ANNUAL REPORT 2019

Building tomorrow's society today

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ANNUAL REPORT 2019

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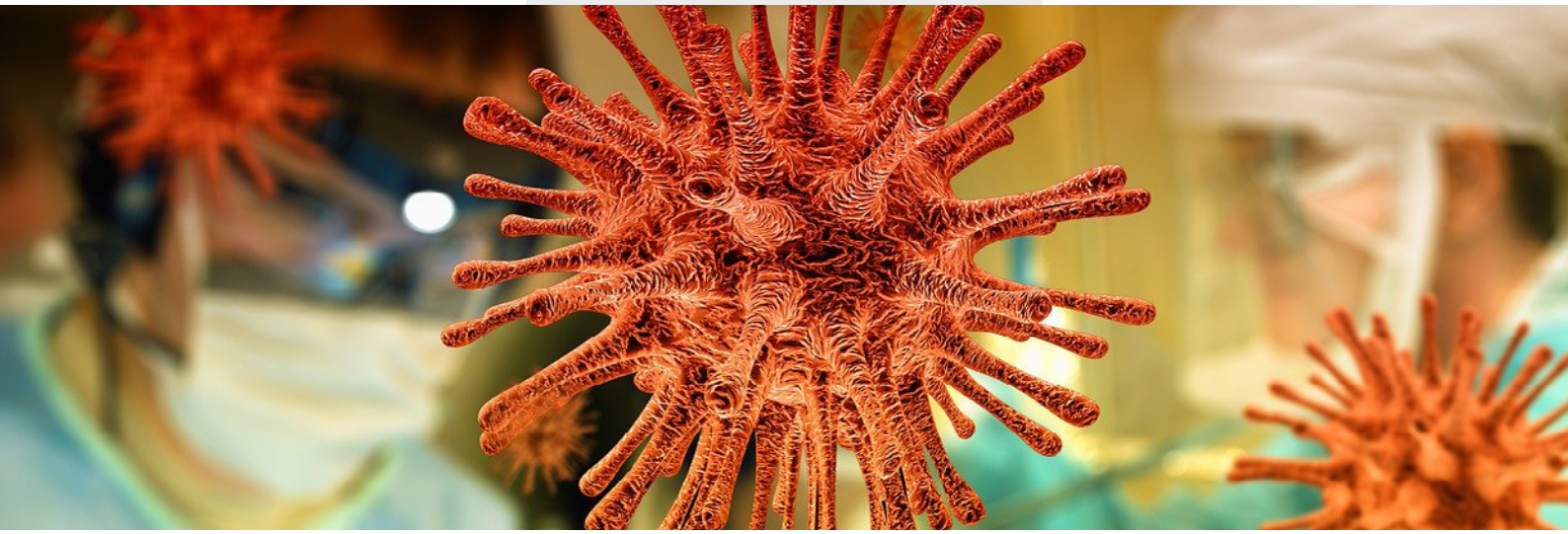


Foreword

When we began preparing this annual report, there was not yet any sign of the health crisis that has gripped France in the last months. But at the time of the report's publication, we feel it is important to give a brief overview of what the CEA has been doing to help combat the virus.

— The CEA rapidly mobilised its teams to carry out research on detection tests, as well as trials on the virus and antiviral medications, and also to contribute technology (devices for emergency respiratory support, instruments for measuring viral exposure rates, reusable masks, etc.).

Alongside this contribution, which demonstrates its responsiveness and agility, the CEA continued to work in its five main areas: nuclear and renewable energy (production, energy efficiency and performance), defence and security, digital transformation, technologies for the medicine of the future, and fundamental research. Without forgetting the clean-up and dismantling of its facilities, which constitutes a significant challenge for the coming years.

This is what is illustrated by the excellent results achieved in 2019, which are presented in this document. And it will be illustrated by the work being done in 2020 as part of the national post-crisis recovery effort.

Key figures 2019

See all the CEA's key figures as at 31 December 2019

STAFF NUMBERS

20,181
employees
1,233 doctoral and
176 post-doctoral researchers
1,334 work-study students

BUDGET

5
billion euros
(civil and defence)

PUBLICATIONS

5,045
papers
in peer-reviewed
journals

TECHNOLOGY TRANSFER

Leading patent applicant
among research bodies in France

Leading French patent applicant
in Europe

6,980 active
patent families

216 technology startups
created since 1971
including **89 startups** since 2010

PARTNERSHIPS

39 research units
under the joint supervision of the CEA and academic partners

More than 700 industrial
partners

56 competitiveness clusters
in which the CEA participates, including
16 administered by the CEA

444 European projects
11 FP7 projects - **433** H2020 projects

Organisation

To fulfil the missions assigned to it by the public authorities, the CEA relies on four operational divisions active at 10 sites in France, supported by a number of functional departments. The functional departments provide all the CEA's support services: finance and programmes; human resources and staff relations; communication, legal affairs and disputes; purchasing and partnerships; international relations; auditing, risks and internal control.

4 OPERATIONAL DIVISIONS

MILITARY APPLICATIONS DIVISION (DAM)	NUCLEAR ENERGY DIVISION (DEN)	TECHNOLOGICAL RESEARCH DIVISION (DRT)	FUNDAMENTAL RESEARCH DIVISION (DRF)
MORE INFO	MORE INFO	MORE INFO	MORE INFO

6 MISSIONS

- DEFENCE AND SECURITY
- ENERGY
- DIGITAL TRANSITION
- MEDICINE OF THE FUTURE
- FUNDAMENTAL RESEARCH
- CLEAN-UP DISMANTLING

LOCATION OF THE CEA'S SITES

10 CEA sites in France

1 Headquarters

Civil research centres

2 Paris-Saclay
Fontenay-aux-Roses and Saclay establishments

3 Grenoble

4 Marcoule

5 Cadarache

Centres for military applications

6 DAM Île de France

7 Le Ripault

8 Valduc

9 Cesta

10 Gramat

THE CEA IN BRIEF

Military Applications Division (DAM)

The CEA's **Military Applications Division (DAM)** is responsible for missions supporting France's defence and security. It designs, manufactures and guarantees the safety and reliability of its deterrent nuclear warheads. It designs and makes the nuclear steam supply systems that power the French Navy's vessels. It also provides technical support to the authorities in the fight against nuclear proliferation and terrorism. In addition, it uses its expertise for the benefit of defence to assess and understand the effects and vulnerability of conventional weapons.

IN FIGURES...

5 030
staff members
(including 136 doctoral researchers, 30 post-doctoral researchers and 214 work-study students)

450
scientific publications

Nuclear Energy Division (DEN)

The **Nuclear Energy Division (DEN)** provides the public authorities and industry with expertise and innovation to develop sustainable, safe and economically competitive nuclear energy. To do this, the DEN works in three main areas :

1/ providing support to the French nuclear industry for the current fleet of reactors, the startup of the EPR, and the fuel cycle facilities;
2/ clean-up and dismantling of its own nuclear facilities at the end of their life;
3/ development of the nuclear systems of the future with the Generation IV reactors to close the fuel cycle and with the SMR (Small Modular Reactor) for greater flexibility and to develop internationally.

Its research is based on the development of validated predictive simulation tools and on a fleet of targeted experimental facilities.

In 2019, to meet energy and climate targets more effectively, the CEA conducted a reflection process on a comprehensive approach to a low-carbon energy system and decided to strengthen the links between its various energy research projects. The aim was to look at all methods of producing low-carbon energy (nuclear energy, renewable energy), their interaction within the network (storage, management, conversion), and the problem of resources in relation to closed-loop materials cycles, while taking account of the technical, economic and societal dimensions. This reflection process led in particular to the creation in February 2020 of the **Energy Division.**

IN FIGURES...

4 899
taff members
(including 320 doctoral researchers, 44 post-doctoral researchers and 211 work-study students)

502
scientific publications

THE CEA IN BRIEF

Technological Research Division (DRT)

The CEA's **Technological Research Division (DRT)** uses the institution's scientific advances to develop technological innovations that boost the competitiveness of French companies through product performance and differentiation. The DRT develops, protects and transfers technologies in areas ranging in scope from traditional industries to the most advanced high-tech sectors, and works with companies of all sizes. This effort is deployed in all regions of France, where it supports local businesses in their approach to innovation. The CEA thus contributes to creating value and long-term jobs nationwide, wherever they are needed by industry.

IN FIGURES...

4 500
staff members

600
industrial partners

600
patents applied for each year

Fundamental Research Division (DRF)

The CEA's **Fundamental Research Division (DRF)** works in the fields of biotechnologies and health, the physical sciences and earth sciences, physics and the nanosciences. Its core objectives are the production and publication of knowledge and expertise at the highest global level. Its work also constitutes an essential source for the CEA's other missions.

IN FIGURES...

6 500
staff members
(CEA, partners, doctoral researchers, etc.)

3 800
scientific publications
(≈ 73% with international contributions)

THE CEA'S MISSIONS

Building tomorrow's society today

FROM RESEARCH TO INDUSTRY

As a leading player in research, development and innovation, the CEA is active in six main areas: national defence and security, nuclear and renewable energies, biotechnological and medical research, technological research for industry, fundamental research (physical sciences and life sciences) and clean-up and dismantling of nuclear facilities.

DISCOVER THE 6 CEA'S MISSIONS

DEFENCE AND SECURITY

ENERGY

DIGITAL TRANSITION

MEDICINE OF THE FUTURE

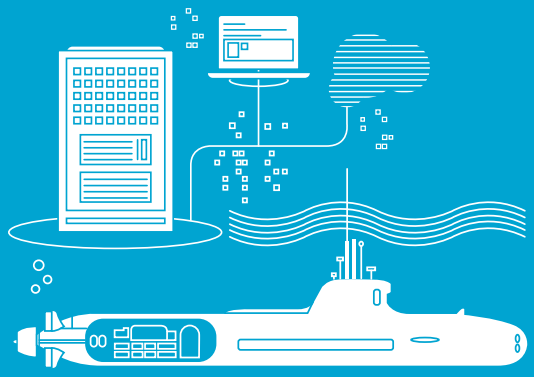
FUNDAMENTAL RESEARCH

CLEAN-UP AND DISMANTLING

Defence et security

The CEA uses its expertise for the benefit of defence and national security by focusing on two main missions:

- responding to the challenges of nuclear deterrence (nuclear weapons, nuclear reactors for naval propulsion, the fight against nuclear proliferation),
- providing technical support (surveillance, analysis) to the public authorities in the fight against terrorism, tsunami alerts and support for conventional defence.



