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# Nuclear Emergency Exercises – A Case Study

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**Vol. 48-1/2024**

# Nuclear Emergency Exercises – A Case Study

*This edition of the BVSABR annals contains the proceedings of a scientific meeting held on 25 March 2022 in Brussels, addressing the thematic of nuclear emergency exercises. The event was organised in order to present the overall process, from the preparation, further to the execution of the exercise and finally up to the debriefing.*

*The BVSABR*

*Redaction Committee*

Annales de l'Association belge de Radioprotection (BVSABR)

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**Vol. 48-1/2024**

# Nuclear Emergency Exercises – A Case Study

## CONTENT

# Application of the Nuclear emergency exercises methodology implemented in Belgium

# A case study – Tihange NPP exercise 2021

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## Abstract

This paper aims at explaining the preparatory methodology for nuclear exercises in Belgium, taking into account, among other things, the guidelines provided for in the Royal Decree of March 1st, 2018.

The annual organisation of the nuclear exercise calendar meeting is discussed, which brings together all the partners involved in the exercises. During this meeting, in addition to the agenda and types of exercises, the progress of the strategic and operational projects implemented the past year is detailed in order to draw the first general conclusions.

It is explained in more detail the different bodies, which are set up during the actual organisation of a methodologically supported exercise, their composition, their specific responsibilities and the preparatory agenda: Steering Committee, Support Committee, Scenario Team, Evaluation process, etc.

Finally, the process that accompanied the organisation of the two Tihange 2020 exercises and postponed to March 17 and June 29, 2021 (due to Covid situation) is addressed, focusing in particular on the objectives of the second part, which tested for the first time in Belgium the measures provided for in the Emergency Plan concerning the transition phase.

**Keywords:** nuclear crisis management, nuclear emergency exercise, transition phase

# 1 Global methodology

The overall coordination of the nuclear emergency plan and the organisation of the resulting exercises are under the responsibility of the National Crisis Centre (RD 1/3/2018 5.1.4 - Nuclear Emergency Plan).

At the end of each year, the National Crisis Centre (NCC) organises a triennial nuclear exercise calendar meeting, with all partners involved in nuclear emergency planning & response at national level: federal departments such as Public Health, Civil Protection, Class I operators, provincial governors and first responders.

This meeting is first of all an opportunity to review all the projects that have been implemented over the past year at national, cross-border and international level (including those financed by the nuclear fund), as well as lessons learned from exercises.

Secondly, as mentioned in the Nuclear Emergency Plan, the meeting provides an opportunity to plan future exercises, taking into account the legal obligations for each Class I operator:

**Belgian Class I nuclear installations in operation**:

- every year for nuclear power plants
- every two years for the other class I nuclear sites.

**These exercises can be either limited i.e.** a test of the interaction and exchange of information between the operator, NCCN and the evaluation cell
**... or a large-scale exercise** i.e. interaction and exchange of information between all committees & cells and population.

The programme also includes international, cross-border and other type(s) of exercise(s), such as for radioactive transport.

Finally, in addition to the schedule of the exercise, the methodology can also be set up. In this context, a steering committee gathering all the major actors of the exercise will meet sufficiently in advance to define and validate the rules of the game: the agenda, the type of alert, the local, national and international objectives, the communication strategy, the evaluation and support strategy, and eventually, will validate the exercise “convention” and the final global evaluation report.

The steering committee will also appoint a support committee and a scenario team for the concrete organisation of the exercise, taking into account the above-mentioned guideline.

## 2 Participants

### *Federal level*

At federal level, the principle of integrated crisis management is applied. All the partners of the management cell, COFECO, CELEVAL, CELMES-Fed and CELINFO are mobilised within the crisis infrastructure of the NCCN. The aim is to facilitate communication flows and the exchange of information, in order to have a common view & understanding of the situation on- and off-site, as precise as possible. On this basis, protective actions are debated in a cross-cutting manner and validated by all participants before being communicated and discussed with partners in charge of their implementation on the field (Governors and Pc-Ops among others).

It is in pursuit of this precise objective that these exercises aims at bringing together as many actors as possible within the NCCN.

Thus, on the basis of the radiological, technical and meteorological information collected on and around the impacted site, the Evaluation Cell (FANC, Bel V, SCK-CEN, IRE, operator, IRM, AFSCA) in close collaboration with the Measurement Cell (FANC, SCK-CEN, IRE, Civil Protection, Defence) and the operator will propose to the Federal Coordination Committee (COFECO) direct (iodine tablets, sheltering, evacuation) and/or indirect countermeasures (protection of the food chain, socio-economic measures,. ) that can be implemented in the radiologically affected area.

COFECO, which brings together the representatives of the federal and federated departments involved in crisis management, will discuss the various options proposed by CELEVAL and be responsible for their preparation and communication to the local partners, for their concrete implementation.

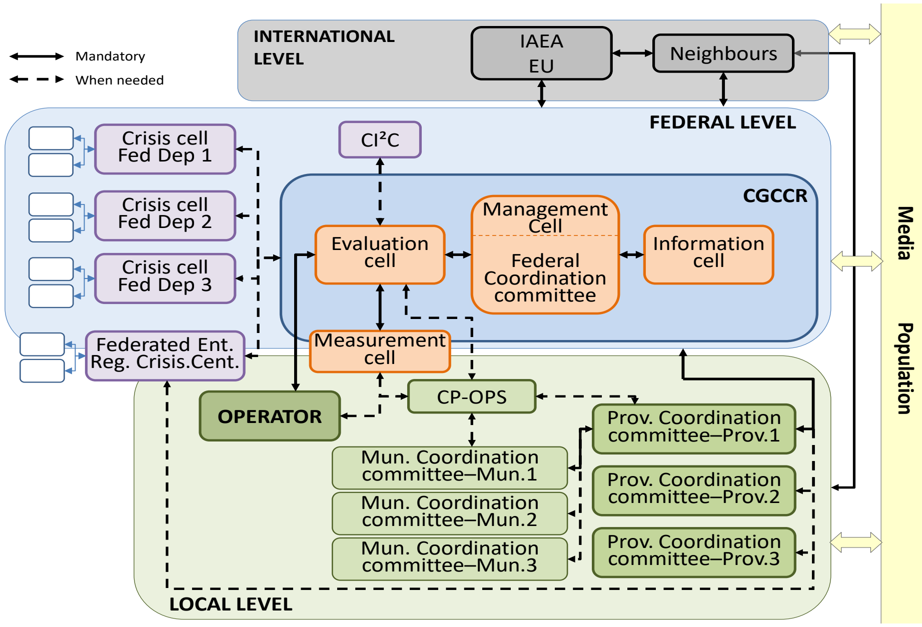


**Figure 1:** Nuclear crisis management at International, Federal and Local level.

The departmental representatives within COFECO will be able to rely on their departmental crisis unit, in order to provide useful information for the federal crisis management, and also to communicate issues or decisions impacting their sector of activity (Mobility, Socio-economic, Public Health, etc.).

The management cell, composed of the competent ministers, is responsible for the final validation of important decisions (on the proposal of COFECO) to be taken on the field.

Finally, the information cell (CELINFO) is responsible for the communication strategy regarding the situation and the decisions taken. In the same vein, CELINFO is also responsible for reporting on the population's perception of the crisis (via media monitoring and the social networks) and will therefore propose a communication strategy adapted to this perception (to be validated by COFECO).

All the above-mentioned radiological, technical and operational information will also be communicated in the long term to the international authorities and neighbouring countries via the NCCN.

***Local level***

The cells and committees at local level (Governors, municipalities crisis cells and PC-Ops) are responsible for the concrete and operational implementation of protective actions. The 5 disciplines (fire brigades, medical aid, police, logistics and communication) and the important departments are also brought together in these committees according to the same principle of integrated crisis management as at federal level.

The COFECO communicates important information to the Governors (e.g. via the Teams and the ICMS tools), who in turn take care of the concrete implementation with the municipalities and the PC-Ops.

# 3 How did it start ?

At the end of 2019, the Federal Agency for the Safety and Control of the Food Chain (AFSCA) sent a letter to the NCCN requesting to evaluate the possibility of testing the post-accident phase during a nuclear exercise.

Indeed, the role of the AFSCA within the CELEVAL radiological pool remains relatively limited during the emergency phase, considering that the radiological releases are still ongoing.

On the other hand, the AFSCA is in a position to play a leading role during the transitional phase, after the end of the releases and the resolution of the technical incident on site. In this context, the AFSCA will be in charge of assessing the impact of the discharges on soil, farms and livestock farms and will be responsible for proposing recommendations for indirect protective actions in these economic sectors.

Beyond the food chain aspects, a series of other measures need also to be implemented during the transition phase such as dosimetry and medical monitoring of first responders and the population (contamination control/decontamination), radioactive waste management and the authorities communication strategy.

The exercise attempted to test these objectives.

# 4 Preparatory agenda

The decision was taken by the Steering Committee to divide the exercise into two distinct phases:

Phase I was a classical alert-mobilisation exercise of cells and committees to test the management of an emergency situation and the simulated implementation of protective actions on the ground. The mapping of radiological deposits ($^{137}$Cs & $^{131}$I) after the releases serve as a basis for post-accident management (phase II).

Due to the health situation related to Covid, the exercise originally planned for April 2020 had to be postponed several times and finally took place on 17 March 2021.

In the meantime, several helicopter flights were organised in June 2021 from the Beauvechain military base in order to test the "Aero Gamma Spectrum" measuring device over the Tihange nuclear power plant. This highly sensitive device, which is capable of measuring radiological deposits over a large area, makes it possible to precisely visualise the impacted zones (in particular the presence or absence of hotspots), for which direct and indirect protective actions have to be implemented.

Finally, phase II of the exercise, to test the transition phase, was organised on 29 June 2021. The important objectives were as follows:

- Exercise played on a **fictitious date**
- Ongoing work of CELEVAL in the **transition phase**
- Test of the crisis infrastructure of the CI²C (FANC crisis infrastructure)
- Ongoing analysis of the **radiological data**
- **$^{137}$Cs** & **$^{131}$I** deposition data were scaled up, in order to meet **the food chain objectives**
- Dosimetric and medical **monitoring** of responders and the population
- Testing **communication** channels & tools between COFECO and CELEVAL

During this exercise, CELEVAL submitted five advises and proposed 9 protective actions to the Federal Coordination Committee, which can be summarised as follows:

- Sheltering of livestock (0 to 4 km)
- Restriction of vegetables and agricultural products
- Complete isolation of the area (population & goods)
- Measurement team to confirm contamination levels in the hotspots.
- Identification of communities involving children (schools, scout’s camps ,..)
- Identification & isolation of medical facilities and nursing homes
- Identification of boats between Huy and Engis
- Structure for the control of contamination and decontamination
- Risk of subsoil contamination

Most of these actions had never really been proposed before in a nuclear exercise, which made this one very interesting. The general conclusions, lessons learned and further details regarding the scenario are presented in the other papers.

