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2021

CEA-LIST
ACTIVITY REPORT

CONTENTS

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CEA-LIST IN 2021

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DIRECTOR'S FOREWORD

ALEXANDRE BOUNOUH

DIRECTOR, CEA-LIST

After a year marked by an economic recovery that was nothing short of spectacular, this latest edition of the CEA-List Activity Report is particularly rich. Inside you will find the highlights that made 2021 a noteworthy one. At a time when virtually all industries were bouncing back from a challenging first year of the pandemic, our researchers continued to break new ground. Over the course of the year, we seized opportunities to start new pump-priming research projects and create new research and innovation platforms, putting us in a strong position to reach the milestones in our strategic development plan.

And, as the French government began to roll out massive support to build back the economy, our people were there, ready to support the research and innovation activities needed to modernize the nation's industrial sector. The financing instruments created by the government included several calls for research and innovation projects, and everyone at CEA-List rallied to help us submit a huge number of proposals. We did much more than apply for funding, however. Our experts helped shape the research roadmaps that underpin the innovation-driven economic recovery platform, and, as always, worked to keep our programs aligned with national strategy.

Our position on the front lines of the nation's efforts to modernize and revitalize its industrial economy resulted in a wide range of new projects with partner labs and companies addressing our flagship research themes. The year also saw some major new projects, like OTPaaS (one-time password as a service) targeting Edge and Cloud applications, the INCCA digital and robotized aeronautics control project, the NeVeOS project to develop centralized automotive computing architectures, the JENII project for interactive, immersive twins for education and training, and the Udd@Orano project on the digital transformation of nuclear plants.

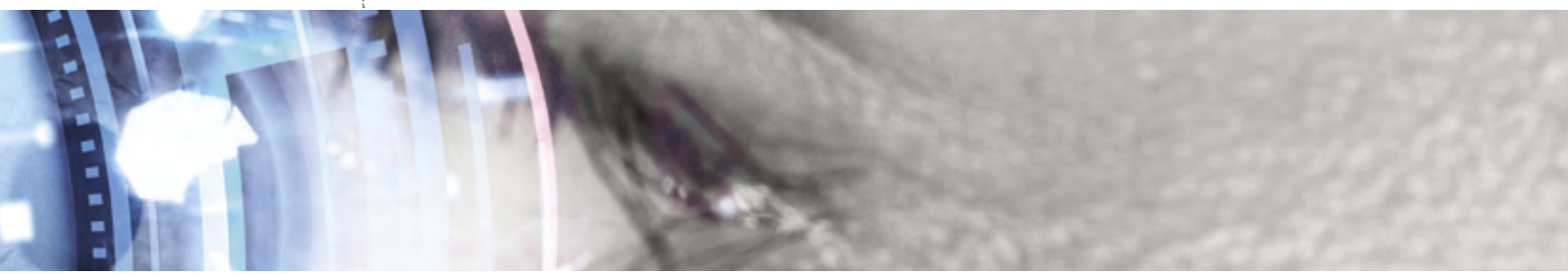
The proposed PRISM Lab2Fab platform will speed up the development of innovative Industry 4.0 solutions for France's industrial sector. The platform will position us to help businesses develop innovative products and solutions based on our portfolio of digital technologies at the international state of the art. Companies in France of all types and sizes from startup to corporate will be able to access not only a range of technologies that can be easily adapted, but also the R&D infrastructure needed to transform their ideas into marketable products and solutions to modernize France's industrial economy.

Pump-priming research is also a pillar of the national strategy. The government has tasked the CEA and other major research institutes (INRIA, CNRS, IMT) with putting together joint research programs on early-stage technologies—a fantastic opportunity to drive advances with some of the best researchers in France in fields like quantum, cybersecurity, cloud computing, 5G, robotics, digital health, and AI.

Europe remained fully present with the Horizon Europe and Digital Europe programs. We submitted a significant number of proposals and, with a 32% acceptance rate, were very successful in 2021. As evidenced by our excellent performance securing EU funding, our research teams have now stepped fully into their role as experts in the European technology landscape, contributing actively to the EU's efforts to coordinate research on AI and robotics.

So, 2021 was an exceptional year for CEA-List in more than one way. We saw some major projects begin and others take flight as we continued to bring our partners the level of scientific excellence that has earned us their trust. We are looking forward to contributing some of our most advanced research to three CEA moonshot demonstrator projects, one on green blockchain, one on a self-learning robot, and one on a multi-mode environmental monitoring platform. These demonstrators will showcase the powerful digital technologies coming out of our labs over the next few years.

CEA-LIST KEY FIGURES



THE YEAR 2021

TALENTS

1,000
EMPLOYEES

128
PhD CANDIDATES

PROJECTS & PARTNERSHIPS

500
R&D PROJECTS WITH INDUSTRIAL PARTNERS PER YEAR

100
EUROPEAN PROJECTS

200+
R&D PARTNERS FROM INDUSTRY

9
TECHNOLOGY PLATFORMS

21
SOFTWARE DEVELOPMENT ENVIRONMENTS

TECHNOLOGY TRANSFER

300
A-RANKED PUBLICATIONS

708
PATENTS (84 NEW IN 2021)

162
LICENSING AGREEMENTS

28
STARTUPS CREATED SINCE 2003

€100M+
ANNUAL BUDGET

78%
FROM EXTERNAL SOURCES

€30M+
IN DIRECT R&D CONTRACTS WITH INDUSTRIAL COMPANIES

CEA-LIST IN BRIEF

RESEARCH IN SERVICE TO SOCIETY

CEA-List, part of the CEA's technology research division, specializes in smart digital systems. We pursue our mission of helping businesses stay competitive through innovation and technology transfer in three major areas: the factory of the future, artificial intelligence, and digital trust. Our facilities are located in Saclay and Grenoble, France, two international-caliber innovation ecosystems.

Our approach—eco-innovation—embodies our core value of putting people, the environment, and society first. From the very first stages of any project at CEA-List, our people assess not only the technology being developed, but the project itself. They make decisions about the project organization, choose suppliers, and work remotely when they can to limit impacts. They also invent new solutions that align with circular economy and eco-design principles. We have made a choice to lead individuals and organizations toward more frugal, less resource-intensive behaviors by example. Our decisions about what we do, make, and use every day reflect this vision.

We break new scientific ground and support a more vibrant economy. We also help people live and work better through advances in personal data protection, energy efficiency, the circular economy, healthcare, and more efficient and carbon-free mobility. We also engage with sports—with research on athletic performance—, the arts, and culture.

In terms of personal data protection, we developed an open-source mobile application called YDSYO (Your Data Stay Yours), which will soon be available for public download. The app leverages photos—on the user's phone and posted on social media—to calculate the level of risk.

Some of our research even makes its way into the arts through the CEA's Atelier Arts Sciences arts and sciences residency program. The WAWY project, for example, gave performance artists access to our haptic (touch) technologies, which they integrated into virtual worlds to create new sensory experiences. This novel use of a technology we originally developed for industrial simulation is one that resonates particularly strongly with us. It proves what we already believe—that technology isn't just for business, it is for all of society.

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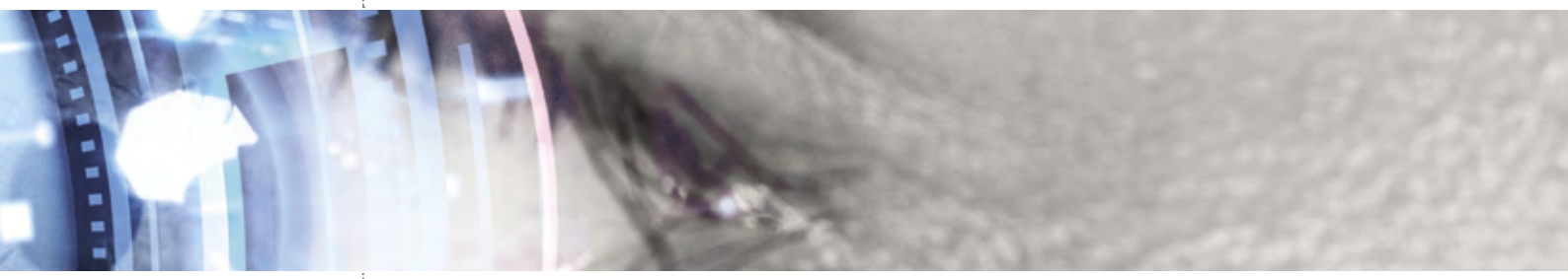
CEA-LIST IN BRIEF



DIGITAL FOR HEALTH

It's clear that personalized treatment is a major trend shaping the medicine of tomorrow. The use of simulation, modeling, and AI in medical robots, diagnostic assistance, hospital management assistance, and other healthcare solutions will only continue to grow.

At CEA-List, we are bringing our long track record in both software and ionizing radiation metrology—the measurement of doses received by patients during diagnostic and therapeutic procedures—to support the emergence of new treatment and care paradigms. In radiation therapy, where treatment can damage healthy tissue, it's crucial to reduce out-of-field radiation as much as possible. Our simulation tools are helping do just that. We are also developing new software to personalize the dose of radiation received by the patient during medical imaging and interventional radiology procedures while improving image quality.

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Some of our innovations come from research that directly targets applications in health and medicine. Others were originally developed for other industries. Non-destructive testing techniques developed for the inspection of manufactured parts are now making inroads into therapeutics. One example is high-intensity focused ultrasound (HIFU), used in treating cancers.

Our research on passive acoustic imaging of cavitation through the human skull also represents a real hope of better treating central nervous system disorders. Drugs are ineffective because their active ingredients cannot cross the blood-brain barrier. However, this barrier can be made permeable by utilizing ultrasound and injecting microbubbles of gas, allowing these active ingredients to reach the brain. In terms of clinical application, the method—reversible, non-invasive, non-ionizing, and reproducible—is very promising.

Another aspect of our research for health is decision assistance. We are developing a tool called PQAi to help personalize the delivery of new radiotherapy treatments. These new approaches to radiotherapy are long to prepare and must meet high quality assurance requirements. Doses must be verified systematically for each treatment plan. The ability to assess the complexity of the treatment plan using metrics allows clinicians to determine whether or not systematic quality controls are necessary. We developed a statistical learning algorithm trained on the results of treatment plans that had undergone systematic quality controls to provide preliminary complexity assessments. A license agreement was signed in October of 2021 with radiation therapy consulting firm RT3C, which will deploy the tool in the radiation therapy centers it operates.

CEA-LIST AND ITS ECOSYSTEM

FROM RESEARCH TO INDUSTRY

Tech transfer and innovation are our mission. Our tech transfer activities are supported by an ecosystem that spans academic research and industrial R&D, both in France and internationally. We also interact closely with our scientific environment—the key to maintaining the level of excellence required to support our innovation activities. These activities ensure that the technologies we develop make a positive impact on the industrial economy and society.

R&D PARTNERSHIPS

The majority of our operating budget comes from our R&D partnerships, whether that's contract R&D services sold to companies or through government funded R&D projects at the national and EU levels, often involving a wide range of partner companies, from startups and small businesses to corporations. Over the years, we have developed a keen understanding of business' R&D issues. This positions us to bridge the gap between research and industry and set up particularly relevant project consortia when applying for government research funds.

