NUCLEAR SECURITY SERIES No. XX-T

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DRAFT

STEP 8: Soliciting comments by Member States

EXPERT SUPPORT IN THE ASSESSMENT OF ALARMS AND ALERTS FOR NUCLEAR AND OTHER RADIOACTIVE MATERIAL OUT OF REGULATORY CONTROL

DRAFT TECHNICAL GUIDANCE

FOREWORD

[Standard NSS foreword to be added]

CONTENTS

1. INTRODUCTION

BACKGROUND

1.1. IAEA Nuclear Security Series No. 15, Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control [1], provides recommendations to States for the nuclear security of nuclear and other radioactive material out of regulatory control, including recommendations for the detection and assessment of instrument alarms and information alerts related to nuclear and other radioactive material out of regulatory control.

1.2. IAEA Nuclear Security Series No. 21, Nuclear Security Systems and Measures for the Detection of Nuclear and Other Radioactive Material out of Regulatory Control [2], provides guidance to States and their competent authorities for the development of an effective nuclear security detection architecture for detection of criminal or intentional unauthorized acts involving nuclear and other radioactive material out of regulatory control. Reference [2] describes the basic concepts for detection by instruments and by information alerts, and provides guidance on the initial assessment of alarms and alerts.

1.3. This publication supplements Ref. [2] by providing detailed guidance on expert support and its role in the assessment of instrument alarms and information alerts related to the detection of nuclear and other radioactive material out of regulatory control.

1.4. This publication also complements the following publications:

– IAEA Nuclear Security Series No. 37-G, Developing a National Framework for Managing the Response to Nuclear Security Events [3];

– IAEA Nuclear Security Series No. 24-G, Risk Informed Approach for Nuclear Security Measures for Nuclear and Other Radioactive Material out of Regulatory Control [4];

– IAEA Nuclear Security Series No. 31-G, Building Capacity for Nuclear Security [5];

– IAEA Nuclear Security Series No. 34-T, Planning and Organizing Nuclear Security Systems and Measures for Nuclear and Other Radioactive Material out of Regulatory Control [6];

– IAEA Nuclear Security Series No. 44-T, Detection at State Borders of Nuclear and Other Radioactive Material out of Regulatory Control [7];

– IAEA Nuclear Security Series No. [NST061], Detection in a State's Interior of Nuclear and Other Radioactive Material out of Regulatory Control [8].

OBJECTIVE

1.5. The objective of this publication is to provide detailed guidance to States on the role of expert support in the assessment of instrument alarms and information alerts for the detection of nuclear and other radioactive material out of regulatory control within the State and at State borders. The publication demonstrates how expert support can aid with hazard determination, locating and identifying the nuclear or other radioactive material responsible for an alarm or alert, and provide competent authorities with advice to decide the outcome (i.e. adjudication of the alarm or alert).

1.6. This publication is intended to be used by competent authorities responsible for the assessment of alarms and alerts related to nuclear and other radioactive material out of regulatory control. It is also aimed at organizations providing expert support, which may include technical and scientific organizations, research institutes, academia, regulatory bodies, intelligence organizations, law enforcement agencies and national security organizations.

SCOPE

1.7. This publication provides guidance on the role of expert support as part of the nuclear security detection architecture and covers the specific tasks to be undertaken by expert support for the assessment of instrument alarms and information alerts. Assessments may involve the detection of trafficking, illegal shipments or criminal or any other intentional unauthorized acts involving nuclear and other radioactive material out of regulatory control. Instrument alarms or information alerts obtained from various sources, such as operational information, reports of regulatory non-compliance and reports of the loss of regulatory control, act as the basis of such assessments.

1.8. This publication does not cover response to nuclear security events, which is addressed in Ref. [3]. Preparedness and response to a nuclear or radiological emergency triggered by a nuclear security event are addressed in Refs [9–11] and are outside the scope of this publication. Voluntary and mandatory reporting under the Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (see Ref. [12, 13]) are also outside the scope of this publication.

STRUCTURE

1.9. Section 2 of this publication provides an overview of expert support in assessing instrument alarms and information alerts, placing such assessments in the context of the overall nuclear security detection architecture. More specific guidance on the assessment of alarms and alerts by expert support is provided in Sections 3 and 4, respectively. Section 5 focuses on the sustainability of expert support, and Section 6 provides guidance on international support for expert support. The Appendix describes additional information that should be provided to expert support by front line officers for alarm and alert assessment. Annex I present examples of expert support measures at State borders, within a State and at major public events. Annex II provides information on the detection of radioactive material using gamma spectroscopy.