Missions fulfilled by the teams at the Military Applications Division (DAM)

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Key events 2019

Simulation Programme

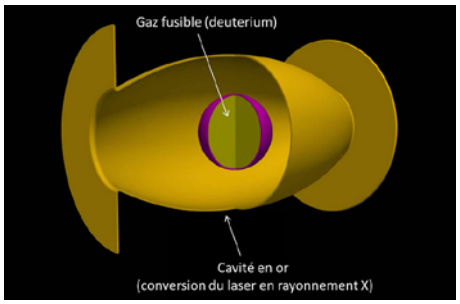
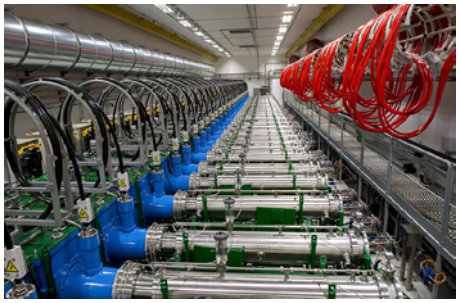


Diagram of the target used for the first fusion experiment with the Megajoule Laser. © CEA-DAM

First successful fusion experiment

— The first nuclear fusion experiment on the Megajoule Laser was successfully run on 11 October 2019. This success marks a major milestone in the Simulation programme to guarantee French nuclear weapons. The experiment consisted of causing the implosion of a millimetre-sized ball filled with deuterium within a gold cavity heated by 48 laser beams, producing three-dimensional irradiation of the tiny ball. Fusion is evidenced by the production of neutrons; several hundreds of billions of them were measured in accordance with calculated predictions, including 3D simulations.



X-ray machine in the Epure facility at CEA-Valduc.
© CEA-DAM

Celebration of the 10th French experiment at Epure

— On 4 July 2019, at the CEA centre at Valduc, the CEA's Director of Military Applications marked the operational success of Epure in a ceremony, following completion of the 10th French experiment. All the experiments conducted in Epure since it was commissioned in 2014 have been successful. The ceremony was attended by the Director of Nuclear Weapons, the Director of the CEA centre at Valduc, the project manager and all the technical and support teams behind the remarkable achievement of Epure and the experiments conducted there to guarantee nuclear weapons. Epure comes under the Franco-British Teutatès Treaty signed in 2010.

Nuclear propulsion

Inauguration ceremony of the Suffren in Cherbourg on 12 July 2019.
© CEA-DAM

Criticality of the nuclear steam supply system in the first "Barracuda"

— Following the inauguration of the Suffren, the first Barracuda class nuclear-powered attack submarine, in Cherbourg on 12 July 2019, attended by the French President, a major milestone was reached on 17 December 2019 when its reactor went critical, a prelude to its first tests at sea prior to delivery in 2020. Going critical means achieving a controlled nuclear reaction in the core for the first time. The design of the Suffren's nuclear steam supply system was CEA-DAM's responsibility as part of the overall Barracuda programme run by France's defence procurement agency, the DGA. This success illustrates France's capacity (both the State and industry) to bring complex projects to completion.

Fight against nuclear proliferation

Commissioning of the last French station contributing to the CTBT

— The last of 24 French geophysics stations contributing to the Comprehensive Nuclear Test Ban Treaty (CTBT), the IS25 infrasound measuring station, was commissioned in December 2019. Once it has been certified by the CTBT Organization, France will be the first country to complete its contribution to the network of stations in the CTBTO's detection system. IS25, which is in Guadeloupe, consists of nine measurement sites connected by optical fibre and equipped with acquisition equipment developed by CEA-DAM. All the infrastructure work required was carried out in such a way as to minimise its environmental impact.

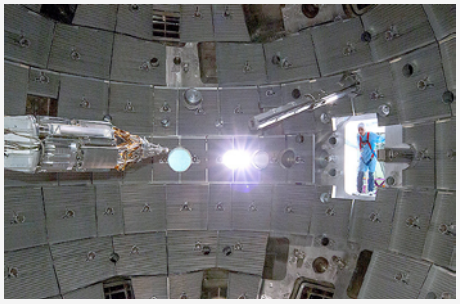
Image showing an infrasound station and a microbarometer used to measure variations in atmospheric pressure. © CEA-DAM

Defence resources for civil requirements

The "Minerve", a Daphné class attack submarine, on the Loire in 1962.
© Maison des Hommes et des Techniques

Decisive contribution to the discovery of the Minerva submarine© wreck

— On 27 January 1968, the submarine Minerve and its 52 crew members disappeared 45 km off the coast of Toulon. At the time, CEA-DAM recorded seismic signals attributed to the accident, but the technical resources available at the time could not precisely locate the wreck. In March 2019, at the Ministry of the Armed Forces' request, CEA-DAM carried out a new analysis of its recordings. Current expertise and calculation methods identified a new search area. These data, coupled with data from the French Navy and its Hydrographic and Oceanographic Service, meant that new searches could be carried out and on 21 July, the wreck of the submarine Minerve was finally found on the seabed, at a depth of 2,370 m.



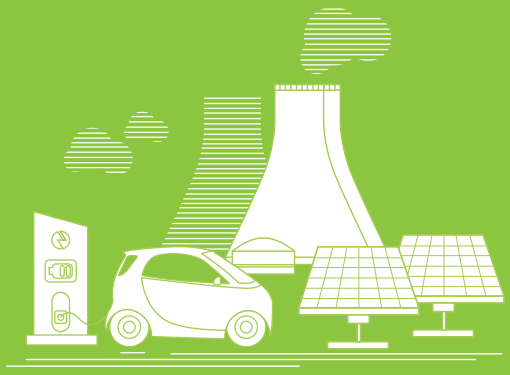
The Megajoule Laser (LMJ) is a major facility of the Simulation programme, which relies also on the Epure facility and the Tera supercomputer.
© CEA/MS-BEVIEW

New experimental campaigns for academic research on LMJ-PETAL

— As part of a policy to open up CEA-DAM's simulation tools, two experimental campaigns were run at the LMJ-PETAL facility between April and May 2019 by academic teams, in collaboration with CEA-DAM. The first led to the creation of a point X-ray source using the petawatt PETAL laser, in preparation for X-ray testing during experiments planned in 2020, and the second observed the reconnection of magnetic field lines under inertial confinement fusion conditions. The proton radiographs obtained with PETAL are of exceptional quality. Only the LMJ-PETAL facility can carry out this type of experiment with the required precision.

Energy

Through its unique positioning in France as an expert research organisation in the fields of nuclear and renewable energy and digital technology, the CEA is at the forefront of the energy transition needed to combat climate change. Accordingly, it conducts research into energy production methods (nuclear, renewables) and energy efficiency and performance.



Missions performed by all the CEA's operational divisions, most notably teams at the Nuclear Energy Division, which recently became the Energy Division.

NUCLEAR ENERGY DIVISION (DEN)

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Energy transition

Perovskite single crystal grown in solution
© Dominique GUILLAUDIN/CEA

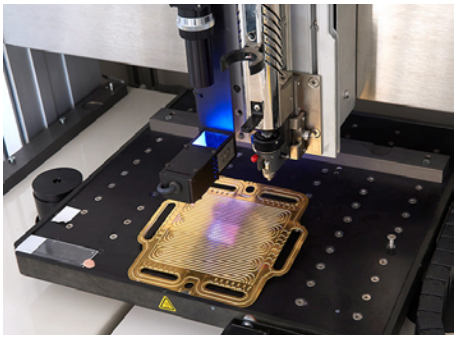
Promising technologies for future generations of photovoltaic cells

— In 10 years, the performance of photovoltaic (PV) cells made from halogenated **perovskites*** has improved substantially to more than 25% efficiency for **single-junction*** architectures in laboratory-scale devices and processes. For these technologies to become an industrial reality, the priority now is to produce them on a larger area and improve their stability in the long term.
2019 saw the first major breakthrough by the CEA with the manufacture of perovskite modules of more than 20% efficiency on 11 cm², which is the best performance worldwide on this area. In parallel, perovskite/silicon **heterojunction*** tandem cells have demonstrated active area efficiencies of more than 22% on 5x5 cm² substrates, heralding future PV generations of more than 30% efficiency.

Perovskite*
A light-sensitive mineral species described in 1839

Single junction*
Photovoltaic cell obtained using silicon applied in one wafer (a single active layer)

Heterojunction*
Combination of two different semiconducting materials

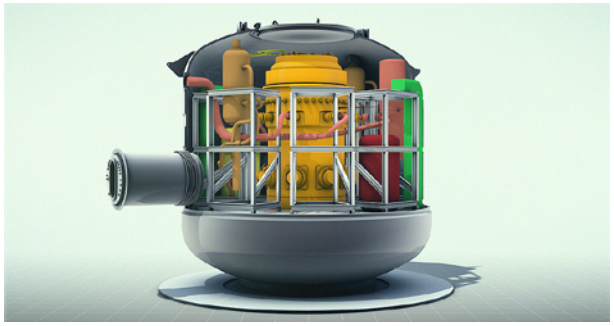


Dispensing equipment for the deposition of bipolar plate joints (PEMFC) © Dominique GUILLAUDIN/CEA

Printed PEMFCs make a big impression!

— The use of printing has many advantages when making the plates for the PEMFCs (proton-exchange membrane fuel cells) that teams at the CEA have been working on for more than ten years: lower costs, finer and more compact components, increased power density of new architectures. CEA-Liten has validated an ultra-compact 100 cm² geometry integrating flow fields with a pattern size of 400 microns. Its production was made possible by the use of a screen printing process. In 2019, about 60 flow field circuits were printed in a robust, reproducible way, enabling various validation and assembly tests to be carried out on the first functional stack of 19 cells, which delivered 1 kW of power.

