# Overview of CEA activities in nuclear criticality safety

## *Focus on the Criticality Safety Experts Group activities*

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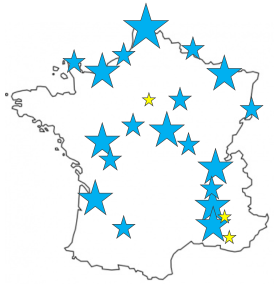
# Summary

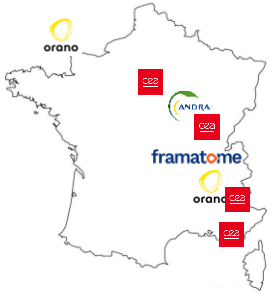
1. **CEA: CSEG, missions and perspectives**

2. **Focus on CSEG recent achievements**

# 1. CEA: CSEG, missions and perspectives

# Introduction






**France is rich of many nuclear reactors**

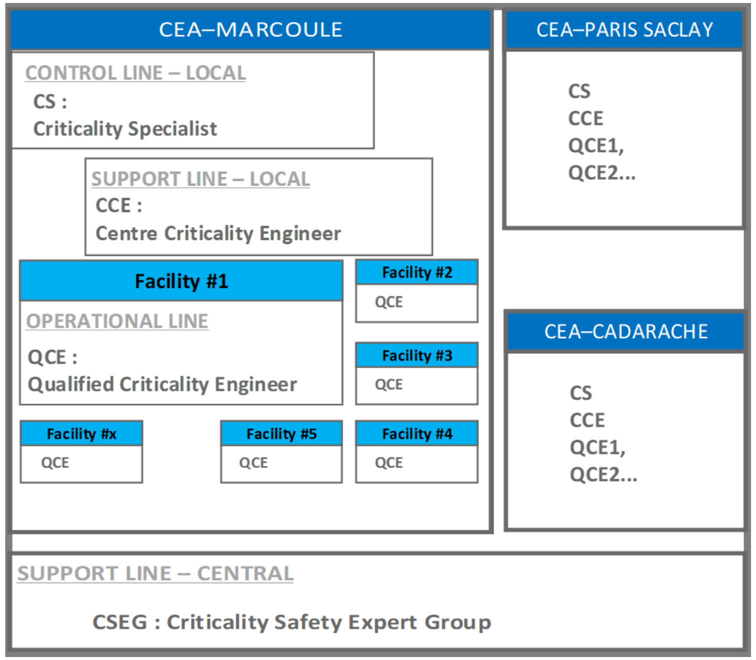
**…but also facilities, research centers, engineerings…**

**where fissile materials in many forms are studied, handled, manipulated, transformed, stored, transported…**

**in which the criticality hazard has to be taken into account**

**through rules and methodology edicted by the French Regulator (Resolution 2014-DC-0462 of October 2014)**

**One main aspect of NCS relies on a specific organization of the licensees.**




*Example : NCS CEA organization*

# CSEG missions

## In this context, the Criticality Safety Experts Group (CSEG) of the CEA:

- **Is composed of 8 experts and engineers (15 to 25 years of experience)**
- **Provides NCS technical support to installations and projects of the CEA (and more): calculations, assessments, expertise, interface with authorities…**
- **Supports CEA activities concerning the criticality accident aspects (from studies to emergency preparedness)**
- **Is involved in international organizations: ISO (WG8, 7753), AIEA (SSG27), NEA**
- **Participates to regulatory criticality trainings (CCE, QCE) and education (master's degree)**
- **Interfaces with research activities or calculations developments related with NCS**
- **Supervises the *"Criticality Annual Meeting"* (French group of experts and engineers from all licensees)**
- **Provides guidance, handbooks, methodology, feed-back**

