IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

IRSN Scientific Strategy

Enhancing nuclear safety, nuclear security and radiation protection

A brief description of IRSN

The IRSN (Institut de Radioprotection et de Sûreté Nucléaire) is a public institution of an industrial and commercial nature that was set up in 2001. Its missions are recognized at the legislative level in the Act No. 2015-992 dated August 17, 2015 on energy transition for green growth. Decree No. 2016-283 of 10 March 2016 on IRSN, which implements the Act, places the organization under the joint supervision of the Ministers of Ecology, Research, Industry, and Health, and the Minister of Defense.

As the public expert in nuclear and radiological risks, the Institute provides scientific and technical assessments of these risks through its research, assessment and monitoring work. Its activities both in France and abroad cover a wide range of fields, including the safety of facilities, transport and nuclear waste; monitoring of the environment, workers and patients; consultancy and radiological emergency response; and radiation protection of humans under both normal and accident situations. Its expertise is also used for defense-related activities.

IRSN contributes directly to government policy in the fields of nuclear safety, the protection of human health and the environment against ionizing radiation, and the safeguard of nuclear materials, facilities and shipping operations against the risk of malicious acts. Within this context, it interacts with all the players concerned by these risks, including nuclear safety and security authorities, local authorities, businesses, research organizations, associations, stakeholders and representatives of civil society. The Institute helps inform the public by publishing the results of its work. Through its activities, it also contributes to other major public policies, such as research, innovation, occupational health and environmental health policy.

The Institute has a staff of around 1,700, including a large number of engineers, doctors, agronomists, veterinarians, technicians, experts and researchers. IRSN has a budget of around €300 M to carry out its missions.

IRSN's scientific strategy was approved by the Board of Directors on October 15, 2015.

For more information, consult the IRSN's website at **www.irsn.fr/EN**

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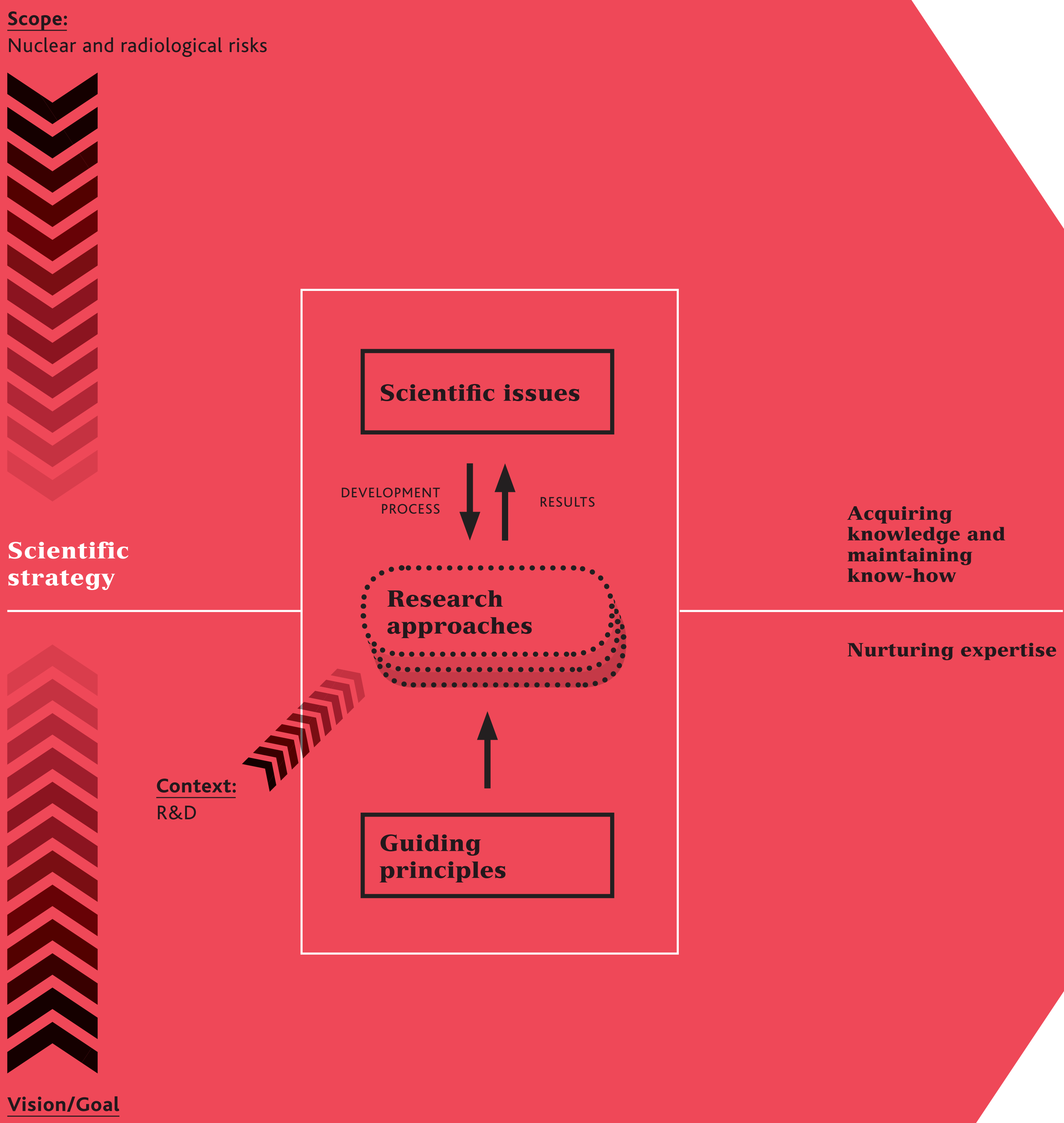
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Message from the Chairperson and the Director General

IRSN's main duty is to ensure that its expert appraisals and its responses (including emergency responses) are based on the best available scientific knowledge. Its aim is also to help improve nuclear safety and security by advancing this knowledge, putting it to use, and sharing it with those who need it. In this way, IRSN can foster the emergence of more relevant technologies and know-how to address nuclear and radiological risks, and of more effective control methods. Research and assessment are closely linked in all of the work it undertakes under its missions.

