

## IRSN PROGRESS ON EMERGENCY PREPAREDNESS AND RESPONSE IN CASE OF CRITICALITY ACCIDENT

Julien Rannou <sup>(1)\*</sup>, Gaël Loubert <sup>(1)</sup>

<sup>(1)</sup> Institut de Radioprotection et de Sûreté Nucléaire (IRSN),  
PSN-RES/SNC/BERAC, PSE-SANTE/SESUC/BSNT, F-92260 Fontenay-aux-Roses, France.

\* [julien.rannou@irsn.fr](mailto:julien.rannou@irsn.fr)

### ABSTRACT

*In France, during nuclear emergency situations, the Institute for Radioprotection and Nuclear Safety (IRSN) provides technical, public health and medical guidance to French public authorities on measures to be taken to protect the population, workers and the environment, while contributing to the restoration of the safety of the facilities. IRSN has an emergency response center where emergency responders are mobilized to assess the emergency situation in several technical units, one of which is dedicated to the assessment of the facility. The main tasks of this “facility assessment” unit are to assess the current state of the damaged “object”, predict the development of the emergency situation, evaluate the radioactive materials releases into the environment, and verify the suitability of the operator's measures to minimize the releases and retrieve a stabilized and safe state of the facility. Within this unit, there is a “criticality specialist”, whose function is to assess an ongoing or ended criticality accident but also to evaluate the criticality risk in any case of an emergency situation. After a brief overview of IRSN's emergency organization, this article details how the “criticality specialist” function fits into this organization and in which cases it is activated. The article also presents the tools and resources used to fulfil this function, how the “criticality specialists” are recruited and trained, and how they practice to ensure that they are operational during emergency situations. A first experience feedback acquired by this function during its participation in drills and real emergencies is also shared, as well as the resulting perspectives.*

### KEYWORDS

*Emergency organization, criticality accident, criticality specialist*

## 1. INTRODUCTION

Beyond a permanent and rigorous prevention policy, France has had an emergency response system in place for more than 30 years to deal with a nuclear accident or radiological emergency situation. The system is based on the organization of four major players:

- the nuclear operator, which is responsible for its facility;
- the French safety authorities that issue regulations to operators and advise the government;
- the French government, which is responsible for the protection of the population in the event of an accident;
- the Institute for Radioprotection and Nuclear Safety (IRSN) that provides technical assessment on radiological and nuclear risks, and support to public authorities, and puts forward recommendations to the safety authorities on technical, health and medical actions to take to protect population, workers and the environment, and recommendations to bring the facility under control.

In addition to its mobile measuring devices and its laboratories, IRSN has an emergency response center, named CTC (french acronym for Centre Technique de Crise), in Fontenay-aux-Roses (near Paris) where emergency responders are mobilized to assess the emergency situation. The “facility assessment” technical unit, which is one of the units in place in the CTC, is in charge of:

- assessing the state of the facility or of the transport package;
- predicting the development of the emergency situation;
- evaluating the radioactive materials releases into the environment;
- verifying the suitability of the operator's measures in order to minimize the releases and bring the facility to a stabilized and safe state.

This unit comprises 9 functions described in section 3.1, including the “criticality specialist”, which is devoted to assessing an ongoing or ended criticality accident but also evaluating the criticality risk during the emergency situation.

Following the reorganization of IRSN's emergency response initiated in the 2010s, the “criticality specialist” function was updated five years ago in terms of its organization, the missions to be performed and the associated resources. After a brief overview of IRSN's emergency organization (section 2), this article details how the “criticality specialist” function fits into this organization and in which cases it is activated (section 3.1), and its missions (section 3.2). After detailing the tools and resources used to fulfill this function (section 3.3), the article moves on to describe how the “criticality specialists” are recruited and trained, and maintained as operational for emergency situations (section 3.4). A first experience feedback acquired by this function during its participation in drills and real emergency situations over the last five years is also shared, as well as the resulting perspectives (section 4).

## 2. IRSN'S EMERGENCY ORGANIZATION

During emergency situation, the IRSN's emergency organization is mobilized to carry out the following missions:

- providing technical support to the authorities to enable them to make decisions regarding the protection of the population, workers and the environment. The reference levels considered for the protection of the population are a predictive effective dose over the emergency phase of 10 mSv or greater for sheltering, 50 mSv or greater for evacuation, and an equivalent dose to the thyroid of 50 mSv or greater for stable iodine intake [1];
- participating to the measurements and the assessment of all measurements of radioactivity in the environment performed during the emergency;
- contributing to communication by providing public information on the situation, putting risks into perspective and reporting on environmental radioactivity results in the environment.