# Development of the technical scenario and the related source term


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## Abstract


The presentation is dedicated to the theoretical elaboration of the scenario for the national nuclear emergency exercise of 17 March 2021 at the Tihange NPP, i.e. the technical, radiological and human inputs constituting the preparation phase.

The first part presents the chronology of events imagined in the elaboration of the exercise, answering to all the requirements from the different participants. It related all the events imagined by the scenarists, their timing, and the actions expected from the participants. The whole scenario is then scripted in order to accompany the participants into the degraded imagined situation leading to an accident with radiological consequences.

The second part is dedicated to the radiological aspect of the scenario, i.e. how the theoretical radiological source term was calculated and adapted to the technical scenario explained in the previous parts, how it was transmitted to the participants of the exercise and under what form. This part will also explain how the radiological data were exploited by the participants and converted into what is called a standard scenario, useful to describe a degraded radiological situation to the nuclear safety authorities.

The third part presents some of the main on-site technical equipments that were planned to be used during this exercise, especially the containment filtered venting system. This technology, recently implemented in all the Tihange units, allow the operators to depressurize the reactor building in situations of severe accidents where steam and gases are produced due to the degradation of the core and associated structures. Gases are filtered several times in order to considerably reduce the contamination released to the environment.

Finally the amelioration points in the scenario elaboration are discussed and conclusions are drawn.

**Key words :** nuclear emergency exercise, exercise scenario

*Note from the Redaction Committee: abstract added here for the sake of completeness, no text available - the presentation can however be consulted through the Document Library on the BVSABR-website (login for members only)*

# Development of the simulated radiological consequences

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## Abstract

During a nuclear emergency, the decisions that will be taken for the protection of the population and the environment will be driven by, among other aspects, the radiological consequences of the emergency. Accordingly, to challenge adequately the emergency plans and procedures in place during a nuclear emergency exercise, the simulated radiological consequences of the emergency exercise need to be suited to the exercise's objectives. The simulated radiological consequences will depend on the plant accidental conditions together with the meteorological conditions during atmospheric releases.

Firstly, the development of simulated radiological consequences for the purpose of exercises in general is discussed. The use of hypothetical, historical or real-time meteorological conditions and compressed, expanded or real- time scales for different exercise objectives is presented. The paper also addresses the balance between meeting specific exercise objectives and keeping the realism of the simulated radiological consequences.

Secondly, the simulation of radiological consequences applied to the national nuclear emergency exercise of 17 March 2021, at the Tihange nuclear power plant, is presented. The objectives of this exercise, that particularly influenced the development of the simulated radiological consequences, is discussed. Finally, the lessons learned during the development of the simulated radiological consequences are addressed.

**Key words :** emergency exercise, radiological dispersion, meteorological conditions

## Introduction

During a nuclear emergency, decisions on direct and/or indirect protective actions for the population should be taken as soon as possible. In the early phase of the emergency, only limited off-site radiological measurements will be available (*e.g.* Telerad early warning network). Accordingly, the decision-making process will mainly rely on simulations of the radiological consequences based on the information available at that moment. With time, more and more measurements will be available. These measurements will allow refining the strategy for the protection of the population (*e.g.* relaxing some protective actions in identified areas).

In Belgium, the 'NOODPLAN' software is used for the simulation of off-site radiological consequences from atmospheric releases at, amongst others, the two nuclear power plants in Belgium. The 'NOODPLAN' software was developed by SCK CEN and is customized for each relevant nuclear installation. For the nuclear power plants, the software contains two different modes. In the first mode, one of the 104 predefined "standard scenarios" can be selected with constant weather conditions to quickly provide an initial radiological assessment. Four of these scenarios have a variant with a release through the Containment Filtered Venting System (CFVS). This first mode is used during the threat phase, when there is no release yet, or in the very early release phase, when there is limited information on the release. This allows to initiate the decision-making process on the basis of potential radiological consequences and to take decisions, when necessary. In the second mode of the software, the time dependence of the source term, release parameters, and weather conditions (*e.g.* as measured at the stack) are taken into account. This mode can be used when the release is on-going or has occurred and when the necessary information is available to further support the decision-making process.

In the preparation process of emergency exercises, simulated radiological consequences of the scenario are used at different stages. First, during the scenario development, in order to ensure that the radiological consequences meet the exercise's objectives (*e.g.* specific protective measures in a certain administrative unit). Then, in advance or during the exercise, to simulate measurements such as those provided by the Telerad network or done by the measurement teams in the field. This allows on- and off-site participants to base their advice not only on their own simulations with the ‘NOODPLAN’ software but also on measurements simulated by the scenario team.

## General approach

Depending on the objectives of the emergency exercise, historical or real-time weather conditions can be used within an exercise time scale that can be normal, compressed or expanded. The use of historical weather conditions allows to create exercises with: i) well-defined areas that are affected by the radiological release and ii) simulated measurements prepared in advance. Another advantage is that in some cases, countermeasures for the food chain are expected as part of the exercise’s objectives, some agricultural seasons being more suitable for such an objective. The main disadvantage of using historical weather conditions is obviously that realism is lost in part. The latter can take place when, for instance, there is heavy rain in the historical weather conditions whereas it is actually a nice sunny day during the emergency exercise itself. Participants might get confused by this difference in weather conditions. On the other hand, the use of real-time weather conditions allows to preserve realism of the exercise for the participants, but it does not allow to test specific objectives, for instance, with regard to the emergency response in well-defined administrative units as the radiological impact (in particular the areas affected by the release) cannot be known during the definition of the exercise. Simulated measurements are possible, but they will need to be acquired using forecast weather conditions just a few hours before or just at the beginning of the exercise to minimize the forecast uncertainty. An expanded or compressed time scale will also affect the realism of the exercise but might be necessary to meet the exercise’s objectives within the foreseen duration. The remainder of the present discussion will address the use of historical weather conditions to meet specific exercise objectives.

The first aspect to be looked at when using historical weather conditions is the definition of the proposed exercise objectives. For example, if a specific area should be affected by the release, in order to allow the testing of procedures between the national and the local authorities, then the scenario team will search for weather conditions that will meet this objective. In this case, the selection of the historical weather dataset will mainly be done based on the wind direction. The scenario team will thus start looking into weather conditions at the site of interest over the last years to find a period where these conditions are corresponding to the needs. As an example, the historical wind rose plot at Tihange is shown on the left part of Figure 2.

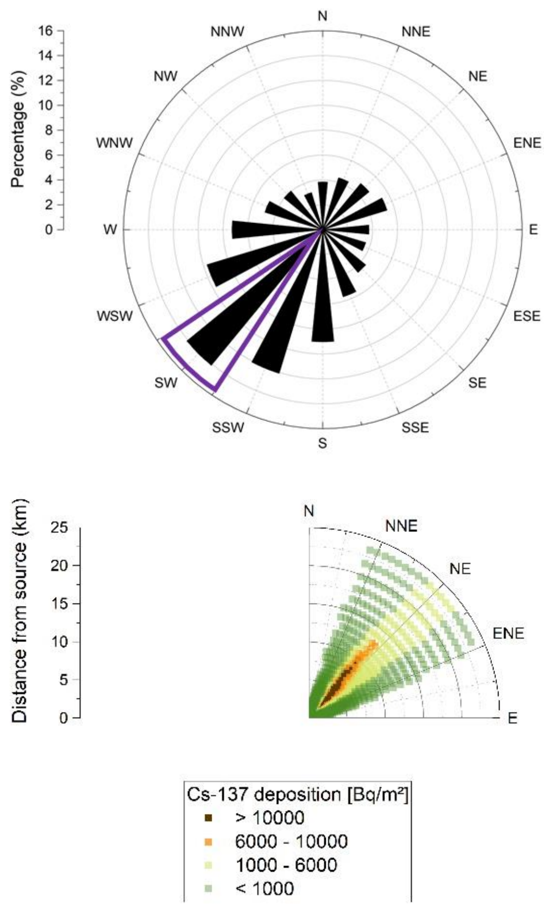


**Figure 2 :** [Top] Historical wind rose plot showing the frequency of the wind direction (i.e. the wind blowing from the corresponding cardinal direction) at Tihange.

[Down] Illustration of the Cs-137 ground deposition (in Bq/m²) resulting from a release during a period of SW wind direction.

If the objectives of the exercise foresee a radiological impact in the northeast direction of the nuclear site, for example to test the communication with the corresponding local authorities, then the scenario team will search for a southwest wind direction (*i.e.* the wind blowing from the SW). In such an example, an historical period with a dominant SW wind direction will be selected.

In addition to the wind direction, other weather conditions can be used to define the relevant historical period. For example, the wind speed and the atmospheric stability can also be used depending on the extent of the areas to be affected by the radiological release. If the plume should be broad to affect a larger area at shorter distances, then the scenario team can search for relatively unstable atmospheric conditions and low wind speeds. Another example is the presence of intermittent rain during the historical period, in order to have local radiological hotspots.

Once the historical period has been selected, a simulation, using the source term and release parameters defined in the technical scenario, will be performed to ensure that the radiological impact is corresponding to the expectations. As an illustration, the Cs-137 ground deposition for a release that would occur during a certain period with a SW wind direction is shown on the right part of Figure 2. Based on the simulated radiological impact, the suitability of the on-site technical and radiological evolution as well as the weather conditions can be assessed, in the light of the pursued exercise objectives. Depending on the outcomes of this assessment, the scenario can either be validated or refined. Hence there is an iterative process within the scenario team, to develop a scenario that fits the objectives of the exercise, but is also as realistic as possible.

Once the scenario has been fully validated, it can be used to simulate measurement results. The first environmental radiological information that the participants will receive is from the Telerad network. Accordingly, the measurements performed by the relevant Telerad stations are simulated with the atmospheric dispersion software. The background and sensitivity of the ambient dose rate monitoring by these stations is well known and can easily be taken into account for the simulated measurements. Next to the environmental measurements provided by the continuous Telerad network, environmental measurements can be performed by the measurement teams of the relevant nuclear installation or by the measurement teams deployed within the national emergency plan. For such measurements, the scenario team will provide simulated measurement results based on the measurement type (ambient dose rate, deposition, atmospheric concentration…) and on the location of the team (*i.e.* GPS coordinates, address or predefined measurement locations). However depending on the equipment used by the team, the sensitivity and detection limit can be very different; these should ideally be taken into account when providing the simulated measurement results.