The choice of strategy to best achieve these scientific and operational goals is therefore a major issue for the Institute itself and, more broadly, for public policy in the field of nuclear safety and security. Thus far, this strategy has been unstated – discernable only through the Institute's major decisions throughout its development, e.g. on performance target agreements with the government, medium-term plans, multidisciplinary research and study programming, and policies regarding partnerships, human resources and knowledge management.

Explaining this strategy constitutes an additional step towards facilitating dialogue with all of the Institute's stakeholders and collecting ideas at the highest level. This includes dialogue on some twenty major scientific and societal issues that have been set as priorities for the upcoming years, and dialogue on the main essential requirements (referred to as "guiding principles" in this document) that guide IRSN's research initiatives within its specific responsibilities as a national public expert on nuclear and radiological risks. In this way, without sacrificing IRSN's independence, synergies with other stakeholders can also be fostered to further nuclear safety and security.

In light of this, drafting IRSN's scientific strategy was the subject of many discussions before we settled on an initial French version that was published in January 2016 with a preface written by Ségolène Royal, Minister of the Environment, Energy, and the Sea. The document has since been translated so as to share this strategy more easily with IRSN's international partners. We thank all those who contributed to the strategy, and invite you to read it and, if you so desire, send us your comments or suggestions.

Dominique LE GULUDEC
Chairperson of the board of Directors

Jean-Christophe NIEL
Director general

Acquiring a Grasp of the Context

Missions as the cornerstone of national strategy

IRSN's strategy is part of a body of legislation and regulations that define its scope in line with the national strategic context. The general framework for radiation protection is specified in the national health strategy, within the framework of the public health act that was presented in 2015. The general framework for nuclear safety and security is specified in the Energy Transition for Green Growth Act, which was voted into law in August 2015. This context is in line with two major European reference frameworks: the European nuclear safety directive and the Euratom directive on basic radiation protection standards. Both of these will be transposed into national law.

For research, the national strategy established by the 2013 Higher Education and Research Act sets goals that are in line with those at European level and which attach considerable importance to risk control and innovation challenges.

These basic frameworks allow for a number of changes that are under way in French civil society. The society's stakeholders are involved to ensure that the focus of concern remains relevant and on target, and to allow for increased involvement in the decision-making processes based on a high level of transparency.

Besides its strong doctrinal role, IRSN's main focus is to deliver its technical expertise on safety, security and radiation protection risks in terms and on schedules that are compatible with the needs. The needs revolve around the status and developments to the French nuclear power program as decided by the public authorities and implemented by the industrial players (in terms of ageing, decontamination/dismantling of existing facilities, waste management, technological options for new facilities, etc.). They also concerns the rapid changes to emerging practices or techniques that use ionizing radiation in the medical field (patients, health professionals) or in the industrial sector. Moreover, one of the Institute's core missions is to ensure that it takes appropriate action in emergency situations, particularly concerning the information and analyses that it makes available to crisis management teams and the population.

A rapidly changing scientific, technological and economic context on the international stage

The international scientific, technological and economic context in which IRSN will be operating over the next decade is based on firm foundations. Nuclear energy is still a major component of the French energy mix, and the aim is to export this mix abroad in all its component forms. Similarly, the use of ionizing radiation for therapeutic or diagnostic purposes constitutes a source of medical progress, and while this is likely to be of use to the general public, its adverse effects must also be controlled. At the same time, despite increased competition among suppliers, the international nuclear economy is founded on more open and more advanced cooperation in the scientific, technical and control fields. Due to this situation, the safety and radiation protection reference frameworks need to be more closely attuned at the international level.

Still, there is always the possibility over the next decade of a major radioactive release into the environment somewhere in the world (and this includes France), so technical and methodological tools are needed to guide appropriate industrial and regulatory actions.

These solid foundations are part of a rapidly changing environment in which the role of the competent authorities is becoming increasingly important. Their needs for scientific and technical support fall under a process of continuous improvement of safety and radiation protection, where R&D plays an important role. These needs focus more and more on complex issues around the management of multiple risks to which society is exposed. They must be seen in the context of the opportunities and risks associated with human resource recruitment at IRSN over the next 10 years, where there is a need to preserve past knowledge: the “pioneers” will soon be leaving while the staff recruited since the Institute was created will only reach their scientific and technical maturity within the same time frame.

To adapt its scientific strategy to all of these developments, the IRSN must take the increasing integration of research at the European and international levels into consideration. It is faced with the two-pronged effect of dwindling resources and skills and the need to develop structures, skills and strategies at the European level as emerging countries continue to develop.

Scientific challenges for the decade ahead

Many scientific challenges must be addressed to achieve a better understanding and to better characterize the human and environmental risks of exposure to ionizing radiation. For example, the major challenges for the decade ahead include understanding the causes of the secondary effects of some medical treatments and characterizing the risks of developing a pathological condition as a result of chronic exposure to low doses. Once the health or environmental risk has been characterized (whether it is naturally occurring, accidental, occupational, or the result of one of the growing variety of medical practices that use ionizing radiation), a more operational challenge consists of developing the scientific criteria for optimized management of the risk on a daily basis and in the event of an accident.

