

# ANNUAL REPORT 2020

## CEA-List



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INSTITUT  
CARNOT  
CEA LIST

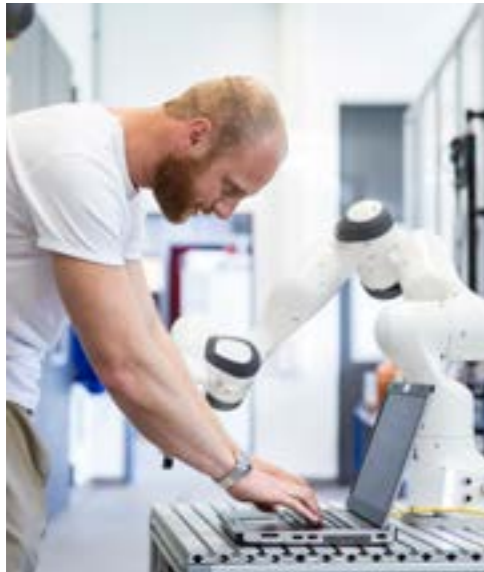
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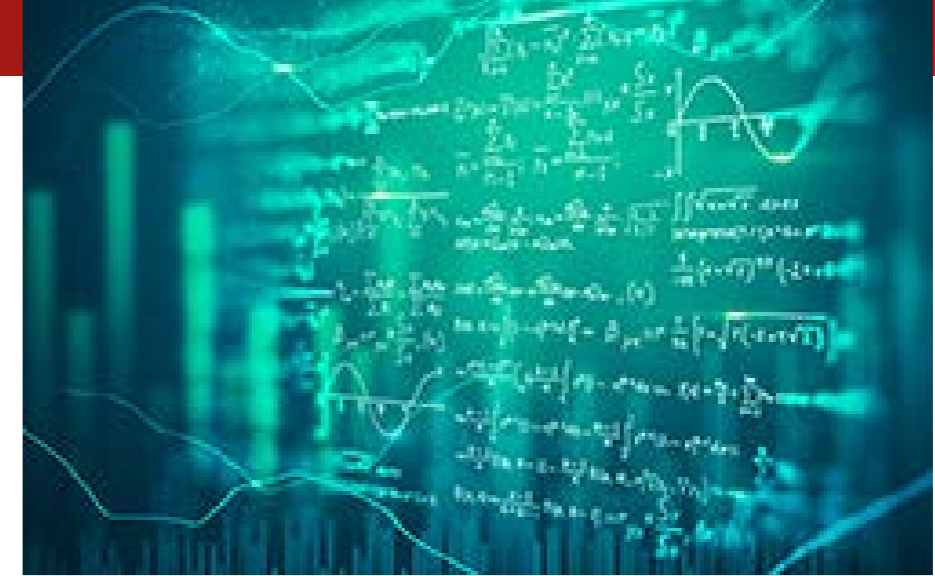
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# POSITIONING

CEA-List, one of the three institutes of the CEA Technology Research Division, is located in Paris-Saclay and Grenoble, France, two major innovation ecosystems. A center for research and development on smart digital systems, CEA-List transfers new technologies to French companies in support of a competitive national economy.

CEA-List R&D programs in AI, the Factory of the Future, cyberphysical systems, computing (including quantum), and digital health all address major economic and societal challenges.

As a member of the Carnot Network, CEA-List conducts R&D projects with more than 200 companies of all sizes and from all industries each year. Carnot was established to facilitate the transfer of new technologies from the lab to the market through research partnerships.

CEA-List engages in research partnerships with institutes around the globe and is active in a large number of European projects each year. Finally, CEA-List runs an ambitious pump-priming program to ensure that we have a steady pipeline of technologies for the future.



## **CYBER-SECURITY**



The growth of smart digital systems and their increasing use in industrial scenarios have raised urgent questions about cybersecurity across these systems' lifecycles. CEA-List research is addressing how to best assess cybersecurity vulnerabilities and implement optimal countermeasures to protect these systems, the services they deliver, and the data they process.

## **ARTIFICIAL INTELLIGENCE**



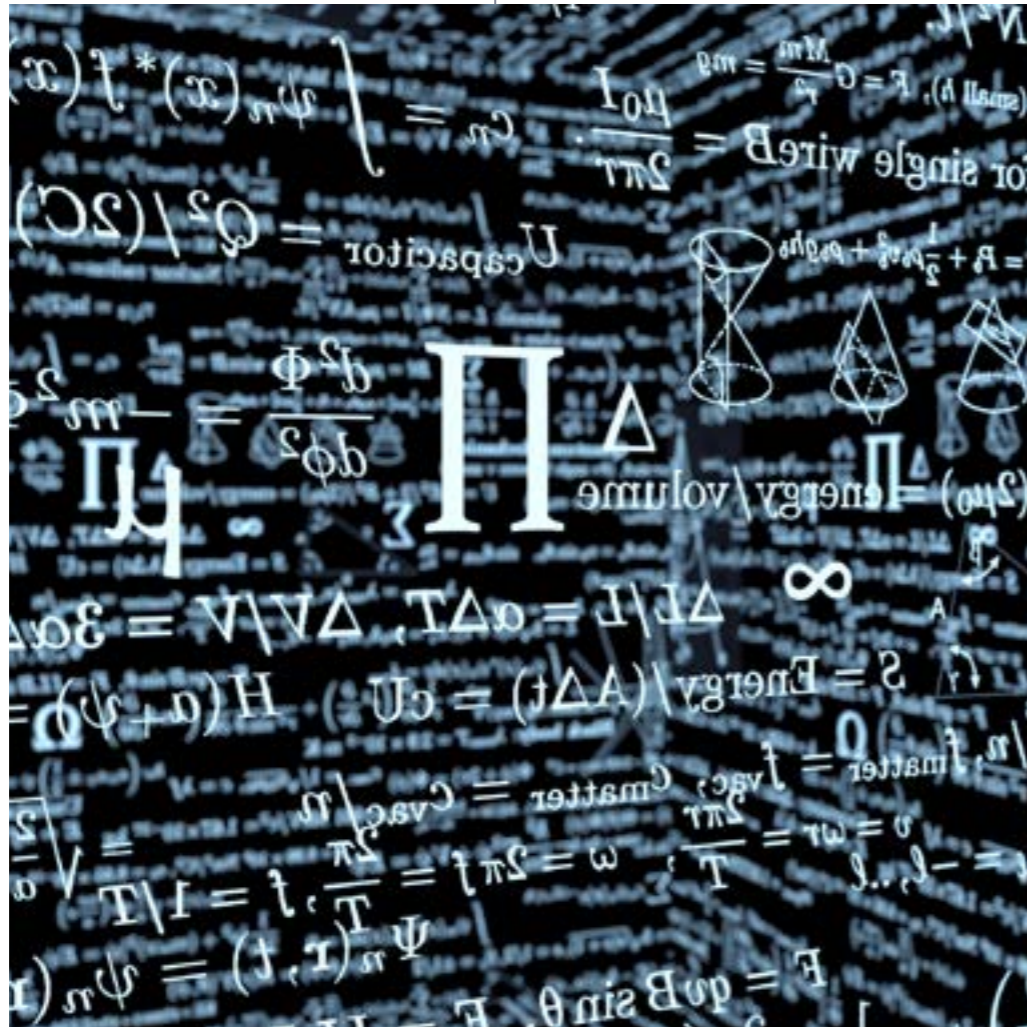
AI is at the center of the energy and digital transitions and will play a crucial role in the medicine of the future. Embedded AI is a key enabler of low-power in - and near - sensor computing. CEA-List is also driving advances in frugal AI to deliver low-data, low-energy AI solutions and in trusted AI to guarantee that the "answers" provided by embedded AI systems are explainable and unbiased, and that any inherent uncertainty is known and measured.



## QUANTUM



CEA has been conducting research on quantum technologies for years. Recently, CEA-List has been working on a quantum software stack and architectures capable of supporting the programming and execution of realistic applications on a future high-performance quantum computer.



## MANUFACTURING



The future of industry is being invented today, and it is all happening at CEA-List laboratories. The institute is conducting research on topics like digital twins, robotics, nondestructive testing, and additive manufacturing. And, to facilitate the scaleup and transfer of these new technologies to companies, CEA-List is setting up pilot production lines.





**ALEXANDRE  
BOUNOUH**  
CEA-List  
Director

### How would you sum up the year 2020 at CEA-List?

**A.B.:** We started the year by revisiting our priority research programs and strategy to make sure that we were well aligned with the CEA's positioning on the energy and digital transitions and on the medicine of the future. Our teams demonstrated an extraordinary level of engagement in ensuring that we were able to realign our research programs to more effectively respond to economic and societal challenges. As a result, in spite of the public health crisis, we were able to maintain our capacity to innovate and we continued to work with our industrial R&D and academic research partners. We published some major articles and papers in top-tier journals and conference proceedings and filed 83 patents on key technological advances. We also continued to move our foundational projects forward. The French Directorate General for Enterprise certified our EDIH (European Digital Innovation Hub) DigiHall submission, for example. We also pursued work on our innovation platforms, which will be operational in 2021.

# "The pandemic has not affected CEA-List's ability to innovate."

In these uncertain times, CEA-List teams have proven themselves to be resilient and agile as they pursued their mission of innovation for France's economy and society. CEA-List Director Alexandre Bounouh told us how the institute successfully leveraged its know-how to support business' digital transformation strategies.



