Evolution of CEA Hot Laboratories
Past, Present and Future

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1945: end of the 2\textsuperscript{nd} World War
1945, Oct. 18: Creation of CEA
by General De Gaulle

1946, March: CEA Fontenay-aux-Roses
1947, May: CEA Saclay Center

1948, Dec. 15: ZOE, 1\textsuperscript{st} French atomic pile
1952, Oct. 21: EL2 reactor = Heavy water,
1955: \textbf{LHA Saclay} (Incl. mechanical tests)
1957, July 4: EL3 reactor
1958: \textbf{Building 18, FAR} (Chemistry hot lab)
1966: Brennilis Power Plant: 70 MWe

\textbf{The first reactors: HWGCR}
Heavy water, Gas-cooled, Natural UO\textsubscript{2}
THE PAST – The early days

1959: LECI - Saclay (Fuel PIE)

1964: LECA – Cadarache

1968: RM2 FAR (Radio-metallurgy)
1956 - 1960: G1, G2, G3 reactors in Marcoule (G = Graphite)
1958: Pu production => UP1 Marcoule => 1958: **Future “NucLab”**
1963 - 1972: 6 EDF NPP Chinon, Saint-Laurent & Bugey (70-540 MWe)
1964: **EDF AMI Chinon - hot lab** (fuel PIE & surveillance capsules)

The second reactors: UNGG
Natural U (metal), CO\(_2\)-cooled, Graphite
1967: Chooz A (first PWR 310 MWe)
1969: Decision to build PWR on Westinghouse license (BWR completely abandoned in 1975)

1973: Oil crisis
1974, March 4: “Plan Messmer”
= 13 GWe launched before 1975

US gasoline ration stamps, printed but not used - 1974

Gasoline shortage, - 1974
1967-1983: RAPSODIE – Cadarache
⇒ LDAC: non destructive PIE hot lab
⇒ 1964: LECA: destructive PIE

1973-2009: Phénix – Marcoule
⇒ CEI Phénix: non destructive PIE
⇒ 1994: ISAI: conditioning of FBR spent fuels

1985-1998: Superphénix
THE PAST – The main experimental reactors

1963 – 1997: Siloe MTR in Grenoble with fission products lab.
⇒ LAMA hot lab (incl. Vercors hot cell for FP)

1966: Osiris MTR – Isis in Saclay

1980: Orphée (neutron beams) in Saclay
THE PAST – Driving forces of hot labs evolutions

⇒ **Economical incentives:**
  ⇒ Program load insufficient to maintain both MTR (Osiris + Siloe)
  ⇒ Two hot labs in Saclay merged into one (LHA → LECl)

⇒ **Too close to the city:** Fontenay-aux-Roses & Grenoble nuclear centers have to shut down their nuclear activities.
  ⇒ Transfer of activities to Cadarache (1981 - LEFCA), Marcoule (1992 - Atalante) and existing hot labs : LECl (creation of 20 hot cells) and LECA-STAR (construction of Verdon hot cells).

⇒ **Safety assessments:** Large refurbishments & modifications
  ⇒ LECA: 2001 – 2011, suppression of Pb line (seism) + VERDON
  ⇒ LEFCA: 2005 – 2013, seismic hazard reinforcement
  ⇒ EDF AMI Chinon: 2005 = no more fuel PIE (only metallic PIE)
Objectives: Safety
  • Improve confinement.
  • Reduce source term:
    – Decrease fissile masses & Clean the cells
  • Improve seismic behavior:
    – Strengthen buildings & cells.
  • Update general safety features:
    – Fire protection, fire and radioactivity detection, power supplies, traveling cranes, ventilation systems, windows, manipulators…

LECA: reinforce concrete wall
LECA: confinement box
LECA: remove weight on the roof
THE PAST: The refurbishments (LECA-STAR-LECI)

Objectives: Upgrades
- Install new scientific apparatuses
- Build new cells

LECI – New microscope – 2004

LECI – construction of line M – 2003

LECI – line M – 2003

VERDON – New cells 2007
THE PAST: The refurbishments (ATALANTE-LEFCA)

Objective: Safety
• Improve seismic behavior
TODAY
TODAY: EDF Nuclear Power Plant fleet

- 58 reactors in operation
- 1 reactor (EPR) under construction
- Technology: PWR
- Spread out over 19 sites

Nuclear generation = 80% Total Electricity Generation

<table>
<thead>
<tr>
<th>NPP</th>
<th>PWR 900 MW</th>
<th>PWR 1300 MW</th>
<th>PWR N4 1450 MW</th>
<th>EPR 1630 MW</th>
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</thead>
<tbody>
<tr>
<td>Nb Unit</td>
<td>34</td>
<td>20</td>
<td>4</td>
<td>1 under construction</td>
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<tr>
<td>License</td>
<td>Westinghouse</td>
<td>Areva &amp; al.</td>
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TODAY: CEA Hot Labs & MTRs

Materials
LECI

OSIRIS

JHR under construction

ATALANTE
Fuel cycle studies

Saclay

Marcoule

Cadarache

ISAI
Spent fuel conditioning

NucLab
Waste analyses

LEFCa
Pu Fuel R&D

LECA/STAR + VERDON
Fuel PIE

Pu Fuel R&D

Fuel cycle studies

Spent fuel conditioning

Waste analyses
To establish performances, predict in-service lifetime or behavior under abnormal or accidental conditions, during transportation & storage of non fissile irradiated nuclear materials.