With respect to French nuclear facilities, where the highest possible level of safety must be guaranteed throughout their lifespan, industrial projects are under way to create new facilities (Flamanville EPR, Cigéo, ASTRID, RJH, ITER, etc.) and to significantly upgrade existing facilities – particularly older, second-generation facilities. Major site dismantling and decontamination operations on end-of-life facilities generate large quantities of waste, raising a large number of safety and environmental protection issues relating to waste streams, disposal solutions and processes.

Over the next ten years, a major development will be safety improvements to second-generation reactors, based on operating feedback and newly available knowledge. These reactors will be maintained in operation to serve as a reference for innovative concepts. For example, improved assessment of the vulnerability of facilities and transportation to malicious acts, or even the most basic scientific characterization of how to manage the ageing of facilities are still major challenges, including for the economy of the French nuclear program. Finally, in-depth scientific knowledge of the potential serious accident scenarios in reactors and, more generally, in fuel-cycle facilities will help to reduce the level of uncertainty when taking operating and post-accident management measures designed to limit the release of radioactive materials into the environment.

Finally, scientific communication, training and education are an integral part of the challenges to be addressed in conjunction with the social stakeholders.

Factors for Success:

Performing IRSN Scientific Activities

To provide some relevant answers to a certain number of priority scientific issues in this context, IRSN needs to prepare effectively and adopt a clear strategic approach. Apart from the issue of the resources at its disposal, the abundance and quality of the Institute's scientific work depend on the organizational structure that underpins the scientific approach (including the contribution from international exchanges) and a core set of essential requirements. The knowledge generated by the Institute can thus be used by its experts and made available to all stakeholders.

An organizational structure to serve the scientific approach

In light of these scientific and technical challenges, IRSN has established a thematic organizational structure that reflects the main scientific issues on which it works. Both the organizational structure and the governance system in charge of the scientific arm of the Institute are key to the scientific quality and enhanced relevance of the work.

For this reason, decisions from the IRSN Board of Directors (especially on IRSN activity programs) are informed by the opinions of the Nuclear Safety and Radiation Protection Research Policy Committee (COR), the Scientific Council (SC), and the Steering Committee for the Nuclear Defense Expertise Division (CODEND) where the orientation of the CODEND activity program is concerned. The COR is more specifically mandated to advise the Board of Directors on the objectives and priorities for the Institute's research in the fields of nuclear safety and radiation protection (excluding defense-related areas). The SC examines IRSN activity programs and ensures that the Institute-defined research approaches are pertinent, in particular with respect to the scientific strategy and monitoring. It may also make any recommendation on the orientation of IRSN's activities.

The Institute also has an External Visiting Committee that reports to the Director General and whose task is to assess the results of IRSN scientific and technical activities, and therefore of its research and assessment processes. The IRSN Evaluation Director supervises all peer reviews of the work undertaken and of the teams performing the work.

Research process definition and development are modeled by the teams under the responsibility of the thematic directors. The Strategy, Development and Partnership Division oversees the overall coherence of these different components of the scientific strategy, in particular to prepare for the annual endorsement of the IRSN activity program by the Board of Directors.

Finally, the IRSN Ethics Division oversees the potential ethical implications of the Institute's work and reports to the Board of Directors.

Strengths to be preserved and consolidated in accordance with its specific features

More so than the variety of topics addressed by IRSN, the establishment's main strength lies in its ability to adopt a systemic (and therefore multidisciplinary) approach to organizing scientific research to meet needs for cross-operational assessment that are clearly expressed internally. The organizational structure in place is designed to facilitate consensus-based internal reflection on relevant cross-disciplinary scientific issues. This work draws on the data collated from operating feedback (radiological monitoring of workers, patients, populations and the environment, facility operational reports, incident reports). By its very nature, such data can also raise specific scientific issues. For research projects, this systemic approach combines the necessary observational, experimental, modeling and simulation methods to develop forecasting and decision-making support tools.

Developing the value of human resources

The Institute strives to create an attractive working space for scientists, help further their careers (in particular through its College of Experts), and promote creativity and excellence to ensure that human resource management serves scientific quality. These goals drive the strategic workforce planning process that was established in 2011. Tangible actions are undertaken to maintain a high level of scientific expertise for all technicians, engineers and researchers. Particular attention is paid to training courses, job mobility (including external mobility both in France and abroad) and more broadly, any other action designed to raise awareness of the technical and cultural realities of French and foreign manufacturers and health professionals. Insofar as possible, the day-to-day organizing of research fosters direct, productive internal and external interpersonal communication and scientific exchanges with other bodies.

Essential requirements

Like any other scientific and technical body, IRSN sets itself stringent requirements. Over and above the requirement for efficient use of public resources in performing its scientific research, scientific excellence is paramount, and is furthered by pooling, transmitting and developing knowledge.

IRSN constantly strives to ensure systematic, broad-ranging scientific and technical monitoring through the use of effective tools, and arranges to make the best use of international sources (other types of reactor, other techniques, etc.). It also gathers and summarizes its knowledge in the form of books, repositories, policies, reports, tutorials, databases, and calculation software. Another of its top priorities is to maintain skills and know-how and to manage critical knowledge, so as to anticipate change in its human resources insofar as possible, using knowledge management and strategic workforce planning.