# CSEG perspectives

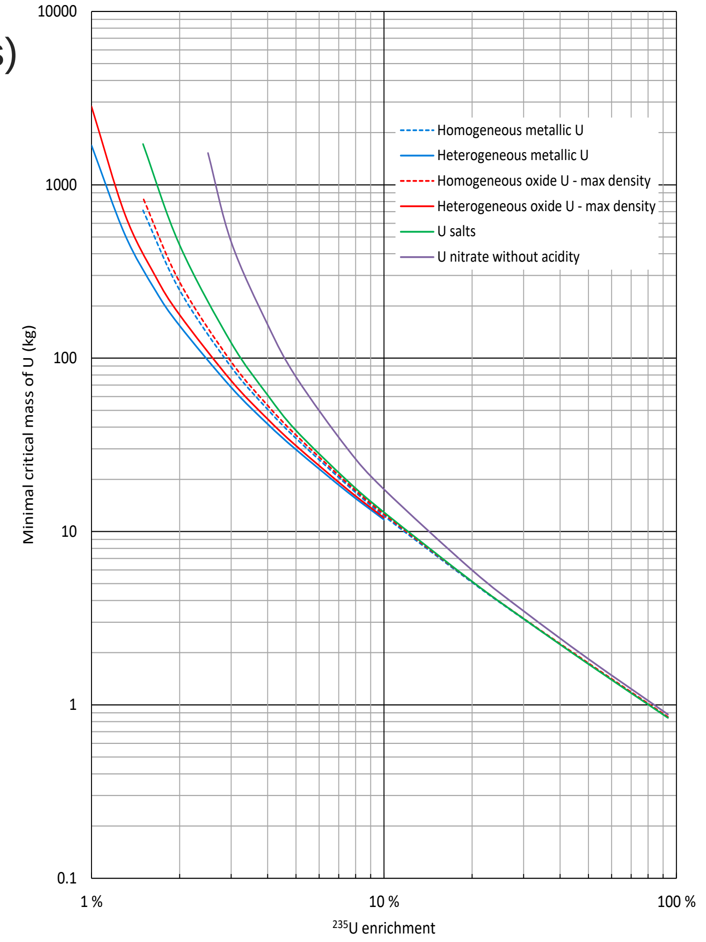
- **Pursue the CEA participation to the Hands-on training session (2-week CSE course)**
  *Until 2014, CCE passed through SILENE (and CALIBAN) practical exercises – now through a virtual reactor*
  *2 CEA persons trained in Aug.22 and Jan.24 – other candidates to be proposed soon*
- **Propose to WPNCS a "practitioner" Project**
  *Build a benchmark, in which each country participant would assess the criticality safety (from calculations to requirements ?) and compare the different approaches*
- **Propose a paper that presents and compares operational NCS organizations of different licensees**
- **Make few of our guidance and handbooks available** *(after being translated)*
- **Pursue our participation to ISO WG8**
- **Specify and formalize few of CEA experimental needs for the future** *(more long term work)*
- **Make our knowledge, experience and expertise a valuable support for any collaboration** *(improvement of safety has no frontier)*

# 2. Focus on CSEG recent achievements

# New CEA handbooks for criticality safety (1/2)

- **Compilation of standard calculations results for several fissile media:**
  - State to the art: “standard” route of the French CRISTAL V2.0 criticality package (APOLLO2 Sn) + TRIPOLI-4® deviation calculation (optimal moderation/dry values)
  - Various fissile media (U, Pu, U+Pu, other actinides) and moderating materials
  - Various reflecting materials (water, concrete, lead, steel…)

    ➔ Tables/curves for various criticality parameters (mass, diameter, volume…)




- **Several handbooks for several $k_{eff}$ values:**
  - A “critical values handbook” ($k_{eff}$ = 1)
  - “Permissible values handbooks” : $k_{eff}$ = 0.95

    $k_{eff}$ = 0.93

    $k_{eff}$ = 0.97



- Done for CEA but dedicated to be **public** (not to be referenced in criticality safety assessments) and **free** for downloading (translation into English ongoing)

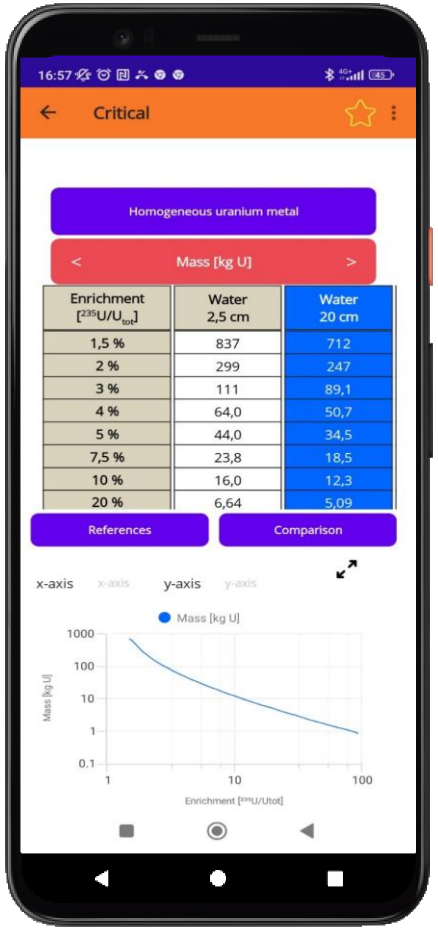
- **See also:** D. Noyelles, A. Dorval, M. Prigniau, “*New CEA handbooks for criticality safety assessment demonstrations*” (ICNC 2023)