Aside from its versatility, this printing process paves the way for ultra-compact designs with much higher power densities and specific energies than PEMFCs developed using traditional processes, opening up new prospects for hydrogen-powered transport applications (drones, light vehicles, etc.).



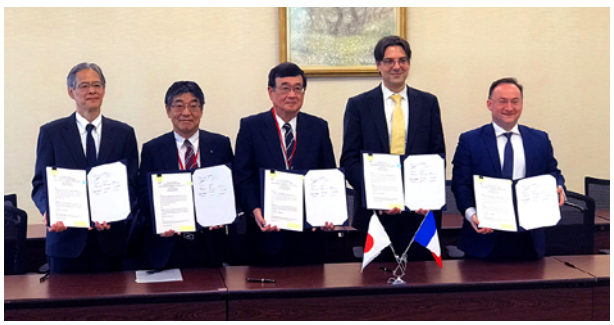
Modelling of an SMR by TechnicAtome. © TechnicAtome

The CEA strengthens its partnerships on SMRs

— The CEA, EDF, Naval Group and TechnicAtome unveiled Nuward™, the French joint Small Modular Reactor (SMR) project. The solution is based on pressurized water reactor technology but will incorporate several major innovations: the simplicity and compactness of an integrated design, flexibility during the construction and operation phases, compliance with the best global safety standards. At international level, the CEA, EDF and Westinghouse Electric Company signed a framework agreement to explore cooperation on the development of SMRs. Under the terms of this agreement, the signatories will look into the possibility of pooling the expertise gained in the Nuward™ project with expertise from the design of Westinghouse's SMR. A detailed road map is expected in 2020.

Restructuring of the CEA's programmes

— Following the decision to postpone construction of the Astrid demonstrator, the CEA restructured its research programme on Generation IV sodium-cooled fast reactors (SFR). Capitalising on all the project's achievements so far, the programme is now structured around three priority areas of R&D: numerical modelling and simulation; definition and qualification of innovative technologies; conceptual designs for other Generation IV reactor architectures and technologies. At the same time, a report was compiled to mark the end of the Astrid programme and record the findings of its 10 years of research. The CEA also signed a collaboration agreement with Japan on the development of SFRs.

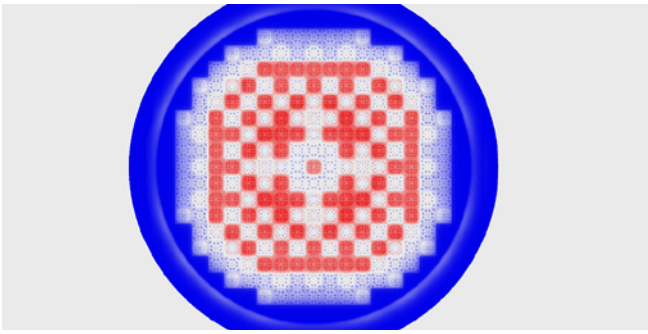


Signature of a collaboration agreement between the CEA and Japan on the development of SFRs. © CEA

Operation to assemble the reactor block in the JHR at Cadarache. © TechnicAtome

New phase in the construction of the Jules Horowitz reactor

— In 2019, the Jules Horowitz (JHR) reactor passed some major civil engineering milestones, in particular with the finalisation of the reactor cavity by TechnicAtome and Cegelec. The very challenging operation to install a stainless steel liner in the cavity demanded many innovations such as new welding techniques and anchoring systems with very high mechanical performance. This step marked the beginning of a new phase of the project: the assembly of the major components. Assembly of the reactor block began in September with parts prefabricated in a factory ready for final assembly on site, in a clean environment compliant with stringent regulations. Finally, the year closed with the assembly of the three primary heat exchangers, designed and fabricated as a contribution in kind by Spanish partners (led by the Spanish research institute CIEMAT).



Core simulation for the Flamanville EPR, providing precise neutronics parameters of interest. © CEA

Support for the Taishan EPR and preparation for the startup of the Flamanville EPR

— Following the startup testing of the Taishan **EPR*** in 2018, EDF and Framatome called upon the CEA to carry out further assessments of the nuclear data and impact studies of several core configurations of interest. In particular this work related to the effective cross-sections of uranium-238 reactions. Functionalities recently incorporated by the CEA into its **neutronics*** computer codes were used for these assessments. They provide access to neutronics parameters of interest with a higher degree of precision than the industrial calculation schemes of EDF and Framatome. This work will also contribute to preparations for the startup of the Flamanville EPR, in which the CEA will be involved especially when the physical tests of the core are carried out.

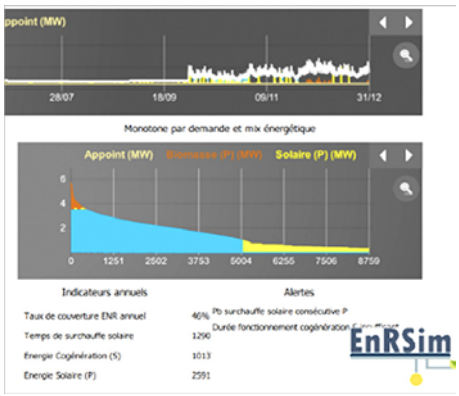
EPR (European Pressurized Reactor)*
Generation III pressurized water reactor. It was developed as part of a Franco-German collaboration that lasted for more than 10 years, with the aim of being safer, more competitive and more environmentally friendly. The Taishan EPR is a Chinese nuclear power plant situated 120 km southwest of Hong Kong. Its first two reactors were started up in 2018 and 2019 respectively.

Neutronics (or neutron physics)*
Study of neutrons passing through matter and the reactions they cause, particularly the generation of power through fission of the nuclei of heavy atoms. This discipline is particularly closely related to the design and monitoring of nuclear reactors to study neutron multiplication, and the establishment and control of chain reactions.
Find out more

Solar car project fitted with solar panels in its bodywork. © CEA

Solar car hits the accelerator

— Everyone pile into a solar car! By integrating photovoltaic panels directly into the bodywork, the CEA is accelerating the solar car project being run with Technopolys and EM-Project. Manufacture, performance, appearance, ability to capture solar power, durability and life cycle: teams at CEA-Liten have made considerable progress in all these areas, having designed, developed and integrated the first solar modules (rigid, curved and glass-free) into a C-Zen Electric. Manufactured by the company Courb, and fitted with panels using silicon cells integrated directly into its bodywork, this vehicle already outdoes current solutions in terms of performance and appearance. The vehicle's average gain from solar has been estimated, with supporting measurements, at more than 4 km per day on average, peaking in summer at more than 10 km/day (2 km/day in winter).

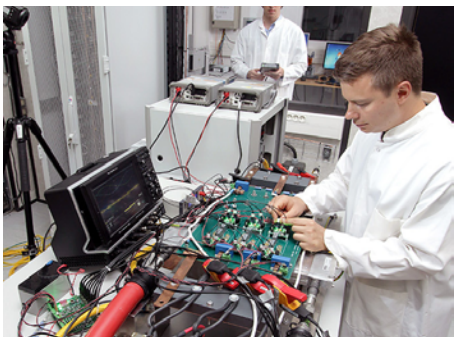


EnRSim software interface. © CEA

EnRSim manages renewable energy production for heating systems

— To increase the share of renewable energy used for heating systems, Ademe commissioned CEA-Liten and its partners to develop an open source software for use by design departments and local councils.
This computing tool, named EnRSim, is used for dimensioning facilities that produce multiple renewable energies for heating systems: biomass, solar thermal, heat pumps and thermal storage. Developed using the **Modelica*** language, EnRSim's computing core is based on the District Heating library developed by the CEA. With its user-friendly interface, the tool can calculate the energy mix of multi-renewable energy production plants, integrating modules for pre-processing the heating system's energy load and for analysing the environmental and economic results.

Modelica*
Object-oriented programming language designed for practical modelling of complex systems.

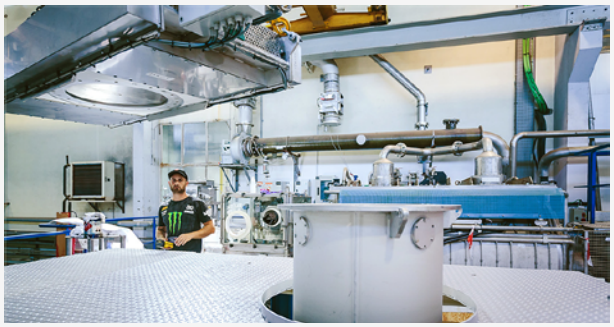


Full SiC voltage source converter for 1500V PV applications. © Patrick AVAVIAN/CEA

Current source inverter or renewal of the power converter

— Producing more renewable energies is good, but combining this with a high performance power conversion system is even better! For this reason, the CEA is developing special power converters with architectures and technologies tailored to cost, reliability and photovoltaic (PV) efficiency constraints. The chosen solution, which is original and innovative, combines an old architecture, the current source inverter (just one conversion stage compared with two in traditional voltage source inverters, and an inductor for input storage), with a recent technology consisting of silicon carbide (SiC) semiconductors. Its increased operating frequency and high efficiency combined with an optimised switching topology and stray inductance control have produced a highly efficient and very compact inverter, achieving a power density of 10 kW/litre compared to around 1 kW/litre for the best solutions available on the market.

Waste management



Pivic process prototype on the CEA site at Marcoule. © S.Le Couster/CEA

Optimised lithium-ion battery recycling

— By dissecting the process of dissolving the metals — cobalt, nickel, manganese and lithium — in Li-ion batteries, the CEA has designed an optimised recycling method for these batteries, cutting effluents by 40%, the stages involved by 35% and the chemical reagents needed by 40%! The process therefore minimises the environmental impact of Li-ion batteries and meets regulatory requirements, while improving the yield of the recycling process. Other benefits? It reduces the risk of dependence on "critical" elements like cobalt, and the thorny problem of supply difficulties. The process is not only of interest to industrial companies like Orano, but also paves the way for the development of new battery precursors.

