IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

Jean Jalouneix

Elements of security and non-proliferation

Elements of nuclear safety, radiological protection and security series

edp sciences

Science and Technology Collection

Elements of nuclear safety, radiological protection and security series

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Cover image: mosaic of photographs related to the subjects dealt with in the different volumes of the Elements of nuclear safety, radiological protection and security series. The photographs illustrating the subjects covered in this first volume of the series are highlighted, outlined in yellow.

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Preface

As part of IRSN's Science and Technology Series, the aim of the "Elements of nuclear safety, radiological protection and security" (*Éléments de sûreté nucléaire, de radio-protection et de sécurité*) series is, like the 1996 publication entitled "Elements of nuclear safety" (*Éléments de sûreté nucléaire*), to provide all those whose work involves ionizing radiation, primarily in the nuclear industry, with information regarding the technological culture relative to prevention and management of the related risks. This new series is the result of the desire — and the necessity — not only to update the 1996 publication, but also to extend its scope to areas previously not covered or only touched upon.

In its collection of scientific works, IRSN promotes the most advanced knowledge acquired either within the Institute or as part of national or international collaboration, focusing particularly on the educational value of its presentation. With this in mind, the "road map" for this new series include clear explanations through recounting the history of developments in techniques, ideas, approaches, organizations and regulations, or through questions raised and lessons learned from accidents and operating feedback in general.

The series also aims to provide access for all those interested in these issues to technical knowledge and information that has been properly established and that can be checked in the subject areas referred to, thereby applying IRSN's three core values, Knowledge, Independence, and Accessibility, as defined in its Code of Ethics and Professional Conduct.

We hope that this "Elements of nuclear safety, radiological protection and security" series, coordinated by Jean Couturier, will contribute disseminating knowledge, especially as a new generation of nuclear scientists and technicians takes over from the old.

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This volume, on security (in the sense of protection against malicious acts) and non-proliferation (in the sense of the "safeguards" undertaken by States within the framework of international treaties), is, in terms of the schedule, the first in the series.

At a time when a significant share of the electricity used within the European Union is produced by nuclear power plants, and given the international context of a serious terrorist threat, controlling nuclear and radiological security, and preventing the proliferation of weapons of mass destruction are major issues for society.

Without disclosing any sensitive information, this work describes and explains the development and monitoring of the measures taken in France, Europe and internationally to protect nuclear material, the most hazardous radioactive sources and nuclear facilities themselves against malicious acts, whether these involve attempted sabotage or diversion. A publication covering in an overall picture the history, concepts, regulations, international agreements and the roles of the different players involved in these issues will undoubtedly prove invaluable.

IRSN's central position as provider of technical support to the French authorities in the areas of safety, security and radiological protection means that it has an integral view over all nuclear risks and can correlate expertise and knowledge in these different areas with a view to assessing security issues in relation to safety and radiological protection issues.

In the conclusions of the third nuclear security summit held in The Hague on March 25, 2014, the Heads of State reiterated that nuclear safety and security initiatives should be mutually supportive and work towards the common goal of protecting human health, society and the environment. As the public expert in these two fields, IRSN plays a central role in this initiative.

In particular, I would like to thank Jean Jalouneix, of IRSN's Defense, Security and Non-Proliferation Division, for writing this first work in the series.

Jacques Repussard
IRSN Director-General

The author

Jean Jalouneix, advisor on nuclear security to the Deputy Director General in charge of Defense-related missions, worked for around 14 years in the field of nuclear safety, notably on safety studies for the SUPER-PHENIX reactor, and was involved in defining the safety options for the EPR. He then worked for around 16 years in the field of nuclear security. He has been involved in drawing up the French regulations in this area, as well as international texts, including the revised version of the Convention on the Physical Protection of Nuclear Material and nuclear facilities, and has been a contributing author to fundamental texts in the IAEA's "Nuclear Security Series".

Foreword

This work on nuclear security and non-proliferation draws on the knowledge and expertise developed at the French Institute for Radiological Protection and Nuclear Safety (IRSN), which provides technical support in these fields to the French authorities. The Institute shall not, however, be held liable for its contents.

It is based on the collective work carried out in the areas of nuclear security and non-proliferation by all the staff at IRSN and, more specifically, the staff belonging to the IRSN's Nuclear Defense Expertise Division.

Jean Jalouneix, who works for IRSN, is the key author of this work and also acted as project coordinator. The following authors contributed to the work:

- Chapters 1 and 2, Jacques Aurelle and the staff of the Technical Support and Study Department, including Pierre Funk and David Ladsous in particular;
- Chapters 3 and 4, the staff of the International Inspections Escort Department, including Romuald Bon Nguyen in particular.

Georges Goué and Odile Lefèvre prepared the work for publication.

Jean Couturier, Michel Brière and Daniel Quéniart were active contributors in proofreading the entire work.

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Introduction

During the second half of the twentieth century, France actively pursued the development of a large-scale nuclear program. This civil and military program now encompasses the entire nuclear fuel cycle, the majority share of electricity production (Figure 1), and numerous test and research facilities. Alongside this nuclear program, we should also mention the widespread use of radioactive sources in a very broad range of activities, including industry, medicine, research, the agri-food industry and education. All these facilities and activities have one thing in common: they involve the use of fissile or fertile materials. The risks associated with such activities are managed within the framework of the French State's responsibility toward its citizens and also toward the international community.

Nuclear facilities and activities carry specific risks since, by definition, they all involve the use of various quantities of radioactive products. Moreover, these products can cause exposure to ionizing radiation and its consequences to workers, the public and the environment.

In the nuclear energy sector, protecting workers, members of the public and the environment is primarily based on safety and radiological protection measures. These measures are designed to prevent events within facilities resulting from human error or equipment failure and events occurring outside facilities, and to mitigate the consequences of any event that does occur in spite of the preventive measures implemented. In addition to prevention and mitigation measures, there are security provisions designed to prevent any action by terrorists or malicious persons and, if necessary, to reduce the consequences. Implementation of all these security provisions is based on the public authorities and the nuclear operators sharing responsibilities.

The international community now considers terrorism to be a major concern. Managing nuclear and radiological security in view of the risk of terrorism or malicious

Figure 1. Tricastin nuclear site and the surrounding area, France. © Geneviève Baumont/IRSN.

acts, together with ensuring the non-proliferation of weapons of mass destruction, are subjects of prime concern for our society. Given the changing nature of the threat at international level, the multiplication of international instruments designed to protect against these risks, and the revision of France's security regulations in 2011, these are sensitive issues, which are subject to change and must be tackled. In this context, it is essential to note that nuclear security concerns should be seen in relation to nuclear safety concerns since the risk to the public and to the environment is the same regardless of whether the initiating event leading to a radiological release is due to natural causes, equipment failure or a malicious act.

There are in fact two aspects to protection against terrorism and malicious acts: first, the measures taken to ensure nuclear security, and second, the measures taken to prevent the proliferation of weapons of mass destruction. Bearing this in mind, when we speak of nuclear security, we mean protecting nuclear and radioactive material, nuclear facilities and the transportation of nuclear material, against malicious acts, a concept that encompasses the theft and diversion of nuclear materials and acts of sabotage. Preventing the proliferation of weapons of mass destruction implies security in the nuclear and chemical fields.

Rather than merely describing current approaches to security and non-proliferation, this work gives a partly historical account which emphasizes how these approaches have changed and the dynamics involved. It contains four chapters dealing, in order, with:

– security of nuclear material, nuclear facilities and the transportation of nuclear material,

- security of radioactive sources,
- non-proliferation in the nuclear field,
- non-proliferation in the chemical field.

Each chapter is structured as follows:

- context and historical background,
- the international framework,
- organization in France,
- the specific role played by IRSN, the French Institute for Radiological Protection and Nuclear Safety.

Definitions needed to understand the different subjects are given, together with the principles and rationale underlying the approaches to security and non-proliferation. Particular emphasis is laid on risk management. Details of the national and international regulatory organizations are also given, together with information on the bodies and entities involved in these areas. Diagrams and photographs are included to illustrate the different chapters, together with some specific developments intended to clarify certain technical points. IRSN's input in these areas is presented in a "Focus" section.

Chapter 1
Security of nuclear material, nuclear facilities and the transportation of nuclear material

1.1. Background

1.1.1. Some definitions

First, it is important to give some definitions which are widely accepted within the international community, based on various IAEA glossaries:

- **"nuclear safety"** is the set of technical provisions and organizational measures – related to the design, construction, operation, shutdown and decommissioning of basic nuclear facilities, as well as the transport of radioactive materials – which are adopted with a view to preventing accidents or limiting their effects;
- **"nuclear security"** is the whole range of measures intended for the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material[1], other radioactive substances or their associated facilities;

1. The IAEA takes into consideration only three types of nuclear material, all of which are radioactive. The definition used in France is broader and includes non-radioactive material.

– **"malicious acts"** refers to the theft or diversion of nuclear material, as well as acts of sabotage or attacks that may impact on human health or the environment, primarily through the release of radioactive substances.

French regulations are based on a broader definition of nuclear security than that of the IAEA; it includes nuclear safety, radiological protection, prevention and protection against malicious acts, as well as civil defense actions in the event of accident (French Nuclear Security and Transparency Act of June 13, 2006). Nonetheless, the more technical definition used at international level will be used in this document.

Furthermore, under French regulations, "nuclear material" includes plutonium, uranium, thorium, deuterium, tritium and lithium 6, i.e. materials which could be used to manufacture a nuclear explosive device. This is the definition used in this document. Note that the definition of nuclear material used for the purposes of international control refers to only three elements: plutonium, uranium, and thorium.

1.1.2. Interface between nuclear safety and nuclear security[2]

The definitions above show that, while the common aim of safety and security is to protect humans and the environment from the effects of ionizing radiation, safety is geared more toward controlling the risks inherent in any nuclear facility, while security aims to protect against acts of malicious intent liable to result in radiological consequences or have devastating effects as a result of using nuclear materials.

Different initiating events are taken into account when considering safety and security. In the case of nuclear safety, the postulated initiating events are either external natural events or events related to industrial activity, or internal events caused by equipment failure or human error. In the case of nuclear security, the postulated initiating events are the result of deliberate acts carried out with the intent to cause damage. Such events are therefore based on "intelligent" or "deliberate" actions, carried out for the specific purposes of theft, diversion or sabotage, and are likely to involve actions aimed at subverting the protective measures designed to counter them.

Given the differences in the type of initiating events that must be taken into consideration, there are substantial differences in the approaches implemented to deal with safety and security. The need for transparency was recognized very early on with regard to nuclear safety, mainly with a view to sharing experience and ensuring that any incident or accident that might occur in one facility should not be allowed to occur again elsewhere. Conversely, and even if the need to share know-how and experience regarding events that have occurred also applies in the case of security, the deliberate and malicious nature of the events to be taken into account implies a need to develop measures to protect confidentiality. Protecting information makes it possible to prevent potential saboteurs from finding out about the protective measures that they would have to overcome, and avoids disclosure of any possible weakness in a facility or activity.

2. Read "A comparative approach to nuclear safety and security", J. Jalouneix, IRSN 2009/117, Reference Documents series, © IRSN/2009, available at www.irsn.fr.

It is also necessary to prevent knowledge of malicious acts that have actually been perpetrated leading to similar copycat actions. Nuclear security implies deterrence and confidentiality regarding classified national defense matters, concepts that do not apply to nuclear safety.

The fields covered respectively by safety and security are also distinct to a certain extent. The aim of nuclear safety being to protect people and the environment with regard to radiological risks, this field obviously covers certain aspects related to protection against ionizing radiation. The aim of nuclear security, on the other hand, is to prevent the theft or diversion of nuclear material, and to prevent any risk of sabotage targeting nuclear facilities and radioactive materials. With regard to the risk of theft or diversion of nuclear material, security is based on a system for nuclear material accountancy and control developed, either at national level or within the framework of international controls whose interface with safety is limited. Thus, it is mainly in protecting against the risk of sabotage that the areas of safety and security have any common ground and reinforce each other.

There are also different approaches to the allocation of responsibilities between the various entities involved in the fields of safety and security, even though there are some similarities. Nuclear operators have prime responsibility for the safety and security of their facilities and under no circumstances whatsoever can this responsibility be delegated. This prime responsibility is based on the same principle in the areas of safety and security alike, i.e. the operator is best placed to identify the risks associated with its activities, to detect any deviation in relation to safety or security requirements, and to take appropriate corrective action at any time. The State ensures that the responsibilities of each party (operators, authorities, etc.) are clearly defined in terms of safety and security. Protection against malicious acts, however, requires a different approach as well as broader and more direct involvement of the State in security than in safety. In particular, an operator alone cannot protect a site or a facility against every form of malicious action, and the State plays a decisive role in security matters:

- firstly, the State is directly involved in gathering intelligence and assessing the risk of malicious action that may impact nuclear facilities and radioactive materials; this type of risk changes constantly, and the State must check that the security measures are constantly adapted to the current situation;
- the State defines the design basis threat that must be used to design and assess physical protection systems;
- the State also plays a determining role in the response to be given to counteract certain malicious acts by means of intervention by law enforcement agencies (police or *gendarmerie*);
- managing a nuclear security event resulting from a malicious act requires input from a greater number of State bodies than managing an emergency related purely to safety issues. For example, law enforcement agencies, the judicial authorities (involved to a lesser extent in the event of a safety emergency) and mine-clearing services, may all be involved;

– lastly, the State defines the rules relative to confidentiality and the protection of information and sets up a security check for anyone requiring access to sensitive activities or information.

As a result, the State safety and security authorities have different positions. In France, the safety authority is independent of the government, whereas the security authority is more closely attached to the State's sovereign activities. IRSN's position as technical support to the French authorities in the fields of safety and security means that it has an integral view over all nuclear risks and can provide the safety and security authorities with assessments factoring in matters of concern in both fields.

In addition, safety and security requirements may potentially be contradictory. For example, providing access for operations conducted by emergency teams (fire-fighters, etc.) must be facilitated for safety reasons, but access to certain areas in the facility must be controlled continuously. Likewise, certain security-sensitive zones are subject to special protection systems (ID badges, etc.), but it must be possible to evacuate personnel from these areas quickly in the event of fire or a risk of criticality. Complying with safety procedures may also imply longer transportation times as it is necessary to take precautions designed to prevent traffic accidents, whereas security requirements may stipulate that transportation times should be kept to a minimum.

Another example involves measures implemented to track nuclear materials. In terms of safety and security, it is necessary to know the amount of materials held as accurately as possible, but safety rules apply safety margins, primarily to guard against criticality risks, whereas security principles demand that the exact amount of nuclear materials held be accounted for precisely to guard against the risk of diversion.

Operating procedures and rules must therefore take account of the respective safety and security requirements and implement measures that are satisfactory in terms of both safety and security.

1.1.3. Security culture[3]

Security culture is a set of characteristics and attitudes which, in organizations and at individual level, ensure that issues relating to protection against, firstly, the loss, theft or diversion of nuclear material and, secondly, deliberate malicious acts in nuclear facilities or during the transportation of nuclear material, receive the attention warranted by their significance.

Security culture has three major components. The first concerns the policy implemented by the State, in particular in relation to the national and international contexts. The second relates to the structure of each body involved, particularly in application of the policy defined by the State: in this component, a distinction must be made between what is related to the body itself and what concerns its managers; it is the managers' role to

3. Read – "Security culture in the nuclear field", D. Winter, IRSN 2005/54, Reference Documents Series, © IRSN/2010 (re-published), available at www.irsn.fr.

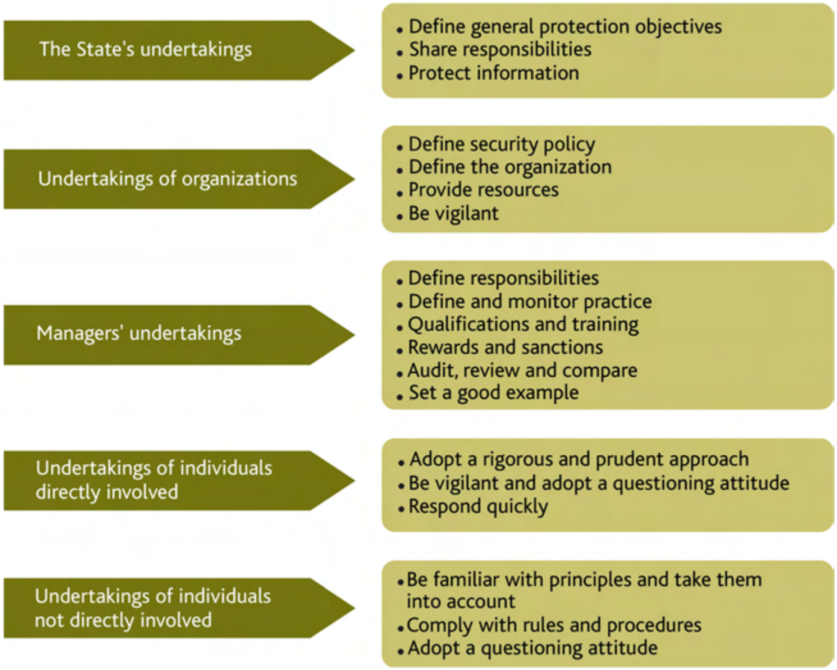

Figure 2. The players involved in security culture.

establish and promote good practice and set a good example in the area of security culture. The third component is the attitude adopted by the various individuals at all levels to implement this policy within the framework of the structure in which they operate and to incorporate it into their work. Figure 2 shows the various players involved in security culture.

It is also crucial to ensure that security culture is not confined to the bodies involved and their employees. Everyone, in their work, must make an effort to raise awareness among the general public of security culture in the nuclear field. The general public should view security culture as a sign of professionalism, skill and responsibility on the part of all the bodies and individuals involved in the protection of nuclear material, nuclear facilities and the transportation of nuclear material.

1.1.4. Historical background

France has actively pursued the development of a large-scale nuclear program for over 40 years. This program has entailed construction of the facilities required to cover the entire nuclear fuel cycle, producing the majority share of France's electricity, as well as developing tests and related research and managing waste storage. All these different facilities have one thing in common: the use of fissile or fertile materials. The risks associated with this program are managed within the framework of the French State's responsibility toward its citizens and also toward the international community.

This led France to develop a general approach to protection against malicious acts. The first legislative texts on this subject date back to the 1980s insofar as regards protection and control relative to the theft of nuclear materials and, prior to that, an ordinance passed in 1958 relative to protecting facilities from sabotage. A review of the entire regulatory system was conducted between 2005 and 2011 with a view to extending and reinforcing protection for nuclear material, nuclear facilities and the transportation of nuclear material. As a result, new or more detailed texts have been introduced which, regarding their legislative and regulatory aspects, bring them within the legal framework of the French Defense Code.

This reform of the regulations, largely completed in 2011, had the following objectives:

- to respond to international requirements (UN resolutions relative to nuclear terrorism, in particular UNSCR 1373 and UNSCR 1540, the amendment to the Convention on the Physical Protection of Nuclear Material and nuclear facilities, and evolutions of ideas and practices in nuclear security promoted by the development of the IAEA's "Nuclear Security Series" publications;
- to align and harmonize the regulations relative to nuclear security, particularly those relative to, respectively, the theft and diversion of nuclear material (nuclear proliferation) and to the protection of nuclear facilities against sabotage (consequences for people and the environment) with a view to having the full benefit of potential synergy in their implementation;
- to factor in the interrelated aspects of nuclear safety and nuclear security in the area of protection against malicious acts (sabotage);
- to update design basis threat (more serious threats given developments in the international context), in particular by defining protection objectives for each threat;
- to reinforce the legal framework, in particular to deal with the growth in the number of private operators now holding nuclear material and with regard to whom it was not possible to enforce certain provisions in ministerial instructions;
- to specify and grade the different types of offences and the sentences to be imposed under the regulations;
- to enhance the performance-based approach by means of a combined approach imposing, in certain cases, compliance with minimum requirements (i.e. the so-called "obligation of means").

As the technical support organization to the French authorities, IRSN contributed to this evolution of the regulations, proposing policy and technical elements based on feedback and new international approaches.

1.1.5. International context

Since the early 1970s, the IAEA (Figure 3) has served as a forum where experts have been able to compare national experience in the physical protection of nuclear material.

Figure 3. View of the International Atomic Energy Agency (IAEA), located in Vienna, Austria. © DR.

This experience was first gathered together in 1972 in the form of technical recommendations, in a booklet entitled "Recommendations for the Physical Protection of Nuclear Material" (INFCIRC 225). These recommendations were followed by negotiations under the aegis of the IAEA for the Convention on the Physical Protection of Nuclear Material, opened for signature by the Member States in 1980. In July 2005, an amendment to this Convention significantly extended the scope of the Convention, with a view to ensuring the protection of nuclear materials and facilities from malicious acts and terrorist action. This amendment was ratified by France in December 2012. It entered into force on 8 May 2016.

The main amendments made in July 2005 to the original convention were as follows:

- the scope of the Convention was significantly extended. Prior to the revision, the Convention primarily covered the protection of nuclear material during international transport. The revised Convention also includes domestic use of nuclear material (at facilities, in storage and during transport). It also includes the protection of nuclear material and facilities to prevent sabotage;
- the revised Convention highlights the State's prime responsibility in the physical protection of nuclear material and facilities to prevent theft and sabotage. It does, however, require that the quality of physical protection implemented in each State must meet minimum criteria;

- each State signing the Convention must set up a physical protection regime based, in particular, on the existence of a legislative and regulatory framework and on the designation of competent authorities;
- twelve fundamental principles of physical protection are set down in the amended Convention (Figure 4);
- new offences are listed to reinforce deterrence and the prevention of theft and sabotage. Similarly, mutual legal assistance mechanisms between States have also been reinforced.

Alongside this, the IAEA has been developing a “Nuclear Security Series”, structured similarly to the “Nuclear Safety Series”. Figure 5 shows the “security wheel”. This series of documents is structured as follows:

- a document presenting the “Fundamentals”, including the objectives, concepts and principles applying to the protection of nuclear material, facilities and transport. It makes a bridge with international instruments relative to nuclear security (international conventions, UN resolutions, etc.);
- three documents presenting Recommendations on:
  - the Physical Protection of Nuclear Material and Nuclear Facilities and transport (INFCIRC/225/Revision 5);
  - Radioactive Material and Associated Facilities;
  - Nuclear and Other Radioactive Material out of Regulatory Control.
- guides to implementing the recommendations;
- technical guidance publications describing protection measures related to specific technical subjects.

