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Topic 3 Hot cells and equipment*

**French R&D facilities for reactor fuel examination
Trends for the next century
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Thirty years after the startup of nuclear power production and of associated R&D facilities, the CEA is faced with choices in order to operate fewer labs:

- revamp some of them so that their safety behaviour matches recent requirements, close down others;
- improve some of them to accommodate future trends as far as new material to be tested and new equipment are concerned.

Existing labs and the strategy will first be presented. Then objectives and motivations will be discussed for the two labs elected to be operated in the next century.

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Since the beginning of the nuclear reactor era, the CEA has operated hot cell facilities in each of its research centers, particularly at:

- Fontenay-aux-Roses, where the RM2 laboratory was successfully operated from 1968 to 1981, and at present is being dismantled because of its now urban location;
- Grenoble, where the dual operation of SILOE, an irradiation facility, and LAMA, a hot cell laboratory, will have been successfully managed since 1961, and will progressively be shut down, in compliance, here again, with the French policy of decreasing nuclear activities near areas of high-density population;
- Marcoule, where the operation of the multipurpose leak proof LSAI facility allows the non-destructive testing of full size FR and PWR fuel assemblies to be performed. This lab will be kept in operation as long as it is needed by the programmes.
- Saclay, where, since 1959, the LECI has examined irradiated fuel and will now be adapted to allow the examination and mechanical characterization of irradiated materials to be conducted;
- And finally, Cadarache, where the LECA-STAR laboratories are used for the examination of full size fuel pins including destructive analysis and fabrication with irradiated fuel. It has been used since 1964 for GNU fuel as well as PWR and FR fuel.

Because of the global situation of hot cell facilities and of the future needs in Research and Development, the CEA has made changes in its strategy, in particular concerning the laboratories of the Nuclear Reactor Directorate.

This change aims at:

- keeping the potentialities in the long term,
- rationalizing and modernizing the existing equipment,
- making the necessary consolidations,
- developing new equipment.

In actual fact, this change entails (Fig. 1):

- a regrouping of the activities on irradiated fuel in Cadarache, using the irradiation means of the Jules Horowitz reactor, of the LECA-STAR hot cell facilities,
- a regrouping of the activities on irradiated material in Saclay in the LECI laboratory within the framework of the development of the expert group on irradiated material mechanics and metallurgy (C3MI).

This requires conducting large study programs in both these laboratories.

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Saclay facilities : irradiated material mechanics and metallurgy

The main objective is to make the LECI the hot cell facility of the C3MI for the examination of non-fissile irradiated material. However, in view of the proximity of the OSIRIS reactor, the LECI will keep its potential for fuel examination, on short experimental rods.

The revamping of the LECI benefits from the new safety requirements, developed since 1990 with:

- a renovation of the ventilation,
- the progressive cleaning of the K and I cells with improvement of the static containment and of the experimental conditions.

The work undertaken since 1995 has concerned:

- modification of the K line, made up of 11 concrete shielded cells,
- modification of the I line, made up of 9 lead shielded cells,
- creation of a new line of lead shielded cells: the M line.

1/ Modification of the K line

This modification consists of:

- the creation of a machining center:
 - . saw, lathe and milling machine,
 - . electron discharge machining,
 - . preparation of absorber examinations.
- the development of a tool for the study of the corrosion of irradiated materials made of a loop in PWR conditions with one to three pressure enclosures in parallel,

- keeping the experimental fuel rod characterization means (of Fabrice type for example),
- the development of waste separation and packaging,
- the installation of a 25 ton universal machine for the mechanical characterizations of large test specimens.

2/ Modification of the I line

This essentially concerns the modernization of the sample preparation and metallurgy means with:

- the preparation of the samples for MEB, MET and RAMAN,
- hardness,
- macroscopy,
- microscopy.

3/ Extension : the M line

The installation of the mechanical and surface characterization means at the LECI requires the creation of a new line of lead shielded cells : the M line.

This line, made up of two parallel containment lines surrounding a handling zone and a zone for surface characterization equipment, will be installed in the new building. This building, constructed within the perimeter of the BNF, is connected to the main building through galleries.

The equipment presently forecast is the following:

- storage, dispatching,
- sample machining and preparation,
- tension,
- toughness,
- low cycle fatigue,
- 50 and 450 Joule impact strength,
- creep due to internal pressure,
- axial creep,
- machine allowing the internal pressure and tension to be coupled,
- metrology,
- electron microscope,
- RAMAN spectrometer.

