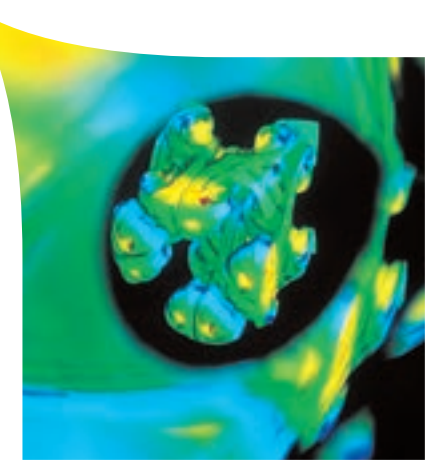
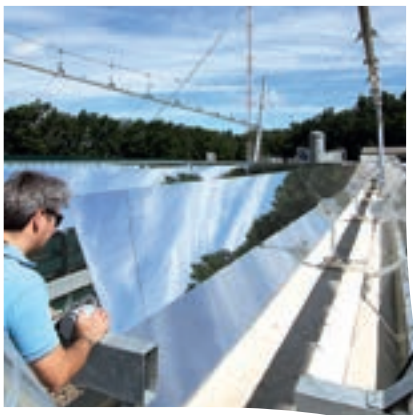
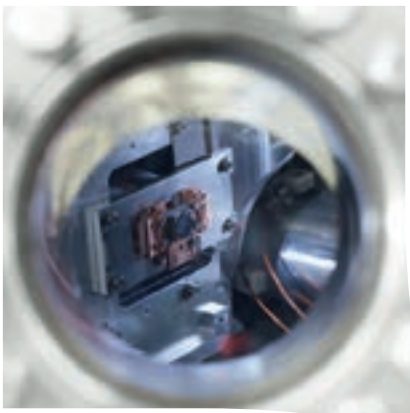


THE CEA
AT THE HEART OF GREAT NEW CHALLENGES

ANNUAL REPORT 2014







FROM RESEARCH TO INDUSTRY

cea

KEY FIGURES 2014

5,022
PUBLICATIONS IN 2013
in peer-reviewed magazines

1 504
PhD STUDENTS AND
276
POST-DOCTORAL RESEARCHERS
at the CEA

MORE THAN
760
EUROPEAN PROJECTS
won with the participation of the CEA in the EU's 7th Framework Programme (FP7) since 2007

751
PRIORITY PATENTS FILED IN 2014
(OEB 2014 – CEA THIRD BIGGEST FRENCH PATENT APPLICANT)

5 600
ACTIVE PATENT FAMILIES

178
TECHNOLOGICAL START-UPS
since 1972 in the innovative technology sector,
115 since 2000

MORE THAN
500
INDUSTRIAL PARTNERS, 300 worth more than 50 k€/year

53
FRAMEWORK AGREEMENTS
in force with **universities and graduate colleges**

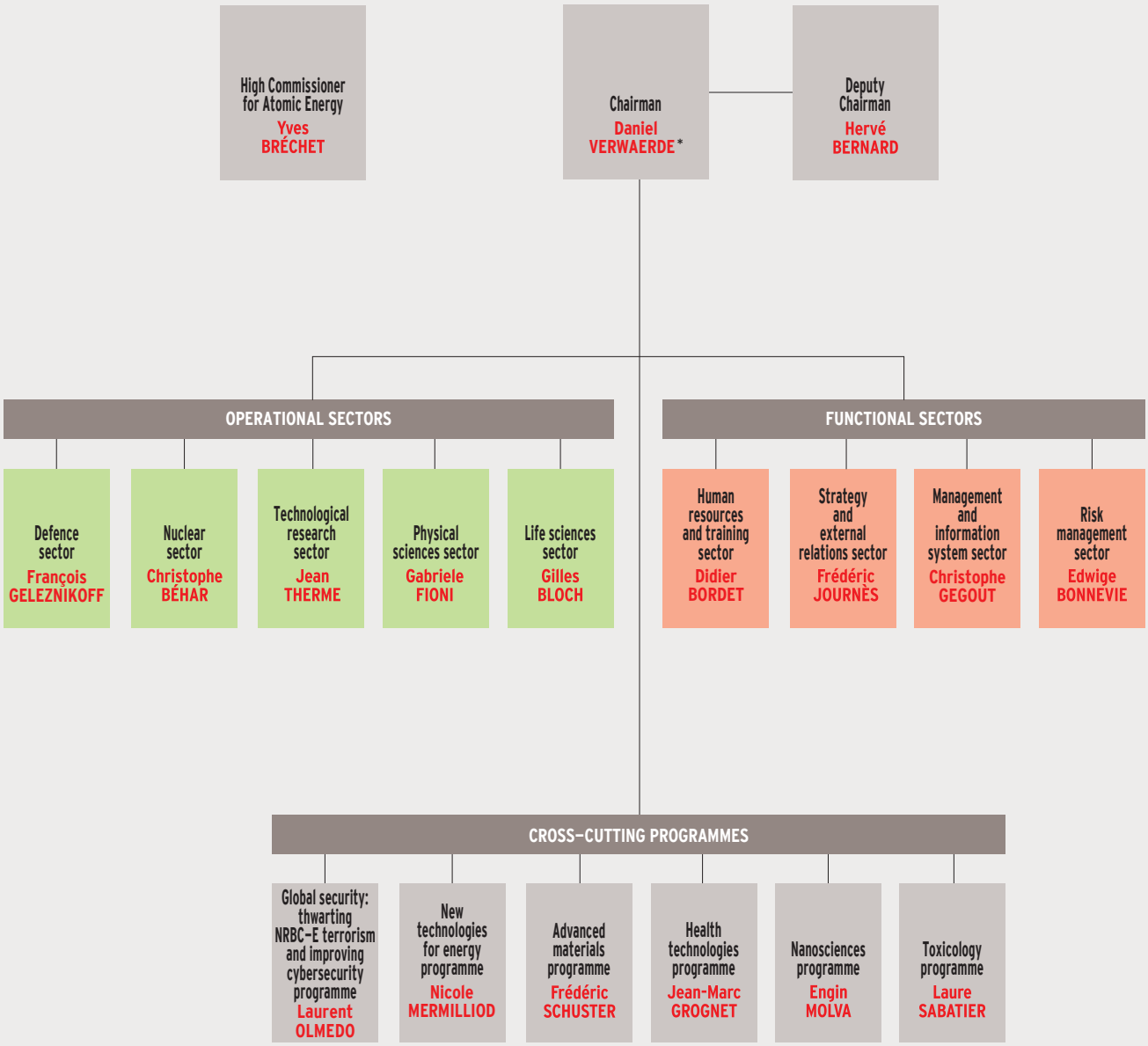
27
COMPETITIVENESS CLUSTERS:
founder of 14 clusters, administrator of 18

51
RESEARCH UNITS
co-supervised by the CEA and academic partners
(45 UMR, 5 UMS, 1 USR)

MORE THAN
200 projects
INVESTMENTS FOR THE FUTURE PROGRAMME

CORPORATE GOVERNANCE

(AS AT 1RST JUNE 2015)



* Daniel Verwaerde succeeds Bernard Bigot, Chairman of the CEA, as of January 28, 2015.

ORGANISATION OF THE CEA

5
OPERATIONAL
DIVISIONS

4
FUNCTIONAL
POLES

THE CEA IS AN EPIC

The Atomic Energy and Alternative Energy Commission is classified as a public research establishment of an industrial and commercial nature (EPIC). Its status and duties are defined in Articles L. 332-1 to L. 332-7 of the Research Code.

At the head of the CEA, the Chairman oversees the running of the CEA. The High Commissioner for Atomic Energy acts as scientific and technical advisor to the Chairman. Both are officially appointed by the Council of Ministers.

INSTITUTIONAL MANAGEMENT BODIES

The main mission of the Board of Directors is to set the establishment's major strategic, economic, financial and technological orientations. The CEA acts as the secretariat of the Atomic Energy Committee, which is similar to an inter-ministerial committee. Its mission is to help draw up France's nuclear policy as defined by the Nuclear Policy Council, under the aegis of the French President. Issues concerning the execution of national nuclear defence programmes, for which the CEA is responsible, are examined by the Armed Forces – CEA Joint Committee, whose recommendations are submitted to the Atomic Energy Committee and to the Management Board by the Managing Director.