France, and IRSN in particular, have been actively involved in revising the above-mentioned Convention and continue to make proposals for the development of the IAEA’s “Nuclear Security Series”.

- Responsibility of the State
- Responsibilities During International Transport
- Legislative and Regulatory Framework
- Competent Authority
- Responsability of the License Holders
- Security Culture
- Threat
- Graded Approach
- Defense in Depth
- Quality Assurance
- Contingency Plans
- Confidentiality

Figure 4. The IAEA’s 12 fundamental security principles.

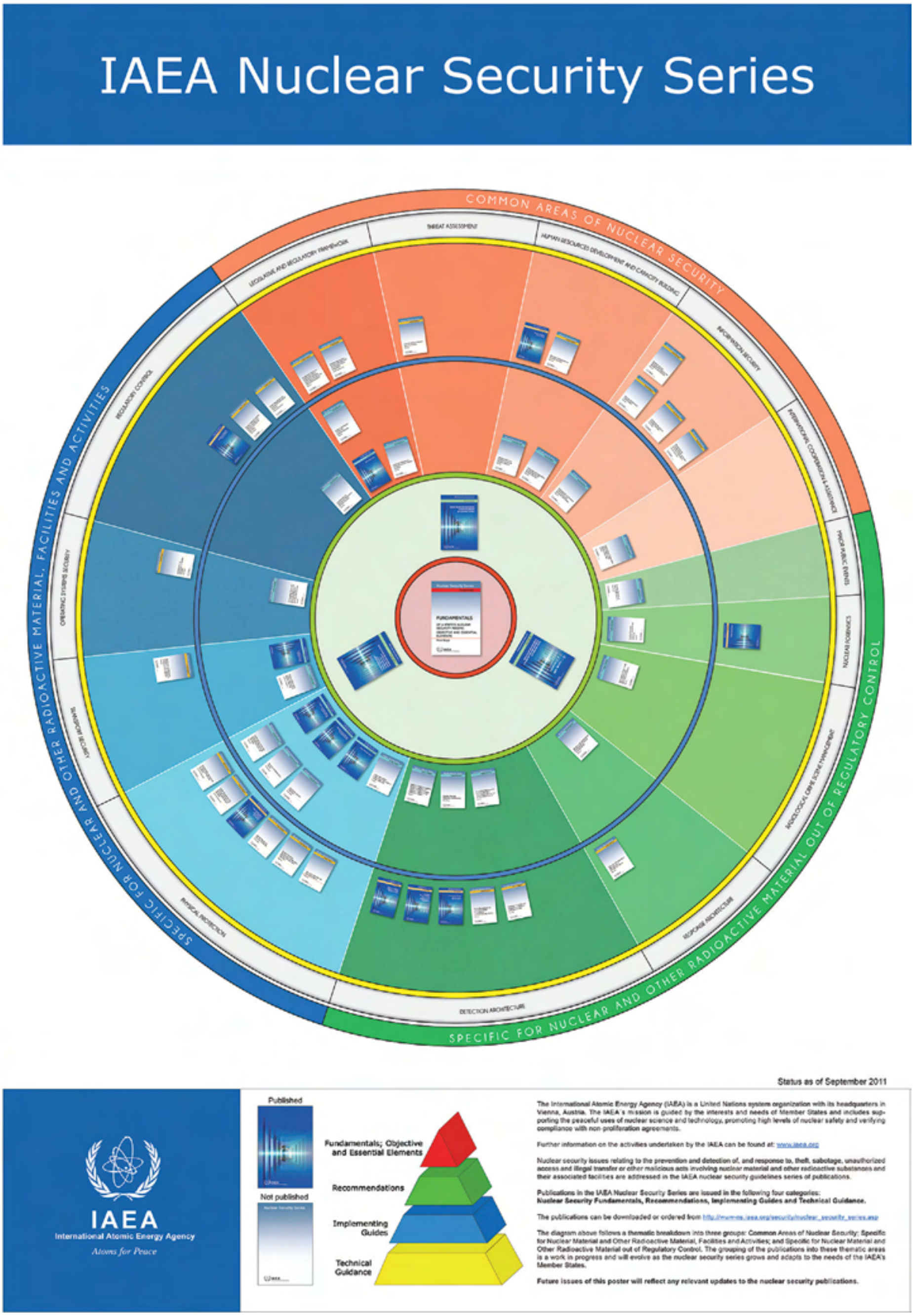

Figure 5. The IAEA's "Nuclear Security Series". © IAEA.

1.2. Guidelines regarding the French nuclear security system

France's nuclear security system is based on the following guidelines:

- the public authorities draw up a series of legislative and regulatory texts on the protection of nuclear material, nuclear facilities and the transportation of nuclear material against malicious acts. This system encompasses the protection of nuclear material with regard to the risks of theft and diversion as well as the protection of facilities and transport with regard to the risk of sabotage;
- the designation of an authority with competence in the field of nuclear security, the Minister of Energy. It should be noted that this authority is distinct from the nuclear safety regulator, French Nuclear Safety Authority (ASN);
- three interlinked pillars, namely the prior authorization (license) to exercise any activity involving the use of nuclear material, control by the public authorities to check compliance with the authorization procedures and the establishment of criminal and administrative sanctions in the event of breach;
- risk analysis leading to the definition by the State of a series of threats that must be taken into consideration for the protection of nuclear material, nuclear facilities and the transportation of nuclear material, together with the protection objectives associated with each threat; operators and the relevant State departments must then implement the appropriate measures to achieve these objectives;
- the prime responsibility of operators in designing and implementing a protection system which complies with the obligations imposed on them;
- responsibilities are shared between the State and the operators, where the State is responsible for continuing assessment of the threat, mainly by means of intelligence gathering; it is also the State's responsibility to organize local and national intervention means to assist the operator in managing malicious acts;
- an integrated approach including physical monitoring and accountancy measures designed to track with accuracy the quantities of nuclear material present at facilities and its location, together with physical protection measures; these two sets of measures complement each other ensuring that the system is effective;
- a system to be deployed by the operators, mainly based on a performance based approach complemented in some cases (mainly in transport) with prescriptive measures defining a minimum level of protection measures;
- a system based on the notion of defense-in-depth, encompassing measures for deterrence, prevention, detection, delay and response which, depending on the case, come under the responsibility of either the operator or the relevant State departments;
- a graded approach specific to the sensitivity of the nuclear material or the possible radiological consequences of sabotage which could impact on such material, a nuclear facility or transport of nuclear material.

1.3. Risk management approach

In the field of nuclear energy, protecting people and the environment relies:

- first, on nuclear safety and radiological protection measures. These measures are designed to prevent internal or external events at facilities (resulting from natural events or equipment failure or human error) and, when necessary, to mitigate the consequences;
- second, on security measures designed to prevent malicious acts and, when necessary, to mitigate the consequences in the event such acts are perpetrated in spite of the prevention measures.

With regard to this second point, a distinction is made between two categories of risk:

- the theft or diversion of nuclear material for the purpose of manufacturing a nuclear explosive device;
- sabotage or attack on nuclear material, facilities or during transport liable to impact human health or the environment due to the release of radioactive substances, irradiation or contamination or due to toxic releases associated with nuclear activities.

In order to define and organize measures to protect and control nuclear material, nuclear facilities and the transport of nuclear material, security needs must first be assessed and then appropriate security systems must be deployed.

The approach to designing, scaling, implementing and assessing the security system for a facility where nuclear material is held or for the transport of nuclear material entails the following key stages:

- define the design basis threat based on scenarios involving the theft or diversion of nuclear material or sabotage;
- determine, for each facility or transportation operation, the equipment and the materials to be protected based on assessment of the potential consequences of malicious acts arising from the design basis threat; i.e. this entails identifying the potential targets of malicious acts;
- design the security system suitable for countering the design basis threats;
- assess the security system defined, bearing in mind the measures implemented and the design basis threat.

The first stage is the responsibility of the public authorities while the subsequent stages are performed by the operators, under the supervision of the competent authority supported by expertise provided by IRSN. At the second stage, the operators should identify all the potential targets of a malicious act and prioritize them according to their attractiveness.

The process of defining the threats requires the involvement of various State departments (civil and military intelligence, the police, the *gendarmerie*, the authorities in charge of nuclear security and safety, etc.), together with the major operators in the nuclear sector. It starts with gathering all the information known on the subject of threats. All reliable sources are taken into consideration.

The threats are analyzed for their relevance to the risk of theft or diversion of nuclear material or of sabotage. They can be divided into two main categories:

- internal threats, related to the action of people who have authorized access to the facility and nuclear material;
- external threats, including actions carried out by an attacker or group of attackers from outside the facility, who have more or less sophisticated resources at their disposal.

Identifying the potential targets is based on:

- safety studies and analysis of the most sensitive zones and related equipment (in terms of the potential consequences of a malicious act targeted at them), in the case of sabotage against a facility or in transport;
- the categorization of nuclear materials (see 1.6.2) in the case of theft of such materials.

The targets thus identified are then prioritized according to the seriousness of the estimated consequences of the acts that could be perpetrated against these targets.

The security system is based on an approach which factors in threats, sensitivity, vulnerability and an assessment of the potential consequences. It is designed on the basis of measures of vigilance, deterrence, prevention, protection, response to any type of threat and mitigation of the consequences. Protective measures can be divided into measures of detection, alert and delay.

The security system is designed in accordance with a defense-in-depth approach and factors in two key aspects:

- the sensitivity of each target in the facility or during transport must be determined; sensitivity is characterized by the level of the potential consequences of a malicious act affecting a target;
- the vulnerability of the different targets to different types of attack must be assessed, i.e. an assessment of the degree of difficulty in carrying out a given attack on the target in question.

It is important to note that implementing the security system presupposes that the respective responsibilities of the public authorities and the nuclear operators have been clearly defined. Figure 6 summarizes the assignment of responsibility.

In particular, the public authorities are responsible for:

- assessing threats based on research, gathering and processing intelligence and defining the design basis threat based on this information and notifying the operators;
- informing operators of any threats to their facilities or activities;
- ensuring the availability of adequate intervention and response capabilities thanks to the available local, regional and national law enforcement agencies;

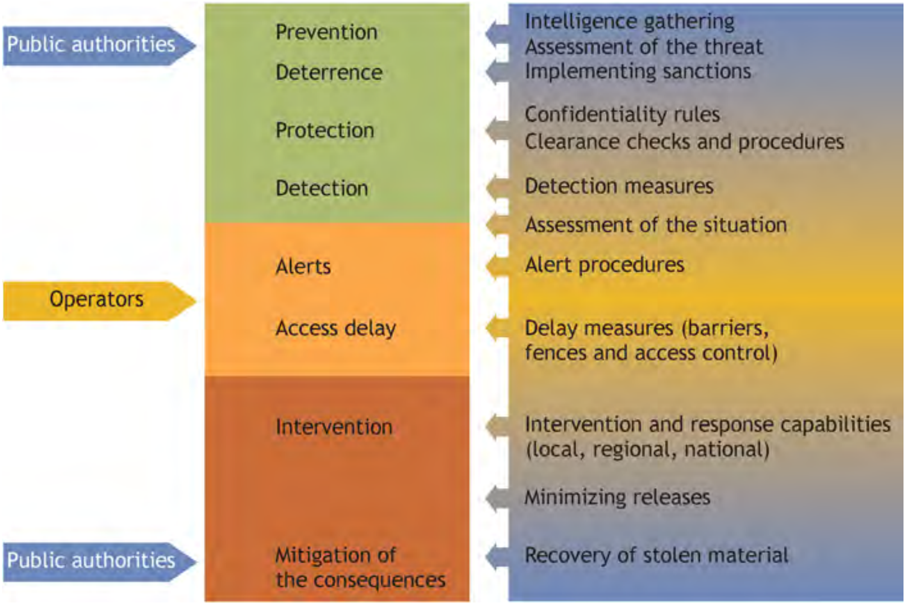

Figure 6. Assignment of security-related responsibilities between the public authorities and nuclear operators.

– defining the regulations required to ensure confidentiality and the protection of sensitive information.

Operators are mainly required to implement measures:

– to detect malicious actions, intrusion or attempted intrusion;

– to alert and inform the public authorities and, when necessary, the relevant bodies (for example, the IRSN operations center in the event of an event involving the transportation of nuclear material); the alert must be accompanied by an initial assessment of the situation;

– to delay or obstruct the action of any person attacking a facility or transportation operation.

The measures to be implemented to mitigate the consequences of a malicious act are defined through close collaboration between the operators and the public authorities, particularly within the framework of emergency response plans developed by these different entities, and dealing with safety and security aspects respectively.

1.4. The government bodies involved

The public authorities include a number of entities which play a role in the nuclear security system. They work in close collaboration with one another and have complementary responsibilities.

1.4.1. French General Secretariat for Defense and National Security

The French General Secretariat for Defense and National Security (SGDSN) is a department of the Prime Minister's Office. It plays a general role in interministerial coordination regarding defense and security policy and, in particular, is in charge of emergency response planning in the nuclear sector. As such, the SGDSN is in charge of drawing up and revising the regulations relative to activities of vital importance, which include defining the threats that must be taken into account. In addition, the SGDSN is responsible for defining policy on confidentiality and drawing up the related application regulations.

1.4.2. Minister for Energy

Responsibility for nuclear material control is assigned by the French Defense Code to the Minister for Energy in the case of nuclear materials for civil use. This Minister is therefore in charge of:

- drawing up and amending the regulations applicable in this area to nuclear material, facilities and the transportation of nuclear material;
- issuing the licenses required by operators to engage in activities involving nuclear material and updating these licenses;
- exercising control over the operators' implementation of the measures stipulated in the licenses issued to them; in particular, the Minister is in charge of inspections at nuclear sites and during transport;
- the application, in the nuclear sector, of the regulations relative to activities of vital importance;
- organizing national emergency response drills and exercises.

To exercise these responsibilities, the Minister for Energy is supported by a specific department which is in charge of assessing files, inspections and drawing up the regulations. This department comes under the responsibility of the Senior Defense and Security Official (HFDS) of the Ministry of Energy; the HFDS is the competent authority for nuclear security. In the exercise of his duties, the HFDS calls on IRSN, a French public body with industrial and commercial activities, for technical support (see 1.4.6).

1.4.3. Minister of the Interior

The Minister of the Interior has authority over all local and national law enforcement agencies likely to be called on in the event of a malicious act. Depending on the location of a nuclear facility or a transport operation, the law enforcement agencies having competence are either the *Gendarmerie nationale* or the National Police. In all cases, relations between these response forces supervised by the public authorities and those established by operators are subject to protocols. In addition, the intelligence services which come under the Minister of the Interior play a key role in preventing malicious acts and assist in threat assessment.

Also, the Prime Minister may decide to confer interministerial management of the operational response to a nuclear crisis to this Minister.

1.4.4. Prefect of the department

In each of France's administrative *départements*, the State's action is managed by a Prefect. The Prefect is responsible for local management of any crisis situation that may arise in the department, particularly if they are accidental or the result of a malicious act that could impact a nuclear facility or the transportation of radioactive material. This central role played by the Prefect of the department in the event of an emergency has led to the Prefect being tasked with approving the specific protection plan (*plan particulier de protection*, or PPP) — drawn up by each operator — and implementing the external protection plan (*plan de protection externe*, or PPE), as set out under the regulations relative to activities of vital importance (see 1.6.1).

1.4.5. French Nuclear Safety Authority (ASN)

As part of its duties as regulator, ASN analyzes the risks and disadvantages that nuclear facilities and the transportation of radioactive material may present to security, public health and hygiene or to the protection of nature and the environment, regardless of the cause (malicious or otherwise) of such risks. Where necessary, ASN notifies operators of the requirements regarding the protection of the public and the environment.

ASN is consulted on draft decrees and ministerial orders relating to nuclear security.

In the event of a radiological emergency situation, regardless of its cause, ASN provides advice to the public authorities (mainly the Prefect, the Minister in charge of crisis response management and the Prime Minister) on matters relative to population and environment protection. ASN also ensures that operators take the appropriate measures to restore a facility subject to a malicious act to a safe state.

1.4.6. IRSN, the French Institute for Radiological Protection and Nuclear Safety

IRSN, a public body with industrial and commercial activities set up in 2002[4], provides technical support to all the government authorities involved in the security of nuclear material, nuclear facilities and the transportation of nuclear material. In particular, on behalf of the HFDS at the Ministry for Energy and within the framework of an agreement made with this ministry, IRSN's responsibilities are as follows:

- it analyzes situations and files with a view to preparing decisions made by the HFDS;
- it provides the HFDS with qualified and trustworthy certified personnel to carry out inspections at nuclear facilities and for the transportation of nuclear material;

4. IRSN came into being as the result of the merger between the IPSN (Institute for Nuclear Safety and Protection), which belonged to the CEA, and the technical branch of the OPRI (Office for Protection against Ionizing Radiation).

- it takes part in drawing up regulations and assists the HFDS' departments in activities conducted to this end at international level;
- it manages the centralized accountancy of all nuclear material used for civil purposes in France;
- it manages and processes agreements to transport nuclear material, monitors transport operations and pass on the alert to the authorities;
- it conducts studies and experiments to support its technical assessments or for tests that may be required for during inspections.

1.5. Regulatory framework

France's regulatory framework applicable to nuclear material, nuclear facilities and the transportation of nuclear material includes legislative texts (laws), and regulatory texts (decrees and implementation orders). These texts are mainly contained in or derived from the French Defense Code; the key references are:

- the legislative parts (Articles L. 1333-1 and following of the Defense Code) and the regulatory parts (Articles R. 1333-1 and following) relative to the protection and control of nuclear material;
- the legislative parts (Articles L. 1332-1 and following of the Defense Code) and the regulatory parts (Articles R. 1332-1 and following) relative to the protection of facilities of vital importance (see 1.6.1);
- the national security directive (DNS) relative to the nuclear sector adopted in application of the Defense Code (a classified document not available to the public which details the design basis threat);
- the orders implementing Articles L. 1333-1 and following of the Defense Code:
  - the order relative to license application procedures and to the form of the licenses (implementing Article L. 1333-2 of the Defense Code);
  - the order relative to the physical protection of facilities where nuclear material is kept and the possession of which requires a license;
  - the order relative to the procedures for conducting the study provided for under Article R. 1333-4 of the Defense Code for the protection of nuclear material and facilities;
  - the order stipulating the conditions for implementing physical tracking and accountancy of nuclear material the possession of which requires a license;
  - the order relative to the protection and control of nuclear material during transport;
  - the order relative to the physical tracking, accountancy and physical protection measures applicable to nuclear material subject to declaration and on the form and procedures of the declaration.

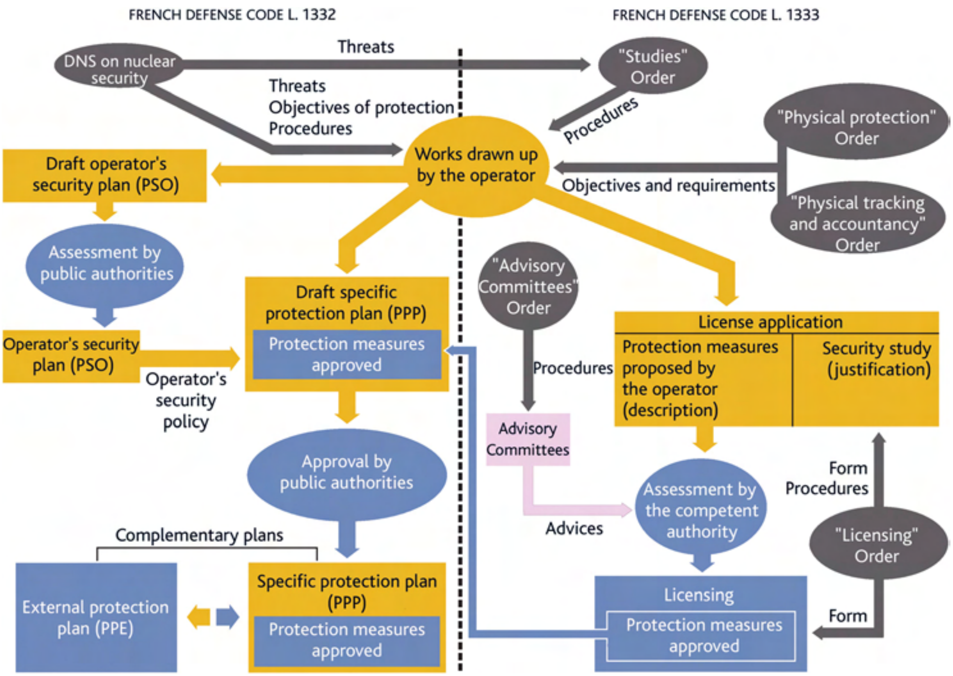

Figure 7. Diagram explaining France's nuclear security regulatory framework.

The provisions set out under Articles L. 1332-1 and R. 13321 and following and those under Articles L. 1333-1 and R. 13331 and following of the Defense Code are interconnected in a coherent whole, which is a key part of the system designed to ensure that nuclear material, nuclear facilities and transport are adequately protected against malicious acts. All these measures and the texts adopted for their implementation form a coherent framework that must be implemented both by the public authorities and by the operators of the nuclear sector. Figure 7 shows the structure of the nuclear security regulatory framework. These measures are described below in sections 1.6.1 and 1.6.2 respectively.

Furthermore, the legislative and regulatory texts relative to nuclear safety also refer to nuclear security, namely:

- the French Act of June 13, 2006 relative to Transparency and Security in the Nuclear Field, known as the "TSN Act";
- the Decree of November 2, 2007, relative to regulated nuclear facilities and to the control, in the nuclear safety field, of the transport of radioactive substances, known as the "Procedures Decree".

Last, the corpus of French legislative and regulatory texts includes other texts which, although not specifically relative to nuclear security, must also be taken into consideration in the field of protection of nuclear material, nuclear facilities and the transport of nuclear material, in particular those texts relative to the protection of sensitive information, the use of weapons and the protection of scientific and technical assets. We should also mention the French Penal Code in which the measures applicable to all crimes and offences are listed.