The structure of the building and the installation of the line allow for the future development of 4 to 5 containments (test specimen reconstitution, characterization means of mini test specimens,...) and of the equipment needed for the characterization of additional surfaces.

The start-up of this new line is forecast for mid - 2000, whereas the start-up of the other equipment in the K line will be staggered from 1997 to 2000.

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Cadarache facilities : irradiation and fuel examination

The CEA has recently decided to concentrate all activities related to research on reactors and fuel in its research center in southern France, Cadarache.

First of all, an irradiation facility called the Jules Horowitz reactor is to start in 2005. It will be a 100 MWth water moderated and cooled pool type reactor. Jointly we will have to operate a hot cell examination facility. It will be designed around the existing LECA-STAR laboratories.

The newly built **STAR hot cells** are seismic tolerant and will only be available for research, in 2005, after a long campaign of former nuclear fuel preparation for reprocessing or long term storage. This facility will then be modified to accommodate the examination and preparation of advanced fuel such as high plutonium content, high burn-up or actinide targets. Specifications for equipment will be made later when appropriate according to schedule. Nevertheless, it is worth mentioning the use, in the near future, of an ionic probe for active fuel examination.

As far as the older lab is concerned, the **LECA fifteen hot cells facility**, the decision to revamp it was taken at the end of 1980, but the tricky decision of how to accommodate :

- the recommendations available for new labs,
- the safety analysis,
- the request for availability during repair and improvement work and
- the budget,

was only taken in 1996. It was decided that all the necessary work and improvement should be performed, except for the complete redesign of the building to enable it to withstand the most heavy earthquake expected locally. Details of this decision are discussed here under.

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The LECA facility and seismic behaviour

The main building and hot cells were presumably designed to withstand a MERCALI 7 intensity earthquake, which is not consistent with what would be required of a new building designed today. The basic design earthquake is intensity VIII on the MSK scale (safety seismic level IX). Moreover the codes to be used today would give a gap of about 2 levels on the guaranteed good behaviour scale, in case of seismic solicitation, compared to codes used in the early sixties; though the main buildings will not withstand the basic design earthquake. Nevertheless, the ultimate safety estimation of consequences of the complete ruin of the building and cells would not require the population to be confined in their houses with respect to the ICRP 63 recommendations.

Primary studies of a total modification of the building to comply with the present requirements would be such a tremendous job that it would require a 4 to 5 year shutdown of all activities, without even taking into account the time required to withdraw all fissile material and decontamination.

In view of these major obstacles, three decisions were taken:

- reduce the fuel and contamination present in the lab to the strictly necessary amount,

- stop contaminative activities and reduce by a factor of ten the amount of fuel by the year 2010,
- set-up a group of experts in building engineering which will:
 - ⇒ give a best-estimate behaviour of the facility versus the seismic intensity of an earthquake. It is foreseen to demonstrate that the primary barrier (the cells) would reasonably sustain high levels of solicitation without major problems;
 - ⇒ suggest obvious works which will improve the safety consequences.

Apart from this analysis, the revamping of the lab will include:

- decontamination work,
- ventilation improvement through a more leak-proof concept of the cells, particularly for those which will be used for high plutonium content fuel,
- analysis and work to reduce fire hazards,
- implementation of a redundant electricity distribution,
- improvement in facility control and human behaviour through safety culture education and other features (management, organization, lower level of contamination procedures).

This work should be completed before the end of the year 2001 and 30 MUS\$ have been allocated for this operation.

This will enable the French Atomic Energy Agency to continue research on fuel and, during the following years, prepare the lab which will be operated later on by 2005 using the STAR equipment and extensions.

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These revamping and extension programmes of the French R&D facilities are intended to fit in with the main phases of the electric nuclear power plant forecast and associated main irradiation facilities. Five items will be considered (Fig. 2):

- the existing fifty PWRs and their life expectancy (up to 2030),
- the foreseen future generation of plants to startup from 2010 to 2020,
- a test plant of a new generation of reactor (EPR) to be started up according to the French utility at the beginning of the next century (at least for the design),
- finally, the forecast irradiated facility, the French JH reactor to be started up in 2005 and for 30 to 35 years of operation, which should replace the OSIRIS test pile.

As far as the availability of our two labs is concerned, we have to meet this time frame requirement, which is quite a challenge when taking into account the existing facilities, safety requirements and availability during revamping operations.