In real emergencies, differences between the simulation, performed with the atmospheric dispersion software, and the measurements are expected due to, for instance, the uncertainties (measurement, release parameters, source term and weather conditions) and the representativeness of the measurement against the considered area. Such differences are thus important for the realism and the challenge of an exercise. Other atmospheric dispersion software such as JRODOS (Java Real-time Online DecisiOn Support, developed within the EU context) and Aeolus (developed by SCK CEN) can be used to produce simulated measurements, which will directly differ (different models, assumptions…) from the simulations by the participants with the 'NOODPLAN' model. In comparison with the current 'NOODPLAN' software, the two other softwares allow to easily export the time dependence of the necessary quantities that can then be fed into the 'Telerad Simulation' tool of the nuclear crisis management web portal. This allows all experts involved to visualise, in real time, the simulated Telerad measurements in the same way as the actual observations. Therefore, the simulation of the measurements is currently performed with either JRODOS or Aeolus.

## Example with the Tihange exercise

For the Tihange exercise, one of the objectives was to have a radiological impact on the city of Durbuy, which is located in the SE direction from Tihange. Accordingly, historical weather conditions with a period of time dominated by wind blowing from the NW direction was looked for. The period from 01/07/2019 00:00 to 02/07/2019 12:00 was identified as a potential candidate. As shown in Figure 3, the wind direction varied from SW to N during this period. It was therefore necessary to align the start of the main release (*i.e.* the CFVS release) with a moment in time where the wind was mainly coming from the

WNW-NW. After a few iterations within the scenario team, the start of the CFVS release was taken to be 01/07/2019 at 20:00.

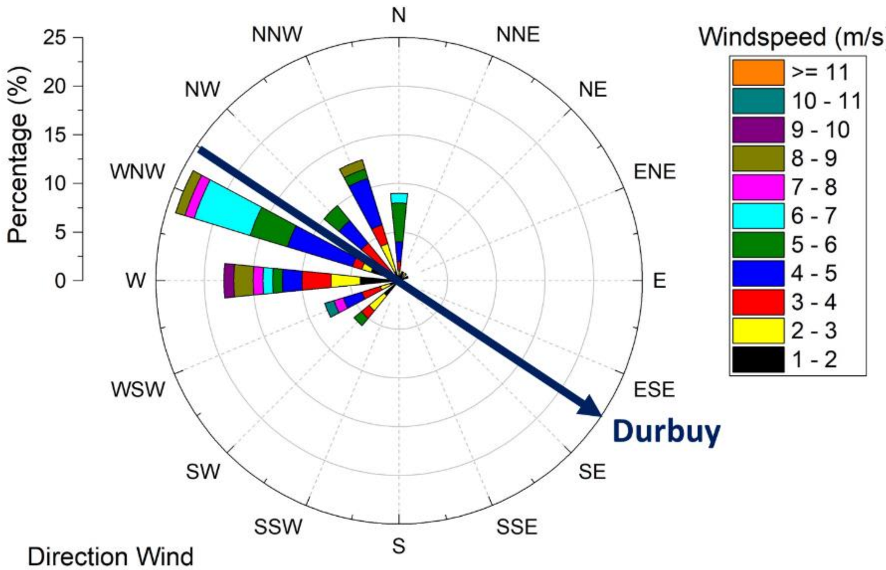


**Figure 3 :** Wind rose for the period from 01/07/2019 00:00 to 02/07/2019 12:00 together with the direction from Tihange to Durbuy (blue arrow).

Once the scenario was fully defined, the Telerad measurements were simulated with the JRODOS software. A typical background of 100 nSv/h was added to the simulation of ambient dose rates to obtain realistic measurements. As an example, a map of the simulated ambient dose rate measurement of the Telerad stations around Tihange on 01/07/2019 at 20:50 (*i.e.* 50 minutes after the start of the CFVS release) is shown in Figure 4. As it was not possible to upload the simulated Telerad measurements on the nuclear crisis management web portal during the exercise, regular snapshots of these measurements were provided to the participants.

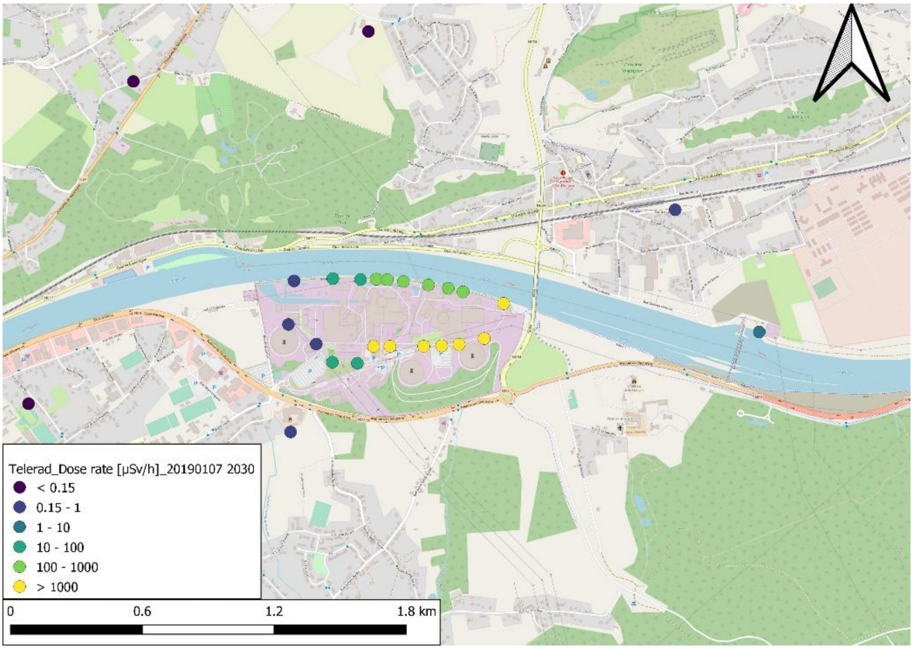


**Figure 4 :** Snapshot, on 01/07/2019 at 20:30, of the simulated ambient dose rate (in µSv/h) measurement at the Telerad stations near Tihange.

In addition, a measurement team of Tihange performed 8 measurements for which the scenario team provided simulated measurements. All measurements were related to ambient dose rate, except for one air sample (*i.e.* paper filter collecting aerosols from the sampled air), which was measured with a NaI detector, in order to determine the atmospheric concentration of the identified radionuclides. The simulated aerosol concentration was too low (as foreseen with the CFVS) to be measurable through this measurement. Accordingly, no artificial radionuclides were reported in the simulated result.

Finally, the results of the simulated radiological consequences were also used during 'Phase II' of the exercise, which was dedicated to the post-release phase. For this purpose, it was necessary to exceed the intervention level for Cs-137 deposition to allow to kick-off the decision-making process pursued by the exercise. However, the use of the CFVS significantly reduces the releases of iodine and aerosols. Accordingly, the intervention levels were not exceeded by the initial scenario, and it was necessary to artificially increase the source term, by a factor 3000, to have areas with deposition values higher than the lowest intervention level (*i.e.* 6000 Bq/m²). This of course reduced the realism of the scenario but was necessary to have the necessary actions, decisions and discussions during 'Phase II', which were anyway not directed towards the technical situation at the nuclear power plant. In addition, another challenge foreseen in 'Phase II' of the exercise was the presence of local hotspots with increased deposition due to a local rain event. The simulated radiological consequences of the initial scenario were post-processed to increase the initial deposition values at two locations, in order to mimic realistically a local hotspot caused by a rain event. The contamination map provided to the participants of 'Phase II' is shown in Figure 5.

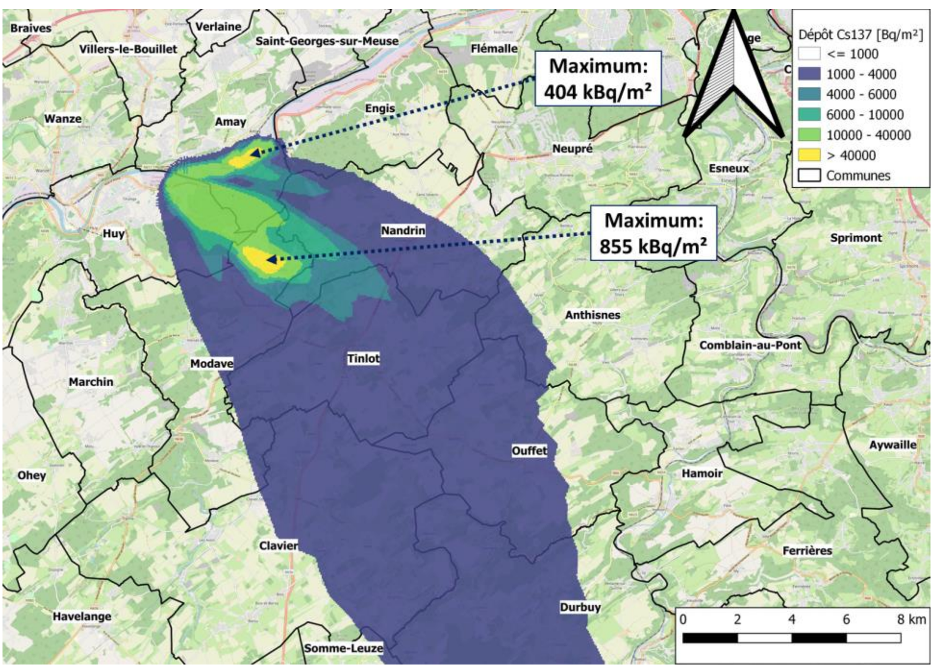


**Figure 5 :** Adapted Cs-137 deposition map (in Bq/m²) to meet the objectives of 'Phase II' of the Tihange exercise.

## Lessons learned

The use of simulated measurements is clearly an added value for nuclear emergency exercises. As long as these simulated measurements are realistic, they allow to challenge the participants with different sources of information on the radiological situation (simulation, early warning network and measurements in the field). In addition, the systematic production of such simulated measurements during exercises helps to further improve, based on lessons learned, the process for enhancing realism.

The Tihange exercise allowed to learn the following lessons:

– The availability of the simulated Telerad measurements on the nuclear crisis management web portal is crucial both with respect to realism and in order to minimize misunderstandings. As it was not possible to upload the data during the exercise, snapshots of the data were provided to the participants at specific moments, which resulted in some misunderstanding on the dynamic of the exercise.

– The use of the historical time (+ 5 hours compared to real time) during the exercise is prone to induce errors, when exchanging simulated measurements.

– During the exercise, the use of a drone during the release and of an AGS (Aerial Gamma Spectroscopy) system after the release was discussed. Such simulated measurements were not foreseen during the preparation of the exercise. This is an aspect that should be considered for future exercises, since these measurements can also be simulated as long as an approach considering detection limits and flight paths, with the necessary post-processing, is used to obtain realistic results.