**OUR INDUSTRIAL AND ACADEMIC RESEARCH PARTNERSHIPS HAVE BEEN FULLY MAINTAINED. OUR PARTNERS' COMMITMENT AND TRUST ALLOWED US TO MOVE FORWARD ON OUR JOINT PROJECTS.**

### What were some of the highlights of 2020?

**A.B.:** First, we launched several initiatives around Covid-19. These included the CLEAR (CEA-List Emergency Assistance for Respiration) project, which resulted in two emergency ventilator concepts, and a project with Foch Medical Center on early virus detection. These advances were made possible by people and outstanding cooperation. We were able to respond to an emergent crisis and contribute to projects that responded to a societal challenge. In this truly unprecedented situation, we were one of the first research organizations to assert that France and Europe should take advantage of the leverage of digital technologies to transform our industries and bring manufacturing back home. We are now spearheading projects around this theme to create research and innovation platforms structuring ecosystems that include industrial companies, end users, integrators, and technology providers. All of this is happening in an internationally renowned ecosystem, that of the University of Paris-Saclay, which has reached the top of international rankings.

### How did CEA-List respond to Covid-19?

**A.B.:** Our teams demonstrated a remarkable capacity for adaptation and agility. During the first Covid-19 lockdown, we very quickly set everything up so that we could maintain our operations. This included implementing digital tools and technologies that allowed our teams to stay connected and work from home. Today, our belief in digital technology as an enabler of tomorrow's world is stronger than ever.

### What's your outlook for 2021?

**A.B.:** The French government is rolling out some major programs that include investments in several key industries through innovation financing instruments created under the nation's economic recovery and broader economic stimulus packages. These programs will step up innovation in key areas like artificial intelligence, quantum, cybersecurity, and the Factory of the Future, which are among CEA-List's areas of expertise and priorities. For us, these programs will be a major driver of the technology development activities we run with our industrial R&D partners. At the European level, the Horizon Europe and Digital Europe programs, which will be launched in 2021, will create a similar dynamic. Once again, our flagship programs are closely aligned with the European focus on digital technologies, industrial innovation, and carbon-free industry in the framework of the Green Deal.

LEARN MORE:



**100**  
TECHNOLOGICAL ADVANCES  
IN 2020

# About CEA-List

Located in Paris-Saclay and Grenoble, France, CEA-List, with its teams of 900 scientists and technicians, conducts advanced research and development in the field of smart digital systems. The institute's mission is to transfer the latest technological innovations to businesses of all sizes, from all industries.



01

## OUR MISSION: TECHNOLOGY TRANSFER

— CEA-LIST DEVELOPS SMART DIGITAL SYSTEMS. Its mission is to innovate and transfer new technologies to companies. Each year, more than 200 CEA-List partner companies integrate the institute's disruptive and differentiating technologies into their products, services, and solutions with the ultimate goal of boosting their economic competitiveness. CEA-List also engages in ecosystem-building activities to support tech transfer. These activities include open innovation platforms to encourage cooperation with and between industrial companies and strengthen ties with technology providers, some of which are CEA-List startups.

02

## A LEADER IN SMART DIGITAL SYSTEMS

— CEA-LIST HAS EARNED INTERNATIONAL RECOGNITION for its research in fields like cybersecurity, e-health, artificial intelligence, and advanced manufacturing. The institute is also recognized for its scientific excellence, and its research is published in leading international journals and conference proceedings every year. The year 2020 was marked by a number of noteworthy advances including the formal validation of learning algorithms, as well as remarkable results in quantum, where our researchers carried out a first formal verification of a program on a quantum machine, and cybersecurity, with new countermeasures to fend off timing attacks. Software also remains one of the institute's key areas of expertise: two open-source software platforms were released in 2020, one for embedded AI, and another for automated online image annotation.



03

## IN-DEPTH KNOWLEDGE OF INDUSTRIAL R&D

— CEA-LIST has earned recognition for its scientific excellence and proven capacity for innovation. In addition, CEA-List experts possess in-depth knowledge of industrial R&D, positioning the institute to deliver relevant responses to partner companies' challenges. CEA-List's solid relationships with businesses facilitate the transfer of new technologies. The institute has a results-oriented culture driven by cost, lead time, and performance targets. This unique capacity to respond to the business imperatives of industrial R&D enables CEA-List to develop, scale up, and transfer technologies to companies rapidly and effectively.

04

## A MEMBER OF THE CARNOT NETWORK OF EXCELLENCE

— CEA-LIST FIRST received the Carnot seal in 2006, and the institute's membership in the Carnot Network was renewed again in 2020. The seal is granted to research organizations that demonstrate excellence in research partnerships with private-sector companies. It also comes with funding, a large proportion of which is allocated to pump-priming research and projects that aim to identify tomorrow's technological breakthroughs. This allows CEA-List to explore technologies that are not yet mature through early-stage research programs on topics like the quantum software stack, for example, and create ecosystems around digital platforms addressing topics like manufacturing.

# Highlights of the year 2020



## CES®

### DEMONSTRATORS IN THE SPOTLIGHT IN LAS VEGAS

CEA came out in force for CES in Las Vegas in January 2020. CES, the world's largest tech event, provided CEA-List with an opportunity to showcase several demonstrator systems for tomorrow's mobility. The first, AI vs Wild, protects systems built on AI and neural networks from adversarial attacks; DeepRed is a software analyzer that utilizes mathematical reasoning to bolster the cybersecurity of both source and binary code; and DeepManta, a joint innovation of CEA-List and Valeo, is a real-time artificial intelligence algorithm for 3D pedestrian and vehicle geolocation, autonomous vehicle path planning, and more.

## With SafeAI, CEA-LIST CARVES OUT LEADER POSITION ON TRUSTED AI

CEA-List Research Director François Terrier keynoted the SafeAI 2020 workshop in New York. His talk explored the concepts of incremental and evolutionary qualification of artificial intelligence-based systems. He underscored the pressing need to bring AI into the relevant qualification standards and guidelines now.



## Arcure

### UNVEILS BLAXTAIR® CONNECT

Arcure, a CEA-List spinoff, recently introduced Blaxtair® Connect, a new solution that detects pedestrians around moving vehicles at industrial sites. Blaxtair® pedestrian detection cameras generate the data, and Blaxtair® Connect, developed through a joint lab CEA-List and Arcure, sends it to the cloud for analysis. This new solution provides a log of time – and location – stamped “near misses” based on an assessment of the risk of vehicle-pedestrian collisions and evaluates the effectiveness of preventive measures.



## CEA-List Carnot

### NETWORK MEMBERSHIP RENEWED

CEA-List's Carnot Network membership was renewed for a fourth consecutive term in February 2020. The Carnot seal recognizes the quality and professionalism of research conducted in partnership with businesses.

# 39

RESEARCH INSTITUTES IN FRANCE ARE MEMBERS OF THE CARNOT NETWORK



## Blockchain recommendations

### SUBMITTED TO FRENCH GOVERNMENT

The French government appointed research organizations CEA-List, Inria, and IMT to steer the nation's blockchain policies. In February 2020 they handed in their recommendations on the scientific technological hurdles to a French blockchain to the Ministry of the Economy. These focus on overcoming the barriers to industrial blockchain implementation and an inventory of France's blockchain education, research, and startup ecosystem.



## Deep learning

### HELPS LIMA LANGUAGE ANALYZER ADDRESS MORE THAN 60 LANGUAGES

CEA-List's popular LIMA language analyzer is available as a new release called Deep LIMA that offers new features. Deep LIMA utilizes deep learning and ad hoc implementation of neural network models from the community to deliver augmented analysis, summarization, and language translation capabilities. The original LIMA could handle six languages. Deep LIMA can analyze more than 60 languages with state-of-the-art performance.



## Lesly-Ann Daniel

### L'ORÉAL-UNESCO FOR WOMEN IN SCIENCE YOUNG TALENTS AWARD

CEA-List PhD candidate Lesly-Ann Daniel won a 2020 L'Oréal-UNESCO For Women in Science Young Talents Award in October 2020. Lesly-Ann, who is now in her third year of PhD research, is doing her dissertation on cybersecurity. Specifically, she is developing software to automatically scan programs for security vulnerabilities to automatically scan programs for security vulnerabilities and guarantee that none are present.

## IEDM 2020

### ZOOMS IN ON TECHNOLOGIES FOR HIGH PERFORMANCE COMPUTING

Denis Dutoit was invited to the prestigious International Electron Devices Meeting (IEDM) in December 2020 to talk about how CEA-List's multicore architectures and CEA-Leti's 3D integration technologies helped bring high-performance computing (HPC) to the exascale level.

# Key figures 2020

## PROJECTS AND PARTNERSHIPS

**137** European projects submitted  
by CEA-List, **30%** success rate

**25** startups created  
since 2003, **3** new startups created in 2020

**200** industrial R&D partners  
**45%** SMBs

**22** technology platforms

## HEADCOUNT

**900** scientists and technicians  
**114** PhD students  
**50%** of employees hired in 2020 are under 30 years old

## TECHNOLOGY TRANSFER

**300**  
A-rank publications in 2019

**83**  
patents in 2020

**+665**  
active patent families

**152**  
active licences

## OUTSIDE



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## INNOVATING FOR INDUSTRY

Each year, CEA-List brings its innovations to a large number of companies – in France and in other European countries and beyond – through R&D partnerships. The operational solutions of tomorrow will emerge in part thanks to these joint innovation projects.



