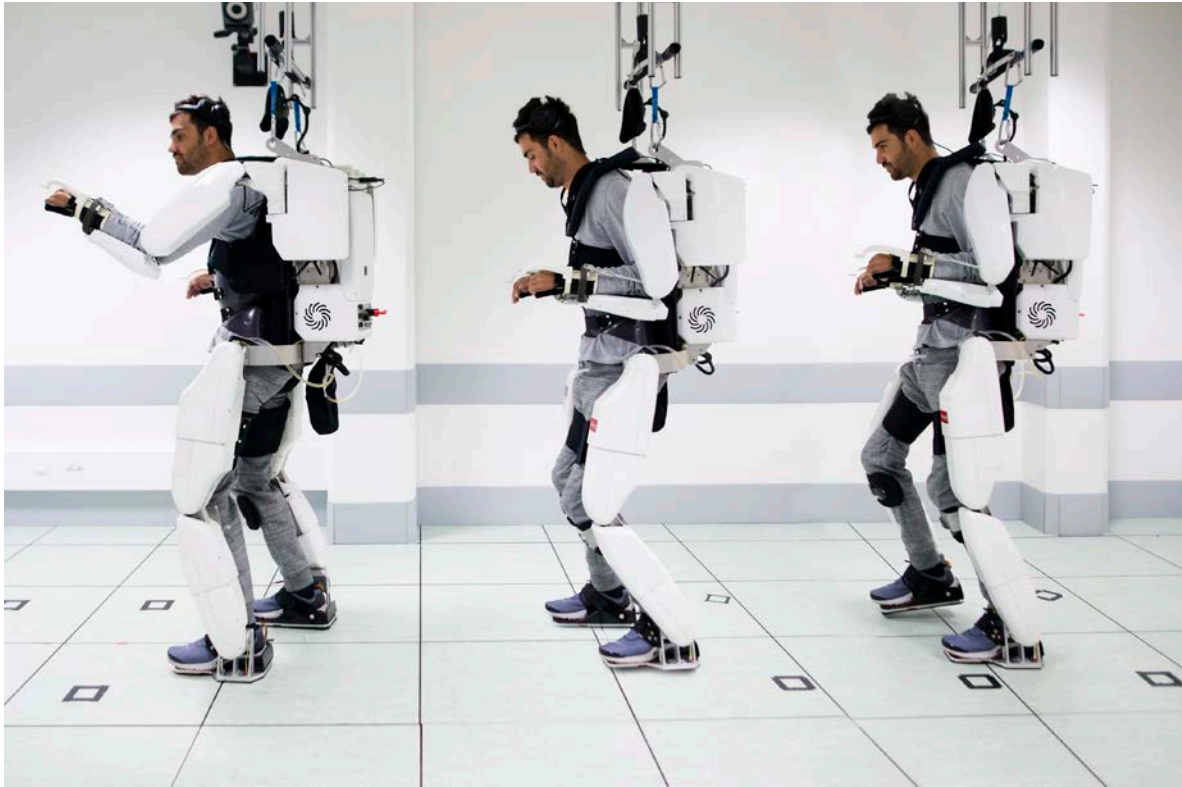
(*Laboratoire National Henri Becquerel*) implemented new reference beams for interventional cardiology equipment calibration. Heart catheterizations are usually performed using X-ray images so that the surgeon can see and control the intervention in real time on a screen. The main drawback is that it is challenging to measure the exact dose of radiation received by the patient. The new reference beams implemented by LNHB, which are comparable to the beams used on patients, solve this problem. An air kerma index was determined for the reference beams (air kerma is the unit of measurement for X-ray dosimetry). The reference beams can be used to calibrate the dosimeters on clinical X-ray imaging equipment much more accurately than before, improving management of the doses received by patients. This project positioned LNHB at the forefront of metrology for interventional radiology in Europe.



ULTRASOUND THERAPY: SIMULATING HEAT ABLATION OF BIOLOGICAL TISSUE

High Intensity Focused Ultrasound (HIFU) is a non-invasive method for ablating tissue. List partnered with INSERM to add a new module to its CIVA software, the world's leading non-destructive testing platform. The new module, called CIVA-Healthcare, simulates the thermal dose delivered to the patient according to the patient's unique biological profile so that the lesion produced can be

evaluated prior to treatment. EDAP-TMS, a partner in the project, has integrated a prototype into Focal One®, its HIFU prostate cancer treatment device. Clinical trials will soon begin to compare images of lesions after treatment with the results obtained by simulation. The next step will be to improve the solution so that it can deliver results in real time.