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Trends for the next century

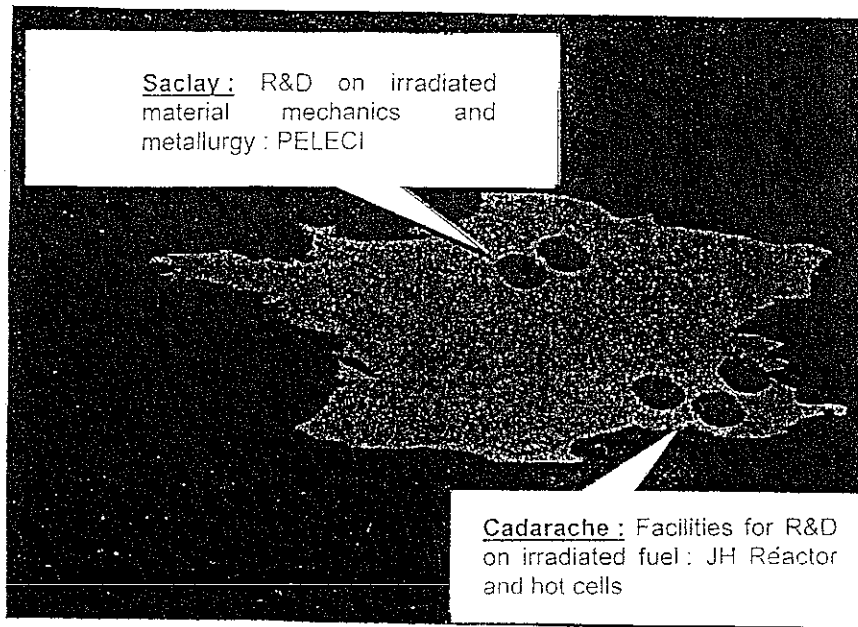


Figure 1



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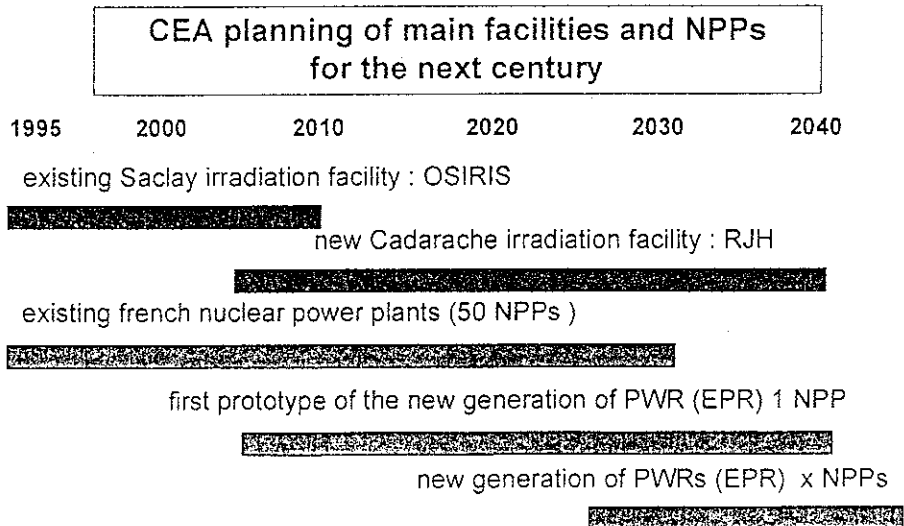


Figure 2



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French research and development facilities for fuel reactor examination

Trends for the next century

Francis LEFÈVRE et Jean-Philippe GIRARD



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Trends

French R&D facilities are 30 years old

- Needs for existing NPPs fuel optimization
- Needs for future reactor concept and advanced fuel programs
 - ⇒ new facilities,
 - ⇒ revamping of older ones,
 - ⇒ closing of some others