## DIGIHALL HELPS BUSINESSES NAVIGATE DIGITAL TRANSFORMATION THROUGH TARGETED SUPPORT

The mission of the DigiHall European Digital Innovation Hub (EDIH) is to drive digital transformation, sustainability, and resilience for businesses.



### Supporting businesses

DigiHall is Europe's largest community of researchers. Located in Paris-Saclay, this center for excellence in digital technologies is home to more than 1,500 seasoned international scientists. Companies come to DigiHall for know-how in artificial intelligence, cybersecurity, digital infrastructure, quantum, and Factory of the Future. The idea is to help these companies leverage digital technologies to develop innovative products, services, and processes. DigiHall provides shared equipment, resources, and support services, plus prime access to key stakeholders from industry, research, and education.

### End-to-end support services

DigiHall EDIH is a consortium of eighteen partners, all offering services to companies operating in industries deemed strategic to the Ile-de-France regional economy. Because DigiHall brings together all of the major providers of innovation support services for businesses, plus stakeholders from higher education, research, innovation, and technology transfer, it is uniquely positioned to serve as a single point of

entry for companies seeking to access digital innovation services. DigiHall streamlines these companies' access to:

- Technology readiness assessments:
- Assessments and solutions that respond to clearly-identified needs provided by DigiHall partners and their networks
- Skilled people to deliver know-how and training for real-world implementation of digital transformation projects

### Expanding our scope to Europe

The DigiHall EDIH certification process started with the French government's calls for expressions of interest. DigiHall EDIH was selected at the national level in France to apply for certification from the European Commission. In 2021 the Commission will select the Digital Innovation Hubs it deems the best positioned to "reinforce the EU's competitiveness in digital technologies and ensure that every business in Europe – whichever the sector, wherever the location, whatever the size – can draw the full benefits from digital innovation."



FactoryLab

## BRINGS COLLECTIVE INTELLIGENCE TO THE FACTORY OF THE FUTURE

The members of the FactoryLab consortium have signed on for another four years of cooperation between research and industry to develop solutions for the Factory of the Future. Their strategy is built on fast project turnaround times and concrete deliverables that meet needs shared by companies from different industries.

### A strategic hub for research and development

FactoryLab, on the Paris-Saclay innovation campus, brings industrial R&D stakeholders together to address common challenges and share best practices. FactoryLab promotes the spread of good ideas between industries that do not habitually work together. It is backed by an R&D ecosystem made up of SMBs and research organizations capable of solving companies' problems. The 29 members of FactoryLab are committed to delivering an innovative resource-sharing model to drive value creation.

### Fast turnaround

As a center for innovation focusing on solutions for the Factory of the Future, FactoryLab offers the major advantage of being able to get new technologies to the market very rapidly. Generally, projects at FactoryLab take place over twelve months, with the goal of producing a functional demonstrator ready to be scaled up within that timeframe. Projects must interest at least three user companies from different industries to be eligible for FactoryLab services. Broad interest for a

technology derisks the investment made by technology providers and gives them the assurance of a large enough potential market for their solution.

### A reproducible model

The FactoryLab model works, and plans are underway to duplicate the model for other industries. Affiliate networks are being set up for companies from different industries to engage in collaborative projects that respond to their shared technology needs.

### Looking back

Since FactoryLab was founded in 2016, 50 innovation projects have been run. The year 2020 was marked by projects like Divora, which focused on the development of an automated voice-recognition solution for report generation. Another project, GECO, produced a smart software suite for dynamic real-time industrial process optimization. The next phase in the FactoryLab development plan started in January 2021. New partners will join the consortium for a crop of new projects, including ones that address energy optimization and low-carbon solutions.

## CEA-LIST A STRATEGIC STAKEHOLDER

CEA-List runs a large number of research and innovation projects in the field of smart digital systems. These projects are backed by a robust technology transfer policy. These research, innovation, and tech transfer capabilities make CEA-List a strategic stakeholder with close ties to academic research and businesses, ideally positioned to set up major projects at the national and European levels anchored on the Saclay innovation campus, where the institute is based. CEA-List plays a central role in building tech transfer ecosystems through infrastructures like DigiHall and FactoryLab.

## A KEY STAKEHOLDER IN INDUSTRIAL ECOSYSTEMS

CEA-List plays an active role in regional and national industrial ecosystems, partnering with companies from a variety of industries on innovation projects. The aim of these projects is to give CEA-List partner companies a competitive edge in today's economy. Read on to discover some of the partnerships that marked the year 2020.

### Embedded AI: new optimization tools in collaboration with STMicroelectronics

CEA-List is driving advances in the microelectronics industry with semiconductor giant STMicroelectronics. The partners are working to speed up the implementation of AI on ST product portfolios for the mass, industrial and healthcare markets. CEA-List is contributing know-how in neural network design, optimization, and implementation on embedded

hardware to the partnership with STMicroelectronics.

### Connecting Food for greater transparency in food manufacturing

CEA-List created a joint lab startup Connecting Food in 2018. The partners developed a blockchain-based food-manufacturing auditing solution to ensure full traceability from farm to supermarket shelves. This innovation has positioned Connecting Food as Europe's leader in blockchain-based solutions for the food manufacturing industry. The startup is drawing on CEA-List's know-how to grow and develop new solutions.

### Optimizing the scheduling process in the logistics industry

CEA-List also transferred a new technology to the logistics industry. The SONARIS project, led by the CEA Tech technology transfer unit in the Hauts-de-France region, is leveraging CEA-List's proprietary Papyrus platform to develop prototype digital twin design and implementation software. The goal is to develop functional digital twins for logistics simulations. An innovative haptic button that uses a magneto-rheological fluid will round out the solution. The button will enable fast, intuitive navigation through the software's menus. The six partner companies on the project include logistics service provider LOG'S, which had previously worked with CEA-List the Digital Twinning project to "right size" logistics services and generate associated cost estimates.



WE TOOK FULL ADVANTAGE OF SYNERGIES BETWEEN OUR RESPECTIVE AREAS OF EXPERTISE TO INTEGRATE THE CEA'S XDE PHYSICS ENGINE INTO OUR INTERACT AND XR TWIN SOFTWARE SOLUTIONS. WE SUCCESSFULLY RESOLVED ISSUES RELATED TO THE ACCURACY OF PHYSICAL SIMULATION IN A VIRTUAL CONTEXT IN AN ADVANCE THAT IS VERY LIKELY TO REVOLUTIONIZE TODAY'S INDUSTRY.

**ALEXANDRE AVENEL**, Interact Product Manager, Light & Shadows

### Safe observation of nuclear reactors

The Digital Reactor project, which kicked off in 2020, is a partnership between the CEA, EDF, Framatome, and six other engineering and nuclear-industry companies. The objective of the project, supported by the French government's nuclear industry program, is to develop digital twin of a nuclear reactor covering the design,

operation, and decommissioning phases. CEA-List is bringing software and critical-systems engineering know-how and tools to the digital twin, which will simulate the reactor's operations in all conditions so that it can be observed 100% safely. A shared operator training platform will also be developed, as will new digital simulation-driven services for export markets.

# SETTING OUR SIGHTS ON EUROPE AND THE WORLD

CEA-List, a leader in smart digital systems, is engaged in a large number of research projects with international partners and is helping shape the European Union's research strategy.

## 30%

The success rate of the 137 European R&D project submissions in which CEA-List was involved.

## 137

The number of European project submissions filed by CEA-List in 2020.

### An active role in European research projects

CEA-List has been bringing excellence in sci-tech research and development to European projects for a number of years. Our proactive European strategy translates into 150 project submissions every year. In 2020 our success rate was an impressive 30%. Our reputation as leaders in the European research space has also earned us seats on the committees and other bodies that steer the EU's research strategy. For example, we represent the CEA within the European Institute of Innovation & Technology Manufacturing, Digital, and Food communities and our teams are members of European big data, robotics, Factory of the Future, embedded systems, and cybersecurity

bodies (BDVA, EURobotics, EFFRA, Artemis, ECSO, etc.).

### Digital Innovation Hubs serving businesses

We are involved in several Digital Innovation Hubs (DIH) and in the AI-DIH network of European DIHs in artificial intelligence. CEA-List is a partner in the proposed DigiHall EDIH, which has earned the support of the Île-de-France regional government (see page 16). The future EDIH in Paris-Saclay will serve as a business accelerator. The eighteen DigiHall EDIH project partners (research organizations, clusters, incubators, and the EIT Digital and Manufacturing communities) will offer new services to support companies in their digital transformation projects.



## ÉTOILES DE L'EUROPE 2020 AWARD

An environmental perception solution for the visually impaired was developed as a result of the INSPEX project, which CEA-List coordinated. The portable device utilizes a data fusion technology and integrates an audio interface that alerts the user to potentially hazardous obstacles in 3D. The 2020 "Étoiles de l'Europe" (Stars of Europe) award recognized the work of the nine INSPEX project partners from six European countries and the virtual "safety bubble" they invented for the visually impaired.

## THE SPARTA CYBERSECURITY COMPETENCY NETWORK

CEA-List is the coordinator of the European Sparta cybersecurity competency network. Sparta is a consortium of 44 stakeholders from fourteen EU member states. The network is rethinking Europe's research, innovation, and education strategy with the broader goal of bolstering EU sovereignty. Sparta is spearheading four research programs addressing people (health), the economy (energy, finance, and



transportation), technology, (ICTs, industry), and government (e-government).



