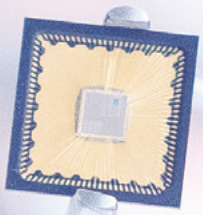

CEA TECH DAY

Deeptech solutions for tomorrow's products

_2023

Contents

ABOUT CEA

CEA, a leading international RTO

CEA is a leading international Research & Technology Organization (RTO) with deep expertise in micro and nanotechnologies and systems integration, smart digital systems design, and new energy technologies and nanomaterials. The technologies we develop enable more powerful, energy efficient, secure, sustainable, and manufacturable sensors, processors, and systems.

We are proud to count Intel, Applied Materials, HP, GlobalFoundries, STMicroelectronics, Mentor Graphics, and other big tech companies in the US among our long-term partners.

These companies turn to us for our demonstrated capacity to build complete systems and ensure a smooth transfer from our industrial-grade cleanrooms to their production facilities.

Our mission is to bridge the gap between early-stage research and R&D at higher levels of maturity to help our partners de-risk innovation by rapidly developing and integrating breakthrough technologies. We support faster time to market and add value to innovative products to bring you a clear business advantage and contribute to a better future.

Start innovating with CEA today!

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A global presence with offices in France, San Francisco, Brussels and Tokyo

€700+
million annual operating budget

4,500
employees

3,200
patents in portfolio

600+
new priority patent applications per year

30+
technology platforms

230
startups created

ISO 9001
certified since 2000

What CEA can do for your business

Did you know? Some of our partnerships have been going on for decades. Our satisfied R&D customers keep coming back for the smooth transition from our labs to their factories and for the continued year-on-year results we achieve together.

Here's how we can help you take high-value breakthrough concepts from proof-of-concept to volume-manufactured product with lower risk and faster time to market.

- **World-class R&D facilities** and cleanrooms for testing, prototyping, and test runs on industrial-grade pilot production lines
- The **multidisciplinary expertise** of thousands of scientists and engineers
- An **extensive IP portfolio** and **robust IP policy** that can include exclusive licensing agreements to protect your innovation and competitive advantage
- Proven experience and processes for **transferring new technologies** to the market for our partners and through CEA startups
- A **rich innovation ecosystem** that spans the entire value chain, from academic research to startups and established companies

With CEA as your R&D partner, you can count on:

A **clear IP policy** (that can include exclusive patent licenses in some cases) that places control over the technology transfer, manufacturing, and commercialization phases firmly in your hands. Our goal is to help you protect your position on your market.

Strict **confidentiality and robust data** protection throughout the duration of our partnership and beyond.

World-class facilities for:
- 12" nanoelectronics,
- 8" & 12" microsystems,
- IC and embedded systems design,
- nanocharacterization, photonics,
- sensor networks & connectivity,
- cybersecurity,
- nanobiotech,
- nanomaterials,
- printed electronics,
- and new energy technologies.

Plus, nearly **110,000 sq. ft. of cleanrooms and clinical testing** through our Clinatec biomedical research center in conjunction with Grenoble Grenoble Alpes University Medical Center.

CEA startups, your technology providers

CEA has spun off more than 200 startups to date. These deep tech ventures bring disruptive technologies based on major scientific breakthroughs to the market so that larger companies can integrate them into their products and services, effectively derisking their innovation projects and shortening the time it takes to get innovative new solutions to the market.

Emblematic CEA startups

Soitec
Founded in 1992, today a leading global semiconductor company and manufacturer of FD-SOI and other innovative substrates.

Lynred
Founded in 1986 as Sofradir, today a leading global manufacturer of infrared detectors for military, space, commercial, and consumer applications.

Notable exits

Bespoon
Acquired by STMicroelectronics in 2020.

Exagan
Majority stake acquired by STMicroelectronics in 2020.

Successful launches

Wormsensing—*founded in 2020*
Innovative plastronic circuits selected by automotive plastic supplier Novares for tomorrow's smart car dashboards with integrated touch functionality.

Wise Integration—*founded in 2020*
Innovative power electronics for more compact and energy-efficient chargers for mobile phones, e-bikes, data centers, and more.

Injectpower—*founded in 2020*
Ultra-miniaturized, easy-to-integrate rechargeable batteries with a ten-year-plus lifetime for autonomous medical devices.

230
startups created since 1972

75%
deeptech

9/10
of CEA startups make it to the ten-year mark

€1B
raised by CEA startups

+100
new startups by 2030

The CEA's new Magellan program is actively nurturing high-potential concepts developed in our labs to bring them to maturity through incubation and, later, fundraising. The goal is to create between 10 and 15 new startups per year for a total of 100 potential new technology providers on the market by 2030.

The CEA's startup policy is backed by venture capital fund SuperNova Invest, a partnership with Crédit Agricole which manages the CEA Investissement fund.

"Advances in micro-electronics at CEA are enabling new computing paradigms for secure, low-latency, low-power IoT solutions."

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MICROELECTRONICS

Edge AI, in-memory computing, and neuromorphic computing for smart, fast, compact, secure, low-power IoT devices

As embedded AI algorithms become more sophisticated, they also become more data intensive. In-memory computing dramatically reduces the power consumption associated with data transfer between memory and logic while helping keep data more secure. New non-volatile memory technologies that imitate the human brain's energy-efficient synapses are also driving new low-power solutions. CEA develops and integrates all these technologies for a range of IoT projects.