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Trends for the next century

Saclay : R&D on irradiated material mechanics and metallurgy : PELECI

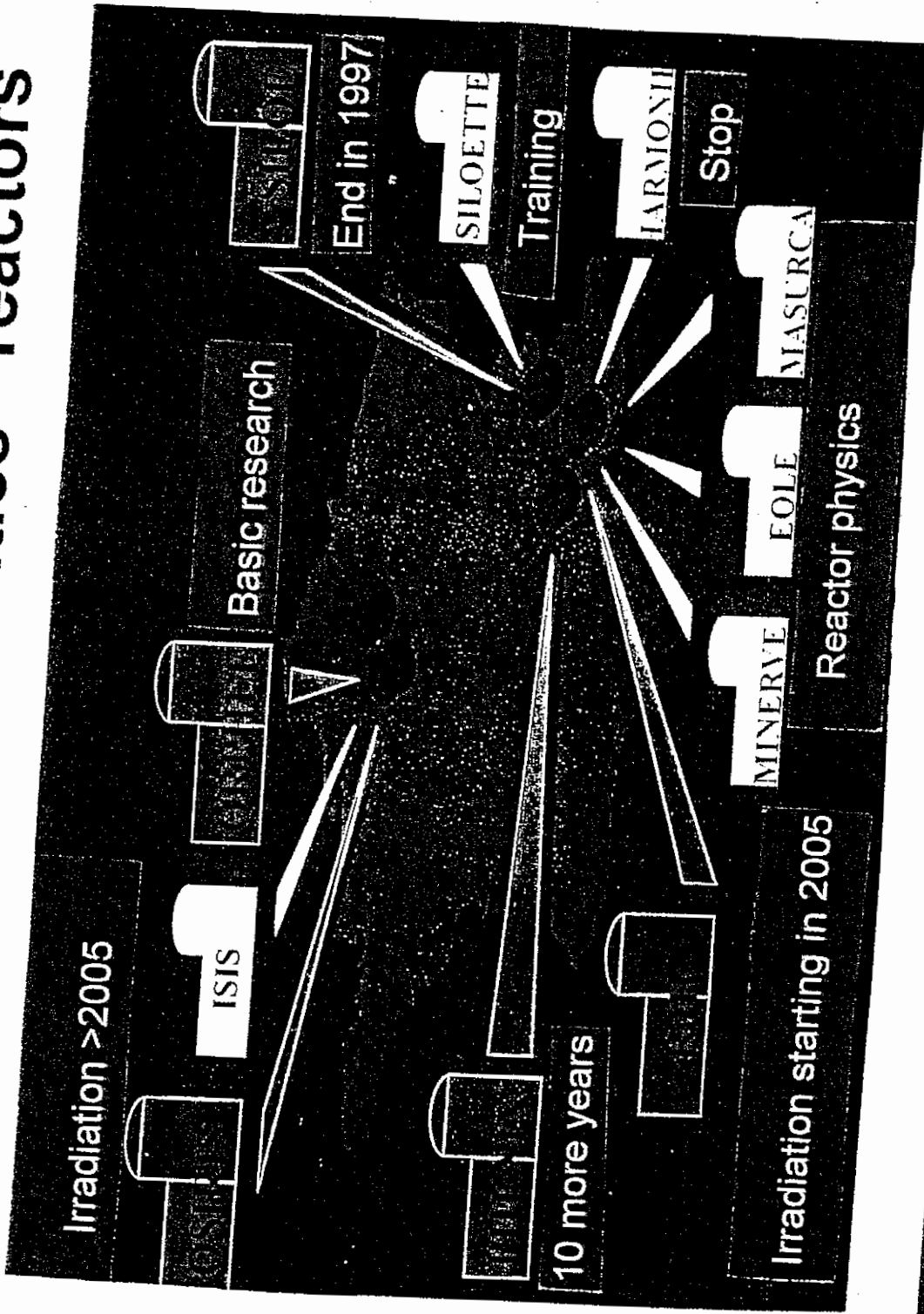
Cadarache : Facilities for R&D on irradiated fuel : JH Reactor and hot cells