To develop and transmit its know-how, IRSN contributes to training through research on major scientific topics. It also participates actively in teaching these topics both internally and with its main partners, and in general, pays regard to scientific and technical communication that is geared towards all audiences. Where required, it tries to participate in procedures to propose changes to standards and risk-management reference frameworks by contributing its knowledge inputs. At the same time, the Institute makes efforts to identify and if necessary, protect the innovative results of its work.

As regards the evaluation of scientific and technical excellence, IRSN coordinates with its scientific director to systematically confront its work with that of its scientific peers in areas where it plays a role. This occurs in particular through its strategy of publishing in peer-reviewed journals and conventions.

Guidelines

Used to Address Priority Scientific Issues

The Institute uses a set of guidelines to work on the scientific topics it has identified as priorities.

1 **Justify the grounds for its scientific directions and the resources to be allocated to them**

2 **Involve the end beneficiaries in the research work**

3 **Take initiatives to consolidate national, European and international research on nuclear and radiological risks**

4 **Develop academic partnerships and participate actively in the National Research Alliances**

5 Develop cooperation with manufacturers, nuclear operators and stakeholders in the medical sector wherever necessary

6 Acquire numerical simulation tools and the skills to use them

7 Ensure IRSN access to research and experimental facilities and to databases

8 Develop operational decision-making support tools and methodologies

9 Perpetuate systematized knowledge and know-how to improve risk assessment

Guidelines

Used to Address Priority Scientific Issues

1 Justify the grounds for its scientific directions and the resources to be allocated to them

IRSN justifies its program choices mainly on the basis of explicit criteria[1] for meeting the challenges and needs in safety, radiation protection or security issues, taking the risk-analysis and assessment missions it is tasked with into account.

IRSN balances its portfolio of activities to ensure that the strategic areas it has identified are given the necessary attention.

To implement its strategy, IRSN justifies the process and reasoning for developing its research approach for each priority scientific issue. In particular, it specifies the scientific fields where it does the research itself and those where it participates in research conducted outside the Institute.

1. The criteria are: the importance of the scientific product for risk control; the innovation potential; the potential for generating collaborative partnerships; the potential for increasing the Institute's image and scope of influence; the potential for increasing the Institute's independence of judgment; the pool of internal and external technical skills available; the technical and financial risks.

2 Involve the end beneficiaries in the research work

To ensure that its scientific work is consistent with the expectations/needs of the stakeholders in French society, IRSN interacts with the government, the appropriate bodies, the agencies and civil society, taking care in particular to:

– seek the opinion of these stakeholders when identifying its research priorities,

– involve them in the long-term monitoring of its research work,

– provide guidance when distributing the results of its work to these stakeholders.

This standing goal is in line with the provisions of the Energy Transition for Green Growth Act, which reinforces the continuous enhancement of transparency, the participation of civil society in areas relating to nuclear safety and radiation protection, and the role that the Nuclear Safety Authority (ASN) can play in ensuring that public research is geared to needs.

3 Take initiatives to consolidate national, European and international research on nuclear and radiological risks

In order to initiate pioneering scientific programs that address challenges over the medium to long term, an active, consistent involvement of the Institute in scientific developments both in France (in particular within the national research Alliances) and abroad will be fostered. The scientific cooperative partnerships initiated by the Institute should enable it to make best use of national, European and multilateral instruments such as the European technical platforms, or the international research agreements such as those managed within the framework of the OECD/NEA, the European Commission or the IAEA.

The appropriate scientific expertise and sufficient resources must be allocated to the areas where IRSN seeks to be an acknowledged player. Being a major player means being directly involved in the implementation of large-scale scientific programs (particularly of the research type), within the framework of potential alliances.

4 Develop academic partnerships and participate actively in the national research Alliances

A key aspect of the scientific strategy of a technical safety organization (TSO) operating in the research field lies in the quality of its national/international academic partnerships. IRSN intends to continue to develop its already well-established partnership strategy with teams providing high added value on upstream topics of interest to it. This includes within the framework of joint research units, when such a framework proves to be best suited to developing, steering and giving visibility to the joint research work. The Institute also ensures that it is active in the national research Alliances[2].

2. Giving priority to the following points:

- the relevance and scientific performance/visibility of the teams with which it works to set up consortia,
- establishing framework agreements wherever necessary, subject to effective monitoring (sitting on the governance bodies), in order to foster exchanges (topics, people),
- helping to define research goals in order to guide collaborative academic work,
- using this collaborative work to foster access to external resources (experimental platforms, calculation tools, basic data, specific skills) and to open up our platforms.

5 Develop cooperation with manufacturers, nuclear operators and stakeholders in the medical sector wherever necessary

Excluding issues on which it deems that it needs to work independently, IRSN keeps up strong scientific ties with industry, nuclear operators and the medical sector in accordance with its ethics charter. In its approach, the Institute sets itself the following priorities:

- ensure that it has field knowledge of the safety, security and radiation protection issues facing manufacturers and operators and that it shares the major challenges of future industrial developments,
- make efforts to obtain the data needed to validate the calculation tools used in confirmation assessments,
- raise awareness of the challenges among these stakeholders and give them the benefit of its knowledge in this area,
- maintain a clearly defined joint collaborative framework for the purpose of undertaking targeted scientific work on research topics of joint interest,
- offer the innovative results of this work to the relevant economic stakeholders.