Edge AI—think smart sensors—is already here. It is what powers most IoT devices, which, instead of sending data to the cloud, process it right at the network "Edge." In other words, the computer is embedded inside the sensor itself. New paradigms like in-memory and neuromorphic computing and new kinds of algorithms like incremental machine learning are helping achieve the necessary reductions in power consumption to make these advanced embedded systems viable options for your IoT projects.

CEA has a complete range of technologies to develop and prototype your Edge AI and tinyML chips to bring your IoT projects to life.

Expertise spanning embedded memory devices and the associated architectures

CEA's **non-volatile memory** solutions include PCRAM, ReRAM, and FeRAM for embedded applications. R&D on SOT-RAM recently begun, with results expected in 2023. FeRAM, which is very low power and offers record endurance, is expected to replace DRAM for embedded and stand-alone uses. We are also working on Back-End-Of-Line selectors like OTS materials. These solutions enable more compact, stable memory devices.

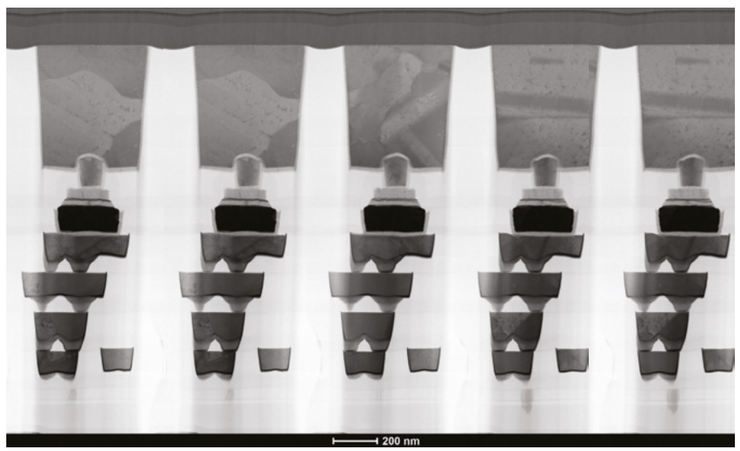
We can also bring our partners low-power, programmable in-memory computing architectures like **FPGA accelerators for deep neural networks** designed to reduce data transfers between processing elements and memory, for huge energy savings.

Our **bio-inspired computing solutions** include SPIKE neural networks that use non-volatile memory as synapses, ideal for low-power vision systems.

CEA produces advanced devices with Gate All Around Stacked Nano-Sheet (GAA) Field Effect Transistors (FETs) as well as advanced demonstrator circuits with FD-SOI CMOS for embedded applications with increased robustness to side-channel attacks.

CEA advantages for Edge AI

- Huge power savings
- Low latency
- Better resistance to hardware cyberattacks
- Solutions on foundry IP



Success stories

Dolphin Design's Tiny Raptor IP for IoT chip designers

This award-winning energy-efficient neural network AI accelerator designed for Edge AI deployment was developed with CEA through a joint R&D lab.

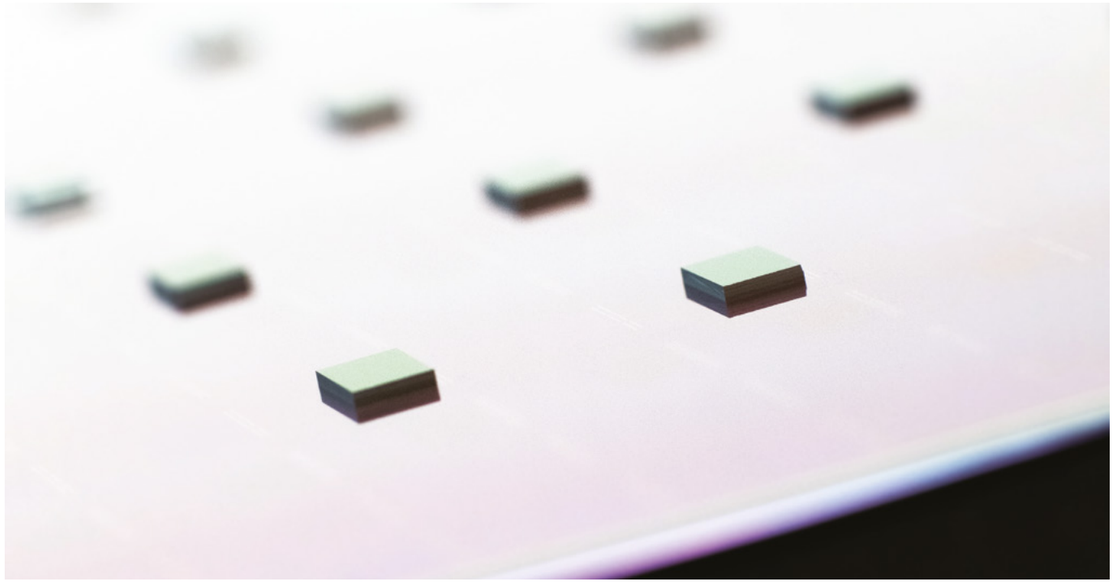
Weebit Nano new-generation ReRAM for smart devices

Israel-based Weebit Nano, founded by seasoned semiconductor industry experts, is a CEA R&D partner on ReRAM IP for SoC designs.