1.6. The Protection and Control System

The public authorities' objective is to establish, within the framework of the security posture, an appropriate system to counter malicious acts targeting nuclear material and facilities designed for their protection and that of the transport of such material. This system has two major parts which are intrinsically interrelated. The first covers the measures adopted for planning security activities, based on the design basis threat and on developing and implementing security plans. The second more specifically covers the security measures deployed to prevent the risks of theft or diversion of nuclear material or of sabotage liable to result in radiological releases into the environment.

1.6.1. Measures adopted for planning security activities

1.6.1.1. Protecting activities of vital importance

Articles L. 1332-1 and R. 1332-1 and following of the French Defense Code stipulate the approach applicable to planning, vigilance, prevention, protection and response to any threat liable to impact on operators and activities of vital importance.

The planning approach is also based on national security directives (DNS) which specify, for each sector of activity, the risk analysis and the principles to be implemented to protect against the design basis threat. These directives are aimed at setting the requirements applicable to the protection of sites, buildings and facilities (which are considered as points of vital importance) which, if damaged, unavailable or destroyed, would, directly or indirectly risk:

- seriously encumbering the Nation's military and economic capabilities, and its security and ability to survive;
- seriously impacting on the health or lives of the population.

The DNS relative to the nuclear sub-sector of the energy sector sets out the approach for analyzing security needs to counter the risks mentioned above. It also presents the design basis threat specifying the means and the characteristics of possible attacks from within or outside the facility.

In addition, this DNS explains the manner in which operators must take into account the attack scenarios related to each different threat. The nature of these threats can vary greatly (for example: demonstration by a hostile crowd, attack by one or more individuals equipped and armed to varying degrees, etc.) and the scale of potential consequences can

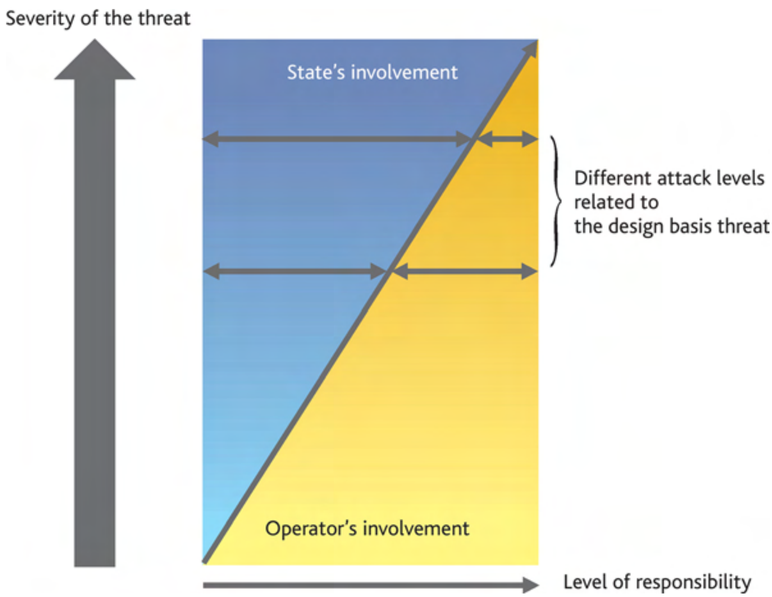

Figure 8. Diagram showing the allocation of the responsibilities assigned to the State and the nuclear operator depending on the severity of the threat.

be very different. The scenarios are prioritized according to the feasibility or simplicity of carrying out the act in question and according to the severity of the potential consequences. In particular, requirements are set out according to the level of the attack in question, first, in terms of acceptance of the consequences and second, in terms of the design of the protection system. Figure 8 shows the allocation of the responsibilities assigned to the State and the operators depending on the severity of the threat. These requirements are defined in relation to safety requirements.

This directive also defines the basic design and assessment criteria of the security system, distinguishing between a constant security posture and temporary, graded measures designed to be tailored to the threat (*Vigipirate* [see 1.6.1.2]). For each threat, general protection objectives are set for the operator and for the public authorities. The protection of facilities and material is ensured by a series of consistent measures agreed between the State and operators in the nuclear sector, thus forming an overall, integrated design. This security system includes:

- internal protection measures, applying within sites and facilities and under the responsibility of the operators;
- external protection measures, under the responsibility of the public authorities.

Along the same lines, the French Defense Code introduces three kinds of security plan:

- the Operator's Security Plan (PSO), in which each operator of vital importance defines its overall security policy and a list of the points of vital importance it runs;

– the Specific protection plan (PPP), which describes the protection measures for each point of vital importance;
– and the External protection plan (PPE), which describes the security measures under the responsibility of the public authorities, in addition to the specific protection plans.

The operator's security plan and the specific protection plan stipulate deadlines by which the operator has to implement the protection measures. These plans are periodically reviewed and updated.

1.6.1.2. Vigipirate

The French General Secretariat for Defense and National Security (SGDSN) carries out risk analysis, plans prevention and intervention measures relative to the terrorist threat and monitors the application thereof. One of the key measures in this system is *Vigipirate*, the government's plan establishing vigilance, prevention and protection measures. Conceived in 1978, the plan has since been updated and redesigned several times, in particular following the attacks of September 11, 2001, and again in 2014, to improve the State's capabilities for protecting the population and activities of vital importance and ensuring the continuity of national vital activities.

The *Vigipirate* plan has two objectives: to protect the population, infrastructure and institutions, and to plan the response in the event of an attack. The most recent version of the plan is based on the premise that the terrorist threat must now be considered permanent. It defines a set of operational measures that can be applied under any circumstances, even if there are no specific signs of a threat.

For each point of vital importance, the operators must, in particular, define security measures and procedures applicable to each different level of the *Vigipirate* plan.

1.6.2. Measures relative to the operator's obligations

The protection of nuclear material is based on physical protection measures and physical tracking and accountancy measures, where the latter are mainly intended for the purpose of detecting any theft or diversion of nuclear material as quickly as possible. A significant development in the approach deployed by the public authorities is the extension of the protection of nuclear material, nuclear facilities and the transportation of nuclear material from acts of sabotage. It should be noted in fact that the initial regulatory protection measures deployed with regard to nuclear material primarily covered the risks of theft and diversion.

Measures designed to protect nuclear material from the risks of theft or diversion and measures designed to protect nuclear material, the associated nuclear facilities and transportation of nuclear material from acts of sabotage obviously work in complement to and in synergy with each other, resulting in the design of a consistent protection system which covers both types of risk.

Articles L. 1333-1 and R. 1333-1 and following of the French Defense Code describe the obligations involving nuclear material and related to certain activities (possession, use, transportation, etc.). These articles provide for the protection and control of nuclear material against theft or diversion or any act of sabotage aimed at tampering with, damaging or dispersing nuclear material.

These regulations provide for:

- a license issued by the public authorities following examination of the measures presented by the operator and a security study designed to demonstrate the effectiveness of those measures; the study must demonstrate how the aforementioned measures meet the protection requirements assigned to the operator;
- a control approach based on a system of inspections carried out by trustworthy personnel;
- criminal and administrative sanctions where necessary.

The regulations also provide for the set up of two advisory committees, one to advise the public authorities on questions relative to security during the transportation of nuclear material and the second to advise on facility protection. Made up of experts from the competent ministerial services and the bodies and operators involved, these committees provide, upon request, advices and recommendations to the Minister for Energy and, where needed, to the Defense Minister. IRSN is tasked with ensuring the secretariat and logistics for these committees, and acts as rapporteur before these committees, presenting reports and assessments on the studies carried out by the operators.

1.6.2.1. Licenses

The import, export, production, possession, transfer, use and transport of nuclear material is, above certain limits, set under the regulations, subject to a license that must be issued by the Minister for Energy prior to engaging in any such activity. The license is issued together with administrative requirements (mainly regarding the quantities of nuclear material in question and the period of time for which they will be held) and appropriate technical requirements. A license may be suspended or revoked in the event of any breach or failure to comply with the relevant requirements. Each license specifies the measures that must be implemented by the operator to ensure that nuclear material is protected, tracked and accounted for. The license applies to nuclear material held, used or transported.

In accordance with the graded approach, the activities that make use of quantities of nuclear material below the limits set under the regulations are not subject to the license regime but rather to a declaration regime. This less restrictive declaration regime requires the annual declaration of the quantities of nuclear material held and the activities carried out, together with the implementation of physical protection measures. Figure 9 shows the limits associated with the different regimes set out in the French Defense Code.

1.6.2.1.1. Licensing procedure

The license application submitted by an operator includes administrative information, a description of the planned activities, a description of the facilities, and specifies the

	Exemption	Declaration	License
Plutonium Uranium 233	less than 1 g less than 1 g	between 1 and 3 g between 1 and 3 g	more than 3 g more than 3 g
Uranium > 20 % ^{235}U content Uranium < 20 % ^{235}U content	less than 1 g less than 1 g	between 1 and 15 g of ^{235}U between 1 and 250 g of ^{235}U	more than 15 g of ^{235}U more than 250 g of ^{235}U
Natural uranium Depleted uranium Thorium	less than 1 kg less than 1 kg less than 1 kg	between 1 and 500 g between 1 and 500 g between 1 and 500 g	more than 500 g more than 500 g more than 500 g
Deuterium Tritium Lithium (^{6}Li)	less than 1 kg less than 0.01 g less than 1 g	more than 1 kg between 0.01 and 2 g between 1 and 1 kg	 more than 2 g more than 1 kg of ^{6}Li
	No obligations	*Physical protection* *Physical tracking* *Local accountancy* *Annual declaration*	*License application* *Physical protection* *Physical tracking* *Local accountancy* *Daily declaration*

Figure 9. Limits regarding quantities of nuclear material applicable under the different regimes set out in the French Defense Code.

nature and the quantities of the materials in question, together with the measures that the applicant proposes implementing to ensure nuclear material tracking and accountancy and physical protection. Figure 10 summarizes the steps involved in completing or updating applications for a license and control file. All license applications must be accompanied by a security study, as described above. The licensing procedure is an iterative process involving the nuclear security authority, IRSN as its technical support and the operator. Figure 11 shows the security dialogue and Figure 12 represents the principles governing dialogue between the different stakeholders.

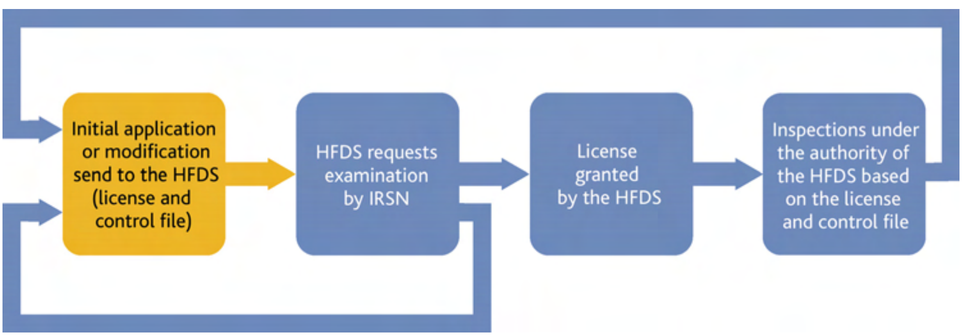

Figure 10. Procedure for preparation and renewal of a license and control file (HFDS: Senior Defense and Security Official).

1.6.2.1.2. Nuclear material physical tracking and accountancy

With regard to the physical tracking and accountancy of nuclear material, the operator must implement all measures required to precisely know the quantity and

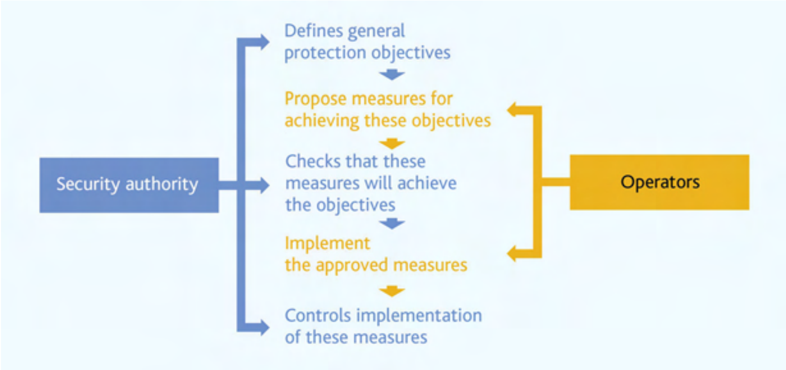

Figure 11. Security dialogue between the security authority and the operators.

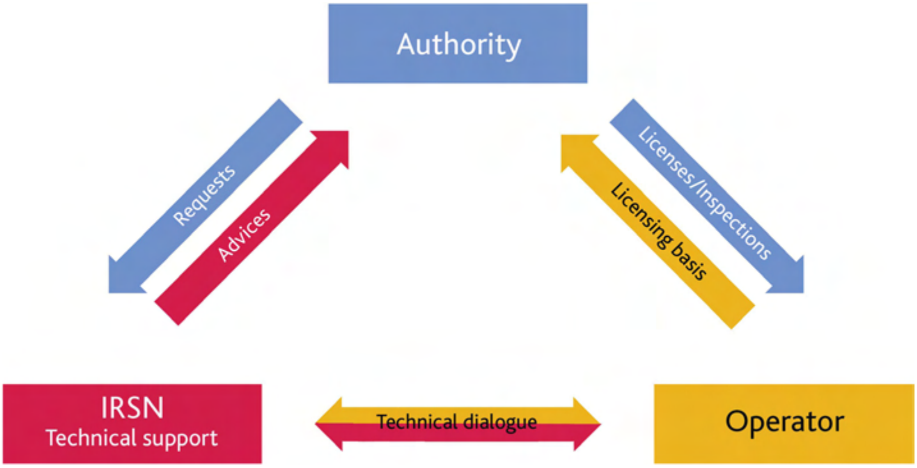

Figure 12. Principle governing dialogue between the different stakeholders.

characteristics of all nuclear material entering or leaving the facility and to know at all times where it is located, and its uses, movements and any change to the nuclear material. In addition, the operator must check, by conducting regular inventory checks, that the physical state of the nuclear material held complies with the physical tracking and accountancy records kept at the facility. These measures are designed to ensure that any anomaly is detected as rapidly as possible. The operator must immediately inform the police or the *gendarmerie* with competence in the region if it appears that any nuclear material has gone missing, or been stolen or diverted.

An Order defines the measures that must be taken by an operator regarding nuclear material accountancy management, particularly with regard to any quantitative or qualitative variation in the inventory of materials held. This Order requires that the operator notify IRSN's national centralized nuclear material accountancy of any such variation. It also introduces a mechanism for information-sharing between shippers and receivers, with cross-verifications by both parties, together with a system for materials acceptance upon reception by the receiver. In the case of the most sensitive materials, the order requires that the partners involved first draw up protocols, approved by the competent authority, relative to dealing with any nonconformance liable to arise during material transfer (e.g. regarding the precision of measurements taken by the shipper and those taken by the receiver). Last, it requires each operator to conduct an annual inventory check, in addition to the regular inventory checks.

1.6.2.1.3. Physical protection of facilities

For the physical protection of nuclear material, the regulations require each operator to identify possible targets and classify them using the graded approach. Thus:

- nuclear material is divided into three categories (categories I to III) defined according to the nature and the quantity of the material, in line with the Categorization of nuclear material table given in INFCIRC 225, revision 5; the most sensitive materials are classified in Category I, i.e. those which are most likely to be directly used to make nuclear explosive devices. For each category, physical protection measures, designed for the operations to which the material is subjected and to local operating conditions, are defined;
- nuclear material which if altered, damaged or dispersed, together with equipment or functions which, if they fail, are damaged or malfunction, could result in significant radiological consequences, must be located in areas which are protected in compliance with the response levels for radiological emergencies set by the ASN in application of the provisions of the French Public Health Code.

The requirements that must be complied with regarding physical protection are set out in an Order. In particular, in the case of facilities, this Order defines the protection zones to be set up in application of the defense in depth approach. Depending on the type of target to be protected, the operator must set up one or more lines of protection, from among the following:

- a limited access area;
- a protected area;
- a high security area;
- an inner area;
- a vital area;
- a storage area, or “strong room”.

A protected area and a high security area are areas located inside a limited access area. An inner area and a vital area are areas located inside a high security area. A storage

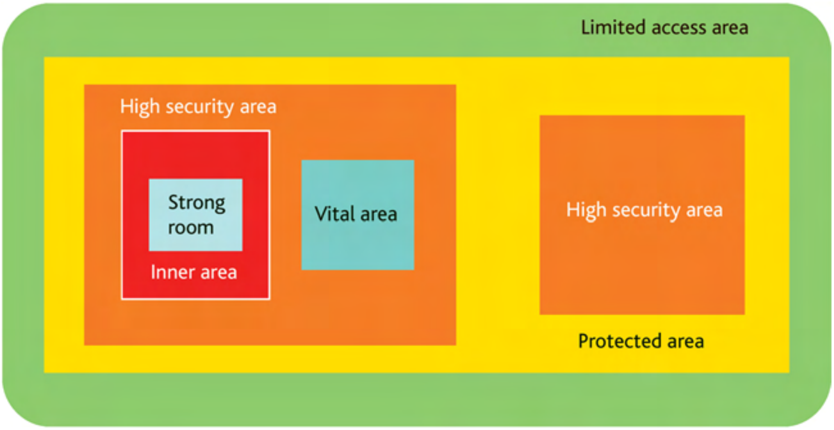

Figure 13. Diagram showing the layout of the different lines of protection in a nuclear facility in compliance with the defense in depth principle.

area is contained inside an inner area. Figure 13 shows the layout of the different areas in a nuclear facility.

The Order defines the key capabilities required for the systems protecting the different areas. Each area is thus defined by a physical barrier separate from the barriers surrounding other areas, unless otherwise specifically provided for. This physical barrier (Figure 14) has a limited number of openings and access points (Figure 15). Each such area is protected with detection, intrusion and delay systems.

Figure 14. Physical protection barrier, Cadarache, France. © Olivier Seignette/Mikaël Lafontan/IRSN.

Figure 15. Access control system at the Fessenheim site, France. © Noak/Le Bar Floréal/IRSN.

1.6.2.1.4. Security study

The organization and resources implemented for the physical tracking, accountancy and physical protection of nuclear material subject to a license are described in detail in a study drawn up by the operator, demonstrating how the organization and resources ensure appropriate protection against the risks that have been identified. The procedures for drawing up and revising this study are specified in an Order. Figure 16 shows the method to be applied when developing a security study.

With regard to physical protection, this study entails analyzing the sequences of actions involved in acts of theft, diversion or sabotage, assessing, at each step in the

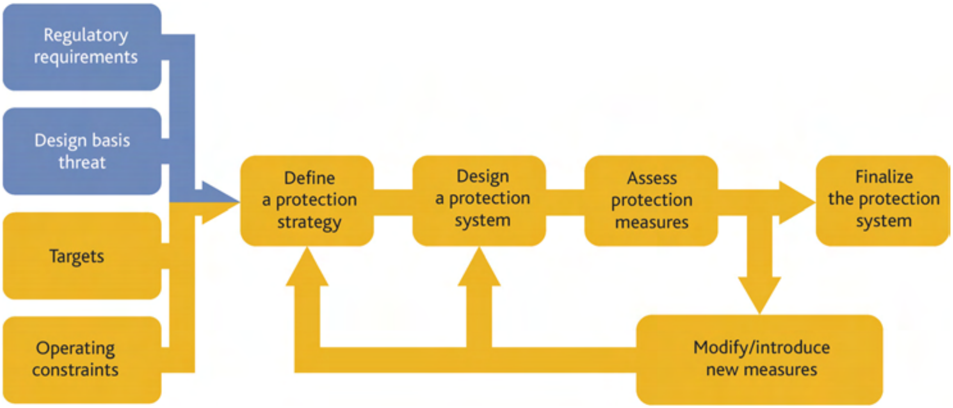

Figure 16. Method to be applied when developing a security study.

attack scenario, the opportunities for detection and access delay, and relating the time it would take to carry out each step to the time needed to deploy an appropriate response after detection. With regard to physical tracking and accountancy, it entails analyzing the capabilities of the tracking and accountancy systems to detect any loss or theft of nuclear material, and also any possible fraud within these systems designed to conceal any illegal operation.

The study, which is a classified document under the protection of secret national defense information, is based on the design basis threat defined by the State. It is structured around internal and external attack scenarios. The nature and the number of attackers are specified, as are the objectives and means at their disposal. These scenarios involve either the theft or diversion of nuclear material, or sabotage liable to result in radioactive releases to the environment or impact on human health.

The threats to be covered in a facility security study are identified on the basis of the reference set of the design basis threat given in the appendix to the national security directive (DNS) relative to the nuclear sector; this reference set can be adapted or added to in order to factor in characteristics specific to the entity or facility in question.

#FOCUS

IRSN's approach based on sensitivity and vulnerability assessments

Objective

There are several stages involved in examining how well a nuclear facility is protected against malicious acts liable to result in radioactive releases. First, the facility's level of protection from the design basis threat defined by the State must be assessed. Once this level is known, it may appear that the protection system needs to be improved to correct any weaknesses or reinforce protection to adapt it to emerging threats.

Organization

To demonstrate its facility's protection level, the operator, with prime responsibility for the facility's security, draws up a security study. This study is submitted for examination by IRSN, provider of technical support to the nuclear security authority. The results of the operator's study and its examination by IRSN are then presented to the authority, either directly in the simplest cases, or within the framework of an advisory committee for larger-scale or more complex cases. When called upon, the advisory committee will provide the authority with an advice and recommendations relative to the facility's security level and to the requirements that should be imposed on the operator (including further assessments). The authority, on the basis of the proposals made by IRSN and, depending on the case, the advisory committee, takes a decision regarding the license application, and, if necessary, notifies the operator of any requirements to reinforce facility protection.