# Nuclear emergency exercise of 17 March 2021
# Emergency phase performed at the Tihange NPP

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## Abstract

The paper is dedicated to the achievement of the national nuclear emergency exercise of 17 March 2021 at the Tihange NPP, based upon the technical, radiological and human inputs planned in the preparation phase and explained in the other papers.

The first part presents some elements of the personnel briefing and the pursued objectives. It also explains how the scenarists use the prepared inputs during the exercise. Tips and tricks for nuclear / radiological emergency exercises are given.

The second part presents the various categories of personnel involved in the exercise and the infrastructure, where the emergency activities are performed. A special emphasis is put on the multiple-unit work organization required for the chosen accident initiator. The back-up emergency coordination center, built within the framework of the post-Fukushima action plan, is described.

The third part addresses the exercise on its own. A timeline approach is used, in order to provide a good understanding of the accident sequence, of the simulated failures (and sometimes the real ones !) and of the interactions between the participants.

Finally the main lessons learnt are discussed and conclusions are drawn.

**Key words :** nuclear emergency exercise, emergency infrastructure, exercise timeline

## Introduction

This paper reports the national nuclear emergency exercise of 17 March 2021, as achieved from the side of the operator, the Tihange nuclear power plant.

The emergency planning and preparedness (EPP) is considered as the 5$^{th}$ level of defense in depth (DID) according to the IAEA [1]. This last level completes the previous nuclear safety layers set in place by all responsible nuclear operators. As such, achievement of emergency exercises is part of the 5$^{th}$ layers and among those the nuclear emergency exercises [2].

The Tihange NPP ensures the drill of its emergency teams through the achievement of an annual program that browses a large range of accidental initiators and different thematic, as shown in the Figure 1.

| **Teams** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Long exercise | Industrial initiator | Security initiator | Multi-unit initiator (BEST) | Severe Reactor accident (SAMG) | Reactor accident (PUN) |
| Short exercise | Combined exercise with first interveners | | | | |
| | 1$^{st}$ hour of a previous long exercise | | | | |
| | … | | | | |
| Training | Training on communication means | | | | |
| | Set-up of radiological arrangements (habitability, personal protective equipment) | | | | |
| | Repowering of emergency centers | | | | |
| | … | | | | |

**Figure 1 :** Annual emergency exercises program for the on-duty engineers at the Tihange NPP. The letters A → E stand for the five on-duty emergency teams, each team changing each year the type of long exercise.

The exercise of 17 March 2021 consisted of a multi-unit initiating event, during which the postulated state of one reactor is degraded, requiring to use the planned accident procedures and severe accident management guidelines (SAMG). It was a national exercise with the participation of the Authorities, therefore labelled as "PUN". As such this exercise is identified in the 3 shaded cells of the Figure 1.

The 1st paragraph focuses on the briefing of the participants, making explicit what is communicated on beforehand to the participants, as well as the pursued objectives. Specific arrangements relating to the prevention against Covid-19 are also pointed out, as the exercise was performed during the pandemic period.

The 2nd and 3rd paragraphs describe the type of participants and the infrastructure used during the exercise. A focus will be put on the recently built back-up Site Operating Center (SOC).

The 4th paragraph explains in more detail how an emergency exercise is played on the field and what has to be done by the scenarists.

The 5th paragraph describes the exercise itself, following the chronology of the main events.

The main lessons learnt are given in the 6th paragraph and finally the general conclusions are finally drawn.

## Briefing of the participants

Different types of emergency exercise can be proposed and performed according to the pursued objectives : choice of the initiating event, choice of the prior announcement of the exercise, which thematic(s), involvement of external stakeholders, involvement of different categories of personnel, consideration of real, fictive or historic meteorological conditions, real-time or accelerated accidental sequence, etc.

Such a choice has to be made by the exercise scenarist during the preparation phase, taking into account the participants and operational constraints of the NPP. The scenarist then decides to what extent some aspects of the forthcoming exercise can be communicated to the participants. Although it seems a priori better to avoid any prior communication, operational constraints and the risk of communication failures have to be put into the balance. For instance it is important for the participants to know either on before-hand or during the exercise who are the external stakeholders involved in the exercise, among which CS112, NCCN, local and regional authorities, etc.

To this end the emergency teams appointed to the national nuclear emergency exercise of 17 March 2021 benefitted from a briefing during which the following elements were communicated :

- Framework of the exercise
- Categories of participants
- Exercise duration
- Achievement of a shift turnover meeting
- Main thematic considered : CSBO, SAMG, CFVS (see later)
- Which reactor unit is simulated in severe accident (here Tihange 3)
- Consideration of historical meteorological conditions dating from 1 and 2 July 2019
- Attention point on the radiological monitoring of the releases, which is not available as a consequence of the initiating event
- Actions required on the field (RP vehicle, SOC repowering and preparation of the equipment for the CFVS working)
- Scenario during which the exercise is interrupted, in order to accelerate 4 hours of radioactive releases (and summarized by the scenarists during a TEAMS meeting).

In addition, the scenarist provided the criteria of success for the exercise, amongst which the fact to have a balanced management of the accident, taking into account the technical aspects, but also the radiological and the human aspects.

A last point of the briefing was dedicated to specific protective arrangements against Covid-19, especially to protect against a too high density of persons inside the emergency infrastructures. A free Covid testing was proposed to the participants the day before the exercise (80% of participants tested – all negative). FFP2 face masks were provided to the emergency teams. Workstations were somewhat rearranged and enhanced ventilation was provided.

## Participants

CNT engaged two on-duty engineer emergency teams in the exercise, each of which being made of 18 persons having specific tasks. In addition one operation team, maintenance and RP agents were involved. Subcontractors working on the CNT site were also involved : G4S security service, the on-site police for the personal safety aspects and the second interveners. As a whole this means approximately 50 on-site participants.

Interaction with the Electrabel Headquarters emergency cell and technical support from ENGIE Tractebel were also integrated in the exercise.

With respect to the external participants, the exercise explicitly planned to simulate the interactions with CS112, the local and regional authorities and CELEVAL.

At least three scenarists were involved, located in the back-up SOC, at the full-scope simulator and in the UOC T3.

## Infrastructure

The various emergency infrastructures and cells involved in the exercise are depicted in Figure 2.

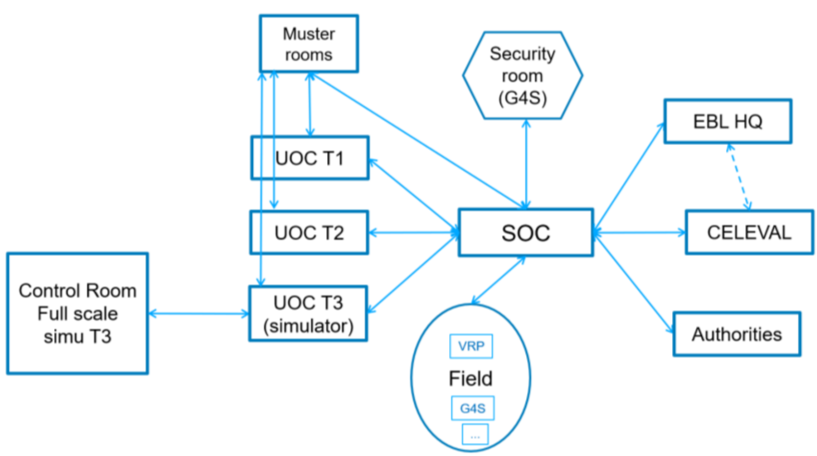


**Figure 2 :** General workflow for preparing and conducting emergency exercises.

The main control room of Tihange 3 was simulated by the full-scale simulator localized in the training center of Tihange NPP. The main control room / full scale simulator T3 is in charge of the technical management of the accident, using the emergency procedures. The main control room, staffed by one operation team, is supported by the associated unit operating center (UOC), mainly staffed by operation and safety engineers. The UOC is also in charge of the severe accident management guidelines, for degraded conditions beyond those for which only emergency operating procedures have to be used.

As the initiating event concerns all units, the exercise also involved the UOC Tihange 1 and Tihange 2.

All UOCs interact with the site operating center (SOC), which is in charge of the general management of the accident. The SOC is the central node of the interactions, that communicates internally with the UOCs and externally with the Electrabel HQ emergency cell, with CELEVAL, with the Authorities, etc.

The SOC is also contacted by the muster rooms, the security room and the interveners on the field, amongst which the RP vehicles.

The exercise scenario foresaw that the main SOC was unavailable and that the emergency team had to staff the back-up SOC, also called COR (Centre Opérationnel de Repli). The COR was made full operational in July 2020, within the framework of the post-Fukushima Belgian stress test (BEST) project.

The COR is a flexible emergency facility made of a light structure, protecting its appointed staff against the radioactive contaminants. Inside this light structure a fully equipped trailer is stored (default configuration). Its main characteristics are :

– Location above beyond-design flooding level
– Seismic resistance up to 0.25 g peak ground acceleration
– Protected against external radioactive contamination with high efficiency airborne and iodine filtration
– Back-up mobile emergency power supply in case of station black-out (autonomy 72 hours).

The building is made of 3 parts: the operational part wherein the trailer is located and which is protected against radioactive contaminants, the technical part wherein the emergency power supply, the RP vehicle and other equipment are located, and finally a air-lock allowing controlled entry / exit of emergency personnel. The COR facility and its trailer are shown in the Figure 3a and 3b.