Spirit co-integrates analog spiking neurons and resistive synapses

It is the world's first fully-integrated neural-network-on-chip with non-volatile resistive memory.

Back-End-Of-Line RRAM Non-Volatile-Memory fabricated at CEA above CMOS



"Chiplets and 3D integration offer a one-to-many approach that lets manufacturers develop new products faster and more cost-effectively than with monolithic circuits."

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ADVANCED PACKAGING

Performance, power, size, weight, cost… The choice is yours!

As the limits of Moore's Law approach, advanced chip packaging has emerged as a solution for continued scaling. CEA offers a complete chiplet and 3D integration toolkit enabling a modular "one to many" approach that speeds up the development of new solutions for automotive, high-performance computing, data centers, imaging, and more.

Manufacturers in a wide range of industries can speed up the development of new products with a "one to many" approach that re-uses Lego-like modules. CEA possesses all the technologies needed to break up monolithic circuits into smaller, modular units called chiplets and reassemble, or "package" them into high-performance, low power 3D integrated circuits for specific use cases and families of chips that offer different levels of performance at different price points, from entry-level to high-end.

CEA's roadmaps for its chiplet and 3D integration technologies are totally aligned. This means that R&D partners can access innovative modular chiplet architectures and the processes to package the chiplets into 3D integrated circuits or families of circuits to meet a variety of needs without having to develop a specific complex circuit for each use case or implementation scenario. It is possible to pick and choose the features you need to reach the perfect tradeoff between criteria like data transfer rate and power consumption, for example.

Solutions for a wide range of industries

Die-to-wafer hybrid bonding is a 3D integration technique of interest to **display** and **imager** makers looking to pack in more pixels and manufacturers of processors for **high-performance computing** looking to boost data transfer rates while keeping power consumption low. In addition to advanced hybrid bonding, CEA offers a large toolbox of solutions such as through silicon vias, bumps, balls, copper pillars, redistribution layers and fan-out wafer-level packaging.

Car manufacturers are always on the lookout for fast, cost-effective ways to add new functions to a variety of vehicle types. CEA offers a baseline chiplet architecture that can be modified to meet specific for a chip or family of chips with a range of functionalities, from multimedia entertainment to advanced driver assistance systems.

Heterogeneous integration is ideal for **IoT sensing and signal processing circuits** built on separate sensing, processing, and memory components. CEA has a wide range of design and interconnection options available and can recommend the right combination for your specifications.

Circuit-to-circuit optical communication, which depends on the heterogeneous integration of photonic interposers and waveguides, will be the future of **high-performance computing** and sensing technologies like **LiDAR**.

Chiplets for simpler, faster, cheaper design	3D integration for more functions & greater performance
• Simpler design and development for faster, more cost-effective design and development • Lower manufacturing costs due to smaller circuits with higher yields • Greater flexibility to re-use modules for a range of chips within the same product family	• Different types of circuits (top-die & bottom-die) can be hybrid-bonded enabling more interconnects and smaller pixel pitches • Top-die circuits can be connected to the substrate using TSVs to connect the power supply, for example • Heterogenous bonding techniques allow different substrates to be combined

CEA's complete chiplet and 3D integration toolkit from design to integration can rapidly take you from concept to prototype.

Success stories

CEA & Intel unveil die-to-wafer self-assembly breakthrough using water

In a breakthrough for the future of die-to-wafer (D2W) bonding, CEA and Intel have optimized a hybrid direct-bonding, self-assembly process that has the potential to increase the alignment accuracy as well as fabrication throughput by several thousand dies per hour. The approach uses capillary forces of a water droplet to align dies on a target wafer.

European Processor Initiative (EPI)

The multi-partner EPI is developing a European processor for tomorrow's high-performance and Edge computing systems. CEA is working on advanced technologies to interconnect the chiplets in this future processor.

IntAct 3D stacked chip-based demonstrator system

The IntAct chip is a proof-of-concept prototype of the CEA chiplet and 3D chip toolkit, fully integrated into this functional chip. The technology bricks in IntAct can be transferred to CEA partners.

"Data transmission is a major energy consumer in all kinds of systems. Our high-performance, low-power, secure solutions address these challenges."

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DATA COMMUNICATIONS

Radiofrequency & silicon photonics for high-performance, low-power, secure data transmission

As the number of IoT connections continues to expand, new data communication link solutions will be needed to cope with the data deluge and enable a more sustainable digital (r)evolution.

CEA's datacom solutions are built on some of the most advanced radiofrequency (RF) and silicon photonic (SiPho) technologies available anywhere, for high-performance, low-power, secure data transfer over the air or using light.

Our RF devices are built on low-cost, off-the-shelf semiconductors, making them ideal for volume manufacturing scenarios. The difference is in CEA's innovative architectures, signal processing algorithms, and antennas.

In fact, antennas play a vital role in overall data transmission efficiency. We offer very advanced smart radiating elements to support new beam-forming/ beam-steering and reconfigurable surface technologies to limit costs and losses.

Silicon photonic devices transmit data using light. They improve power efficiency, latency and capacity of optical data links and can be manufactured using proven 12" wafer CMOS processes. CEA's photonic devices draw on our unique expertise in III-V materials integration using the most advanced deposition and bonding techniques around and state-of-the-art patterning technologies for increasingly tiny features.

