ICRS-13 & RPSD-2016

13th *International Conference on Radiation Shielding*
&
19th Topical Meeting of the *Radiation Protection & Shielding Division*
of the American Nuclear Society -2016

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Ladies and Gentlemen,

First of all, I want to welcome all of you again in Paris for the ICRS & RPSD joint conference. On behalf of the CEA I would like to thank the representative of the co-organizer and partner institutions:

- Dr. **Andy Klein**, President of the *American Nuclear Society* (ANS),
- Prof. **Takashi Nakamura** *Tohoku* University who could not come and is here represented by Dr. **Masashi Hirano** from the *Japan Nuclear Regulation Authority* and also Dr. **Kimiaki Saito** from *Japan Atomic Energy Research Institute*,
- Dr. **Gianni Bruna**, the Scientific Director of the *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN) in France,
- Dr. **Daniel Iracane**, **NEA** Deputy Director-General and Chief Nuclear Officer of Nuclear Energy Agency of OECD.

I want to thank them both for their attendance and the messages they delivered.

Many thanks also to the two Honorary Chairs of this conference, that is Dr. **Enrico Sartori** formely *Head of Computer Program Service and Reactor Physics* at the NEA and Dr. **Jean-Claude Nimal** formely Research Director at the CEA.

The CEA applauds the format of joint ICRS & RPSD conferences that promotes the exchanges inside the international Radiation Protection and the Radiation Shielding communities.

During this presentation, I will now try to stress the importance of the radioprotection activity within CEA and particularly within its Nuclear Energy Division, and will try to underline that this topic has been a major preoccupation for CEA from its very creation.

1. General presentation of the CEA

As you probably know CEA is a key player in research, development and innovation in four main areas : defence and security, nuclear energy (fission and fusion), technological research for industry and fundamental research in the physical sciences and life sciences.

2. Presentation of the DEN activities

Within the CEA, the Nuclear Energy Division carries out research in three main fields:

- Developing nuclear systems of the future – dubbed "4th generation" reactors – and their fuel cycles,
- Optimizing the current nuclear industry;
- Developing and operating large experimentation and simulation tools needed for its research programs.

The detailed programs are defined with the French government and the industrial partners of the CEA, in order to provide them with technical expertise and innovation in nuclear power generation systems to develop sustainable nuclear energy that is both safe and economically competitive.

As a nuclear operator, the CEA/DEN also has to manage and upgrade its own fleet of nuclear facilities. It carries out numerous construction and refurbishment programs on these facilities, together with clean-up and dismantling programs for those that have reached the end of their service life.

3. A historical overview of the place of the radioprotection at the CEA

If we take a look in the past : on the 15th of December of the year 1948 in the Paris suburbs (Fort de Chatillon de Fontenay-aux-Roses) the first French nuclear reactor, called ZOE for *Zéro énergie (Zero power), Oxyde d'uranium (Uranium Oxyde), Eau lourde* (*Heavy Water*) achieves divergence.

A very recent book tells that from the very beginning the CEA primary concerns in the field of biology were centered on the protection against the ionizing radiations.

A health control service was created in February 1947 to follow the staff devoted to ZOE reactor operation. **Lew Kowarski**, a prominent ZOE team member, had previously made a sojourn at the Harwell Atomic Center in UK in order to learn about the best practices in radiation shielding.

In 1951, the CEA thus created the *Service of Protection against Radiations* (*Service de Protection contre les Radiations* SPR) under the direction of Dr. **Henri Jammet** who later became a member of the *International Commission on Radiological Protection* (ICRP).

Then the CEA defined a complete nuclear worker radiation protection policy and created various overseeing bodies.

At the same time, the CEA undertook extended research in the field of life sciences including *radiobiology, radiotoxicology, radiotherapy*. Today, this activity relies on digital and computational sciences but also on the experimental and computational facilities distributed over the different CEA centers.

Furthermore, the CEA has shared a long and fruitful common history with IRSN, since one of the original components of IRSN was the *Institut de Protection et de Sûreté Nucléaire* (IPSN) unit from CEA.

I will now focus on the genesis of CEA/DEN radioprotection activities more directly related to the ICRS & RPSD conference topics. It will be the opportunity to highlight the international opening of the "Radiation Shielding" domain, and the very important exchanges CEA has had, in particular with the Oak Ridge National Laboratory.

