Research, expertise and knowledge transfer

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FOREWORD

Research at IRSN is productive and valuable

The 2008 edition of IRSN’s Scientific and Technical Report concludes a four-year cycle in which IRSN has presented research and development work conducted to enrich its expertise in nuclear safety and radiation protection. This report, meant to be the research supplement to the Annual Report, is mainly aimed at the wide ranging scientific community that has naturally formed ties with the Institute, through partnerships or collaborative projects.

Far from being exhaustive, the editorial line has always placed the accent on the most significant or “promising” results in the past year, in a scientific style that is appealing to both specialists and non-specialists alike. With its attractive format and inviting style, the Scientific and Technical Report has succeeded in stimulating interest and reflection by reconciling scientific rigor, clear reasoning, and educational value.

Contrary to publications in scientific journals, the authors have made an effort to describe their results in the more general context of IRSN’s missions, highlighting the immediate or long-term with assessment needs that their work is intended to fulfill.

At the end of this four-year cycle, all the Institute’s research topics have been covered and, given the positive feedback that we have received, it can safely be claimed that the goals assigned to the Scientific and Technical Report have been met; it has contributed significantly to display the Institute’s research work, and to illustrate the high level of quality expected by the Institute from its employees. Above all, it has shown how knowledge newly acquired through research can enhance safety and radiation protection by reinforcing the understanding of the phenomena involved in the expression of risks, and by refining the methods and tools used to analyze those risks, and the proposed solution for their prevention and mitigation.
Research at IRSN is alive and productive, and it is meeting expectations. These achievements demonstrate the motivation and quality of our researchers. They also result from efforts made in the last few years to impart a new drive to research programs, and a strategy to work with other research institutes such as CNRS and universities (through partnerships and joint laboratories), CEA, and European and International programs. The scientific assessment system directed by the Scientific Council and the Institute’s Scientific Division has also become fully operational.

Research at IRSN does not follow the usual discipline oriented route. It is guided by an original scientific and technical approach: on an average, in IRSN, 270 researchers (out of over 1,000 qualified engineers, doctors...) devote of 35% of their working time to nuclear safety and radiation protection expertise.

The Scientific and Technical Report, over the last four years, has successfully given a detailed panorama of this approach, and of the resulting scientific production.

I would like to thank all the contributors to this publication, both for inside IRSN and outside reviewers, and I hope that you will find it pleasant to read.

Jacques REPUS SARD
Director General
Like every year, the Scientific Director is pleased to present IRSN’s Scientific and Technical Report. A spotlight on the Institute’s scientific output, this report provides the opportunity to capture a view of research activity, to measure progress, review new topics, and challenge research priorities.

To open the report, the Scientific Division would like to pay tribute to the Institute’s researchers whose results are presented in the following pages. Research at IRSN has its own particular characteristics and evolves in a specific dynamic context.

Once research has been finalized, its purpose is to produce tools to serve the diagnostic, modeling, or forecasting functions deployed in assessments by developing basic knowledge where it is still needed. To serve this purpose, the Institute relies on teams formed between research organizations and universities who carry out academic work in a partnership context where the Institute provides the subject matter, and benefits from the tools and methods developed in these laboratories.

This notion of integrated research is also characterized by the extremely wide variety of fields involved and the strong multidisciplinary aspect that makes this type of cooperation essential. As one of the many players in nuclear research, along with plant operators and industry, IRSN must conduct collaborative research with its partners, while preserving its independence. Research must serve the purposes of assessment, since the Institute is called on to provide technical support to the French nuclear safety authority, who relies on our experts’ opinions to make its decisions.

The context in which this research activity develops merits particular focus. The Institute’s experts and researchers operate in two different time frames. On one hand they are asked to react immediately to incidents, accidents, or emergency situations, and must be capable of providing reliable technical answers to the public’s concerns. On the other, scientific work is achieved over the long term, through research programs lasting several years. This double time constant, dealing with emergencies that often receive wide media attention, requires a strong collaborative mindset, both with the Institute’s partners and with the public. The Institute’s mission is to contribute to the safety of nuclear installations and to the health and well-being of the population as a whole.
coverage, and scientific publications, which are less visible, makes it complicated to combine both practices. The ideal "researcher-expert" is a difficult role to play and the IRSN researcher always claims an identity that is quite distinct from that of colleagues working in other R&D teams, since it is rare that researchers are required by their governing authorities, and by society at large, to respond to emergency situations such as the incidents that took place last summer at the Tricastin site, or the radiotherapy accidents in the headlines this past year.