Analysis method

In France, a specific approach to the security studies has been developed by IRSN for many years. This is known as the "sensitivity-vulnerability" approach and can be summarized as follows:

- First, the sensitivity of each area or potential target in the facility is determined; sensitivity is characterized by the level of the radiological consequences likely to result from a malicious act in the area or to the target in question.
- Second, the vulnerability of the areas or targets presenting the highest level of risk is assessed in relation to each type of attack, i.e. the degree of difficulty in carrying out a given attack in the area or to the target in question is assessed.
- If it seems that additional measures are necessary to enhance the protection of areas or targets, in view of the estimated consequences of an attack, a review of the study is required in order to ensure that the measures implemented are appropriate and effective. Such measures are designed either to reduce the level of sensitivity or increase the degree of difficulty involved in carrying out a given attack.

1.1 Determining sensitivity

Analyzing the sensitivity of a facility entails identifying, based on the available safety analyses, possible accident sequences liable to result in significant consequences for people and the environment.

An "accident sequence" is a series of events, triggered by one or more initiating events (failure of one or more components or functions, human error), which places the facility in a degraded situation and may, in spite of backup systems and the means implemented to mitigate the consequences, lead to the release of radioactive substances or toxic chemicals. Conventional safety analyses examine such sequences and the related protective measures, mainly based on a conventional list of design basis incidents and accidents.

Analyzing the sensitivity of a facility entails, first, examining the safety-related equipment and functions at the facility and identifying any for which a failure or loss, assumed in this case to result from a malicious act, could result in a degraded situation.

It is also necessary to examine the initiating events of degraded situations specifically related to malicious acts. To do this, specific failures liable to result from a malicious act and result in the loss of functions or equipment that have not been covered in the safety case are examined.

The method is thus used to identify the most sensitive elements within the facility (components, systems and functions), and the areas in which they are located. These targets or areas are then classified using a graded approach according to the severity of the consequences of a malicious act within that area or to that target. In particular, an area or target is said to be critical if an act leads to significant radiological consequences which are, however, deemed admissible in the safety case, and an area or target is said to be vital if an act is likely to result in radiological or toxic consequences which are more significant than those compatible with the operating conditions defined in the safety case.

To illustrate this in reference to reactors in France's nuclear power plant fleet, safety analyses used to determine sensitivity are mainly those used in the "deterministic" approach based on the study of postulated incidents and accidents. The lessons learned from probabilistic safety analyses, drawn up either by *Électricité de France* or developed by IRSN, can also be used. It should also be remembered that, in the case of nuclear reactors, three basic safety functions must be ensured:

– control of reactivity;
– residual-heat removal;
– and containment of radioactive material.

1.2 Assessing vulnerability

Two points are addressed in assessing the vulnerability of the areas or targets that have been identified:

– an estimation of the means required to destroy or damage equipment or a function (e.g. the amount of explosives needed);
– the identification of the pathways to reach the sensitive area or target.

The second point can be addressed by identifying all the paths leading to each sensitive area or target, and, for each one, estimating the difficulties and therefore the average amount of time required to breach obstacles, and the possibilities of detecting the attackers.

The former approach, which should be assessed in relation to the response capabilities of on site and off site security forces, provides at least a qualitative assessment of how vulnerable a sensitive area or target may be, and demonstrates the need to implement additional measures (design modifications, additional physical protection measures, etc.). This analysis should make it possible to reconcile the need for adequate physical protection and the constraints related to facility operating conditions, nuclear safety and the response conditions in the event of an emergency.

It should be noted that the measures to be adopted to reduce the vulnerability of equipment or a function are generally not the same, depending on whether the threat comes from inside or outside the facility.

1.3 Acceptance criteria

Admissible consequences are deemed to be consequences resulting from radioactive releases lower than or equal to the levels taken into consideration in the facility's safety case. This kind of approach implies that the vulnerability of vital areas is reduced to such an extent as to ensure an excellent level of protection for these areas. For critical areas, the level of protection is assessed on a case by case basis according to the consequences of a malicious act and the degree of difficulty in carrying out such an act.

1.6.2.1.5. Protection during transport

Protection measures for the transport of nuclear material are, in principle, designed to ensure a level of physical protection equivalent to that deployed in facilities. Such equivalence is achieved through the design and manufacturing of transportation devices and through the conditions under which nuclear material is transported. As in the case of facilities, strict confidentiality must be kept to ensure that protection measures are effective.

1.6.2.1.5.1. Physical protection

The choice of route and the planned dates for transporting the most sensitive materials (namely, Category I and II nuclear material) must remain confidential to meet the stated objective of protecting nuclear material.

Prior to the transport operation, routes and dates are examined by the operator with a view to minimizing risks. Various factors serve to determine the possible routes:

- give priority to fast roads, primarily highways;
- avoid densely-populated residential areas and urban areas where traffic is liable to be congested;
- as far as possible, avoid dangerous roads.

The routes are selected following reconnaissance in the field, giving preference to routes involving minimal risk of accident or of stopped vehicles. For the same points of departure and arrival, the operator selects several different routes so as not to use the same one each time.

Furthermore, the dates scheduled for transport are chosen at propitious times, avoiding peak travel days (for example, days when people depart on vacation). Weather conditions which could cause certain transport operations to be delayed in the event of bad weather (storms, snow, black ice, etc.) are also taken into account.

Last, it should be recalled that the transport of nuclear material is a transport of hazardous material and is therefore subject to the relative regulations and the various traffic restrictions and prohibitions pertaining to such transport.

Nuclear material can only be transported by companies authorized to do so by the Ministry of Energy (see Figures 17 and 19).

Figure 17. Truck transporting uranyl nitrate in an ISO standard LR 65 container. Manche. © EURODOC CENTRIMAGE, AREVA.

In particular, transport is carried out by drivers who have completed special training which includes knowledge of the regulations applicable to the transport of dangerous materials, driving in extreme situations and responding to attack.

Transporting the most sensitive nuclear materials (Category I and II nuclear material) is carried out under escort. This is provided by the French national *gendarmerie*. It entails monitoring traffic flow to ensure that the convoy can progress in good conditions.

Transport packages containing nuclear material are designed to limit the radiological impact of transport operations, including during accident situations defined under the safety regulations. The more serious the potential consequences for people and the environment, the more robust they must be. Tests are carried out under severe conditions to test their resistance, as per the international regulations (especially the European Agreement concerning the International Carriage of Dangerous Goods by Road [ADR]).

In addition to the nuclear safety measures implemented, experiments and studies have been carried out by IRSN in conjunction with the operators in question and with the nuclear security authority, with a view to assessing the strength of transport packages to withstand conditions related to malicious acts. In particular, the ultimate strength of several different types of package when subject to different types of weapons has been tested.

All means of transport used to transport nuclear material must be approved by the Ministry of Energy. More particularly, this approval, which is subject to meeting requirements set by orders which are not public, covers the means implemented to protect the load from attempted theft, to protect the crew, and to alert the law enforcement agencies so that they can respond to the attack. Within this framework, IRSN monitors and controls the design and manufacture of all transport vehicle equipment on behalf of the nuclear security authority.

In addition, transport operations are kept under constant surveillance, primarily by the drivers and the escort provided by the *gendarmerie*. In particular, at the end of a leg, the vehicle must park overnight at a site selected in advance, called a “stopping place”, which must be approved by the Minister for Energy.

In addition to protecting the nuclear material being transported, the vehicle must have specific systems to protect the drivers in the event of attack.

#FOCUS

Studies carried out by IRSN on protection against malicious acts during transport

Safety during the transport of nuclear or radioactive material mainly relies on the design and suitability of the transport packages in relation to the quantity of material transported and related hazards. The accident situations predefined in the regulations relative to transport safety are taken into consideration in the design of transport packages. The higher the level of radioactivity contained in the packages, the more robust they must be. Tests are carried out under severe conditions to test their strength (resistance to impact, perforation, fire and immersion).

In addition to these safety provisions, the packages’ resistance to a certain number of security-related attacks is also tested. The behavior of the packages to the effects of an explosive charge or of a penetrating or cutting weapon must be assessed and, if necessary, additional protection must be implemented to limit the radiological consequences that could result from such attacks. Within this framework, IRSN has initiated a large-scale program aiming to assess the resistance to acts of sabotage displayed by various packages used to transport nuclear materials. It should be remembered that, by definition, an act of sabotage is carried out with intent to disperse radioactive material at the scene of the act and in the immediate environment, unlike attempted theft or diversion, where the aim is to appropriate the nuclear material.

As part of this program, IRSN has developed an approach for assessing the potential consequences of an attack on a transport package (i.e. on the container and its contents) divided into four stages and certain number of actions.

Stage 1: description of the package

a. The material transported in the package is characterized by the quantity contained in the package, its location, its physical-chemical form, its state and the radionuclides in its composition. In the event of dispersion, this material can cause doses either by direct irradiation or by inhaling the suspended fraction, or by ingestion.

b. A package is made up of several successive protective casings, some of which serve as containment barriers and are designed to ensure a level of leak tightness. Nonetheless, in the case of protection against sabotage, it is important to examine not only the containment barriers but also all the casing layers through which a penetrating weapon, for example, would have to penetrate to reach the radioactive material (see Figure 18). The characteristics (thickness, materials, etc.) of the different casings are crucial to the assessment of the vulnerability of a package inside its means of transport.

Stage 2: description of the attack

a. The characteristics and the means of the attack are determined using the reference set of the design basis threat which specifies the means attributed to attackers (the equipment they may use, types and quantities of explosives, types and calibers of weapons, etc.).

b. Any aggravating factors are thus determined: the material contained may, in certain conditions, react upon contact with the device used for sabotage, in particular due to the energy released. Such a reaction and the resulting changes in thermodynamic conditions can make any damage to the package worse and increase the possibility of radioactive releases from the package.

Stage 3: assessment of damages caused by the attack

a. The factors contributing to resistance to attack are assessed using theoretical approaches, digital simulation and experiments, which serve to assess mechanical and heat damage to the package and its different casing layers, likely to lead to loss of integrity or loss of leak tightness and thus result in the release of radioactive material.

b. The quantities of material impacted by the attack. In general, it is unlikely that all the nuclear material contained in a package would be impacted by the attack. Only a fraction of the material would be impacted and likely to be released to the environment. It is therefore important to estimate the quantity and quality of such a fraction, as accurately as possible.

Stage 4: radioactive releases

a. The quantity of radioactive material likely to be released into the environment, partly or entirely and over time, must be precisely calculated, albeit with a certain degree of conservatism.

b. The reduction factors, thanks to which the quantity of radionuclides actually released is reduced in relation to the quantity theoretically likely to be released into the environment, either naturally or by design, must be assessed. An example of a natural reduction factor is the adhesion of particles to surfaces. Design-related reduction factors include all the means and measures implemented to reduce radioactive releases.

c. Possible leakage paths must be listed and characterized in order to estimate the kinetic of the releases. Leaks are characterized by the number and the dimensions of breaches made in the last containment barrier when it is damaged. By relating these to known pressure and temperature conditions inside the package, it is possible to estimate the leak rate.

d. Releases to the environment. To determine the fraction of material released from the package, it is necessary to know certain intrinsic characteristics of the material in question, for example, the rate of resuspension for a powder. It is also necessary to determine the duration of the release, which may vary depending on the scenario under consideration. It may be short (a puff) or prolonged; in the latter case, it is important to know if the concentration of radioactive products is constant over time or if it is variable.

All the information obtained using this approach is then used to calculate the radiological or chemical consequences which may include contamination of the environment or radiation doses to people.

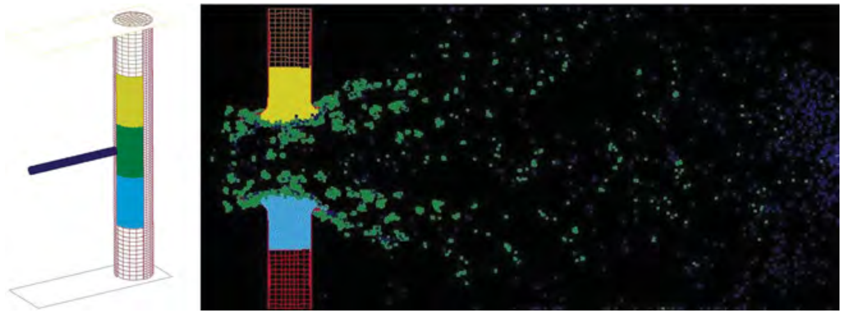

Figure 18. Modeling the impact of a hollow charge on a fuel assembly.

1.6.2.1.5.2. Monitoring transport

The *Gendarmerie nationale* escort team remains in constant radio and visual contact with the vehicle transporting sensitive nuclear material and also in radio contact with the *Gendarmerie nationale*'s operations centers. In the event that an incident occurs during transport, the escort intervenes immediately and puts out the alert.

The transport of sensitive nuclear material is kept under constant surveillance by a special IRSN operations center. This includes telephone contact at regular intervals and in the event of an incident with or possibly having consequences on the progress of the transport operation. In addition, the exact location of the vehicle is known at all times thanks to a satellite positioning system. Any abnormal movement of the shipment can thus be detected in real time; if those responsible for transporting the materials fail to respond a fast alert and response is triggered.

In the event of an incident affecting a transport operation, the escort is the first-level response team. The local law enforcement agencies — police or *gendarmerie* — respond to reinforce this level and, if needed, to serve as a second level of response. To this end, the services involved are systematically informed beforehand of any movement of nuclear material within the area under their jurisdiction.

Figure 19. Ship transporting nuclear material. © Arnaud Bouissou/MEDDE-MLET.

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IRSN Transport Operations Center

IRSN has a special operations center for monitoring nuclear material transport, called IRSN Transport Operations Center (EOT).

Responsibilities

The EOT has three main responsibilities which it carries out on behalf of the nuclear security authority as part of nuclear material protection and control. It manages and monitors nuclear material transport operations in real time, performs technical controls on the means of transport (tractors and trailers) to check for compliance with regulatory requirements relative to nuclear security and performs inspections during transport operations. These activities are called technical support responsibilities, since they are technical activities that come under the State's sovereign functions carried out on behalf of the competent authority. All the different modes of transport used for transporting nuclear material are monitored (road, rail, sea and air) and this at national and international levels.

Organization

Managing and monitoring nuclear material transport operations relies on constant communications between the State services involved, the carriers and all the other stakeholders (national police and *gendarmerie*, customs, port authorities, etc.) and also including those involved in obtaining transport licenses. To manage this activity, the EOT has its own premises equipped to ensure the confidentiality and security of all information held and communicated (e.g. premises within a limited access area monitored by an alarm system, secured communications, protected computer network, etc.), and to ensure the availability of the service (e.g. emergency power backup, redundant communication networks, etc.). The EOT also uses transport management and monitoring software specially developed in-house. A team of around twelve people (engineers and technicians) work 2 x 8-hour shifts.

Some figures for 2014 (Figures 20 and 21)

– 1,318 nuclear material transport operations were carried out in France;
– 66 technical controls and 42 inspections during transport operations.

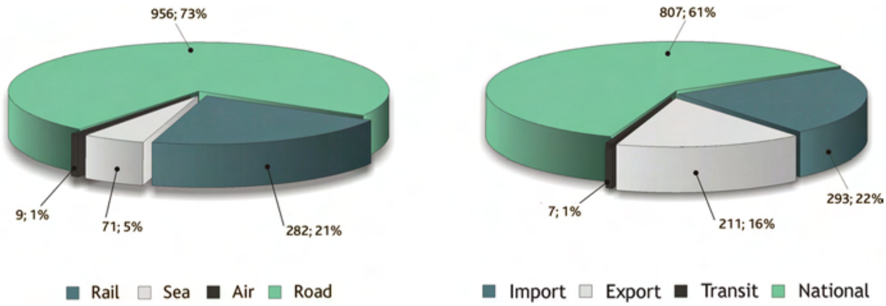

Figure 20. Breakdown of nuclear material transport operations monitored by IRSN by mode and by type of activity in 2014.

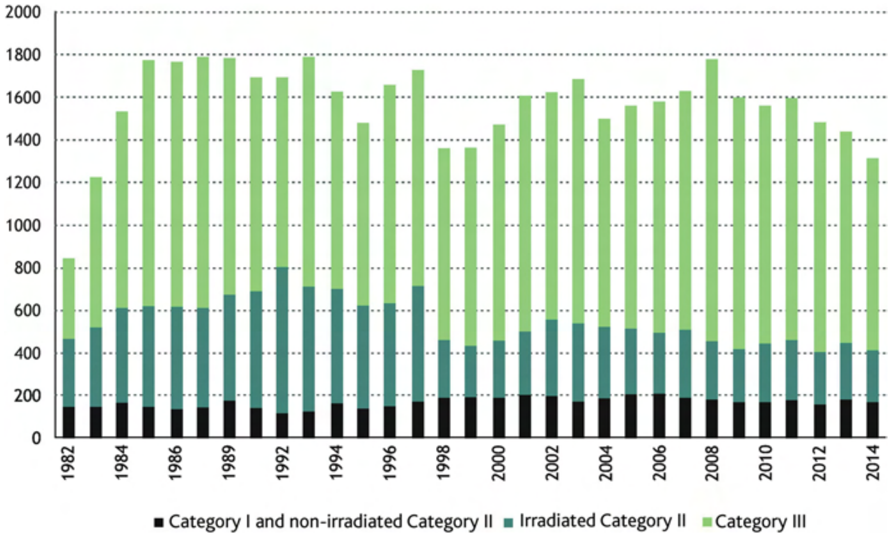

Figure 21. Histogram of nuclear material transport operations monitored by IRSN from 1982 to 2014.

1.6.2.1.6. Reporting anomalies and events relative to malicious acts

Any event liable to affect the protection or control of nuclear material must be reported to the Minister for Energy. In particular, any anomaly affecting the physical protection system and requiring implementation of compensatory measures not defined in the license, together with the detection of any event liable to affect the protection of targets and corroborated by more than one sign, must immediately be reported to the Minister for Energy. This information must be followed, within 48 hours, by a report detailing the measures taken by the operator.

Within two months of the date of the event, the operator must submit a detailed analysis report to the Minister for Energy, unless the latter releases him from this obligation, specifying in particular the characteristics of the anomaly detected and the measures taken to deal with it, the lessons learned and measures taken to prevent any future occurrence of the anomaly.

1.6.2.2. Control

Under the French Defense Code, control covers the administrative and technical aspects of licensed activities. The operator has prime responsibility for implementing this control (first-level control).

Nonetheless, the system deployed, mainly based on a performance based approach, is reinforced by a mechanism for inspection by the competent authority of the operator's application of the regulations and fulfillment of the undertakings contracted. This inspection mechanism is part of second-level control. This entails the inspection of compliance and can result in finding deviations from the license reference documents and all the documents drawn up to support the license application.

The personnel in charge of control and of application of the protection measures are specifically and individually vetted for this purpose by the Minister for Energy, in application of Article L.1333-5 of the French Defense Code. They are certified and designated by name by Order of the Minister for Energy. The personnel work either for the Senior Defense and Security Official (HFDS) of the Ministry of Energy or for IRSN.

Prior to every inspection, the Minister for Energy notifies the operator of the date and purpose. In the case of an unannounced inspection, notification may be given on the same day.

The general purpose of inspections is to ensure that licensees comply with regulations and fulfill their undertakings. They can also be more targeted, in which case they may focus on specific points such as nuclear material inventories, possibly with measurements of the materials concerned, performance and reliability checks on the different physical protection equipment used, the examination of procedures governing alarms, response, or access to nuclear material storage areas, checks on the operator's accountancy system and exercises to check the operator's behaviors. Other inspections may focus on a particular operating phase of a facility (for example, reception or shipping of nuclear material, or checking that there is no more material held at the facility).

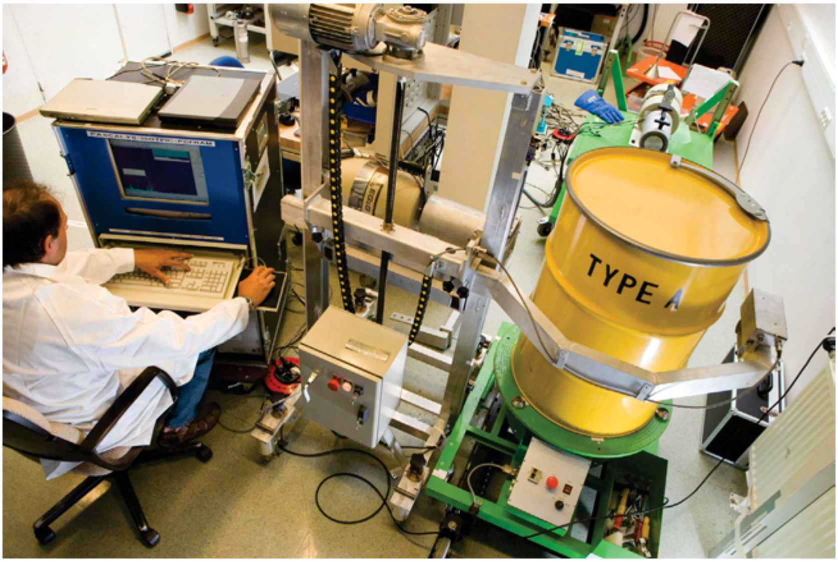

Figure 22. Gamma spectrometry system used to measure nuclear material at IRSN, Fontenay-aux-Roses, France. © Noak/Le Bar Floréal/IRSN.

Two main types of measurement are used on nuclear material during an inspection: (active and passive) neutron measurements and gamma spectrometry measurements (see Figure 22). IRSN has developed specific tools and methods for certain applications (material contained in waste, containers that are difficult to move, etc.). The aim here is to develop measuring instruments that are both portable and as accurate as possible.

Any deviation from the license terms and conditions and any failure to meet the regulatory obligations must immediately be reported by the inspection personnel to the Minister for Energy.

The Minister for Energy notifies the operator which has undergone an inspection of any requirements to remedy the deviations or failures observed and invites it to present any observations it may have in writing.

Nuclear material transport inspections are carried out to check compliance with regulations. Unlike inspections of nuclear material hold at facilities, transport inspections are always unannounced. This is because they primarily involve checking in real time that the carrier, through its employees' actions, commits no fault or error relative to the applicable texts.

Inspection of a transport operation involving the most sensitive nuclear material includes, in particular, checking the information given in the prior notice and the conditions regarding going through motorway tolls and crossing borders, or *gendarmerie* escort reliefs, and checking the conditions regarding reception and protected parking for convoys at stopping places when breaking for meals or overnight. In the case of less sensitive material, the inspection checks that vehicles are locked and kept under surveillance during stops.