## INTEGRADDE, ADDITIVE MANUFACTURING FOR THE FACTORY OF THE FUTURE

CEA-List researchers are playing a very active role in the Integradde project with 26 partners from eleven countries. The two primary objectives of the Integradde project are to develop a solution covering all process steps involved in the manufacturing of large parts and to test the feasibility of direct energy deposition (DED) for the additive manufacturing of certified components. The certification of parts made by additive manufacturing is a challenge faced by stakeholders in the aeronautics, automotive, metallurgy, and construction industries.

## INTERNATIONAL COLLABORATIONS

CEA-List has research partnerships with some of the world's leading international institutions. We are working with Stanford University on advanced orchestrators, for example. These "guardian angels" operate at the interface between the physical and virtual worlds to secure a wide range of "next web" services. We are also partnering with the University of California at Berkeley to design mixed-criticality systems, including RISC-V-based systems. Our startups also reflect our international positioning. Sport Quantum's interactive electronic target shooting solution is sold now in 20 countries in Europe, Asia, and North America. In 2020, Kalray set its sights on the fast-growing Chinese market, signing a distribution agreement for its HPC solutions for artificial intelligence applications. Last but not least, smart manufacturing solutions provider Arcure operates in more than 30 countries around the world. This CEA-List spinoff is a leader in smart sensors for more autonomous industrial vehicles.

# CEA-LIST, A LEADER IN BLOCKCHAIN TECHNOLOGY



CEA-List has been active in blockchain since the early days of this technology, which is now making inroads into a number of industrial applications. The French government has turned to CEA-List to help steer the nation's blockchain strategy.

LEARN MORE:



CEA-List researchers have been working on blockchain for a number of years now. The technology is strategic for secure data storage and transmission. Most recently, the institute's blockchain research has focused on an immediate consensus protocol that does not waste energy. Based on an analysis of possible user behaviors, the researchers identified effective incentive mechanisms capable of making transactions more secure. In 2018, startup Connecting Food turned to CEA-List for help developing a blockchain-based solution for the real-time tracking of the compliance of food products with product specifications from farm to supermarket shelves. The immediate consensus protocol was transferred to the startup and integrated into a solution that encourages food

manufacturing stakeholders across the value chain to enter their certificates into the blockchain to ensure greater transparency for consumers.

CEA-List is also working with Engie and Bureau Veritas on a blockchain-based traceability solution for green energy and with EDF on a blockchain application simulation tool that incorporates representative use cases with the purpose of certifying nuclear plant processes.

As a leader in blockchain, CEA-List (along with Inria and IMT) has been chosen by the French government to issue recommendations on the technological barriers to the widespread rollout of blockchain. A report was submitted to the French government in February 2020 with guidance spanning research, innovation, education, and financing.

## INSIDE



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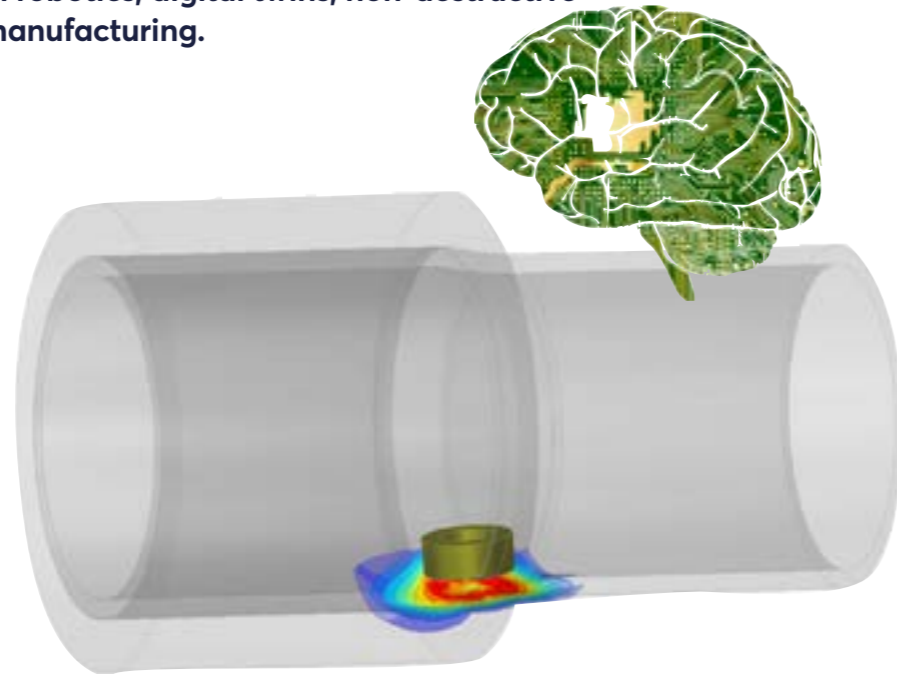
38  
HEALTH,  
WELLNESS,  
AND SPORTS

## RESEARCH PROGRAMS

CEA-List runs five major research programs: advanced manufacturing, cybersecurity, mobility, digital, and health. These programs are driving technological advances for industry and society.

# Manufacturing

CEA-List's advanced manufacturing research enables more agile, responsive, and efficient manufacturing for higher overall quality. Here are some of our most significant advances in robotics, digital twins, non-destructive testing, and additive manufacturing.



## CIVA 2020, A STATE-OF-THE-ART SOFTWARE SUITE

A NEW VERSION OF CIVA NON-DESTRUCTIVE TESTING (NDT) SOFTWARE WAS RELEASED IN 2020. THIS CEA-LIST SOFTWARE SUITE OFFERS THE LATEST ADVANCES IN SIMULATION, DATA PROCESSING, AND ANALYSIS FOR NDT.



## AI ENHANCES DIAGNOSTICS IN NON-DESTRUCTIVE TESTING

Automated and assisted diagnostics are useful in a variety of industrial scenarios, including locating and characterizing defects after inspection. They are of high importance for structural health monitoring and inspection in additive manufacturing. Artificial intelligence (AI) and machine learning have not yet made major inroads into automating non-destructive testing (NDT). However, these technologies could have a significant impact on NDT data processing. CEA-List developed AI and physical-simulation-based NDT diagnostic tools for its CIVA software platform. These new tools will be very useful in the short term for industries such as aeronautics, energy, and NDT equipment manufacturing.



## FIRST COMPANION ROBOT USE CASE IN FACTORY OF THE FUTURE SCENARIO

Tomorrow's manufacturing plants will have to be extremely agile and rapidly reconfigurable. And robots that are smarter, more powerful and interactive than the ones found in factories today will play a key role in this transformation. These robots of the future will be easy to use and capable of learning new tasks quickly. CEA-List kicked off the Carnot *Robot-Compagnon* (Companion Robot) project in 2019 to design a multi-technology solution to endow robots with new physical and cognitive capabilities. The goal is for the robot to be able to perform complex tasks and rapidly move from one workstation to another depending on operators' needs. The first version of the robot was completed in 2020. "Right now, the robot is fixed, not mobile, and can recognize, locate, grasp, and assemble a variety of parts alone or with the help of a human operator if needed," said Florian Gosselin, CEA-List senior scientist. The robot was tested on tasks that included assembling around a dozen nuts, gears, connectors, and other parts. A set of performance indicators was also developed, in order to ensure continuous

## A ROBOTICS SOFTWARE DESIGN COMMUNITY

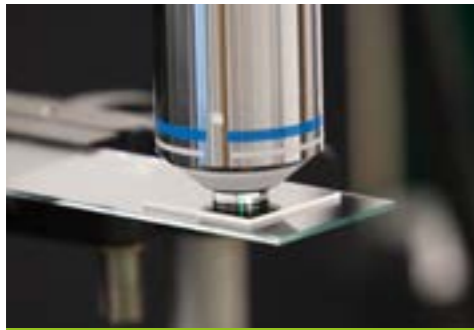
The four-year EU H2020 RobMoSys project led by CEA wrapped up in 2020. The project led to the development of a shared platform and a common software development standard for robotics. The idea is to give robotics stakeholders access to an environment for the affordable development of modular, flexible, and powerful robotics software. Leveraging CEA List's open-source model-driven engineering platform, the project delivered a new method and software development environment, called Papyrus for Robotics. Several companies are already using these new resources. One of them, GMV, applied the tools to an autonomous inspection robot.



THE COMPANION ROBOT MARKS A STEP FORWARD TOWARD OUR VISION OF INDUSTRY 5.0. AS MORE RESOURCE-EFFICIENT AND EFFECTIVE AI TECHNIQUES EMERGE, WE WILL SEE MACHINES THAT CAN LEARN AND THAT ARE MORE INTERACTIVE. THIS WILL ENABLE RECONFIGURABLE FACTORIES CAPABLE OF LEARNING FROM HUMANS AND FROM THEIR ENVIRONMENT. THE OVERRIDING OBJECTIVE IS TO MAKE PRODUCTION MORE AGILE, ECONOMICAL, AND SUSTAINABLE

**Gregorio Ameyugo**, head of ambient intelligence and interactive systems research at CEA-List

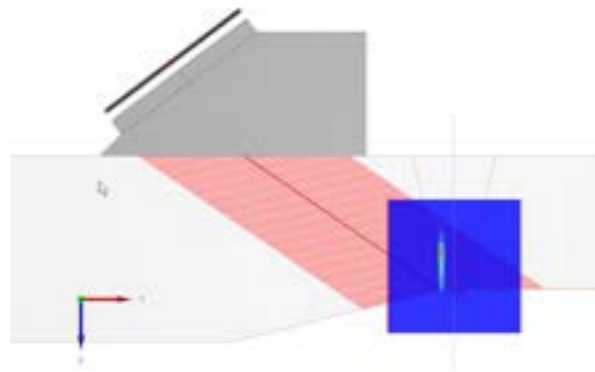
improvement of the system. Over the next several years, the focus will be on improving the robot's performance and gradually adding new features. In 2021 the robot will have two arms so that it can work faster, and a new dynamic planning algorithm enabling it to adapt to unforeseen situations.



