DE LA RECHERCHE À L'INDUSTRIE

cea

Marcoule

→ Atalante

in service of sustainable nuclear energy

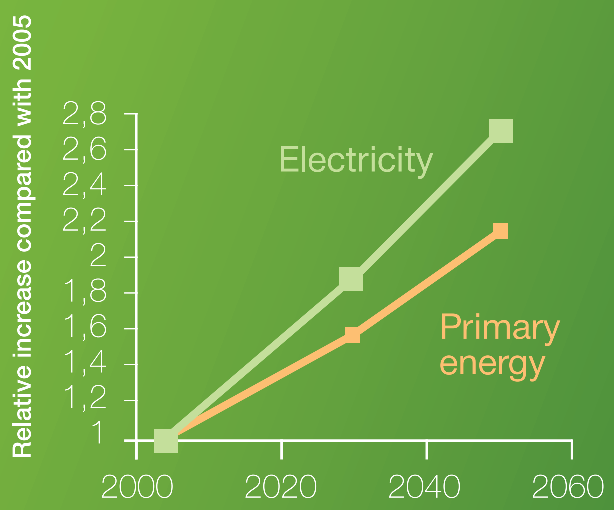
ATALANTE

at the heart of **international** nuclear research

Global energy demand will more than double in the next 40 years. Competitive, with minimal CO_2 emissions and with abundant resources, nuclear energy has serious advantages as a key asset in a sustainable energy mix. However, it must offer safe and responsible waste management routes and develop robust processes to recycle reusable energy-producing materials.

How can we develop and optimize industrial processes for separating the constituents of spent nuclear fuel while optimizing the conditioning of the ultimate wasteforms? The Atalante complex was designed to address these challenges.

At the heart of the CEA Marcoule Center, Atalante is the largest nuclear facility in the world dedicated to research and development in actinide chemistry. In a single place, basic and applied research experiments can be performed covering many stages of the fuel cycle, and in particular the back end.



Expected progression of global energy demand between 2000 and 2060 (International Energy Agency, 2008)

The **actinides** are the heaviest chemical elements found in nature. They are radioactive, emitting energy (gamma radiation) and particles (alpha and beta radiation). Among them, uranium and plutonium are capable of splitting and releasing a large quantity of energy (nuclear fission); they thus constitute a powerful source of energy. Other actinides such as americium, curium and neptunium, but also plutonium, are created artificially in nuclear facilities. Their management is a major challenge for the nuclear industry.

The back end of the nuclear power cycle covers the processes for **managing spent nuclear fuel,** from its removal from the reactors to recycling of reusable materials (uranium and plutonium) and safe confinement of the ultimate wasteforms, especially long-lived high-level waste.

Programs and **challenges**

The research programs carried out in Atalante focus on the chemistry of spent fuel treatment and recycling as well as waste management and investigation of processes for the future fuel cycle. CEA teams also meet the current industrial needs of AREVA to optimize the operation of its fuel treatment plants at La Hague, on the English Channel.

▸ Improve the existing treatment process in support of AREVA

- Optimize the recycling process to move toward co-management of uranium and plutonium in order to strengthen the proliferation-resistance of the fuel cycle.
- Reduce emissions from the plant to minimize its environmental impact (recycling of reactants, trapping, containment matrices).
- Support new fuels to demonstrate their reprocessability and optimize the treatment process implemented in the La Hague plants.

▸ Define future treatment and recycling processes

- Multiple recycling of **plutonium**: 4th-generation reactors will recycle plutonium and uranium several times. The available inventory of these two materials will eliminate the need for using natural resources (prospecting for new uranium deposits) over the very long term, ensuring energy independence and stable energy prices. Atalante teams conduct studies to demonstrate the technical feasibility of these processes.
- **Minor actinide** recycling: in Atalante, the CEA defines enhanced actinide separation processes. Through "selective sorting", these elements can be "burned" in 4th-generation nuclear reactors. The toxicity of the ultimate wasteforms, limited to fission products alone, would thus be reduced to that of natural uranium after about 300 years, compared with 10 000 years or more at present.