Inspections may also include checking a specific point in the regulations. For example, examining the conditions under which packages are protected in ports and at airports when a stage of the transport operation is by sea or by air. In the case of road transport, inspectors intercept road convoys carrying nuclear material only at points where the convoy has to stop (stopping place, border, escort relief, etc.).

As in the case of facilities, IRSN draws up a report on each inspection of a nuclear material transport operation, which is sent to the competent authority which then notifies the operator of its conclusions, together with any corrective active that may be required. Future inspections will check compliance with any requirements requested by the competent authority.

It should also be mentioned that inspections are carried out on vehicles that must be approved. Such inspections aim to ensure compliance with technical requirements set out in the license.

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Measurements of nuclear material during inspections

The measurements of nuclear material carried out by IRSN during inspections on behalf of the nuclear security authority mainly involve uranium and plutonium. Before carrying out any measurement of nuclear material during an inspection, the control objectives are specified, thereby indicating the type of measurement required. The objectives may include:

– identifying the nuclear material;

– determining its isotopic composition;

– estimating the relevant mass.

In all cases, the results are checked against the information provided by the operator to ensure that they are consistent.

Most of the measurement methods developed and used by IRSN are based on conventional non-destructive measurement methods adapted to the specific constraints imposed by the inspection context. These constraints are as follows:

– the measuring devices used must be transportable. The equipment used must be robust, reliable, easy to transport and deploy, and afford excellent performance;

– inspection measurements are non-destructive and generally indirect measurements, since the nuclear material is enclosed in containers that create a screen between the material and the measuring device;

– the measurements must be performed as quickly as possible. During an inspection, the aim is to check a large number of items within a limited amount of time. A compromise must therefore be found between the time taken to perform the measurement and the level of accuracy required.

The simplest measurement is that of the mass of the nuclear material. The best method is to weigh it to obtain the mass, once the material has been correctly identified. The mass is determined using weighing scales whose accuracy and precision are known. Periodic certified checks must have been made on the scales and the results of such checks archived. In addition to weighing, it is obviously essential to ensure that the item does contain nuclear material and to know what that material is.

Exhaustive and precise control of all the products held at a facility would require very lengthy inspections. The controls are therefore usually limited to quick controls to verify that the material being controlled is in fact nuclear material and to determine its nature. The term "foolproofing" is used for this type of control.

IRSN uses various types of measurements to perform a quantitative control of nuclear material from a batch from which a certain number of items have been preselected (sampling):

- passive neutron measurement, consisting in measuring the neutrons naturally emitted from the material. This type of measurement is suitable for quantifying plutonium;
- active neutron measurement, consisting in detecting the neutrons emitted from fission induced in the material by an external source of radiation. This type of measurement is suitable for quantifying uranium and can also be used to measure plutonium;
- gamma spectrometry measurements, used to determine the isotopic composition of plutonium and to quantify the mass of plutonium and uranium.

1.6.2.3. Sanctions

Certain activities involving nuclear material are punishable offences and can be subject to severe sanctions. Such offences include the undue appropriation of nuclear material, the unauthorized exercise of activities regulated by the law, the abandonment, dispersion or alteration of nuclear material, together with the destruction of any structural elements of premises in which such material is processed. It should be noted that the same sanctions apply to any attempt to commit the above-mentioned offences. Obstructing the exercise of control and failing to declare the disappearance, loss, diversion or theft of nuclear material within 24 hours of detection are also considered offences.

Furthermore, within the framework of application of the International Convention on the Physical Protection of Nuclear Material, the French Defense Code allows for any person who has held, used or transported, outside French territory, any nuclear material without authorization by the foreign competent authorities, to also be sanctioned.

Last, French law also provides for sanctions in the event of intrusion into or degradation to the site of a nuclear facility, as for any sensitive facility, with a view to protecting the site itself, establishing a graded sentencing system in relation to the dangerousness of the behavior and the motive of the author or authors.

1.6.3. Emergency response management and exercises relative to security

The approach described above is supported by exercises, or drills, designed to verify the suitability and sustainability of the system implemented, particularly with regard to implementation of emergency response plans in the areas of safety and security. There are three levels of security exercise:

- local exercises organized by the operator in which the public authorities are not involved. This includes alert or mobilization exercises, testing specific procedures or the performance of security teams;
- local exercises organized by the operator with the participation of local public authorities, namely to test their alert and mobilization procedures and to check coordination with the operator;
- national exercises organized by the authorities, testing the overall organization and coordination between operators and public authorities (safety and security authorities, the judicial authority, the nuclear operator, local and national law enforcement agencies, etc.) to manage a serious attack on a nuclear facility.

Such exercises are carried out at intervals defined in agreement with the nuclear security authority.

It should be emphasized that managing an emergency resulting from a malicious act implies the involvement of many different stakeholders to deal with all the different aspects inherent in such an event. Carrying out an exercise that would cover every aspect may be complex, expensive and difficult to implement. This is why several different types of mutually complementary exercise have been developed at national level. We thus distinguish the following:

- protection and security assessment exercises (EPEES), testing the overall organization of the response to a malicious attack at a nuclear facility which could lead to significant releases of radioactivity to the environment. In particular, these imply implementing the safety and security emergency response plans and testing the coordination and interaction of all the entities involved. These exercises are based around attacks defined in the design basis threat. They are especially centered on the deployment of the various response forces involved; the safety aspects are simulated;
- safety drills where the initiating event is a malicious act. The objective of these drills is to assess the decision-making processes between the safety and security authorities and to specify the allocation of responsibility between the authorities and the operator at national and local levels. The security aspects are simulated. This type of exercise does not require communicating sensitive information about the threat or the facility's possible vulnerabilities;

– table-top exercises, allowing for a great deal of flexibility and providing a forum for discussion in which all the stakeholders can train and discuss issues without divulging sensitive information. These are based around an attack scenario at a fictional nuclear facility, requiring the involvement of all the local and national stakeholders. The objective is to identify and develop good practices in crisis management to respond to such an attack and thereby facilitate interfacing and decision-making.

In addition, the competent authority can order a physical inventory of the nuclear material held at a facility or several facilities and compare the results with nuclear material accountancy data. Within this framework, emergency situation inventory control exercises are regularly organized by the Minister for Energy in conjunction with IRSN and an operator. In particular, operators are required to have established emergency situation inventory control procedures.

Last, nuclear material transport security exercises are also held regularly. The scenarios for these exercises involve either the theft of material or sabotage targeting the transport operation.

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Nuclear security table-top exercises

Security exercises are primarily carried out to ensure that smooth and effective running of the entire organization needed to respond to a malicious act at a nuclear facility liable to cause significant releases of radioactivity into the environment.

Table-top exercises developed by IRSN in addition to field exercises provide an excellent forum for discussion of the safety and security aspects of crisis management, enabling all the stakeholders to get to know one another, train and learn to work together, without divulging any sensitive information.

Such exercises are based on a predefined scenario, divided into stages designed to train and stimulate discussion leading to decision-making. The scenario is defined assuming a serious attack on a nuclear power plant, inspired by the design basis threat; it therefore requires the involvement of all the stakeholders affected. This means the security and safety authorities, their technical support units, the local and national operators, the local and national law enforcement agencies, the judicial authorities and mine-clearing services, among others. The scenario is designed to generate a series of safety function failures intended to trigger implementation of coordinated and appropriate responses to counter the attack and restore the facility to a satisfactory safe state. The objective is to identify and manage the crucial aspects of managing such a situation through information-sharing and discussion. The scenario is divided into stages and sequences of actions, used by the facilitators to stimulate discussion of the viewpoints and opinions of those participating in the exercise. A final debate serves to identify good practices and recommendations.

Table-top exercises are a useful tool to take into account in a comprehensive way two major issues related to manage a nuclear security crisis:

- nuclear facility safety (failure or loss of safety functions and management of a degraded situation);
- and security (presence of a terrorist group at a site, hostage taking, impossibility for the local response operators to repair damaged equipment, etc.).

The threat level and the scenario are chosen to require that the attackers be neutralized before the situation at the facility becomes irreversible (for example, serious damage to a nuclear reactor core) with the various levels of law enforcement progressively becoming involved as the situation deteriorates at the facility site.

The exercise is structured around four phases that have been identified for a nuclear security emergency:

- the reflex action phase, during which emergency response procedures are initiated in the areas of safety and security;
- the reflection phase, during which the situation is assessed, including implementation of safety and security emergency response plans;
- the response phase, which generally leads to an assault by the law enforcement agencies to neutralize the attackers;
- the recovery phase, aiming to restore satisfactory safety and security conditions at the site.

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Nuclear material inventory in an emergency situation

At the request of the public authorities, IRSN regularly organizes exercises in inventory taking in an emergency relative to the nuclear material present in a facility or facilities.

Principles

A nuclear material inventory in an emergency situation may be triggered at a facility (or several facilities) in the event of a suspected malicious act involving nuclear material (theft or diversion of nuclear material, act of sabotage) in order to confirm or rule out such an act. Any facility in which nuclear material is held may be the target of this type of event and must be prepared to manage it. The approach entails drawing up a physical inventory of all items containing nuclear material suspected of being the target of the attack, and comparing this inventory with the local and national accountancy records, and, if necessary, performing precise measurements of the material and analyzing the information from the physical protection system of the facilities affected. Inventory taking must take no longer than a few hours. To ensure this, exercises are held regularly.

Aims of the exercises

The main objective of such exercises is to test the decision-making channels and coordination between the various entities involved (operators and public authorities) to clarify the role and responsibilities of each. More specifically, these exercises are also held to train the emergency response teams, test procedures, check the effectiveness of the system implemented and assess how much time is needed to carry out each stage.

Organization

Exercises are organized jointly by the operator(s) of the facilities in question, the security authority and IRSN, and are based on scenarios (theft, substitution, sabotage, etc.) proposed by IRSN. A protocol sets out the procedures for the exercise, the entities involved, the objectives to be achieved and the existence or not of media pressure. Exercises are carried out annually and have served to test the emergency response procedures applicable at the major nuclear operators in France.

Key results

In particular, these exercises have served to clarify the roles and interfaces between the different emergency response organizations, and the measures to be taken to transmit, when necessary, classified information regarding the quantities and location of sensitive nuclear material. They have demonstrated the importance of affixing seals after characterizing nuclear material and having emergency instructions for carrying out an inventory in an emergency situation.

1.6.4. Interrelation between safety and security measures

It is, of course, essential to ensure that safety and security approaches are interlinked. This is ensured as follows. First, the Nuclear Security and Transparency Act (TSN Act) stipulates that the construction and operation of a regulated nuclear facility (INB) is subject to authorization. The license granting such authorization comes in addition to that provided for in the French Defense Code relative to the protection and control of nuclear material, nuclear facilities and the transportation of nuclear material. Any operator planning to operate a regulated nuclear facility which also comes under the provisions of the French Defense Code relative to holding nuclear material must therefore hold two licenses.

Further, the TSN Act introduces the notion of nuclear security in its very first article (with a broader definition than that widely used by the international community [see 1.1.1]), and the "Procedures" Decree (see 1.5) specifies that the safety analysis report for a regulated nuclear facility must describe accidents liable to affect the facility, whether the initiating event comes from inside or outside the facility, and including malicious acts. This information must be included in the preliminary safety analysis report. Similarly, during a facility's final shutdown and dismantling phases, safety and security aspects must be managed in conjunction, with the operator required to apply for authorization from the French Nuclear Safety Authority and, where required, update the security study. A similar approach applies to managing any significant modifications to a facility and to periodic safety reviews.

A regulated nuclear facility can, therefore, only be licensed to operate following examination and approval by the competent authorities of the measures adopted by the operator to protect against and counter malicious acts. The French Nuclear Safety Authority therefore consults with the nuclear security authority with regard to these aspects.

To take account of the sensitive nature of security-related information, a separate application, not available to the public, is drawn up containing the security information required for the safety analysis reports of the facilities in question.

Chapter 2
Security of radioactive sources

2.1. Background

2.1.1. The specific case of radioactive sources

Radioactive sources (see Figures 23 and 24) are widely used all over the world, in many different sectors including industry, medicine, research, the agri-food industry and education. There are risks involved in activities which use radioactive sources due to the potential for excessive exposure to ionizing radiation. The possibility of excessive exposure as a result of a malicious act cannot be ruled out. Misappropriate use of radioactive sources must therefore be prevented in order to protect people and the environment. The approach must take account of the huge number of existing sources, their diversity (in terms of activity, radioactive half-life, the type of radiation, physical and chemical form, packaging, etc.) and the many different sectors in which they are used.

Strengthening security for radioactive sources with regard to malicious acts implies first identifying the sources that may be dangerous to humans and the environment if used with malicious intent and, secondly, taking measures to protect these sources in view of the potential consequences of such use. This approach entails prioritizing the sources according to the hazard presented and applying protection and control measures factoring in the risk of malicious use (in line with the principle of a graded approach) during their use, transport or storage. Within this framework, IRSN conducted a program aiming to better assess the risks of any potential malicious use of radioactive sources. The program was structured as below:

- listing radioactive sources and grouping them into different types or families;
- assessing the sensitivity of the different types or families of radioactive sources in terms of the level of the consequences of a malicious act involving their use;

- analyzing the vulnerability of the most sensitive radioactive sources;
- determining the technical and organizational measures to ensure the security of the most sensitive and the most vulnerable radioactive sources.

Figure 23. Reconditioning radioactive sources at IRSN, Fontenay-aux-Roses, France. © Olivier Seignette/Mikaël Lafontan/IRSN.

The results of these studies were then used in an international framework and also to draw up French regulations in this area.

2.1.2. Theft and loss of sources

One of the difficulties in the radioactive source security approach is the huge number of existing sources (around 47,000 sealed sources in France in 2014), the huge number of places where they are located and the huge number of movements of these sources.

In France, the theft or loss of high-activity sealed sources is extremely rare. On the other hand, the theft or loss of unsealed sources or low-activity sources is more common. Loss mainly occurs during transport, sometimes due to delivery error or when sources are not disposed of through the correct channels.

Worldwide, the theft or loss of high-activity sealed sources is also relatively uncommon and decreased in 2014, but can have dramatic consequences for workers and the population; they are the result of negligence or inadequate control. As in France, the main sources lost or stolen involve mobile devices and incidents usually occur during transport, sometimes as a result of a delivery error.

Two significant events which occurred in France in 1999 can be described here. The first involved a gamma radiography projector (Figure 25) containing a high-activity source which was found on a beach, while the second involved a van also containing a gamma radiography unit which was stolen. In the first case, the police investigation pointed to a suspected malicious act by an employee of the company in question; in the second case, the vehicle and the source were found at a non-ferrous metal waste conditioning plant, leading one to think that the thieves did not intend using the source for malicious purposes but rather that they were more interested in the equipment in the van.

These cases serve to remind us of the importance of early detection when a source goes missing, reporting its loss or theft and the need to recover it as quickly as possible.

2.1.3. Historical background

In 1995, the IAEA launched a broad program aimed at combating the illicit trafficking of radioactive material and, more generally, reinforcing security for radioactive sources. This program resulted in the implementation of an action plan, approved in 1999 by the IAEA Board of Governors, and the organization of several international conferences on this subject. This all led to publication of the "Code of Conduct on the Safety and Security of Radioactive Sources", together with technical guides presenting, in particular, a categorization of radioactive sources and setting up a database of incidents involving radioactive sources.

The "Code of Conduct" was approved by the IAEA in September 2003 after reinforcing its scope, bearing in mind the attacks of September 11, 2001 which, although they did not involve radioactive material, demonstrated the level of preparation achieved by certain terrorist organizations.

Figure 24. Sealed radioactive sources in their lead box, Université Toulouse III - Paul- Sabatier (France). © Albin Millot/IRSN.

At the same time, following a case of atmospheric radioactive pollution due to the accidental incineration of sources in Europe, the European Commission drew up a text aimed at stricter control over radioactive sources. This text, adopted in December 2003, is the Euratom Directive on the control of high-activity sealed radioactive sources and orphan sources (see 2.2.3).

2.2. International framework

2.2.1. Categorization of sources

To provide guidance for Member States in their approach to protection against the malicious use of radioactive sources, the IAEA has developed specific documents as part of its "Nuclear Security Series" mentioned above (see 1.1.5). These include Recommendations and a number of guides to implementing the recommendations and technical guidance manuals.

In one of these guidance manuals, the IAEA proposes classifying radioactive sources into five categories numbered from 1 (the most dangerous) to 5 (the least dangerous) based on the concept of the "D value" (D for danger), i.e. the activity value causing severe deterministic effects. A severe deterministic effect is defined as a health effect due to radiation which is inevitably fatal or life threatening or results in a permanent injury that reduces quality of life. From this is derived the concept of dangerous source; this concept is implemented in terms of operational parameters by calculating the quantity of radioactive material which, for a human organism, causes severe deterministic effects in human exposure scenarios and for given dose criteria.

Figure 25. Gamma radiography projector containing a radioactive source, France. © Nedim Imré/IRSN.

2.2.2. "Code of Conduct"

The aim of the IAEA's "Code of Conduct" on the safety and security of radioactive sources is to attain a high level of safety and security for the most dangerous sealed sources. To this end, it presents guidelines on the principles of protection to be implemented and on the regulations relative to the safety, radiological protection and security of radioactive sources (physical protection). It is intended as a guide to Member States, particularly in drawing up and harmonizing their policy and regulations regarding the safety and security of radioactive sources. In this Code, only the first three categories out of the five mentioned above are subject to recommended security measures, excluding unsealed sources, nuclear material and defense-related sources which come under specific regulations.

In addition to the "Code of Conduct", the IAEA guidance relative to imports and exports of radioactive sources recommends a system for notifications between States to improve tracking of Category 1 and 2 sources.

2.2.3. Euratom Directive

The EU directive known as the "Euratom Directive" on the control of high-activity sealed radioactive sources (HASS) and orphan sources makes certain sources subject to specific requirements. This directive, the main purpose of which is not the security of radioactive sources with regard to malicious acts but radiological protection, nonetheless includes general measures related to security, such as the obligations regarding labelling sources, the need for holders of radioactive sources to obtain prior authorization, the need for a competent authority in charge of keeping a register of all holders and the sources held, etc.

2.3. French organization

2.3.1. Regulatory framework

The French regulations relative to the use of ionizing radiation are primarily contained in France's Public Health Code and Labor Code. The regulations factor in the recommendations contained in the IAEA's "Code of Conduct" on the safety and security of radioactive sources and the provisions of the Euratom Directive on the control of high-activity sealed radioactive sources (HASS) and orphan sources.

The Public Health Code has been extended, in addition to radiological protection concerns, by provisions relative to the security of radioactive sources. This Code specifies, for every radionuclide, the activity level above which a sealed source is a high-activity sealed source and provides for general measures for tracking such sources:

- identification and labeling;
- submission to the competent authority of an annual inventory of sources held and the capability of the holder to conduct an emergency inventory at any time;
- a control system for transfers of sources with submission to the competent authority of a source movement report by suppliers.

These measures are supplemented by general provisions also relating to the security of sources:

- a system of authorization licenses for manufacturers, suppliers and users, and also for the transport of radioactive material;
- recovery by the suppliers, by an approved entity or by another licensed holder, of sources at end of life or after 10 years, with the supplier under obligation to inform the competent authority of any source not returned within the set periods;
- the implementation of security measures at storage sites (a locked room with controlled access).

Based on the IAEA's categories of sources and the measures mentioned in the "Code of Conduct" and the Euratom Directive, it can be observed that, of the 47,000 sources registered in the French national inventory in 2014, approximately 10% (4,600 sources) are HASS in the meaning of the Euratom Directive, liable to cause severe exposure to ionizing radiation. Figure 26 shows the breakdown of sealed sources registered in France by activity, by radionuclide and by type of use. The security measures deployed in France mainly apply to these high-activity sources in accordance with the principle of a graded approach and based on the IAEA's categories. The approach adopted is primarily prescriptive (as opposed to a performance based approach developed for the protection of nuclear material) insofar as it applies to a diverse range of operators, some of which (hospitals and universities, for example) do not have the necessary resources to design a

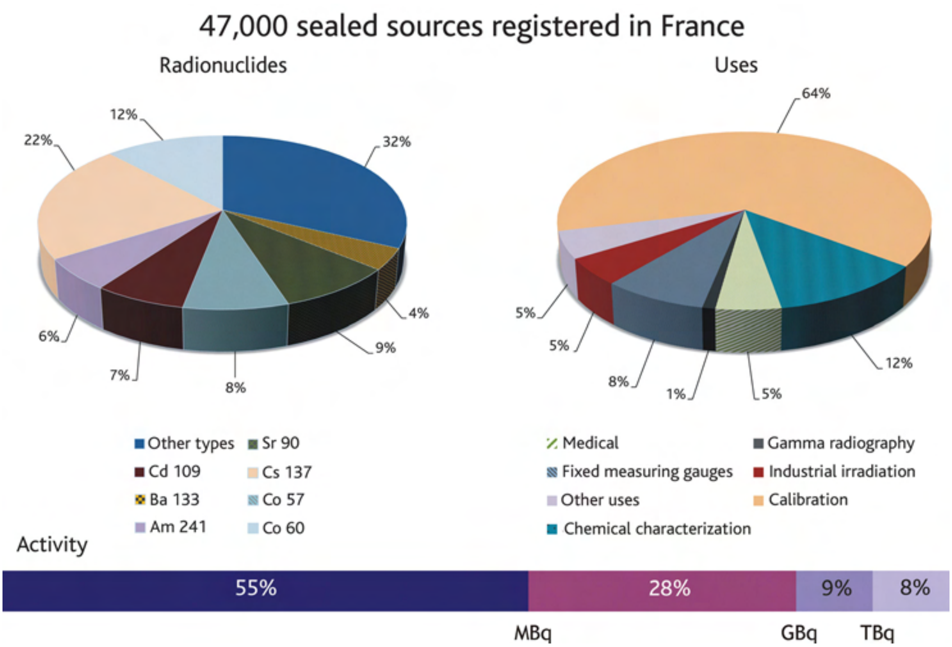

Figure 26. Range of activities in which sealed sources are used in France, broken down by activity, radionuclide and type of use.

protection system for their sources and manage sensitive information specifying, for example, the threats against which they need to be protected.