6 Acquire numerical simulation tools and the skills to use them

Because its strategy regarding scientific calculations is a determining factor in the quality of its assessment work, IRSN prioritizes the following points:

- ensuring the availability and control of the modeling and calculation tools that are of strategic importance to complete its research and expertise missions, and fostering their rational use internally,
- controlling insofar as possible the modeling uncertainties and biases of the tools it uses and develops,
- rationalizing software investments by justifying its choices to develop, purchase or adapt software while retaining control and independence with regard to their validation and with standard practice,
- facilitating and speeding up the diffusion of the Institute's software.

7 Ensure IRSN access to research and experimental facilities and to databases

To ensure the relevance and independence of its assessment work, IRSN relies on its ability to consolidate and optimize the existing pool of knowledge by enriching it with new data from experiments. Because the data from experiments is of differing types, acquiring it entails the use of experimental equipment at different scales. The Institute's policy in terms of scientific equipment and its procurement is based on four requirements:

- availability of the "major experimental equipment"; this includes the guarantee of their long-term availability at national, European and international level;
- control over the technical characteristics and development of the "main experimental equipment";
- optimization of the resources dedicated to infrastructure and consistency of the various sources of costs (investment, in-service support, defining systems based on researchers' technical requirements, etc.) with the proposed use of the resources over the medium and long term;
- rational data storage and protection to enable targeting sensitive and/or unique data of major scientific importance; to avoid producing and storing redundant and obsolete data, this should take account of the specific attention paid to generating or acquiring new priority data (e.g. regarding nuclear data).

8 Develop operational decision-making support tools and methodologies

IRSN needs to have a set of highly operational decision-making support tools and proven methodologies in order to provide the public authorities and/or the general public with rapid, relevant answers that can be adapted for different situations – for example, when the implementation of reference tools turns out to be inadequate for the required time frame, or to support information or a decision during a radiological and/or nuclear emergency. The distribution of these tools is a key aspect of the Institute's policy.

9 Perpetuate systematized knowledge and know-how to improve risk assessment

To maintain and build on the "know how, know why" culture that it has developed on topics that it must control fully, IRSN focuses on further developing the explicit and implicit practices deployed when developing a generic approach to a scientific issue.

The scientific and technical knowledge acquired from R&D and through assessment work must be built on and further developed so that it can be used to address new issues that will surely arise before new facilities (e.g. Flamanville EPR, Cigéo, ASTRID, RJH, ITER) are commissioned. It should also serve to assess the safety of fuel cycles and of the related waste. Also, in light of the new technologies used in diagnostic radiology or in radiation therapy, it should serve to assess the safety of radiation protection for patients and health professionals. This aspect is taken into account with regard to staff turnover.

Priority scientific issues

The IRSN scientific strategy hinges on a limited number of scientific issues that it considers it needs to work on over the next decade in relation to two priority challenges: avoiding a severe accident in a nuclear facility, particularly if it involves a power reactor in Europe; and how best to support radiation protection efforts, along with the related high costs in areas where there are real challenges. These issues not only provide a broad perspective for projects that may or may not have already started, but also provide a framework for upgrading them.
While the strategy does not specifically and systematically include new scientific issues that could arise from interactions with other risks (chemical and other), the aim is to address them insofar as is necessary. In addition, the different thematic research approaches developed by the Institute's teams are described in specific supplementary documents.

Radiation protection

Understanding, assessing and controlling nuclear and radiological risks for humans and the environment are a real challenge to smooth nuclear power operations. The uncertainties that surround the scientific basis of the radiation protection system are under public scrutiny. We have to reduce these uncertainties in order to fine-tune the radiological risk management system.

The first strategic focus is to understand the impact on biological organisms (humans, animals, plants and their ecosystems) of chronic exposure to low doses of ionizing radiation, typically in contaminated areas. This involves two significant scientific goals over the next decade:

- gaining a mechanistic understanding of the effects of chronic exposure to low doses. For humans, this means assessing the health effects (risk of developing cancerous diseases or not, effects on descendants, adaptive phenomena), in order to understand the mechanisms in place at the different biological scales and to identify the best ways to prevent the risks. The entire process helps to determine whether or not the model currently used to manage radiation protection (which assumes a linear no-threshold relationship between the cancerous effects and the dose ingested, based on observations of survivors of the Hiroshima and Nagasaki bombings who had been exposed to high peak external doses) is still valid in the area of exposure to chronic low doses. For ecosystems, gaining a better understanding of the potential emergence of long-term environmental impacts helps to shed light on the modes and extent of disruption to an ecosystem in a contaminated environment.
- optimizing uncertainty management under normal and accident conditions by reducing the uncertainties associated with quantifying the risks from exposure to ionizing radiation. Taking account of the health risk (to humans) and the environmental risk (to ecosystems) in an overall impact assessment is also a significant challenge.

The second strategic focus concerns people who are potentially subjected to acute exposure to ionizing radiation, and involves two scientific goals:

- controlling and optimizing the use of the full range of new techniques that use ionizing radiation for diagnostic or therapeutic purposes in order to prevent the risks to patients and health professionals.
- improving medical care for people who have been exposed as a result of a nuclear or radiological accident or a malicious act, by correctly characterizing the risk incurred through the use of relevant indicators and an appropriate selection of therapeutic approaches.

More broadly, the issue of nuclear and radiological risk control leads us to question the applicability and effectiveness of our preparedness to manage an accident and its consequences, especially since the issue has been revived in the wake of the Fukushima accident. This is true both for emergencies (regarding the decisions to make in order to protect the exposed populations) and over the longer term (rehabilitation, remediation of contaminated areas, life in a contaminated environment, etc.).