SCIENTIFIC EVALUATIONS

A Scientific Council assists the High Commissioner for Atomic Energy in evaluating the CEA's research activities, and proposes scientific orientations. Alongside the Scientific Council, there is a Visiting Committee composed of internationally recognised experts. This committee is elicited to give its view on the CEA's research strategies and orientations.

The evaluation of the CEA in 2014 and of its units at the Saclay, Fontenay-aux-Roses and Marcoule Centres was carried out by AERES.

ORGANISATION

CEA's research in the fields of defence and security, greenhouse gas-free energy, and technology for information and health is conducted by five operational divisions. Fundamental research is also conducted throughout all the divisions.

Set up in 2006 and 2009, the six cross-cutting programmes are Advanced Materials, Health Technologies, New Technologies for Energy, Nanosciences, Global Security: thwarting NRBC-E terrorism and improving cybersecurity, and Toxicology. They share the same mission: promote, form and lead inter-division collaboration. In this way, at the interface between science and technology in specific areas, the meshing of different skills and competences generates major innovations, and lends the CEA's action greater visibility.

Four supporting functional divisions ensure coherence inside the organisation.

These divisions:

- Risk management,
- Information systems management,
- Strategy and external relations,
- and Human resources and training

also interface between the CEA and its outside partners.

CEA Headquarters.

THE CEA

THE FRENCH ATOMIC ENERGY AND ALTERNATIVE ENERGY COMMISSION IS A PUBLIC RESEARCH ORGANISM ACTIVE IN FOUR MAJOR FIELDS: NUCLEAR AND RENEWABLE ENERGY, DEFENCE AND SECURITY, INFORMATION TECHNOLOGIES AND HEALTH TECHNOLOGIES.

THE CEA IS PRESENT IN FRANCE IN

9 REGIONS
10 CENTRES AND
4 REGIONAL TECHNOLOGY TRANSFER PLATFORMS

4.3 BILLION EUROS
CIVIL AND DEFENCE BUDGET

16,110 EMPLOYEES

In each of these four major areas, the CEA draws on first-rate fundamental research. It also contributes to the design and operation of the research infrastructures (RIs).

The CEA enjoys a strong regional presence, with its 16,110 researchers and collaborators working in 10 centres throughout France. Closely linked to academic research and industrial world, it supports industrial operators and fosters the creation of innovative companies and technologies.

Doted with unique expertise built on a culture of innovation, the CEA, through CEA Tech, has as its mission to produce and disseminate technologies to support and assist industry, bridging the gap between the worlds of science and the economy. It also gives access to generic technologies developed for other CEA units.

CEA Tech operates in the Midi-Pyrénées (Toulouse), Aquitaine (Bordeaux), Pays de la Loire (Nantes), Lorraine (Metz), and Nord-Pas de Calais regions, and works in closely collaboration with local players. It is also strengthening its activities in the Provence-Alpes-Côte-d'Azur region. It is directly affiliated to the two historical centres of Grenoble and Saclay in relation with industrial operators.

The CEA develops active partnerships with other research organisms, local government and universities. As such, it is a stakeholder in national alliances coordinating French research in the fields of energy (ANCRE), life and health sciences (Aviesan), digital science and technology (Allistene), environmental science (AllEnvi), and human and social sciences (Athena).

Recognized for its expertise in all its domains of competence, the CEA is a full player in the European Research Area, and increasingly present internationally.

LOW-CARBON ENERGIES

IN LINE WITH THE 2005 ENERGY PROGRAMME ACT AND THE LEGISLATION PASSED IN 2009 AND 2010 FOLLOWING THE GRENELLE ENVIRONMENT FORUM, THE CEA IS CARRYING OUT RESEARCH AND DEVELOPING NEW ENERGY TECHNOLOGIES FOCUSING ON ELECTRICITY GENERATION. THIS RESEARCH SETS OUT TO FIND SOLUTIONS TO THE MAIN ENERGY ISSUES, NAMELY PROVIDING SECURE ENERGY SOURCES, CONTROLLING THE COST OF ENERGY, AND PROTECTING THE ENVIRONMENT (CLIMATE CHANGE AND GREENHOUSE GASES).

Studies on nuclear systems for the future, such as the Astrid integrated technology demonstrator.
© PF.Grosjean/CEA

NUCLEAR FISSION

The CEA Nuclear Energy Division (DEN) provides the public authorities and industry with the expertise and innovation needed to develop safe, sustainable nuclear energy that is also economically competitive. Its research is centred on three key issues: nuclear systems for the future, optimisation of the current nuclear industry, and major experimental facilities and simulation tools essential for research.

The CEA also has to manage and upgrade its set of nuclear facilities through the implementation of construction, refurbishment, clean-up and dismantling programmes.

INDUSTRIAL NUCLEAR SYSTEMS FOR THE FUTURE

In France, the CEA is responsible for carrying out research on innovative nuclear systems – dubbed 4th Generation – that offer technological breakthroughs compared with the previous reactor generations. It is mainly focusing its research efforts on the sodium-cooled fast reactor (SFR) technology and on the gas-cooled fast reactor (GFR) technology to a lesser extent. The DEN is the owner of the 4th Generation reactor project called Astrid, which stands for the "Advanced Sodium Technological Reactor for Industrial Demonstration".

The CEA is preparing the future fuel cycle in line with the results of its studies by developing advanced processes to ensure the multiple recycling of plutonium. This consists in assessing the options available for the separation and transmutation of long-lived radioelements (minor actinides) within a long-term perspective. In this context, the CEA has collaborated with its partners – EDF and Areva – to investigate the potential industrial scenarios for deploying SFRs. These studies take into account the fuel cycle and the transition from the current fleet which ensures the single recycling of plutonium to a fleet comprising SFRs capable of multiple recycling.

OPTIMISATION OF THE CURRENT NUCLEAR INDUSTRY

The CEA supports the current nuclear industry both in the field of nuclear reactors and in the nuclear fuel cycle sector.

2nd and 3rd Generation Reactors

The CEA carries out research on pressurised water reactors (PWRs) for the current French fleet (2nd Generation), covering issues such as reactor competitiveness, service life, performance, availability and nuclear safety. It also provides support for the deployment of the 3rd Generation of reactors, such as the European Pressurised Reactor (EPR).

Tensile tests on zirconium cladding as part of support for the current reactor fleet.
© PF.Grosjean/CEA

13 COUNTRIES
IN THE WORLD HAVE JOINED THE GENERATION IV INTERNATIONAL FORUM (GIF), THE COOPERATIVE R&D BODY IN THIS FIELD

Studies on the fuel cycle in the Atalante laboratory at the Marcoule centre. © S. Le Couster/CEA

Back-end of the current fuel cycle

Research is not only conducted to support Areva when it needs to optimise or adapt spent fuel treatment processes at La Hague plant or MOX fuel fabrication processes at the Melox plant, but this research also supports the operational maintenance of such plants. The CEA also works in collaboration with Andra (French national radioactive waste management agency) by providing the scientific and technical information needed to validate the Cigeo project - the deep geological radwaste repository - for which Andra has been made the owner. The CEA also helps elaborate specifications (technical, material and nuclear safety) for the disposal of long-lived intermediate level (LL-ILW) and high-level waste (HLW).

Front-end of the fuel cycle

Like many other countries, France will be faced with the increasing scarcity of uranium resources. To compensate for the reduced ore concentrations, the CEA is conducting research to improve the performance levels of selective uranium extraction, purification and conversion to reach the required levels of purity for enrichment. This specifically involves qualifying new molecules.

LARGE EXPERIMENTAL MEANS FOR THE DEVELOPMENT OF NUCLEAR ENERGY

Research focusing on current and future nuclear systems requires highly specific experimental devices and simulation tools.

Experimental facilities

The Jules Horowitz Reactor (JHR) - currently under construction at the Cadarache centre - will provide a truly unique tool for investigating materials and fuels subjected to irradiation in support of the current and future nuclear reactor fleets. It will also produce a considerable quantity of radioisotopes needed for medical purposes. The experimental reactors called Eole and Cabri represent part of the research means used to conduct neutronic experiments.