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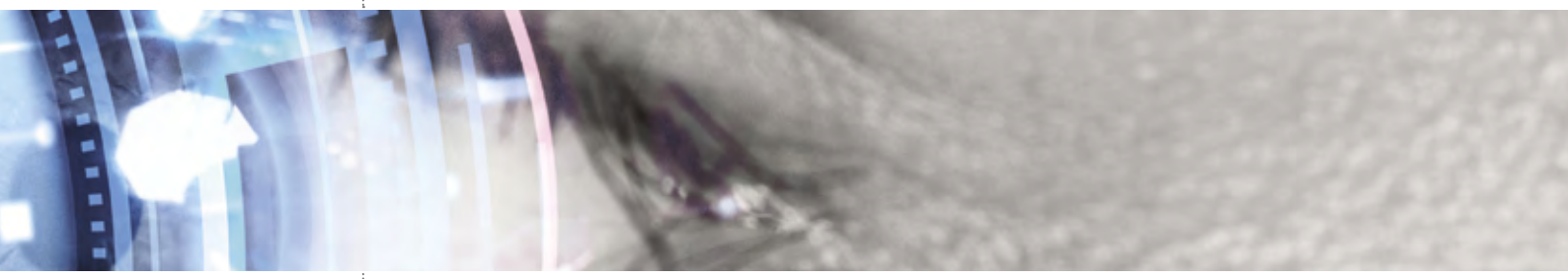
OUR ECOSYSTEM IN FRANCE

We are deeply involved in the French government's research and innovation strategy, contributing actively to national pump-priming research, AI, Industry 4.0, and cybersecurity initiatives. We bring the strength of our two international-caliber multidisciplinary campuses in the innovation hubs of Paris-Saclay and Grenoble, home to nearly 25% of all research jobs in France, to all of our projects.

And, with communities and innovation platforms like FactoryLab (for Industry 4.0), we break down the barriers between academic research and businesses. FactoryLab is a shared resource designed to meet the needs of a variety of industries. It is where CEA-List, technology users (corporations), and technology providers (startups and small businesses), come together to produce demonstrators with a very short implementation time horizon (under a year). Our strong partnerships with businesses helped us obtain France's Carnot seal in 2006 and have it renewed four times since. Carnot is a network of research institutes recognized for their quality research partnerships with companies. Membership unlocks access to funding for several kinds of projects, including pump-priming research to overcome major technological hurdles to the development of disruptive technologies and industry-specific projects like Carnauto, for example. **"Carnauto financed an electric vehicle, which we are using to develop and test embedded systems,"** said CEA-List research engineer Etienne Hamelin.

CEA-LIST AND ITS ECOSYSTEM



OUR ROLE IN EUROPEAN RESEARCH

We are deeply involved in the European artificial intelligence and cybersecurity research spaces. We take a "responsible AI" approach to supporting European technological and industrial autonomy and sovereignty. At any given time we are engaged in or coordinate more than 100 European projects, with around 30 new ones each year. These projects provide us with an opportunity to bring new technologies to a sufficient level of maturity to be implemented in industrial or other use cases of benefit to society. These are some of the major EU projects we are working on.

• SPARTA

The SPARTA network, funded through the EU H2020 framework program, unites 44 partners from 14 EU member states around European cybersecurity research. SPARTA has reshaped cybersecurity research in Europe. As coordinator, CEA-List is helping develop long-term EU policies to combat cybercrime, with solutions that include education and training. The project is organized around four pillars: the supervision of complex systems on heterogeneous time scales (T-SHARK), secure intelligent infrastructure by design using formal methods (HAII-T), new evaluation solutions for the management of tomorrow's digital systems (CAPE), and new approaches for more reliable and resilient artificial intelligence-based systems (SAFAIR).

• STARLIGHT

The purpose of the STARLIGHT (Sustainable Autonomy and Resilience for LEAs using AI against High priority Threats) project, which kicked off at the end of 2021, is to develop artificial intelligence systems for law enforcement to support European sovereignty and strategic autonomy. The four-year project has a total budget of €18.8 million, including €17 million from the European Union. The CEA is coordinator of this project with its 52 partners (15 from law enforcement) from 18 European countries. They will develop a long-term multidisciplinary community to deliver reliable and interoperable AI-based law enforcement solutions capable of addressing high-priority threats and that align with the EU's ethical and societal values.

• EPI

The H2020 EPI (European Processor Initiative) project was established to secure Europe's independence in the field of high-performance computing. CEA-List is one of the 27 partners on this European Commission funded project to design a European supercomputer infrastructure. The first phase of the project, which ran from 2019 to 2021, has already delivered significant results.

- Application/architecture co-design methodology
- Architecture for the first-generation European Rhea processor

The CEA developed and integrated the variable-precision (VRP) accelerator tile during this phase.

It also contributed to the formal analysis of timing based on the instruction set architecture of a processor, essential for operational safety. This technology will be transferred to the automotive industry.

EUROPEAN COMMUNITIES

CEA-List represents the CEA on several European organizations, including BDVA (big data), EU Robotics, EFFRA factory of the future, Artemis (embedded systems), and ECSO (cybersecurity). We belong to the European Institute of Innovation and Technology (EIT) Digital, Food, and Manufacturing communities. And we are involved in several Digital Innovation Hubs (DIH) and in the AI-DIH network of European DIHs in artificial intelligence. Most notably, we are leading the DigiHall-EDIH project, backed by the Île-de-France region, to help companies speed up digital transformation.

"This is about developing an ecosystem of technology providers capable of stepping into a major role in the industrial value chain," said CEA-List Director **Alexandre Bounouh**.

CEA-LIST'S THREE R&D THEMES

OUR RESEARCH AREAS

As a research and technology organization, our role is to respond to the needs of companies and, more broadly, society. The challenges we address mirror our increasingly digital economy—and world.

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ARTIFICIAL INTELLIGENCE

Fueled by growing computing capabilities, artificial intelligence (AI) is making inroads into all facets of society, from people's daily lives to factories. Our AI research focuses on trusted and embedded AI and, above all, how to make AI more frugal and, therefore, sustainable.

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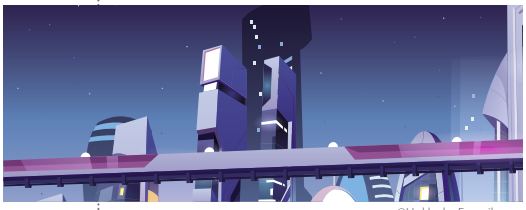
DIGITAL TRUST

As our dependence on digital technology grows, we must ensure that it is safe and robust. We are bringing a unique vision to digital for health, banking, industry, and other sensitive sectors of the economy and society—one that focuses not only on technology but on standards, too.



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FACTORY OF THE FUTURE

The factory of the future is about more than just manufacturing. It also encompasses the supply chain and, more broadly, entire systems like cities. Industry 4.0 is becoming more and more tangible, with increasingly connected, agile, automated, and frugal factories. In the near term, the factory of the future will also be a critical component of the circular economy. With human operators and their working conditions as our guide, we are helping make industry more efficient with smart companion and autonomous robots, digitalization, simulation, and data collection and processing.

ARTIFICIAL INTELLIGENCE

ENABLING DISRUPTIVE INNOVATION IN VIRTUALLY ALL AREAS OF OUR LIVES

Artificial intelligence is rapidly making inroads into the economy and society at large—promising deep transformation across both. In its February 2020 white paper on AI, the European Commission pointed out that "[AI] entails a number of potential risks…" that will need to be addressed for the technology to be widely adopted.

PROMISE VS. PRACTICAL APPLICATIONS

Given the extremely broad scope of potential uses for AI, it comes as no surprise people are talking about all the amazing things the technology can do. But the reality is far more nuanced. AI can analyze vast quantities of data, model physical phenomena, and solve complex problems. It can even mimic human intelligence using mathematical models of human cognitive processes.

At CEA-List, we are a driving force in the development of AI—but in a way that reflects French and European ethical values around technology. We are developing responsible AI-powered hardware and software solutions. That means AI that is trusted, explainable, and frugal, whether it's in terms of data, computing resources, or power consumption.

TRUSTED AI

Safety is front and center in our AI research. **"For an on-board aircraft collision detector, you have to be able to verify that the system's response is reliable for a given configuration,"** said **Zakaria Chihani**, who manages trusted AI projects at CEA-List. **"We developed PyRAT, a tool that analyzes the robustness and safety of neural networks, to do just that."** The processes at work in large neural networks—complex by definition—can be opaque. It is hard to establish a detailed description of what elements a decision was based on and how it was arrived at. Aircraft collision detection is a particularly salient example. Medical diagnostics is another.

EMBEDDED AI

Embedded, or "Edge," AI is what will ultimately place the power of AI in business' hands. AI solutions will be integrated into devices at the network edge, and the data they generate will no longer need to be sent to the cloud for processing—great news for security and privacy. **"Optimized neural networks are crucial to the success of embedded AI, and our N2D2 engineering environment is designed with this in mind,"** said **Olivier Bichler**, head of our embedded AI laboratory. **"We also design chips specifically for data-intensive calculations."** Mobility is a particularly exciting testing ground. We are using sensor data fusion algorithms and AI to deliver driver assistance and environmental perception and analysis capabilities. Imagine cars that can read signs, monitor their own speed, and keep an eye on the traffic to help drivers make better decisions.

FRUGALITY

Technology is at the forefront of the major societal and environmental challenges of today—and AI is no exception. We are responding to legitimate concerns about AI's impacts by making frugality a priority across the AI lifecycle, from design and manufacturing through to implementation in embedded scenarios. The goal is to build AIs that need less data, computing resources, and power. We are doing this through innovations in data management, learning, and hardware and software implementation.

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GNSS-FREE
NAVIGATION USING ENVIRONMENT MODELING TECHNIQUES

Modern navigation systems rely on the use of high-quality 3D maps in conjunction with GNSS information and are often delivered in the form of mobile applications. However, successful military operations —and the safety of personnel on the ground— will depend on more reliable and secure navigation systems that do not require external equipment.

CEA-List worked with Nexter Systems to develop a novel system that consists of a headset equipped with four cameras and an inertial measurement unit (IMU), used alongside a portable computer carried in a backpack. Wearers are localized in real time in relation to an initial point of reference. The system was developed for the French national research agency (ANR) and French military procurement agency (DGA) MALIN indoor localization technology challenge.

The concept leverages CEA-List research on automated 3D reconstruction of learned environments, calculating the positions of the sensors within these environments. The system is extremely precise: Trajectories can be reconstructed more than 99% accurately over distances of several kilometers. It also performs well in smoky, enclosed, and poorly lit environments.

Future developments will include adding semantic information about the nature of and relationships between objects observed for automated map generation, a new collaborative mode enabling information sharing between wearers, and—potentially—rollout for infantry personnel.

LIGHTENING ELITE ATHLETES' COGNITIVE LOAD

In elite sports, the physical, technical, and tactical are all optimized to the extreme in a relentless quest for performance. In team sports, however, psychological and sociological aspects also have a major impact. CEA-List is involved in the multidisciplinary TeamSport project, launched last year, to model and optimize group behavior to provide France's national teams with new tools and information to maximize their performance in the runup to the 2024 Paris Olympics.