Question › 1

What are the effects of exposure to low doses?

››› Are there biological, environmental and health effects (illness, diminished quality of life) resulting from chronic exposure to low doses? What are the biological mechanisms behind the emergence of and adaptation to such exposure?

››› Are there any no-effect levels of exposure for ionizing radiation, as is the case with certain chemical or physical toxic substances?

››› Can we determine molecular signatures for radiation-induced effects?

››› Are the effects of radiological exposure cumulative? What about their synergy/antagonism with other stress factors?

››› What types of links can be established between the early radiation-induced molecular effects and the later cellular and tissue effects producing the impacts on the organism?

››› What variabilities, which can be evaluated using statistical methods, can exist between individuals or groups of individuals, from biological response mechanisms to the overall effects that denote a specific sensitivity?

››› Can some molecular or cellular effects be transmitted (and exacerbated) from generation to generation and bring about health effects?

Question › 2

What improvements to methods and tools should be proposed to provide relevant predictions of radionuclide transfers into the environment, ranking the processes by order of priority?

››› What are the main characteristics of the mechanisms for radionuclide transfer into the environment that contribute significantly to human and environmental exposure?

››› What new data needs to be acquired in order to better configure the key processes in the models that govern radionuclide transfer into the different compartments of the environment?

››› How can transfer and exposure models be improved so that they take account of the physical, chemical and biological interactions, as well as the spatial and time variabilities?

››› Have we identified all the transfer parameters that have a significant impact on the dose estimates on a regional or global scale, and how can the related uncertainties be reduced?

Question › 3

How can we improve the concepts, methods and tools designed to assess the risk arising from the exposure of workers, the general public, patients and ecosystems to ionizing radiation, taking account of ethical considerations?

››› Can we characterize the radiation dose limits as an indicator of individual risk? What does this signify in the case of widely differing levels of radiation exposure for humans or ecosystems? Is this concept suited to internal contamination situations?

››› How can we improve the relevance and sensitivity of epidemiological studies by comparing them with other statistical models and by refining studies that use molecular epidemiology?

››› Is it possible to develop other risk quantification tools for individuals (workers, patients, public) and for populations (animals and plants)? Could these tools take things like individual or species sensitivity, the modeling of radionuclide transfer within biological organisms in the case of internal exposure, and co-exposure with other non-radiological stressors into account?

Question › 4

How can the knowledge from other research topic fields be integrated? Up to what level of integration is it possible to build an integrated radiation protection system?

››› Have the main characteristics of the propagation mechanisms for the effects of irradiation been identified for all levels of complexity of biological organisms, from the molecular to the ecosystem level?

››› What are the most appropriate methods for integrating the different epidemiological, toxicological and eco-toxicological approaches based on the issues under examination?

››› How can population dynamics, trophic interactions and indirect effects be integrated?

››› Are we capable of proposing an "ecosystem approach" to environmental radiation protection that is in line with international conventions established in other environmental areas (biodiversity, RAMSAR, OSPAR, etc.)?

››› What improvements need to be made to decision-making support tools so that they include all aspects of managing an accidental contamination situation?

››› Up to what level is it possible to integrate the use of all of the data collected from routine environmental monitoring?

Question › 5

How can the side effects from the use of ionizing radiation for diagnostic and therapeutic purposes be better identified and prevented?

››› Has the causal link between the different levels of phenomena and scales (energy deposition, early radiation-induced molecular effects, late cellular and tissue consequences) that causes side effects on healthy tissue been sufficiently well characterized?

››› Can we make an early determination of one or more molecular signatures in order to identify patients at risk, and to prevent these risks?

Question › 6

What innovative therapeutic approaches can be proposed to improve treatment of the different diseases associated with high radiation doses?

Question › 7

How can we respond more appropriately and effectively to the need to rehabilitate living conditions in contaminated areas based on the type and severity of the accident?

››› What are the most viable and effective techniques for decontaminating water, soils, urban areas or contaminated environments that could be implemented to rehabilitate these areas in the event of contamination? What performance levels can be expected?

››› Do we know how to optimize the inevitable production, management and disposal of low-activity waste generated by these contamination techniques, from an organizational and logistical perspective?

››› How can we take better account of the human, societal and economic dimension within the framework of the collective and individual management of accidents and emergency and post-accident situations?

››› At what level of contamination and under what conditions of epidemiological and dosimetry monitoring of the exposed populations can these areas be reinhabited?

Nuclear Safety and Security

IRSN's priority scientific issues on safety and security are rooted in the need to limit the impact on people and the environment of the some 180 French civilian or defense nuclear facilities, and the sources and transport of radioactive materials. Here, the major challenges are:

- the safety and security of day-to-day operational activities in nuclear facilities throughout their service life and decommissioning phase, and of impact mitigation activities, particularly with respect to radiation protection;
- the collective need to avoid a severe accident, or at least to limit the potential consequences thereof, particularly in the case of unforeseen events (and therefore for which the extent and principle were not taken into account during the design stage);
- anticipating potential safety problems in connection with the ageing of certain materials and structures;
- a sound working knowledge of safety issues relating to technological innovations, including for technologies intended for export.

Scientific inquiry is what drives progress in terms of the safety and security of operating facilities. It must take account of the fundamental issues at the earliest upstream stage in order to reinforce safety guidelines for future facilities, as of the design phase. The Institute's priority scientific issues are either generic (e.g. safety assessment methodologies that are applicable to a large number of facilities) or specific (e.g. issues that are linked to a specific facility or a limited number of facilities). The goal in both cases is to revisit the safety/security benchmarks and define their future development on a scientifically sound basis.