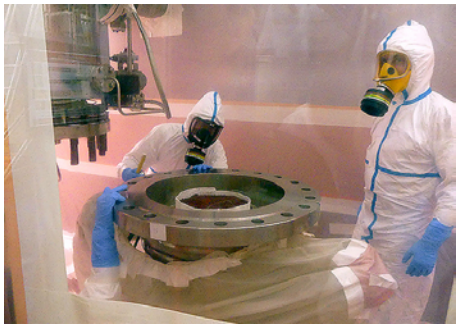
18650 format Li-ion batteries.
© Dominique GUILLAUDIN/CEA

Technological demonstration of an in-can incineration/vitrification process

— The Pivic in-can incineration/vitrification process, developed by the CEA in partnership with Orano and Andra under the Investments for the Future programme, will be used for the treatment and conditioning of mixed technological waste (i.e. both organic and metallic waste). This waste, contaminated by alpha emitters, is produced by the activities of the Melox (recycling) and La Hague (disposal) plants. In October 2019, the first full test was successfully carried out on a prototype built and started up at the Marcoule site. All the industrial targets set by Orano, particularly in terms of the waste treatment rate, were met.

Radioactive waste is characterised by:
- **the type of radioelements it contains, the radiation emitted (alpha, beta, gamma), and its activity (number of atomic nuclei that decay spontaneously per unit of time, expressed in Becquerels),**
- **its half-life (time necessary for the activity of a radioelement in a sample to reduce by half).**

Safety & security

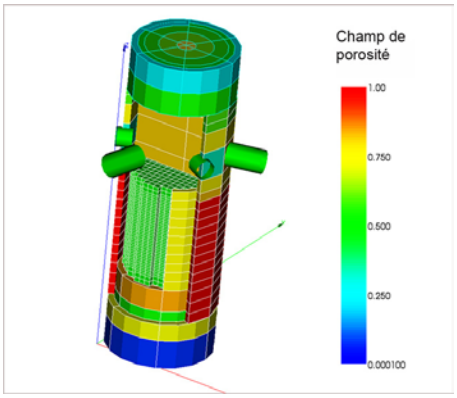


Installation of the device at the Plinius facility in Cadarache. © CEA

Success of the first corium reflooding experiment

— The CEA successfully carried out the first **corium*** reflooding as part of an Investments for the Future programme conducted in partnership with EDF and Framatome. It was done at the Plinius facility in Cadarache and involved melting 74 kg of «prototypical» corium consisting of depleted uranium, which was then covered with 90 litres of water. The aim was to study the cooling and solidification of the corium under conditions that represent a severe accident in a pressurized water reactor. The results will be used for modelling heat exchanges between the corium and the water, with the eventual aim of validating computer codes for corium-concrete interaction.

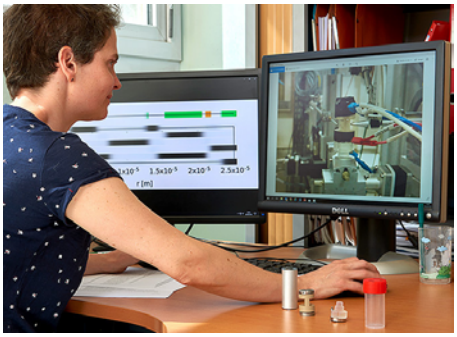
Corium*
Liquid mixture consisting particularly of fuel and molten elements of the core of a reactor in a severe accident.



3D mesh of a PWR reactor vessel for a computation with Cathare 3. © CEA

Delivery of the first industrial version of the CATHARE 3 thermohydraulics code

— The first industrial version of the CATHARE 3 thermohydraulics safety code was delivered at the end of 2019 and welcomed by all partners. This version has been verified and validated for pressurized water reactor (PWR) applications. It has a wealth of new features, including an overhauled software architecture, the possibility of modelling different components of a PWR reactor vessel using 3D modules, and better description of dispersed flows for modelling droplet fields. The next version, which is already being discussed, will apply not only to PWRs but also to experimental reactors and nuclear propulsion systems.



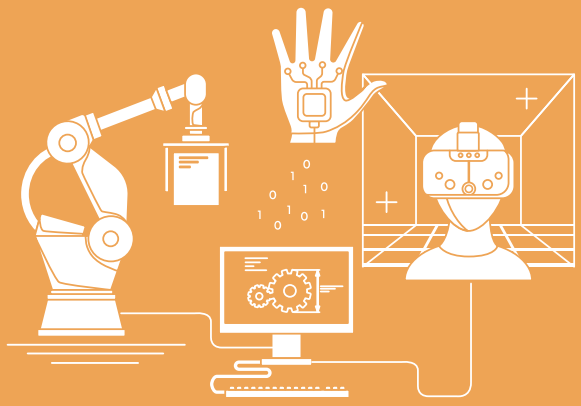
Modelling for batteries. Simulation of lithium intercalation in graphite.
© Dominique GUILLAUDIN/CEA

Platform for understanding and designing safer batteries

— The battery test platform, which was commissioned in 2019, enhances CEA-Liten's approach to battery innovation, in which safety plays a central role. Run jointly with the company SERMA Technologies, the platform offers a combination of simulation/modelling resources and equipment for understanding physical phenomena, along with dedicated teams. The equipment is designed for tests on single batteries or modules of up to 1,000 Wh. The resources cover battery preparation and instrumentation, testing under extreme conditions (cycling, short-circuit, penetration, overheating) and post-mortem battery characterisation and analysis. Combining experimental and simulation results significantly enhances the value of modelling tool input data and predictive tool output data, providing a much more detailed understanding of how batteries function.

Digital transition

Through its research on the atom and more generally on low carbon energies, over time the CEA has gained cutting-edge expertise in electronics and digital technologies. It also has unique capabilities for designing, building and managing innovative technology platforms that benefit the scientific and industrial community.



Missions performed by the Technological and Fundamental Research Divisions

The CEA's **Technological Research Division (DRT)** uses the institution's scientific advances to develop technological innovations that boost the competitiveness of French companies through product performance and differentiation. The DRT develops, protects and transfers technologies in areas ranging in scope from traditional industries to the most advanced high-tech sectors, and works with companies of all sizes. This effort is deployed in all regions of France, where it supports local businesses in their approach to innovation. The CEA thus contributes to creating value and long-term jobs nationwide, wherever they are needed by industry.

The CEA's **Fundamental Research Division (DRF)** works in the fields of biotechnologies and health, the physical sciences and earth sciences, physics and the nanosciences. Its core objectives are the production and publication of knowledge and expertise at the highest global level. Its work also constitutes an essential source for the CEA's other missions.

Key events 2019

Information technologies

Illustration of the blockchain concept. © denisismagilov

A less energy-hungry blockchain

— Blockchain technology, of which bitcoin is one of the best known use cases, meets every one of the strategic challenges of storing numerical data and transmitting them in a decentralised, transparent, secure and tamper-proof way. However, bitcoin consensus protocol validation times are too long and too energy-hungry to be used in the industrial sector, or even in banking. To meet these sectors' needs, researchers at CEA-List looked to another existing protocol, Tendermint, correcting its last few flaws. They also removed obstacles to building a blockchain and improved the process so that it would cope with problems such as viruses.

Spirit demonstrator - Spiking neural networks enabling massive parallel, low power and low latency computations. © folienfeuer

Spirit, the first on-chip neural network

— This on-chip neural network, baptised Spirit, is largely inspired by brain function. Like "real" neurons, Spirit uses unary coding (rather than the binary coding usually used in digital electronics). Each event adds weight to the relationship between two neurons until a firing threshold is reached. Another biological similarity is the ultrafast resistive memory or ReRAM installed on the chip, which avoids energy-hungry data transmission, cutting consumption by a factor of (at least) five. Spirit is a first step towards chips designed specifically for "deep learning" solutions; it combines performance and low energy consumption, one of the main pathways to the computing of the future. The next step is a new version of Spirit in 28 nm technology.

Human-machine interface

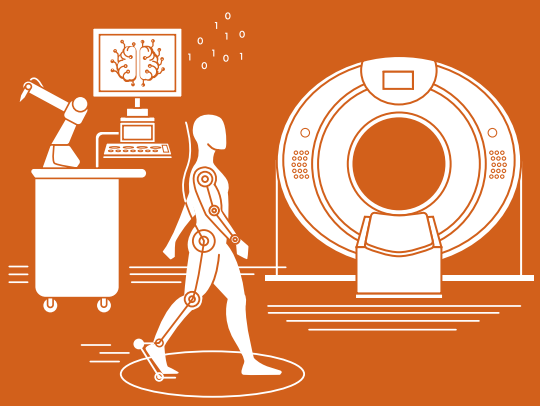
Tractor spraying a soy field in spring © Dusan Kostic

Simplifying tractor control

— Farm machinery is more powerful than ever and packs in more features, making it increasingly complex. Leading global equipment manufacturer AGCO turned to CEA-List for help developing simpler control interfaces. Its teams developed a «2.0 control wheel» which combines an on-screen visual display with tactile feedback for the driver. This ingenious rotating knob reacts to obstacles encountered by the tractor, can be configured to provide increasing resistance based on the forces the tractor is subject to and, depending on the case, emits vibrating alerts. Having obtained proof of concept in real conditions, the CEA presented a variant of this technology in the form of a joystick, at CES event in Las Vegas in January 2020.

Medicine of the future

The CEA has been involved since its creation in biological and health research. Over the years it has also become a key player in France in the design and integration of innovative technologies in the field of medicine of the future.