The diversity of subjects and disparity in their state of progress makes it impossible to cover all the Institute’s research activities in a single report. This year’s Scientific and Technical Report is the fourth in a series that began in 2005, drawing to a close a four-year cycle covering an almost complete panorama of the main lines of research at IRSN. The body of knowledge and results accumulated over the past four years and recorded in these volumes will provide the basic elements that experts from Aeres (the French agency for the evaluation of research and higher education) will consult to evaluate and assess IRSN’s scientific strategy and the quality of its teams. This assessment, considering the specific characteristics of the Institute and the complete range of its public service obligations, will provide the opportunity for IRSN to affirm its unique position in the national research system.

IRSN must conduct collaborative research with its partners, while preserving its independence.

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* Michel SCHWARZ was appointed Scientific Director of IRSN as of January 1, 2009.
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fter a transitional year in 2007, marked by renewal of its members and new initiatives, in 2008 the IRSN Scientific Council, in addition to its regular activities, completed reports on two scientific and technical audits and pursued reflection on a certain number of strategic options. The Council held two plenary sessions (in May and November) and, in compliance with its mission, issued an opinion on both the IRSN Annual Report and the Scientific and Technical Report. The members of the Scientific Council were also involved in Institute activities throughout the year, having participated in the committee meetings where IRSN PhD projects were decided (in June and September), in the Dissertation Days event (in September at Vogüé), and at the Institute’s Science Day event (in November).

The first completed and published scientific and technical audit, entitled "Research in Radiopathology and Therapy for Irradiated Persons", was set out to assess research activities at the Radiopathology Laboratory (LRPAT) and the Laboratory for Cell Therapy and Accident Radiation Protection (LTCRA). The purpose was essentially to report on various areas related to the laboratory’s mission, including scientific knowledge improvements, the most significant results, special and unique skills, research programs, international activities, collaborative projects, organization, human resources, communication capability, visibility, any problems, and the laboratory’s development perspectives.

The audit committee was composed of the following members:
- three members from the Scientific Council: Dietrich Averbeck (audit leader), Pierre Laroche, Ethel-Esther Moustacchi;
- six outside members: Dr. Wolfgang Sauerwein, Universität Essen, Germany; Dr. Jacques Balosso, Grenoble University Medical Center; Dr. Luc Rochette, LPPC, Dijon; Dr. Jacqueline Godet, Ligue contre le cancer (association to fight cancer); Dr. Norbert-Claude Gorin, Saint-Antoine, Paris; Dr. Jean-Philippe Peyrat, Centre Oscar Lambret, Lille.
- Alain Biau, IRSN Assessment and Scientific Coordination Manager, was the IRSN audit coordinator. The audited laboratory was represented by Marc Benderitter (DRPH/SRBE/LRPAT).

The final version of the audit report was adopted at the plenary session held on November 13, 2008.

The second audit, on "The Role of Global Tests in Reactor Accident Simulations", had three goals:
- to review work conducted by the PHÉBUS international expert group. The group examined needs inherent to running in-pile tests (in particular for the PHÉBUS experimental reactor) in the study of severe accidents (source term analysis) and loss-of-coolant accidents (LOCA). It also examined future needs for Generation IV reactors, and in its final report issued recommendations based on the three summary reports corresponding to these topics;
- to examine the need to use the CABRI test reactor to qualify models of PWR core behavior in reactivity-initiated accidents;
- to assess the relevance of IRSN R&D strategies combining detailed numerical simulation, separate-effect experiments, "phenomenological" analyses, and global experiments. This audit was limited to severe accidents and fuel behavior in LOCA and reactivity-initiated accident situations.

The underlying issue was to determine the extent to which the development and qualification of simulation tools still depends on the use of increasingly expensive experimental facilities and ser-
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We aim to reinforce the independence, rigor, and quality of these audits.