Our researchers drew on their knowledge of video analysis to identify and qualify player attitudes during matches. An analysis of footage of the French national rugby team in training at Marcoussis has already led to the identification of important features of players' body language during effort and other phases of play.

AI can process vast quantities of data from training and match video feeds in real time, detecting signals that were previously impossible to quantify. Coaches can use this new information to refine their strategy and boost team performance.

The insights into group dynamics offered by psychology and sociology, supported by AI-processed data, will contribute to improving mental preparation, tailored to the team and situation.

Learn more on the CEA-List website

FOCUS

MOHAMED TAMAAZOUSTI
A CALL TO SCIENCE ANSWERED AT CEA-LIST

The first time Mohamed Tamaazousti felt the call to science, he was an applied mathematics student at the University of Orléans. A professor there showed him some of the more practical aspects of math, bringing the discipline to life for Tamaazousti, who ended up coming to CEA-List to do the final student internship he needed to earn his degree. While still at CEA-List, Tamaazousti went on to earn his PhD in computer vision for robotics at the University of Clermont-Ferrand, one historic partner institution in the field. Today, he is a research engineer at CEA-List.

RESEARCH INTERESTS

Tamaazousti studies visual rendering techniques and the way images (high dimensional objects) are created by the complex physical interactions between matter and light. Applying fundamental physics to classic AI problems, he works on furthering our understanding of the mechanisms used to extract information from complex data like images —the way the human brain does this is remarkable. Tamaazousti would like to move away from empirical research and establish the theoretical foundations for deep learning in his field.

WORKING WITH CEA-LIST

The CEA is an ecosystem of experts with a culture of collaboration. This creates opportunities to build communities around Tamaazousti's areas of interest—something he particularly appreciates. Plus, his research just happens to be in a field that is expected to see major growth at CEA-List in the future.

Technology transfer —a CEA-List hallmark— is something Tamaazousti has also developed a strong affinity for. **"For research to be considered successful, it has to have a positive impact on the economy and society. And partnerships are a great way to do that."**

ARTIFICIAL INTELLIGENCE

YOUR DATA STAYS YOURS (YDSYO)

THE MOBILE APPLICATION THAT PROTECTS YOUR PRIVACY

"If it's free, then you're the product." Social networks—easy to access, but with terms of use you'd need a corporate lawyer to understand—can make huge profits from users' personal data. Once data is uploaded to a website, it can be exchanged with or sold to third parties, at which point the original owner loses all control.

CEA-List developed the YDSYO (Your Data Stay Yours) application to raise users' awareness of privacy issues on social media. Once downloaded, with the user's consent, the application analyzes photographs on the user's device and/or social media accounts to determine their degree of **"exposure."** Essentially, the application lets users know how their profile will be perceived—by anyone from recruiters to banks and insurance companies. A score is calculated by searching for pre-defined visual concepts, which form part of a situation model, within the user's personal images.

YDSYO is funded by the Fondation MAIF (USCAP project) and by the European Commission via its PURPETS and AI4MEDIA projects. The final, open-source version of the application will be released via the Android app store in the near future.

Download YDSYO app

METHODOLOGICAL ADVANCES IN FRUGAL DEEP LEARNING

To perform well, deep learning requires large quantities of tagged data. While obtaining enough data is generally relatively easy, the tagging process tends to be prohibitively expensive. Image annotation services, for example, cost tens of dollars per 1,000 units. Given that millions of tagged units may be required to fully train a deep learning network, the costs involved are simply too high for most companies.

In his PhD research at CEA-List, Khanh Hung Tran worked on innovative semi-supervised classification models using non-tagged data. If the quantity of tagged data available is not sufficient, neighborhood relationships across the full data set may be exploited to create an optimization scheme which can then be integrated into any supervised or semi-supervised neural network learning algorithm. This approach offers significant benefits in terms of classification precision and robustness. The advance will create new opportunities for improving the performance of predictive models.

Read full PhD thesis

MASTERMIND:

STRUCTURING LARGE DATA SETS FOR IMPROVED LEARNING

Supervised statistical learning techniques, such as those based on neural networks, struggle to handle high levels of semantic variation. For large data sets, and in cases which rely on incremental acquisition, smart indexing techniques based on the semantic content of the mass of data are crucial to success.

As part of the DGA (French defense procurement agency) Mastermind project, CEA-List has developed new techniques for rapidly indexing large data sets while respecting their semantic content. This pre-processing stage simplifies the learning process, meaning that some of the most costly processing operations are only applied to a reduced and statistically homogeneous portion of the data. Information is organized topologically using a flow clustering method. The principle has been tested using a bank of high-res satellite images. Our method offers higher levels of semantic coherency across the new groups than existing partition-based methods, without increasing algorithmic complexity.

This software module can detect changes in temporal image series and has been used for automatic cloud cover analysis, notably in terms of the degree of opacity. The technique can be applied to all data types, and applications for audio signals and machine logs are currently in the pipeline.

ARTIFICIAL INTELLIGENCE

SPEED:

PROTECTING DEEP LEARNING DATA IN NEURAL NETWORKS

The best way to protect data is to store it on secure servers. But huge amounts of data—a potentially invaluable resource that could be used to train algorithms if it could be shared securely—is stored in private databases.

CEA-List has developed an innovative end-to-end-secure data exchange method that could make private data more shareable.

SPEED—for Secure, PrivatE and Efficient Deep learning—ensures privacy by design by:

- **Minimizing information/data sharing** by protecting data in distributed learning contexts.
- **Preventing retro-engineering of the model** so that original data cannot be reconstructed.
- **Defending against server threats** using homomorphic encryption, which offers an additional layer of privacy: the aggregating server operates "blind," using encrypted tags.

When federated learning is secured in this way, private data can be used to train AI systems without unacceptable security risks during learning or use.

CEA-List is part of the European PRIVILEGE (PRIVacy and homomorphIc encryption for artificiaL intelligence) project to develop and test a federated learning strategy for highly confidential military data—just one example of the potential uses for this approach.

This research was published in the journal *Machine Learning*.

Read article on SpringerLink

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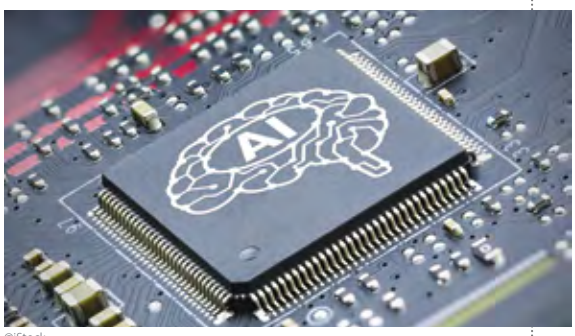

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DOLPHIN DESIGN AND THE CEA

CREATE A NEW EMBEDDED AI PLATFORM

One way for AI, 5G, and IoT to continue to grow without generating a data deluge and the associated environmental impacts is to integrate data processing capabilities directly onto chips. Dolphin Design SAS and CEA-List launched a joint R&D lab in 2019 to develop Edge AI solutions that deliver software flexibility, energy efficiency, and high performance.

Dolphin Design uses CEA-List's PNeuro® AI hardware accelerator alongside its own processing platform. The company is also taking advantage of our SESAM/VPSim simulation environment for rapid design space exploration and design validation, and our N2D2 code generator for more efficient programming.

As a result, Dolphin Design SAS added two innovative new products to its lineup: Chameleon, an event-based MCU platform, and Raptor, a neural network hardware accelerator for AI.

A demo chip using 22 nm FD-SOI technology has been produced, and initial characterization and measurement data will be soon available. The next step will be to produce a software generation flow that Dolphin Design's customers will be able to use to develop lean, low-power applications.

"75% of data will be processed locally by 2025."

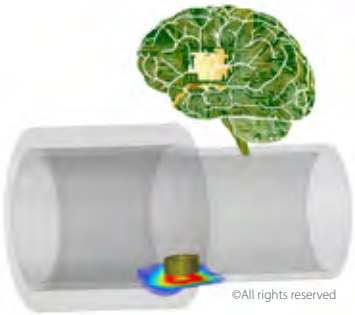
CIVA

BRINGS AI TO AUTOMATED DIAGNOSTICS

CIVA, CEA-List's non-destructive testing (NDT) software suite offers innovations for the design, evaluation, and implementation of diagnostic algorithms based on AI. Learning data, for example, can be generated and processed using powerful analytical and simulation tools. A first data classification module has now been integrated into CIVA and used to develop an automated weld monitoring system proof of concept.

Each step in the monitoring process can be virtualized and evaluated. Learning data can be optimized, and the large quantities of statistical measurements obtained from intensive simulation models ensure consistency.

CIVA is the industry leader in design and performance demonstration for NDT, a position we plan to consolidate by harnessing the full power of AI. The new CIVA Data Science module, which builds on this recent advance in data classification, is due for release in H1 2022.



PYRAT

ANALYZES THE SAFETY PROPERTIES OF NEURAL NETWORK-BASED AI

Technip Energies provides engineering services to the energy industry. The company turned to CEA-List to ensure that the neural network-based AIs it is developing for its critical systems are reliable. CEA-List responded to the call, leveraging its knowledge of formal validation methods.

CEA-List developed a tool called PyRAT that can analyze neural networks' safety properties and evaluate how stable they will be if they are subjected to adversarial attacks or sensor noise, for example. PyRAT can also be used to certify that a neural network is behaving as expected.

PyRAT can be implemented in Python, so that neural networks can be processed directly. It also supports matrix implementation and abstract interpretation techniques. Finally, it can address a variety of domains, including intervals, polyhedra, and zonotopes. Heuristics can be used to partition inputs so that they can be classified.

It has been tested on different use cases at Technip Energies, of course, as well as at Renault and Airbus, where it was used on anticollision systems. These ongoing partnerships will continue to fuel improvements, for a faster and more accurate PyRAT.

FOCUS

ZAKARIA CHIHANI

ACADEMICS

Zakaria Chihani studied at Badji Mokhtar - Annaba University in Algeria before coming to France, where he earned two graduate degrees and a PhD in computer science. His PhD research, at École Polytechnique and Inria, focused on proof of certification in first-order classical and intuitionistic logic. He joined CEA-List's software safety and security laboratory as a research engineer in 2015.

RESEARCH

Chihani has been investigating the security of artificial intelligences (AIs) since 2017, a little-studied field at that time. Today, he is looking at how to ensure the quality of the models used to train AIs and verify AIs' safety properties. These formal properties are expressed in a logical language that can be understood by formal proof and testing tools like PyRAT, which uses a technique called interval uncertainty propagation to check whether or not all of the data in the intervals will always generate the same results. While it may sound abstract, Chihani's research supports real-world solutions like safe anticollision systems for aircraft and other vehicles.

WHAT HE HAS TO SAY ABOUT CEA-LIST

Zakaria Chihani appreciates the wide variety of work at CEA-List. With projects that range from industrial R&D to more academic pursuits like research and the co-supervision of PhD students and student interns, CEA-List offers a particularly rich professional environment made possible by strong partnerships. Connecting with the companies that depend on our research is one of the things that motivates Chihani the most. **"Our tools simply have to work, and they have to work well,"** he said.