The IRSN's emergency organization is a structure specifically defined to meet the needs of emergency management. It comprises:

- a “crisis director”, acting for the Chief Executive Officer (CEO) by delegation, responsible for coordinating the entire emergency organization;
- a set of units, consisting of 50 to 60 people in total:
  - units within the CTC, each with specific areas and a platform of tools and resources dedicated to emergency management. There are 7 units in total, including the “direction” unit, the “facility assessment” unit, the “radiological consequences” unit, the “health” unit, the “communication” unit, the “international” unit, and the “logistics support” unit (total of 40 to 50 people);



**Figure 1. A view of the CTC (left) and of the “facility assessment” unit (right)**

- a mobile unit (12 people) that contributes to the assessment, by deploying, on or near the scene of the event, means of measurement and analysis in the field of radioactive contamination of the environment and people;
- IRSN representatives deployed to external bodies in the event of an emergency (interministerial emergency centers, operational centers in prefectures, embassies, etc.);
- IRSN's permanent laboratories, in the fields of the environment and health.

This dedicated emergency management organization has been defined in order to respond to a wide variety of plausible situations. Due to the specific nature of each situation, the organization is flexible and can be deployed completely, or partially, or even by calling on the IRSN's assessment and resources non dedicated to the emergency management. Mobilization of the IRSN's emergency organization can be triggered by an explicit external request (national alert system triggered by an operator of a nuclear facility or by the nuclear safety authority, telephone contact with the IRSN on-call manager) or by internal request (remote monitoring of ambient gamma radiation in the air with the TELERAY network [2], media tracking, etc.). The mobilization decided by the IRSN CEO commits the whole Institute. Once the decision is made, the emergency organization is mobilized within one hour after CEO decision. The CTC objective is to be able to send the first results of its assessment within one hour. All employees are expected to contribute to emergency management in some way but some, called "emergency responders", are identified to perform a specific function within the IRSN's emergency organization. Some functions may or may not on-call. A pool of emergency responders is associated with each function to ensure its availability during an emergency. An emergency responder is an IRSN employee holding a function in the IRSN's emergency organization, having received training for this function and providing personal contact details so that he can be reached outside regular working hours. The IRSN emergency responders consist of more than 400 IRSN employees out of about 1700.

### **3. THE "CRITICALITY SPECIALIST" IN THE IRSN'S EMERGENCY ORGANIZATION**

#### **3.1. A specialized function of the "facility assessment" unit in the CTC**

The "criticality specialist" is a member of the "facility assessment" unit of the CTC. The organization of the "facility assessment" unit differs slightly depending on whether the emergency affects a nuclear power plant, another type of facility or a transport of radioactive materials. However, the role of the "criticality specialist" remained identical regardless of the encountered situation.

During an emergency situation, the "facility assessment" unit has the following missions:

- to assess and prognosticate the state of the facility or of the transport package;
- to estimate the actual and/or potential release to the environment (known as the source term, e.g the nature of the release, the released activities, and the release height) and forward it to the "radiological consequences" unit;
- to inform the "radiological consequences" unit and the "direction" unit of the facility state and potential developments;
- to participate in periodic consultations with the operator through audio conferences in order to retrieve information and compare the results of IRSN's assessments with the operator's;
- to verify the appropriateness of the means proposed by the operator to minimize releases outside the facility and to bring the facility back to a stabilized state.

In order to carry out its missions, in case of an event affecting a facility other than a nuclear power plant (case the most relevant for the criticality risk), the "facility assessment" unit is composed of 9 functions, each occupied by one person (possibly two), and which interact with each other as needed, including:

- 4 functions mobilized for every type of accidented facility and composed of the same pool of emergency responders, regardless of the type of accidented facility: "unit leader", "security/malicious specialist", "audioconference responsible" and "release evaluation specialist";

- 2 functions mobilized for every type of accidented facility, but composed of a pool of emergency responders that depends on the type of accidented facility: “unit deputy” and “information procurement specialist”;
- 3 functions mobilized only for given situations: “thermalhydraulics”, “safety liaison” and “criticality specialist”.