To ensure the desired level of consistency between safety, radiological protection and security requirements, a single authority, the French Nuclear Safety Authority is in charge of enforcing these regulations in France.

In addition, the regulations impose requirements for the radiological protection of workers which may be useful in ensuring security of sources, such as the technical control of sources and the conditions in which they can be used and stored or the existence of internal procedure to be followed in the event that a sealed source is lost or stolen.

The regulations also provide for improved security training for personnel who have access to high-activity radioactive sources.

An implementing order specifying the tracking and physical protection measures for radioactive sources according to a graded approach will soon be added to this system. Within the framework of implementing these new regulatory measures designed to tighten security of radioactive sources, IRSN will be providing technical support to the French Nuclear Safety Authority.

2.3.2. France's national register of sources

One of the key measures recommended in the IAEA texts is to keep records of and track radioactive sources, particularly of Category 1, 2 and 3 sources, by means of a national register of sources.

In France, IRSN is responsible for national tracking of sources. It requires that:

– anyone responsible for a "nuclear activity" as defined in the Public Health Code shall provide information to IRSN on the characteristics of the sources, identification of the places where they are held or used and details of their suppliers and buyers. The procedures for maintaining the inventory of ionizing radiation sources, including keeping an up-to-date national register of radioactive sources, are defined in the regulations;

– all holders of radionuclides in the form of radioactive sources, or of products or devices containing them, must be able to demonstrate at all times the origin and destination of the radionuclides present on their premises for any reason whatsoever. For this purpose, they shall set up a tracking system on their premises to ensure that the inventory of products held is available at all times.

To track radioactive sources at national level, IRSN has developed a management tool and an Internet portal accessible to all source holders. For every holder, the following information is registered using this management tool: the source reference, the radionuclide, its activity, its source number where available, the source supplier and also the device reference and number if the source is contained in a device. No source can be moved unless the required information has been recorded in the management tool. Furthermore, IRSN receives annual inventories submitted by the source holders and users, compares these data with any movements of sources registered in the management tool, analyzes any differences and regularly updates the national inventory of ionizing radiation sources.

Chapter 3
Non-proliferation in the nuclear field

With regard to international control of nuclear material, there are two organizations which oversee control in France: the International Atomic Energy Agency (IAEA) (international control) and the European Atomic Energy Community (Euratom) (regional control). This control comes within the framework of France's undertakings regarding non-proliferation.

3.1. Historical background

3.1.1. IAEA

On December 8, 1953, when the President of the United States set out his "Atoms for Peace" plan, he laid the foundations for what was to become the International Atomic Energy Agency (IAEA). It was also the first step toward the international initiative to ensure the non-proliferation of weapons of mass destruction.

In October 1956, the Statute of the IAEA was adopted in New York, on the fringes of a UN conference. In July 1957, after 26 Member States had deposited their instruments of ratification, the IAEA Statute (Figure 28) entered into effect. The Statute sets forth two fundamental and complementary principles: first, the aim of the Agency is to promote the peaceful use of nuclear energy, and second, it must ensure that nuclear material said to come under international safeguards is not used for military purposes. The IAEA's headquarters are in Vienna, Austria (Figure 27).

Figure 27. IAEA headquarters in Vienna, Austria. © Rodolfo Quevenco/IAEA.

From 1959 to 1961, the General Assembly of the United Nations adopted a number of resolutions relative to non-proliferation and, during the 1960s, several draft treaties were debated. In the end, on July 1, 1968, the Non-Proliferation Treaty (NPT) was opened for signature in Moscow, Washington and London. It came into force on March 5, 1970, following ratification by the three depositary powers and forty other Member States.

According to the Treaty, Nuclear-Weapon States, known as NWS (States that exploded a nuclear weapon prior to January 1, 1967), must not assist any Non-Nuclear Weapon State, or NNWS, to acquire nuclear weapons. There are five NWS as defined in the NPT (the United States, the Russian Federation, the United Kingdom, France and the People's Republic of China). According to the terms of the NPT, all other States are non-nuclear-weapon States.

Every NNWS which becomes party to the NPT undertakes not to acquire nuclear weapons or any other nuclear explosive device. It also agrees to conclude a comprehensive safeguards agreement with the IAEA, which provides for the application of safeguards to its present or future nuclear activities, with a view to verifying compliance with the State's obligations under the terms of the Treaty.

In return, the Treaty recognizes the Party's right to the fullest possible exchange of equipment, nuclear material and scientific and technological information for the peaceful use of nuclear energy. The Parties also undertake to pursue negotiations regarding nuclear disarmament in good faith, meaning full and comprehensive disarmament, and, in the preamble, reaffirm their determination to stop nuclear weapons testing.

On August 2, 1992, France was the last of the five nuclear-weapon States to join the NPT, regarding which, up to then, it had declared that it would comply with the provisions therein.

In New York, on May 11, 1995, the NPT was extended for an unlimited period of time. To date, three States have not signed the NPT: India, Israel and Pakistan. It should be mentioned that North Korea has announced its intention to withdraw from the NPT.

The fundamental objectives of the NPT are the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection. IAEA control is focused on the end use of nuclear material. Control is exercised over the body regulating the use of nuclear material, namely the State. It is based on a system of safeguards.

The IAEA's international safeguards "*are applied to verify a State's compliance with its undertaking to accept safeguards on all nuclear material in all its peaceful nuclear activities"*. The safeguards system for non-proliferation was created in 1957, at the same time as the adoption of the IAEA Statute, but the system did not really come into its own until 1970 when the NPT came into effect, particularly Article III. There are three main types of safeguards agreement:

1. **Comprehensive Safeguards Agreements.** Affording an appropriate and identical legal framework for all signatories, a model comprehensive safeguards agreement was drawn up in 1971. It is mainly based on the verification by the IAEA of nuclear material accountancy and physical monitoring for all declared nuclear material.

2. **Voluntary Offer Agreements.** France, like the other four NWS, was not obliged to sign a safeguards agreement with the IAEA. It did, however, sign, on a voluntary basis, and as did the other four recognized nuclear powers, a safeguards agreement inspired by the model comprehensive safeguards agreement signed between the IAEA and the NNWS, but adapted to the specific status and interests of France. Under this agreement, signed on July 27, 1978, France notifies the IAEA's safeguards system of all the nuclear material it designates, in selected facilities or parts of facilities. To factor in the security control exercised by the European Atomic Energy Community (see below), the safeguards agreement signed by France is trilateral, with Euratom also party to the agreement.

3. **Item-specific Safeguards Agreements.** Certain States (India, Israel and Pakistan), which have not signed the NPT, have signed more limited agreements with the IAEA, applicable only to nuclear material, equipment and facilities specified in the agreement.

The discovery that Iraq was developing a clandestine military nuclear program and the difficulties encountered by the IAEA in North Korea have since revealed the inadequacy of the measures applied under the safeguards agreements, even in the case of the comprehensive safeguards agreements. With a view to mitigating these inadequacies, the IAEA Secretariat began, in 1993, working on an ambitious program to strengthen the safeguards system. The fundamental objectives of this program were, first, to improve the IAEA's capabilities for detecting clandestine activities and, second, to improve the effectiveness and the results of the safeguards. This program was divided into two parts. The first focused on measures that could be implemented without altering the existing legal framework. The second focused on measures whose implementation would require giving the IAEA new legal powers. The result of these new measures has been a model additional protocol to the existing safeguards agreements. This was adopted at an extraordinary meeting of the IAEA Board of Governors, on May 15, 1997.

On September 22, 1998, France signed an Additional Protocol, also inspired by the model drawn up for NNWS. Like the agreement to which it is an addition, this protocol also involves Euratom. France must therefore comply with new undertakings and regularly submit declarations to the IAEA, including:

- research and development activities relative to the fuel cycle conducted in cooperation with NNWS;
- operations relative to the manufacture of non-nuclear material or equipment that could potentially be used in nuclear programs, conducted in cooperation with persons or companies in a NNWS;
- the import and export of medium- and high-level radioactive waste containing plutonium, uranium 235 or uranium 233, from or to a NNWS;
- the export to a NNWS of certain non-nuclear material or equipment that could be used in a nuclear program;
- activities planned in cooperation with a NNWS for the ten years to come which are related to developing the nuclear fuel cycle.

On behalf of France, Euratom also declares to the IAEA all production from uranium mines and ore concentration plants, together with any transfer of such ore.

It should also be mentioned that the IAEA can require additional information (clarifications) relative to these declarations and, under certain conditions, perform verifications ("complementary access") at any site in France.

France's implementation of the Additional Protocol is managed by the Euratom Technical Committee (CTE, see 3.4.2) and its technical support, IRSN, which is more specifically tasked with preparing declarations (see below).

Since the 2000s, the IAEA has also been developing the concept of "Integrated Safeguards". Integrated Safeguards are defined as the optimum combination of all safeguards measures available to the IAEA under comprehensive safeguards agreements and additional protocols. Only when the IAEA has drawn a conclusion of the absence of undeclared nuclear material and activities in that State does it develop for that State a specific control approach based on higher level of trust, leading to a reduced number of inspections and more unannounced verifications.

3.1.2. Euratom (the European Atomic Energy Community)

The Euratom Treaty, signed by France in Rome on March 25, 1957, founded the European Atomic Energy Community (EURATOM). Membership of the European Union implies ratification of this treaty. The history, drafting and entry into force of this treaty coincide with the treaty founding the European Economic Community. The objectives of the Euratom Treaty are to contribute to the development and growth of nuclear industries

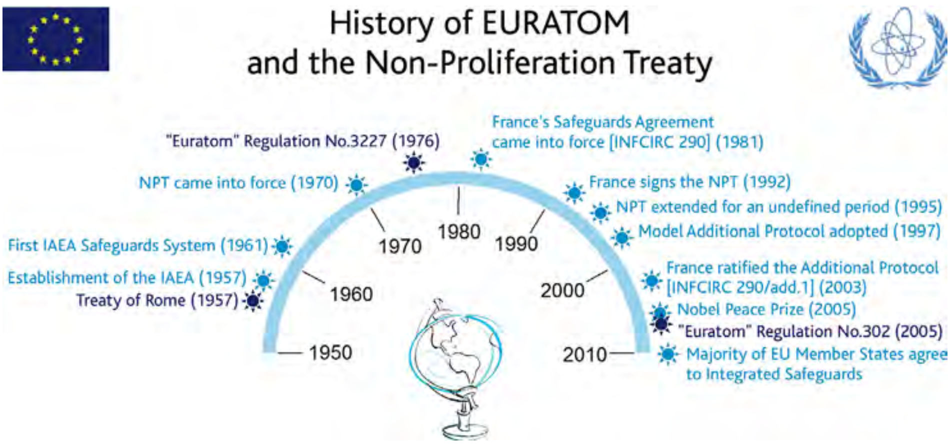

Figure 28. Key dates in the implementation of the Euratom Treaty and the Non-Proliferation Treaty.

in Europe, ensuring that all EU Member States may benefit from the development of atomic energy for peaceful ends, particularly the non-nuclear-weapon States, and to ensure security of supply regarding ore and nuclear fuel. Figure 28 shows the key dates in the implementation of the Euratom Treaty and the Non-Proliferation Treaty.

Under the Treaty, Euratom is specifically responsible for:

- developing research and disseminating technical knowledge;
- setting harmonized security standards to protect the health of the population and of workers, and oversee their application;
- facilitating investment and ensuring that the basic facilities essential to the development of nuclear energy in the European Union are built;
- ensuring the regular and fair supply to all users in the EU of ore and nuclear fuel (Euratom Supply Agency set up);
- by means of appropriate control measures, ensuring that nuclear material is not diverted and used for purposes other than those intended. This control could be considered as a conformity control;
- promoting progress in the peaceful use of nuclear energy by working with non-EU countries and international organizations;
- setting up joint companies.

The key provisions of the Euratom Treaty have not changed since it came into force on January 1, 1958. The above-mentioned responsibilities are set out in ten chapters of the Treaty. Implementation of Chapters VI and VII directly concerns French industry.

Chapter VI is about supply. "*The supply of ores, source materials and special fissile materials (see below) shall be ensured […] by means of a common supply policy on the principle of equal access to sources of supply. For this purpose […]: b) an Agency [the*

Supply Agency] is hereby established; it shall have a right of option on ores, source materials and special fissile materials produced in the territories of Member States and an exclusive right to conclude contracts relating to the supply of ores, source materials and special fissile materials coming from inside the Community or from outside."

Chapter VII of the Euratom Treaty establishes safeguards in the Community Member States. These safeguards are based on a system of declarations and inspection procedures.

Under the terms set out in this Chapter, "*the Commission shall satisfy itself that, in the territories of Member States:*

a. *ores, source materials and special fissile materials are not diverted from their intended uses as declared by the users;*

b. *the provisions relating to supply and any particular safeguarding obligations assumed by the Community under an agreement concluded with a third State or an international organisation are complied with."*

Technical developments in the nuclear industry in general, and in the area of safeguards in particular, together with the Additional Protocol entering into force in EU Member States, have made it necessary to publish a series of regulations which take account of such developments. The most recent, Regulation 302/2005 on the application of Euratom safeguards, was signed on February 8, 2005. It came into force 20 days after its publication on February 28, i.e. on March 20, 2005.

In addition to the application of additional protocols (trilateral agreements between EU Member States, Euratom and the IAEA), Regulation 302/2005 updates all the obligations applicable under previous regulations. It enables the European Commission to extend safeguard provisions to technological developments in the nuclear industry. There are three changes of particular note: safeguards applicable to waste treatment and waste storage installations (the previous regulation stopped safeguards once nuclear material was considered waste), changes to the format of declarations, and the more widespread transmission of information in electronic form.

The European Commission also set out recommendations, which are not legally binding, as guidance for operators in the application of this Regulation.

3.1.3. Some definitions

The Euratom Treaty and Article XX of the IAEA Statute give the international definition of nuclear material, which applies only to uranium, plutonium and thorium, whereas French regulations extend the definition to deuterium, tritium and lithium 6 (see 1.1.1). In Regulation 302/2005, four categories of nuclear material are defined:

– "special fissile materials", i.e. plutonium 239, uranium 233, uranium enriched in uranium 235 or uranium 233, and any substance containing one or more of the foregoing isotopes and such other fissile materials as may be specified by the Council, acting by a qualified majority on a proposal from the Commission; the expression "special fissile materials" does not, however, include source materials;

- "uranium enriched[5] in uranium 235 or uranium 233" means uranium containing uranium 235 or uranium 233 or both in an amount such that the abundance ratio of the sum of these isotopes to isotope 238 is greater than the ratio of isotope 235 to isotope 238 occurring in nature;
- "source materials" means uranium containing the mixture of isotopes occurring in nature; uranium whose content in uranium 235 is less than the normal; thorium; any of the foregoing in the form of metal, alloy, chemical compound or concentrate; any other substance containing one or more of the foregoing in such a concentration as shall be specified by the Council, acting by a qualified majority on a proposal from the Commission;
- "ores" means any ore containing, in such average concentration as shall be specified by the Council acting by a qualified majority on a proposal from the Commission, substances from which the source materials defined above may be obtained by the appropriate chemical and physical processing.

It should be mentioned that neither the IAEA nor the French regulations consider ores to be nuclear material but that they are subject to Euratom safeguards.

3.2. Declarations

3.2.1. General approach

3.2.1.1. Notification of imports/exports of nuclear material

The effectiveness of the non-proliferation regime depends largely on the system of declarations made to Euratom and the IAEA of operations involving nuclear material, together with onsite verification by independent inspectors (from Euratom or the IAEA). According to that, any movement of nuclear material is strictly controlled. This is why nuclear operators are required to declare any transfer of the materials mentioned in the Euratom Treaty and the IAEA safeguards provisions. Figure 29 shows the principle of nuclear material control in France.

In practice, the notification of nuclear material transfers has five main objectives:

- to plan verification operations covering nuclear material upon being removed from a facility or upon arrival at a facility;
- to apply for authorization to transfer nuclear material to another State within the framework of certain agreements undertaken by France or Euratom;
- to receive information on transfers prior to such transfer;
- to monitor the flow of material and verify that States comply with their international undertakings;
- to detect any problems during transport.

5. Enrichment is the ratio between the combined mass of uranium 233 and uranium 235 isotopes and the total mass of the uranium in question.

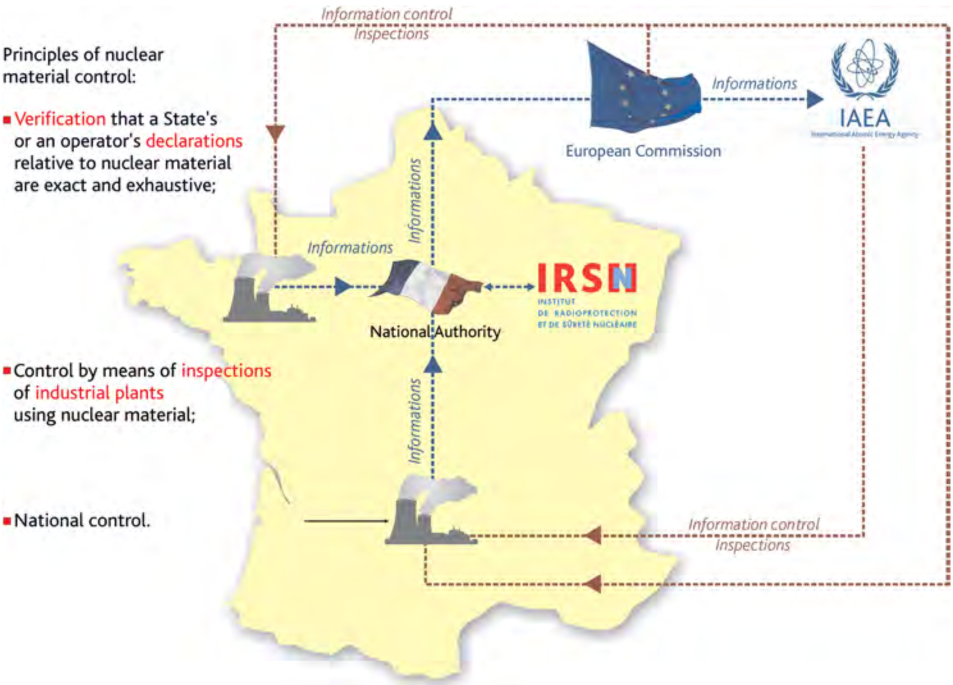

Figure 29. Illustration of the principle of nuclear material control in France.

All French operators that import or export nuclear material are subject to the regulatory obligation to notify all such transfers to the European Commission. Under the agreements signed by France, these notifications are, where necessary, transmitted to the IAEA, and possibly to the authorities in certain third countries within the framework of agreements between France or Euratom and said third countries.

Nuclear material cannot be transferred before contracts have been signed, information shared and authorization granted (trade contracts, export licenses, notification of nuclear material transfer, customs declarations, etc.).

Any transfer of nuclear material from one country to another (whether or not it belongs to the EU) implies that the nuclear material in question comes under the provisions of one or more treaties or agreements. Have to be distinguished the agreements signed by the European Commission, those relative to the application of IAEA safeguards and the bilateral agreements undertaken by two countries:

- application of Euratom Regulation 302/2005 requires notifying the European Commission of any transfer of nuclear material. This Regulation specifies the conditions relative to exports and imports;
- some international IAEA agreements, published in the form of information circulars (INFCIRC), cover, among other points, application of safeguards during the transfer of material from one country to another. In this context, France has

signed undertakings that provide for the transmission of prior notification before any transfer of nuclear material;

- intergovernmental agreements between France and other countries — including Australia and Japan — provide the framework for nuclear cooperation and set out the undertakings of each party.

Several government entities are involved in managing France's various non-proliferation and nuclear cooperation undertakings at international level. Nonetheless, to simplify entry points, all import and export notifications are transmitted to the Euratom Technical Committee (CTE) and IRSN, which processes them on behalf of the operators and the authorities in charge.

To assist French operators in drawing up their nuclear material transfer notifications, IRSN provides an internet portal for industry players to transmit the required information as simply as possible. IRSN has also developed a handbook setting out the main regulatory obligations and describing how to use the tools for transmitting notifications to the French authorities. This handbook is widely disseminated to the industry players in question.

3.2.1.2. Other types of declaration

- any person or company which uses nuclear material is required to declare to the Commission the "basic technical characteristics" of the installation in which it is intended to hold nuclear material at least 200 days prior to the initial delivery of nuclear material to this installation. This means general information on the installation which must specify the purpose and the nuclear material tracking and accountancy methods implemented. A specific guide is provided in the Regulation for each type of installation (energy generation in reactors, research activities, storage, waste treatment, etc.);
- for each installation in question, a general activity program for the coming year must be transmitted annually to the European Commission, *via* the CTE, so that inspections can be scheduled. This document must include the date scheduled by the operator for the annual inventory and the date scheduled to verify this inventory by Euratom inspectors;
- for each area in which nuclear material is held, or MBA (Material Balance Area), the people and companies subject to Regulation 302/2005 must send the Commission reports of any inventory change for all the nuclear material held. These reports must include identification of the material, the types of inventory change, the dates of inventory changes and, where applicable the shipper's MBA and the recipient's MBA or the recipient. The reports must also mention end-of-month stock and, where applicable, stock on the date that the inventory is taken;
- for each MBA, a "Material Balance Report" must be sent to the Commission. This report is drawn up after a physical inventory to validate the physical inventory with the accounting inventory for the MBA and balancing any accounting inventory changes since the previous inventory;

- for each MBA, a physical inventory report must be sent to the Commission. This is a document drawn up by the operator, stating the inventory of the batches of nuclear material held in each MBA;
- the transfer of conditioned waste to an installation located within or outside the territory of a Member State must be declared to the Commission every year;
- in exceptional circumstances (loss or discovery of nuclear material), a special report must be sent to the Commission, *via* the CTE. This special report must be drawn up immediately;
- operators may be required by IRSN to submit other information, not required under the Regulation or the Euratom Treaty, on an exceptional and occasional basis, for example, to clarify any inconsistency.

The French authorities regularly ask IRSN to analyze the above-mentioned information before it is transmitted to the European Commission.