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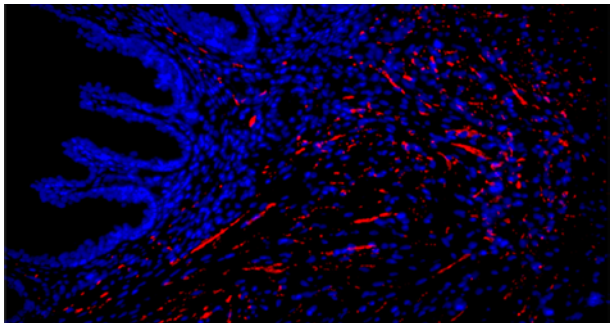
Key events 2019

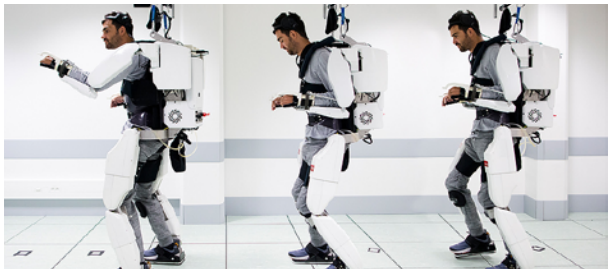
Neurosciences



Network of adrenergic nerves (in red) in high-risk prostate cancer tumours. © Science

How the brain plays a role in cancer

— The production of new neurons is a fairly rare event in adults, restricted, it was believed, to two particular regions of the brain: the dentate gyrus in the hippocampus and the subventricular zone. A team from CEA/Inserm proved this assumption wrong by showing that new neurons are also produced outside the central nervous system, in tumours. They thus contribute to cancer development. These nerve cells come from progenitors in the brain and are carried in the blood system. This surprising discovery paves the way for a completely new research field related to the nervous system's role in cancer development and to the interactions between the vascular, immune and nervous systems in tumour formation.
Find out more



Clinatec exoskeleton demonstration. © Juliette Treillet

The Clinatec exoskeleton: 14 patents and a multitude of innovations

— For the first time, a tetraplegic patient was able to move around and to control his two upper limbs by means of a neuroprosthesis controlling an exoskeleton. The results of the clinical trial of the Brain Computer Interface (BCI) project, run at Clinatec (CEA, CHU Grenoble Alpes), were published in The Lancet Neurology journal on 4 October 2019, and validated the proof of concept of controlling an exoskeleton with four specific limbs by means of an implanted neuroprosthesis developed at the CEA. The neuroprosthesis measures and digitalises the neuronal signals and transmits them in real time via a wireless link. Its algorithms decode the digitalised signals and translate them into movement intentions and control commands. The Clinatec exoskeleton, which has led to the filing of 14 patents, is based on the technological building blocks of the Brain Computer Interface (BCI) project and on generic building blocks developed by CEA-Leti and CEA-List. In the long term, this technology should give greater mobility to individuals with motor disabilities.
Find out more

Medical imaging

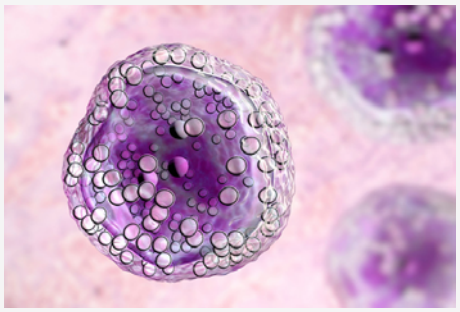
Arrival at Saclay of the Iseult project's superconducting magnet on 18 May 2017.
© P.Dumas/CEA

World record for Iseult!

— The Iseult project achieved a decisive step in July 2019 when the magnet of its whole-body **MRI*** scanner reached its nominal field of 11.7 teslas. This world record is the crowning achievement of years of R&D at the forefront of innovation in the field of superconducting magnets. Over the coming months, equipment will be installed around the magnet to create an MRI scanner capable of examining the human brain more accurately than ever before, for the benefit of fundamental research, the cognitive sciences and the diagnosis of neurodegenerative diseases.

Find out more

MRI *
Magnetic resonance imaging. A medical imaging technique for obtaining 2D or 3D views inside the body non-invasively.



Burkitt lymphoma cells. © Dr_Microbe

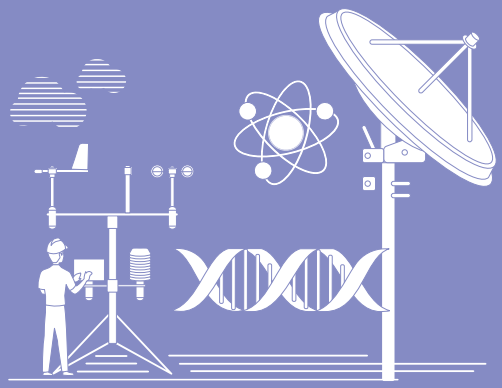
Forthcoming innovative radioactive tracer

— Under a licence agreement, the CEA has tasked the company Zionexa with the exploitation and marketing of an innovative radiopharmaceutical, Fludarabine, labelled with fluorine-18. Radiopharmaceuticals are used particularly in **PET*** imaging to target tumour cells and watch how they respond to treatment throughout the patient's care. [18F] Fludarabine should make it easier to see the tumour cells implicated in lymphoproliferative disorders, where other diagnostic techniques have limitations in terms of specificity and sensitivity. Clinical trials are in progress.

PET*
Positron emission tomography. Medical imaging technique used for 3D measurement of the metabolic or molecular activity of a cell or organ using the emissions produced by positrons from a radioactive product injected beforehand.

Fundamental research

In parallel with its activities in the fields of defence and security, energy transition, digital transformation and medicine of the future, the CEA invests in a high standard of fundamental research, which generates a very broad spectrum of knowledge and know-how.



Missions performed by the Fundamental Research Division

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Key events 2019

Earth system

French Dumont d'Urville Station © Matthieu Weber

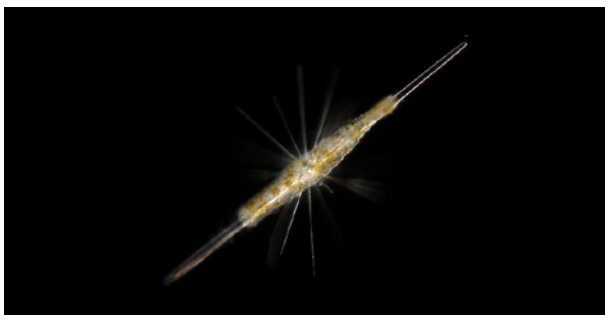
Focus on the Antarctic

— Changes in the Antarctic ice cap have a huge impact on the world's climate. Yet there is little instrumentation of this part of the world. Climatologists from the Laboratory of Climate and Environmental Sciences (LSCE) therefore conducted several campaigns in Antarctica during the austral summer. They collected snow and ice samples showing evidence of Antarctic climate variability over the centuries and installed instruments to analyse the atmosphere. By refining their knowledge of past and current variations in the ice cap, they can predict future changes more accurately.

The secrets of photosymbiosis

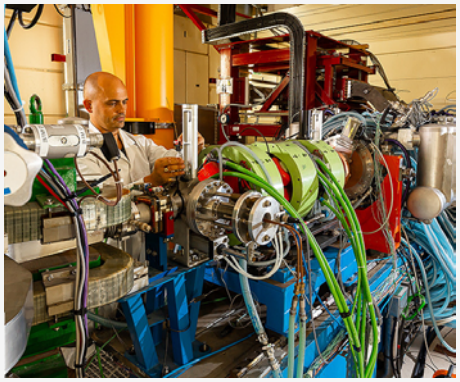
— In 2012, while studying the symbiosis between unicellular organisms and marine plankton microalgae, researchers at the CEA noticed that once microalgae are incorporated into their host, their appearance changes compared to their free state. But does this association actually benefit the two organisms? Using subcellular imaging technologies together with physiological analyses, the researchers now have something of a response: this new type of **symbiosis***, which is nothing like the symbiosis observed with corals or lichens, maximises the microalgae's photosynthetic activity and efficiency.

Symbiosis*
Almost indissociable combination of two very different organisms to make a symbiotic form that could be considered a new organism in its own right. When one of the organisms in a symbiosis uses photosynthesis (such as a microalgae), it is referred to as photosymbiosis. This type of association, found for example in coral reefs, is essential to marine ecosystems.



An acantharea (host) measuring 100-200 µm in length with its intracellular symbiotic microalgae (yellow cells). © Johan Decelle

Materials



Installing equipment on the diagnostic line.
© P.Dumas/CEA

First successful experiments with Iphi-Neutrons

— Thermal neutron diffusion is used by a very large community of researchers (8,000 scientists in Europe) to study condensed matter and materials science. Up to now, demand for thermal neutrons has been met by nuclear research reactors, but these have been diminishing in number. However, the production of thermal neutrons by compact sources could provide an interesting alternative. Since 2018 the CEA has been developing the Iphi-Neutrons demonstrator, the most advanced prototype in Europe, which uses a low-energy proton accelerator. Initial experiments have confirmed the choice of technologies for development of the future «Sonate» compact neutron source, which could offer similar performance to that of nuclear research reactors.

Fusion

Inside the tokamak: on the left are two antennas for ICRH heating on the outside walls. The two heating systems can heat plasma by induction. © C.Roux/CEA

Excellent interim assessment for the West tokamak!

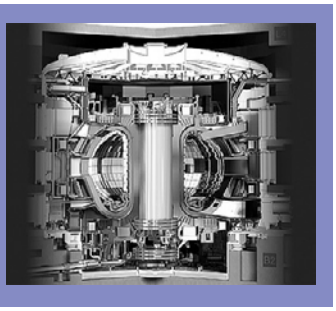
— The C4 experimental campaign at the WEST **Tokamak*** was completed in mid-November 2019. Its achievements include long plasma duration times of around one minute, and the first tests of prototypes of a key component (a tungsten divertor) of the ITER demonstrator under construction at Cadarache. West is now preparing to host a complete divertor, which should extend plasma durations to a thousand seconds, and to determine the life of this component under the extreme conditions in ITER.

Tokamak*
Experimental machine designed to demonstrate the scientific and technical feasibility of fusion energy. Its name is an acronym of the Russian for «toroidal chamber with magnetic coils».

FOCUS ON...