There are 5 functions that are on-call at all times: “unit leader”, “security/malicious specialist”, “audioconference responsible”, “release evaluation specialist” and “thermalhydraulics specialist”. Although the “criticality specialist” is not on-call, he can be reached at any time to join the CTC. If the call is made during working hours, the “criticality specialist” is required to report to the CTC. Outside of regular working hours, he does his best to be available and fulfill his function, but there is no obligation to do so. The pool of “criticality specialist” emergency responders consists currently of 6 people. This relatively small number is a compromise between ensuring that at least one person is available in the event of an emergency and maintaining minimal practising for each of these people.

In practice, the “criticality specialist” is mobilized according only to the type of facility affected. He is called upon at the very beginning of an emergency if the emergency situation concerns a pre-identified laboratory or a fuel cycle facility (civil and military) among about 70 different facilities, which obviously include those with the highest criticality risk. In other cases, the “unit leader” may request the “criticality specialist”’s assistance if deemed necessary. The choice of a single criterion for the call of the “criticality specialist”, based solely on the name of the facility, is motivated by the objective of the quickest possible mobilization, because of the limited information available at the beginning of an emergency. Having multiple criteria for mobilization could slow down the process of mobilization in an emergency situation. On the other hand, this wide range of facilities leading to the reflex mobilization of the “criticality specialist” may lead this specialist to evaluate an emergency situation where the criticality risk is in fact excluded, due to factors such as the nature of the materials involved for example.

If the criticality risk is not intrinsically ruled out, the presence of the “criticality specialist” in the CTC enable the most accurate criticality risk assessment. Furthermore, an emergency is characterized in particular by its rapid evolution through multiple stages, making it inherently unstable by nature. An emergency situation with no initial criticality risk may “degenerate” into a situation with a potential criticality accident situation. Thus, having the “criticality specialist” present at the CTC from the beginning ensures a more reliable assessment and prognosis of the situation and ensures that any action that could have an impact on the criticality risk is analysed.

### **3.2. Missions of the “criticality specialist”**

The “criticality specialist” has several missions that suit to those of the “facility assessment” unit. These missions depend on whether a criticality accident is ongoing (or has occurred) or whether the situation is likely to lead to a criticality accident. The main objective is to contribute to the evaluation of the radioactive material releases into the environment and allow the CTC to recommend actions of protection of the populations. In the particular case of a criticality accident, the dosimetric consequences due to direct irradiation (neutron and gamma) must also be evaluated to make these recommendations.

#### **3.2.1 Emergency situation with a criticality accident**

In an emergency situation with a criticality accident, the “criticality specialist” must assess and prognosticate the status of the situation, collaborate with the “release evaluation specialist” and the “radiological consequences” unit of the CTC to evaluate the predicted dosimetric consequences of the criticality accident, and verify the appropriateness of the measures suggested by the operator to stop the criticality accident.

In practice, the assessment consists first confirming or ruling out the reality of the criticality accident. The “criticality specialist” must analyze the information received and gather the first elements necessary

for the assessment, in particular to be able to judge the reality of the criticality accident. This may include for examples: the triggering of the Criticality Accident Alarm System (CAAS), an higher than background levels of neutron and/or gamma dose rate measured by radiological protection instrumentations, the detection of an increase in the activity released, the measured release of iodine or noble gases, the identification of operations that could have triggered a false criticality alarm (such as periodic tests, handling of an irradiating material near CAAS detectors, high increased temperature, etc.), others sensitive operations that were recently conducted out, testimony from the operators, etc. This step may involve participating in audio conference discussions with the operator and requesting additional information.

Once the criticality accident is confirmed, the first step is to evaluate the source term. To accomplish this task, the “criticality specialist” must determine the type of criticality accident (e.g; accident in solution, powder, etc.) and estimate the total number of fissions. These two pieces of information directly influence the fission product release calculation. The release also includes a fraction of the radioactive material involved in the criticality accident. The characteristics of the radioactive material (e.g. mass, isotopes and activity) to be taken into account are discussed between different functions (“unit deputy”, “release evaluation specialist” and “criticality specialist”) of the unit. Based on all these data, the “release evaluation specialist” determines the source term, taking into account the suspension coefficients adapted to the situation and the filtering. The source term is then transmitted to the “radiological consequences” unit which calculates the resulting doses at different distances, taking into account the release height and the current meteorological conditions.