Small production line in the RM2 building in Fontenay-aux-Roses, with two concrete blocks having been removed. © CEA

Numerical simulation

The CEA develops software platforms and computational codes to cover the main fields of nuclear energy, e.g. neutronics, thermal hydraulics, mechanics, heat transfers, fuel cycle chemistry and materials. Most of these activities are shared with the key players of the French nuclear sector (EDF, Areva, IRSN, etc.) and set out to model all the phenomena coming into play during normal and accident conditions in a reactor. Modelling relies on data collected from large experimental facilities and tools.

CLEAN-UP & DISMANTLING

As nuclear operator, the CEA is responsible for managing any radwaste it produces and for dismantling its own facilities; the 22 projects currently underway are mainly located on the sites of Marcoule and Fontenay-aux-Roses. The CEA is also involved in research on technologies and techniques used in dismantling operations.

ZOOM ON...
NUCLEAR FUSION ENERGY

The thermonuclear fusion reaction consists of the fusion of two atomic nuclei, releasing large quantities of energy, as occurs in the core of a star. On Earth, this reaction can be triggered in a tokamak. The CEA, within the wider Euratom framework, contributes to the European research program into magnetic confinement fusion. The CEA is involved in building ITER—the International Thermonuclear Experimental Reactor—, preparing the ground for operational commissioning, and developing ahead for the next stage of the project, dubbed Demo (DEMOnstration Power Plant). The tokamak behind CEA's Tore Supra facility is being repurposed as a testbench for Iter, and rebaptized West (Tungsten W Environment in Steady-State Tokamak). The ITER international megaproject brings together the EU, Russia, the US, Japan, China, South Korea and India. The tokamak under construction at the Cadarache Centre is designed to demonstrate the feasibility of energy generation based on thermonuclear fusion.

600 MWe
THE POWER TO BE PRODUCED BY THE INTEGRATED TECHNOLOGY DEMONSTRATOR CALLED ASTRID WHICH WILL BE CONNECTED TO THE GRID

Thermal solar platform.
© P.Avavian/CEA

ALTERNATIVE ENERGIES

The CEA has been very active in this field for some thirty years. As a priority, it is working on solar energy (thermal and photovoltaic) and its integration in housing, batteries for electric vehicles, hydrogen, and second and third generation biofuels:

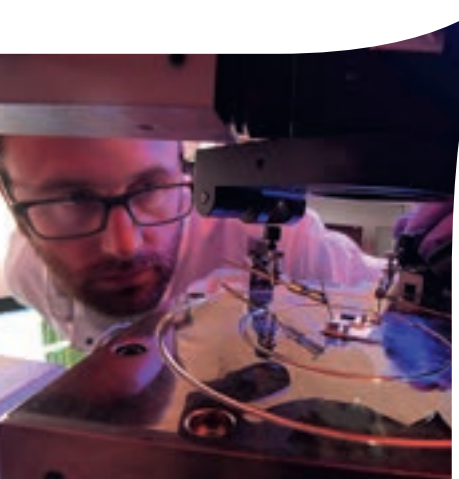
SOLAR ENERGY

Thermal solar energy is mainly used to heat water (for domestic use or swimming pools) or for space heating. This increasingly popular technology allows energy self-sufficiency at moderate cost with no grid connection. A R&D platform for the optimisation of thermal solar systems has been set up at INES. It enables innovative components and systems to be tested and characterised.

In the field of **photovoltaics**, the concern of current research is to improve yields and reduce the costs of cells. Yields are constantly improving, by about 4% every ten years, at laboratory scale prior to industrialisation. However, major technological breakthroughs are still needed to further reduce the cost of the photovoltaic kilowatt and enhance the performance of photovoltaic systems (cells, modules, storage, electronics, etc.). Research includes work on the manufacture of solar cells, the storage of energy to overcome the variability of the solar source, and the management of solar energy in buildings.

900 TIMES
THIS IS HOW MUCH MORE SOLAR ENERGY IS AVAILABLE OVER THE WHOLE EARTH THAN THE WORLD ENERGY DEMAND

Characterisation of a multijunction photovoltaic solar cell.
© P.Avavian/CEA



Using the sun's thermal energy, electricity can be generated **thermodynamically in a concentrated solar powerplant** (CSP). Two technologies are being studied for the concentration of light with cylindrical parabolic mirrors, and arrays of hundreds of mirrors (heliostats).

The CEA is working on several critical points: heat exchangers, energy storage in heat form, and system management.

ELECTRIC VEHICLES

CEA researchers are working on battery technologies, in particular for transport. Thanks to their competence in chemistry, in the fields of materials and electronics, and in information technologies, they can offer industrial operators solutions to lower the cost of batteries, improve their performance, and make them as safe and reliable as possible.

New generations of low-cost lithium-ion accumulators are being proposed for applications that need high energy density (electrical vehicles), or high power (hybrid vehicles).

The CEA is designing the sensors and electronics that will equip these accumulators to measure their operability in real time. They will optimise levels of charge, avoid dangerous electrochemical reaction, and instrument battery packs to facilitate their maintenance. The CEA is also developing software to give drivers advice on getting from A to B allowing for road profile, weather conditions and battery state of charge.

Pilot assembly line for lithium battery modules and packs.
© D.Guillaudin/CEA

BIOFUELS

For second generation biofuels, the CEA prioritises the thermochemical pathway for the production of diesel fuel or kerosene from raw materials of plant origin that are not needed for food or industrial uses: forestry residues, leaves, stalks, green waste, etc. It is developing technological "bricks", which are offered to French industrial players. In parallel, it is steering or participating in demonstrator projects for the validation of these "bricks", and acquire knowledge that can be used in the stages of process industrialisation and product distribution.

2008

SETTING-UP OF THE HELIOBIOTECH BIOTECHNOLOGICAL PLATFORM TO EXPLORE ENERGY PRODUCTION BY MICRO-ALGAE

Culture of micro-organisms in vials (micro-algae and cyanobacteria). These are naturally able to produce compounds with high energy content.
© G.Lesénéchal/CEA

On the same basis of non-competition with food crops, CEA scientists are conducting fundamental research on third-generation biofuels, made from micro-algae with high energy potential.

The two main avenues of research are the exploration of their ability to produce hydrogen or energy-rich carbon compounds (lipids, ethanol, etc.) and the study of certain processes in living organisms, such as photosynthesis and hydrogenase activity, to favour the development of new ways to produce hydrogen or operate fuel cells.

HYDROGEN AND FUEL CELLS

Hydrogen technologies have been the subject of numerous research programmes at the CEA since the end of the 1980s, supported by the expertise of researchers in materials, high-temperature and high-pressure processes, and technologies integration. For the production of hydrogen, the CEA is laying stakes on high-temperature electrolysis processes. In addition, various storage solutions (pressurised gas, solid hydrides) are being studied according to the applications.

The Myrte platform in Corsica is the first "life-size" experimental set up to evaluate the technical and economic potential of the hydrogen vector as a storage means between a photovoltaic source and feeding to the grid.

In the transport sector, the CEA has been developing fuel cells since 2000. The first practical uses have been in construction and farming vehicles, handling machinery, pleasure boat and aeroplanes. Research conducted by the CEA and the other organisations or industrial actors involved have targeted the development of a hydrogen-fuelled vehicle, equipped with a fuel cell.

The CEA's constant objective is to strengthen the economic relevance of this energy vector, and to take top place in the hydrogen technology research sector supporting industrial actors.

SMART BUILDINGS

Through its research effort, the CEA is strongly involved in developing renewable energies. It deploys its competences in R&D programmes for the building industry, in particular for low consumption and energy efficiency. As part of this project, CEA researchers at INES are testing different innovative technologies that meet the needs of industrial operators, from concept through to "live" scenario in demonstration platforms set up at INES (Incas) and Cadarache.

Instrumented experimental buildings at the Incas platform.
© P.Avavian/CEA

ZOOM ON...