Question › 1

How can we better characterize contamination transfer, both within a facility and into the environment, and the effectiveness of the filtering or purification systems designed to reduce releases during normal and accident conditions?

››› What fraction of the radioactive contaminants that are likely to migrate is suspended (by a fire, explosion, core melt accident, containment failure, etc.)?

››› What level of accuracy in the modeling (air flow, turbulence, aerosol physics) is required to quantify the transfer of pollutants within the facility via the ventilation networks and the leak paths, to better assess how representative the workplace air monitoring is? What level is required to detect and quantify a potential leak as quickly as possible and estimate any releases into the environment?

››› Do nanoparticles have any specific features (for example in terms of their reactive surface rather than their mass) that need to be taken into account during their transfer or in order to guarantee their containment?

››› Do the new filters, adsorbent materials and dynamic containment processes offer significant opportunities to improve the effectiveness of the purification of gaseous radioactive waste and in particular, reduce the source term of releases using venting/filtering systems in the event of a severe accident?

Question › 2

How can we better characterize and model the loads placed on the facility by internal or external stresses or hazards (including natural ones), and which could have an impact on safety?

››› How can the safety and security of nuclear facilities be maintained in light of potential changes to their operating range and mode?

››› What new, naturally occurring or human-induced contingencies could give rise to scenarios that need to be taken into account from a safety and security perspective?

››› Can we characterize with the required precision all of the thermal and chemical stresses generated by the wide range of complex fire sources that could damage safety-significant facility structures and equipment?

››› How can we improve our predictions of the intensity of the mechanical stresses caused by a (gas and/or dust particles) explosion to the containment barriers and which could cause their degradation?

››› What are the accident conditions within the fuel cycle that could cause process malfunctions leading potentially to unacceptable consequences [1]?

››› How can we improve our predictions of the stresses caused by contingencies (especially seismic events) and deduce the loads to be applied to the civil engineering structures and the facility's equipment?

Question › 3

How can we assess the reliability of the systems and/or equipment that are important for the protection of the nuclear facilities?

››› Are the various passive systems[2] that are or could be proposed by the operators to limit the consequences of accidents effective and reliable under representative accident conditions?

››› Do we have reliable and usable data (and if so, how can they be used) on the manufacturing processes, inspection, maintenance and replacement of some of these systems?

››› How can we characterize the degradation of the functionalities of safety-significant components[3] under accident situations, or in situations exceeding the design bases?

››› Have we correctly assessed the risks due to the development of instrument and control (I&C) systems and more generally to the computerization of the I&C systems in reactors, taking account of their dependence on the various external malfunctions and changing threats (cyber-attacks)?

››› How does pre-standardization research help to improve the robustness of the containment systems and components?

1. Chemical runaway reactions, the consequences of which are thermal and potentially mechanical (massive gas release or even explosions).

2. Hydrogen recombiners, core catchers, passive thermo-hydraulic core and containment building cooling systems, etc.

3. This includes exposure to fire smoke of electronic components, degradation of HEPA filters, fire doors and dampers, clogging of sump filters, ageing of electric cables, degradation of equipment hatch seals in a LOCA situation, cracking of the concrete containment barriers, or damage to the insides of the reactor vessel.

Question › 4

How can we realistically assess the safety impact of changes to the characteristics of the facilities throughout their lifespan?

››› Do we have enough data to analyse the degradation modes due to ageing (and the physical, chemical and mechanical processes involved) that are likely to limit the lifespan of non-replaceable safety-significant PWR components, especially through change to their structure and composition?

››› Are the methods used to predict the behavior of outmoded PWR components over the long term (and according to different time scales) taking account of the potential degradation of their properties sufficiently well-tailored to the kinetics of the different degradation mechanisms (changing kinetics during the ageing process)?

››› Do we have suitable non-destructive testing means for the damage that we are seeking to detect, given our knowledge of the different degradation mechanisms over time?

Question › 5

Do we have all the knowledge we need to assess the risk of damage to the fuel cladding (first barrier) under normal and accident situations, taking account of the changing operating conditions for the fuel in the reactor and in the back-end cycle[4]?

››› How can we better characterize and model the phenomena that either cause thermo-mechanical and chemical stresses on the primary barrier or change its degradation or failure modes?

››› Does compliance with the safety criteria help to protect against anticipated adverse phenomena?

››› How can we determine whether or not the margins quantified by operators are applicable in light of the safety criteria for new methods of managing current fuels and potential innovative fuels to come[5]?

››› Without calling into question the utility of representative integral tests, how can we optimize the use of experiments on spent fuel in the reactor (an operation that is complex and expensive to perform), in particular by using simulation and/or experimentation that makes use of materials which simulate real spent materials?

››› Have the risks of insufficient cooling, or even the fuel cladding failure in pressurized water reactors that are configured (under accident conditions) to recirculate water through the sumps, been accurately characterized?

4. We have seen that operators are diversifying their fuel supply (which means that safety demonstrations for increasingly heterogeneous mixed fuel are required), products are changing and operating is becoming increasingly subject to constraints (power grid monitoring, for example).

5. To ensure the adequacy of the safety demonstration for design basis accidents (for example, loss-of-coolant accident, reactivity accidents, or dewatering operations in the storage pools).

Question › 6

How can we better characterize and model the degradation modes for the containment of radioactive materials (in particular the second and third barriers) in the event of internal or external hazards?