The first radiation shielding experiments and set of computational methods were developed inside the *Service d'Études de Protections des Piles* (SEPP) led by the mathematician and physicist **Pierre Lafore**, at the CEA center of *Fontenay-aux-Roses*. The first experiments were dedicated to the determination and validation of the water cross sections through the facility called *NAIADE* next to ZOE. Next, the reactor TRITON of 6.5 MWth, came into service in 1959. The SEPP unit has also developed a very important activity centered on dosimetry and instrumentation.

Starting in 1956, information exchanges were established between *Oak Ridge National Laboratory* in USA and the CEA/SEPP concerning both the experiments and the calculation methods in the field of Radiation Shielding.

At CEA, the first radiation shielding calculations using the Monte Carlo method were performed by three researchers: **Pierre Lafore**, **Robert Lattès** and **Jean-Paul Millot.** Their work was published in 1958, making references to that of **Henry C. Honeck** from ORNL.

These works were presented at the first edition of the ICRS (ICRS-1) or the *European Atomic Energy Society Symposium VI-58 Radiation Shielding* held at Cambridge *Caius College* in UK, from 26 to 29 August 1958**.**

In 1965, **Jean Rastoin** and **Jean-Claude Nimal** visited the *Radiation Shielding Information Center* (RSIC), at ORNL that had been created three years earlier. They met the RSIC director, the scientist **S. Keith Penny**, and **David Trubey** and **Fred C. Maienschein**, two other eminent specialists in the field of Radiation Shielding.

In 1966, the ongoing discussions were focused on theoretical aspects, in the frame of a seminar held at the CEA center of Fontenay-aux-Roses. The main topics discussed were geometry description and acceleration techniques dedicated to Monte Carlo particle transport simulations.

In the 60's CEA built a full body of knowledge on shielding computational methods and codes. At the same time radiation protection became a major subject in the nuclear world, both academic and industrial.
Indeed, in parallel to his experiment mockups, the CEA developed his first transport codes:

- NIOBE: a deterministic S_N code developed with the collaboration of **Everitt P. Blizard** from ORNL,
- The MERCURE and ORPHEE codes based on the straight line point kernel attenuation method, applied respectively for gamma rays and fast neutrons transport,
- The Monte Carlo simulation codes ZEUS and POKER written by **Jeanne-Marie Lanore**.

The CEA also went looking for radiation shielding calculation tools and nuclear data libraries in American, English and Italian nuclear centers, for instance:

- Two Monte Carlo codes SANE for the neutron propagation and SAGE for the photon propagation from ORNL.
- The 1D S_N transport code ANISN again from ORNL.
- The *Removal-Diffusion* neutron transport code SABINE code written by **Carlo Ponti** from ENEA Ispra center
- The cross section libraries from US (known as *Union National Carbide* libraries) or the *United Kingdom Nuclear Data Library* (UKNDL).

The result of the effort of the CEA to reach an international level was presented by **Christian Devillers**, **Pierre Lafore** and **Jean Rastoin** at the *Joint ENEA/IAEA Specialist meeting on the physics problems of reactor shielding*, held in Paris from 8 au 10 of December in 1970, under the title « *Reactor Shielding in the "Commissariat à l'Energie Atomique" »*.

The attention put to experimental code validation is shown by the measurements made on the HARMONIE facility: a 1 kWth source reactor built in CEA Cadarache in the frame of EURATOM-CEA cooperation. HARMONIE achieved it first divergence in 1965.

During this same period the TRIPOLI (*Monte Carlo Tridimensionnel Polycinétique*) code project was started with a great ambition.

This forward-thinking project has been decided jointly by **Pierre Lafore** and **Jean Rastoin**. The first TRIPOLI team was a small one composed of just two persons: **Jean-Claude Nimal** and **Shlomo Katz.** The latter left France shortly thereafter and **Thérèse Vergnaud** took his place.

The first version of TRIPOLI, TRIPOLI-1 was presented to the *ICRS-4* held in Paris in 1972. TRIPOLI-1 simulations were used to study the sodium activation of the PHENIX fast neutron reactor.

At CEA, the radiation shielding studies were the main driving force for the development of the Monte Carlo method and the associated computational codes.