INES

The National Institute of Solar Energy (INES) was created in 2006 at Chambéry. Its objective is to promote and develop solar energies in France, and to become an European leader and world reference in this field.
INES brings together more than 250 pure and applied scientists, trainers and industrial operators.
They are spread over three platforms:
- **a "research, development, industrial innovation" (RDI) platform, constituting core competences at international level,**
- **a "demonstration" platform, used to characterise the components and systems derived from the RDI platform,**
- **and an "education" platform, with four key objectives: information, training, evaluation and promotion.**

THE CEA'S RESEARCH ON THE CLIMATE

In 1998, the CEA created the Laboratory of Climate Sciences and the Environment (LSCE), bringing together climatology facilities in partnership with other French research organisms (CNRS and University of Versailles Saint-Quentin). This laboratory forms part of the Institute Pierre-Simon Laplace (IPSL). It helps draft the reports of the IPCC (Intergovernmental Panel on Climate Change).
The collection and analysis of natural climate archives (ice cores, sediments, tree rings, etc.) help climatologists gain a better understanding of how the earth's climate has evolved over all time scales.
The study of past climates is coupled to modelling and simulation, both indispensable for understanding the phenomena in play and the processes that regulate exchange and transfer of water between oceans, continents and atmosphere.
Climatology and simulation also enable scientists to study the impact of climate change, which is linked in part to human activity, and to predict future climatic conditions.

DEFENCE & SECURITY

DEFENCE AND SECURITY IN VARIOUS FIELDS: NUCLEAR WARHEADS THAT EQUIP FRANCE'S SEA– AND AIRBORNE DETERRENCE FORCES, NUCLEAR REACTORS AND REACTOR CORES FOR NAVAL PROPULSION OF THE FRENCH NAVY SUBMARINES AND AIRCRAFT CARRIER, AND COMBATING NUCLEAR PROLIFERATION AND TERRORISM.

General view of the Tera 100 computer room.
© P.Stroppa/CEA

The CEA's Military Applications Division (DAM) is responsible for the design, manufacture, through-life support and dismantling of the nuclear warheads that equip France's sea- and airborne deterrence forces.

The DAM is responsible for the design and manufacture of the nuclear reactors and reactor cores on French Navy submarines and aircraft carrier. It assists the Navy with in-service follow-up and through-life support for these reactors.

The DAM is also in charge of procuring strategic nuclear materials required for the nation's deterrence.

In a world undergoing profound change, the DAM also contributes to national and global security through the technical support it provides to the authorities relative to the prevention of nuclear proliferation and terrorism and to disarmament.

Since 2010, the DAM has put its expertise in conventional weaponry at the service of the Ministry of Defence.

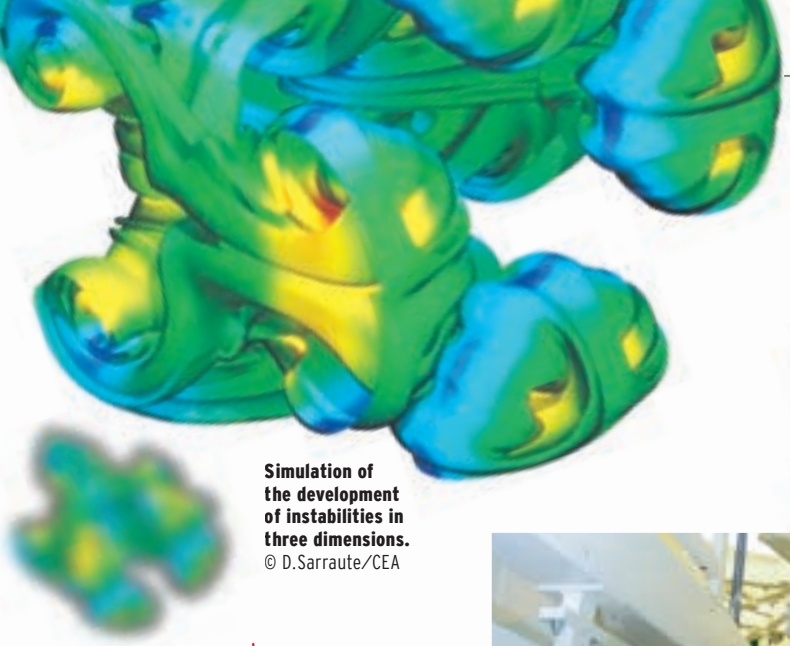
THE SIMULATION PROGRAMME

The nuclear warheads destined to replace existing weapons when these come to the end of their lifetime must now be guaranteed without further nuclear testing. The Simulation Programme, launched in 1996, meets this objective to guarantee their reliability and safety. It relies on physical models of the phenomena involved in the functioning of nuclear weapons, translated into mathematical equations which are solved inside numerical codes by high-performance computers. These models are validated by comparing the results of calculations with the measurements of experiments conducted at the major facilities Epure and Laser Megajoule (LMJ).

1.3
QUADRILLION
OPERATIONS
PER SECOND CARRIED
OUT BY TERA 100

Supercomputers

The supercomputers are sized to match the requirements of the nuclear weapons design and guarantee. The Tera 100 supercomputer can perform 1.3 quadrillion operations per second (1.3 petaflops). Its successor Tera 1000 currently under development will achieve 25 petaflops in 2017.



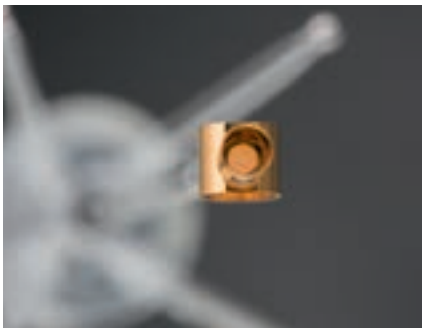
Simulation of the development of instabilities in three dimensions.
© D.Sarraute/CEA

176
BEAM FOCUSED
ON A MICROTARGET MEASURING 2.4MM: A CHALLENGE OF THE LASER MEGAJOULE

Laser Megajoule experimental chamber.
© PF.Grosjean/CEA

The Epure facility

The Teutatès Treaty between France and the United Kingdom, signed on November 2nd 2010, is related to sharing radiographic facilities for the purposes of their respective deterrence programmes. The radiographic facility Epure, under construction at the Valduc Centre, falls within this context. It will eventually include three high power radiographic axis. Its commissioning with a first radiographic axis, since end 2014, makes it possible to characterize, to the highest level of precision, the state and hydrodynamic behavior of materials, under the conditions encountered in the pre-nuclear phase of weapon functioning.



Laser target.
© MS/CEA - 2015

The Megajoule Laser

The Megajoule Laser, at the Cesta Centre, is an indispensable tool for simulating the nuclear phase of weapon functioning and for certifying the competence of the physicists who design the weapons. At the end of 2014, after its commissioning by the Prime Minister of France, a first experimental campaign of weapon physics was successfully conducted.

NUCLEAR PROPULSION

The French Navy's fleet of nuclear-powered vessels has twelve steam supply systems equipped with nuclear reactor cores in service. This includes four new-generation nuclear-powered ballistic missile submarines (Le Triomphant class), six nuclear attack submarines (Rubis class) and the Charles de Gaulle aircraft carrier.

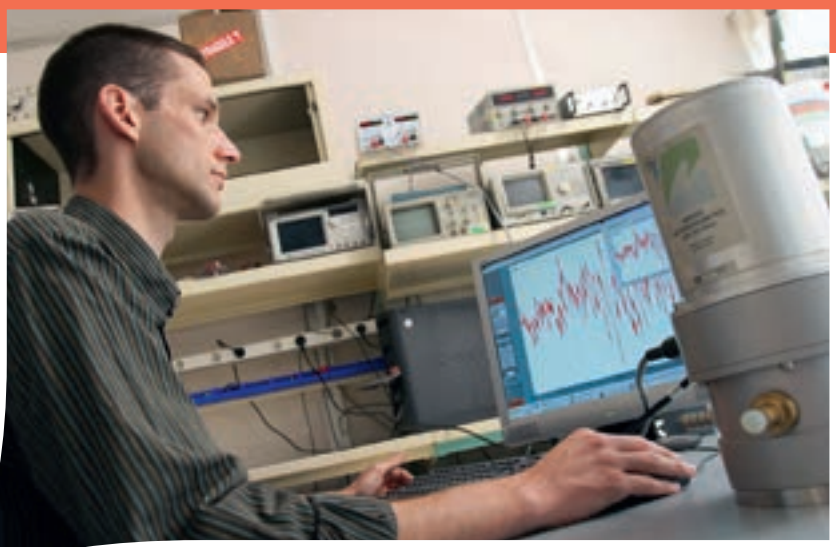
The Barracuda programme

France's current fleet of nuclear attack submarines (SNAs) will begin being replaced in 2017 by a new generation. This is the subject of the Barracuda Programme, jointly coordinated by the DGA (the French Defense procurement agency) for the vessel and the DAM for the design and manufacture of the nuclear steam supply systems and the cores, together with all the logistics resources for maintenance.