### FEMTOSECOND LASER USED TO STRUCTURE A PLANAR SUBSTRATE

CEA-List scientists used a femtosecond laser to etch a periodic fiber Bragg grating (FBG) type structure into a  $\text{SiO}_N$  guide fabricated on the surface of a planar  $\text{SiO}_2$  substrate. This direct femtosecond laser process free from intrinsic photosensitivity and is extremely versatile in terms of the type and location of structures that can be produced on photonic chips and other planar surfaces. This advance marks progress toward the development of ultra-sensitive sensors for photo-acoustic trace gas detection. This research also opens up a new field of investigation that will take full advantage of CEA-List's FemtoBragg femtosecond laser microstructuring platform to explore the potential of etching to functionalize photonic chips with waveguides, resonant cavities, FBGs, and other optical components.

## ADAPTIVE ULTRASONIC IMAGING FOR COMPLEX MATERIALS



In order to obtain high-quality ultrasonic images, the wave propagation model and real propagation within the material being inspected must match. This is particularly true for ultrasonic non-destructive testing (NDT), where real time material properties are vital for generating reliable images. One application where this information is missing is the on-site weld inspections in the primary and secondary circuits of nuclear power plants.

To address the complexities of highly anisotropic welds in nuclear plants, CEA-List developed image-correction methods for a specific ultrasonic technique called TFM (Total Focusing Method). The research was carried out under the EU H2020 ADVISE project. The methods developed were tested on lab samples and validated using statistical approaches. High-contrast images of complex welds were generated with minimal defect-positioning errors.



### IN SITU PROCESS MONITORING FOR ADDITIVE MANUFACTURING THROUGH CONTACTLESS ACOUSTIC EMISSION TECHNIQUE

Additive manufacturing (AM) processes are advanced production techniques which can, for example, be used to make large-sized metal parts. In research for the EU H2020 INTEGRADDE project, CEA-List investigated how laser vibrometry could be applied to probe micro-defects inside AM parts. CEA-List designed a laser scanning vibrometer (LSV), controlled by a tailored human-machine interface to perform contactless in-line quality controls. The system was assessed on a wire-laser AM machine at IREPA LASER coupling signal-based acoustic emission (AE) technique. When compared to conventional AE methods, LSV achieves higher sensitivity and bandwidth comparatively to conventional AE methods.

### CORTEX SOFTWARE SUITE FOR REAL-TIME ROBOT CONTROL

CEA-List scientists developed the C++ CORTEX (Component Oriented Real-Time EXecution engine) software solution for faster, easier robot controller development. The software includes a real-time, modular framework, a resource library of robot components, and modeling, code generation, and other tools. The first version of the software was implemented in 2020; additional development is now underway for two robot controllers in partnership with ORANO and Cybernetix, a Technip Energies company.



## INTERACTIVE SIMULATION: XDE NOW IN UNITY3D STORE

CEA-List has been working on XDE, its interactive multi-physics simulation environment, for 20 years, regularly adding new features and improvements. In XDE, which industrial companies can use to simulate their own use cases, actual human operators act and interact thanks to extended reality technologies. And now XDE is available in the global Unity3D store, where it can reach a much wider audience.

The technologies that power XDE are also found inside the XR Suite by CEA-List partner Light & Shadows. XR Point Cloud, a new application built on XDE, was added to XR Suite in 2020. This extended reality tool lets users view and interact with point clouds generated from scans of their industrial environments.

### NEW SHM MODULE INTEGRATED INTO CIVA

The latest release of CEA-List's non-destructive testing software CIVA includes a new structural health monitoring (SHM) module. The new module simulates elastic guided-wave inspection of structures like aircraft fuselages and pipelines. CEA-List scientist Olivier Mesnil said, "We integrated this new module into CIVA to get it out to a wide range of external users, in both academic and industrial R&D settings". For example, users can determine the optimal placement of their sensors to improve their overall SHM system design. The solution is commercialized by Extende.

# Cybersecurity & security

The digital transition comes with an increased risk of cyberattacks. Keeping information systems and data safe and secure has become a major challenge for businesses. CEA-List runs a number of research programs addressing these topics.



## FENDING OFF TIMING ATTACKS, HACKERS' LATEST WEAPON

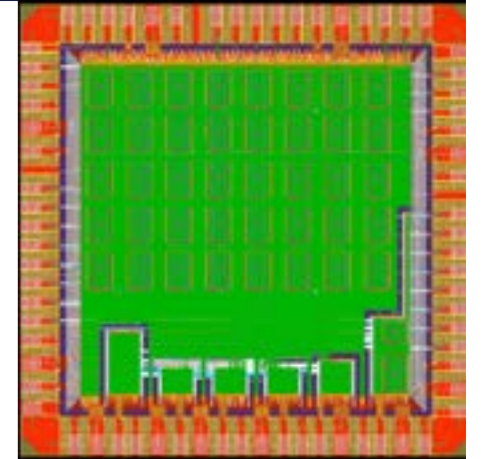
Timing cyber attacks are becoming increasingly common. They represent a growing threat to the cryptographic software used to secure internet communications and protect data. Timing cyber attacks use information about the time it takes a program to respond to a query to hack sensitive data. A technique known as "constant time" programming can effectively counter timing cyber attacks by making sure that a program's response time cannot be correlated to its queries. "Constant time programming is a challenge to implement. So it is important to be able to verify whether or not

a program is actually compliant with constant time requirements," said Sébastien Bardin, a senior researcher at CEA-List. His team at CEA-List, in partnership with Inria, developed a software verification tool that can automatically analyze an executable program and ascertain whether or not it is constant-time compliant. The tool, a module called REL, has been added to CEA-List's BINSEC platform for machine code analysis. In short, REL assesses whether or not cryptographic software is vulnerable to timing attacks. REL was successfully tested on 338 programs, with bugs being detected on actual software that

had been previously certified based on analyses of their source code (as written by the programmer), demonstrating the value of analyzing machine code (as executed by the computer). This breakthrough in automatic program analysis benefited from advances made in formal methods in 2020. The research was published in the proceedings of the IEEE Symposium on Security & Privacy 2020, the leading international conference on cybersecurity. Researchers at CEA-List are now turning their attention to other types of attacks at the frontier between software and hardware, to see if similar methods can be applied.

## FDSOI TECHNOLOGY COULD OFFER THE PERFORMANCE REQUIRED FOR SECURITY CORES

When it comes to reaching very high power-efficiency targets, FDSOI (fully-depleted silicon-on-insulator) holds great promise as an alternative to conventional bulk CMOS technology. The security aspects of FDSOI, however, had not really been addressed until recently. CEA made two GF 22 nm test circuits; one has integrated security bricks, the other is a quick-erase SRAM. Testing and characterization of the circuits' performance in terms of security is now underway, with results expected later in 2021.



## AI VS WILD MOVES FROM BASIC SCIENCE TO TECH DEMONSTRATOR

As artificial intelligence improves, so does hackers' ability to attack AI systems. Some of the new techniques being used take advantage of the vulnerabilities inherent to deep learning algorithms to trick them into making the wrong decisions. For sound and image recognition models, the impact on reliability could be significant. CEA-List has been exploring the theories of how neural networks work to develop countermeasures effective at shielding AIs against emerging risks. PhD candidate Rafaël Pinot did his thesis on this topic at CEA-List (with Paris-Dauphine University). He was able to demonstrate that introducing random processes into neural networks can stave off malicious attacks. A paper on the research was accepted at the prestigious NeurIPS conference on artificial intelligence. CEA-List also had several opportunities to present its research to a broader audience in 2020. A demonstrator illustrating the effectiveness of CEA-List's approach at coming up with defense strategies to shield an autonomous vehicle from adversarial attacks was presented at CES® in Las Vegas. Several companies have expressed interest in the technology.

### FIRST SECURE SOFTWARE KERNEL PROOF-OF-CONCEPT PROTOTYPE COMPLETED

IoT operating systems are plagued by vulnerabilities that expose them to software attacks. CEA-List is rethinking the way these operating systems are built. The goal is to have trusted and low-cost operating systems that meet the needs of the target applications. The institute is developing an automated OS generation framework called XanthOS.

Specifically, the researchers want to be able to generate a minimalist kernel with only those features required by the target applications. XanthOS uses RUST, a secure programming language, to remove vulnerabilities related to memory management and concurrent access, for example. A proof-of-concept prototype was tested on the QEMU emulator. A kernel for the ARMv8 AARCH64 architecture was generated, and 98% of the code was determined to be secure. This is far better than a C/C++ kernel, which offers no protection at all. This test implementation shows that the technology is feasible at a reasonable cost and with a high level of security.