Michel Quintard
Scientific Council Chairman,
Toulouse Institute of Fluid Mechanics
COLLEGE OF EXPERTS
Valuable involvement in Gast and exploratory research

The College of Experts has just reached the end of its third year. With the number of members rising to 48, the third seminar held at the end of September 2008 was the occasion for newcomers to become familiar with the rest of the group as the College took stock of the year’s activities.

The highlights to be remembered are the achievements made by the cross-disciplinary scientific interaction groups (Gast) and the College’s participation in the exploratory research structure. The purpose of the scientific interaction groups is to bring together interested members of the Institute to exchange views on scientific topics, thereby encouraging the dissemination of knowledge. Today there are four of these groups within the Institute.

The GATMC (cross-disciplinary scientific interaction group for Monte Carlo codes) met in June to exchange thoughts on fourth-generation reactors, and in October organized a seminar on “Initiation to Monte Carlo Computer Code by Rolling the Dice”, led by John Hendricks, developer and leader of the MCNPX computer code team at the Los Alamos National Laboratory (LAN/USA). The statistics group that met in June to provide technical support in statistics on subjects studied at the Institute was organized around mini-projects, such as the optimization of dosimetric monitoring incorporating uncertainty, the evaluation of uncertainty across the measuring system, and the analysis of sensitivity and uncertainty in numerical models, to mention a few.

The aerosols club held their first meeting in June to establish a map of aerosol activities conducted at the Institute. In October the club organized a seminar on aerosol metrology, led by internationally renowned figures. The group on droplet flow was created at the end of the year, with focus placed on how droplets evolve and how they affect gas flows. Some of the areas concerned by these phenomena include severe accidents, means used to mitigate accidents and fires, and fighting back a particular type of contamination using water mist.

In exploratory research, 16 members of the College of Experts were involved in the project assessment committee proposed for the year 2008. These research projects were initiated by the various operational divisions and were assessed based on criteria involving challenge, creativity, and risk. Five subjects were examined and four projects were selected by assessors after a majority vote.
The first subject, proposed by the Reactor Safety Division, dealt with the study of reactor vessel embrittlement induced by liquid metals, an “exotic” phenomenon produced through the mechanics of metal materials interacting with a chemical environment.

The second and third subjects, introduced by the Prevention of Major Accidents Division, involved the development of heat flux measurement through concrete walls exposed to fire, a creative project proposing to couple heat flux measurement with the thermal and physical properties of materials; and characterization of hydride precipitation kinetics in fuel cladding zircaloy using synchrotron radiation.

The last subject, suggested by the Radiation Protection and Human Health Division, concerns the study of pathologies induced by chronic exposure, in particular radiation-induced cataracts in interventional cardiologists.

This subject was proposed in response to demand for radiation protection from a profession increasingly aware of the impact of ionizing radiation, and will reinforce IRSN’s position in epidemiological studies on the protection of health professionals.

The College of Experts was called on to lead a working group composed of College members and representatives of the operational and functional divisions to propose improvements in the structure set up to develop exploratory research. The conclusions of this group were submitted in a report prepared by the Scientific Division (DS/COLLEXP/2008-01).

Jacques VENDEL
Senior Expert, Airborne Pollutants and Containment Study and Research Department
In the last four years, each time universities have opened their doors in the fall, close to 25 doctoral students have begun working on their theses at the Institute. In an establishment where assessments meet and merge with research, where a vast number of scientific disciplines are represented, this figure may seem insignificant in comparison to other organizations.

But in today’s context where so many students are turning away from the sciences, making it difficult to recruit high-level doctoral students, it is important and satisfying to recall that for each student who begins a thesis, the Institute is sure to have taken all the necessary steps to make the experience a success. All subjects proposed by one of IRSN’s laboratories have been carefully reviewed, and all thesis candidates must defend their project before a selection committee composed of scientists who work at IRSN or other organizations. These different steps ensure that all the necessary conditions have been met to initiate theses that not only qualify as part of IRSN’s missions, but also correspond to research work expected to produce applicable results at the end of three years, for both the laboratory and the doctoral student.