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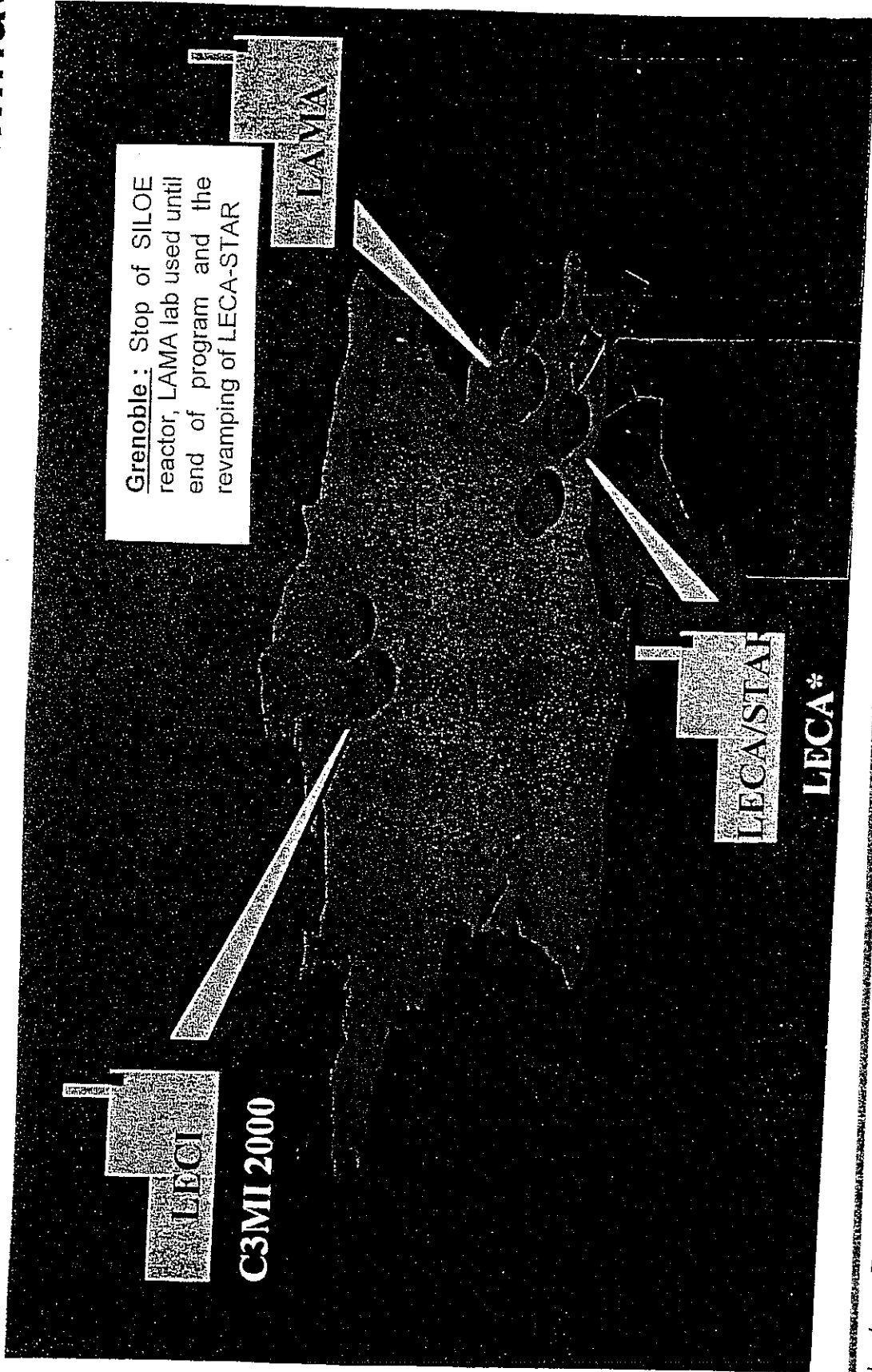
French R&D facilities - reactors



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Hot cells for irradiated material and fuel examination



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LECI project

**for expert group on irradiated material
mechanics and metallurgy
(C3MI)**



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Existing facilities on Saclay center

LECI : Irradiated fuel examinations
Metallography

LHA : for several activities

and particularly mechanical characterization
on non fissile material



Objectives of the LECI project

**To make the LECI
the hot cells facility for
non fissile material examination**

- with :
- regroup of all examination means
 - keep its potential for fuel examination on short experimental rods



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For this :