DIGITAL TRUST

POLITICAL AND ECONOMIC SOVEREIGNTY COME TO THE FOREFRONT

In today's increasingly digital world, individuals, companies, and services are not only connected, but they are also interconnected. The potential for growth and progress is exciting. But it can only be realized if data, transactions, and digital infrastructures—with or without AI—are safe and secure.

The European Commission invests around €20 billion in digital technology each year. At the national level, the French government has launched a massive stimulus program to digitalize the country's industrial economy. At CEA-List we are ideally positioned to leverage our expertise in smart digital systems to respond to the challenges around digital trust.

COMBATTING CYBERTHREATS

The rise of increasingly sophisticated—and organized—cyber-crime poses a significant threat. Attackers put substantial resources into scanning millions of interconnected machines for vulnerabilities, sometimes even automating the process. Conventional cyberattacks like data theft, phishing, and ransomware aren't going anywhere. And new bad actors have entered cyberspace: government-backed cyber-crime organizations that threaten to bring down whole sectors of an enemy's economy or destabilize its government.

Evidently, defensive strategies are needed to counteract these threats. AI is used in conjunction with cybersecurity technology to monitor networks, identify the source of threats, and deploy effective countermeasures. CEA-List is using its Frama-C suite and other tools to develop a full range of technological defense solutions with the capacity to detect software vulnerabilities.

PRIVACY AND DATA PROTECTION

When algorithms mine millions of patient medical records for data to make correlations that support better diagnostics, for example, keeping that data private is paramount—regardless of where the data is stored or used. CEA-List's Cingulata technology can compute on end-to-end encrypted data without ever revealing the information it contains. Cingulata can be implemented in the cloud, a solution that responds to business' need to retain control over their data. **"Very early on, as soon as the concept emerged, we were able to make advances in homomorphic cryptography and contribute scientifically to the questions that were being raised. We were three to four years ahead of other organizations just starting to work on the topic,"** said CEA-List's **Renaud Sirdey**.

BLOCKCHAIN TECHNOLOGY

Blockchain technology, used for cryptocurrencies like Bitcoin, for example, is, by definition, decentralized. Data is distributed across interconnected participants and is not stored in a central location like on a server. The downside to blockchain is its phenomenally high energy consumption. At CEA-List, we place a strong emphasis on frugality, and we aim to minimize energy consumption from design through to use of the technologies we develop. Factoring in impacts on people and the planet is part of who we at CEA-List are. According to **Antonella Del Pozzo**, one of our research engineers, **"Using theoretical knowledge to solve the real-world problem of reducing blockchain energy consumption is one of the most interesting parts of my job!"**

DIGITAL TRUST

SNOWPACK

A SOFTWARE SOLUTION FOR ANONYMIZING AND SECURING NETWORK COMMUNICATIONS

Ensuring the integrity of online exchanges is a challenge startup Snowpack is addressing with a solution based on an innovative CEA-List technology that delivers both anonymity and security. Data packets are divided into anonymized, complementary fragments called "snowflakes" that look like noise, and then routed through separate pathways. This makes it impossible for hackers to correctly reconstruct the original information.

Snowpack does away with the need for trusted third parties. And, because it measures and controls network security in real time, trusted hardware and software are no longer required. Snowpack can also prevent attacks that exploit the visibility of metadata like IP addresses in data streams on telecommunication networks, including on the internet.

The solution is designed for use in addition to encryption technologies, filling in the gaps where vulnerabilities remain. With Snowpack, service providers have an ethical invisibility solution that does not reveal users' identities, but can still filter access to illegal sites.

Snowpack will be commercialized by a startup of the same name, created on May 30, 2021. The company is currently deploying its overlay infrastructure in data centers in several European countries and aims to become the leading invisibility network on the internet.

Visit the Snowpack website

CINGULATA

OPTIMIZED FHE (FULLY HOMOMORPHIC ENCRYPTION) HELPS BRING ENCRYPTED DATA COMPUTATION TO THE MARKET

In a world where increasingly frequent cyberattacks are impacting everything from retail and banking to healthcare and industry, shielding personal data from prying eyes is a particularly timely topic. Due to growing outsourcing of hosting and data analysis services—often on remote servers—data is more exposed than ever. **"The millions of lines of code in the software on computers harbor a multitude of vulnerabilities. Our homomorphic encryption technology addresses this,"** said CEA-List cryptography expert **Renaud Sirdey**.

Fully Homomorphic Encryption, or FHE, strengthens data privacy by enabling computing on encrypted data. The results must be "unlocked" using a decryption key, which can be given only to authorized persons. With CEA-List's FHE-based Cingulata technology, developed in 2011, data processing and analysis can be done on remote servers with end-to-end privacy, without the need to verify the trustworthiness of the hardware.

Cingulata's rollout is being supported by the CEA's Bigπ cloud platform. Bigπ has already enabled testing on real-world business cases, with the implementation of two predictive maintenance demonstrators. The tests confirmed the technology's added value and our ability to deploy it—opening the door to a sovereign cloud solution for France and all of Europe.

CLEARMATICS

CLEARMATICS ENABLES IMMEDIATE CONSENSUS FOR A MORE RELIABLE BLOCKCHAIN

The Clearmatics peer-to-peer blockchain has to be able to tolerate "bad" participants disrupting its proper functioning. Researchers at CEA-List are helping trace certain behaviors, reduce their occurrence on the blockchain, and make transactions more reliable. In a real market context, each transaction logged must be recorded immediately, without the confirmation time required on conventional blockchains, like Bitcoin, and without the transaction disappearing.

Immediate-consensus blockchains meet this requirement because they can tolerate a certain number (less than a third of the total number) of "nuisance" participants. Whether they are malicious, opportunistic, or inactive, these participants can prevent the system from functioning properly. This raises the question of how to distinguish between harmful behavior and system flaws. For late message deliveries, for example, this means being able to tell whether the sender meant the message to be late or not.

CEA-List developed two algorithms that can detect bad participants and limit their presence on a blockchain.

- The first, inspired by CEA-List research on distributed systems, is an algorithm that provides proof of protocol violations and identifies the participants responsible.
- The second, a participation incentive algorithm, rewards active members based on the number of messages exchanged.

The algorithms are being used for the Carnot Fantastyc project to automate responsibility tracing module design based on a specific protocol.

INTERVIEW

Sara Tucci

Antonella Del Pozzo

Álvaro García Pérez

INTERVIEW WITH SARA TUCCI, ANTONELLA DEL POZZO, AND ALVARO GARCIA PEREZ

Sara Tucci, lab manager and head of the blockchain program, **Antonella Del Pozzo,** and **Álvaro García Pérez** are research engineers at CEA-List. Together, they cover a wide range of blockchain-related research topics, from computer engineering to federated learning. They shared their latest thoughts on digital trust.

HOW IS CEA-LIST LEVERAGING BLOCKCHAIN TO SUPPORT DIGITAL TRUST?

ST: We position ourselves differently depending on the nature our partners' needs. Some of our partners are blockchain experts themselves. They come to us to help them develop even better solutions. I find this particularly rewarding, because so few labs in the world can do what we do.

ADP: Our partnership with Clearmatics is a great example. We helped them make their blockchain for the financial markets more reliable by doing things like eliminating the latency of traditional blockchains.

ÁGP: We work with partners in a wide range of fields, including finance, logistics, energy management, supply chains, IoT, and federated learning. There are many, many scenarios where parties that don't know each other have to interact. A reliable blockchain gives them the trust they need to work together.

WHAT ELSE CAN YOU TELL US ABOUT YOUR RESEARCH?

ST: We do interact with people—at companies from startups to corporations like Veolia—who know very little about blockchain. They come to us for help building innovative services for their customers. Product certification and traceability are a couple of examples. With blockchain, you can create a "product passport," with end-to-end information about each stage in the manufacturing process. In the automotive industry, for example, the ability to give cars a digital maintenance log attesting to all of the work that has been done on the vehicle, from manufacturing to maintenance, is a real plus.

ADP: I'd like to come back to Clearmatics. In the best-known blockchains, the ones used for cryptocurrencies, transactions can disappear. This is one problem. Latency in recording transactions is another. Here, we are helping increase reliability with immediate consensus. And, since we are dealing with peer-to-peer transactions, there is no central authority.

ÁGP: I was thinking about the Carnot Fantastyc project, where we are implementing federated learning systems. These systems combine artificial intelligence, formal methods, game theory, machine learning, distributed systems, and, of course, blockchain. It is the combination of knowledge of different areas related to decentralized trust that really makes the difference in our work. There's also the issue of energy consumption. Blockchains are energy intensive, and we are working on improving that. Environmental impacts are now a key indicator like any other. Early this year, we started a moonshot project on green blockchain. The goal is to be able to gather, process, and display large volumes of data without the usual energy costs. The project's test case involves climate data like greenhouse gas emissions.

THE COGITO COMPILER

OPTIMIZED COMPILE-TIME APPLICATION OF A MASKING COUNTERMEASURE AGAINST SIDE CHANNEL ATTACKS

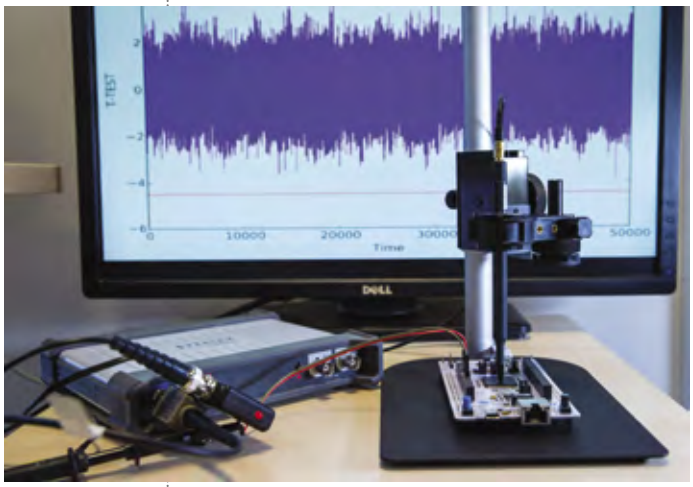
IoT devices create opportunities in many fields. The EU SARMENTI project, for example, is developing solutions to monitor the chemicals in soil and air for farming. The adoption of such solutions, however, depends on the security of those devices against cyber attacks.

Side channel attacks occur when hackers measure a circuit's physical properties—like electromagnetic emissions—to reconstruct information about the data and instructions involved in executing a program. Side channel attacks are remarkably effective at finding encryption keys, leaving the IoT vulnerable.

Although there are many countermeasures to fend off side channel attacks, they can be difficult to implement and can have a substantial negative impact on performance. Masking, a well-known countermeasure with some definite advantages in terms of cybersecurity, suffers from these problems.

The CEA began developing its COGITO compiler in 2013. With COGITO, it is possible to automate countermeasures against physical attacks on systems, making them more secure. Boolean masking can now be applied automatically using COGITO's Maskara feature, which includes several performance optimizations.