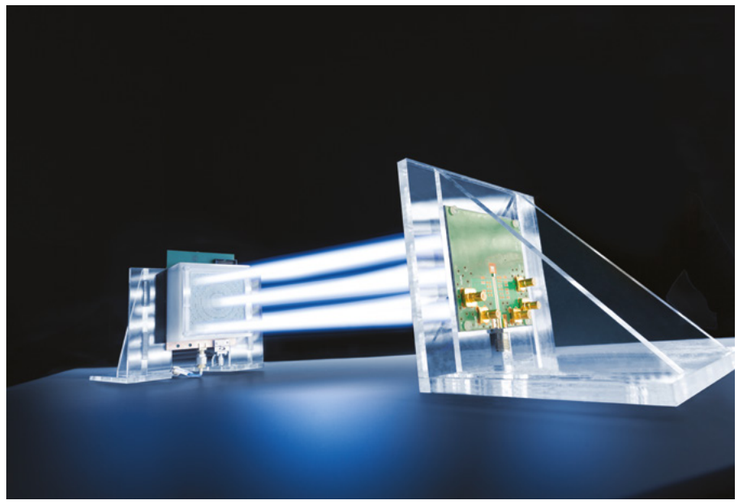
Datacom chips at or beyond the state of the art

CEA's RF devices address datacoms for mobility, IoT and object/asset tracking, and personal radar. Manufacturers like STMicroelectronics, Astrocast, Radiall, and Safran have developed new products or improved existing ones with our RF solutions. Our SiPho technologies are found in Scintil Photonics high-speed transceivers, and we are working on integrated pulsed lasers and low-power pJ phase shifters for spiking neural networks and ultra-low loss SiN photonic chips with integrated single-photon detection capabilities for secure quantum communication and computing.

CEA's state-of-the-art (and beyond) RF chips and systems leverage holistic architectures developed specifically to deliver high performance and very low power consumption from 1 GHz up to the sub-THz/140 GHz bands. Our very advanced packaging techniques enable high-density, low-loss chip designs, and highly efficient radiating antenna designs. We support complex modulation schemes and UWB data transmission for full CMOS implementation. We also possess all the IP blocks needed for the RFIC front end.

Our silicon photonics labs can produce 60 nm feature sizes on 12" SOI wafers with integrated Ge photodiodes, modulators, and III-V/Si lasers. We also possess expertise in packaging and photonic through-silicon vias, which allows us to create high-density interconnects.

With its enhanced RF performance, it is no surprise that Soitec's RF-SOI substrate and Smart Cut™ process, invented at CEA, are used to make the circuits and transmitter-receiver modules inside every smartphone on the market.



CEA has developed a first demonstrator that reaches speeds of up to 140 Gb/ s. This technology meets both high performance, low energy and low cost requirements

Success stories

Scintil Photonics pioneers high-speed transmission for data centers

This CEA startup develops silicon-based photonic integrated circuits and creates high-speed optical transmission solutions for data storage centers, high-performance computing, and 5G.

Astrocast nanosatellite network uses CEA RF chip

Astrocast worked with CEA to develop a low-cost, bidirectional communication module that companies can use to stay connected to remote assets in areas not covered by terrestrial networks.

HEALTH

Enabling technologies for health at all stages of life

Human and animal health and the environment are inextricably linked. CEA is developing enabling technologies to support an integrated approach that spans diagnostics, therapeutics, prevention, and monitoring.

We can bring proven sensors, lens-free imagers, biomaterials, microneedles, and microfluidics technologies to future products like wearables, implants, tools for pharmaceutical and biotech research and production, and exposome monitoring solutions.

For diagnostics and therapeutics, our R&D capabilities go right up to clinical trials with the Clinatec biomedical research center in conjunction with Grenoble Alpes University Medical Center.

"Our sensors, lens-free imagers, biomaterials, microneedles, and microfluidic circuits are making new diagnostic, therapeutic, and monitoring solutions possible."

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Integration of heterogeneous technologies into innovative systems

CEA leverages a wide portfolio of advanced sensors and transducers (PPG, GSR, bioimpedance, PMUT, OLED, and electrochemical) that can be integrated with the associated electronics and signal processing capabilities to measure multiple heterogeneous parameters simultaneously and extract relevant physiological information. Some examples of innovative devices:

- Optical and ultrasound measurements to monitor blood pressure continuously with no arm cuff
- Bioimpedance measurements to track body composition parameters like fat mass and hydration
- Innovative combinations of electrical and optical measurements to calculate mental states

CEA technologies are developed based on processes already in use in volume-manufacturing scenarios for innovative solutions that are easy to scale up.

Another example of solution is our microneedle technology based on absorbable polymers. We can fabricate microneedles on-demand for specific use cases like:

- Dissolving microneedle patches for timed-release drug delivery or painless vaccination
- Microneedle patches combined with sensors to measure interstitial fluid for diagnostic and monitoring purposes

Our microfluidic chips can be co-integrated with other devices like sensors and lensless imagers, for example, to monitor the functionality and viability of organoids-on-chip encapsulated within the chip and designed to replicate the in vivo functioning of specific human cells to:

- Speed up biotech and pharmaceutical discovery and development by anticipating safety and efficacy in humans, by screening multiple candidates on a single chip rather than on cells in traditional culture or on animals
- Personalize medical treatments for specific cases by testing a cancer treatment on a chip that replicates an individual patient's tumor, for example, before administering the most relevant treatment

Success stories

Diabeloop's implantable blood sugar monitor with integrated insulin pump

This medical device is already helping people with diabetes around the world. The closed-loop system with an embedded algorithm co-developed by CEA helps patients and caregivers manage treatment more efficiently.