The second step in calculating dosimetric consequences is the estimation of the dose due to the direct irradiation (neutron and gamma), which is performed by the “criticality specialist”. This process requires determining the type of criticality accident (moderate energy spectrum or not) and estimating the resulting number of fissions, these data being consistent with those used to calculate the source term, and also the nature and the thicknesses of the shieldings. The “criticality specialist” must collaborate with the “radiological consequences” unit to determine the distances at which the dose due to direct irradiation need to be calculated, i.e. the calculation points of interest (distances used for the release calculation, site boundary, location of ambient irradiation measurement beacons, populated areas, etc.), consistent with the distances used for the release impact calculation. The “criticality specialist” sends then the results of the effective dose due to radiation at the selected distances to the “radiological consequences” unit, which adds it to the estimate of the dose due to the release. The combined result (sum) is then used to determine any necessary actions to protect the population.

The calculation of dosimetric consequences implies having some idea of the location and type of the criticality accident, which may not be necessarily the case at the beginning of an emergency situation. By default, it is therefore appropriate to consider bounding assumptions. The calculation is subsequently updated as soon as more precise information on the emergency situation become available.

If the prognosis of the situation concludes that the criticality accident has self-stopped, the “criticality specialist” must then ensure that the actions taken by the operator are not likely to challenge the subcritical state. If the criticality accident is self-sustaining, the “criticality specialist” verifies the appropriateness of the measures proposed by the operator to stop the criticality accident. This verification may concern the technical feasibility of the means envisaged, their effectiveness and the limitation of the dosimetric consequences (release and direct irradiation) due to the intervention. For example, if the only way to stop a criticality accident in solution is to evaporate the solution, this action will generate a release that must be discussed with the authorities.

### **3.2.2 Emergency situation without a criticality accident**

In an emergency situation without a criticality accident, the “criticality specialist” must assess and prognosticate the status of the situation to assess the conditions under which a criticality accident could

potentially occur, verify the appropriateness of the measures suggested by the operator to avoid a criticality accident. In the event of a proven risk of a criticality accident, the “criticality specialist” must collaborate with the “release evaluation specialist” and the “radiological consequences” unit of the CTC to evaluate the predicted dosimetric consequences of the potential criticality accident.

In this type of situation, the most frequently encountered, the “criticality specialist” must ask himself whether the situation in progress can “degenerate” into a criticality accident. If the answer is “no” at a given moment, this conclusion must be periodically reassessed based on the events during the emergency. For example, in the event of a fire in a cell where moderation is limited, the operator will initially prohibit the use of water; nevertheless, if the means initially planned to put out the fire are ineffective, the question of the use of water as a last resort may be raised. This assessment is difficult for the “criticality specialist” because the information is often fragmented and arrives later: it is therefore necessary to anticipate the evolution of the situation. In general, this type of assessment is in line with the “classic” assessment of safety cases, which should make it possible to avoid having to improvise during emergency management. The assessment of the “criticality specialist” is then based on an approach of identification of the status of criticality safety “barriers” (what are the means of control of criticality-safety affected ? what are the criticality-safety requirements no longer respected ? Can the current or planned intervention affect the subcriticality ?).

If there is a significant risk of a criticality accident, the “criticality specialist” follows the same organization as for a criticality accident emergency situation (see section 3.2.1) and participates in the evaluation of the predicted dosimetric consequences of the criticality accident, taking into account knowledge of the status of the situation (location of the potential criticality accident, type of fissile material involved, feared mechanism of criticality reaching, etc.). Anticipating the consequences is critical in this situation because it allows for proactive measures to protect the population (if the current event has not already imposed protective actions), rather than reacting after the consequences have already occurred in part during an ongoing criticality accident.

### **3.3. The tools and resources for the “criticality specialist”**

The assessment performed by the “criticality specialist” at the CTC is very different from the daily criticality risk assessment. That’s the reason why the “criticality specialist” has access to tools and resources at the CTC to fulfill his missions. One of the primary tool available to him is a checklist that the specialist takes as soon as he has entered the CTC. This practical document lists the tasks that need to be carried out in a chronological order, specifying those that must be renewed periodically (assessment and prognosis).