### EXPRESSIF® BRINGS THE POWER OF AI TO DECISION ASSISTANCE

CEA-List and CGX partnered on the development of a decision-assistance technology to more rapidly identify and respond to potential civil security risks. The project, which was run with the support of the CEA Tech Occitanie regional tech transfer office, centered on ExpressIF®, an artificial intelligence algorithm that reproduces human reasoning. Here, the research focused on managing firefighters' response to forest fires. "The idea is to ascertain whether or not features like campgrounds contained in geographical databases are potentially at risk," said CEA-List scientist Laurence Boudet. ExpressIF® performs spatial reasoning; however, it can also monitor temperature changes over time and lift warnings when the situation allows. The project also resulted in the development of a human-machine interface.

In 2020 CEA-List also worked on the learning capabilities of ExpressIF® with Paris-Saclay University engineering school CentraleSupélec. This research focused on relationship learning, which leverages the spatial relationships between objects in an image, for example. "The solution takes an object made up of sub-objects, like an image, and uses the spatial relationships between the sub-objects to make decisions," said CEA-List scientist Jean-Philippe Poli. The solution was able to learn from a small number (fewer than ten) of annotated images before being able to identify objects on its own.

## CEA-LIST STARTUPS

CEA-List spun off three startups in 2020. Startups play a strategic role in CEA-List's technology transfer activities, helping bring innovations from the lab to the market.



### AI HERD

AI Herd was founded in April 2020 by veterinarians, AI programmers, and management specialists. The company is developing an AI-based solution to analyze cattle behavior in real time. Ultimately, the solution will enable remote monitoring of livestock for earlier disease detection, for example. Dairy farms are getting bigger and becoming more automated, which means that humans do not have as much contact with livestock as they once did. This led to a need for effective monitoring solutions. AI Herd use five patents from the CEA List which will continue to develop technological bricks to bring more solutions to the startup.



### ALKALEE

Alkalee was founded to develop a new generation of automotive electrical and electronic (E/E) architectures for tomorrow's smart, connected, autonomous vehicles. The company was established to develop and commercialize the results of a joint innovation project between the CEA and carmaker Renault. Specifically, Alkalee is leveraging innovative formal methods to translate all of a car's systems into equations. Alkalee's solution combines modelling and embedded software to ensure the safe integration of new services into a central computer at any stage in the vehicle development lifecycle.

### KENTYOU

Kentyou was founded in April 2020 to bring to the market seven years of R&D in CEA List labs. The company offers digital twin solutions built on open source technologies. Users can collect, integrate, and analyze data generated by connected devices, open data platforms, and users (via apps) in urban environments to create innovative services. The company is marketing its solution to medium-sized municipalities, which are generally more agile and better able to roll out innovative services for their citizens. The solution has been already implemented and tested in a dozen cities in Europe and Asia.



### 25 STARTUPS FOUNDED BETWEEN 2003 AND 2020

- **FACTORY OF THE FUTURE:** Arcure (smart embedded vision for pedestrian detection), Bag-Era (connected heterogeneous systems management), Bespoon (indoor location accurate to within a centimeter for Factory 4.0), Creaform (formerly Acti-CM; engineering and 3D measurement technologies for industry), Diota (augmented reality for industry), Extende (non-destructive testing simulation), Haption (commercial-grade force feedback systems), Isybot (collaborative robotics), M2M (an Eddyfi Technologies brand, ultrasonic non-destructive testing equipment), RB3D (cobots and exoskeletons for industry), Tridimeo (multispectral and ultra-fast 3D industrial vision), Win MS (reflectometry-based cable network diagnostics).
- **AGRI-FOOD:** Connecting Food (blockchain-based food traceability platform).
- **DIGITAL:** Antinno (electronic document and knowledge management), Invensense (formerly Movea, value-added detection solutions, connected objects, drones, etc.), HRV (virtual reality for healthcare training and workplace ergonomics), Kalray (programmable manycore processors), Light & Shadows (custom virtual and augmented reality solutions), WiseBIM (automated generation of Building Information Model files).
- **MOBILITY:** Krono-Safe (OS for real-time critical embedded systems).
- **SPORTS AND LEISURE:** Sport Quantum (interactive and connected electronic shooting targets).
- **CYBERSECURITY:** Trustinsoft (source code analysis for enhanced cybersecurity).



# Mobility

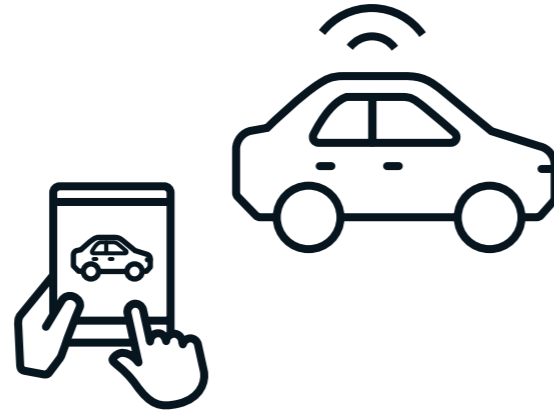
Digital twins of railway signaling systems, structural health monitoring of rail materials, and vehicle platooning are just a few examples of the kinds of smart systems that will enable and enhance tomorrow's mobility.

SacHeMs



## SACHEMS TO PROMOTE SHM RESEARCH AND INNOVATION

The SACHEMS structural health monitoring (SHM) research and innovation platform was set up in 2020 to support national efforts to bolster the SHM industry. CEA-List is coordinating this consortium composed of academic partners developing SHM technologies and industrial users. The equipment are available for use by all partners at CEA Digiteo Saclay.



## OPTIMIZED COMMUNICATION SYSTEM FOR PLATOONING AUTONOMOUS VEHICLES

Platooning is a method for moving autonomous vehicles by coupling and conveying them behind a human-operated vehicle. Information must be exchanged constantly, not only between vehicles so that each vehicle can replicate the movements of the vehicle in front of it, but also between vehicles and urban signaling networks.

CEA-List developed an optimized communication system for this kind of scenario for the European H2020 AUTOPILOT project. The system is built on a multi-interface architecture, software, and a communication system.

And, because the system does not depend on cameras or radar, the location information calculated from GPS positions is exchanged via IP, bringing the distance between vehicles down to about 2.5 meters, a clear advantage over current solutions. The new concept performed well in a test rollout in Versailles, France, highlighting the relevance and efficiency of the solution.

## MODELING AND VALIDATION FOR TOMORROW'S RAIL SIGNALING SYSTEMS

CEA-List researchers made notable progress toward digitalizing railway systems. Together with their partner Systemel, they won a contract with French national rail infrastructure provider SNCF Réseau to develop the modeling module of its AMS Computer-Based Interlocking (CBI) systems software design suite. The partners delivered the module in 2020, giving SNCF Réseau its first-ever software design tool for the specification and formal validation of tomorrow's CBI control stations. "The module will allow SNCF Réseau to formally describe the logic for operating a control

station, set the parameters for the station, and instantiate it," said CEA-List scientist Jérémie Tatibouët. The project is already advancing into its next phases, which aim to develop a module for formal verification of safety properties, simulation of operating scenarios and track plan design. "This new phase in the project will allow SNCF Réseau to use powerful animation and formal verification tools to exhaustively and cost-effectively check that our CBI control stations meet the highest safety standards," said Systemel CEO François Bustany.



THE AMS SOFTWARE SUITE MARKS A STEP FORWARD IN SNCF RÉSEAU'S STRATEGY OF COOPERATION WITH MAJOR STAKEHOLDERS IN RESEARCH AND INDUSTRY AROUND INNOVATIONS IN ENGINEERING. WE ARE FOCUSING ON THE SAFETY AND PERFORMANCE OF RAIL SYSTEMS.

Thibault Lemaire, AMS project manager, SNCF Réseau

## WIRELESS SHM SYSTEM FOR RAILWAY MONITORING COULD SOON BE SCALED UP BY ALSTOM

In 2019, CEA-List and Alstom developed an innovative guided-elastic-wave structural health monitoring (SHM) system to pinpoint defects in rails. A prototype was rolled out at a railway testing center in Bar-Le-Duc, France and a test implementation in which sensors were installed at one-kilometer intervals to detect breaks in the rails was validated. Alstom was won over by the solution and began work scaling it up in 2020. CEA-List scientist Bastien Chapuis said, "We spent a good part of the year transferring the technology. We transferred our knowledge of the system and of how it behaves during operation so that Alstom can manufacture and, ultimately, commercialize it." CEA-List is making further improvements, like integrating the detection of tiny defects indicative of incipient breakage. These kinds of advances are paving the way toward predictive rail maintenance.



WORKING CLOSELY WITH CEA-LIST HAS HELPED US GET TO A POINT WHERE WE ARE LOOKING AT THE COMMERCIAL ROLLOUT OF THE SHM SOLUTION ON OPERATING LINES. AND THIS KIND OF EARLY-STAGE BREAKAGE DETECTION IS SOMETHING OUR CUSTOMERS HAVE BEEN ASKING US FOR.