EXOSKELETON RESTORES MOBILITY TO QUADRIPLÉGIC PATIENTS

In a world first, a tetraplegic patient was able to walk and use both arms with a system that combines the EMY (Enhanced Mobility) exoskeleton designed by CEA List and a brain implant to control the exoskeleton. The semi-invasive brain implant, designed by CEA Leti, decodes brain signals in real time, interpreting the patient's intention to move into commands sent to the exoskeleton. This major breakthrough is the result of the Brain Computer Interface project at biomedical research center Clinatéc (CEA/Grenoble-Alpes University Medical Center). It was published in *The Lancet Neurology*.

IA REDUCES PAPERWORK FOR DOCTORS

CEA List and major French healthcare administration service provider DocteGestio kicked off the DIM-IA project in 2019. The project is exploring how to best use artificial intelligence to support hospital practitioners in their medical data coding tasks. Coding consultations and other medical interventions is a purely administrative task that keeps doctors away from higher-added-value activities. List's semantic analysis algorithms were adapted to medical terminology to automate coding. The List-DocteGestio partnership also produced diagnostic classification software to be integrated into medical billing processes that will be implemented across DocteGestio's 300 facilities.





**DIM-IA PROJECT
BRINGS HOSPITAL
PRACTITIONERS
THE BENEFITS OF AI**

Up next: The partners would like to automate the generation patient liaison file from an automated summary of the patient care pathway.

**MEDICAL IMAGING:
DOSE OPTIMIZATION AND
DIAGNOSTIC PERFORMANCE**

Repeated medical imaging procedures expose patients to doses of radiation that may pose a future risk to their health. The challenge is to reduce the dose received by patients to a minimum without compromising the quality of the image and, therefore, the diagnosis. CEA List developed two new mathematical indicators to help achieve this. The first leverages a Monte Carlo model of the scanner at the DOSEO platform to reliably estimate the dose received by the patient. The second calculates a lesion detectability index



used to assess the quality of the image obtained. Ultimately, correlating these two indicators will give radiologists a method for optimizing their medical imaging protocols.



**WORLDWIDE
SUCCESS**

SCIENTIFIC EXCELLENCE
AND DEEP KNOWLEDGE
OF INDUSTRIAL R&D



OUTPUTS
OUTSIDEFRANCE
OUTOFTHEBOX
OUTDOOR

OUTSIDE



CEA List is home to a unique range of world-renowned knowledge and expertise and talented people of all nationalities working together to drive the next advances in technology. The institute's activities span the entire research and innovation continuum in France, across Europe, and around the globe.



AN INTERNATIONAL SCOPE

In 2019, CEA List continued to raise its profile in Europe and internationally, gaining substantial traction over the course of the year.

A STRONGER POSITION IN EUROPE

We contributed to three major initiatives in 2019:

- The development of the DigiHall European Digital Innovation Hub (DIH). CEA List is leading this DIH with the support of the Ile-de-France regional government, which is playing an active role in bringing digital transformation to industry. DigiHall has already been selected by the European Commission as one of the more than 250 Digital Innovation Hubs across Europe. This has translated into roles coordinating or contributing to EU projects like RIMA, HERO, and AgRO-BOFood and

leading AI-DIH-EU, the European network of DIHs in Artificial Intelligence.

- The launch of EIT Manufacturing, headquartered at DigiHall (Nano-INNOV). This new Knowledge and Innovation Community (KIC) of the EIT (European Institute of Technology) brings together more than 50 academic and industrial partners from across Europe to drive the transformation of European manufacturing through technology transfer, innovation, education, and training.
- The expansion of the European network



THE NUMBER OF INTERNATIONAL INDUSTRIAL R&D PROJECTS INCREASED BY 80% BETWEEN 2016 AND 2019.

KEY FIGURES:

- 150+ projects
- 30 % success rate for our submissions
- 29 R&D topics covered

of excellence in cybersecurity, SPARTA, led by CEA List, which is coordinating European cybersecurity research via some 50 centers of expertise.

PUBLIC-PRIVATE PARTNERSHIPS

CEA List bolstered its relationships with major European RTOs (Research and Technology Organizations) through the following initiatives and major European public-private partnerships:

- EARTO Defense and Security Group
- Partners Board of the Big Data Value Association (BDVA), the private-sector component of the Big Data PPP
- Board of Directors of euRobotics, the private-sector component of the SPARC PPP (robotics)
- Board of Directors of the European Cybersecurity

Organisation (ECSSO), the private-sector component of the Cybersecurity PPP

- EFFRA (European Factories of the Future Research Association) Partners Board
- Manufature High Level Group and contributions to the group’s Manufacturing 2030 strategy plan
- Many more European research and innovation organizations in fields such as automotive and mobility (EARPA, ERTICO) and embedded systems (ARTEMIS)

A GLOBAL REACH

CEA List’s international strategy has led to an uptick in the proportion of European projects in List’s R&D partnerships. The institute is currently engaged in around 100 ongoing European projects, a number that has grown by 50% over the last two years. The number of international industrial R&D projects (mainly in the United States and Japan, but also in Spain and Hong Kong) also increased by 80% between 2016 and 2019 and accounted for more than 6% of all of our industrial R&D partnerships in 2019.