The RES programme

Maintaining availability targets and ensuring high standards in terms of safety is dependent not only on rigorous equipment maintenance, but also on skilled teams and land-based resources. These means are located at the regulated nuclear Defence facility (INBS) at Cadarache, under the nuclear operator responsibility of the Director of the DAM Île-de-France center. They include in particular the test reactor (RES), the construction of which is nearly complete. Once it is in service, this experimental reactor will be an invaluable simulation tool used in the design and through-life support for reactors and reactor cores on board French Navy vessels.

Nuclear attack submarine (SNA).
© Marine Nationale



Microbarometer for detecting and localising a possible atmospheric nuclear test, lightning, a volcanic eruption, etc.
© C.Dupont/CEA

COMBATING PROLIFERATION AND TERRORISM

The DAM provides its expertise, based on its nuclear fuel and weapons cycles knowledge, in combating nuclear proliferation and terrorism. To inform the French authorities in the event of a nuclear test, the DAM participates in the implementation of the means for verifying compliance with the Comprehensive Nuclear Test Ban Treaty (CNTBT).

The observance of this treaty is verified by the analysis and characterisation of data collected by the 321 stations of the International Monitoring System and 16 radionuclide analysis laboratories, in which the DAM is strongly involved.

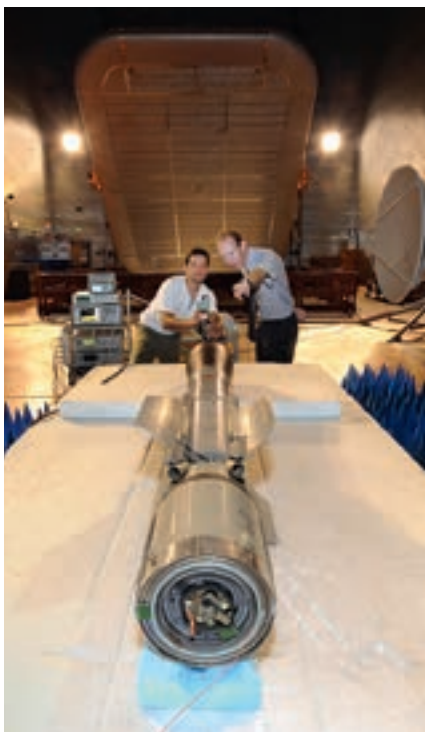
Supported by its competencies in geophysics, the DAM is also responsible for the French Tsunami Early Warning Centre for the Mediterranean and North-East Atlantic (Cenalt). The Cenalt's mission is to alert the French authorities responsible for protecting the population. The authorities of the countries bordering on the Mediterranean or North-East Atlantic that subscribe to Cenalt's services are informed simultaneously.

321
STATIONS AND
16
RADIONUCLIDE
ANALYSIS LABORATORIES
IN THE INTERNATIONAL
MONITORING SYSTEM

On the request of the French government, CEA carries out research to combat chemical biological, radiological, nuclear and explosives (CBRN-E) threats, structured around an inter-ministerial R&D Programme, which the DAM is appointed to lead. This programme is transversal across all the CEA's Directions. Cybersecurity is another focus of the CEA's research for French authorities.

CONVENTIONAL DEFENCE

The DAM, mainly at the Gramat Centre, provides the DGA with project management assistance for conventional defence activities, based on an expertise concerning weapons efficiency and systems vulnerability.



Electromagnetic aggression test in an anechoic chamber.
© L.Godart/CEA

ZOOM ON...
CERTIFICATION OF THE SEABORNE NUCLEAR WARHEAD (TNO)

The TNO allows the exploitation of the full capabilities of the new M51 ballistic missile. Its certification is a formal procedure, officially declared by the Director of military applications. Its purpose is to demonstrate that the design of the TNO meets all the characteristics specified by the Ministry of Defence, that the existing means of production enable the manufacturing of all the warheads, in compliance with the validated design, and that the nuclear warhead will meet safety requirements throughout its lifetime.

INFORMATION TECHNOLOGIES

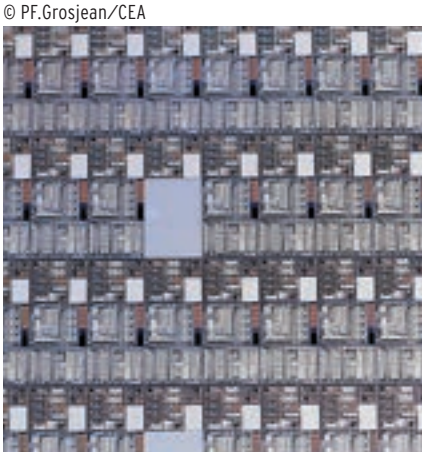
THE CEA CONDUCTS HIGH-LEVEL TECHNOLOGICAL RESEARCH IN THE FIELD OF DIGITAL SYSTEMS, FROM MICRO- AND NANOTECHNOLOGIES TO THEIR INTEGRATION IN APPLICATIONS THROUGH THE DEVELOPMENT OF EMBEDDED, COGNITIVE AND INTERACTIVE SYSTEMS, SENSORS AND SIGNAL PROCESSING. THE INDUSTRIAL APPLICATIONS OF THIS RESEARCH COVER IN PARTICULAR HEALTH, TRANSPORT, SECURITY AND TELECOMMUNICATIONS.

Lithography area in a clean room, one of the stages in the production of 300 mm 3D wafers.
© L.Godart/CEA

MICROELECTRONICS

In the field of microelectronics and microtechnologies, the CEA-Leti Institute conducts research in close collaboration with industrial operators and the whole scientific community.

Example of structured patterns produced in a clean room
© PF.Grosjean/CEA



Its priorities include further:

- Miniaturisation of microelectronic components ("More Moore"). To this end, the CEA is developing new FDSOI substrates and components with SOITEC and STMicroelectronics. It is also studying novel transistors, such as the single electron transistor (SET) or transistors with semiconductor nanowires.
- Diversification, or "More Than Moore". The CEA carries out research on the integration of mechanical, chemical, biochemical and photonic functions. Using the innovative assembly methods SoC (System on Chip) and 3D integration, not only computational capacity (CMOS components) but also sensors and actuators can be integrated on chips.

The innovative devices stemming from this research make use of nanometric miniaturisation and the new properties this confers. These new components can meet the needs of new communications systems and associated services in many sectors of activity, such as telecommunications, health, and more generally what is known as the Internet of Things (IoT). These developments are being pursued in partnership with numerous French, European and international industrial operators.

8 000 SQ. M
OF CLEAN ROOMS

iSurf technology touch-sensitive table for remote control function.
© P.Stroppa/CEA

NANOTECHNOGIES AND NANOSCIENCES

The fields of nanosciences and nanotechnologies emerged in the 1980s with the development of new tools for fabrication, measurement and characterisation at atom scale. These tools, such as tunnel-effect microscopes and tomography, allow not only observations at atomic or even subatomic scale, but also three-dimensional reconstitution of the localisation and displacement of atoms.

Today the nanosciences aim to elucidate and reproduce phenomena, laws and properties that appear in nanometre-sized objects. Understanding why and in what conditions matter organises itself spontaneously in nanostructures, and establishing the link between the structure of a material at nanometre scale and its physical and chemical properties, opens the way to novel applications. For example, carbon nanotubes can be used to store energy, or semiconductor nanowires to store and process information in computers. The chemical and biochemical properties of these nano-objects also open exciting perspectives on health-related applications.

Nanotechnologies cover the instruments, manufacturing techniques and derived applications that exploit the phenomena specific to this nanometre scale, the billionth of a metre.