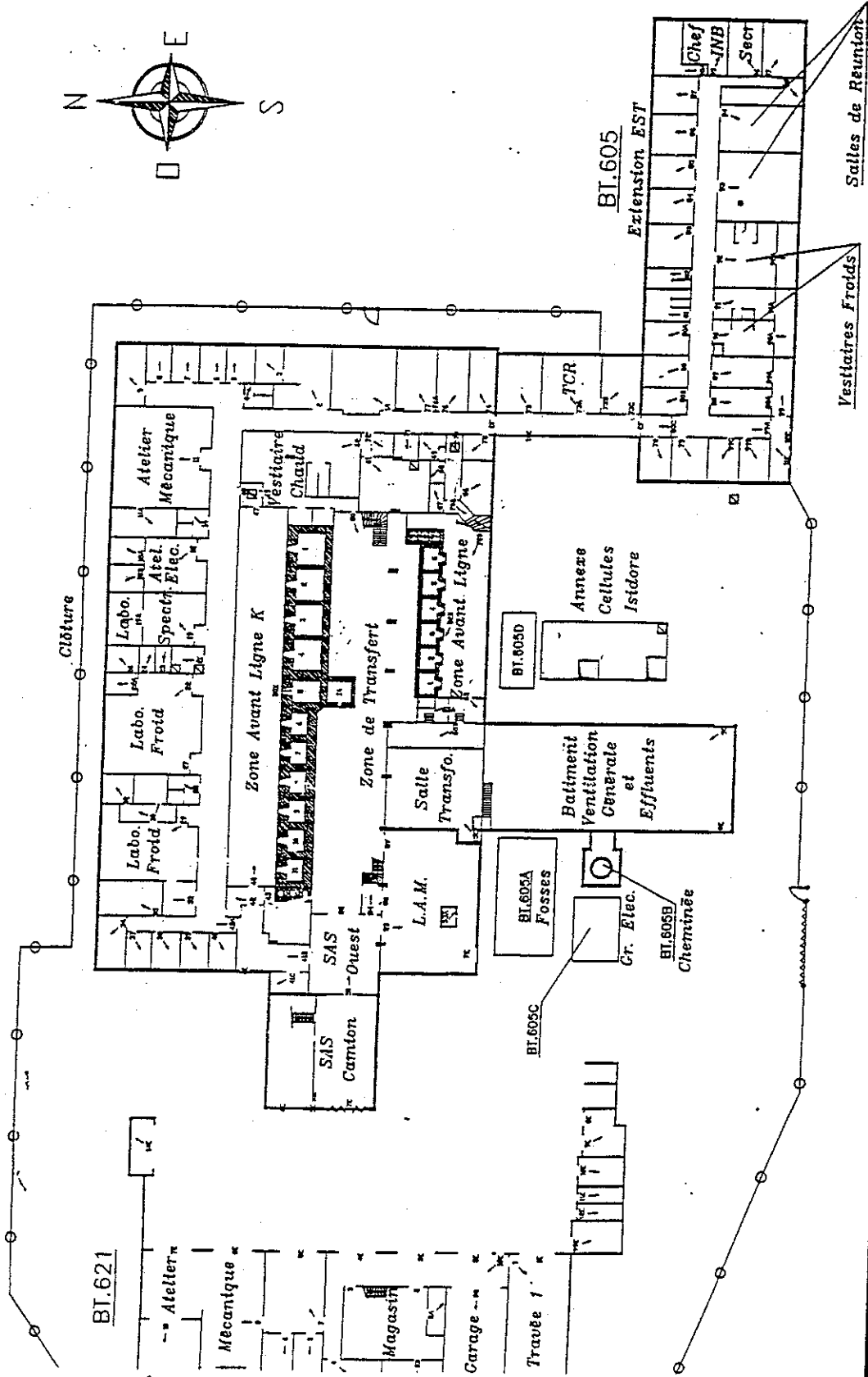
- continuation of the cleaning of the existing cells**
- modification of the experimentation in these cells**
- creation of a new line of cells :
→ M line**



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Schema of LECI



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Future status : K line

Machining center

- saw , lathe , milling machine
- electron discharge machining
- preparation of absorber examination

Corrosion studies

- loop in PWR conditions with 1 to 3 autoclaves



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Future status : K line (continuation)

- waste separation and packaging**
- 25 ton universal machine**
- experimental fuel rods examination means**