Learn more about SARMENTI



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EPI: THE EUROPEAN PROCESSOR INITIATIVE

For its supercomputers, Europe is still largely dependent on world-class processors, especially from the United States. The European Processor Initiative (EPI) launched by the European Commission addresses this need for strategic independence by bringing together 27 partners, including the CEA and, specifically, CEA-List. The initiative has several objectives: the development of the European high-performance computing processor that will equip the EuroHPC exascale machines, and the creation of a European HPC processor design industry, whose profitability will depend on closer ties with the automotive industry.

The first phase of the EPI project (SGA1) ended in 2021 with the consortium making some major achievements to which the CEA actively contributed.

The CEA specified the Common Platform based on a co-design methodology between application and architecture. CEA-List made its virtual platform SESAM/VPSim available to its partners for this purpose.

Concerning the design of a first-generation European processor, called Rhea, the CEA contributed to several functional blocks (IPs). CEA-List evaluated the high-bandwidth memory controller (HBM) and the chip-to-chip interconnect controllers. It also designed a variable-precision (VRP) accelerator tile and integrated it into a test circuit and into Rhea. CEA-Leti developed a non-chip power management system (voltage selector).

For automotive applications, the technologies resulting from the EPI offer an innovative approach to multi-circuit co-simulation via interfaces for the software toolchain and supervision. In this context, and to guarantee operational safety, CEA-List also contributed to the formal analysis of timing based on the instruction set architecture of a processor.

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CEA-LIST FIRST IN FRANCE TO EXPERIMENTALLY BENCHMARK AN ANALOG QUANTUM COMPUTER

NEW RESEARCH MARKS ADVANCE TOWARD OBJECTIVE QUANTUM COMPUTER EVALUATION AND SELECTION CRITERIA

To say that gate-based quantum computers are the only approach to quantum computing would be over-simplifying the issue. There are alternative routes to quantum, like the one developed by Canadian company D-Wave, which is a quantum accelerator specialized in resolving optimization problems.

In theory, this approach would use a quantum process (the adiabatic evolution of the Hamiltonian) to enable a transition over time from a zero-point energy state to a second, more complex state whose minimum energy corresponds to the solution to the problem considered—but only if the transition is slow enough.

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CEA-List researchers studied certain optimization problems that are relatively simple, but difficult to solve using classical heuristics—like simulated annealing. The D-Wave 2X computer can make only 5% of the connections needed to instantiate a general problem—a limitation that requires a workaround which, in turn, makes the problem more difficult to solve. This puts a cap on how good D-Wave-type quantum computers can become at solving optimization problems.

We identified qubit profitability issues due to lack of connectivity (100 variables require around 1,000 qubits because certain variables must be duplicated to address the machine's deficiency). Although the machine is definitely fast (a few dozen microseconds per result), the results remain unsatisfactory on the tricky optimization problem described above. We concluded that the connection topology was not dense enough, which indicates that density could be more important than absolute number of qubits.

The next generations of computers (especially D-Wave Advantage computers released in late 2021) considerably improve this last point, and hopefully improve also on the optimization results. Our partnership with the Jülich Supercomputing Center (JSC) on the AIDAS project will contribute to building an international ecosystem around this approach to quantum.

ADVANCES IN QUANTUM PROGRAM VERIFICATION

Quantum computers will increase today's computing capacities exponentially. Work to ensure that the programs installed on tomorrow's quantum machines will operate as intended must start now. The methods used to verify classical programs are not directly applicable to quantum computers. In some cases the cost is prohibitive, and in others, the methods simply don't work. Researchers at CEA-List took the formal methods the institute has developed for conventional software verification and adapted them for quantum code verification. The new tool is called QBrick. They tested it on the particularly complex quantum phase estimation algorithm which underpins Shor's algorithm, used to crack banking transaction encryption keys.

We also started QStack, a research program on the quantum software and architecture stack. These layers between the algorithms and hardware are what will allow realistic applications to be programmed and executed on tomorrow's quantum computers.

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FACTORY OF THE FUTURE

A DIGITAL REVOLUTION IN INDUSTRY

THE FOURTH INDUSTRIAL REVOLUTION

Industrial process digitization and robotization are currently taking place on a massive scale, presenting a real paradigm shift for businesses. And the amount of data generated by these new ways of working is equally massive: Automations are increasingly sophisticated; machines are communicating with each other, operators, and the outside world more than ever; augmented reality and learning robots are making inroads into factories; and real-time in-line process control is on its way to becoming the norm. The factory of the future is an ecosystem—one that requires purpose-built, configurable software components. Adding artificial intelligence to these tools can help make production systems more autonomous and agile—but this mustn't come at the expense of security, cybersecurity, or robustness. **"These technologies must work together, which means that we need to develop solid software architectures,"** said CEA-List intelligent robotics engineer **Matteo Morelli**. "The objective is simple: Humans have to be able to enter into a robot's work cycle safely."

ENVIRONMENTAL ISSUES AT THE FOREFRONT

The current industrial revolution will only come to fruition if it is frugal—whether that's in terms of energy or other resources, like materials. CEA-List research is addressing these issues. The race toward environmentally responsible, low-carbon factories with task-by-task monitoring capabilities is officially on. One solution worth mentioning is additive manufacturing, which consumes less material and offers in-process control, enabling further optimization of resource use and the product lifecycle.

SHIFTING THE TECHNOLOGICAL PARADIGM

Two of our research areas, self-learning robots and digital twins, promise considerable industrial efficiency improvements. The first, equipped with the ability to learn in natural language, can receive explanations about tasks, understand situations presented, and call on other robots for assistance. **"We need new types of robots that are more versatile, more agile, and faster. So, we are exploring a number of different avenues, from mechatronics and communications to advanced perception systems and decision-making intelligence,"** **Morelli** said.

Digital twins—virtual replicas of processes, objects, or systems that can be used to simulate different configurations—offer great potential for operational optimization, predictive maintenance, and more. **Saâdia Dhouib**, who manages Industry 4.0 projects at CEA-List, said, **"A digital twin can be used to simulate different components of a factory, and can also monitor production, collecting energy consumption data, for example, which can then be used to reduce energy spending."**

THE ECOSYSTEMS THAT DRIVE OUR RESEARCH

As a research and technology organization, CEA-List works with other research institutes and with businesses. According to **Ariane Piel**, a modeling, simulation, and complex systems optimization project manager at CEA-List, **"Technology transfer is our mission."** We partner with companies on specific R&D projects and engage in collaborative projects—many of which are European in scope and business-oriented thanks to framework programs like H2020, Horizon Europe, and Digital Europe. These multi-partner projects bridge lab research and industrial R&D, supporting the creation of new scientific knowledge while ensuring that our research aligns with real-world economic and societal challenges. **"It's an enormous source of motivation for our researchers to see the technologies that we develop in our labs adopted by businesses."** said **Dhouib**.

FACTORY OF THE FUTURE

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DIGITAL TWINS

FOR MORE AGILE FACTORIES

Industry 4.0 is synonymous with agile factories, mass personalization of products, and on-demand manufacturing of production runs large and small. This vision of the factory of the future will be built on generic production methods, greater connectivity, and new technologies like digital twins that integrate the latest industrial standards.

CEA-List researchers are responding to this need for flexibility with the Papyrus platform, a unique model-based engineering environment. For the factory of the future, we're using it to model and simulate different aspects of a production system from multiple points of view.

Papyrus4Manufacturing is an AAS-standard tool for the design and implementation of digital interfaces in factories. It can handle information exchange and interoperability between the different components within the smart factory using Industry 4.0 communication protocols.

The 30-partner EU DIMOFAC project with its six pilot manufacturing lines is taking full advantage of Papyrus4Manufacturing. The advances made for the project will position manufacturing companies to create their own digital twins, for "plug & produce" factories built on completely modular production methods, equipment, and digital tools. Digital twins are also useful for testing reconfiguration strategies before deploying them on the shop floor and for virtual commissioning, a strategy that helps avoid wasting resources.

The DIMOFAC project's ultimate goal is to help keep European manufacturing competitive by reducing factory reconfiguration time by more than 20% and overall production costs by 15%.

Discover and download Papyrus4Manufacturing

Learn more about DIMOFAC

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SOUND:

SPATIO-TEMPORAL INVERSE FILTERING TURNS SURFACES INTO SPEAKERS

The Sound system can transform virtually all surfaces—walls, glass, aluminum, wood, carbon fiber, and potentially many more—into audio speakers.

Spatio-temporal inverse filtering enables sound-emitting surfaces by utilizing vibration induced by piezoelectric actuators or electrodynamic exciters. And, thanks to ultra-precise localization of the vibrations and the ability to fine-tune the technology, several sound-emitting zones can be created on the same surface. Additional research is underway to reduce harmonic distortions and improve sound reproduction to perfect the concept.

The technology is highly promising. Direct surface functionalization reduces weight (by 50%–90%) and volume (by 80%–95%), a spectacular improvement over traditional speakers—exactly the kind of solution automotive manufacturers and the smart home and hotel industries are looking for. A demonstrator sure to pique companies' interest is already available in the CEA-List showroom.

Learn more about Sound

Learn more on the Paris-Saclay University website

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INTERACTION WITH POINT CLOUDS IN EXTENDED REALITY

OCTOPCL, , CEA-List's latest interactive simulation technology, supports the processing and display of massive point clouds.

Increasingly, industrial companies are turning to 3D scanning systems to capture real-world facilities and equipment, either instead of or in addition to CAD models. The ability to display data captured by laser scanners interactively with 3D models or digital twins enables new use cases like virtual collaborative construction site tours and detecting and rapidly resolving non-conformities on a production line, for example.

OCTOPCL has been used in a plug-in called Stipple by startup Light & Shadows and in CETO®, a Technip Energies application, enabling:

- Unparalleled rendering of massive (more than 1 billion points) 3D point clouds
- CAD model and point cloud comparisons
- Interaction with the point cloud (user movements, interference with a mesh or model, 3D environments)
- Automatic generation of synthetic point clouds
- Simulation of point cloud acquisition by LiDAR and depth camera
- Remote collaboration on the results

Next, CEA-List will make further improvements to the tool's visual rendering capabilities. They will also harness the power of AI tackle point cloud idealization and segmentation.

GRIPPING

A KEY ROBOTIC CAPABILITY

At CEA-List, we are working with partners from the public and private sectors to make industrial robots more versatile and adaptable. One of the things we are focusing on is improving robots' ability to grip various objects in constantly changing environments. Specifically, the solutions under development will help simplify tasks and improve operator safety and efficiency.

With AI-based planning, robots can more effectively explore the space to find the safest, most stable grip on an object using multi-digit, underactuated—with fewer actuators than degrees of freedom—adaptive grippers, for example. The idea is to enable on-the-fly gripping for more versatile robots. This innovative research has been published in two international journals and one patent has been filed.

The method delivered a 99.54% success rate for 7,000 simulated tests; the experimental results obtained were also very convincing.

INTERVIEW

Selma Kchir

Matteo Morelli

Mehdi Darouich

THE COMPANION ROBOT: MULTIDISCIPLINARY RESEARCH FOR THE FACTORY OF THE FUTURE

CEA-List research engineers **Selma Kchir**, who heads the institute's companion robot research project, **Matteo Morelli**, and **Mehdi Darouich**, gave us their insights into the companion robot, an innovation expected to transform tomorrow's factories.