▸ Define matrices for waste and actinide materials

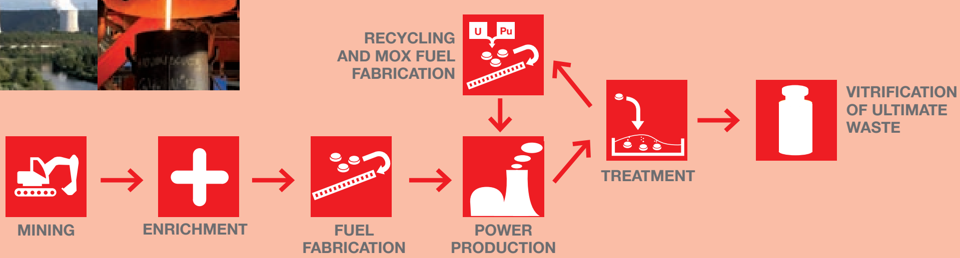
- Immobilize ultimate radioactive waste in durable matrices by fabricating dedicated glass or ceramic materials for long-term waste conditioning.
- Investigate the long-term behavior of conditioning matrices to determine their chemical durability under the conditions of a deep geological repository.
- Synthesize actinide compounds for specific applications (fabrication of sources and new fuels).

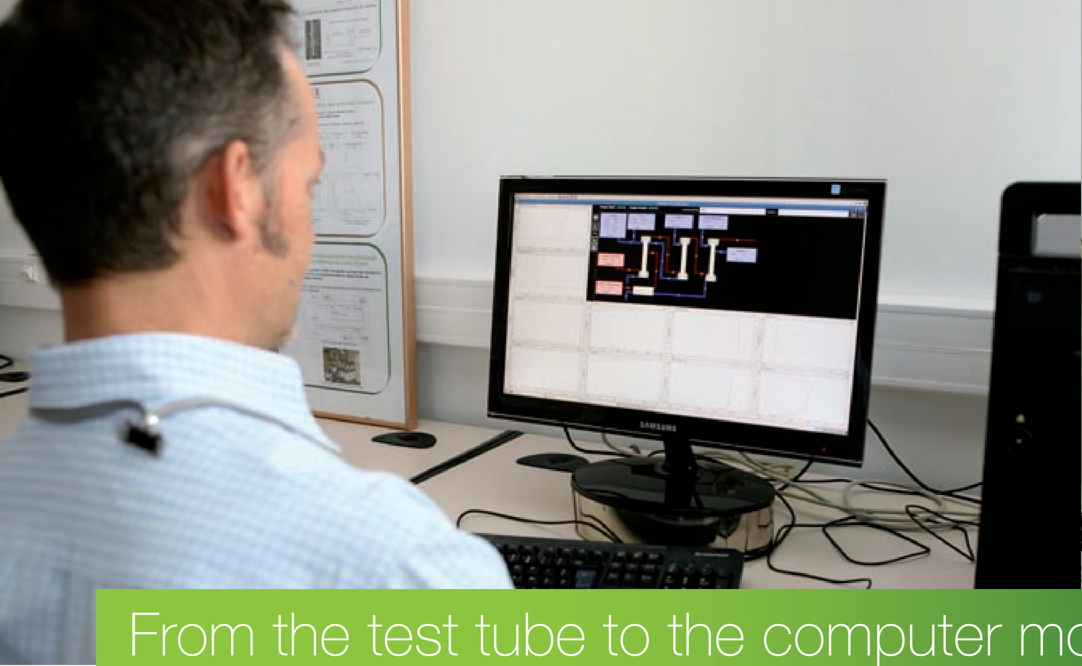
Spent fuel treatment separates the reusable elements (uranium and plutonium) from the minor actinides and fission products, which are currently considered as ultimate wasteforms.

Once-through **plutonium** recycling is an industrial reality in France, in the form of "MOX" fuel. About twenty nuclear power plants in France currently use MOX fuel, saving nearly 17% of natural uranium. The new EPR reactor is also designed for use with recycled plutonium. The toxicity of the ultimate wasteforms is divided by 10.

The **minor actinides** (americium, curium, neptunium) are produced in very small quantities in nuclear reactors, but they are responsible for most of the radiotoxicity and heat released by spent fuel, once the plutonium has been recycled.

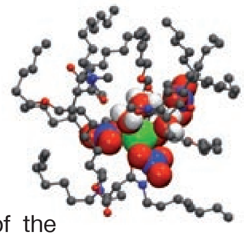
Fuel Cycle





From the test tube to the computer model: scientific **performance and innovation**

Example: the development of separation processes



Understanding atomic-scale interactions between actinides and extractant molecules

Designing molecular traps capable of selective or group separation of the actinides requires the selection, synthesis, and laboratory testing of dozens of molecules each year. The design program is guided by an understanding of the interactions between actinides and extractant molecules.