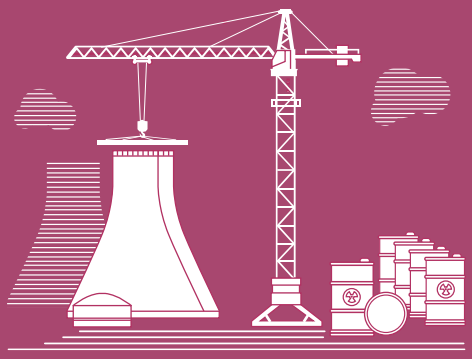
ITER

35 countries are involved in the construction of ITER (meaning «path» in Latin), the largest tokamak ever designed, which will be used to demonstrate that fusion — the energy of the Sun and stars — can be used as a large-scale, carbon-free energy source to generate electricity. The results of the ITER scientific programme will be decisive in paving the way for the fusion power generation plants of tomorrow.
Find out more



Clean-up and dismantling

Clean-up and dismantling is a key issue for the CEA, which has 36 facilities in the process of being dismantled, more than 1,000 employees working in this area, and genuine expertise in the field. The largest clean-up and dismantling site in Europe is at Marcoule. The CEA's general strategy was validated by the safety authorities in 2019, and it is currently running projects and cutting-edge R&D to find methods that are safer, as well as technically and economically more efficient.



Missions fulfilled by the teams at the Nuclear Energy Division (DEN)

The Nuclear Energy Division (DEN) provides the public authorities and industry with expertise and innovation to develop sustainable, safe and economically competitive nuclear energy. To do this, the DEN works in three main areas:

- providing support to the French nuclear industry for the current fleet of reactors, the startup of the EPR, and the fuel cycle facilities
- clean-up and dismantling of its nuclear facilities at the end of their life
- development of the nuclear systems of the future with the Generation IV reactors to close the fuel cycle and with the SMR (Small Modular Reactor) for greater flexibility and to develop internationally.

Key events 2019

IN FIGURES...

36 facilities
to be dismantled by the CEA at 5 civil centres (Fontenay-aux-Roses, Saclay, Marcoule, Cadarache and Grenoble)

740 million euros
allocated annually to dismantling the CEA's facilities and recovering its legacy waste.

1,100 employees
working directly or indirectly on dismantling.

© S.Le Couster/CEA

Clean-up and dismantling covers all the operations carried out after a nuclear facility is permanently shut down, up to its delicensing. These include operations to dismantle equipment, clean up premises and soil, demolish civil engineering structures, and treat, condition and remove the waste produced. Each of these operations is carried out in liaison with the civil (ASN) and defence (ASND) nuclear safety authorities. The CEA also recovers and conditions legacy waste.

A variety of facilities to be dismantled

Since there are reactors of different technologies, high-activity laboratories, fuel cycle plants, waste treatment and storage facilities, etc., each facility is a specific case and each dismantling operation poses a technical challenge. The CEA has genuine expertise both in the overall management of operations and in the methodologies and expertise required to carry them out.

Innovative R&D for dismantling

Some operations require the development of particular technologies, in a break with the traditional approach. For this purpose, the CEA runs R&D programmes aimed at optimising the costs, duration and work conditions on dismantling sites. New virtual reality training tools, remote-control robots for carrying out operations in complete safety and ultrasensitive measuring devices are some of the innovations developed at the CEA.

A general strategy validated by the safety authorities

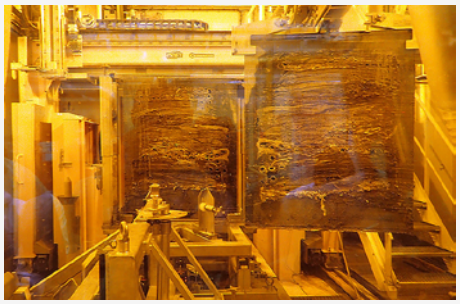
In 2019 the nuclear safety authorities validated the general principles of the CEA's clean-up and dismantling strategy. In particular this strategy sets priorities for different operations depending on radioactivity, radiotoxicity and the facility's robustness. It also takes account of technical, economic and human constraints. This strategy enables the CEA to cope with the increase in the number of facilities undergoing dismantling.

DISMANTLING AT MARCOULE: MANY COMPLEXITIES ON ONE SITE

With priority projects, a variety of different facilities, and the need for legacy waste recovery, the CEA-Marcoule site alone covers all the different aspects of clean-up and dismantling at the CEA. The dismantling of the former spent fuel reprocessing plant, UP1, is the largest dismantling project in France and one of the largest in the world. It is expected to be completed by 2060 with the removal of the last waste. Another major project, the pilot workshop at Marcoule, consists of no less than 30 hot cells, five shielded process lines and 230 glove boxes. Recovering irradiating or long-lived waste is also a real safety priority. Often, little is known about this waste, which can be chemically and radiologically very diverse, so intense R&D is needed both to characterise it fully and to find ways to condition or recondition it. Finally, there are also six reactors of various technologies (UNGG reactors, sodium-cooled fast reactors, high flux reactors) at different stages of dismantling.

© S.Le Couster/CEA

Legacy waste management



Cutting open of the first active package in the Chicade facility at Cadarache for characterisation.
© CEA

Characterising legacy waste packages

— In August 2019, the first active package dating from 1995 was cut open in a special cell in the Chicade basic nuclear installation at Cadarache. This operation marked the start of the Recar project, which aims to check all the characteristics of the CEA's packages in order to improve knowledge of them and define appropriate disposal methods. Once characterised, the packages will be sorted and conditioned so that they can be disposed of appropriately and to reduce management costs. A total of 4,000 packages are involved. Many of them could then be sent to Andra's Aube disposal facility for low-level and intermediate-level short-lived waste.

Start of sorting and reconditioning of "rich" drums from the storage area at Cadarache.
© CEA

Sorting and conditioning of 37 "rich" drums from the storage area at Cadarache

— Stored until now in a facility at Cadarache, 37 "rich" drums of legacy waste, so called because they contain several grams of fissile materials, were transferred in 2019 to the plutonium processing facility, which has the technical equipment for sorting and reconditioning this type of waste.
With the green light from the French nuclear safety authority, sorting and reconditioning began on 26 September 2019. It will result in the conditioning of this waste in 100-litre drums or 870-litre packages, in accordance with disposal facility requirements. These packages will then be taken away to the waste treatment and storage facilities at Cadarache.

Remote control

Gobie, a remote control device for clean-up of working areas. © CEA

Gobie and Murène, remote control equipment for clean-up and dismantling projects

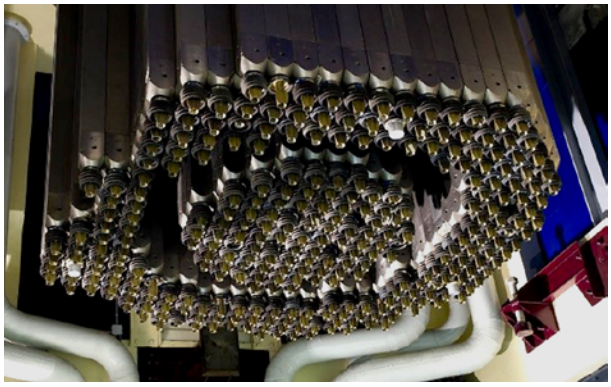
— Operations to recover legacy waste drums used to be carried out using shielded nuclear trolleys heavy equipment requiring a driver, which limited production time.
To make these operations more efficient, remote control equipment has been designed by the CEA in partnership with industrial companies. As it can be operated remotely, it avoids the exposure of technicians to radioactive environments and increases drum recovery rates. In 2019, the implementation of two particular devices continued: the Gobie "super-vacuum", which can clean up working areas, and Murène, which underwent acceptance at the end of 2019 and will be used to recover drums from bunkers on the dismantling project sites at Marcoule. Gobie and Murène offer a perfect illustration of the development of innovative equipment for clean-up and dismantling projects: they are technically exceptional and play an effective role in source term reduction, one of the CEA's priorities for clean-up and dismantling.

Computation

Computation to demonstrate the very low activity of waste at the Masurca facility

— The Masurca reactor at Cadarache, which was permanently shut down in late 2018, is one of the CEA's facilities to be dismantled. To prepare for the dismantling operations, computations were done to clarify the category of the waste produced. Based on the reactor's operating history and on analyses particularly of concrete samples taken from the reactor, these computations are fundamentally important because they demonstrate that the waste from this facility will be very low level waste. This represents a major simplification in terms of logistical flows and cost cutting in the management of secondary waste. It is also essential information for Andra, which can therefore manage the waste in the most effective way. Finally, these computations can be used to define very accurately the clean-up work required in the reactor.

View of the Masurca reactor core from below. © P.Dumas/CEA



Human resources

Attracting talent, developing skills.

So that the CEA can fulfil in the long term all the missions assigned to it, HR deploys the necessary resources to attract talent, develop skills and create the conditions to keep employees motivated. It is responsible, in liaison with the social partners, for building the "social contract" that sets the framework and conditions for the relationship between the CEA and its staff, constantly adapting it to changes in the organisation's context and challenges.

© Andréa Aubert/CEA

Supporting careers

— During the 2016-2019 period, the CEA worked particularly on developing a strategic workforce planning system with three aims: to be able to predict the way jobs will need to change in response to its programme's needs, to support employees as these changes occur, and to identify strategic career paths to manage them better. This was done in accordance with the government's rules on staff numbers (limit on the number of posts, medium and long term plan), payroll monitoring requirements, and requirements for HR policy effectiveness measurement.

The CEA worked to create a reference list of occupations and jobs across all the divisions, which is currently being deployed in all HR processes and tools (staff reviews, employment plan, training, etc.). This reference list, which defines 60 occupations and nearly 300 jobs, was finalised at the end of 2018. The process continued, taking account of details specific to each division, leading to the production at the end of 2019 of a **mapping representing around 99.5% of permanent employees at the CEA**. This is particularly useful for identifying critical skills and jobs and therefore mitigating the associated risks.