Cross-disciplinary research is not new to CEA-List. What makes the institute's companion robot research so exciting is how so many of our different robotics disciplines intersect. We are using technologies like AI for vision and language, digital twins, communications, model-driven software engineering for autonomous systems, embedded computing architecture design for perception in autonomous systems, and embedded artificial intelligence.

MANY INDUSTRIES ALREADY USE ROBOTICS EXTENSIVELY. WHAT WILL THE COMPANION ROBOT ADD?

Selma Kchir: It is true that some industries are already highly robotized. Here, however, we are talking about the industry 4.0 movement, which hinges on mass production and IoT. Robots are connected agents, and to extract full value from their data, we will need more tightly integrated AI. Now it is time to lay the groundwork for what's next, industry 5.0. In this new paradigm, robots will have to be increasingly versatile and rapidly reconfigurable for small and medium-sized production runs. Another challenge will be to make it easier to manufacture new products and manage operations in downgraded mode, especially in times of crisis—a key success factor for large manufacturing corporations and SMBs alike.

WHAT ARE THE MAIN MILESTONES ON THE ROAD TO A COMPANION ROBOT?

SK: We must make progress on several different technologies—mechanics, vision and perception, AI, and communications—and get them to work together. Modular architectures and generic interfaces will be the key to making this happen. We will also need simulation capabilities—digital twins of robots and their work situations—to see how a sequence of tasks will be carried out and look at the impacts of changes in the environment. Digital twins are useful for generating collision-free trajectories, simulating different positions for picking up objects, improving robots' grasping capabilities, and helping them move about safely with humans. The CEA is one of the few organizations in the world that not only has all these technologies, but that can also integrate them.

Matteo Morelli: What stands out the most for me is how we are integrating such a wide variety of technologies. For the module interfaces, for example, you need abstraction layers. We use formal modelling languages with well-defined semantics to do this. Once you have the abstraction layers, you can determine how information is exchanged between modules and how the different computing operations will be put together to perform a task. And then you have the human-machine interfaces, which have to be designed to make communication between operators and robots as efficient as possible. All these moving parts need to be carefully orchestrated.

Mehdi Darouich: The physical robot itself also has to be designed—an important step. For more versatile, energy-efficient robots, we are looking at how to integrate embedded computing architectures and distribute them across different computing resources. If we can integrate critical functions on processors near the sensors or actuators, it will open the door to exponentially more responsive robots capable of handling new kinds of work in cooperation with humans.

WHAT WILL THE IMPACT OF THIS RESEARCH BE?

SK: Human expertise is central to industry 5.0. What's new is that robots are there to assist human operators, not replace them. Operators will be able to count on their companion robots to adapt to their needs, rather than the other way around. Robots will augment the human capabilities in the factory and help humans with strenuous tasks. In the future, anyone will be able to configure robots easily, without the need to learn complicated programming languages. Education, age, and gender will no longer be obstacles to using robots. Robots will also be easier to adapt to many different use cases. They will support the circular economy and help bring manufacturing jobs that were once offshored back to Europe. The companion robot will help make this vision a reality.

MM: The impact will be significant. And everyone will benefit. Companion robots will make industrial jobs safer. Factory workers will no longer have to perform repetitive tasks, freeing them to focus on tasks that add more value. It is great to be able to apply the latest advances in computing to smart robots. The solutions we are developing here will serve as a solid foundation for a new self-learning robot project in the works.

MD: Our research opens the door to a more flexible, responsive, and human-centered production model that will also be more energy- and resource-efficient.

FACTORY OF THE FUTURE

SIMPLER,

MORE EFFICIENT REQUIREMENTS MANAGEMENT FOR SYSTEMS ENGINEERS

In industrial environments, the procedures that guide operators through the daily tasks that keep a facility and its equipment running smoothly are written in natural language.

Command-control software is built on formal expressions not only of operating procedures, but also of specific requirements like operating conditions, temperatures, how "hard" rules have to be, and any ambiguities in the instructions. Until now, the process of "translating" this information, expressed in natural language, into a set of formal requirements has been long, tedious, and, above all, manual. CEA-List now has tools that can automate these tasks, for more efficient industrial process management.

CEA-List researchers were able to validate these new tools on two use cases. The first, for electric utility EDF, focused on simplifying nuclear plant operators' work for better plant safety. CEA-List's STE2ARTIMon model automatically formalized operating procedures in natural language, clarifying procedure wording and removing any ambiguities from the rules.

The second use case, at RTE, involved managing the storage and distribution of renewable, intermittent renewable energy in real time, preventing downtime, grid overloads, and operating losses. As part of the EU CPS4EU project, CEA-List developed a grammar for expressing functional requirements and is creating formal analysis techniques to improve them and study their causal connections. The method and results were implemented in MAAT, a tool designed to formalize requirements. The CEA and RTE also co-authored a paper presented at the International Conference on Software Engineering and Knowledge Engineering (SEKE 2021).

CEA-List provided IRSN with a complete solution covering everything from structured textual documentation and source code to software validation reports. This integrated software chain was able to inject 273 requirements from documentation into the first code attempted almost instantaneously—a task that would have previously taken hours. In addition, error propagation in the software chain can then bring anomalies like calculation inconsistencies in nuclear facilities' embedded code to light.

Download Frama-C

CORRELATIONS BETWEEN PROCESS PARAMETERS AND MATERIAL INTEGRITY IN PARTS MADE USING

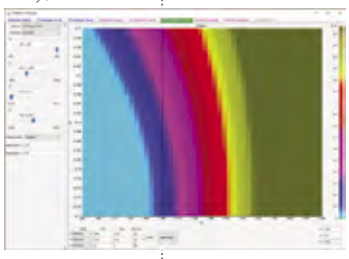
ADDITIVE MANUFACTURING

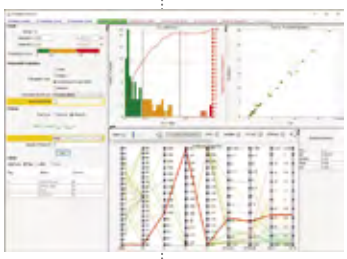
Digital systems experts at CEA-List and nanomaterials experts at CEA-Liten have been teaming up to create a database on the manufacturing of parts using laser powder-bed fusion (L-PBF), an additive manufacturing process. CEA-List is contributing its non-destructive testing methods to this joint endeavor.

First, L-PBF samples were manufactured and subjected to a battery of tests. The Archimedes method was used to calculate part density; resonant ultrasound spectroscopy (RUS) to measure the resonant frequencies within the material; and X-ray tomography to generate high-resolution (20 µm) images of the parts. The results clearly show a correlation between the process parameters and the quality of the material obtained. They also highlight the relationship between RUS spectral quality and porosity—a potential new approach to rapid sample characterization.

The research is ongoing. We are now manufacturing parts with defects so that we can measure the defects' signatures.

The results of the research will go into the **3DManufacturing@CEA** database, a repository of the CEA's wealth of knowledge about AM processes. It is also available as a plugin in the CIVA simulation and analysis environment, a welcome addition the CEA's digital toolchain for additive manufacturing.





INSTRUMENTATION AND *IN-SITU* MONITORING

FOR ADDITIVE MANUFACTURING

CEA-List and CEA-Liten combined their expertise in smart digital systems and nanomaterials to develop new *in situ* monitoring techniques for powder bed additive manufacturing. Here, eddy current and ultrasonic wave testing techniques leveraging CEA-List research were implemented, and CEA-Liten's Farsoon laser powder bed fusion machine was equipped with electromagnetic and ultrasonic probes.

The eddy current technique was studied to ascertain its ability to detect defects that appear during the manufacturing of aluminum parts. The defect detection limits of the probe implemented here were identified, using the opening size and height of artificial control defects intentionally introduced into the part during additive manufacturing as reference points. The ultrasonic probe can be used to monitor the part as each layer of material is deposited by the additive manufacturing machine. A break in the continuity of the material due to problems with the manufacturing process parameters was also successfully detected.

This multi-technique approach will be used to produce measurement data for analysis, modeling, and the development of a monitoring protocol that can be transferred to additive manufacturing stakeholders.

FACTORY OF THE FUTURE

©Cyrille Dupont

AUGMENTED

NDT ASSISTS HUMAN OPERATORS

Some non-destructive testing techniques are manual, which creates room to improve inspection traceability and quality. In industries like nuclear energy and oil and gas, for instance, inspection procedures are complex, and there is a shortage of experienced operators. In addition, inspection performance is generally not analyzed so that it can be improved.

Researchers at CEA-List are designing and developing new hardware and software to help human operators improve the performance and efficiency of their inspections. The new system is built on a high-performance industrial-grade software suite with motion tracking, augmented reality, and deep learning capabilities. Data from a variety of acquisition modes is synchronized, processed, and logged. 3D location data, which can be filtered depending on the inspection, is displayed in augmented reality using a third-party application.

TRANSFEROMETRY

TO MONITOR LOW-VOLTAGE ELECTRICAL DISTRIBUTION NETWORKS

Energy optimization in buildings—and, more generally, monitoring of electrical distribution networks—can support higher uptime, help protect people and property, and aid in managing energy consumption.

When it comes to industrial buildings and equipment, electrical distribution network monitoring is often addressed. However, the information obtained is not always as precise as it could be. CEA-List took measurements at a variety of industrial facilities, and used the information gathered to detect and locate soft defects (faulty insulation, hotspots, excessive bending, etc.). The study led to the development of an isolation module capable of performing reflectometry/transferometry on a live low-voltage network that could be used to deliver either partial or complete monitoring.

NON-DESTRUCTIVE AERIAL CABLE DIAGNOSTICS FOR

RTE

RTE, which manages France's electric power transmission grid, came to CEA-List for a cable diagnostic solution. To streamline its maintenance operations and qualify its service providers, the operator needed a proven diagnostic toolkit capable of assessing damage to the internal and external layers of aerial cables. The complex twisted structure and presence of multiple materials makes diagnosing cables particularly challenging.

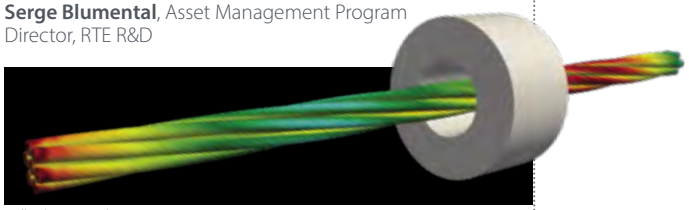
CEA-List brought its expertise in non-destructive testing to RTE's problem, opting for electromagnetic and guided ultrasonic wave inspection methods.

- CIVA was used to develop a software application for the inspection of aerial cables in which electromagnetic methods are used to determine sensitivity to relevant parameters and to identify the detection thresholds.
- Tests conducted using guided ultrasonic waves to interact with faults in internal and external cable layers were carried out successfully on a tension test bench. New simulation tools designed for multi-strand and twisted cable geometries are providing new insights intowhat goes on within the cables and how to interpret echoes.

The research will continue in 2022. For the electromagnetic inspection method, the evaluation of tools used by service providers will be completed. The researchers will also continue to explore the ultrasonic wave method's detection and measurement capabilities.