Characterization of extractant properties

Tests carried out in glove boxes on small quantities of material provide basic data defining the extractive and separative properties of the molecules.

Development of models

The experimental data are compared with data obtained by modeling to understand the extractive properties at atomic scale. Chemistry and molecular modeling allow us to understand these phenomena.

Development of process flowsheets for selected molecules

Thermodynamic and kinetic data concerning actinide separation are supplied to the physical and chemical models integrated in simulation tools to calculate separation schemes and process operating conditions, as well as to extrapolate their performance from laboratory scale to industrial scale.

Flowsheet testing

The technological feasibility of separation processes is demonstrated in shielded cells with a few kilograms of spent nuclear fuel in liquid/liquid extractors representative of industrial technologies, whose performance can be transposed to full-scale industrial plants.

Large-scale nucle

- Physical, chemical and radiochemical measuri electron probe microanalyzer, ICP-MS, ICP-QM controlled potential coulometer, thermobalance.
- Isotopic assay tools: thermal ionization mass sp
- Speciation tools: Fourier transform infrared spec spectrometer.

Unique **expertise:**

Atalante is also teams of scientists with expertise in:

- quantum chemistry, molecular chemistry, and structural chemistry for the design of new molecular structures,
- radiochemistry to study and understand the specific reactivity of radioactive materials,
- analytical chemistry and analytical techniques in high-activity environments to analyze solid or liquid samples,
- process modeling to incorporate the experimental results in physicochemical models, which are the building blocks of the simulation tools used to design and validate industrial processes,
- chemical engineering through integral tests, technology development, and optimized device control,
- materials engineering to produce and characterize containment matrices and fuels,
- operation of basic nuclear installations, particularly with regard to ensuring conventional and nuclear safety of employees and safe management and operation of nuclear facilities.

From **ACSEPT** to **SACSESS**

ACSEPT (Actinide reCycling by SEParation and Transmutation) is a joint project among more than 30 European partners with European funding from 2008 to 2012 to develop minor actinide recycling processes. It is one of a series of projects around which European research in this area has been organized since the early 1990s. It is succeeded in 2013 by SACSESS (Safety of Actinide Separation Processes).

International projects and networks

Atalante is an unparalleled research facility that is central to many R&D programs carried out in collaboration with international organizations under bilateral or Community agreements (projects within Seventh Framework Programme of the European Atomic Energy Community - FP7 EURATOM).

Atalante hosts foreign researchers, university students and experts in an exceptional working environment.

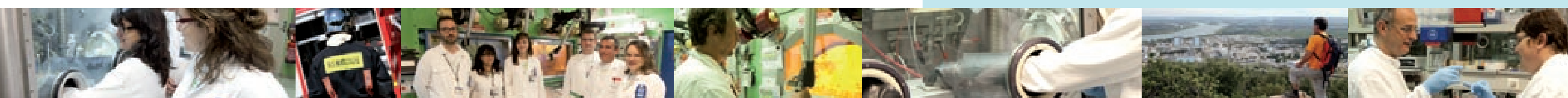
The European Commission is funding networking and access to major research infrastructures such as Atalante by researchers from other countries (ACTINET and TALISMAN networks). The objective is to develop knowledge in actinide science, a pillar of nuclear safety.