Exposome monitoring in factories, cities, and more

Direct Analysis is detecting pathogens and allergens in food manufacturing plants and Apix Analytics is monitoring urban air quality. A new project will result in an in-room monitoring unit, already proven on SARS CoV-2, that can detect pathogens in the air.

Medical wearables and implants for treatment and monitoring

Urgotech is commercializing an EEG headset for in-home sleep improvement. The FollowKnee instrumented knee implant is reducing complications after knee-replacement surgery. The NIR project is using light to stop Parkinson's disease. The BCI (Brain-Computer Interface) project is developing a thought-controlled exoskeleton to get patients with spinal-cord injuries walking.

“The ability to print devices on materials like paper and stretchable, conformable plastics opens the door to a wide range of innovative smart products.”

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FLEXIBLE ELECTRONICS

2D and 3D smart surfaces for total design freedom

Integrating electronics into materials enables more compact and durable product designs for IoT, medical, and automotive systems. CEA can print and bond electronics on a variety of substrates for 2D and 3D conformable and even stretchable surfaces.

If a sensor can be printed, it can be manufactured affordably and integrated easily! CEA offers screen printing, gravure printing, and slot-die printing for electronic components affordable enough for volume manufacturing scenarios. If you have an idea for a smart surface, smart object tracking tag, or thin conformable sensor, CEA can make it a reality.

Our facilities offer a wide range of sensors, designs, and patterning for thin, flexible, easy-to-integrate multi-sensor solutions for a wide range of use cases. We have a 1,000 sq. m clean room for sheet-to-sheet processing of 320 mm × 380 mm substrates. Stretchable/flexible antennas, EEG/ECG electrodes, strain gauges, humidity sensors, and piezoelectric sensors can be printed; microcontrollers, bare dies, thin batteries, and LEDs can be embedded.

Components can be printed on glass; on flexible polyimide films, polycarbonate, or PET; on conformable TPU; and on stretchable silicone. Our experts can help you choose the right substrate for the desired final specifications and thermal budget.

Electronics are now flexible, conformable, and stretchable

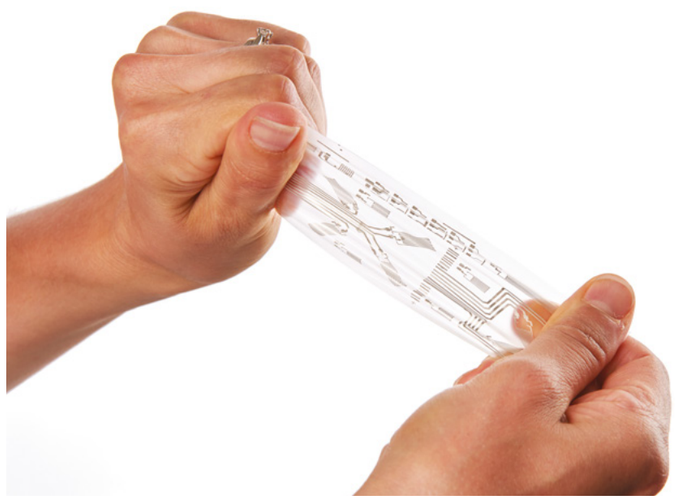
In a world where batteries are everywhere, tiny, easy-to-integrate solutions can help batteries perform better and last longer through preventive maintenance. Printed electronics can be used to make multi-sensor structural health monitoring devices: Multiple printed acoustic and temperature sensors can be fabricated on a single thin substrate for a cost-effective and easy-to-integrate battery monitoring solution that can detect degradation and failure mechanisms before loss of performance, enabling a new generation of battery management system (BMS).

Wearable devices are another area where flexible, stretchable electronic components are a plus! Printed electronics make it possible to manufacture low-cost, multi-sensor devices like patches that monitor several physiological parameters.

The automotive industry is looking to plastronics to respond to a number of challenges. Smart substrates can be manufactured using printing techniques, thermoformed, and then over-molded to obtain final 3D products like smart car dashboards free from mechanical buttons.

We are also developing flexible electronics leveraging techniques like additive manufacturing and sustainable bio-based substrates and inks to support the objectives of the European Green Deal.

From smart car dashboards to flexible, comfortable wearable medical devices, plastronics and printed electronics take integration to new levels.