DESIGN AND EMBEDDED SYSTEMS

Designing materials and software for embedded systems with high levels of safety, security fiability and performance is the aim of research at CEA List Institute. These systems integrate calculation and information processing capabilities in many everyday objects: mobile devices, household appliances, automobiles, medical implants, “smart” cameras, etc., that must meet numerous requirements in terms of security, consumption, cost, lifespan, response time, etc.

In this field, CEA List develops its research activities in partnership with major industrial groups such as Renault, STMicroelectronics, Thales, EADS, Airbus, Areva, EDF and Delphi, and also SMEs such as Esterel Technologies, Sherpa Engineering, All4Tec, etc.

One of the challenges that List has taken up is that of the integration of dedicated embedded systems on a single chip, in order to offer new functions such as connectivity, data processing, energy consumption management and signal generation. Eventually, billions of objects the world over will thus be able to communicate with each other wirelessly via the Internet with total security.

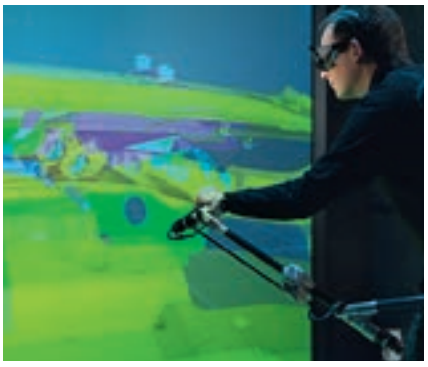
Observations with a scanning electron microscope.
© PF.Grosjean/CEA

1967
CREATION OF LETI,
THE REFERENCE LABORATORY
FOR RESEARCH IN
MICROELECTRONICS

Prototype of enhanced reality on a mobile device.
© S.Renard/CEA

INTERACTIVE SYSTEMS

Interactive systems are designed to help us communicate with our environment. For tomorrow's factories, List is developing innovative technologies to help industrial operators achieve more agile and responsive production, with better performance and quality. Robotics, interactive simulation, enhanced reality, sensory interfaces and multimedia, multilingual information processing are so many technological "bricks" to be integrated into products manufactured by the CEA's industrial partners to make them more user-friendly and transparent.



Demonstration of windscreen wiper assembly by virtual reality.
© P.Stroppa/CEA

TELECOMMUNICATIONS

Research on systems of transmission and telecommunication is ongoing to design, develop and integrate innovative functions using components derived from micro- and nanotechnologies into everyday objects. This research takes into account energy yield and data security requirements. Applications also concern the security and defence fields.

Ultrasound inspection of a rail.
© P.Stroppa/CEA

SENSORS AND SIGNAL PROCESSING

Gaining a better understanding of the environment, extracting intelligible and relevant information from it, and using this information in innovative applications: these are the aims of the research conducted by CEA List. Through its competences in the fields of instrumentation, advanced simulation tools and ionising radiation metrology, List is developing new applications for non-destructive inspection, energy, healthcare and security.

60
CONTRACTS
SIGNED BETWEEN LIST AND INNOVATIVE COMPANIES ON AVERAGE EVERY YEAR

20%
ANNUAL GROWTH IN THE VALUE OF INDUSTRIAL CONTRACTS WITH LIST SINCE 2009

TECHNOLOGIES FOR HEALTH

RIGHT FROM THE START THE CEA DEVELOPED ITS EXPERTISE IN RADIOBIOLOGY AND NUCLEAR TOXICOLOGY TO SUPPORT ITS ACTIVITIES IN THE NUCLEAR FIELD, ALONG WITH THE INTERDISCIPLINARY COMPETENCES NECESSARY FOR TECHNOLOGICAL DEVELOPMENTS IN THE USE OF NUCLEAR SCIENCE IN HEALTHCARE.

The research currently being conducted by the CEA in healthcare biotechnologies is firmly anchored in advanced engineering, and in its capacity to build and operate large research installations. With the construction of platforms and large shared research infrastructures, the CEA is helping to develop new technologies for health, such as large-scale biology (proteomics, genomics, etc.), medical imaging and structural biology.
Research efforts focus on the fundamental molecular and cellular mechanisms of living organisms. They are also mobilised to further innovation in the field of diagnostics, therapeutics and vaccines, including for neurological and infectious diseases and cancer.

Laboratory of Genomics and Radiobiology of Keratinopoiesis.
© C.Dupont/CEA

MEASURING THE IMPACT OF ENERGY TECHNOLOGIES: RADIOBIOLOGY AND TOXICOLOGY

CEA research in this sector is multidisciplinary, and concerns the characterisation of the effects on humans and on the environment of ionising radiation (radiobiology) and radionuclides (nuclear toxicology), and now also of nanoparticles (nano-toxicology), in response to their increasing use in energy processes.

Phytotechnology platform dedicated to studies of the biological effects of environmental pollutants.
© L.Godart/CEA

The work being done in radiobiology focuses in particular on the effects on somatic and germ

4 BIO-IMAGING UNITS

NEUROSPIN, MIRCEN, FRÉDÉRIC JOLIOT HOSPITAL AND CYCERON

National sequencing centre at Genoscope.
© L.Godart/CEA

cells of exposure to low doses of radiation, on individual radiosensitivity, and on new developments in radiotherapy. They contribute to the updating of standards in the nuclear industry and the rational use of medical radiotherapy.

In toxicology, the aim is to study the fate and the health and environmental impact of radionuclides, nanomaterials and chemical compounds used in the technologies developed by the CEA. This work helps to carry forward evidence-based standards of protection and to devise new methods for remedial action and radionuclide decorporation.

UNDERSTANDING PATHOGENIC PROCESSES

The technological expertise developed at the CEA and access to installations for imaging, structural biology, large-scale biology, high-throughput screening and preclinical models, enable the study of both normal and pathological phenomena. They cover the analysis of living systems at several scales: from molecules, cells and organs up to whole organisms.

For example, integrated structural biology and imaging are dedicated to the study of the architecture and dynamics of macromolecules, cells and organs.

In addition, the "omics" (genomics, transcriptomics, metabolomics, etc.) provide information on the quantitative and qualitative variations in cell components during a normal or pathological event.

In this way, researchers at the CEA are helping to advance fundamental knowledge of cell function and of the mechanisms that can switch certain physiological processes to pathological states. Such information can be used to identify therapeutic or diagnostic avenues.

Representation of 38 bundles of cerebral white matter (one colour per bundle) in human brain connections.
© C.Poupon/CEA NeuroSpin

18
STARTUP
CREATED AT THE DSV

60
NEW INDUSTRIAL CONTRACTS
IN 2014

CYCERON biomedical imaging platform.
© P.Stroppa/CEA

INNOVATING IN DIAGNOSTICS AND THERAPY

The CEA draws on its fundamental knowledge base and on the technological developments it fosters to propose innovative approaches to diagnostics, therapy and the study of vaccines.