- Understanding
- Modeling & simulations at different scales
- Operational management of the LECI
- Adaptations for new programmes
- In-cell adaptation of equipment
- Expertise
- Lifetime prediction

Experimental reactors surveillance programs
Industrial irradiated materials

Behavior laws

- Cladding fuel pellets interaction + SCC-I
- SCC-I

Temps (°C)
Energie (Joules)
Matériel témoin (non irradié)
Points expérimentaux matériau témoin
Matériel irradié
Points expérimentaux matériau irradié

Microstructural, physical, chemical & mechanical characterizations,
≈ 50 hot cells with all machining and irradiated sample preparation equipment for mechanical testing, microstructural and physical & chemical characterizations
Today: The LECI - Saclay

New equipment:

- X-rays bench 2014
- Focused Ion Beam to be commissioned by 2015
- SEM commissioned July 2013
- Glove box: hot temperature extraction (project)
- Glove box: Diffusivity dilatometry to be commissioned in 2014
- Decontamination room for remote handlers (project)
- Tomographic Atomic Probe to be commissioned in 2015
- High temperature Tensile machine to be commissioned in 2014
- PADIRAC door - 2013

Decontamination room for remote handlers (project)
TODAY: The LECA-STAR - Cadarache

Non-destructive examinations on experimental fuel rods

Re-fabrication of experimental fuel rods

Fuel rod puncturing

VERDON laboratory
Severe accident studies

Non-destructive examinations on LWR fuel rods

MERARG
Fission gas release

Micro-analysis:
- SEM
- EPMA
- SIMS
- µ-XRD

Optical microscopy
TODAY: The LECA-STAR - Cadarache

Micro-analysis laboratory

- FEI-WDX XL 30 (FEI)
- SX100R (CAMECA)
- Shielded IMS 6f (CAMECA)
- ARCHE (GE-Seifert)

Samples preparation and OM

- EPMA
- SEM
- Storage
- SIMS
- XRD
- MEB EPMA
- SEM-WDX XL 30 (FEI)
- SIMS IMF-6F (CAMECA)
- µDRX "ARCHES" (GE-Seifert)
TODAY: The LECA-STAR - Cadarache

**MERARG-2**: fuel heating with on-line fission gas measurement

Complementarity between gamma spectrometry and gas chromatography
**Objective:** To study fission product releases from a fuel

- **Capabilities:**
  - Air flow conditions (Ru oxides releases)
  - FP releases from MOX fuel.

- **Outcomes:**
  - Good knowledge of UO$_2$ fuel release
  - Improved modeling required for MOX fuel releases and transport during air ingress
  - The iodine chemistry in circuits and within containment still questionable
The International Source Term Program

• **Objective of the ISTP**
  - Reduce the remaining uncertainties for PWR Source Term assessments
  - French part: CEA, EDF, IRSN + Europe, USA, Canada, CH, South Korea
  - Continuation of the previous VERCORS program, performed at Grenoble

• **4 VERDON tests funded under the ISTP**
  - High burn-up UO$_2$ fuel (70 GWd/t) → CER configuration
    • performed on Sept. 30, 2011
  - Air ingress test on MOX fuel (55 GWd/t) → CET configuration
    • performed on June 27, 2012
  - MOX fuel (55 GWd/t) → CER configuration
    • 1 test under oxidising conditions, performed April 17, 2013.
    • 1 test under reducing conditions, to be performed.

• **Post ISTP program**
  - Under elaboration, oriented in the context of the Fukushima accident
TODAY: LEFCA - Cadarache

Laboratory for study & fabrication of advanced fuels

Key dates:
- 1984: Commissioning with Pu
- 2010: End of refurbishment, after safety assessment in 2003
- 2013: New file for safety assessment

Programs on Pu, U and minor actinide fuels:
- Development of fabrication processes
- Characterization of fuel materials
- Preparation of irradiation experiments
- Service activity: Treatment of exotic, unused fissile materials
- 70 glove boxes, large fissile material capacity for manufacturing fuel pins

Partnerships: Areva NP (MOX fuel) & Areva TA (naval propulsion)
TODAY: ATALANTE - Marcoule

General view

19,000 m² of laboratories – staff: 210
A large facility in support to AREVA NC & GEN IV studies
- Investment cost ~ 310 M€\textsubscript{2008}
- 1\textsuperscript{st} active lab commissioned in 1992.
- 1\textsuperscript{st} spent fuels arrived in 1999.
- Last lab commissioned in Sept. 2009.
- Final license obtained on the 22\textsuperscript{nd} June 2007.
- … continuous evolution to adapt to R&D program