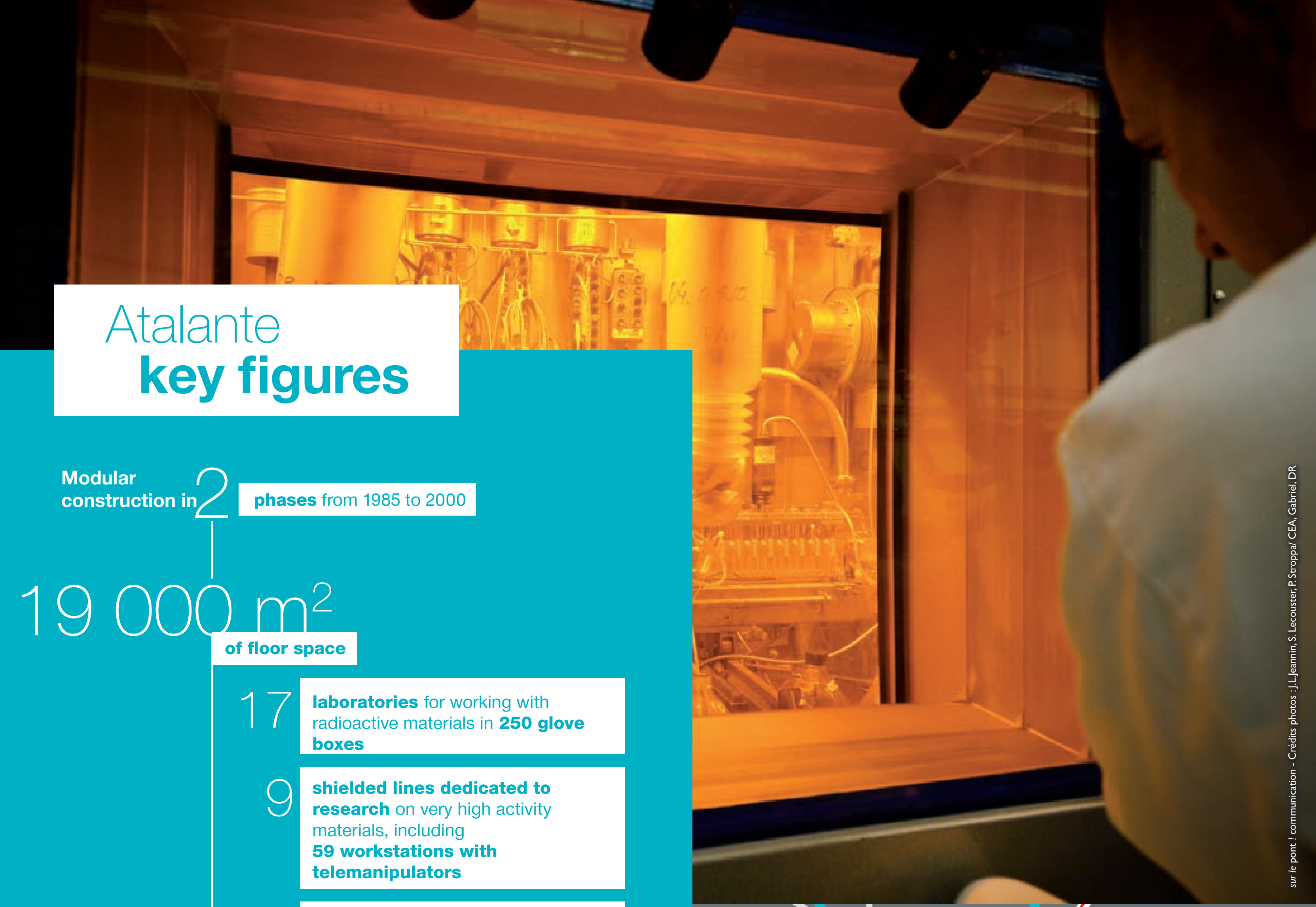
earized analysis equipment

ng instruments: X ray diffractometer, scanning electron microscope (SEM),
MS, and ICP-AES, gamma and alpha spectrometers, isothermal calorimeter,

ectrometer (TIMS) and ICP-MS.

trometer, ESI-MS, RAMAN spectrometer, TRLIFS, nuclear magnetic resonance





Atalante
key figures

Modular construction in **2** **phases** from 1985 to 2000

19 000 m² **of floor space**

- **17** **laboratories** for working with radioactive materials in **250 glove boxes**
- **9** **shielded lines dedicated to research** on very high activity materials, including **59 workstations with telemanipulators**
- **1** **organic liquid waste treatment unit**
- **1** waste drum **radioactivity measuring** station
- **2** **shielded lines** for managing liquid and solid waste in the facility

More than **270** **CEA employees**

- **200** **research engineers and technicians** involved in research work, including more than 30 young trainees
- **70** **CEA employees responsible for operation of the facility** (conventional and nuclear safety, liquid and solid waste management, maintenance operations)

sur le pont ! communication - Crédits photos :J. L.Jeannin, S. Lecouster, P. Stroppa/ CEA, Gabriel, DR

CEA Marcoule

Centre de Marcoule • BP 17171
30207 Bagnols-sur-Cèze cedex
France
Tel. 04 66 79 60 00
www-marcoule.cea.fr