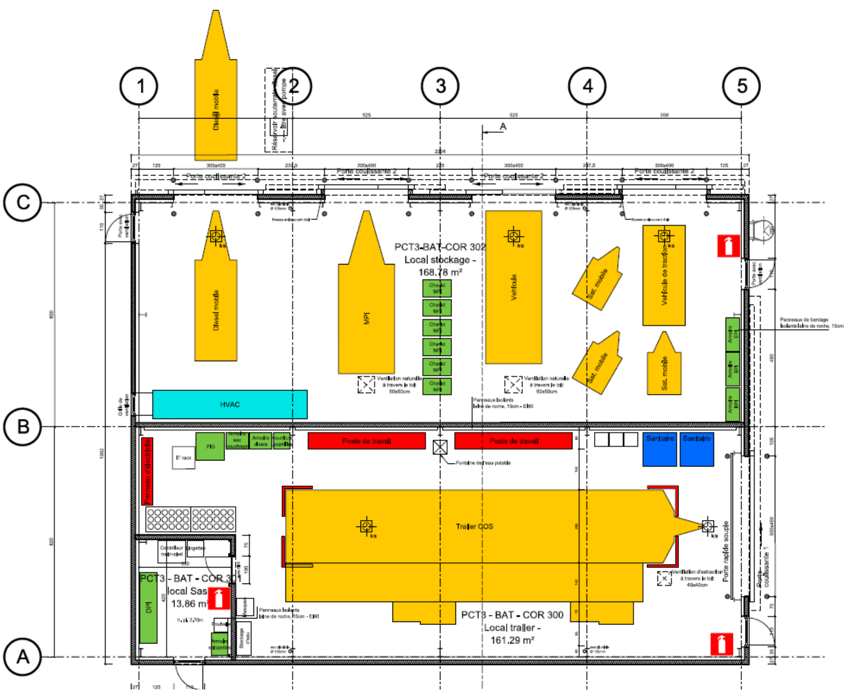


**Figure 3a :** Picture and scheme of the COR facility

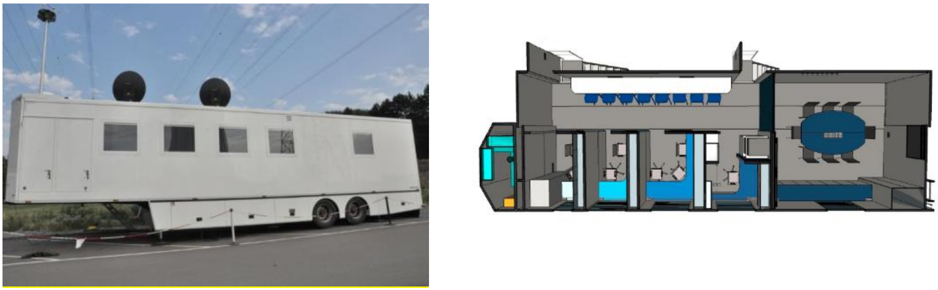

**Figure 3b :** Picture and scheme of the COR trailer.

The COR trailer is equipped with the same communication means as the base SOC, as all functions of the SOC are expected to be backed up by the COR. The base fiber network communication is backed-up in successive way by ADSL network, 3G/4G network and finally satellite. The trailer has a capacity of maximum 10 persons distributed in 5 workstations. The trailer has its own electrical power supply with an autonomy of 72 h in case of use of the trailer in an off-site configuration.

The national emergency exercise of 17 March 2021 was the opportunity of a first full test of the facility, with an on-duty emergency team.

## Emergency cycle and inputs

In case of a real nuclear power plant accident with radiological releases, both the operator and the Authorities would decide actions on the basis of inputs and analysis, following the scheme here below.

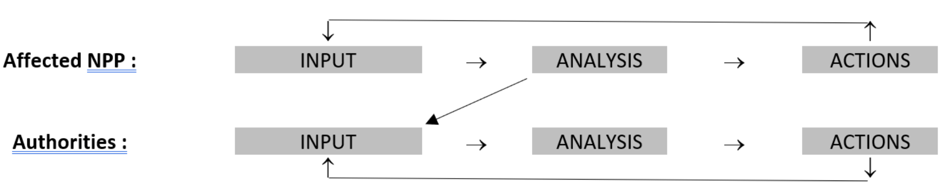


**Figure 4 :** Emergency process cycle

Such inputs have to be provided by the scenarists and by the full-scope simulator during an emergency exercise. We can distinguish 3 main types of inputs : (i) technical, (ii) radiological and (iii) human.

What concerns the technical inputs, those are provided by the full-scale simulator according to a defined range of plant states and to the programmed reactor transient. Beyond the working range of the full-scale simulator, the scenarist located at the UOCs provides periodically the participants with paper forms fulfilled with the postulated plant states. The results of the emergency team analysis will be summarized into dedicate forms F-TEC, which will be sent to the Authorities.

What concerns the radiological inputs, the scenarist located at the SOC provides the crisis team with the following inputs with a periodicity of ~ 10 minutes :

- the meteorological parameters, when the exercise is based upon a historical meteorology
- the dose rate values displayed by the TELERAD stations [3] surrounding the affected NPP site (typically with a radius of max 10 km)
- the source term released by the stack, when available ; indeed according to the accident circumstances, the releases can occur via a monitored route or not (e.g. releases at roof level for a SGTR event or releases not properly monitored because the ventilation motors are no more working in case of a loss of electrical supply).
- simulated measurements of the field RP vehicles
- etc.

In order to support the analysis work, the emergency engineer in charge of the radiological assessment, can envisage 2 main types of calculations: either **diagnostic** calculations and **prognostic** calculations.

Diagnostic calculations are performed on the basis of the measured radioactive releases through the stack, for which the released activity is refreshed every 10 minutes and can be combined with the meteorological conditions. For this purpose ENGIE Electrabel uses the dispersion software developed by SCK CEN and customized for the purpose of emergency situations. Diagnostic calculations thus provide a best-estimate mapping of the off-site radiological consequences [4].

Prognostic calculations can also be performed. They may consist of extrapolation of diagnostic calculations, making some assumptions about the later periods. Or else the calculations are based upon a set of predetermined source terms, each associated with a well-defined plant state. The ENGIE Electrabel NPP sites uses a catalogue of ~ 100 predefined accidental plant states.

The result of the emergency team analysis will be summarized into dedicate forms F-RAD, that will be sent to the Authorities.

Last but not least, human inputs are introduced into the emergency exercise. Those inputs can be communicated by the main scenarists or by other participants appointed by the main scenarists. For example :

- communication with muster rooms coordinators
- on-site inventory of the personnel
- simulation and real personnel evacuation / return to home
- blocked lifts events communicated by the second interveners
- management of personnel injuries
- simulated contact with journalists
- etc.

The results of the emergency team analysis will be summarized into dedicate forms F-MED, which will be sent to the Authorities.

Other forms (e.g. notification form) are used to communicate with the Authorities but they will not be detailed herein.

The scenarists located in the various emergency infrastructures have to synchronize the delivery of their inputs in order to respect the established scenario and to assure the global exercise coherence (e.g. correspondence between a postulated plant state of the radiological situation).

**The emergency exercise**

The emergency exercise timeline is summarized in **Appendix** to this article. The exercise started at 8 AM local time.

A storm was assumed to happen in the surroundings of the Tihange NPP, leading to the loss of the external grid, and the loss of the 3G/4G network, because of a fall of a communication pole. The postulated on-site consequences were :

- All three nuclear units face a station black-out initiator (SBO)
- Loss of lighting
- Loss of desktop computers
- Loss of the display screens,
- Loss of satellite phones
- Loss of 3G/4G network
- Blocked elevators.

In the UOC's and in the back-up SOC, each equipment assumed not to work properly, because of the external grid loss, was labelled with a yellow sticky.

The start of the exercise was given from the full scope simulator T3, that began to simulate the reactor transient, as expected by the technical scenarist.

A G4S team was requested to ensure the call to Astrid beepers of the on-call emergency team. The emergency team staffed the emergency infrastructures according to a multi-unit initiating event, i.e. all UOC's were staffed, as well as the back-up SOC / COR.

The emergency teams located in the various emergency rooms were contacted as soon as 8:30, by scenarists simulating colleagues at muster rooms and trying to know what is happening and what to do. This allows to introduce the people management aspect within the exercise.

The emergency team performed a first notification towards the 112 service, claiming a preliminary emergency level of Site Area Emergency (SAE) [5]. Unfortunately, the call to CS112 was finally aborted, as the call from the COR reached a service located in Brussels instead of Liège.

Meanwhile the emergency team located at the COR managed to repower the facility with its emergency power supply. As soon as this information was communicated to the scenarist, the post-its were removed from the recovered equipment.

At ~ 9:20 a first simulated personnel inventory was provided by the scenarist to the SOC emergency team. This hypothetic inventory was made such that a significant part of the personnel was not yet located in muster rooms.

Subsequently a contact between the FANC and the CNT emergency director happened in order to communicate about an early return to home of the personnel, with no added value in the management of the emergency situation.

At about 10 AM the COR emergency team launched an ECOS call in order to prepare the shift turnover with another emergency team, as it was clearly identified that the situation would last for a long time. Indeed at this moment Tihange 1 and 2 are assumed to be in a stable state, the cooling safety function being assured by the unit emergency power supplies. Unfortunately, Tihange 3 is supposed to be in a worse situation, without any properly working emergency power supply; what is called a Complete Station Black-Out (CSBO).

From 10 AM it was the beginning of the radiological scenario. This means that from that moment and until the exercise interruption, the scenarist at the COR provides the emergency engineers with the historical meteorological conditions and simulated dose rate monitoring of the 44 TELERAD stations surrounding the Tihange NPP with a radius of 10 km, with a periodicity of 10 minutes.

A first start of a RP vehicle was decided for field measurements and samplings. At about 11 AM, this local action was performed by two interveners duly equipped with radiological personnel protective equipment.

At ~ 11:30 the full-scope simulator reached a primary temperature exceeding 650 °C and stopped working (working limit of the full-scope simulator). From this moment the scenarist continued to inform about the reactor state with dedicated forms. At this moment the UOC emergency team decided to initiate the Severe Accident Management Guidelines (SAMG), one step beyond than the emergency procedures. Approximately at the same time it was decided to redistribute the emergency team according to a single unit organization centered on T3 (action expected according to the scenario).

The shift turnover meeting began at ~ 12:00, and the 2$^{nd}$ emergency team started its shift from ~ 12:50.

The situation of T3 was supposed to further degrade : increase of the primary temperature and increase of the reactor building pressure. The emergency team decided to prepare the actuation of the containment filtered venting system (CFVS) at ~ 14:00. This was communicated with the expected stakeholders, to determine the appropriate protection of the population.

Meanwhile the Electrabel headquarters announced the activation of an off-site base at Flawinne, nearby Namur.

At 15:15 the CFVS was supposed to start working. In order to illustrate this, local dose rate monitors were simulated in alarm and the simulated TELERAD inputs showed a significant increase. The technical inputs simultaneously showed a decrease of the reactor building pressure.