To quickly perform a bounding estimation of the release and its dosimetric consequences in order to define possible actions to protect the population (“how large is the playing field ?”), the “criticality specialist” has access to 5 “typical criticality accident sheets”. Each sheet addresses a specific type of criticality accident: plutonium solution, dissolution solution of spent fuel, solid plutonium metal, plutonium powder and fuel rods in water. For each sheet, the calculation of the release and its consequences is carried out in integrality, considering assumptions that are deemed penalizing (such as the number of fissions, inventory of fission products created, rate of suspension, boiling in fissile media in solution, etc.). These sheets were created in 2000 and revised in 2018. During this revision, the scope of application of each sheet was specified, the recommendation of an initial total number of fissions equal to  $5.10^{18}$  was generalized to all types of accidents, short-lived fission products ( $^{90}\text{Kr}$ ,  $^{137}\text{Xe}$ ,  $^{140}\text{Xe}$  for example) were added to the inventory, and the characteristics (isotopy, activities) of the radioactive materials involved in the criticality accident were updated to align with current nuclear fuel cycle data. Each sheet comprises of 3 sections: the first section specifies the assumptions used to calculate the release and the corresponding tabulated results, the second section deals with the calculation of the impact of the release (reaching distance of the reference dose levels, doses for predefined distances, depending on meteorological conditions), and the last section is about the calculation of the long-term

impact of the release on the environment and the health of the population. The first section is dedicated to the “facility assessment” unit, while the others two are for the “radiological consequences” unit. In practice, the “criticality specialist” selects the most suitable sheet and specifies the assumptions to be considered to the “release evaluation specialist”. It is essential to remember that the sheets are merely an initial calculation of the consequences, and that the criticality accident may certainly not precisely align with the assumptions of the selected sheet. During an emergency situation, when the assessment has to be conducted with incomplete data, significant uncertainties, and the use of simplifying assumptions, estimations of order of magnitude are permitted. The evaluation of the release and its consequences are then refined, taking into account the information obtained during the emergency.

To calculate effective doses due to direct irradiation at various distances, the “criticality specialist” can use direct-reading abacuses, available for two families of criticality accidents: a criticality accident in a moderate fissile system and an accident in a fast fissile system. These abacuses are normalized to  $5.10^{18}$  fissions, in the air, and for two types of shielding (concrete and water with variable thicknesses). These abacuses take into account empirical results and Monte Carlo calculations up to 1 km. However, comparisons with similar tools have shown discrepancies on the calculated dose with these abacuses, so they will be replaced within two years by a new tool based on the calculation results obtained in the context of the “slide rule” update work in which IRSN has been participating since 2015 [3].

These abacuses are featured on a form within the “criticality specialist” guide, which comprises 10 additional forms, each addressing a theme relevant to the missions of the “criticality specialist”. The purpose of these forms is to provide concise and synthesized information. In addition to the radiation dose calculation abacuses, some forms provide a list of questions to ask at the start of an emergency situation to ensure an accurate assessment and prognosis (confirm/deny the criticality accident, main points of the assessment to be carried, how to write a message intended for the CTC, criticality calculations, how to interpret the French CAAS information, recommendations on the number of fissions according to the type of criticality accident [4] and field of validity of each “typical criticality accident sheet”). This guide is regularly updated with new forms based on feedback from the previous drills. Thus, future updates to the guide will include new forms on the criticality risk in a fuel storage pool or in case of an enriched UF<sub>6</sub> leak.

The “criticality specialist” can also perform criticality calculations at the CTC using CRISTAL package [5] and the Licorne tool [6] if necessary. These calculations can be helpful in removing doubt about the criticality risk and assessing the appropriateness of a mean envisaged to stop a criticality accident (such as calculation the required amount of neutron poison). To ensure the availability of results in a timely manner, these calculations must be “simple” (typically standard calculations). They can also be carried out by a person outside the CTC who is not part of the emergency responders, allowing the “criticality specialist” to remain available for the “facility assessment” unit. Finally, a compilation of more than 200 criticality studies (calculation of reference values for different fissile media) and criticality standards are available at the CTC. Significant effort has also been done to collect facilities specific documents that may prove useful in the event of an emergency situation (processes, criticality risk prevention measures, means of detecting an accident, dose maps, etc.).

### **3.4. Recruitment, training and practise of the “criticality specialist”**

The “criticality specialists” are recruited through a call for applications open to all IRSN employees. Those who are already specialised in criticality risk assessment are obviously the main target. Thus, the ideal candidate is someone with a strong knowledge of the criticality risk and the physical phenomena associated with a criticality accident. The skills required include teamwork, stress resistance, adaptability and information processing.