# New CEA handbooks for criticality safety (2/2)

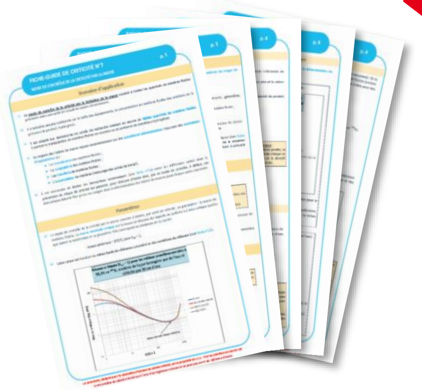
- **Development of a** **mobile app** **to consult easily, rapidly a combination of media/parameter/$k_{eff}$**
  - Nicknamed “ADDN” (Aurélien Dorval, David Noyelles)
  - Available on Apple Store (iOS) and Play Store (Android) : **“CEA ADDN”**
  - In French AND English
  - **Free**

Download on the App Store

GET IT ON Google Play



# Criticality safety guide sheets



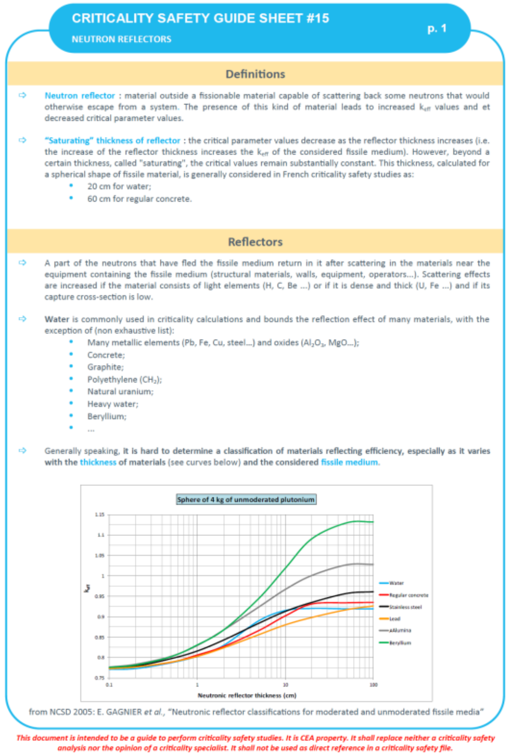
**A guide for criticality safety engineers to lead criticality safety analyses**

- Purpose: gather useful elements in order to get sufficient knowledge to perform a criticality safety analysis for a nuclear installation containing fissile material

- The guide aims at presenting **all the aspects of criticality safety analysis**
  - Structured in **25 chapters**, each focusing on a specific topic
  - Including basics of criticality safety, piece of advice, requirements, recommendations, application examples…
  - Pedagogical document
  - Provided and used during training sessions

- Done for CEA but dedicated to be **public** (not to be referenced in criticality safety assessments) and **free** for downloading (translation into English ongoing)

- **See also:** A. Dorval, M. Prigniau, P. Casoli, E. Fillastre, E. Gagnier, "*The new version of the criticality safety guide sheets collection*" (ICNC 2019)



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NEUTRON REFLECTORS

**Definitions**

⇨ Neutron reflector : material outside a fissionable material capable of scattering back some neutrons that would otherwise escape from a system. The presence of this kind of material leads to increased $k_{eff}$ values and et decreased critical parameter values.

⇨ "Saturating" thickness of reflector : the critical parameter values decrease as the reflector thickness increases (i.e. the increase of the reflector thickness increases the $k_{eff}$ of the considered fissile medium). However, beyond a certain thickness, called "saturating", the critical values remain substantially constant. This thickness, calculated for a spherical shape of fissile material, is generally considered in French criticality safety studies as:

- 20 cm for water;
- 60 cm for regular concrete.

**Reflectors**

⇨ A part of the neutrons that have fled the fissile medium return in it after scattering in the materials near the equipment containing the fissile medium (structural materials, walls, equipment, operators…). Scattering effects are increased if the material consists of light elements (H, C, Be …) or if it is dense and thick (U, Fe …) and if its capture cross-section is low.