At 15:45 the scenarists stopped the exercise and invited all participants to a meeting (use of TEAMS to gather all participants (internal & external)). The scenarists explained the evolution of the situation during 4 hours of venting :

- The reactor building pressure decreased down to 3.2 bar absolute pressure and showed a continuous decreasing trend
- The wind speed and wind direction during 4h was summarized, showing which radial sectors were under the radioactive plume
- The evolution of the dose rate of the 2 most and the 2 least exposed TELERAD ring monitors was communicated [see Figure 5]. The most exposed monitors were the ring T17 and T18 located south-east of the CNT site, whereas the least exposed were located at the west. The dose rate was strongly varying with peaks above 2 mSv/h, according to the wind speed and direction. Such a dose rate was also measured at the COR.
- Accumulated doses since the beginning of the radioactive releases, measured by the electronic dosemeters at the UOC and SOC were communicated to be approximately 5 to 6 mSv (values in coherence with the dose rates vs time measured at the ring stations)

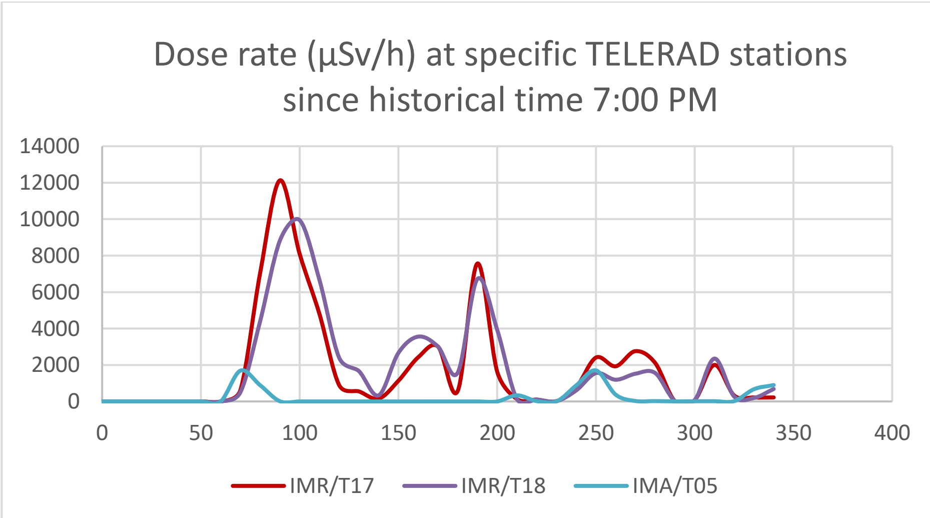


**Figure 5 :** simulated dose rate evolution at given TELERAD stations during CFVS working (X axis expressed in minutes)

At 16:10 the exercise started again. The emergency team had to focus on the closing of the CFVS, as soon as the cooling safety function is recovered. The scenario led the emergency team to think about the local intervention : determination of the local radiological conditions and choice of the personnel protective equipment.

The unit was assumed to be stabilized at ~ 17:10 and the CFVS was closed. This led to the end of the exercise.

## Lessons learnt

The debriefing of the exercise and the subsequent analysis led to identify about 20 improvement actions in a graded manner : main actions, minor, recommendations (not mandatory). The actions are distributed according to the following thematic : logistics, organization and procedures, technical management of the accident, radiological management of the accident but also scenario actions, as sketched in the Figure 6. Some examples are given below.

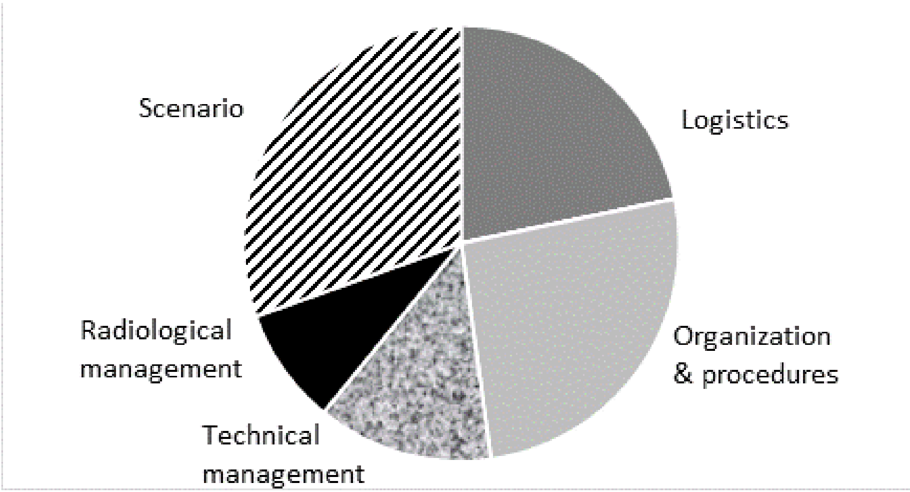


**Figure 6 :** Overall view of the Tihange action plan derived from the national emergency exercise of 17 March 2021

Concerning the logistics domain, as the various emergency infrastructure are not equipped in an identical way with the communication means, that provoked some questioning from the participants regarding the impact of the SBO initiator on the availability of the equipment. It was therefore decided (i) to enhance the training of the on-duty emergency engineers with the communication means and (ii) to install phone devices with audio-conferences functionalities in all emergency centers of the Tihange NPP.

O&P domain gathers several improvements in the procedures, that cannot be described in this paper. Nevertheless, one particular example was the use of the ECOS system to set up a second emergency engineers' team. The application was first used inside the trailer COR but it did not work as the COR trailer is an independent IT entity, not integrated to the one of the Tihange NPP. This caused a delay of about half an hour in order to solve the issue and use the application ECOS from an appropriate connection.

In the technical management domain, it was found that clarifications should be implemented in the procedure supporting the choice of radiological source terms (standard scenario catalogue). Also, the F-TEC forms, forms whose layout is agreed upon with the Safety Authorities and used to efficiently communicate about the plant status, should be updated according to the additional safety systems that have been installed within the BEST framework.

For the radiological domain, some shortcomings have been identified through the formalized F-RAD forms. It was indeed found that (i) no VRP radiological measurement were reported, (ii) contribution from the various radionuclides families was sometimes not correctly evaluated, (iii) hand-written F-RAD were sometimes difficult to read, and (iv) a confusion occurred between the TELERAD ring station IMR-T05 and the agglomeration station IMA-T05, what underlines in turn the importance of the secured communication.

Improvement actions were also identified with respect to the scenario itself (i.e. actions addressed to the scenarists). As explained, the exercise used historical meteorological conditions and the exercise was supported by the providing of inputs with a double timing. Such a double timing should be avoided in the inputs given to the participants, as it is a source of confusion. Also, the exercise required to use exercise email listings that were not effectively implemented, as they are not available as the real emergency email lists available in the ENGIE Electrabel IT system. This caused delay in the sending of technical F-TEC and notification forms.

## General conclusions

The paper reports the highlights of the national nuclear emergency exercise of 17 March 2021, as performed by the Tihange NPP. It covers the briefing, the involved personnel and infrastructure and it also evidences how an emergency exercise is executed, with some tips and tricks, from the viewpoint of the scenarist.

The execution of the exercise according to a timeline is described and some lessons learnt are given.

The exercise was successfully performed by the appointed emergency teams and most of the pursued objectives were reached.

Nevertheless, several improvement actions were identified for both the emergency plan and preparedness itself, and for the exercise scenario in the other hand. The lessons learnt were communicated to all Electrabel on-duty emergency teams, and were shared with the Belgian Safety Authorities. They are now considered at Tihange for further improvement of the emergency plan and preparedness and for completing and enhancing the realism of the exercises.

## Glossary

| | |
|---|---|
| BEST | Belgian Stress Tests |
| BR | Building Reactor |
| CARA | Centre d’Accueil et de Repli Arrière |
| CFVS | Containment Filtered Venting System |
| CELEVAL | Cellule d’Evaluation |
| COR | Centre Opérationnel de Repli |
| CSBO | Complete Station Black Out |
| DID | Defense In Depth |
| ECOS | Emergency call-out System |
| NCCN | National Crisis Centrum Centre de Crise national |
| NPP | Nuclear Power Plant |
| PGA | Peak Ground Acceleration |
| PUN | Plan d’Urgence Nucléaire |
| SAE | Site Area Emergency |
| SAMG | Severe Accident Management Guidelines |
| SBO | Station Black Out |
| SGTR | Steam Generator Tube Rupture |
| SOC | Site Operating Center |
| UOC | Unit Operating Center |

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# Appendix

## Timeline of the national nuclear emergency exercise of 17 March 2021

| ***Real time*** | ***Historical time*** | ***Main events*** |
|---|---|---|
| 8:00 | 13:00 | Storm in the surroundings of Tihange<br>→ Loss of the external grid<br>→ Loss of lighting, computers, screens, satellite phones, 3G/4G network<br>Activation of the emergency team using ASTRID network<br>Main SOC unavailable → Back-up SOC (COR)<br>+ distribution of the emergency team according to a multi-unit event (COR, UOC T1, UOC T2, UOC T3 and full-scope simulator) |
| 8:30 | 13:30 | First briefing @ COR |
| 8:30 – 8:45 | 13:30 – 13:45 | Phone calls from personnel towards the COR and UOC |
| 8:50 | 13:50 | Call CS112 : National nuclear emergency – level : Site Area Emergency (SAE) |
| 9:05 | 14:05 | COR repowered by its emergency power supply<br>→ Get back lighting, screens, satellite phones (Post-Its ⚐) |
| 9:20 | 14:20 | First simulated personnel inventory provided to the emergency team |
| 9:25 | 14:25 | Contact between CNT emergency director and FANC to inform about a preventive evacuation of the personnel not involved in the emergency management |
| 9:30 | 14:30 | Emergency team informed by G4S about personnel not at the muster rooms<br>Emergency team requests site Police to support the personnel preventive evacuation<br>Emergency team informed by the Second interveners about blocked lifts with personnel |
| 10:00 | 15:00 | Automatic call-out to prepare a shift-over emergency team) |

| | | |
|---|---|---|
| 10:00 | 15:00 | T1 and T2 are in a stable situation using their own emergency power supply (SBO)<br>T3 without any power supply : CSBO |
| 11:00 | 16:00 | Start of the RP vehicle for on-site measurements |
| 11:30 | 16:30 | Stop of scenario with the full scope simulator as the primary temperature > 650 °C (and building reactor pressure ~ 2.5 Bar) → time acceleration ⚐ !<br>Start using the Severe Accident Management Guidelines (SAMG) |
| 11:45 | 16:45 | Emergency team relocated according to a single-unit (T3) event |
| 12:00 | 17:00 | Arrival of the 2nd emergency team |
| 12:00 – 12:50 | 17:00 – 17:50 | Shift turnover meeting |
| 14:00 | 19:00 | Second start of the RP vehicle (off-site)<br>Primary temperature and BR pressure still increasing → start of the containment filtered venting system (CFVS) |
| 14:05 | 19:05 | Corporate informs about the set up of a rear base at Flawinne (Army camp @ Namur) |
| 14:40 | 19:40 | CNT emergency director informs NCCN about the coming use of CFVS |
| 15:15 | 20:15 | CFVS working – scenarists activate the SOC and UOC dose rate alarms ⚐ |
| 15:45 – 16:10 | NA | Scenario pause and explanation (by the scenarists) of the technical and radiological evolution during 4h of venting |
| 16:10 | 00:45 | Restart of exercise – focus on stabilizing the unit and terminating the venting |
| 16:50 | 01:25 | Determination of the radiological conditions and protective arrangements in order to terminate the venting with a local action |
| 17:10 | 01:45 | Unit stabilized. CVFS closed. Surrounding dose rate strongly decreases<br>End of exercise |

# Aerial Gamma Spectroscopy campaigns in the context of the Tihange exercise

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## Abstract

Many countries have implemented Aerial Gamma Spectrometry (AGS) in the context of their nuclear and radiological emergency preparedness and response plan. In general, large volume scintillation detectors are used, carried by a helicopter or small airplane, collecting gamma-ray spectra, each for one or a few seconds, stamped with location (GPS) and altitude above ground data. This allows the rapid mapping of large areas and quantifying the contamination levels in the aftermath of a nuclear or radiological event, as was, for example, demonstrated during the Fukushima accident. Also the search for radioactive sources can be performed efficiently with this method.