Candidates whose applications are accepted go through a one-day general presentation of the emergency response organization, followed by an initial training which includes a one-day common core relating

to the operating of the “facility assessment” unit, and an one-and-a-half day specific training for the “criticality specialist” function. The first day of this specific training aims to introduce the role and the missions of the “criticality specialist”, as well as the initial and periodic actions to be carried out at the CTC. The training covers the available tools and resources available at the CTC, along with the best practices to be applied during an emergency response. This includes knowing how to carry out an assessment with incomplete data and/or significant uncertainties, recognizing that the accuracy of the assessment may vary over time, seeking orders of magnitude and being satisfied with them, knowing how to use simplifying assumptions, anticipating, sharing and confronting information, not waiting indefinitely for information, avoiding preconceptions about information and understanding how to write concise, clear and well-organised messages. These points are very important as the assessment required during an emergency is different from the assessment that an emergency responder typically performs as part of their routine daily activities. This theoretical training is completed with a half a day scenario-based drill, played in real time, as close as possible to a real situation. The drill includes simulated pressure, reversals of situations and other realistic elements. At the end of this drill, the trainers assess the candidates' ability to join the IRSN “criticality specialist” emergency responders pool. Trained individuals who are considered suitable are then integrated into the pool for a four-year term. The first emergency drill for an emergency responder is carried out in pairs or under the supervision of a coach. In order to maintain their skills over time, “criticality specialists” are required to take part in a drill at least once every two years. Due to the limited number of drills that focus on criticality theme, scenarios can be specifically developed for them. Observing a drill is also a way to maintain skills.

The “criticality specialist” pool is led by two coordinators who manage feedback, information exchange and the collection and reporting of members needs. The coordinators and the pool members meet for round table discussions once or twice a year to review the actions plan and annual roadmap. Each “criticality specialist” is expected to spend approximately 10 days per year on emergency preparedness. This time includes participation in drills, round table discussions, and contributions to action plan.

#### **4. FIRST EXPERIENCE FEEDBACK AND PERSPECTIVES**

Based on the last five years, a preliminary assessment can be made on the performance of the criticality specialist function and the potential areas for improvement. During this period, the function was activated 12 times at the CTC: 10 mobilizations for drills and 2 mobilizations for real events ([7] notably). Among these 10 drills, 2 simulated a criticality accident in a fuel fabrication facility.

##### **4.1. Organizational aspects**

The first observation is that due to the low frequency of mobilization of the function, it is challenging to maintain the skills of each team member who should typically participate in at least one drill every two years. To compensate for this, since last year, it has been decided to perform systematically once a year an internal IRSN drill involving a criticality accident, dedicated to train specifically the “criticality specialists”. Another development strategy is to encourage operators to invite the IRSN to participate in their internal drills, particularly if they include an issue related to the criticality accident. It is also suggested to “criticality specialists” to have periodic visits of the CTC to prevent loss of reflex and knowledge regarding the location of tools and documentation.

During the 12 mobilizations, the “criticality specialist” was often contacted several hours after the beginning of the emergency (no reflex mobilization due to the affected facility), usually by the “unit leader” of the “facility assessment”, essentially to rule out the possibility of a criticality risk. Integrating the “facility assessment” unit into the emergency response process “along the way” can be challenging since the “criticality specialist” must quickly assess a large amount of information before beginning his assessment. To facilitate this process, the “unit leader” (or another function of the unit clearly designated by the “unit leader”) should present to the “criticality specialist” the status of the situation upon his arrival at the CTC after receiving a call during the emergency. On the other hand, there have been



instances where the “criticality specialist” was not called in at the very beginning of a drill, even though the damaged facility was a reflex mobilization criterion. To ensure that this reflex call criterion is now well integrated by the emergency organization, during a drill with reflex mobilization, the criticality specialist is pre-positioned in his office and awaits the call, rather than already being present at the CTC while waiting for the drill to start.