A **career pathway for safety and security** was also created in 2019, and another for **projects** is currently being finalised. For **management**, in 2019 the CEA rolled out a **single, organisation-wide training pathway** for all divisions. Finally, it introduced some **change management** initiatives, particularly to support the new organisational structures set up in late 2019 and early 2020.

Finally, having worked for a long time to support the inclusion of its non-permanent employees (doctoral researchers, post-doctoral researchers, employees on fixed term contracts, etc.), the CEA stepped up its efforts in 2019 to help them find out about permanent jobs at the CEA and their employability on the job market. Special training courses to support all these employees were offered to more than 200 of them in 2019.

© Sebra - Fotolia.com

Quality a priority in training

— To ensure its employees benefit from the latest innovations in learning, particularly digitally, in 2019 the CEA invested much more than in previous years in remote learning and online learning tools (webinars, micro-learning, MOOCs, etc.). These new methods have the additional virtue of giving learners greater flexibility over when and where they take training.

Enhancing quality of life at work

— Because it considers quality of life in the workplace to be an important issue, on 14 May 2019, the CEA signed up for the first time to **an agreement on quality of life at work**. It reaffirms in this agreement that employee dialogue and expression, particularly when managing change and to prevent psycho-social risks, help to improve well-being and the working environment. It also introduces the option for employees to work remotely to encourage a good work/life balance, and finally, for staff solidarity, it sets up a scheme for employees to donate leave to one another. Among the significant advances introduced by the agreement is the option for employees to ask for a remote working account, subject to their manager's approval, enabling them to work from home for up to 42 days per calendar year, with a limit of two days maximum per week. At the end of 2019, about 3,500 employees had an account.
Notably, in the first six months of 2020, remote working was widely used to enable many of the CEA's activities to continue during the lockdown imposed to contain the COVID-19 epidemic.

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A dynamic social dialogue

— To take account of the new conditions for social dialogue within undertakings, introduced by the "Macron" orders of 22 September 2017, on 25 October 2018 the CEA signed a unanimous agreement on staff representation bodies with the unions that represent its staff (CFDT, CFE-CGC, CFTC, CGT and UNSA SPAEN). This agreement reaffirms the fact that social dialogue is an essential component of life within an organisation, and sets up **new staff representation bodies**. As a result, staff elections were held in the first half of 2019 to choose the staff representatives and their assistants for the new staff representation bodies nationally and at each centre. The CEA also organised or helped to organise elections of members to represent staff on the CEA's Executive Board, representatives for the COMUEs, the CNESER, and Université Paris-Saclay.
In addition to the pre-electoral memorandums of understanding, seven other collective agreements were signed in 2019, a testament to the dynamism of social dialogue at the CEA.

Administrative management and payroll

— 2019 was a busy year in terms of specific actions related to personnel administration and payroll with, among other things, the introduction of **tax deduction at source and electronic pay slips**, the signature of framework agreements to share staff with different partners (ITER, JHR, FRAMATOME, national guard, etc.), and the recruitment of personnel from STMicroelectronics involved in the Technological Research Division's missions (DRT). Various work was done in late 2019 to contribute to the CEA's reflection process on its staff **remuneration policy**, including benchmarking of pay against a panel of private sector companies and public research bodies.

Management information system renewal

— The CEA began **the renewal of its management information system** (HR, purchasing and finance) to modernise it and make it more agile, in particular using an **HR process mapping and a three-year vision** of the HR information system defined at the start of 2019. In parallel, projects to digitalise certain management processes were launched in 2019.

ACTIVE POLICY TO SUPPORT PEOPLE WITH DISABILITIES

For more than 30 years, the CEA has been active in supporting the employment, retention and training of staff with disabilities. To combat prejudice and publicise the potential benefits of declaring a disability, an information campaign was run in 2019, with posters displayed at all the CEA's centres, the posting of several video portraits online on the intranet, and the distribution of information leaflets containing personal stories, definitions and contact details of the CEA's disability network, one for existing employees and the other for future recruits. For the second consecutive year, three online recruitment fairs were held for people with disabilities. The CEA also took part in the national "duoday" initiative, when an employee hosts a person with a disability for a day. This provides an excellent opportunity for people to meet and overcome prejudices at work.

Sustainable development

Having worked for several decades to be a responsible enterprise, the CEA puts sustainable development at the heart of its concerns, striving to reduce the environmental footprint of its R&D activities while boosting their economic benefits and its employees' well-being. These actions, coordinated at national level, are supported locally by initiatives run by each centre in line with its specific activities. A few examples are presented here.

© Pierre JAYET/CEA

— Two flagship initiatives were run by the CEA in 2019. The first was a 3% reduction in its energy consumption. Based on a regulatory energy audit of its installations completed in 2019, the CEA launched the "energy efficiency" project for 2020-2023 with three main objectives: to draw up an energy policy for itself; to adapt the organisation and processes of its operational, maintenance and renovation activities to achieving better energy efficiency in the long term; and to develop a method of reducing energy consumption by 3% per annum on a like-for-like basis.

In parallel, it continued its effort to reduce, make greener and renew its vehicle fleet, which consists of 494 vehicles (this reduces significantly each year). In terms of engine type, diesel vehicles accounted for 43% of the fleet in 2017 but were down to 30% in 2019, while the proportion of electric and hybrid vehicles had risen to 40% in 2019 (from 33% in 2017).

The second initiative launched in 2019 concerns responsible purchasing. The CEA carried out a detailed analysis of its plastic waste consumption, and more specifically of the plastic cups used by staff on a daily basis (around 25 tonnes per year, which has a significant environmental impact). Knowing this, and after the law on energy transition and the circular economy was passed, the CEA opted for washable products (glasses, cups) combined with cleaning by the catering service, a cleaning service or the purchase of portable dishwashers, which were the best economic/environmental compromise.

Cadarache improves the management of its sanitary waste

— The Cadarache centre replaced the mechanical dehydration process used to treat its sanitary effluent with a new sanitary sludge drying facility. It combines a greenhouse function with a heated floor supplied by a water-to-water heat pump, whereby heat is recovered from the treated sanitary waste. Cheap to run and requiring minimal energy inputs, this process can dry sludge all year without creating unpleasant odours, and has a drying rate of more than 80%. The mass of sludge produced is also significantly reduced. Energy recovery from this sludge was implemented through a partnership with an approved waste incinerator.

Cesta makes employees' lives easier

© CEA

— As part of efforts to improve quality of life in the workplace, in December 2018 the Cesta centre opened a company concierge service which has proved increasingly popular, with nearly 600 users. It offers general services (dry cleaning, shoe repairs, ironing, clothing repairs, etc.) and vehicle maintenance services (servicing, repairs, washing), delivery of organic or integrated farming products, and household services (childminding, gardening, cleaning). It helps to improve employees' work/life balance while offering them high quality services based on local, fair and ethical trade.

Grenoble integrates its R&D with its CSR activities

— In 2019, the Grenoble centre launched a three-year corporate social responsibility (CSR) strategy that, in particular, gives employees the opportunity to undertake CSR activities during their working hours, subject to their line manager's agreement. CEA-Grenoble also took up the joint presidency of the Isère association of inclusive companies, and launched a working group to help people with autism to integrate into long-term employment. This initiative, a first in France, was praised by Claire Compagnon, interministerial delegate in charge of the national strategy for autism and other neurodevelopmental disorders, during her visit to the centre.

© CEA

Ripault protects biodiversity on its site

— The Ripault centre has introduced differentiated management of its green spaces. This initiative has considerably reduced the area that requires mowing as well as mowing frequencies, and has increased the diversity of flora and fauna, while improving the appearance of the environment and reducing noise nuisance. It has also cut costs by about 45%. By managing its spaces sustainably, the CEA reduces the volume of its green waste and improves the ecology of its unbuilt spaces.

Technology transfer

As a key player in innovation, the CEA is responsible for transferring the technologies it develops to support competitiveness, job creation and France's technological sovereignty. It was one of the very first research bodies to encourage spin-offs, and for two decades has provided assistance and support for the creation of start-ups in cutting-edge technological fields.

IN FIGURES...

For **10 years**
it has been one of the
"Top 100 Global Innovators"
according to Clarivate Analytics, and the only French research body to appear in the 2020 Clarivate list.

Leading patent applicant
among research bodies in France

Leading French patent applicant
in Europe

670 new patents
applied for in 2019

6,980 active
patent families

70% of 216 startups
created since 1971 still active (90% after 5 years), representing a total of more than **4,000 jobs**

5 startups
launched in 2019, including 4 managed by CEA employees

— The CEA pursues an active policy of transferring skills and technologies, which it mainly protects with patents and transfers to industry, in the key areas of energy, health, future mobility and the factory of the future, in response to societal and industrial challenges.

The CEA among the top patent applicants in France and Europe

— The CEA is one of the top patent applicants in both France and Europe, mainly in the fields of microelectronics (semiconductors), new energy technologies, instrumentation and health, addressing the current major transitions: energy, digital and medical. These patents reinforce a foundation of globally recognised scientific excellence and strengthen the CEA's portfolio, which already consists of 6,980 active patent families in these cutting-edge sectors.
On the strength of its expertise and the protection of its technologies, in 2019 the CEA entered into more than 900 partnerships with industrial companies ranging from startups and SMEs to mid-caps and large groups.

A dynamic approach to technology transfer

— The dynamism of the CEA's technology transfer is also reflected in the granting of licences to its industrial partners and in its sustained support for the creation and development of startups based on its technologies, over more than two decades. In this context, the CEA relies on its investment funds managed by its subsidiary, CEA Investissement, and Supernova Invest, cofounded with Amundi in 2017.