"The testing CEA-List did for us confirmed that our chosen non-destructive testing methods are the right ones. The simulationswere a great addition to what we can do on our tension test bench at Campus Transfo in Jonage, adding significant value to the evaluation of inspection quality and selectivity."

Serge Blumental, Asset Management Program Director, RTE R&D



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FOCUS

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GWENAËL TOULLELAN

Gwenaël Toullelan joined the instrumentation and sensors lab at CEA-List in 2004. The lab runs the non-destructive testing platform, whose equipment he helped design. He earned his Masters in applied physics in his home region of Brittany before moving on to Grenoble Alpes University for a postgraduate degree in applied physics, with a focus on ultrasound.

Today, he manages robotic non-destructive testing (NDT) projects that involve ultrasonic methods, including one to adapt a medical device for metal parts inspection.

"We specialize in developing methods you can't get off the shelf for very demanding use cases like nuclear power plant pipe inspection," said **Toullelan.**

"To create high-added-value solutions, we combine existing technologies developed by different CEA-List departments like NDT and robotics." The EIT Manufacturing FLEXNDT project to develop flexible, adaptive, and efficient NDT processes for manufacturing, which CEA-List is working on with cobot startup Isybot, is one example.

Toullelan, a musician with a keen interest in acoustics and sound engineering, has always been fascinated by sound and what it can do, so his affinity for ultrasonic technology is no surprise. At CEA-List a steady flow of new projects means there are always opportunities to explore. His next assignment: operational manager of SPRING, the CEA-List/Safran robotized NDT platform.

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SACHEMS PLATFORM NOW LIVE

Non-destructive testing plays a central role in maintenance strategies in aeronautics, rail, nuclear energy, and many other industries. This type of inspection—for cracks, corrosion, and other defects—is often done at regular intervals by either human operators or robots, and specific equipment must be brought to the site each time. A recent approach called structural health monitoring, or SHM, leverages sensors, electronics, and algorithms installed permanently on structures to deliver continuous monitoring—good for both safety and equipment uptime.

Spearheaded by CEA-List, SACHEMS is a new multi-partner platform for SHM research and innovation. Its mission is to provide academic research labs and companies with a place where they can come together around SHM and lay the foundations for a strong SHM industry with a global reach.

The development work done at SACHEMS will create new opportunities for the design, implementation, and testing of complete SHM systems on complex parts and structures representative of real-world use cases. The objective is to validate SHM software components.

SACHEMS is a crucible for SHM technologies, bringing together technological innovation, knowledge sharing, collaboration, and people. While the launch was delayed due to the pandemic, SACHEMS is fully up and running today.

INTERVIEW

Guillaume Laffont

Bastien Chapuis

FIBER OPTICS AND STRUCTURAL HEALTH MONITORING

Read what CEA-List's **Guillaume Laffont**, head of the Fiber Optic Sensor Lab, and **Bastien Chapuis**, structural health monitoring (SHM) expert at the Instrumentation and Sensors Lab, have to say about the advances made in SHM in 2021.

Guillaume Laffont: A fiber Bragg grating (FBG) is a type of fiber optic sensor used to measure physico-chemical parameters like temperature, deformation, and pressure. These sensors are suitable for a wide range of environments, including particularly harsh ones like measuring temperatures in aeronautics systems. And, because they are relatively non-intrusive and can measure multiple parameters on different kinds of structures, FBG sensors are of interest in a wide range of use cases, including SHM. The idea is to use the measurements to develop tools capable of predicting a structure's remaining lifespan and of monitoring defects like cracks, for example, during operation. And, when interrogated at high frequencies, FBGs can also be used as acoustic receivers in ultrasonic-wave-based systems that monitor what is happening below the surface of structural materials. This technology fills a gap that the piezo sensors typically used for SHM cannot. And there are other advantages, as well. First, because a single optical fiber can cover several measurement points, the monitoring system can be less intrusive. Second, FBGs can be used in high-temperature, radioactive, and other severe environments. The FBG acoustic receiver is an original approach we are investigating with Bastien Chapuis' team.

Bastien Chapuis: When used as acoustic receivers, FBGs enable multiplexing. This is what allows you to have several measurement points on the structure, for more reliable monitoring. In addition to the acoustic receiver application, we also combined FBG sensor measurements with passive analysis—a world first. Passive methods involve analyzing ultrasonic waves emitted by a structure, such as an aircraft engine, during operation to see how the waves propagate through the material. This information can then be used to detect the appearance of cracks, corrosion, and other structural defects. Our work with Guillaume Laffont and his team led to a successful demonstration of this use of passive analysis of ambient noise with FBG sensors. We were able to show that the underlying principle is valid and that the technologies chosen work, so that solutions combining passive analysis and FBGs can be developed for more complex structures. The exemplary cooperation between our two labs delivered one of the year's major advances. The challenge ahead of us now is to develop more mature solutions, including with R&D partners like Safran for the monitoring of composite structures used in aeronautics, and EDF for nuclear plant piping. We are also working more and more with academic partners like Gustave Eiffel University and Hauts de France Polytechnique on these topics, to name just two.

FACTORY OF THE FUTURE

CREATING SURFACE SOURCES

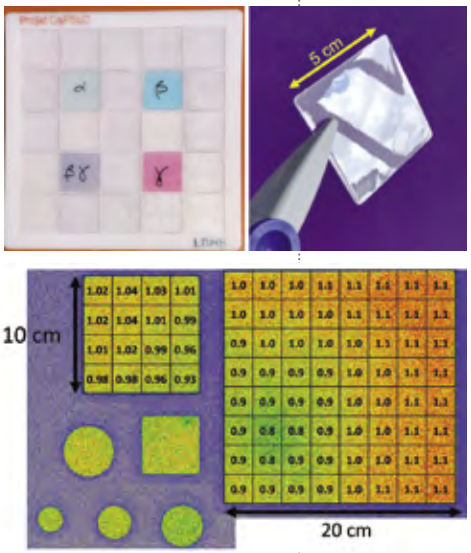
FOR THE CHARACTERIZATION OF RADIATION DETECTORS USED IN DECOMMISSIONING

For the operators of nuclear power plants, reactors, laboratories, and other facilities that use radiation, decommissioning presents a number of challenges. The process of dismantling equipment is costly and time consuming, of course. And then there is the issue of where to send waste for treatment.

CEA-List is developing, evaluating, and calibrating new surface radiation detectors—a task that can benefit from a library of reference sources as similar as possible to the kinds of contaminated surfaces encountered on decommissioning projects.

Our approach entails encapsulating a radionuclide in the reticulated network structure of an epoxy resin to obtain flat, curved, smooth, and rough surface sources varying in size from one to several hundred sq. cm. These reference sources are traceable to SI (International System of Units) measurements, are more than 90% uniform, and bear no labile surface contamination.

The method is easy to implement and a broad range of radionuclides—even volatile ones—can be incorporated, as long as they can be dissolved in liquid. Sources with a wide variety of shapes and surface roughnesses can also be obtained using special molds. With so many options, these non-contaminating reference surface sources are well-suited for use in the field, where conditions are much more severe than in the lab.



SMART CHEMICAL DETECTION

TO HELP LOCATE BURIED DISASTER VICTIMS

When an urban area is hit by an earthquake or other disaster, rescue workers need to proceed quickly and efficiently to find victims. Robots equipped with advanced detection capabilities and designed to navigate through rubble could soon join the sniffer dogs already used by search and rescue workers.

As part of the EU CURSOR project, CEA-List broke new ground with the world's first miniature robot equipped with a biosensor-based artificial nose. Commercially available gas sensors (like the ones used to measure exhaled CO2) and volatile organic compound sensors (which use proteins to link smells to human presence) do the sniffing, while a database of chemical markers is used to confirm the presence of living or deceased victims.

Throughout 2022, the detection module's performance and robustness will be tested so that the technology can be scaled up. The goal is to make sniffer robots an indispensable tool for first responders.

AQUASPEC:

NEW NEUTRON SPECTROMETER FOR THE MEASUREMENT OF RADIOACTIVE SOURCES

CEA-List developed a new neutron emission flux measurement system called Aquaspec to characterize radionuclide-based neutron sources. The system is built on a polyethylene container with a central channel for the radioactive source and twelve channels to hold Helium-3 counters and plastic scintillators that can discriminate between neutron and gamma radiation. The container is filled with water—a neutron moderator—during characterization so that the instruments can provide readings at different moderation distances. A regularized ML-EM (maximum likelihood-expectation maximization) or MAP-EM (maximum a posteriori-expectation maximization) algorithm that performs better than conventional ML-EM analyzes the counts.

Aquaspec provides a rich enough dataset to reconstruct the neutron spectrum without introducing an a priori known reference, resolving the issue of highly underdetermined problems. This is a major advantage over the usual Bonner sphere spectrometers. In addition, the Lithium-6-doped plastic scintillators used here were developed specifically to separate the fast and thermal neutrons in the same measurement. In 2021, Aquaspec was used to evaluate two methods:

- The conventional method of counting thermal neutrons with a Helium-3 counter and different moderation thicknesses in the measurement unit, similar to conventional spectrometers.
- An alternative method, using a Lithium-6-doped plastic scintillator to detect fast neutrons (direct measurement of the incident neutron energy via the recoil proton spectrum in the scintillator) and thermal neutrons (via the reaction on the Lithium-6).

The project is backed by France's national testing and measurement lab, LNE.

CEA-LIST STARTUPS

28
STARTUPS CREATED SINCE 2003

400
DIRECT JOBS

THE COMPANIES ON THESE PAGES WERE FOUNDED TO DEVELOP AND COMMERCIALIZE TECHNOLOGIES INVENTED IN OUR LABS. A PILLAR OF OUR TECH TRANSFER STRATEGY, OUR STARTUPS CONTINUE TO WORK CLOSELY WITH CEA-LIST. A TOTAL OF 28 STARTUPS HAVE BEEN CREATED SINCE 2003 FOR A TOTAL OF 400 NEW JOBS.

SNOWPACK

Snowpack, founded in May 2021, is developing a software layer for communication networks to make user data invisible. Data packets are split into anonymized fragments indistinguishable from noise and are then transmitted over separate pathways. This prevents hackers from reconstructing the original data or locating or identifying users. Snowpack offers a strong guarantee of privacy without raising the usual ethical concerns of this type of solution. Users (telecoms operators) can filter access to illegal websites and block fraudulent activity.

ALKALEE

Alkalee, a CEA-List spinoff created in 2020, offers a scalable suite of tools for easier implementation of software functions on complex embedded systems. In particular, the company's solutions help respond to strong demand for new embedded software functions in connected and autonomous vehicles. The company's Euphilia modeling and deployment tool, based on a Polygraph, a mathematically sound model, helps engineers design and ensure the safe integration of new functions. Its Receef embedded software development environment helps ensure the correct execution of software applications in the vehicle. Alkalee also offers a scalable computer called Koreel that can be expanded by adding daughter boards equipped with general-purpose processors or specialized (FPGA, GPU, many-core, etc.) accelerators. With Koreel, engineers can prototype embedded systems in a representative environment and verify system-level performance. Alkalee addresses the automotive industry and use cases like embedded AI and industrial vehicles that require scalable high-performance computers.