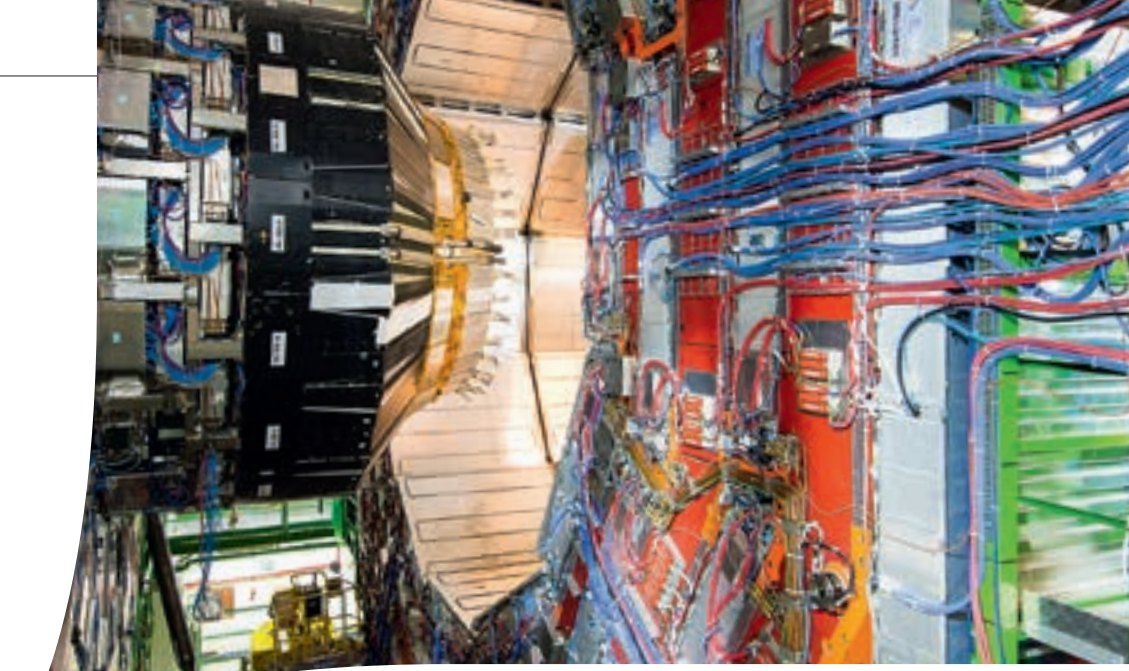
Researchers are exploring this field from several angles: the search for biomarkers for use in early diagnosis and therapeutic monitoring, the search for targets and the development of new therapeutic strategies (molecular, cellular or genic) or vaccine-based. The efficacy and safety of new treatments are assessed in preclinical trials. This work gains from CEA expertise in leading-edge technology (high-throughput screening, large scale biology, imaging and preclinical models) and the top-level research facilities run by the CEA (MIRCen and NeurATRIS for translational research in neuroscience and biotherapy, NeuroSpin and France Life Imaging for biomedical imaging, and IDMIT for preclinical research in infectiology).

Patients with neurodegenerative, neuro-inflammatory, cardiovascular, infectious, metabolic or genetic disorders will enjoy the benefits of these therapeutic innovations.

Isotope labelling platform.
© D.Morel/CEA

ZOOM ON...
MIRCEN: AT THE HEART OF TRANSLATIONAL RESEARCH

MIRCen is a preclinical research installation that possesses leading-edge imaging equipment and a set of platforms dedicated to the development of animal models of human diseases. These are used to assess innovative therapies, mainly in the field of neurodegenerative disorders, but also for infectious illnesses and heart disease.
For example, MIRCen has carried out preclinical tests on a novel gene therapy for Parkinson's disease. This new approach has proved highly promising in human trials, which showed it to be safe and well-tolerated, and to significantly alleviate motor symptoms over a four-year period. MIRCen is at the heart of the NeurATRIS infrastructure for translational research in neuroscience and biotherapies coordinated by the CEA.



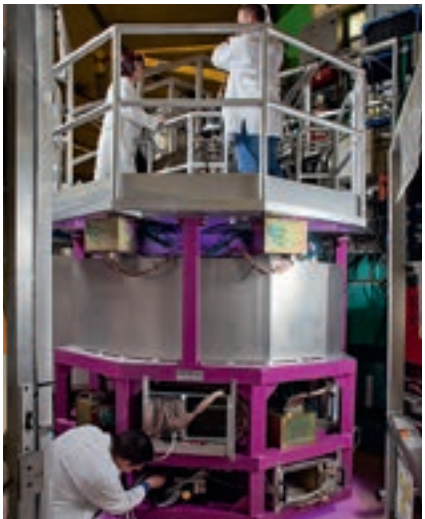
CMS detector at the LHC.
© P. Stroppa/CEA

THE RESEARCH INFRASTRUCTURES (RIs)

The CEA's high efficiency and top-level scientific and technical performance are present in the design, construction, running and use of the European very high research infrastructures, which are essential for the progress of knowledge and innovation.

Ever since its inception, the CEA has contributed to their development and their technological missions, and made available to the scientific community instruments to probe matter in its different states.

Neutronics experiments with the reactor ORPHEE.
© F.Rhodes/CEA

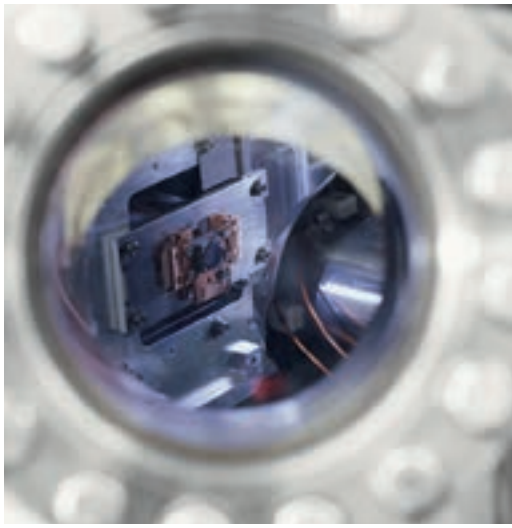


In line with national directives, the CEA's action forms part of the national roadmap for large infrastructures. While at the same time strengthening its role in existing infrastructures, it participates in the development of future RIs. It represents France, with the CNRS and sometimes alongside other organisations, on the steering committees of the RIs, both national and European.

The CEA provides the French and international community with:

- user experts in key areas (nuclear and high-energy physics, materials science, nanosciences, chemistry, etc.);
- constructors: a broad range of basic skills (accelerator engineering, instrumentation, metrology, vacuum and cryotechnology) and project-based organisation bringing users different branches of engineering.

Over the years, the CEA's fundamental and technological research teams have acquired unique competences in fields such as engineering, cryomagnetism, detection, electronics and data processing, making the CEA an essential player worldwide for the development of the major tools of physics such as lasers, space instrumentation, accelerators and particle detectors.



ANTARES beamline on the SOLEIL synchrotron.
© F.Rhodes/CEA

The fields of application and the associated instruments are:

- Neutron sources (Orphée – Léon-Brillouin Laboratory and Laue-Langevin Institute),
- Light sources (Soleil synchrotron, ESRF and XFEL),
- Nuclear physics, high energies and astrophysics (Ganil, Spiral 2, LHC, Fair, telescopes such as Herschel),
- Laser physics (Megajoule Laser),
- Environment (Icos),
- High-performance computing (Genci, Prace).

PROGRAMME SUPPORT

THE CEA IS RELIES ON FOUR FUNCTIONAL CENTRES COMPOSED OF DIVISIONS THAT PROVIDE FULL SUPPORT FOR RESEARCH PROGRAMMES. STRATEGY, HUMAN RESOURCES MANAGEMENT, EDUCATION & TRAINING, VALORISATION, INTERNATIONAL RELATIONS AND RISK MANAGEMENT – COMPETENCES THAT LET THE CEA STRIDE CONFIDENTLY INTO THE FUTURE.

EDUCATION

The National Institute for Nuclear Science and Technology (INSTN) is a higher education establishment managed by the CEA that depends jointly on the French Ministry of Secondary and Higher Education and Research, the Ministry of the Ecology, Sustainable Development and Energy, and the Ministry of the Economy, Industry and Digital Affairs.

INSTN was created in 1956 to train engineers, researchers and technicians for both initial qualifications and in-service training. It offers highly specialised education and training in nuclear sciences and technology as applied in the energy and healthcare fields.

Both initial full-time and blended job-release courses are organised jointly with academic and industrial partners. In all, 38 study paths and 240 inter-company internships are offered as continuing education, leading to individual certifications. INSTN also offers customised in-house training, in French or in English, on request from clients (research organisations, major industrial groups, SMEs/SMIs, institutions, hospitals, pharmaceutical firms, etc.).

The Institute pursues an European and international course, alongside I2EN (see box), actively participating in the creation of the European Higher Education Area in the nuclear sector. It is a founding member of the ENEN Association (European Nuclear Education Network), a network bent on promoting this specific teaching, chairing this body from 2003 to 2013. INSTN is also involved in projects of the Framework Programme for Research and Development (FPRD) aimed at developing and harmonising education and training in Europe.