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Future status : I line

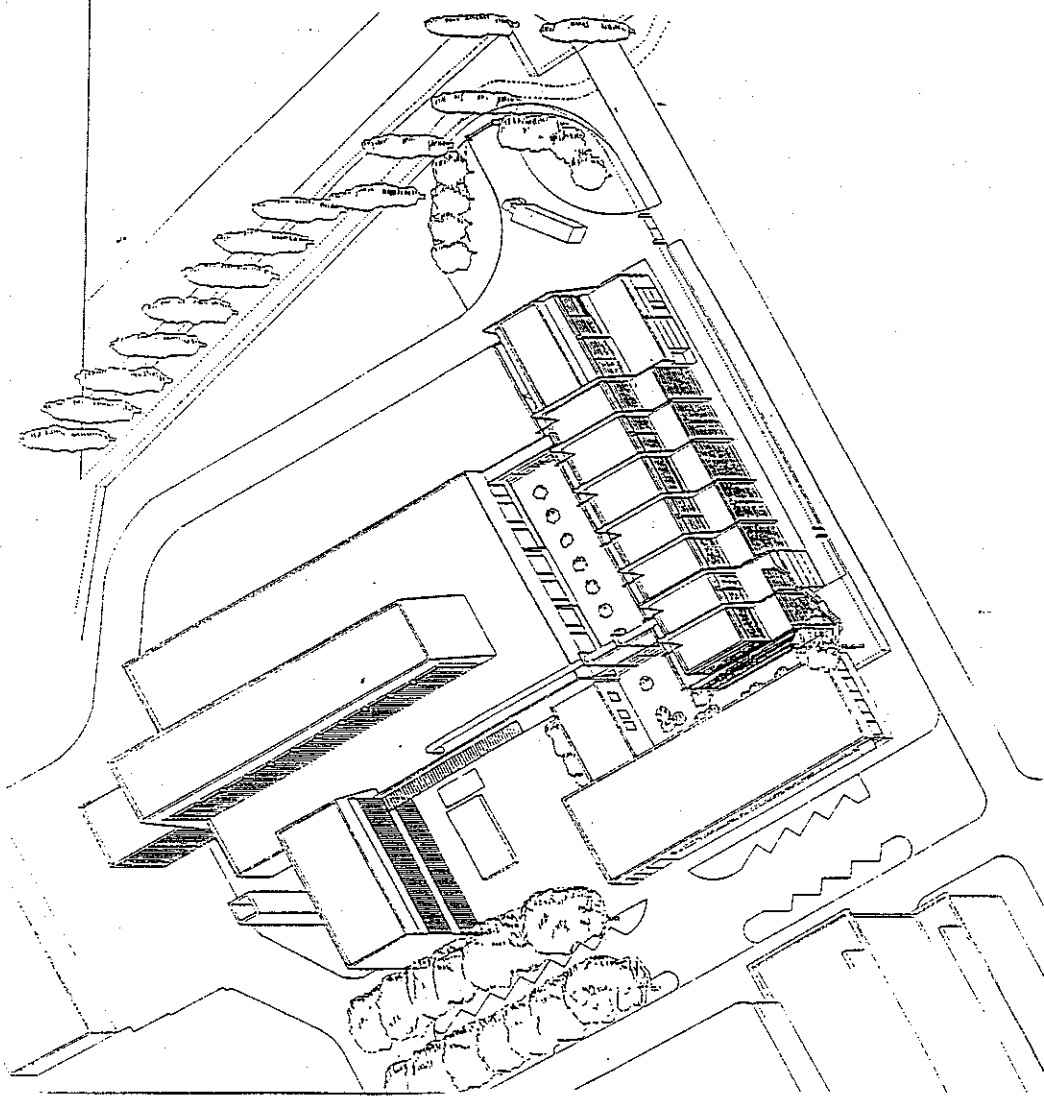
- modernization of sample preparation for MEB, MET and RAMAN
- Hardness
- Macroscopy
- Microscopy



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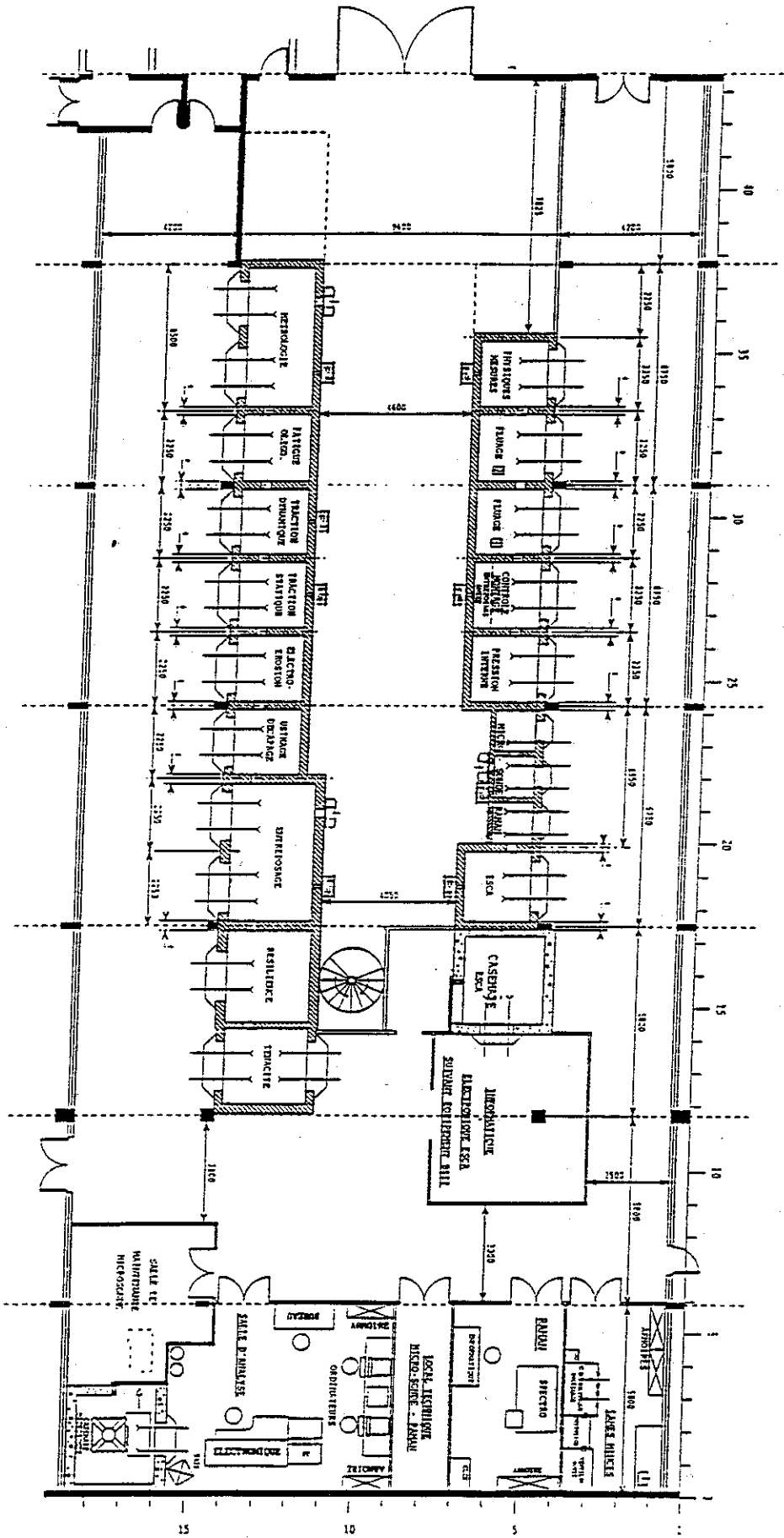
M Line localization