Success stories

Cardiac and respiratory monitoring patch

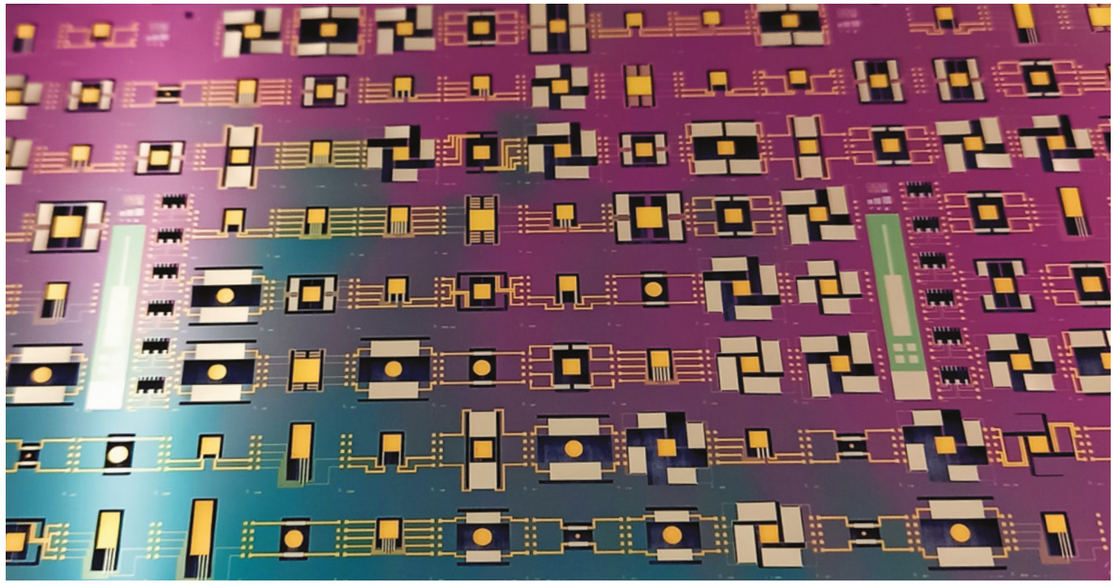
CEA and PLUX developed a wearable cardiac and respiratory monitoring demonstrator for the EU SmartEES project. CEA developed printed ECG electrodes, strain gauges, and conductive tracks on a single stretchable substrate. The demonstrator shows the potential of stretchable, conformable, biocompatible, and compact printed and hybrid electronics for sports, wellness, and medical applications.

Isorg on-display fingerprint sensor

This CEA startup’s large-area image sensors for the smartphone and security markets leverage photodiodes printed on a variety of substrates for up-to-four-finger biometric fingerprint scanners. The technology also addresses smart inventory management.

Symbiose plastronics for button-free controls

Developed with CEA, the startup’s in-mold electronic (IME) components offer a more durable, less bulky, and more affordable alternative to mechanical buttons for human-machine interfaces.



"Today's perception systems call for multiple sensors. M&NEMS devices enable smaller, more cost-effective devices that respond to this need."

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MEMS AND NEMS SENSORS & ACTUATORS

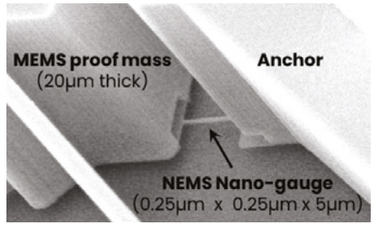
Enabling technologies for small, lightweight, cost-effective devices

MEMS and NEMS—micro- and nano-electromechanical systems—are tiny devices like sensors, actuators, and micromirror arrays, with moving parts that are sensitive to a physical quantity like speed, pressure, or direction. They convert this physical quantity into an electrical signal, which can, in some cases, operate an integrated micro-actuator.

CEA's M&NEMS technology, based on piezoresistive detection using silicon nanowires (nanogauges), technology offers many advantages over capacitive sensors, from a better linear response to less sensitivity to parasitic capacitances and enhanced performance.

Our new MEMS micromirror with piezoelectric actuation allows the mirror reflector material to be adjusted to the final application. One of the advantages of this MEMS micromirror is an operating voltage of just 20 V, compared to 150 V for conventional electromagnetically-actuated micromirrors.

Finally, our capacitive (CMUT) and piezoelectric (PMUT) components with neural-network-based AI can generate, receive, and process ultrasound signals.



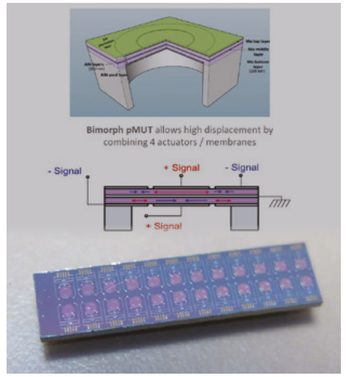
Devices compatible with the demands of ubiquitous sensing...

CEA's **M&NEMS multi-sensor platform** enables multi-accelerometer, gyrometer, and pressure sensor devices with a variety of use cases, including environmental monitoring, medical devices, robotics, the Factory of the Future, defense and security, gaming and other consumer electronics.

Solid-state devices are of particular interest for automotive perception systems. Increasingly autonomous vehicles will contain more and more cameras and sensors, and LiDAR (light detection and ranging) is the frontrunner for long-range perception.

CEA's 2D MEMS micromirrors, developed for the EU VIZTA project, enable a **miniaturized MEMS-based LiDAR sensor** that is more compact and less expensive than conventional LiDAR sensors. This means that redundant sensors can be implemented to improve safety.

Ultrasonic smart sensors are useful in automotive perception systems, of course, but also in simultaneous location and mapping (SLAM) systems used to orchestrate robots in the Factory of the Future, as well as for medical applications.