⇨ **Water** is commonly used in criticality calculations and bounds the reflection effect of many materials, with the exception of (non exhaustive list):

- Many metallic elements (Pb, Fe, Cu, steel…) and oxides ($Al_2O_3$, MgO…);
- Concrete;
- Graphite;
- Polyethylene ($CH_2$);
- Natural uranium;
- Heavy water;
- Beryllium;
- …

⇨ Generally speaking, **it is hard to determine a classification of materials reflecting efficiency, especially as it varies with the thickness of materials** (see curves below) **and the considered fissile medium.**



from NCSD 2005: E. GAGNIER *et al.*, "Neutronic reflector classifications for moderated and unmoderated fissile media"

*This document is intended to be a guide to perform criticality safety studies. It is CEA property. It shall replace neither a criticality safety analysis nor the opinion of a criticality specialist. It shall not be used as direct reference in a criticality safety file.*

# Guidebook for criticality accidents studies

© CEA, CRAC facility – NSE 161, 160–187 (2009)

© CEA – SILENE reactor – NSE 161, 160–187 (2009)

**A large and unique knowledge built during 30 years of experimental programs**

- A guidebook to **gather**, **preserve** and **transmit** information on criticality accidents
  - Importance of international results, collaborations, studies… also included for reference
- The guide aims at presenting **all the aspects of criticality accidents safety studies**
  - Structured in **11 chapters**, each focusing on a specific topic (phenomenology, experimental programs, dosimetry…)
- Over a period of 30 years, multidisciplinary teams of physicists, biologists, dosimetrists, etc. have collected an invaluable and unique wealth of results → **A knowledge that is fundamental to preserve and perpetuate**.

**This guidebook is today an internal CEA reference: 650 pages covering 11 aspects of criticality accident safety studies.**

- And now? This work is certainly of great interest for the whole, international, criticality community.
  A long path forward, with some new challenges:
  - Authorize: Rights have to be granted for public diffusion
  - Update: an update is necessary to account for technical and regulatory changes since 20 years
  - Homogenize: An editorial work is necessary: several authors worked on it and the degree of details of chapters varies
  - Translate it to English
- **See also:** M. Laget, F. Barbry, "*Completion of the CEA guide for criticality accidents studies*" (ICNC 2023)

# Thank you for your attention

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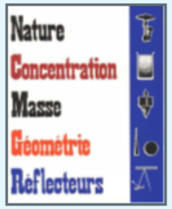
# Backup

# New CEA handbooks for criticality safety
# Fissile media

- **Homogeneous uranium media**, enriched from 1.5% to 93.5% in $^{235}U$ :
  - U, $UO_2$ (several powder densities), $UO_2F_2$, U salts, U(VI) nitrate (0 or 3N acidity), $UF_6$-0.1HF
- **Heterogeneous uranium media,** enriched from 1% to 10% in $^{235}U$ :
  - U metal and $UO_2$ in shape of spherules
  - “PWR” $UO_2$ rods
- **Plutonium media** with $^{240}Pu$ content from 0 to 25%:
  - Pu, $PuO_2$ (several powder densities), Pu salts, Pu(III) and Pu(IV) nitrate (0 or 3N acidity)
- **Mixed media “U+Pu”**:
  - Oxides with variable %Pu
- **Others actinides** (fissile and fissible)
- **Others moderating materials** ($CH_2$, graphite)
- **Others reflecting materials** (25 different)
- Homogeneous **poisoning** (B, Cd, Gd)

# Criticality safety guide sheets
# Contents

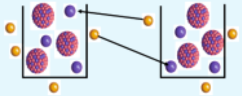





CRISTAL
FORMULAIRE DE CRITICITÉ

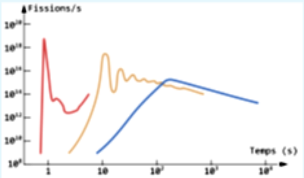










# Guidebook for criticality accidents studies
# List of chapters

**The guide aims at presenting all the aspects of criticality accidents safety studies.**

Structured by chapters, focusing on a specific topic, and written in the most synthetic form possible.

Those are supplemented with an almost exhaustive list of references.

1. Reminder on the risk of criticality and general provisions on its prevention
2. General considerations on the criticality accident and its phenomenology
3. State of knowledge resulting from experimental programs
4. Energy estimation and physics modeling
5. Criticality accidents dosimetry – radiation field characteristics and associated exposure risk
6. Fission products formation and release rate – Releases to the environment and radiological impact on humans
7. Criticality accident detection and alarm
8. Medical management of criticality accidents victims
9. Emergency management - Internal emergency plan - Response
10. Feedback from past criticality accidents
11. Methodology proposal for a facility that requires a criticality accident study