Driven by the need to respond to questions posed by the scientific community, public authorities, and society at large on nuclear safety and radiation protection issues, research work covers several major areas, naturally including engineering sciences (civil engineering, thermodynamics, materials, neutronics), health (biology, toxicology, dosimetry) and the environment (ecology, geology, seismology), but also encompassing social sciences (human factors) and economics (safety economics), where demand is yet low, but will undoubtedly grow in the next few years.
Depending on the scientific field, the technical resources and tutoring skills available at the Institute may require that the doctoral student be physically and contractually assigned to a partner university or institution. Nearly 60% of the theses under way on December 31, 2008 were the result of a co-funded collaborative project contract, and close to 15% of the doctoral students were employed by an organization other than IRSN.

Each thesis being carried out in a specific environment, it is naturally the responsibility of tutors and the relevant laboratories to accompany doctoral students and ensure that their work will find recognition. Doctoral students and post-doctorates at the Institute are nonetheless asked to present the state of progress of their work at resident seminars held every year. At the last seminar, the 2008 Dissertation Days event held in Vogüé in southern France, over 170 people, including IRSN scientists or partner institutions, attended presentations of research work and debates on training-through-research at the Institute. The valuable contributions of these presentations and discussions demonstrated that the commitment of laboratories and the Scientific Division to pursue the training-through-research policy has been beneficial, and that each of our young researchers, doctoral students and post-docs alike, devoted to a unique research project, plays a real part in the collective process of acquiring knowledge at the Institute.

Gauzelin BARBIER
Head of Research Training Program (DICST),
Scientific Division

Research is conducted in response to questions posed by the scientific community, public authorities, and society at large.
Since July 1, 2007, IRSN, CNRS and the University of Montpellier II have acquired shared laboratory facilities devoted to nuclear safety: the Micromechanics and Structural Integrity Laboratory (MIST). This structure is the fruit of a joint, proactive policy that aims to reinforce synergy between basic and applied research. This virtual laboratory, consisting of members from IRSN’s Prevention of Major Accidents Division (DPAM) and from the Mechanical and Civil Engineering Laboratory (LMGC, CNRS-Montpellier II University) has a dual purpose: first, to propose tools for understanding and predicting phenomena explicitly related to nuclear safety; and second, to take up broader scientific themes for results that are beneficial to each partner and their research community. As early as 2008, this young laboratory proved the relevance and efficiency of pooling research resources by successfully tackling problems recognized as scientifically difficult.

Specialized skills

The general theme of the MIST laboratory involves heterogeneous and evolving structures. This naming refers to the behavior of materials and structures subject to aggressive environments, such as the intense thermomechanical loads or natural aging conditions (imposed and induced) frequently encountered in the nuclear field (reactor core, waste disposal, etc.). In 2008, the MIST lab approached this ambitious theme along two major lines: micromechanics and fast mechanics. Micromechanics aims here to quantify the impact of microstructural changes induced by these aggressive environments on material integrity. In the nuclear context, there are numerous changes to be considered: alteration of concentration of existing phases and their properties, occurrence of precipitates, dispersion in size and shape in a collection of grains, etc. The challenge is to build predictive models and numerical simulations when it is practically impossible to obtain “on-line” experimental measurements.
Fast mechanics involves analyzing nuclear materials and structures under accident conditions. This can involve global dynamics (extremely fast thermomechanical loadings) or local dynamics (material failure, stability of granular stacks).

Understanding fast phenomena requires going through an experimental stage, while computer codes are often capable of handling this type of problem already.

These two lines of research have led to the development of quite various subjects covering a large panel of applications, from fuel cladding to dispersing contaminants in a fluvial environment. In practical terms, the first eighteen months of MIST laboratory work focused on transition from continuous to discrete media, the hydro-poro-mechanics of saturated granular media, strongly coupled thermomechanics, cracking in heterogeneous materials, multi-scale numerical strategies, and experimental identification through field measurement.

“MIST research is published in major journals and produces concrete applications.”

Practical scientific results

The following are three concrete examples of the promising results already obtained:

- In terms of experimentation, local damage models were identified in metals at a spatial resolution on the order of a few tens of microns;
- With regards to modelling, a method was proposed for determining optimal representative elementary volumes for quasi-brittle failure of metal-matrix composites;
- In numerical simulation, a tool was developed to analyze the stability of a mesostructure.

These recent works were all published simultaneously in major scientific journals and have led to practical developments in nuclear safety analysis tools.

Yann MONERIE (IRSN)
Robert PEYROUX (CNRS)
MIST Directors