A EUROPEAN YEAR

As one of the world's premier centers for smart digital systems research and development, CEA List organizes and participates in a large number of major international events each year. These conferences, trade fairs, seminars, and other events provide opportunities for CEA List to showcase our researchers' work in a wide variety of fields (AI, advanced manufacturing, additive manufacturing, cyberphysical systems, and more).



SPARTA



SPARTA TACKLES CYBERSECURITY IN EUROPE

CEA List is the coordinator of SPARTA, a network of 44 European cybersecurity stakeholders. Funded under the European Commission's Horizon 2020 instrument, SPARTA will completely reshape Europe's cybersecurity research strategy. SPARTA will outline a

strategy to deliver advanced cybersecurity solutions across four areas: people (healthcare), the economy (energy, finance, and transport), technology (ICTs and industry) and government (conventional and e-government services).

January 27, 2019



SAFE AI WORKSHOP

CEA List organized the Safe AI workshop at AAAI, the largest international AI conference, held in the United States. The workshop is a prime example of List's pioneering efforts to raise awareness of the risks associated with AI and evidence of the institute's leadership in trusted artificial intelligence research.

April 24, 2019



EIT DIGITAL OEDIPUS

CEA List is overseeing the EIT Digital Oedipus project and the associated iCenter with eleven European partners, including Siemens. The goal is to develop innovative technological solutions and create a community of tech users to advance Industry 4.0 in Europe.

July 3, 2019



EU CPS4EU PROJECT

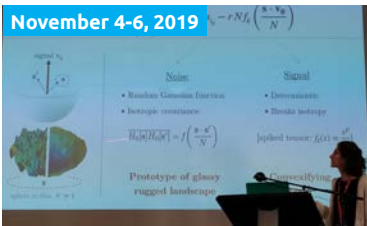
The CPS4EU project launch meeting was held at Nano-INNOV and was attended by 33 partners from five countries and the French Directorate General for Enterprise. CPS4EU is a major project for European sovereignty in the field of cyberphysical systems. The goal is to develop and facilitate the widespread adoption of CPS via a common software and hardware base.



PARTNERSHIP WITH BERKELEY

CEA List is working with researchers at the University of California at Berkeley (UCB) to design mixed-criticality systems.

November 4-6, 2019



FIRST FRENCH-GERMAN MEETING IN PHYSICS, MATHEMATICS & AI THEORY

CEA List ran the first French-German Meeting in Physics, Mathematics and Artificial Intelligence Theory in Paris. The goal was to get researchers in theoretical physics, mathematics, and artificial intelligence working together and spark new partnerships between French and German institutes in these fields.

November 7, 2019



EIT MANUFACTURING

Inauguration of EIT Manufacturing headquarters on the Paris-Saclay campus. This 50-member consortium of European stakeholders from industry, higher education, and research will innovate solutions for the digital transformation of industry on a global scale.

November 13, 2019



NDT IN AEROSPACE

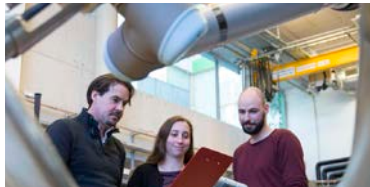
The eleventh NDT in Aerospace meeting was held by CEA List on the Paris-Saclay campus, bringing in 280 participants from 31 countries, a prime opportunity for List to showcase its NDT expertise in front of an international audience.

December 10, 2019



C-BORD WINS "STARS OF EUROPE" AWARD

The C-BORD project (Effective Container Inspection at BORDER Control Points), consortium of eighteen European partners led by the CEA, was given a Stars of Europe award by France's Minister of Higher Education, Research, and Innovation, Frédérique Vidal. The purpose of the project is to develop a non-intrusive monitoring solution for maritime freight containers and the detection of hazardous and/or prohibited materials and substances.



3DPRINT, FORMNEXT, AND ICWAM

CEA List was present at the 3DPrint trade fair in Lyon, France, one of the leading European additive manufacturing events; FormNext, the world's largest additive manufacturing trade event in Frankfurt; and the ICWAM conference in Metz, France. These three flagship events gave List opportunities to present its eddy current, ultrasound-laser, and X-ray tomography techniques.



EXPERT INSIGHTS

ON CEA LIST'S PODCAST

Listen to CEA experts talk about their top projects and get their insights into what is over the horizon in artificial intelligence, e-healthcare, advanced manufacturing, and cyberphysical systems.

LISTEN ON THE CEA LIST WEBSITE: WWW-LIST.CEA.FR