2. ESTABLISHING EXPERT SUPPORT FOR NUCLEAR SECURITY DETECTION

2.1. In order to achieve the objectives of a State's nuclear security regime, the functions of competent authorities include detection, through an instrument alarm and/or information alert, of the presence or indications of a criminal or other intentional unauthorized act with nuclear security implications involving nuclear or other radioactive material out of regulatory control and, in particular, to "perform the initial assessment of the *instrument alarms* and *information alerts* promptly to determine if a *nuclear security event* has occurred" (see para. 2.1 of Ref. [1]).

2.2. Paragraph 5.22 of Ref. [1] states:

> "An *instrument alarm* or an *information alert* should lead to the conduct of an initial assessment. The relevant *competent authorities* should ensure the establishment of procedures and protocols for the initial assessment of both an *instrument alarm* and an *information alert* by the designated staff and, as applicable, by other designated organizations."

2.3. For the assessment of instrument alarms, para. 6.7 of Ref. [1] states that: "The *competent authorities* should define the roles and responsibilities of technical staff, assigned experts and support organizations who may be involved in resolving an *instrument alarm*, if the initial assessment is not conclusive." For the assessment of information alerts, para. 6.9 of ref. [1] states that: "The *competent authorities* should define the roles and responsibilities of, and obtain the necessary assistance from, the assigned experts and the support organizations, if the initial assessment is not conclusive."

2.4. Paragraph 6.3 of Ref. [2] states:

> "Technical support should be available for assessing alarms and assisting in the initial assessment activities. Technical support in the form of expert support[1] teams should include persons equipped and trained to use basic radiation monitoring instruments for categorization of radioactive material and to perform radiation protection tasks. Technical support organizations may provide the necessary expertise and coordinate the support needed for the initial assessment of alarms".

[1] Expert support is also referred to as 'technical reachback' in some States.

2.5. Paragraph 3.15 of Ref. [2] describes technical support for detection:

> “This is the (often remote) capability to assist those at the detection site in the assessment of radiation alarms or information alerts or on the discovery of suspicious or unauthorized material that could be used to manufacture an IND, RED or RDD[2]. Technical support relies heavily on radiation analysts and subject matter experts who can identify specific isotopes and potential threats based on data collected from the detection site, either remotely or in person.”

Reference [2] further states that “The term ‘technical support’ refers to mechanisms for engaging subject matter experts, including researchers, scientists and analysts, to assist with technical expertise in investigating and resolving alarms and alerts.”

2.6. Technical support from experts (hereinafter referred to as ‘expert support’) is a cross-cutting element of the nuclear security detection architecture. Expert support assists in the assessment of alarms and alerts that cannot be resolved by competent authorities or front line officers who are conducting detection operations by confirming whether alarms are *false*, *innocent* or *non-innocent* (see Section 3), as well as whether information alerts are credible (see Section 4).

2.7. The provision of expert support involves the following:

(a) Establishing a network of subject matter experts providing technical, scientific and operational advice to the competent authorities;

(b) Assessing and adjudicating alarms and alerts in a timely manner, and providing advice to assist front line officers and other competent authorities;

(c) Integrating processes into the nuclear security detection architecture so as to support the assessment of alarms or alerts in the context of potential nuclear security risks.

2.8. Cooperation between local, national, regional and/or international organizations can help to ensure the effectiveness of expert support. Organizations might have different objectives and areas of expertise, as well as different working methods, internal structures and organizational cultures. For this reason, the following steps should be completed by the relevant decision makers before expert support can be given the task of assessing instrument alarms and information alerts:

(a) Determining the nature of the expert support needed, in accordance with the results of the national threat assessment;

(b) Identifying the organizations that will receive and supply the necessary expert support, according

[2] IND – improvised nuclear device; RED – radiation exposure device; RDD – radiological dispersal device.

to an analysis of existing expertise;

(c) Assigning the necessary human and technical resources to the organizations involved in expert support;

(d) Establishing cooperation arrangements and communication channels between the identified organizations;

(e) Establishing a joint concept of operations and secure communication channels for exchanges among expert support.