*From basic research to demonstration experiments*
- Separation science. Actinide chemistry
- Containment material science

Glass reticular structure
Glass alteration by water
Micelle of DMDOHEMA + water
Major equipments:
- 7 shielded cell lines (~60 workstations)
- 17 laboratories with radiochemistry equipment in glove boxes
TODAY: ATALANTE - Marcoule

I – Actinide and Fission Product basic chemistry
II – Fuel dissolution
III – New extractants
IV – Partitioning processes
V – Conversion processes
VI – Actinide compound synthesis
VII – Conditioning, Long term behavior
VIII – Analyses
CBP: Demonstration scale

- Experimentations involving up to ~ 15 kg of irradiated fuel
- Same technologies as in the industrial plant
TODAY: ISAI - Marcoule

Packaging of irradiated fuel and high level sources.
- 2 large cells
- 11 remote handling workstations
- Fuel storage units.
- Staff: 25

Current and future programs:
- Dismantling of PHENIX spent fuels
- Nuclear propulsion spent fuels packaging
- Packaging of radioactive waste and sources
TODAY: CEI Phénix - Marcoule

Transfer cell inside Phénix reactor

Programs:
- Dismantling of Phenix spent fuels
- And irradiation capsules

Extraction, washing and shipment of Futurix-CERCER experiment – March 2013
TODAY: NucLab - Marcoule

An analysis laboratory for nuclear cleanup & dismantling projects

Key dates:
- 1958: Central Laboratory for Pu production at Marcoule (UP1 plant)
- 1997: End of plutonium production
- 1998: Laboratory upgrade
- 2012: Creation of NucLab (CEA-AREVA partnership)

Key figures (2012):
- 78,900 hours of engineering & analysis services
- 3,500 samples - 14,000 determinations

Organization:
- Analytical chemistry Lab.
- Radioactivity measurements Lab.
- Design, Methods and Nuclear Measurements Lab.
- Industrial chemistry and projects Lab.

Quality Control
THE FUTURE
The FUTURE – Main trends

⇒ Two large programs at CEA Nuclear Energy Division:
  ⇒ Jules Horowitz Reactor: 100 MW MTR under construction
  ⇒ JHIP OECD/NEA program proposal
  ⇒ VERDON
  ⇒ ASTRID: 600 MWe Na-cooled FBR under preliminary design.

⇒ Economical incentives:
  ⇒ Budget constraints = reduce the overall number of facilities
  ⇒ Discussion with industrial partners

⇒ Too close to the city: Next center to be concerned is Saclay.
  ⇒ Reduction of fuel activities in LECI.
  ⇒ Transfer of activities from Osiris - Saclay to JHR – Cadarache

⇒ Complementary safety assessments: post-Fukushima
  ⇒ All facilities are concerned but with different impacts.
The FUTURE – Main trends

Jules Horowitz Reactor: 4 hot cells under construction

⇒ New “Fission Platform” to be built in Cadarache, near JHR?
= A new hot lab to replace the old ones?
JHR: A new MTR funded and steered by an international Consortium

- JHR International Consortium:
  - A European Framework with International Partners (India, Israel, Japan)
  - Industrial Partners (France, Sweden, Spain, Finland…)
  - Operation Rules allows flexibility for:
    - Implementing bilateral programs with full property of results
    - Participating to Multilateral Programs open to non Consortium Members

- CEA is mandated by the Consortium to promote JHR and its ancillary labs to the International Community and to build international joint Programs

The 12 JHR Consortium Members (as of May 2013):

March 2013: UK/CEA agreement, NNL is taking the role of UK representative to JHR
A new OECD/NEA Project: Jules Horowitz Int’l Program (JHIP): LOCA studies complementary to Halden & Studsvik projects

- Strategic Scope: **JHIP** to address fuel and materials issues of common interest that are key for operating plants and future NPP
- Proposal: a Two-Phases Project:
  - Phase 1: Pre-Operational Research programs **on CEA existing facilities** complemented by joint analytical works & reflections aiming at the definition of future JHR test programs devoted to Safety questions on LOCA
  - Phase 2: R&D programs on JHR (**JHIP3: 2019-2021**)
CONCLUSIONS

- CEA hot labs = a coherent and complete panel of installations for irradiated fuel & material examinations and fuel cycle studies.

- Strong links with Osiris -> Jules Horowitz MTR

- Safety assessments have induced many upgrades to keep up with up-to-date safety regulations.

- Continuous improvements on analysis techniques: e.g. mechanical testing in LECI, fission gas release and micro-structural analyses in LECA, reprocessing studies in Atalante,…

- Open to European and international R&D (Verdon ISTP, JHIP OCDE/NEA, …)
Thanks for your attention