3.2.2. Declarations required under the Additional Protocol

The Euratom Technical Committee (CTE) is in charge of drawing up the French declaration to submit to the IAEA under the terms of the Additional Protocol. IRSN, as technical support to the CTE, contacts French industry players, informs them of their obligations and collects their declarations. To do this, IRSN has drawn up a guide to declarations, enabling industry players to determine whether they are affected by the Additional Protocol and, if so, to draw up their declarations. An online declaration portal was also developed in 2014 to enable industry players to submit their declarations online.

An annual declaration is required for:

- public research and development activities conducted in cooperation with a NNWS;
- private research and development activities conducted in cooperation with a NNWS;
- cooperation with a NNWS planned within the coming 10 years;
- imports from a NNWS and exports to a NNWS of high- and intermediate-level conditioned waste;
- activities relative to the manufacture of equipment that could potentially be used in nuclear programs, conducted in cooperation with a NNWS.

The annual declaration serves to describe a new activity or update the description of activities submitted in the initial declaration or in the preceding annual declaration (modification, no change in activities, activities stopped, etc.).

A quarterly declaration is required for exports from or to a NNWS of equipment or non-nuclear material (which could potentially be used in nuclear programs) during the preceding quarter.

3.3. Inspection procedure

3.3.1. General approach

The procedure for inspections by the European Commission or the IAEA begins when these entities send advance notification of inspection. In the case of inspection by the European Commission or the IAEA, it is France which is inspected, even if the inspection actually is held at the site of a French nuclear operator (AREVA or EDF, for example) (Figure 30). Inspections are carried out by European inspectors or IAEA inspectors who are certified by the French authorities. What follows mainly describes the procedure adopted for European Commission inspections, by far the most numerous carried out in France compared to those carried out by the IAEA. These inspections are defined in the Euratom Treaty, other than which there are no specific documents regulating this activity.

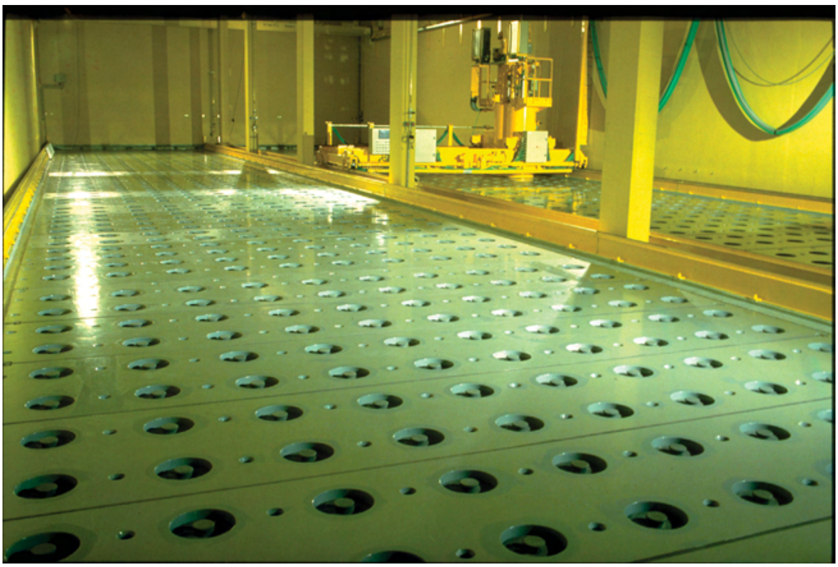

Figure 30. Intermediate storage building, AREVA La Hague site, Cherbourg. France. © AREVA, Philippe Lesage.

There are several types of inspection:

– routine inspections (or systematic inspections). This is the most common type of inspection. The main checks made during this type of inspection include verification of accountancy, physical verifications and checking measurements and automated recordings since the last inspection (if cameras or recording equipment belonging to Euratom are installed at the site);

– inventory verifications. This consists in verifying a physical inventory and comparing it with the material accountancy system;

– high frequency inspections, held at installations for which the provisions stipulate special safeguards measures and which contain significant quantities of special fissile material (plutonium or highly enriched uranium);

– verifications of imports and exports declared by prior notification. These mainly focus on physical verification of declarations of nuclear material imports/exports outside the EU;

– special inspections in the event of loss or accidental discovery of nuclear material, subject to special reports, or of accidentally breaking a seal, or in an emergency;

– unannounced inspections (with no advance notice sent to the Member State specifying the installation to be inspected) or short notice inspections; this type of inspection is carried out as a result of the EC's desire to harmonize inspection practices across the European Union. Short notice inspections are associated with the implementation of new containment and surveillance measures and aim to reduce the Commission's burden of inspection;

– verifications limited to "basic technical characteristics", aimed at verifying that the information submitted is consistent with physical reality.

Since 2005, the Commission has introduced what it calls new control approaches. In addition to physical verifications and accountancy verifications, the Commission inspectors now examine the practices and quality assurance systems implemented by the operators, especially in the area of nuclear material accountancy, through an approach similar to an "audit".

Since the early 2000s, and all the more so since the enlargement of the European Union since 2005, the number of inspections performed by the European Commission in France, and their length, has decreased for financial reasons.

In 2002, in France, verifications necessitated a total of over 2,700 person-days (one person-day means one inspector spending one day at a facility); this figure fell to only 1,389 person-days in 2010. Since then, the number of person-days spent on inspections in France by the European Commission has stabilized (Figure 31).

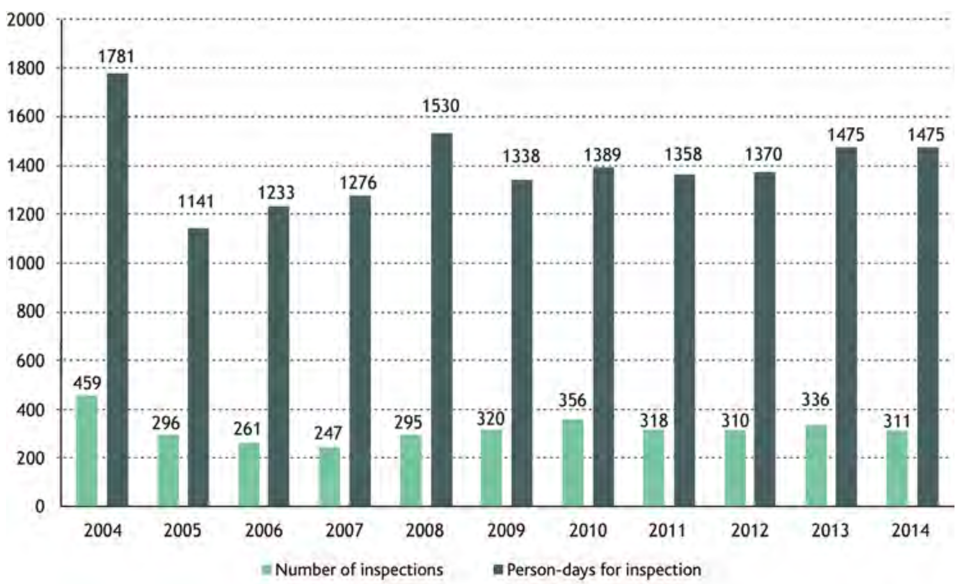

Figure 31. Histogram of inspections performed in France by Euratom from 2004 to 2014.

An inspection is usually based on three phases:

1. A preparatory phase, mainly involving Euratom inspectors since it consists in planning the inspection, collecting information on previous inspections, defining objectives and then sending notice as required to give the inspectors access to the site.
2. An *in situ* phase, at the facility, which usually consists in (accountancy and physical) verifications. Depending on the size of the facility, the type of inspection and the sensitivity of the material to be controlled, this phase can take from one to ten days. It entails physical verifications, measurements based on the list of items in stock, and verifications on the accountancy system implemented at the site (Figure 32).
3. A "post-inspection" phase, enabling the Euratom Commission to draw conclusions based on the inspection's findings and to transmit any observations it may have, and enabling IRSN people, in cooperation with the operator, to then implement any actions required as a result of the Euratom Commission's observations.

Following an inspection, the operator must draw up a report for the national authorities so that they can monitor Euratom's actions.

At the site, inspectors may be escorted by the French authority (the CTE) or its representative, usually someone from IRSN. It should be mentioned that IRSN does not escort every inspection held; priority is given to inspections held to verify the annual inventory. However, if any difficulties are foreseen, an operator may request support from IRSN for an upcoming inspection. The escort (from CTE or IRSN) is tasked with enabling the inspectors to perform their verifications correctly while protecting the operator's interests (to protect manufacturing secrets and industrial know-how, etc.). More specifically, the escort must:

– assist and advise the operator on the behaviors during the inspection and the responses given to the inspectors;

Figure 32. Samples for Euratom inspection. © European Community — Directorate-General for Energy and Transport.

– ensure that inspections at French facilities proceed smoothly;
– ensure the application of French authority directives negotiated with the Commission's services;
– ensure that the inspectors do not overstep the prerogatives defined in their inspection mandate.

Following an inspection, the escort must draw up an escort report to be submitted to the CTE and the operator.

3.3.2. Complementary access

Complementary access is dealt with by the IAEA in accordance with the provisions set out in France's Additional Protocol. Such access may be required for:

– case 1: sites declared by the operator under the Additional Protocol and regarding which a declaration has been submitted to the IAEA;
– case 2: any other site in France.

A complementary access inspection is held on the decision of the IAEA:

– in case 1, to verify that a declaration is accurate and exhaustive or to resolve any inconsistency;
– in case 2, to enhance its ability to detect any clandestine nuclear activities in a non-nuclear-weapon State.

The IAEA shall send notice by fax to the French authorities (the CTE) that such access has been decided at least 24 hours in advance. This document specifies:

– the site and purpose of complementary access;
– the objective of complementary access and the activities likely to be performed by the inspectors (e.g.: visual observations, collection of environmental samples, utilization of radiation detection and measurement devices, examination of production and shipping records);
– the date and time that complementary access will start;
– the names and nationalities of the inspectors who will visit the site.

An escort team, led by a person representing the French State to the IAEA inspectors and the operator, shall take part in complementary access. Its role is to ensure that complementary access proceeds smoothly and to ensure that the verification operations performed comply with the provisions of France's Additional Protocol. It is important to mention that the operator or its representative is required to be present throughout the complementary access.

Upon receiving advance notice, IRSN analyzes the request for complementary access to assess its compliance with the requirements of France's Additional Protocol. The CTE (or IRSN, as technical support to the CTE) then informs the operator, mainly to determine all the formalities required to enable access to the site for the various people involved and any equipment that may be used. This contact with the operator also serves as an opportunity to specify site access procedures, give instructions regarding protecting sensitive information and to organize the workload.

To perform their verification operations, the inspectors use their own equipment. The use of this equipment must be agreed in advance by the French authorities.

As soon as the activities related to complementary access have been completed, the head of the escort team draws up a report relating the result of verification operations, which must be signed by the operator's representatives and the head of the escort team. A list of any documents consulted by the inspectors is appended to this report.

3.4. French organization

3.4.1. Regulatory framework

The responsibilities of government bodies involved in nuclear non-proliferation are specified by decree. In addition, the regulations relative to nuclear material import and export operations are specified in special documentation.

3.4.2. Government bodies

The **General Secretariat for European Affairs (SGAE)** was set up in 2005, replacing the General Secretariat for the Interministerial Commission on European economic cooperation (SGCI). Reporting directly to the Prime Minister, the SGAE examines and drafts France's positions expressed within EU institutions, including Euratom. An advisory committee provides technical support to the SGAE as required for the exercise of its remit regarding issues relative to application of the Euratom Treaty (except in the case of security control). This advisory committee is called the Euratom Technical Committee (CTE).

The **Euratom Technical Committee (CTE)**, reporting directly to the Prime Minister, is made up of experts from the French Alternative Energies and Atomic Energy Commission (CEA). It monitors implementation of international controls on nuclear material in France by the European Commission under Chapter VII of the Euratom Treaty and by the IAEA under the safeguards agreement signed between France, the IAEA and Euratom. It also oversees France's implementation of the Additional Protocol to the Safeguards Agreement. The CTE is also the European Commission's and the IAEA's points of contact regarding these issues.

Also, within the framework of asset management of nuclear materials required for defense purposes, the CTE authorizes nuclear material transfers between activities subject to Euratom safeguards and activities which are not subject to these safeguards.

The **French Alternative Energies and Atomic Energy Commission (CEA)** advises the government on international policy in the nuclear field. The CEA monitors scientific, technical and economic developments with a view to clarifying the government on these subjects, notably in its negotiations on international agreements.

The **Ministry of Foreign Affairs** is responsible for defining foreign policy, under the authority of the government, and conducting and coordinating France's international relations. With regard to those aspects related to international verifications in the nuclear field, the Ministry is backed by its permanent representations to the European Union in Brussels, to the United Nations in New York and to the international organizations based in Vienna (notably the IAEA).

The **Governor for France at the IAEA:** a diplomat attached to the Ministry of Foreign Affairs and Director of International Relations at CEA, the Governor for France oversees the IAEA's entire scope of competence and the implementation of certain multilateral agreements. He represents France on the IAEA's Board of Governors.

The **Directorate-General for Energy and Climate (DGEC)**, part of the Ministry of Energy, contributes to defining French nuclear policy. In particular, the DGEC drafts France's positions for international and EU discussions, and takes part in negotiating international agreements. It manages stocks declarations relative to highly-enriched uranium and to plutonium used in civil activities.

Other institutions: other ministries, particularly the Ministry of Defense, are involved in nuclear material controls, specifically of material used in defense activities.

3.4.3. IRSN, the French Institute for Radiological Protection and Nuclear Safety

IRSN provides technical support to the public authorities and to operators for implementing international non-proliferation safeguards within France. IRSN, providing technical support to the government authorities, holds a special position in this field insofar as it advises operators on the declaration procedure and on the inspection process. An agreement signed by IRSN with the CEA and the CTE stipulates the Institute's remit in the field of nuclear material control, namely:

- to manage France's declarations as provided for under treaties and agreements;
- to prepare, escort and monitor international inspections. Within this framework, IRSN must both ensure that France complies with its international undertakings made to the relevant bodies (IAEA and Euratom) and protect the interests of French operators (protecting sensitive information and industry secrets, etc.);
- to analyze technical documentation required of entities subject to international control bodies and provide assistance and advice to entities subject to such control within the framework of implementation for treaties and agreements;
- to analyze and monitor developments or planned developments within the national and international judicial framework;
- to provide training to French industry;
- to participate in certain international working groups.

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IRSN, providing support to operators in their relations with the international bodies in charge of non-proliferation control

In endorsing the two key non-proliferation systems, one relative to nuclear weapons and the other to chemical weapons (see Chapter 4), France has made strong commitments to the international community and to the organizations tasked with implementation of these treaties (the International Atomic Energy Agency — IAEA — and the Organization for the Prohibition of Chemical Weapons — OPCW). Further, France's membership of the European Union also implies Euratom controls on the nuclear industry.

These undertakings imply *submitting declarations to* and *receiving inspections* by these organizations in French territory.

In light of their control activities, inspectors from the OPCW, the IAEA and Euratom can have access to sensitive information relative to:

- trade secrets, through access to lists of products, customers and material quantities;
- industrial property, through access to drawings, industrial processes, chemical formulae, etc.;
- non-proliferation, for the Georges Besse II plant, access to certain areas may entail disclosing information which, if disseminated, could result in the dissemination of centrifuge enrichment technology;
- national defense, through access to sites which, apart from industrial activities and civil research, also carry out activities on behalf of national defense.

As provider of technical support to the French authorities, IRSN is tasked with defending France's interests when escorting international inspections in France. IRSN therefore ensures that inspectors have access to information within the limits of the requirements set forth in an international or multilateral treaty, agreement or convention; or it will seek compromise solutions to allow the inspectors to perform their tasks without disclosing any information deemed confidential by the industrial operator.

As a result, IRSN regularly finds itself in the position of providing support or advice to an operator. Thus, as the interface with the inspectors, IRSN advises the operator on the interpretation and implementation of the applicable texts, indicating, for example, cases where inspectors may go beyond their prerogatives or where their questions are warranted but inappropriately formulated (in terms of methods rather than objectives). In all cases, IRSN makes every effort to facilitate relations between the operator and the inspectors, recalling to the latter the limits of their mandate or its objectives, and proposing, for example, alternative solutions to those planned initially.

This position of providing advice and support to French industrial operators in the chemical and nuclear fields, within the context of international non-proliferation inspections, is rather an original feature in the remit of IRSN, which traditionally provides technical support to the authorities.

Chapter 4
Non-proliferation in the chemical field

4.1. Historical background

The first "chemical weapons" appeared during various conflicts in Greek/Roman antiquity. Although rudimentary to begin with (simple poisons made out of plants), they were perfected over the centuries — as were weapons in general — and used with increasing frequency, particularly during the First World War.

Toward the end of the twentieth century, States had become aware of the need to ban the use of chemical weapons. A certain number of conventions and agreement protocols therefore came into existence. The most recent and most important of these texts is the Chemical Weapons Convention (CWC), which came into force on April 29, 1997.

As for other weapons of mass destruction, the international community has long sought to prevent the military use of chemicals. The earliest international agreement dates back to 1675 and was signed in Strasbourg by Germany and France. This treaty prohibited the use of poison bullets. In 1874, the Brussels Convention on the Law and Customs of War prohibited the employment of poison or poisoned weapons, and the use of arms, projectiles or material to cause unnecessary suffering. This convention was added to in 1899 with an agreement that prohibited the use of projectiles filled with poison gas, signed during an international peace conference in The Hague.

In spite of these agreements, the First World War saw the first use of chemical agents on a massive scale on the battlefields. Growing awareness across the world of the risks entailed in the use of such weapons, for soldiers and civilians alike, led the international community to intensify its efforts to prohibit their use. The outcome of these discussions was the signing of the 1925 Geneva Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and Bacteriological Methods of Warfare.

Nonetheless, this Protocol had some serious shortcomings: it only prohibited the use of chemical and bacteriological (biological) weapons. It did nothing to ban the development, production or possession of such weapons. In addition, the determination of the signatory countries to ban chemical weapons did not go very far: many countries were to sign the Protocol with reservations allowing them to use chemical weapons against countries that had not signed the Protocol or to respond in kind if attacked with chemical weapons.

Attitudes changed and the emergence of new kinds of weapons of mass destruction led, in 1971, to negotiations by the Eighteen Nations Disarmament Committee (now known as the multilateral Geneva disarmament conference) regarding the text of the Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) or poisonous weapons, commonly known as the Biological Weapons Convention. This prohibits the States Party to this Convention from developing, producing or possessing biological weapons, but includes no mechanism for verifying compliance with the prohibitions on the part of the States Party to the Convention. The Convention also states that the signatory States undertake to continue negotiations with a view to attaining an international prohibition of chemical weapons.

In 1988, negotiations were held in Geneva with a view to signing a credible treaty on the elimination and prohibition of chemical weapons. At the Paris Conference in 1989, negotiations were taken up from the Conference on Disarmament and pushed ahead.

In 1992, the text of the Convention for the prohibition of the development, production, stockpiling and use of chemical weapons and on their destruction, more commonly known as the Chemical Weapons Convention (CWC), was submitted before the Conference on Disarmament. The CWC, which, for the first time, includes a verification regime, was opened for signature in Paris on January 13, 1993. It was then deposited with the United Nations Secretary-General in New York.

According to the terms of the Chemical Weapons Convention, it would enter into force 180 days after the 65th country ratified the treaty. At the end of 1996, Hungary became the 65th country to ratify the Convention and on April 29, 1997, with 87 States Party to the Convention, the Chemical Weapons Convention entered into force and became binding under international law. At the end of 2014, 190 States were Parties to this Convention. Figure 33 shows the key dates in the implementation of the CWC.

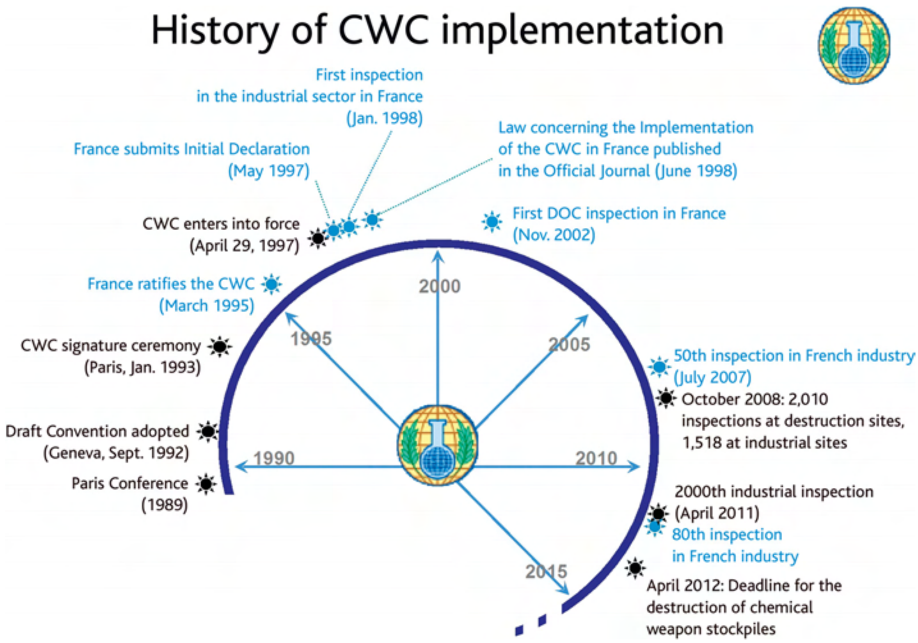

Figure 33. Key stages in the implementation of the Chemical Weapons Convention (CWC).

4.2. International context

4.2.1. Chemical Weapons Convention

The CWC has a preamble, 24 articles and annexes on chemicals, on verification of application of the Convention and on confidentiality. It is structured around three major subjects:

1. prohibition and destruction of chemical weapons,
2. non-proliferation,
3. assistance and cooperation.

4.2.1.1. The prohibition of chemical weapons and their destruction

The CWC provides for:

– the destruction by the States Parties, within a period of 10 years, of all chemical weapons held within their territory or abandoned by them in the territory of other States Parties, together with the destruction of facilities intended for their production; this deadline can be extended up to 15 years in exceptional circumstances;

– the undertaking by the States Parties not to use riot control agents as weapons of war;

– the possibility of converting, under very strict conditions, certain facilities used for the production of chemicals into facilities for civilian use;

– a declaration regime and a systematic verification regime by means of inspections performed onsite and by surveillance systems at all locations where chemical weapons are stockpiled or destroyed (see Figures 34, 35 and 36).