››› How do the thermal, chemical and/or mechanical stresses generated by the hazards degrade the containment barriers[6]?

››› To what level of precision do we know the characteristics of the leaks in the containment building in the event of damage?

››› How effectively does the water in the reactor vessel contribute to cool a core that has been degraded, melted and/or fragmented into debris?

››› Can we accurately define the conditions under which the presence of water in a second-generation reactor pit can practically stop the penetration of the third barrier by cooling the fuel debris during corium-concrete interaction?

››› How can we better model the impact on damage to the containment from mechanical stresses caused by earthquakes?

››› Do we take correct account of the vulnerability of the venting/filtering systems to internal hazards (clogging, hydrogen explosion) and external hazards (earthquakes, etc.)?

6. Facility compartmentalization systems and walls, reactor vessel with or without external cooling, reactor containment building in the event of a serious accident.

Question › 7

What changes need to be made to safety assessment methods and their implementation tools to increase the relevance of the safety assessment and avoid overlooking significant risks?

››› Which assessment methods help utilities to better apply their risk management efforts in their facilities, in particular for new concepts?

››› What changes need to be made to probabilistic assessment methods, in particular by taking into account the gaps in knowledge and uncertainties associated with the modeling of complex phenomena, in order to ensure better complementarity with the deterministic approach?

››› Assessing certain accident operating conditions requires acquiring and/or developing advanced simulation software to be incorporated into a calculation tool that links the thermohydraulic phenomena in the reactor with core neutronics and fuel thermo-mechanics. For users, how can we better validate the computing and assessment methods that apply these simulation tools?

››› The medium and long-term changes under consideration for transport casks or fuel-cycle facilities must guarantee sufficient margins as regards the criticality risk. Are the calculation tools and methods sufficiently reliable to verify that these margins have been factored into the design of such changes?

››› What qualitative and quantitative elements can be used to examine the discrepancies between the demonstration assumptions and the actual situation of the facilities, and take them into account in the safety/security assessment?

Question › 8

What knowledge can be drawn on at IRSN and, where applicable, what new knowledge needs to be acquired in order to assess the safety of the ITER fusion reactor within the time limits of the chosen development schedule?

››› What lack of basic practical knowledge in vacuum technology (and more generally, low-pressure technology) and in the field of dust particles[7] could potentially hinder an exhaustive safety assessment of the fusion reactors?

››› Have the ITER reactor designers and operator chosen an exhaustive range of accident scenarios? Are the probabilities of the scenarios relevant in light of the quantum leap in scale between the existing facilities and this reactor?

››› In terms of safety and radiation protection, what are the challenges raised by the tritium fuel cycle (production, transport and management in the "tritium building", including on-site production over the long term) and by the radioactive waste generated by the activation of the reactor components?

››› What are the methods best suited to assess the probabilities and potential consequences of a loss-of-vacuum or loss-of-coolant accident: dust-particle or hydrogen explosion (for which the source terms must be characterized) and dispersal within the facility and then in the environment of tritium (radioactive risk) or beryllium (chemical risk)?

7. IRSN's expertise in the field of PWR safety is based on in-depth knowledge of pressurized equipment, which is not necessarily directly transposable to vacuum equipment. Moreover, with major vacuum equipment (particle accelerators, for example), vacuum conditions usually go hand in hand with a high level of cleanliness.

Question › 9

What significant phenomena influence the long-term safety of the geological disposal of low-level, medium-level, high-level, and long-lived waste? How can these phenomena be modeled?

››› Over and above our knowledge of the basic mechanisms and our ability to model them, have we clearly identified the technical difficulties associated with creating various barriers (packages, engineered barriers) and the phenomena likely to degrade them with an impact on their effectiveness?

››› What means will be used to monitor and measure the key parameters of the repository over time (operational and reversibility phase)?

››› Are new treatment processes needed to significantly reduce the risks in the different waste disposal facilities?

Question › 10

What knowledge is available to assess the safety of operations to decontaminate and dismantle nuclear facilities?

››› Do we have enough available knowledge and methods to characterize both the risks (radiological inventories, particle dispersion, etc.) during reactor decontamination and dismantling operations based on the reactor type under consideration, and the risks for laboratories and fuel-cycle facilities?

››› Given the very broad range of facilities involved, is the available metrology suited to managing risks during dismantling operations?

IRSN is developing scientific activities around a final priority issue that cuts across the fields of safety/security and radiation protection. This cross-disciplinary issue can be described as follows.

Cross-disciplinary issue

How can we better evaluate both the safety and security impact of human activities that are linked to the operation of nuclear facilities or equipment that uses ionizing radiation, and the risk management?

››› Have we clearly identified the technical and organizational provisions designed to enhance the control of risks linked to subcontracting practices and the use of new technologies?

››› What are the dynamics for individual and collective actions during emergency situations? Which organizational and human factors contribute to their performance?

››› What are the effects of risk management methods and tools on assessment activities?

››› Which technical and organizational provisions foster stakeholder involvement in the assessment and risk management processes?

A systematic approach – refocusing topics, updating practices

This document frames the choices to be made regarding current priority issues in terms of the available resources and the status of knowledge in each field. Other specific documents describe the research approaches and assessment processes developed by the Institute, and identify key internal and external factors to activate in order to provide some responses to the scientific and societal issues in question. These documents also clearly identify both the results achieved so far and the work still to be undertaken, which is described in the Institute's medium-term plan. All the above-mentioned documents are open-ended in nature, ensuring that IRSN can refocus its priority topics and update its practices and scientific partnerships.

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