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Schema of M Line



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M Line Experimental equipment

Mechanical characterization

Tension, toughness, low cycle fatigue,
creep due to internal pressure, axial creep,
50 and 450 joule impact strength

Analysis

Electron Probe Microscopy Analysis
Raman spectroscopy



DRN

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P-LCCad project

Cadarache hot cells for fuel examination



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Objectives of the Cadarache fuel examination facility

In conjunction

- with the irradiation facility JHR,
- with the life expectancy of the French NPPs

⇒ *insure the availability of hot cell for fuel examination from now on to year 2040*



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Duties for the Cadarache hot lab.

- **Fuel qualification and optimisation: PWR, FR, other projects including Pu and actinide burning**
- **Others activities in conjunction with major equipment of the Cadarache Center : transient test reactors for safety analysis (PHEBUS, CABRI, SCARABEE), fuel encapsulation before storage or reprocessing**

Examination, fuel pin fabrication, encapsulation



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Existing facilities on the Cadarache Center

LECA : 15 cells, started in 1964
design for R&D on fuel

STAR : 3 large cells started in 1994
design for former fuel encapsulation, available for R&D in
2005

Both in the same place, manage as one nuclear facility



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Safety analysis and strategic decision

Seismic hazard in this region is level VIII (historical) and IX (safety) on the MSK scale

The LECA has been design before seismic regulation: demonstration of ability to withstand such earthquake will not be possible
⇒ *improvement is not possible*

The STAR facility has been design according to new regulation, it is built on anti seismic pads



Safety analysis and strategic decision

As far as the LECA is concerned demonstration is being made that **radiological effect** of the potential ruin of the building would nevertheless induced a total dose lower than **EEC recommendation** for one year *public* on the first inhabitants,

This level is 50 time less as the recommended value for population home-confinement according to the ICPR 63

Fuel storage amount and cells' contamination will nevertheless be reduced



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Though:

- ⇨ **The LECA will be revamped, but operation will be drastically limited after year 2010,**
- ⇨ **In the mean time the STAR facility will be transformed to accommodate R&D activities, it will be enlarged to allow consolidation of all activities on fuel in Cadarache**



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Planning of activities in the Cadarache hot cells

2000 2005 2010

Revamped LECA

STAR former fuel encapsulation

enlarged STAR for R&D



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CEA planning of main facilities and NPPs for the next century

1995 2000 2010 2020 2030 2040

existing Saclay irradiation facility : OSIRIS

new Cadarache irradiation facility : RJH

existing french nuclear power plants (50 NPPs)

first prototype of the new generation of PWR (EPR) 1 NPP

new generation of PWRs (EPR) x NPPs



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