In 2008, in the context of the Belgian nuclear and radiological emergency plan, two similar sets of equipment (currently known as SPIR-Ident from Mirion Technologies inc.) were made available via the Nuclear Fund (Ministry of Interior). The systems have been gradually tested and implemented, first car-borne, later airborne including more than 15 test flights by experts of IRE and SCK CEN.

More recently an agreement with Belgian Defence was made, including the practical arrangements, to perform two exercises per year with the equipment on-board of an Agusta A109 helicopter from the 1st Wing operating from Beauvechain. In the context of the 2021 Tihange nuclear power plant nuclear emergency exercise flights have been executed in June 2021. This was the first time that flights were accomplished over a nuclear power plant in Belgium.

The paper addresses the flight planning, the execution of the flights, the results used for the radiological assessment and the results after post-processing. Potential options are also discussed, based on the flights over Tihange and flights over the nuclear power plant of Doel in October 2021, in order to improve the system in the context of a real nuclear or radiological emergency.

**Key words :** gamma spectroscopy, aerial survey, emergency exercise

## Introduction

Although initially introduced for uranium exploration, Aerial Gamma Spectroscopy (AGS) has become a measurement technique to map the radioactive contamination over large areas in the aftermath of a nuclear or radiological event. In general, large volume scintillation detectors (NaI[Tl]), sometimes complemented with a high purity germanium detector are used on board of a helicopter or small airplane to survey the potentially affected area. This allows, as was for example clearly demonstrated in the aftermath of the Fukushima-Daiichi nuclear accident, to get a detailed and complete overview of dose rate levels and radionuclide specific (I-131, Cs-137, Cs-134) contamination data, in a relative short time after the release of radioactivity to the environment. Many countries have implemented AGS as part of their emergency preparedness monitoring strategy complementing data from early warning network stations, mobile teams and sampling campaigns with analyses in radionuclide laboratories.

Since 2008, two AGS systems are available in Belgium via the Nuclear Fund governed by the Ministry of Interior in the context of nuclear and radiological emergency preparedness. Their use and deployment in an emergency context are discussed in Gepeto CELMES, a working group chaired by FANC-AFCN and consisting of all partner institutes in emergency monitoring. One system is stationed at IRE and one at SCK CEN and both institutes have operators trained to use the system and analyze the data. The systems each consist of two times two large volume -4 liter each- NaI[Tl] scintillation detectors and the necessary electronics. Gamma ray spectra are collected, typically for acquisition times between 1 and 5 seconds and are stamped with a GPS location and altitude above ground. The altitude above ground level is important to perform corrections for the attenuation of the gamma-rays in air. It is obtained on the basis of GPS height and the use of a high-resolution digital elevation model. Over the last years the systems have been tested and used in more than 15 flights, using different airborne vectors, over different areas including sites with increased radiation levels (mainly originating from radium 226), nuclear sites (IRE and the nuclear area Mol-Dessel) and environments with different natural backgrounds. However, the nuclear power plant sites of Doel and Tihange and their environment had never before been investigated by AGS. The deployment of the AGS system installed in an Agusta helicopter of Belgian Defense and surveying the Tihange area was defined as an objective of the Tihange 2021 federal emergency exercise. The Tihange 2021 exercise consisted of two parts, first an exercise on the early phase of the accident and a second part on the transition phase (June 26, 2021). The AGS measurements were scheduled in between the two phases on June 8, 2021 corresponding to the chronological order in which the AGS measurements can provide radiation and contamination maps after the release as input for decisions to be taken during the transition phase.

## Preparation and execution of the AGS flights

The deployment of the AGS during the exercise fits into a recent Convention with Belgian Defense to perform two training flights a year with the AGS installed in helicopters of Belgian Defense. Although it was not the first time that flights were performed in collaboration with Belgian Defense the first objective of the AGS flights in the federal exercise was to practice the deployment and train the staff involved. Because it was the first flight over the site of a nuclear power plant in Belgium also the aspects of coordination with the relevant authorities and the operator of the power plant were important goals of the exercise, in particular the flight planning. A 7 km x 7 km square area, with in its center the Tihange NPP, was defined as the survey area. This area was not specifically linked to the emergency exercise, but was defined to map the background radiation levels above and around the Tihange NPP site. Having knowledge of these levels before an incident is important in a real emergency. Straight flight lines were defined in two perpendicular directions, one set of lines in the main direction of the valley of the river Meuse and one set perpendicular to that direction. Further, the distance between consecutive flight lines was defined to be around 333 m.  Combined with a typical flying altitude above ground of 150 meter this guarantees that the area is well covered, without too much overlap in the field of view of the detectors.

The AGS equipment was installed inside an Agusta A109BA of the 1st Wing of Belgian Defense at the Beauvechain air base on a special support platform which has been constructed in the past for this purpose. Installation, pre-flight testing and discussion of the flight plan with pilots was realized in less than 1 hour (see Figure 6) . The flights were executed in two phases to cover the pre-defined area in the two directions: a morning and afternoon flight. This allowed refueling, training of two different AGS operators and also changes in the flight plan for the afternoon flight based on the results from the morning flight.


**Figure 6 :** Agusta A109BA with AGS equipment installed, ready for take-off.

During the flight, the AGS operator has control over a number of parameters. The software contains mainly two functionalities: i/ radionuclide identification and ii/ mapping of ground dose rates, and radionuclide specific quantities such as deposition levels (in $Bq/m^2$) for artificial radionuclides or activity concentrations (in Bq/kg) for natural radionuclides. Correction for the altitude of the detector above ground is performed online using the GPS altitude corrected with a digital elevation model. In the presence of artificial radionuclides, the system will automatically display the radionuclides identified. The evolution with time (data every second) can be followed in the form of a ground dose rate plot, waterfall spectra and a map with the trajectory colored according to a selected parameter (such as ground dose rate): see Figure 7.

After the flights, the data were directly exported from the AGS database as specific data files for direct upload in the GIS system of the crisis Centre and as back-up. Also, some pre-defined pdf reports were exported and exchanged in the context of the exercise.

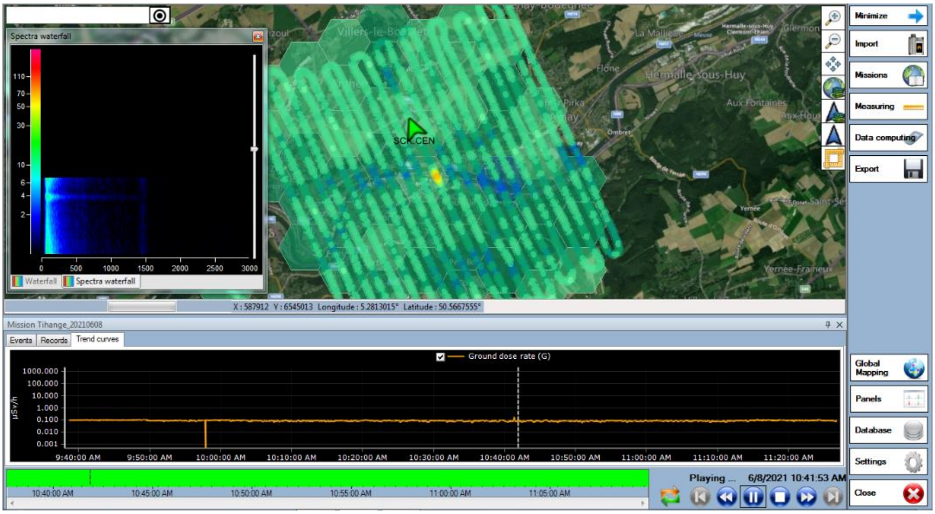


**Figure 7 :** AGS interface as available for the operator – can be customized by the operator to follow most important parameters. Image made in Replay mode after the flight.

## Results

During the flights the vast majority of measurement points showed normal background levels and no artificial radionuclides. The average ground dose rate (ambient dose equivalent rate) over the surveyed area was 79 nSv/h, which is a typical background level. Ground dose rate values extracted from the AGS measured above the dose rate stations of the TELERAD network around Tihange NPP gave very similar results as those measured by TELERAD. Only above a part of the Tihange NPP site a slight increase in dose rate levels was observed, the maximum extracted ground dose rate value being 220 nSv/h. At this spot also Co-60 was identified in the spectra collected (see Figure 8) . The increase in dose rate and detection of Co-60 can be attributed to radiation from the storage of radioactive waste on site. While this radiation is largely shielded in the lateral directions, some increase in dose rate is visible from above. It has to be noted that no increase at all was detected above the nuclear reactors.

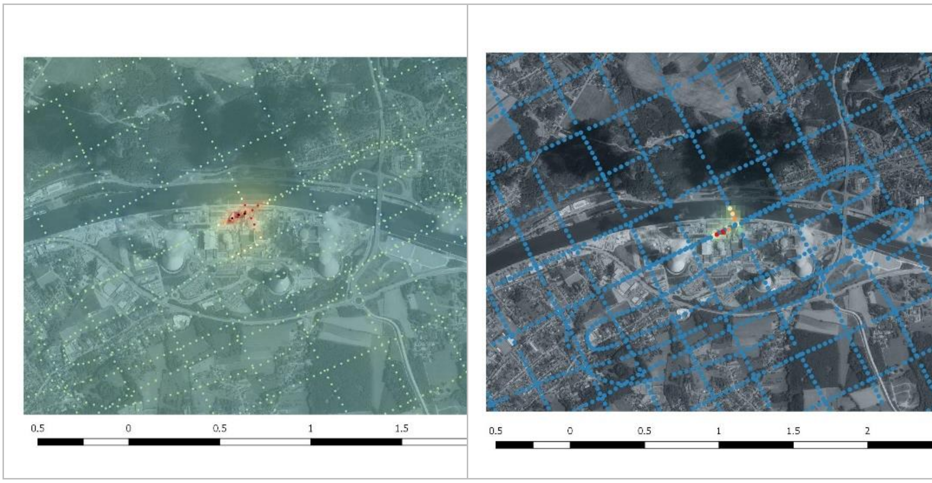


**Figure 8 :** Zoom on surveyed area. Left: ground dose rate levels measured (dots) and interpolated. Right: Co-60 levels extracted from measured spectra (dots) and interpolated (for an unshielded point source the values would correspond to MBq). Both images are using the measurements from both (morning and afternoon) flights.