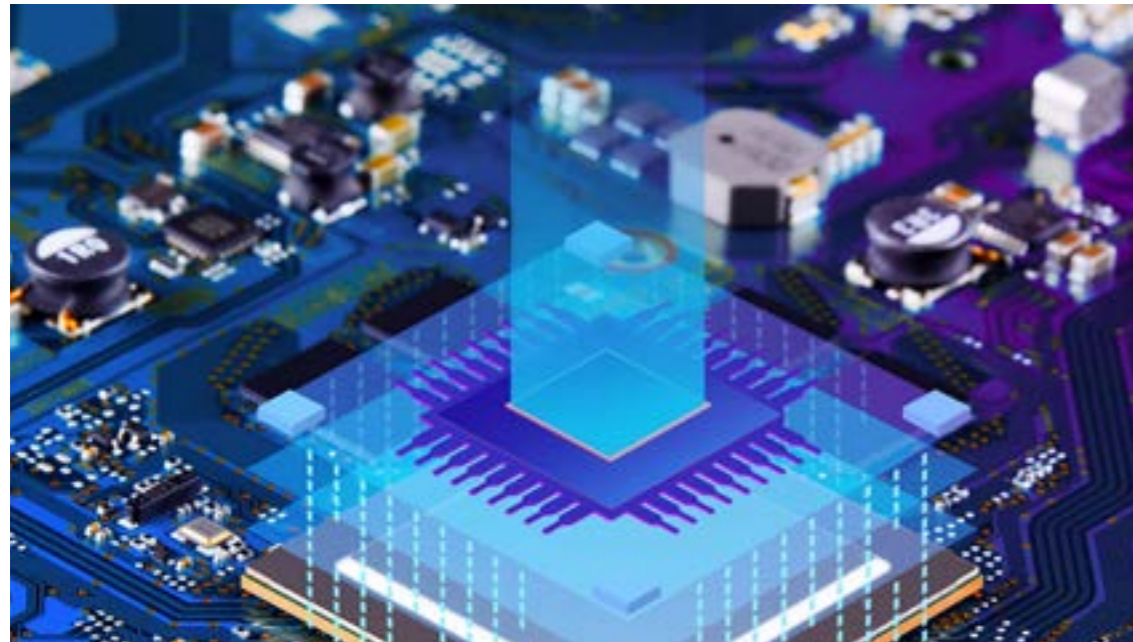
Maxime Darbois, Head of Innovation, Alstom Infrastructure

## EMBEDDED REFLECTOMETRY DETECTS WEAK-SIGNATURE FAULTS

Electrical cables are used for data transmission and electrical distribution in the automotive, aeronautics, rail, and many other industries. The capacity to pick up increasingly hard-to-detect faults on cable networks is vital to the safety and reliability of these industries' potentially-critical systems. CEA-List partnered with high-performance connector manufacturer Nicomatic in 2020 to tackle this problem. They developed a new technology to compensate for a phenomenon called self-blinding that is inherent to embedded reflectometry and that negatively impacts the devices' ability to pick up very-weak-signature faults. The technology, now patented, was integrated into the new Ariane V3 reflectometry circuit.

# Digital

CEA-List is utilizing its digital technology know-how to develop a number of key enabling technologies. Read on to learn more about our latest advances in AI. Our solutions for the formal validation of neural networks, voice dictation of reports, image annotation, and high-performance, low-cost, energy-efficient architectures for embedded AI can all be adapted to meet the unique needs of companies.



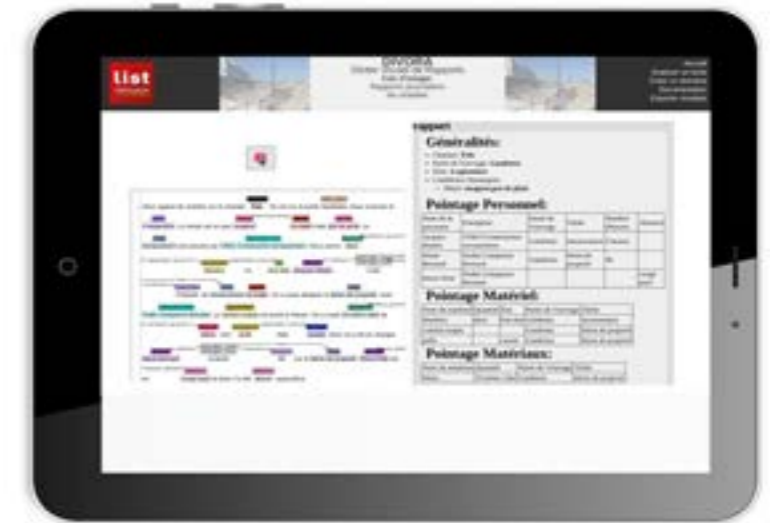
## HPC: SESAM TO SPEED UP DEVELOPMENT OF EPI PROCESSOR

The H2020 EPI (European Processor Initiative) project was established to secure Europe's independence in the field of high-performance computing. CEA, a major stakeholder in the project, is developing the SESAM/VPSim simulator, which the project partners will use to perform verification testing, explore architectures, and develop software for the future European HPC processor. CEA-List will focus in particular on accelerating EPI virtual prototype architecture simulation without compromising accuracy. The scientists' patented solution makes it possible to utilize fast processor emulators

(QEMU in this case) to their full potential. Specifically, the solution enables instrumentation of memory accesses for asynchronous and parallel evaluations of their impact on the performance of the system being modeled. The simulator performed 154% better than a sequential solution in terms of millions of instructions per second (MIPS). Parallelizing the processor models is expected to further improve performance. This advance will speed up architecture exploration and decision making, for a positive impact on the quality of the architecture of tomorrow's European processor.



**A STRONG START FOR FACTORY-AI COMPUTER**  
AT END-2020 A TOTAL OF 110 USERS HAD SET UP ACCOUNTS ON THE FACTORY-AI ARTIFICIAL INTELLIGENCE COMPUTER, INITIATING MORE THAN 73,000 JOBS AND UTILIZING 130 TB OF DISK SPACE. THE FACTORY-AI COMPUTER'S CAPACITY WILL BE EXPANDED FURTHER IN 2021.



## AUTOMATED VOICE-DICTATION REPORT-GENERATING SYSTEM PROTOTYPED

Written reports are one of the main ways that organizations capture and pass on knowledge. But to be effective, an organization's knowledge management system needs complete, clearly-written reports that can be generated in a reasonable amount of time. In research conducted for the Divora project at FactoryLab, CEA-List leveraged its semantic analysis and speech understanding know-how to simplify and speed up the process of organizing and writing business reports. Users can capture information on site to include in their reports, reducing the loss of information. Divora automatically generates a written formal report. The prototype was implemented on two use cases: forklift inspection reports for standards organization Bureau Veritas and work site status reports for Vinci Construction.



## PIXANO OPEN-SOURCE IMAGE AND VIDEO ANNOTATION SOFTWARE

For artificial intelligence to be integrated into machine vision systems, a large amount of information – annotated images – has to be learned. The difficulty is that the quality of the annotations tends to vary significantly from one image to another. CEA-List recently released PIXANO, an open source web-based software

solution that delivers automated, precision image and video annotation. The level of automation provided by PIXANO makes training and evaluating algorithms much easier. PIXANO brings the speed of machine learning together with human validation. It is available to the academic and industrial AI communities.

### INITIAL MEASUREMENTS COMPLETED ON IMPACT CIRCUIT

The energy-hungriest part of today's high-performance computing systems is the data transfer between memory and processor. It is also the primary hurdle to achieving the level of performance that would be required to effectively address embedded AI (AIoT) applications. To overcome this challenge, CEA developed and tested a dedicated in-memory C-SRAM (Computational SRAM). The results were published in IEEE Solid-State Circuit Letters. Worth noting: The researchers obtained computational energy efficiency per unit area up to 35.6 TOPS/W/mm<sup>2</sup> on 8-bit operations. That is 2.3 times better than the state of the art.

### NEW JOINT LAB BETWEEN CEA-LIST AND DOLPHIN DESIGN

CEA-List and Dolphin Design, which develops modular, energy-efficient hardware IP and systems-on-chip, formed a joint lab in 2020. The goal is to bring a flexible new computing platform to embedded electronics markets. CEA-List's PNeuro<sup>®</sup> hardware accelerator SESAM and N2D2 simulation and code-generation environments will support embedded AI. CEA-List scientist Benoit Tain said, "The first year of the joint lab was devoted mainly to programming." In 2021 the partners plan to build a demonstrator circuit and a software generation stream that Dolphin Design customers will be able to use to develop energy- and resource-efficient applications.