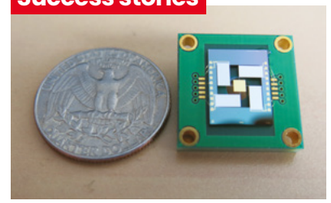


Piezoelectric MEMS micromirrors offer several advantages over electromagnetic and electrostatic micromirrors, not least of which is their much lower operating voltage.

Focus on automotive perception systems

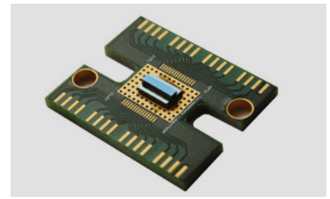
Conventional LiDAR	Miniaturized MEMS LiDAR
• Bulky & expensive • Difficult to interface with other sensors • Possible safety issues	• Small, lightweight, and affordable, so many more sensors can be used for redundant image capture • The ability to use more sensors is a good tradeoff for the lower image quality than conventional LiDAR • Can be co-integrated or interfaced with other sensors to further increase safety by monitoring temperature or protecting pedestrians from the laser

Success stories



MEMS LiDAR

CEA developped a 2D MEMS micromirror that can withstand high laser power. An ongoing collaboration with BEAMAGING aims at integrating this MEMS into a solid state LiDAR. This work is supported by the ECSEL Joint Undertaking.



Apix Analytics

The technology was invented by CEA and Caltech and is now transferred to Apix Analytics. It features a miniature chromoatography column machined on silicon to separate the gases in the sample. The gases are then detected by nanoresonators NEMS that vibrate at a given frequency.
The surface of each nanoresonator is coated with a chemical layer that promotes the adsorption of specific molecules. The adsorbed molecules increase the resonator's mass and consequently modify its resonating frequency thus allowing to determine the concentration of each component in a gaz sample.

"Imaging and display technologies are playing a growing role in systems that address everything from cars to smart homes to computer-assisted surgery."

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IMAGERS & DISPLAYS

Technologies for the entire image chain from capture to processing to display…

While imaging is now virtually ubiquitous in our day-to-day lives, developing new imager and display technologies capable of meeting increasingly stringent requirements is still a challenge. Whether it is for autonomous vehicles, medical diagnostics, or IoT devices for smart homes, CEA uses an integrated approach to the image chain, and can provide advanced technologies designed to work seamlessly together.

Imaging sensors are so intriguing because—increasingly—they replicate the very rich human sense of sight's ability to create a faithful representation of the world around us. Ideally, we would capture images everywhere! But there are a number of challenges to overcome first, not least of which is energy consumption. CEA's near-sensor computing strategies can help consumer component and systems manufacturers lower the energy consumption of their smart building and other IoT products.

Displays are another key component of the image chain. CEA is leading the way in microLED technology for next-generation lighting and display components, from the very tiny (think smart glasses) to the very large. From smart lighting to automotive and XR displays, CEA's display R&D spans materials, processes, devices, and systems to bring our partners more pixels, higher-quality images, and new features like transparent, foldable, and self-powered displays.

Lighter-weight, brighter, smarter, more energy-efficient…

Smart image sensors are the future of the IoT. CEA's, µWAI smart imager offers low-power "always on" performance with smart wake-up capabilities. Its compact neural network reconstructs images with limited data. More complex algorithms can be integrated for smart building, automotive, and other applications.

CEA also develops **wavefront imagers** that can "see" through human tissue or focus a laser beam on tissue to destroy or stimulate it. Our adaptive imaging solutions can "correct" optical variations, eliminating the need for bulky, heavy mirrors in systems like ground telescopes.

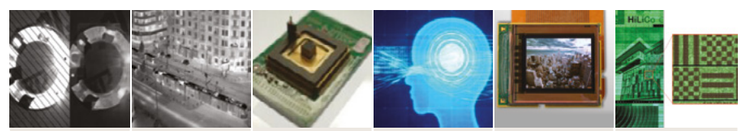
Our 5M fps high-speed image sensor and 5.5k fps-85GOPS smart imager are two other examples of solutions we have developed to bring new levels of performance beyond the state of the art.

Head-up displays and **head-mounted displays** must be tiny or transparent or both! CEA's GaN microLEDs are bringing pixel pitches towards 1 µm and pushing brightness to new heights.

We are uniquely positioned to bring you advanced technologies that can be manufactured at scale using our own process equipment, from epitaxy reactors to a full III-V semiconductor line, simulation and characterization equipment, and a LED die packaging line, to develop the solutions you need.

CEA offers a wide range of 2D and 3D, multicolor, and multi-energy imaging technologies with near-sensor computing capabilities that enable AI functions. Our microLED displays are miniaturized, transparent, or both, for integration into advanced systems.

CEA imaging and display technologies



Pixel	Readout circuits	Signal conditioning	Algo & image processing	ICs for emissive & photonic devices	Light sources
• Low noise • HDR • Multi-tap • Multi spectral filters	• Infrared ROICs • APD & LiDAR readout	• Light shaping & demodulation • X-ray CT-scan • THz imaging	• Archi & for integrated vision systems • Low-power inference • 3D imaging	• Display • OPA • LiFi	• GaN • QCEL

Success stories

SEEL: smart imager for ORIOMA's LOBX

The SEEL ultra-low-power sensor was developed at CEA and transferred to ORIOMA for its smart sensor LOBX, where it enabled a 10X to 100X gain in power efficiency. The sensor can produce useful data like the number of people in a room for power consumption of just 1 mW, making it ideal for smart building, smart city, and UAV/drone applications.