OUR STARTUPS BY INDUSTRY SERVED

AIHERD

AIHerd brings artificial intelligence to livestock management. The startup's solution allows dairy farmers to visually monitor their cows in real time. Using AI algorithms developed with CEA-List, AIHerd cameras installed inside dairy barns detect unusual behavior indicative of disease so that farmers can act fast and improve the welfare of their livestock. AIHerd is currently part of the SATT Paris Saclay business incubator. The company already has five employees and expects to generate €7 million in revenue in 2022.

CEA-LIST STARTUPS

HERE ARE SOME OF THE HIGHLIGHTS OF 2021 FROM SOME OF OUR FASTEST-GROWING STARTUPS.

ARCURE


©Arcure

With some 10,000 pedestrian-involved accidents on industrial and construction sites each year in Europe, Arcure's Blaxtair® pedestrian detection camera for industrial and construction vehicles responds to a real need. The company introduced Omega, a robust, high-resolution 3D sensor compatible with severe industrial environments, in 2018. In 2020 it introduced Blaxtair® Connect, which performs a predictive analysis on the data gathered by the Blaxtair® camera to improve risk management.

A CEA-List spinoff created in 2009, Arcure currently has around 60 employees, including around 20 engineers and PhDs. The company, which has been listed on Euronext Growth since 2019, reported revenue of €10.4 million in 2021, a year-on-year increase of 33%, mainly driven by strong growth on European markets outside France and in the US.

Arcure still has a joint lab with CEA-List that is currently developing novel image processing algorithms for new industrial and transportation use cases and plans to release a new version of its Blaxtair® camera in 2022.

Learn more

EXTENDE

Extende, founded in 2009 by a team of CEA-List engineers, is now the world leader in NDT simulation. The company is the distributor of CEA-List's CIVA simulation software and provides CIVA training and technical support. In addition to NDT-related services, the company also sells its own TraiNDE immersive NDT training tools.

France-based Extende opened a US subsidiary in Norfolk, VA, in 2011. Extende works with major companies in the nuclear, aeronautics, energy, mechanical, metallurgical, and probe manufacturing industries worldwide.

It currently has fifteen employees, including eleven scientists and engineers, and reported annual revenue of €3 million in 2021. With 350 companies in 40 countries using CIVA, 60% of Extende's sales are outside France.

Learn more

KALRAY

©Kalray

Kalray, a CEA-List and CEA-Leti spinoff, was founded in 2008. This fabless semiconductor company develops and commercializes smart data processors leveraging its patented MPPA® manycore architecture. Kalray's products enable smart, efficient, and energy-saving computing solutions for data centers, 5G, AI, Edge, and autonomous vehicles.

The company's annual revenue grew 41% to €1.5 million in 2021, despite the global semiconductor shortage. Today, Kalray's investors include Alliance Venture (Renault-Nissan-Mitsubishi), Safran, NXP Semiconductors, the CEA, and Bpifrance.

It developed the new Flashbox™ storage solution in 2021 with Viking Enterprise and recently announced its plans to acquire Arcapix Holdings LTD to strengthen its position on the intelligent data storage and processing market.

Visit the Kalray website

ISYBOT


©Isybot

ISYBOT designs collaborative robots based on technologies developed at CEA-List. The company brings unique mechanical capabilities that enable the robotization of repetitive manual tasks that are normally considered difficult to automate. Without making changes to the work environment, Isybot's interactive cobots provide agile, cost-effective automation with the flexibility and versatility needed to improve productivity and make operators' work easier.

Isybot provides pre-painting surface preparation solutions to customers in the aeronautics, rail, and shipbuilding industries. Founded in late 2016, Isybot recovered from a pandemic-related slowdown in 2021, reporting more than €1 million in revenue, expected to double in 2022. The company is also planning a new round of fundraising in 2022 to scale up a heavy-duty cobot—slated for release at the end of the year—and develop its export sales.

Visit the ISYBOT website

THE EVENTS THAT MARKED 2021

JANUARY

ENGIE, BUREAU VERITAS, AND THE CEA PARTNER ON A BLOCKCHAIN SOLUTION FOR GREEN ENERGY TRACEABILITY

CEA-List and Bureau Veritas used formal methods to validate smart contracts for startup ENGIE TEO (The Energy Origin), which offers a digital solution that provides consumers with a guarantee that the green energy they purchase really is green.

JANUARY

SNOWPACK ATTENDS TOP CYBERSECURITY EVENT

CEA-List startup Snowpack, founded in 2021, exhibited at the International Cybersecurity Forum (FIC) 2021, Europe's leading cybersecurity and digital trust event.

MARCH

EU HIPEAC NETWORK VISION 2021 REPORT PUBLISHED

According to CEA-List, AI will drive advances in cyberphysical systems. As a result, new solutions will be needed to ensure trust, autonomy, safety, security, and efficiency while limiting power consumption and environmental impacts.

JUNE

DIGITAL TWINS FOR TOMORROW'S FOOD PRODUCTION PLANTS

The CEA worked with Siemens and packaging equipment manufacturer Guelt on a digital twin tailored to the needs of France's largest industry: food manufacturing. It was unveiled at major French food industry supplier trade show CFIA, held in Rennes.

JULY

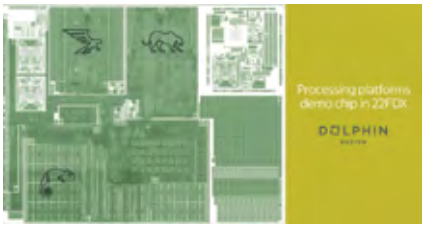
CONFIANCE.AI PROGRAM LAUNCH

This new program, which brings together thirteen French companies and research organizations, addresses the challenge of how to scale up AI systems for critical products and services.

JULY

DOLPHIN DESIGN AND CEA JOIN FORCES TO CREATE A NEW EMBEDDED AI PLATFORM

This new Edge AI solution combines software flexibility, energy efficiency, and performance. Built on CEA-List's PNeuro® hardware accelerator and Dolphin Design's processor solutions, the solution is used to embed AI functions on computing platform developed by the partners.



THE EVENTS THAT MARKED 2021

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SEPTEMBER

FRENCH GOVERNMENT SIGNS STRATEGIC PLAN FOR **INDUSTRY 4.0**

The French economy ministry's Agnès Pannier-Runacher and Frédéric Sanchez, chair of the government's industrial strategy committee, signed the nation's strategic plan for Industry 4.0 in a ceremony held at the Global Industrie trade show in Lyon.

SEPTEMBER

FRENCH GOVERNMENT CYBER CHALLENGE: TWO CEA-LIST PROJECTS SELECTED

The winning projects were: LEIA on automated software analysis for more secure IoT devices and IMRC on IoT device security for network-critical vulnerabilities.

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OCTOBER

FRENCH GOVERNMENT REPORT ON **AUTONOMOUS VEHICLE ROLLOUT IN EUROPE**

The report includes numerous references to CEA-List technologies for mobility, including a safe, trusted, cost-effective embedded AI solution developed with Valeo that can recognize all road users for tomorrow's driver assistance systems.

NOVEMBER

CEA-LIST JOINS **SOFTWARE HERITAGE**

CEA-List became the first strategic member of Software Heritage at the group's fifth anniversary held at UNESCO (the United Nations Educational, Scientific and Cultural Organization).

Software Heritage
THE GREAT LIBRARY OF SOURCE CODE

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DECEMBER

ORANO AND THE FACTORIES OF THE FUTURE

Orano and its partners kicked off a project to speed up the implementation of factory of the future solutions at the company's factories. The project's partners (eight companies and three research organizations) include CEA-List; small companies Aeraccess, Axionable, Diota, Ob'dO, Shark Robotics, and Sileane; large companies Predict, and Probayes; and universities École des Mines and Université Jean Monnet, both in Saint-Etienne.

AWARDS AND DISTINCTIONS

YUMAIN WINS EMBEDDED SYSTEMS AWARD IN IIOT AND SERVICES CATEGORY

CEA-List department head Fabien Clermidy gave startup Yumain an Embedded *France Trophée de l'Embarqué* award for E.C.S., a product that uses industrial vision sensors with embedded AI to detect and analyze worn or damaged pantographs.

RAFAËL PINOT

WINS PARIS DAUPHINE UNIVERSITY JUNIOR SCIENTIST AWARD

He won the award for his PhD research on trusted AI conducted at CEA-List in partnership with Paris-Dauphine University. His research addressed how to make neural networks more robust against antagonistic attacks (imperceptible disruptions voluntarily introduced into NNs by hackers).

WAISE BEST PAPER AWARD

Agnes Delaborde of LNE and Huascar Espinoza, Chokri Mraidha, and Prajit Rajendran of CEA-List won the award for their detailed review of human intervention methods in AI learning.

2021 RESEARCH AWARD

FROM FRANCE'S NATIONAL METROLOGY AND TESTING LAB

Anne de Vismes Ott of IRSN, Christophe Bobin of CEA-List, and Jérôme Bobin of CEA-IRFU won the award for their metrological approach to spectral unmixing for identifying radionuclides with low statistics.

AWARDS AND DISTINCTIONS

FRENCH GOVERNMENT INNOVATION AWARD FOR IA RÉPONSECONSO PROJECT

RéponseConso is the French government's automated consumer information system powered by CEA-List's hybrid AI-based classification solution.

EU SERENE-IOT PROJECT WINS

PENTA INNOVATION AWARD

The award goes to project to develop secure means for delivering high quality care services and connected diagnostic tools around smart medical equipment in hospital environments.

PARIS-SACLAY UNIVERSITY DOCTORAL SCHOOL

POSTER AWARD

Sharvanee Mauree, a PhD candidate studying innovative materials and their applications won the award for a poster on the synthesis of scintillating porous materials for the detection of radioactive gases.

PARIS-SACLAY UNIVERSITY DOCTORAL SCHOOL

DISSERTATION AWARD

Régis Pierrard, who studies complex systems engineering, won the award for his dissertation on artificial intelligence and, specifically, new methods based on the learning of fuzzy spatial relations.

AWARDS AND DISTINCTIONS

RESEARCH INTERNSHIP AWARD
FROM ÉCOLE POLYTECHNIQUE

Stéphane Latil, who interned with the Binsec software team at CEA-List, won this award for his idea for powerful and inexpensive protection against ROP cyberattacks, which execute parts of a system to bypass the usual protections.

DISTINGUISHED PAPER AWARD AT ICSE

A paper on aassembler code analysis authored by CEA-List's Frédéric Recoules, Sébastien Bardin, and Matthieu Lemerre won this award at the International Conference on Software Engineering.

NEW BOOK
PLASTIC SCINTILLATORS: CHEMISTRY AND APPLICATIONS
PUBLISHED BY SPRINGER NATURE

CEA-List engineer Matthieu Hamel and his team published a book on the state of the art of plastic scintillator chemistry and use for the detection of ionizing radiation.

REPORT ON
BARRIERS TO THE DEVELOPMENT OF BLOCKCHAIN

CEA-List contributed to this report published by the French government's Directorate General for Enterprise. It lists eighteen barriers to the development of blockchain technologies and makes fourteen recommendations (support for research, training, financing, partnerships) to drive the development of blockchain in France.

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