Figure 34. Illustration of the chemical weapons verification regime. © OPCW.

4.2.1.2. Non-proliferation

The Convention stipulates that:

– the States Parties may develop, produce, acquire, stock, transfer and use chemicals subject to the Convention provided that activities related to their use are carried out for purposes not prohibited under the Convention (including medical, pharmaceutical, research or protection);

– toxic chemicals and their precursors[6] are classified according to four categories (three schedules and the additional category of discrete organic chemicals) depending on the level of toxicity and the uses to which they can be put. Carrying out any activity in relation to these chemicals implies that the State agrees to be subject to the verification regime. This regime is based on the annual declaration of all activities and facilities related to these chemicals and on inspections which are more or less stringent and intrusive depending on the nature of the activity and the quantities of chemicals used;

6. "Precursor" means any chemical reactant which takes part at any stage in the production by whatever method of a toxic chemical.

– the transfer, as part of commercial activities, of any chemical listed in Schedules 1 and 2 to States which are not Parties to the CWC (States which have not signed or ratified the Convention) is prohibited. Any chemical listed in Schedule 3 which is transferred, for purposes not prohibited under the CWC, to any country which is not Party to the CWC, cannot be transferred a second time.

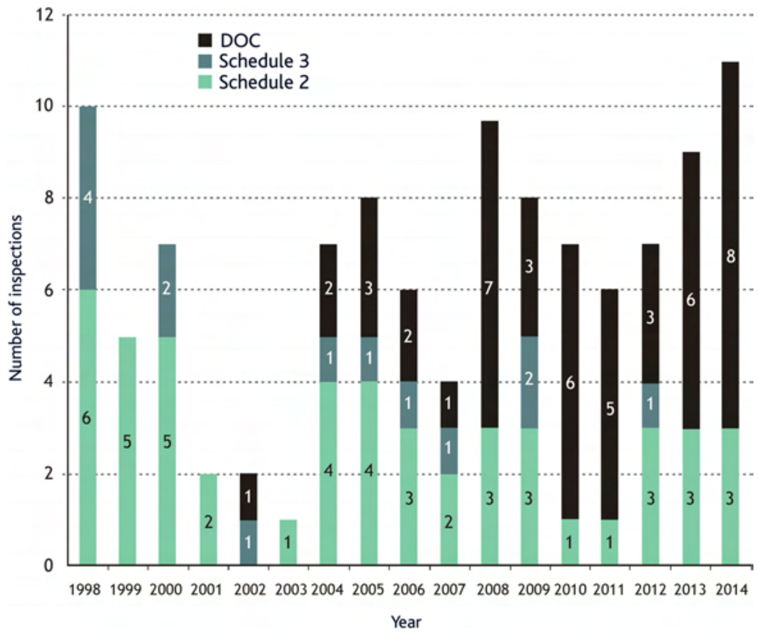

Figure 35. Histogram of inspections performed in France by the OPCW from 1998 to 2014.

In addition to the measures relating to verification at declared facilities, designed to control the chemical industry and trade, the CWC provides for various tools to detect and sanction any violation of the provisions of the treaty. It provides for:

– the possibility for a State Party to request a challenge inspection of any facility, or place, even if it has not been declared, in the territory of another State Party, to resolve any doubt about possible non-compliance with the Convention;

– the possibility of implementing coercive measures against a State Party which fails to comply with the terms of the Convention and, if necessary, to refer the matter to the General Assembly of the United Nations or the UN Security Council;

– the possibility of holding an inquiry into allegations that chemical weapons or riot control agents have been used as weapons of war, in the territory of any State Party (at the request of a State Party).

4.2.1.3. Assistance and cooperation

The Convention provides for:

– assistance and protection against chemical weapons;

– measures aimed at promoting international trade, technological development and economic cooperation in the chemical industry.

4.2.1.4. Schedules of Chemicals

As mentioned above, the chemicals subject to the CWC are classified into four categories according to the risk they pose to the object and purpose of the Convention:

– Schedule 1 lists chemical weapons and structurally-related chemicals (main characteristics: lethal or incapacitating toxicity, high risk to the object and purpose of the Convention, little or no use for purposes not prohibited under this Convention);

– Schedule 2 lists precursors to Schedule 1 chemicals (main characteristics: lethal or incapacitating toxicity, significant risk to the object and purpose of the Convention, is not produced in large commercial quantities);

– Schedule 3 lists chemical weapons that have been used in the past and precursors to Schedule 1 and 2 chemicals (main characteristics: lethal or incapacitating

Figure 36. OPCW inspection of a chemical warehouse in the USA under the terms of the Chemical Weapons Convention. © DTRA/SCC-WMD.

toxicity, a risk to the object and purpose of the Convention, may be produced in large commercial quantities);

– Schedule 4 lists discrete organic chemicals (DOC), i.e. any chemical not listed on Schedules 1, 2 or 3 belonging to the class of carbon compounds.

4.2.2. Organization for the Prohibition of Chemical Weapons

The Organization for the Prohibition of Chemical Weapons (OPCW) is the implementing body of the Chemical Weapons Convention. The OPCW's mandate is "*[…] to achieve the object and purpose of the […] Convention, to ensure the implementation of its provisions, including those for international verification of compliance with it, and to provide a forum for consultation and cooperation among States Parties*." The OPCW headquarters are located in The Hague, in the Netherlands (Figure 37).

Figure 37. The headquarters of the Organization for the Prohibition of Chemical Weapons (OPCW), The Hague, the Netherlands. © OPCW.

The OPCW has three main organs:

– the **Conference of the States Parties**. This is the principal organ of the OPCW. Major decisions relative to implementation of the CWC are taken at the annual meetings of the Conference. As its name suggests, the Conference brings together all the States Parties to the Convention. The Chairman of the Conference is appointed by the representatives of the States Parties;

– the **Executive Council**. The OPCW's Executive Council takes decisions relative to the functioning of the OPCW. It is made up of 41 members elected for a term of two years by the Conference, in accordance with a principle of rotation among the six regional groups and taking into account the importance of the chemical industry, as well as the political and security interests of each State Member. The

Executive Council meets four times a year and its Chairman is appointed by the members of the Council;

- the **Technical Secretariat**. With a staff of around 500 people, the Technical Secretariat assists the Conference and the Council. It is tasked with implementing the CWC in all areas of verification (around 180 inspectors), international cooperation, protection and assistance. It also assists the States Parties in implementing the provisions of the CWC at national level. The Technical Secretariat is headed by a Director General appointed by the Conference upon the recommendation of the Executive Council.

The Executive Council and the Conference of the States Parties are the decision-making bodies. Their main task is to make general policy decisions and settle any differences between States Parties regarding technical issues or interpretation of the CWC. The Technical Secretariat is in charge of day-to-day management and implementation of the Convention, and of inspections in particular. Under the Convention, three subsidiary bodies are established to assist the three principal organs:

- the **Scientific Advisory Board** (SAB). The SAB is a group of independent experts tasked with assessing scientific and technical innovation in the field of chemistry and reporting to the Director General. It also renders expert opinions on any proposed amendment to the Schedules of Chemicals and any other opinion that may be needed, mainly on issues such as verification practices;
- the **Advisory Body on Administrative and Financial Matters (ABAF)**. The ABAF meets regularly to advise the Technical Secretariat and the States Parties on matters pertaining to the OPCW budget and programs. It examines draft budgets drawn up by the Technical Secretariat before they are presented to the Council and the Conference for approval;
- the **Confidentiality Commission**. It main function is to settle any disputes between States Parties and the OPCW related to confidentiality.

At the beginning of 2015, 190 States had ratified the Convention, two States had signed but not yet ratified it and four States still remain outside the Convention.

4.3. French organization

4.3.1. Regulatory framework

Articles L. 2342-1 and following and D. 2342-1 and following of the French Defense Code deal respectively with the legislative and regulatory aspects of implementation of the Convention of January 13, 1993 for the prohibition of the development, production, stockpiling and use of chemical weapons and on their destruction. Implementing orders stipulate the procedures for application of these texts with regard to completing declarations, carrying out inspections, and the conditions relative to taking samples, etc.

4.3.2. Government bodies

Presided over by the French Prime Minister or his representative, the **Interministerial Committee for implementation of the Chemical Weapons Convention (CICIAC)** brings together the Ministers of Justice, of the Interior, of Foreign Affairs, of Defense, and the ministers (or their representatives) for Research, Industry, Agriculture, the Environment, Overseas France, Health and Customs.

Its main function is to monitor implementation of the Convention, propose measures to improve its implementation and contribute to defining France's position in relation to the OPCW.

The **Minister of Foreign Affairs** is the National Authority, as defined in Article VII-4 of the CWC. S/he serves as the national focal point for effective liaison with the OPCW and other States Parties, maintains an up-to-date list of OPCW inspectors who may come to inspect facilities in France, transmits national declarations to the OPCW, acknowledges receipt of any notice of inspections and immediately transmits them to the relevant ministers.

France's permanent representation to the OPCW is based at the **French Embassy in the Netherlands**. This representation informs the OPCW of France's official positions on the subject of implementation and undertakes any other procedure requested by the National Authority, including the submission of declarations.

The **Minister of Defense** is responsible for implementation of the Convention at sites placed under his/her authority. S/he protects defense interests at sites where defense activities are or have been carried out, in particular classified national defense contracts.

The **Minister of the Interior** is responsible for the collection, transportation and intermediate storage of former chemical munitions. Pending commissioning of the site for dismantling and destroying such munitions, this Minister is responsible for the storage of existing chemical munitions and those still to be collected. The Minister of the Interior is also responsible for declarations relative to the riot control agents held, to former chemical munitions and the facilities in which they are stored.

The Minister for Industry is responsible for implementation of the Convention at all civil facilities save where jurisdiction is conferred under Articles D. 2342-95 through D. 2342-102 of the French Defense Code to the Ministers of Foreign Affairs, Defense, the Interior, Overseas France and Local and Regional Authorities, Immigration and Customs. As such, the Minister:

- oversees administrative control and policing of implementation of the Convention;
- maintains an up-to-date list of facilities subject to declaration and international verifications;
- advises the organizations subject to the obligations provided for under the Convention;

- collects, formats and sends the declarations provided for under the Convention to the Minister of Foreign Affairs;
- organizes and ensures escorts for inspectors performing international verifications.

The Minister is supported by IRSN in dealing with all the technical tasks incumbent upon him/her.

The **Senior Defense and Security Official** (HFDS) of the Ministry of Industry ensures national implementation of the implementing texts of the CWC in all sectors relating to civil activities. S/he has a specific department for this.

The **Minister for Customs** is responsible for implementation of the provisions of the Convention relative to imports and exports. A special office is in charge of customs regulations applicable to dual-use items (goods and technologies that may have both civil and military uses).

4.3.3. IRSN, the French Institute for Radiological Protection and Nuclear Safety

IRSN provides technical support to the Ministry of Industry on industrial issues related to implementation of the CWC. Within the framework of an agreement signed with this Ministry, IRSN has the following duties:

- **advice and assistance**: IRSN informs and advises the representatives of the establishments affected by implementation of the CWC (advising on drawing up declarations and preparing for inspection, etc.). IRSN assists the authorities by taking part in its area of competence in various international working groups and advisory committees organized by the OPCW. At the request of the Ministry of Industry, IRSN takes part in interministerial meetings tasked with drawing up instructions given to France's representatives to the Conference of the States Parties and the Executive Council of the OPCW. Last, IRSN organizes training on the CWC and its implementation for industrial operators and officials at the relevant ministries;
- **document analysis**: IRSN analyzes all the national and international documents sent to the Ministry of Industry within the framework of the CWC and national implementation texts;
- **obligations management**: IRSN receives directly from the establishments affected by implementation of the CWC all documents and declarations containing information to be submitted to the OPCW and analyzes, controls and processes all these declarations. IRSN transmits to the National Authority all declarations to be submitted to the OPCW, drawn up using the basic declarations sent by the establishments, together with the aggregated data after processing. IRSN draws up and updates the list of establishments affected by implementation of the Convention;

– **inspection monitoring**: IRSN prepares for the inspections carried out by the OPCW at establishments which come under the jurisdiction of the Ministry of Industry and ensures a system of on-call personnel with a view to responding within the deadlines set for inspection requests. It monitors inspections in France, managing the logistics for these inspections (reception of the inspectors, control of material likely to be used during an inspection, transfer to the sites, etc.) and provides an escort for all OPCW inspections at said facilities. It monitors "post-inspection" actions, where applicable. In the event of a challenge inspection, a procedure that has not been implemented to date, IRSN would join the escort teams in accordance with the organization defined in an interministerial circular dated September 26, 2012.

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The history of chemical weapons

Greek/Roman antiquity

- wells poisoned with rye ergot (Assyrians and Persians, 6th and 4th centuries B.C.);
- hellebore roots used to poison the River Pleistos (Solon of Athens, 600 B.C.);
- incendiary devices and sulfur dioxide gas blown by the wind to cities under siege (e.g.: by Demosthenes at Sphacteria against the Spartans – Peloponnesian War, 428-424 B.C.);
- Roman equestrian soldiers wielded suffocating smoke and caustic ash in the air (siege of Ambracia, 187 B.C.);
- "Greek fire": toxic fumes from an incendiary paste invented by the Greek Kallinikos (673). For five centuries, "Greek fire" was the secret weapon used by the Byzantines against the Turks. The Turks were later to use it themselves for their conquest of the Greek Empire in the 14th century.

Middle Ages and the Renaissance

- toxic and sleep-inducing vapors (Hassan Abrammah, late 11th century);
- barrels of blinding quick lime catapulted by the English fleet at French ships (mid-13th century);
- bombs, grenades and rags soaked in arsenic and set on fire (used against the Turks by the defenders of Belgrade in 1456, weapons factory in Berlin in 1457);
- poisoned arrows dipped in curare (used by Amazonian Indians up to the 20th century), batracyotoxin from frog venom (in Hawaii), aconitine (used by the Moors in Spain in 1483);

- various devices made using sulfur, mercury, turpentine and even nitrates and other "*stratagemae*" cited in many military treatises. They were only used for limited objectives;
- cluster cannonballs that "poisoned" assailants from the tops of city walls (15th century);
- "stink pots" and toxic bombs, used in large quantities by the Imperial army (Thirty Years War, 1635-1648).

18th century

More advanced devices were made using arsenic, orpiment (or yellow arsenic), lead, white lead, minium, *vert-de-gris*, antimony with added belladona, euphorbia, hellebore, aconite, nux vomica and venom (!) (cited by German military author, Flemming, 1726). We do not know if these were ever used or not.

19th century

Projects which never came to fruition since priority was given to ballistics, guns and cannon and because some discredit was attached to "poisoned" weapons:

- a British plan to fatally fill the Russian garrison at Sebastopol with smoke from 500 tonnes of sulfur and 200 tonnes of coke (Crimean War, 1854-1855); this plan was never executed, and nor were the plans to use bombs filled with "Cadet de Gassicourt" liqueur;
- development of chlorine shells to use against the Confederates (United States – War of Secession, 1861-1865); the plan was rejected.

Contemporary era: the Great War (1914–1918)

- April 22, 1915: near Ypres, 6,000 containers (30,000 according to some writers) containing 180 tonnes of chlorine were dispersed by two battalions across six kilometers at the Front. Blown by the wind, the cloud of gas caused the deaths of 5,000 soldiers and put 1,500 out of combat, causing intense panic;
- May 31, 1915: further and more deadly attacks were made using a mixture of chlorine and phosgene on the Russian Front: 12 km at Bsura-Rumka. There were 9, 000 casualties, including 6,000 dead, after 12,000 canisters of the gas were used;
- July 1915: 100,000 "T-Stoff" shells (benzyl bromide) were shot using 155 mm guns in Argonne;
- March 1916 in Verdun: 75 mm shells containing phosgene ware used causing instantaneous death;
- July 1916, for the Somme Offensive: shells containing hydrogen cyanide were used;

- March 1917: phosgene sprayed from aircraft, causing significant and deadly concentrations of phosgene;
- July 1917: chemical warfare reached its apogee with the use of yperite, or "mustard gas" (dichloroethyl sulfide [see Figure 38]) in the area of Ypres — hence its name. Its toxic effects do not only act on the respiratory system. It is a persistent and insidious blistering agent, causing agonizing burns. Its psychological effects are disastrous. 9,500 tonnes of mustard gas were produced;
- September 1917: the first use of "Clark 1 agents" based on arsines, which induce nausea and vomiting and which are not blocked by gas mask filters;
- 1918: large-scale use of shells filled with aggressive gases by all the warring parties; during attacks, around 25% of the projectiles used by both sides were chemical shells.

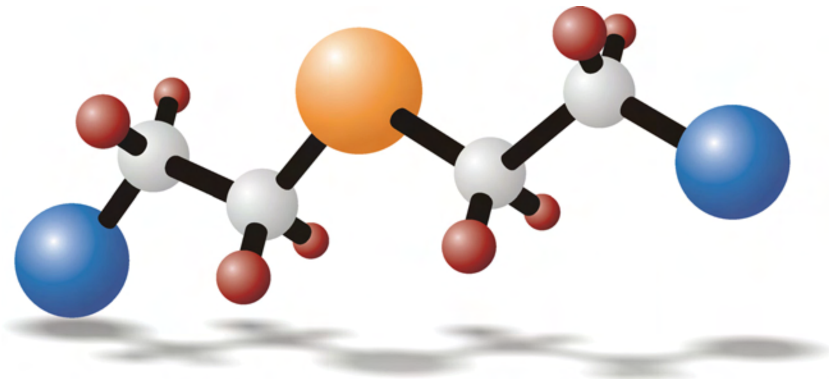

Figure 38. Chemical formula of yperite $C_4H_8Cl_2S$ (mustard gas).

Number of deaths

The total number of lives lost due to combat gases — mainly yperite —, although substantially reduced thanks to improved gas masks and other immediate protective equipment, was 1,300,000 men (including nearly 100,000 killed in battle), while losses due to other types of weapons are estimated to be 26,700,000 men (including 6,800,000 killed in battle). The survivors, suffering from lesions of varying degrees of severity caused by the use of gas, subsequently often fell victim to fatal infectious diseases. These estimates seem much lower than the actual number of lives lost.

It should be noted that it was the Russian troops who suffered the heaviest losses caused by gas, accounting for 11% of deaths by gas, compared with an average 7% all sides combined.

Between the wars

- 1920: in Russia, chemical weapons were used during the civil war;
- 1925 (the year that the Geneva Protocol was signed): yperite was used in the Rif War;

- 1935-1936: large-scale use of yperite against the Abyssinians, leading to the fall of Ethiopia;
- 1937 to 1941, Japan, a huge producer of yperite and arsines on Okinoshima Island, used toxic gas against China, particularly in the attack on Yichang (yperite and Lewisite; use of these chemicals subsequently came to an end after B.A.L. antidote was discovered).

The Second World War

Except in the Far East, practically no chemical weapons were used by the warring parties, for a number of reasons:

- the new nature of the campaigns: the “Blitzkrieg”, wars of movement instigated by the Axis forces and then by the Allied forces who quickly gained supremacy in the air;
- the deterrent effect of the type of chemical weapons that the Allies pretended to have compared to those of the Germans, notably the large-scale production and stockpiling of new toxic gases — including tabun and sarin, with similar efforts having been made by the Russians, even while Hitler’s armies were advancing on Stalingrad (1942).

However, it is doubtful that there was any actual “balance” in the potential chemical weapon resources held by any side.

The Post-war period

During the 1950s, the Cold War years, a decisive turning point was reached. The United States and NATO forces on the one hand, and the USSR and the Warsaw Pact countries on the other, tried to out-rival each other in their research and large-scale production of increasingly sophisticated and effective chemical weapons:

- from 1963 to 1968: Egypt used yperite in Yemen, and the USA used dioxin in Vietnam;
- in 1973, during the Arab–Israeli War, the Israelis intercepted various Soviet devices which revealed the USSR’s new chemical warfare capabilities;
- this development was confirmed during the War in Afghanistan (1979-1983), which afforded the Russians a test field for new chemicals that were difficult to detect;
- from 1975 to 1983, Vietnam used a huge quantity of toxic chemicals and toxins against the rebel forces in Laos, and especially in Cambodia (Haig Report);
- from 1982 to 1988, Iraq used chemical weapons on various occasions:

    a. the Iran-Iraq War: Iraq used yperite, cyanide and tabun against Iranian troops, who suffered heavy losses (10,000 seriously injured and an unknown number of deaths). The Halabja affair (1988), a "simple" policing operation which resulted in the deaths of 5,000 demonstrators;

b. the Gulf War (1990), "a major event in the history of chemical warfare" when the threat posed to the international community by Saddam Hussein's arsenal of chemical agents reached its peak. Iraq's stocks were then the third largest in the world, including nearly 50,000 shells and bombs containing yperite, sarin and cyclohexyl sarin;

c. similarly, there is no longer any doubt that tabun gas and yperite were used on a massive scale against the Kurds and Shi'ites in the south, killing thousands;

- December 1987 to December 1990, the USA, after a break of 19 years, again started to produce chemical weapons to catch up with the Russians.

Some accidents… and incidents

- 1968: USA, VX nerve agent accidentally spilled from a Phantom fighter jet flying out of Dugway air base (Utah), killing 6,000 sheep;
- 1969: Belgium, one or two barrels of yperite leaked offshore; seals and fish were killed and some fishermen and children (on the beaches) suffered burns;
- 1972: at Fort Greely (Alaska), 50 reindeer were killed by sarin gas (200 canisters that had been stored on the frozen lake sank as the ice melted);
- 1979: near Hamburg (Germany), a child was killed by tabun (stored canisters);
- 1990: in Libya, in the desert in Tarhuna (65 km from Tripoli), the chemical plant in Rabta, thought to be the largest chemical weapons factory in the world, was destroyed by a mysterious fire;
- 1995: a terrorist attack released sarin gas in the Tokyo metro, causing dozens of victims (and eight deaths);
- 2007: chemical attacks using chlorine gas were made against the population in Iraq.