µWAI autonomous imager

This is the first-ever µW-class compact recognition engine in a smart image sensor. Developed with STMicroelectronics, it can activate any device upon recognition of a specific pattern, such as capturing a face to unlock a phone. CEA can adapt this technology to numerous other use cases.

MicroLED array for head-up aeronautics displays and augmented reality systems

CEA developed a microLED array for head-up aeronautics displays in research for the Clean Sky 2 JU H2020 Hilico project. An array with 1,750 x 1,200 pixels at a 9.5 µm pitch obtained a record brightness of 1,000,000 cd/m². CEA also demonstrated that a 1 µm pitch, essential for AR, is possible.

"Energy is now a strategic topic in the C-suite. CEA energy technologies can help organizations be more sustainable and resilient, reduce their costs and carbon footprint, and manage flexibility."

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ENERGY OPTIMIZATION

Renewable energy production, energy storage, and energy system optimization technologies...

With the effects of climate change more visible than ever, energy is now a pillar of virtually every organization's strategy, whether it is making their products or their own operations more energy-efficient. CEA develops technologies across the energy value chain, from making more innovative solar cells to designing advanced software to optimize entire energy systems for greater resilience.

CEA develops advanced technologies for the energy transition. Our labs are innovating at every scale from nanomaterials for energy production and storage to futuristic conformable plastics with integrated solar panels for products that produce their own energy.

We use our knowledge of every material and component inside complex multi-energy systems to generate databases and models like those that power our PERSEE energy optimization software for complex systems.

In today's energy landscape, new solutions are needed at every scale—from individual products like electric vehicles to factories and data centers to entire cities—to integrate more renewable energy. CEA can help increase system robustness and flexibility by combining multiple energy vectors like electricity, heat, cold, natural gas, and hydrogen; ensure greater flexibility and connectivity for V2G and V2H solutions; enable self-consumption; allow prosumers to feed energy into grids of all scales; and, ultimately, increase energy efficiency and reduce the overall environmental footprint.

24/7 carbon-neutral data centers could soon be a reality—yours!

One of CEA's flagship energy-efficiency solutions is its PERSEE energy optimization software, which targets both the design and operation phases. It is a technology-agnostic tool used to maximize energy savings and minimize carbon emissions. Data centers can leverage PERSEE to reduce the costs associated with downtime risk mitigation, ensure cost containment amid fluctuating energy prices, and take concrete action toward greater sustainability. PERSEE has already helped put industrial manufacturing and oil & gas plants on the path to zero emissions while minimizing CapEx and OpEx.

PERSEE leverages CEA's in-depth knowledge of complex, multi-vector energy systems and their components, including hardware. It recommends the best combination of energy bricks for minimal CapEx, OpEx, and carbon emissions and/or other KPIs. The initial study takes a few months, and ROI is rapid and massive. Once PERSEE is applied to a test perimeter, it can be easily expanded organization-wide.

CEA technologies for the energy transition

Solution	Results
PERSEE energy system optimization software for industrial facilities and data centers	Dramatically lower energy consumption and carbon emissions quickly and cost-effectively
Integrated solar photovoltaic systems	Integrate PV production into electric vehicles, for longer range and a smaller carbon footprint
Decarbonized energy storage (on-board and stationary batteries, cold, heat, hydrogen)	Store energy over various time horizons to enable V2G and V2H connectivity, increase flexibility, and boost the use of renewable energy in any energy system
Innovative cooling systems	Produce cold from waste process heat to reduce GHG emissions
Water management systems	Align your facilities with circular economy principles by recycling process water

CEA energy efficiency and resilient energy management technologies can help facilities like factories and data centers and products like cars dramatically lower their energy consumption and carbon emissions through increased integration of renewable energy, waste heat conversion, energy storage.

Success stories

PERSEE puts factory on path to zero emissions

A $1 billion organic cosmetics company implemented PERSEE on an energy system using electricity, heat, steam, and cold, plus process water treatment. Without PERSEE, business-as-usual would have let to +36% carbon emissions within ten years. With PERSEE, the plant will reduce its carbon emissions by 88% at equivalent NPV.

Solar Hood advanced vehicle-integrated PV demonstrator

CEA and Stellantis developed a light-weight, glass-free solar car hood presented at CES 2023. The cost-effective, high-performance heterojunction PV cells are integrated into thermoplastic materials that can be molded into 3D shapes offering total design freedom.

Oil&Gas: decarbonation of liquid natural gas production

A multi-billion-dollar oil & gas engineering company came to CEA to decarbonize their complex (multi-location, multi-energy-source, multi-production-technology) LNG operations. PERSEE recommended several energy architectures combining wind, PV, heat, and battery storage to lower CO_2 emissions by 50% to 85% for a 5% to 50% NPV increase over business as usual.

Interested in these technologies?

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cea leti

Miniaturization technologies

cea liten

Sustainable energy technologies

cea list

Smart digital systems

Supported by the Carnot network of French RTOs

CARNOT Research for industrial innovation

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