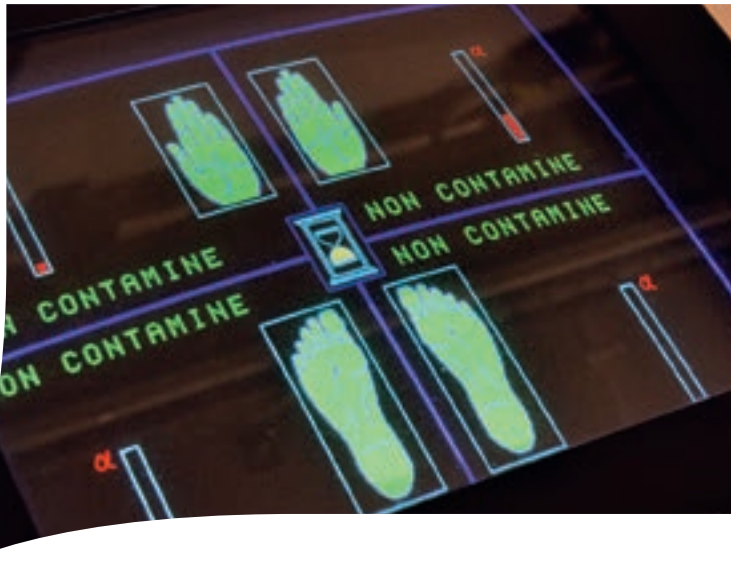
38
STUDY PATHS
AND
240
STAGES
INTER–COMPANY INTERNSHIPS ARE OFFERED AS CONTINUING EDUCATION

Practical work on a simulator for graduate students in their specialisation year in atomic engineering.
© PF.Grosjean/ CEA

ZOOM ON... I2EN

The mission of the International Institute of Nuclear Energy is to put forward to France's international partners the best training solutions for the development of human resources in the nuclear energy field. The aim is to share best practices in safety

I2EN International Institute Of Nuclear Energy



Screen of a radiological inspection carried out on a hand–foot monitor.
© L. Zylberman/CEA

EVERY YEAR,
THE CEA PUBLISHES ITS
"RISK MANAGEMENT REPORT"
AVAILABLE AT
WWW.CEA.FR

VALORISATION

The CEA is engaged in high-value research in several fields – energy, information and health technologies, defence and security. Ever since its creation, it has been committed to a valorisation policy. Teams dedicated to economic intelligence and strategic marketing have as their mission to draw up and follow good practice in protection and valorisation of knowledge and expertise in all sectors of activity.

The CEA's research results often lead to applications for patents, making the CEA the leading research organisation for patent submissions to the French National Institute of Industrial Property (INPI). The CEA's patent portfolio is exploited mainly through actions of technology transfer towards industry, in particular in the framework of collaborative contracts in which this intellectual property capital is invested in production.

The CEA has placed its competences at the service of companies, whether internationally-sized major players or SMEs/mid-tier firms, to develop and dynamize their capacity for innovation.

Through this strategy, the CEA plays an essential role in the creation of innovative enterprises that carry forward the technologies it has developed, or that have grown out of a strong R&D collaboration. To accompany them into the industrial growth phase, two subsidiaries, CEA Investissement and EMERTEC Gestion, can provide funding.

HUMAN RESOURCES

The CEA is an research establishment of an industrial and commercial nature (EPIC). As such, in the management of its relations with its employees, the CEA is governed by private company law. It applies the French Work Code as its legal and regulatory framework.

Team working on the Genepi platform at Grenoble. © D.Guillaudin/CEA

The Human Resources and Social Relations Division is entrusted with steering the CEA's human resources and social relations management policy, monitoring its application and ensuring its consistency.

In this framework, it leads a network of managers and human resources staff present in its clusters, centres and operational units.

It takes into consideration the employees' aspirations through individualised career management, and sustains a permanent dialogue with workforce representatives and trade unions.

It implements means for the adaptation and renewal of competences for the success of CEA programmes in a context marked by numerous new scientific, economic and social evolutions.

THE CEA'S INTERNATIONAL RELATIONS

The CEA's International Relations Division advises the government on questions of external nuclear policy, and represents France in the international organisations of the nuclear sector, such as AIEA and AEN.

It impels and develops cooperations in its different domains of activity with counterpart organisations in other countries.

The CEA's European and international policy hinges around several major objectives: these include participating in the construction of the European Research Area, developing its international scientific outreach, and supporting France's nuclear energy export policy, in particular through its collaboration with international partners engaged in civil nuclear energy programmes.

RISK MANAGEMENT

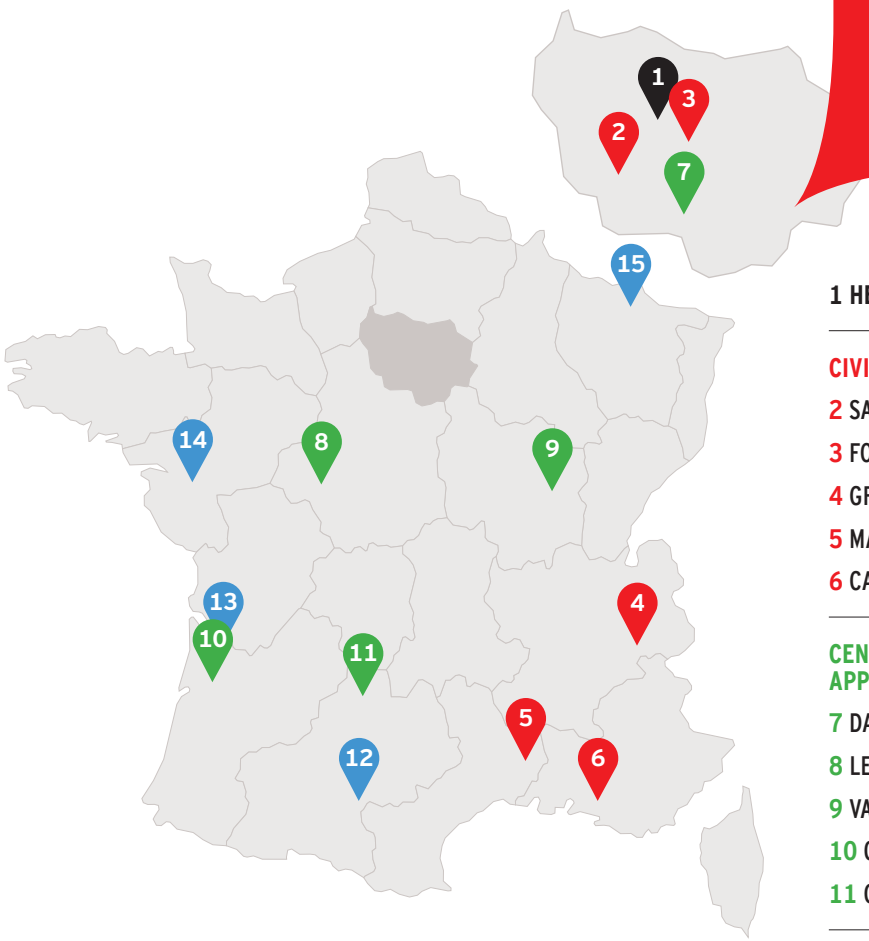
Risk management is a unavoidable requirement for the projects entrusted to the CEA and in the different activities involved in exploitation the installations and laboratories in its charge. Permanent mobilisation to ensure security, nuclear safety, and protection of human populations and the environment, takes top priority among all the CEA's staff.

Identifying risks, assessing them and ranking them forms the basis of annually updated risk mapping. This mapping serves as a reference for the CEA's risk management policy and sets its programme of audits and inspections, a central part of its continuous improvement strategy in this domain.

This risk governance is exercised in:

- the protection and monitoring of the environment,
- nuclear safety, transport security,
- health, staff security and radioprotection,
- protection of sites, plant and assets,
- crisis management,
- management of legal risks.

10 CEA'S CENTRES IN FRANCE



1 HEADQUARTER

CIVIL RESEARCH CENTRES

2 SACLAY (Headquarter)
3 FONTENAY-AUX-ROSES
4 GRENOBLE
5 MARCOULE
6 CADARACHE

CENTRES FOR MILITARY APPLICATIONS

7 DAM Île-de-France
8 LE RIPAULT
9 VALDUC
10 CESTA
11 GRAMAT

REGIONAL TECHNOLOGY-TRANSFER PLATFORMS

12 TOULOUSE
13 BORDEAUX
14 NANTES
15 METZ

FROM RESEARCH TO INDUSTRY

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