Based on the observation of Co-60 during the morning flight, only for exercise purposes, some additional flight lines had been introduced during the afternoon flight to increase the spatial resolution above the NPP site. Further analyses showed that both flight directions gave very similar results, although for the lines perpendicular to the Meuse valley the variations in altitude above ground are much more pronounced. This shows that ground clearance corrections work well.

## Lessons identified

During the exercise it was demonstrated that the fast deployment of the AGS system with Agusta helicopters from the 1st Wing of the Belgian Defense (Beauvechain) can be realized, that provides reliable results, directly after the flight. The pre-defined flight pattern was very well reproduced in the actual flights by the pilots. Based on experience from other flights, however, this is not always the case, and this remains an attention point. Flying lines not strictly to the plan, can result in important variations in the sensitivity and spatial resolution of the results over the area of survey.

Apart from the need for regular practicing, for both the helicopter staff, including the pilots and the AGS operators some future work can be identified:

– Flight planning for this exercise was pre-defined somewhat outside the exercise scenario with the specific objective to survey the site and close environment of the Tihange NPP. In reality, flight plans should be defined to guide decisions on (lifting of) protective actions. This could be practiced in future exercises or specific table-tops;

– In a real emergency, (residual) releases to the atmosphere can interfere with low altitude surveys for deposition measurements and result also in the contamination of the helicopter. Some practical rules should be developed to guide decisions on first flights (for example based on airborne concentration measurements);

– The radionuclide vector can be complex shortly after a release, which will make radionuclide quantification difficult in a first survey. Ground dose rate values will anyway be available.

– To check consistency of measurements, between flights, but also between helicopter measurements and ground-based measurements such as available from TELERAD and mobile teams, a reference area should be selected from the beginning to compare results and investigate differences if they show up.

## Acknowlegment

Making AGS surveys successful is the work of many teams and people, the author would like to thank FANC-AFCN (David Rasquin, Thibault Vanaudenhove for coordination and planning), 1st wing Belgian Defense **(**Agusta staff and pilots), SCK CEN (Johan Paridaens, Christophe Gueibe & Geert Olyslaegers), IRE (Benoit Lelandais, Tony Dieudonné), Engie Electrabel - NPP Tihange (for collaborating in granting access to fly over the site) and the NCCN **(**AGS equipment funded via nuclear fund).

# National nuclear emergency exercise
# of 17 March & 29 June 2021
# Main outcomes and lessons learned

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## Abstract

In addition to the other papers detailing the successive steps of defining, preparing and conducting a nuclear emergency response exercise, the purpose of this paper is to present and describe the last step of the process: how an exercise is assessed, in order to identify the outcomes and lessons to be learned. The two-phased exercise held on 17 March and 29 June 2021 is used to illustrate this process by summarizing the main outcomes and lessons learned from the exercise, including elements related to the definition, preparation, conduct and development phases of the exercise. These outcomes and lessons learned obviously result from the contributions of all actors involved in the exercise.

More general and personal reflections on exercises, their challenges, constraints and limitations conclude the paper.

**Key words :** emergency exercise, return of experience

## Introduction and background

Organizing a nuclear emergency response exercise to test the arrangements and level of preparedness for the transition phase[1] was a novelty for the various actors, but also presented undeniable challenges and constraints.

This is one of the reasons why the exercise was organized in phases separated by several months, in order to be able to refine the scenario elements for the second phase devoted to testing the transition phase. Unfortunately, due to the health situation induced by COVID-19, the initial schedule had to be postponed several times, impacting on the necessary serenity for the preparation and conduct of the exercise. The initial objectives of several partners therefore had to be reduced both in the preparation phase and in the course of the exercise.

Specific biases or conditions were introduced, such as a shortened timeframe between the two phases, an adaptation of the exercise format (from table-top to command post exercise), a lack of involvement of the operational level in the preparation, arbitrary and artificial increase of radioactive deposits or a working of the evaluation cell (CELEVAL) at the CI²C, the internal FANC-Bel V crisis centre, instead of at the NCCN[2]. It is therefore important to be particularly careful with the findings, outcomes or lessons learned directly related to such biases or conditions.

This paper is based on the general evaluation report issued by the NCCN, based on various contributions: reports and debriefings of the actors and their respective organization, findings of the observers deployed amongst the involved crisis entities.

## Main outcomes & lessons learned

The scenario and the exercise were generally considered interesting and innovative. However, the biases introduced brought some confusion and

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[1] The transition phase is defined as the phase coming just after the emergency phase, from the moment the technical situation is under control and that no further degradation is further expected, neither any radioactive release. See the complete definition at §1.4.2 of the Nuclear and Radiological Emergency Plan for the Belgian Territory, Royal Decree 1st March 2018

[2] National Crisis Centre (Nationaal CrisisCentrum – Centre de Crise National)

discontinuity in the course of the emergency situation, which disturbed significantly some involved actors.

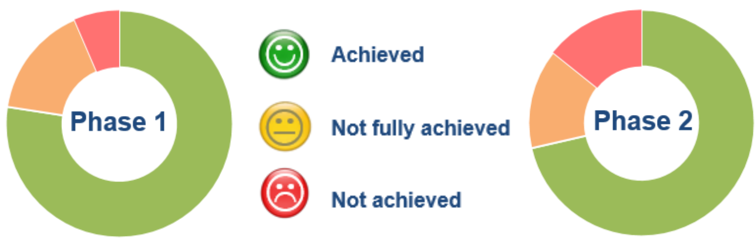


**Figure 1 :** assessment of the achievement of the two-phased exercise.

As illustrated, the overall assessment of the achievement of the objectives at the different levels (operator, CELEVAL, Federal Coordination Committee COFECO, Province) is more than 70% (78% for phase 1 and 72% for phase 2), which is a good result. Few examples of the assessed objectives are: the test and use of the ICMS[3] exchange platform, the test of the IAEA Reactor Assessment Tool to support and assist the technical assessment performed in CELEVAL or the test of sending fictive BE-alert messages.

The main positive aspects identified and noted are the following:

- An interesting and innovative scenario;
- A great interest in an exercise involving effective team shift/turnover;
- The test of the Host Nation Support concept was appreciated;
- The use of Controllers network was also appreciated;
- The establishment of a response cell by the NCCN to reinforce the realism of the exercise.

The following points of attention have been identified regarding the preparation of the exercise:

[3] Incident & Crisis Management System

- The need to strengthen the precision of the “exercise convention”, particularly on the roles and missions of the controllers;
- In the event of a time jump (two-phase exercise) or a shift in the start of the exercise (T0+ x hours), it is necessary to compile a detailed and robust “exercise book” that must be owned by the players (consolidated logbooks, prior advice and decisions, mapping, etc.);
- The importance of a deeper involving local authorities and operational services in the preparatory stages (objectives, scenario, exercise concrete arrangements);
- The importance of avoiding the use of fictitious dates and/or times that could lead to a major source of confusion.

The following structural improvements have been identified:

- Some ad hoc reinforcement of the COR[4] infrastructure on-site;
- The need to a structural strengthening of alert and mobilization mechanisms;
- The need to establish a procedure for the organization of the CELEVAL members shift/turnover;
- The importance of the systematic presence of the permanent representative of the FANC at COFECO to facilitate exchanges and understanding of the development of the emergency situation;
- The importance of involving the information cell in exercises focusing on communication actions;
- The importance of avoiding the use of non-explicitly defined concepts to avoid confusion or interpretation;
- The need to integrate as much as possible the different crisis management and information exchange tools & platforms (WAPITI[5], ICMS…).

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[4] Backup on-site emergency facility (Centre Opérationnel de Repli)

[5] Web-based Application Platform to Improve Transfer of Information

As for the general conclusion of the exercise resulting from these different outcomes, and although they must be, as stressed above, considered with caution in view of the specific circumstances and biases, it allowed many concrete lessons to be drawn, which undoubtedly demonstrates the seriousness with which the exercise was prepared, conducted and evaluated. It also reaffirmed principles that are crucial to good nuclear crisis management, such as a need for an integrated response and the presence of the permanent representative of the FANC in COFECO.

## Some more personal thoughts...

Beyond the specific context of the exercise described in these presentations, I would like to broaden my remarks around the following key-question: *"How can we ensure, through regular exercises, that the teams and stakeholders are sufficiently trained to respond in the most appropriate way possible to a situation which, by definition, is an unforeseen situation?"*

Indeed, based on experience of several decades of various exercises, whether in terms of the situations addressed, the circumstances, conditions or constraints (geographical, linguistic...), it seems essential to me to maintain a balance between robust and proven organizational, expertise, human, material and logistical modalities **AND** sufficient flexibility at all levels to be able to adapt to the specific circumstances of the actual emergency situation.

This implies not only the development of efficient arrangements, infrastructures and tools and adapted technical skills, but also – I would even say more importantly – the development of appropriate "Knowledge", “Skills” and “Attitudes” (KSA).

As such, exercises should be able to reinforce these aspects by varying the scenarios and conditions or by integrating disruptive elements. They should also contribute to strengthening the level of understanding and trust between stakeholders (*common understanding*), which is essential for an effective response to a situation that is by definition unpredictable.

As highlighted above, it is important to be fully aware of the intrinsic limits of such exercises, such as prior knowledge of the situation (which induces a certain level of anticipation), time constraints (frequent use of a compressed time-scale leading to a rapid and unrealistic sequence of events), a lack of realism in the exercise conditions or a level of stress that is not really adapted to the real conditions, which can, however, in my opinion, lead to both inappropriate behaviour (high stress) but also lead to unsuspected resources or initiatives (positive stress).

To illustrate the chronic lack of realism in exercises, how many times have I heard: "Don't worry, in reality this would not happen...". A key element is that these unrealistic elements and constraints do not reach such a level that an exercise becomes a demonstration or leads to inappropriate or useless lessons being learned.

Before concluding, some key words for successful and useful exercises: *realism*, *variety of scenarios and conditions*, *KSA*, *Common Understanding*, *humility* and *openness*.

To conclude, I cannot resist sharing with you an anecdote that I personally experienced more than 25 years ago but which, I think, is still very relevant today: a few minutes after the start of a press conference organized after the end of an exercise, a journalist took the floor to summarize its progress, and I quote: “*if I have understood correctly the course of this day's exercise, a real emergency would be needed to allow the exercises to be tested!*”

This journalist summed up the course of the exercise perfectly and the press conference ended with this statement...

This is obviously a conclusion that should be avoided for any nuclear emergency response exercise.

Hoofdredacteur Mr. Michel Sonck Rédacteur en chef