In support of this mission, the Revenue Division has all the necessary expertise for technology transfer, in intellectual property, contracts and spin-offs, and knowledge of markets and industrial stakeholders, supplemented in 2019 by economic intelligence passed on by special teams within the **CEA's four operational divisions.**

THE CEA ON ALL FRONTS

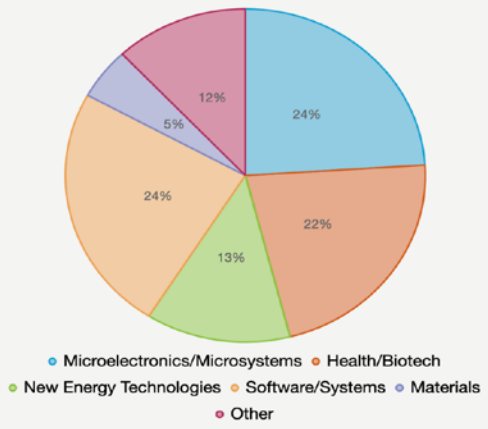
To ensure its most promising startups benefit from the best national and international exposure and to introduce them to new partners, for the fourth consecutive year the CEA attended **CES 2019** in Las Vegas, with eight demonstrators covering five topics: electric mobility, renewable energies, connected health, blockchain and FoodTech. For the first time in 2019 it also took part along with six startups in the **Viva Technology – VivaTech** trade show in Paris, with two aims: to present their expertise in three main areas (big data and health, energy transition and industry of the future), and to meet students, who attended in large numbers on the final day, in order to attract talent.

Finally, with the same objectives, the CEA was in Lyon in September 2019 for the first **Sport Unlimitech** event, with six demonstrators including an autonomous cycle power meter system and a connected tennis racquet created by a startup specialising in sport gaming.

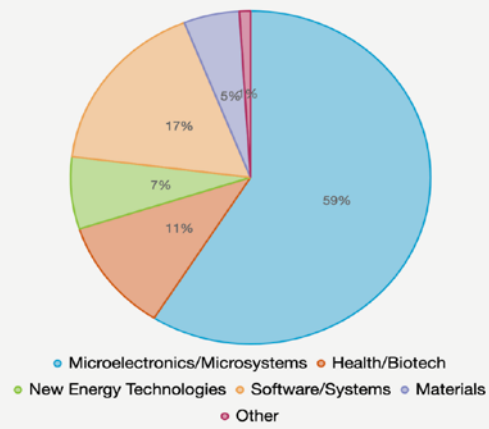
© CEA

2019, an excellent year for startups supported by the CEA

Breakdown of companies set up by technological field



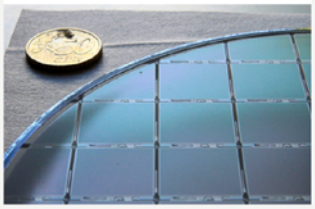
Breakdown of workforce by technological field



THE CEA AND ITS ECOSYSTEM

Aledia

With €90 million raised in total, Aledia is expanding and establishing its site in Grenoble to launch full-scale production of its 3D LEDs by 2021.



iskn

ISKN, which specialises in graphic tablet design, joined forces with Bandai Namco to develop a game for 6 to 12 year olds using "augmented interaction" technology.

ARCURE

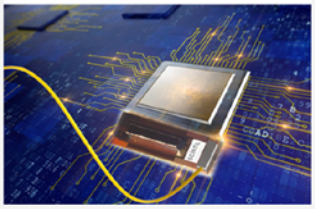
A specialist in artificial intelligence applied to image processing in industry, ARCURE was successfully listed on the stock exchange in 2019 on Euronext Growth Paris.

NAWA TECHNOLOGIES

Among the 16 most promising deep tech startups according to Bpifrance, and startup of the year according to E&Y, Nawa Technologies raised 13 million euros to accelerate the industrial production of its carbon nanotube supercapacitors.

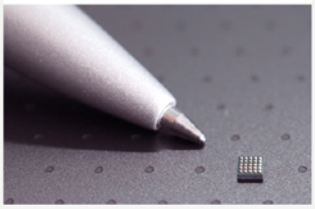
SCINTIL PHOTONICS

Winner in 2018 of Bpifrance's i-lab competition, Scintil Photonics reached a milestone by raising 4 million euros to develop innovative silicon photonics fully integrated circuits, which can exchange up to 800 Gbits per second.



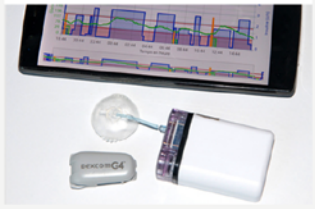
Remedee Labs

The French medtech company that developed an endorphin stimulator, Remedee Labs raised 11 million euros in "Series A round" from Hardware Club, with participation from Habert-Dassault Finance, Partech, C4 Ventures, Supernova Invest, and private investors.



diabeloop

The French medtech company that produces a solution for automated type 1 diabetes treatment, Diabeloop finalised the largest raising of funds in Europe in therapeutic artificial intelligence of 31 million euros.



wattalps®

Wattalps raised €2.2 million to continue developing high performance modular batteries for vehicle electrification, which offer the same performance as combustion engines.

Science in society

For the CEA, sharing knowledge, being involved in promoting and spreading scientific and technological culture and, more generally, encouraging dialogue between science and society, are among its major priorities. To reach audiences that increasingly follow digital media, in 2019 the CEA upgraded the tools it uses to spread scientific culture, particularly by opening Facebook and Instagram accounts.

142,000 people reached including 42,000 pupils and teachers (primary and secondary).

© CEA/ScienceLoop

Digital resources

ScienceLoop, a web series on scientific culture

— This web series takes over from the magazine Les Savanturiers, which for eight years shone the spotlight on the women and men who, in laboratories and in the field, work, explore and travel the planet to improve our knowledge of the world around us. Presented by astrophysicist Roland Lehoucq and biologist Pauline Maisonnasse, ScienceLoop explores one science topic (periodic table, cryptography, the genome, etc.) every month for young people aged 15 to 18 years. Each topic is presented in three episodes lasting 3 to 5 minutes each, broadcast once a fortnight on the CEA's YouTube channel (ScienceLoop playlist). The entire topic can be viewed on **www.cea.fr**.

"Become a scientist" careers platform

— In partnership with Artips, the CEA created a careers platform to encourage secondary pupils and their parents to consider science subjects among the many career options available. The platform is designed to support them in their research and to help them with career choices. With an interactive guidance process, it enables them to explore careers in research (technician, engineer and researcher) in different fields (biology, chemistry, IT and physics) and explains the courses they should take to enter these careers.

© CEA/Artips

THE CEA AND ITS ECOSYSTEM

© J. Lignier/CEA

The Quantum Prisoner at Paris Games Week

— The first research body to design a serious game of this size, in October 2019 the CEA unveiled The Quantum Prisoner, a free adventure video game to give a wide audience, and particularly young people, a taste for science and technology. As Zoe, the player heads off all over the world on the trail of Artus Cropp, a physicist who mysteriously disappeared in the 1960s, and his amazing legacy: a discovery that will change the world!
To promote its game and talk about science in unexpected places, the CEA took part in France's largest video games event, Paris Games Week. Every day, visitors were given puzzles to solve and team challenges to take part in: optimize an energy mix, programme a robot, manufacture atoms, etc. The CEA also invited YouTubers Sora and Julien Chièze to battle the public!

Fancy playing the game?
Play free online at **https://quantum-prisoner.com** and share your experience on social media with the hashtag #PrisonnierQuantique.

Schools

"Science For All" internships for secondary pupils

— These internships were set up by the CEA in 2016 in the wake of the November 2015 terrorist attacks. They are designed to enable secondary pupils at schools in more deprived areas, who would otherwise lack the necessary contacts, to discover the scientific world. Buoyed by the success of previous years, in 2019 the CEA joined forces with two other organisations working to promote scientific and technical culture: the Essonne Science Association and the Orsay Science Faculty.
To enable more secondary pupils to benefit, the CEA and the Essonne Science Association set up the "Science For All" network of secondary internships, with support from the Ministry of Higher Education, Research and Innovation and the participation of the Association of Museums and Centres for the Development of Scientific, Technical and Industrial Culture (AMCSTI) and various other partners.

© CEA

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General public

"Spies" exhibition at the Cité des Sciences et de l'Industrie

— Presented in partnership with the producers of the *Le Bureau des Légendes* series, the exhibition "Spies" is an opportunity for the CEA to present its expertise in fighting nuclear proliferation to a very wide audience, and possibly to generate interest in a career in the field.

Researchers from the CEA were involved in developing the scenario for a nuclear test in a fictitious republic. Because it has the expertise to detect nuclear testing, the CEA is the first organisation to feature along the visitor pathway. Visitors discover the challenges of detection, location and characterisation that must be met by the CEA's experts before it alerts the authorities. The general principles of analysing seismological results and finding ultra-trace elements in samples taken by the DGSE's secret agent are also explained.

Credits

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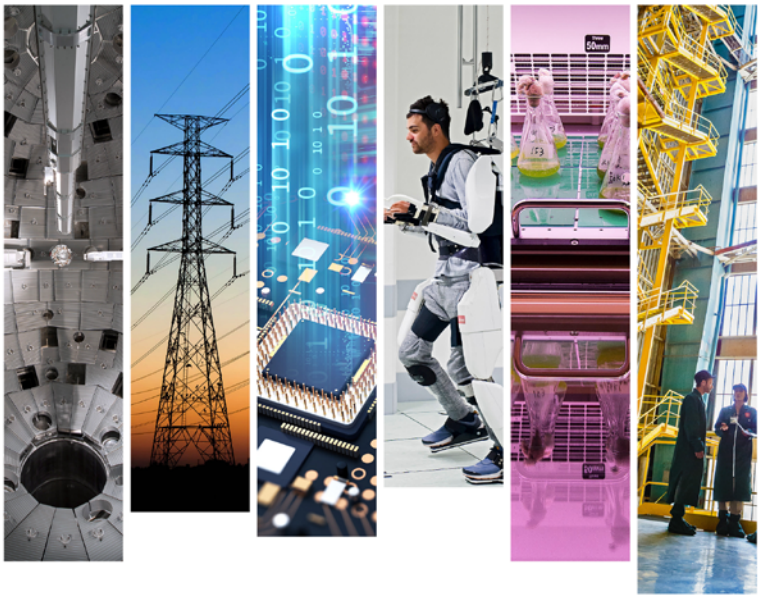

Building tomorrow's society today

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