During some drills where a “criticality specialist” was not present, the “facility assessment” unit did not always identify a potential criticality risk, despite the involvement of fissile materials. The unit was totally focused (“tunnel effect”) on managing the ongoing accident (typically a fire or a UF<sub>6</sub> leak) and did not consider the impact of the intervention methods used (use of water to put out the fire or limit dispersion of the HF cloud) on the risk of criticality. In recent years, there has been a growing presence of individuals with knowledge in criticality risk in various roles at the CTC, which helps to mitigate the risk of not identifying a criticality risk during an emergency. However, there is still a need to increase awareness of the criticality risk during a nuclear emergency among key functions. The awareness-raising initiative that was started last year for the emergency responders of the “radiological consequences” unit will continue this year with the “unit leader” and “release evaluation specialist” functions of the “facility assessment” unit. The aim is to clarify the interface between the “radiological consequences” unit and the “criticality specialist” regarding the calculation of dosimetric consequences of a criticality accident (who does what?), following the example of the interface already predefined with the “release evaluation specialist”. This awareness-raising also made it possible to define the organization set up in an emergency situation that would require the assessment of the “criticality specialist”, but where he would not be present because he is not on-call. The decision was made to assign the responsibility of assessment to the on-call functions in the absence of the “criticality specialist” during an emergency. Specifically, the “radiological consequences” unit would be responsible for calculating the dosimetric consequences resulting from direct irradiation, while the “release evaluation specialist” would be responsible for the entire calculation of the source term. Upon arrival at the CTC, the “criticality specialist” would take over these tasks in accordance with their designated duties.

#### **4.2. Technical aspects**

For drills with a criticality accident, feedback indicates that there were no real technical difficulties for the “criticality specialist” to assess the situation. However, this observation must be nuanced because it pertains to only 2 drills scenarios that were very similar to those already provided for in the emergency plans evaluated elsewhere. One of the lessons to be learned for the future is to create more complex criticality accident scenarios to challenge the “criticality specialist”, especially regarding the appropriateness of the means to stop a criticality accident and the assurance of permanently stopping the accident. During these 2 drills, only basic questions about a criticality accident were asked to the “criticality specialist” (about CAAS or orders of magnitude on the number of fissions for examples), indicating a need for pedagogy during a drill or a real emergency that was not previously anticipated. The awareness-raising actions planned for the criticality accident (see section 4.1) are based on this observation and should be extended to IRSN's external communication in the event of a criticality accident. Furthermore, the management of individuals seriously irradiated during a criticality accident should also be simulated during drills, to clarify the role of the “health” unit of the CTC and its interface with the “criticality specialist”.

Feedback from drills that could potentially lead to a criticality accident shows that, in a majority of cases, the situations involved leakage of enriched UF<sub>6</sub> (resulting from a transport accident on the road or an explosion in open storage) or fire, which led to the reflex use of water or a risk of water entering the fissile material (rainwater, a UF<sub>6</sub> cylinder falling into a river, etc.). Another feedback from this type of situation is that the assessment should also ensure subcriticality is maintained during remediation actions (such as during the recovery of UO<sub>2</sub>F<sub>2</sub> deposits formed after a UF<sub>6</sub> leak or of fissile material following an explosion). While the roadmap of the “criticality specialists” identifies the management of these feared events, discussions on the operators' policy on the management of criticality risk during

emergency situations will be necessary. The untimely triggering of a criticality alarm during an emergency has also been encountered. The elements indicated on this subject in the guide proved to be sufficient to help the “criticality specialist” to assess quickly whether or not the alarm is linked to a criticality accident.

The number of emergency scenarios initiated by a malicious act is increasing. These situations are specific because, when they involve fissile material, the resulting criticality accident (although this is not the objective of the malicious act) can exceed the bounding consequences foreseen in the emergency plans: the criticality accident can take place in a totally unexpected place, result in consequences much greater than those typically expected, or even occur on several locations simultaneously. These particular situations will be integrated into the initial training course of the “criticality specialists”.

Finally, at the request from the authorities, the operators have defined “reflex” messages to be sent to the CTC to provide data on the state of the facility. This approach is intended to help the CTC quickly gather essential data for its assessment. For criticality accident, these messages include, for example, the inventory of the materials involved, the response of the CAAS and of radiation protection instrumentations or the measurements of releases at the chimney. Such messages will be tested during drills starting this year.

## 5. CONCLUSION

IRSN progress on emergency preparedness and response in case of a criticality accident have made it possible to redefine the missions of the “criticality specialist” at its CTC, with specific emphasis on their interfaces with the other specialists. These efforts have also focused on their initial training. The tools and resources available to the “criticality specialist” have been expanded, and will be updated based on feedback from upcoming drills/real events. The most significant area of improvement identified is practice, to enable the “criticality specialists” to remain in operational conditions, through an increase in drills relating to the criticality accident.

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