The turn of the new decade 1970 could be considered as the entrance of the CEA in the international community of radiation shielding. The relationships with RSIC (that became RSICC: *Radiation Safety Information Computational Center* in 1996) became closer thanks to two persons: **Betty Maskewitz** from **RSICC** and **Enrico Sartori** from NEA. They were instrumental to the CEA allowing his own codes MERCURE, TRIPOLI and PEPIN (a depletion code) to be made available to NEA and RSIC: a rightful payback!

Another key moment was the seminar "*Monte-Carlo Methods and Applications in Neutronics, Photonics, and Statistical Physics*", in the Château of Cadarache in the South of France, from 22th to 26th of April 1985. This meeting brought together the researchers from *Los Alamos National Laboratory* (LANL) and those from the *Commissariat à l'Énergie Atomique*. It has been organized respectively by **Robert Alcouffe** and **Robert Dautray**. **Daniel Verwaerde**, the current General Administrator of the CEA was present at that meeting.

The famed **Nicholas Metropolis**, the father of the modern Monte Carlo method with **John von Neumann** and **Stanislas Ulam,** was among the American delegates.

The CEA/DEN exposed there its theoretical and radiation shielding studies carried out with the TRIPOLI-2 code, which had been released in 1978.

In France, the Monte Carlo transport had finally demonstrated its ability to deal with complex, industrial scale radiation shielding problems. It was also the demonstration of its practical usefulness for nuclear engineering.

During the following decades, the CEA/DEN has pursued his R&D activity on the various types of methods traditionally used in the radiation shielding studies: deterministic methods, probabilistic methods and methods based on simplified models to compute dose rates, material structure activation, radiotoxicity and so on.

Our current calculation codes devoted to radiation shielding, TRIPOLI-4, DARWIN, MENDEL, NARMER, etc. are the heirs of this past briefly sketched.

Thanks to our nuclear data treatment system GALILEE still partly based on the NJOY American system, our calculations tools are connected to the most recent nuclear data evaluations, either American with ENDF/VII or European with JEFF-3 or TENDL, but also Japanese with JENDL-4, Chinese with CENDL-3, Russian with RUSFOND, and even international through IAIA with FENDL-2 or PDL.

Our simulation codes stand comparison with the best codes from other countries. In this respect, the SINBAD shielding benchmark data base, created by **Enrico Sartori** at NEA, plays a central role.

In order to deal with the present needs and to prepare the future, CEA continues to investigate the various radiation shielding problematics related to the different phases of the life of nuclear reactors: design, operation, dismantling/decommisionning, waste management. Its aim in to answer to EDF and AREVA industrial needs but also to the CEA internal needs as well.

The same tools are used to respond to the needs of research as those related to the MTR research reactors (OSIRIS, RJH…), related to the thermonuclear fusion devices (ITER project) or the power lasers.

In the field of code development, the advent of *high computing performance* opens new exciting challenges and perspectives both for the developers and the "end-users".

Furthermore, we observe a trend to extend the application scope of the tools developed, particularly towards nuclear instrumentation.

At last we can highlight the increasing involvement of the radiation shielding tools developed in the curricula of engineering school and of universities at the graduate level.

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In conclusion, this brief focus on the CEA/DEN radioprotection activity, very much centered on the Monte Carlo simulation, must not overshadow the other branches of research and development related directly or indirectly to the radiation shielding.

Along those lines, we want to highlight the major contributions of CEA/DRF and of the CEA Bruyères-le-Châtel concerning the production of cross section data so essential for our numerical simulations as well as the radiation shielding studies around accelerators and power lasers

We are aware of the magnitude of the work that has been achieved and the progress made by the whole radiation protection and shielding international community aiming to respond to the crucial objective of human and environment protection. We can also add the objective to limit the material structure damages induced by particle irradiations.

If the radiation protection field has been led at the beginning by the nuclear reactor engineering for historical reasons, it is no longer the case today. This is shown by the diversity and the richness of your conference technical program and we think that that's a good thing.

You can be certain that the results of your works have been and will be carefully examined. They are an essential contribution to the orientations and planning of future R&D in our respective institutions.

Dear attendees, I wish you a wonderful and fruitful ICRS & RPSD conference. Having looked at the program, I have no doubt about it.

Thank you for your attention.