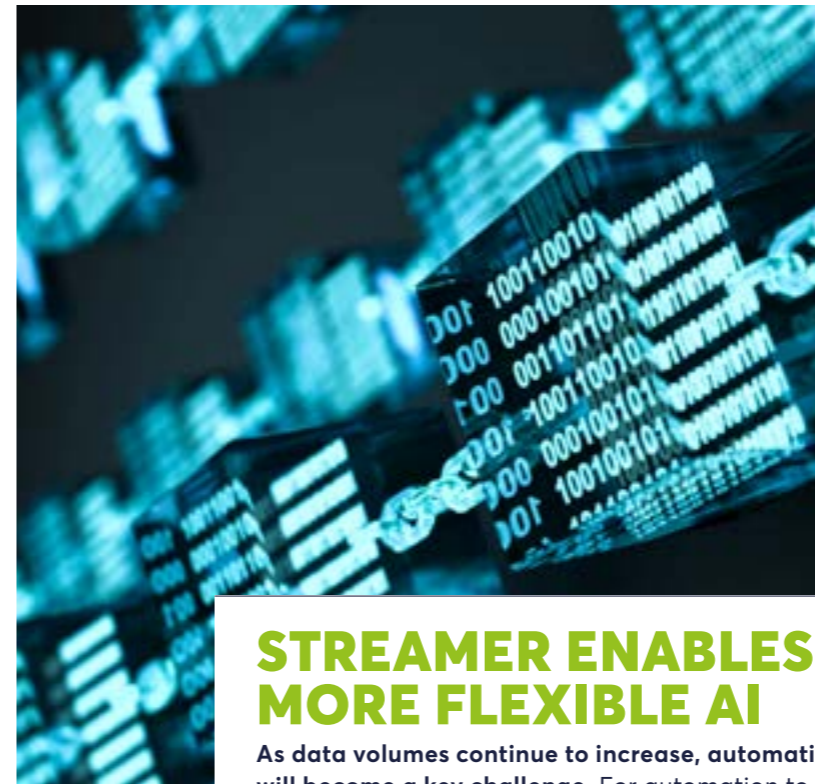
### PROGRESS TOWARD THE FORMAL VALIDATION OF NEURAL NETWORKS

The validation of neural networks is a major global challenge in the development of trust in smart digital systems. CEA-List scientists are bringing their knowledge of formal methods and critical software analysis to this timely issue. They are focusing on two main topics that have to do with image recognition. The first looks at how to obtain formal specifications for the objects to be recognized and the properties to be proven; the second investigates how to demonstrate that neural networks are operationally safe and robust. Their research led to a novel idea: to use image generators that train the neural networks as specifications. The results were published jointly with Inria in the proceedings of ECAI 2020, a major artificial intelligence conference. CEA-List scientists also ran a joint R&D project on this topic with Technip Energies in 2020. "The company utilizes neural networks to detect disorders on oil platform anchor lines," said CEA-List scientist Zakaria Chihani. "This latest innovation by CEA-List enabled Technip Energies to formally validate the decisions made by their neural networks".



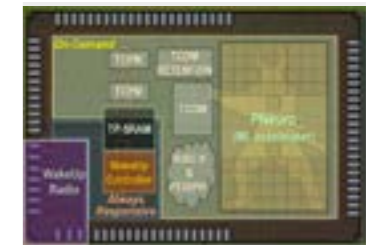
WE ARE THRILLED WITH THE WORK WE HAVE DONE WITH CEA-LIST TO DEVELOP NEURAL NETWORKS TO DETECT MOORING LINE FAILURES ON FLOATING OFFSHORE PLATFORMS. THE CEA'S KNOW-HOW AND VALIDATION TESTING CAPABILITIES HELPED US CONFIRM THAT OUR MODELS ARE HEADING IN THE RIGHT DIRECTION AND THAT THEY WILL BE UP TO THE TASK WE HAVE SET FOR OURSELVES.

DJONI SIDARTA, Chief Technologist, Technip Energies



### STREAMER ENABLES MORE FLEXIBLE AI

As data volumes continue to increase, automating AI will become a key challenge. For automation to happen, however, machine learning algorithms will have to be scalable and flexible. CEA-List scientists are developing a design and evaluation environment called Streamer to address these issues. This open-source environment is compatible with Linux, Windows, and Mac OS and can be used to integrate algorithms in any programming language (Python, R, Java, etc.). Streamer, which occupies a unique space at the frontier between academic research and industrial R&D, allows users to fine-tune their algorithms. It is powerful, robust, and easy-to-use. It will enable several new cybersecurity and trusted AI projects in 2021. CEA-List continues to develop Streamer in research conducted in partnership with the University of Versailles-Saint-Quentin-en-Yvelines and Foch Medical Center as part of the StreamOPS project supported by the DATAIA Institute. The next new features slated for release very soon include an algorithm supervisor to monitor learning and updates.

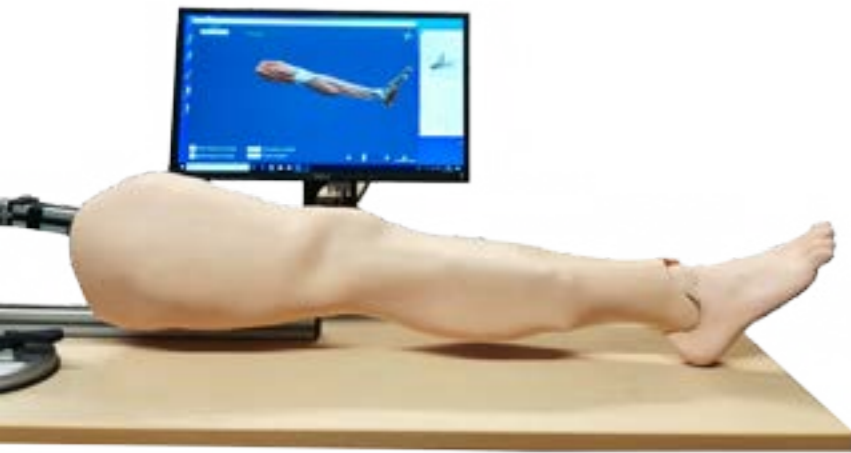


### AI OF THINGS: PROOF-OF-CONCEPT PROTOTYPE SHOWCASED AT VLSI 2020

In a world first, CEA-List scientists presented their breakthrough SamurAI circuit at the VLSI (Very Large Scale Integration Technology and Circuits) International Symposium in June 2020. The circuit combines a low-power node for IoT applications, a very-low-power artificial intelligence accelerator, and an ultra-fast wake-up receiver. This circuit could help integrate data acquisition and processing more tightly, for lower energy consumption and latency and enhanced data protection.

# Health, wellness, and sports

One of the CEA's missions is to support the transition to the medicine of the future. We are developing applications for our key enabling technologies in healthcare, wellness, and sports and leisure.



## SURGICAL TRAINING TOOLS DELIVERED TO AMIENS-PICARDIE UNIVERSITY MEDICAL CENTER

To ensure high-quality surgical training, medical students must be able to actually feel how much force they are applying during a surgical procedure. Haptic (from the Greek haptain, or touch) feedback systems can provide realistic sensations and help medical students learn how much force to apply. CEA-List worked with Anatoscope (a digital anatomical solutions provider) and Institut Faire Faces (a head and neck surgery research center) to develop two interactive training tools, which were delivered to the Amiens-Picardie University Medical Center in 2020. The first consists of a knee prototype that provides a realistic experience of examining a patient with a ruptured cruciate ligament. A magneto-rheological fluid-based "brake" realistically simulates joint laxity. Trainees can see the knee from different angles and at different scales (skin, muscle, bone) via a display interface. The second system is a mandibular joint. CEA-List scientist Sylvain Bouchigny said, "It simulates a dislocation reduction." This complex procedure is difficult for inexperienced practitioners to perform. "This training tool will give interns the experience they need to respond rapidly and with precision." The two tools are currently being evaluated by surgeons at the Amiens-Picardie and Pitié-Salpêtrière University Hospitals to prepare for their future use by medical students.



## SIMULATING INDUCED RADIOACTIVITY IN MEDICAL ACCELERATORS

Many of the medical accelerators used in cancer treatment facilities are nearing the ends of their lifespans. This is creating a need to ascertain which parts of these machines have become radioactive and, if so, to what extent. ANDRA, the French government agency that oversees the management of radioactive waste, turned to CEA-List to conduct "a comprehensive and precise Monte Carlo simulation of an accelerator in operation," said CEA-List scientist Valentin Blideanu. The simulation was used to characterize the different components' induced radioactivity, providing valuable information for the treatment of waste from the dismantling of medical accelerators at the end of their useful life.



## PARIS 2024: PERFORMANCE-BOOSTING TECHNOLOGY FOR CHAMPIONS

As the 2024 Paris Olympic and Paralympic Games draw near, the French government has issued two calls for proposals for very-high-performance athletics projects. The goal is to facilitate the emergence of innovative technologies to improve the performance of French athletes. CEA-List is engaged in three of the projects selected. Patrick Sayd, who heads the AI for Vision program at CEA-List, said, "We are using our AI expertise to enhance video analysis on these projects." The first project, Fulgur, aims to develop a technology to capture sprinters' movements during competition. Individualized modeling is used to improve the athlete's technique for greater efficiency and reduced risk of injury. The second project, Team Sports, focuses on analyzing players' behavior during team sports to help coaches improve group dynamics. Finally, the Best-Tennis project is bringing automated video analysis to French tennis players, so that they can assess their opponents' games, particularly in the serve-and-return phase, and gain a strategic advantage.



## ECHOBRAIN MAKES ADVANCES TOWARD TRANSCRANIAL ULTRASOUND

CEA-List adapted technologies it originally developed for non-destructive testing (NDT) for transcranial imaging for the EU EchoBrain project, in partnership with BIOMAPS, a fellow CEA institute CEA-Joliot. Distortion of the ultrasonic beam due to the crossing of the skull wall is detrimental to the quality of the brain images that can be obtained using this technique. Here, the idea is to correct for these aberrations. Initial *ex vivo* testing on a human skull determined that the technique is feasible. In the tests, images of artificial targets placed behind the skull were significantly improved.



## CLEAR PROJECT RESULTS IN TWO NEW EMERGENCY VENTILATOR SYSTEMS FOR COVID-19 PATIENTS

CEA-List set up the CLEAR (CEA-List Emergency Assistance for Respiration) project in March 2020 in response to the Covid-19 crisis. This project resulted in the design of two emergency ventilator systems. The first, CLEAR-M, is a monitoring solution that makes existing emergency ventilators compatible with Covid-19 patient care. BA-Healthcare is scaling up the technology for manufacturing. The second, CLEAR-R, is a low-cost, high-performance robotic emergency ventilator. The CEA-List design and complete specifications are available to manufacturers to use to meet the needs of countries facing ventilator shortages.

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