2.9. Expert support is commonly organized in the following three operational concepts:

(a) On-site: expert support personnel are located at the same site as the competent authority conducting the detection operations;

(b) Mobile: a mobile expert support team or expert support personnel along with technical resources are deployed to the location where the competent authority is conducting detection operations;

(c) Remote: expert support personnel are located at an off-site location and provide advice remotely to the competent authority conducting the detection operations.

CAPABILITIES AND TASKS OF EXPERT SUPPORT

2.10. The tasks that should be undertaken by expert support within the nuclear security detection architecture are related to technical, scientific and operational capabilities.

2.11. The technical, scientific and operational capabilities presented in paras 2.12–2.13 are not exhaustive, as expert support may take various other forms depending on the activity undertaken. The focus of the present publication is on the role of expert support in assessing alarms and alerts, which involves related information sharing between the competent authorities and expert support. At the same time, all types of expert support for nuclear security will deal with information management. For example, radiological expertise is essential in the recovery of lost radioactive sources, crime scene management that involves nuclear and other radioactive material out of regulatory control and event consequence analysis.

2.12. The technical capabilities of expert support can support the efficient cooperation between the competent authorities and expert support and include the following tasks:

(a) Development of the instrument deployment plan. Expert support can provide advice on the type of equipment to be deployed at each location (e.g., fixed or portable radiation detection systems) taking into consideration the type of traffic. For example, pedestrian radiation portal monitors can be used for sites where a large number of people need to be monitored. More information on types of radiation detection equipment can be found in Ref. [14].

(b) Development of the concept of operations. Expert support can develop estimates of the expected alarm rates at a site.

(c) Procurement of equipment (e.g. development of equipment specifications).

(d) Equipment life-cycle management (e.g. performing equipment maintenance).

(e) Detection equipment parameter configuration to ensure detection goals are met based on the threat assessment (e.g. sensitivity setting of equipment)

(f) Quality control of the detection systems (e.g. calibrations, acceptance testing and periodic testing of detection instrument.

(g) Participation in the organization of training courses and exercises for front line officers.

(h) Participation of representatives in international cooperation, including exercises and performance evaluations.

2.13. The scientific capabilities of expert support are capabilities that are specific to nuclear security systems and measures and include the following:

(a) Having the skills and tools for analysing data and spectra from radiation measurements;

(b) Providing support to competent authorities for alarm assessment by rapidly processing information on measurements conducted by the competent authorities;

(c) Providing advice for the conduct of further measurements on the site of detection operations;

(d) Conducting research on nuclear security systems and measures, including performing suitability tests on new technologies that are to be adopted in the national detection system.

2.14. Depending on the nature of the alarm or alert, expert support may need to examine various measurements and information from the analyses that have been undertaken in the field. Expert support should have access to capabilities (e.g. equipment and other resources) that would allow them to detect and measure alpha, beta, gamma and neutron radiation, as well as to perform identification of radionuclides.

2.15. Spectrometric analyses and related alarm assessments can be demanding tasks, particularly under field conditions. A mobile support team deployed to the incident location may itself need remote expert support since the latter would likely have better resources for the analyses. Remote expert support reduces the number of tasks that need to be conducted on-site and simplifies some of the remaining tasks to be carried out by front line officers and expert support in the field, making field work less prone to error and helping to ensure safety.

2.16. The operational capabilities of expert support should be tailored to the concept of operations. All such capabilities should be prepared jointly, tested and then reinforced through continual training and exercises to ensure improvements. These operational capabilities are, inter alia:

(a) Real time availability of expert support;

(b) Advanced analyses for alarm adjudication (i.e. the capability to effectively handle technical and non-technical information with the objective of reaching a decision);

(c) Expert advice to law enforcement operations on adjudication;

(d) Supervision of a network of automated detection systems designed to detect gamma and neutron radiation, including the timely notification of alarms to the responsible competent authorities;

(e) Characterization of nuclear and other radioactive material, with advice and advanced measurements;

(f) Modelling of nuclear and radiological detection systems and special detection geometries;

(g) Research and development (R&D) on systems and measures;

(h) International assistance, if requested.

2.17. Expert support also needs to give due consideration to the possibility of shielding and masking when performing secondary screening with portable radiation detection equipment and conducting the subsequent analysis to identify isotopes that may be present.

2.18. Expert support provides advice to competent authorities on the nature of the material, on the information being gathered and on the implications for national security.

2.19. Expert support should be integrated into the nuclear security detection architecture and a coordination and communication mechanism should be established between competent authorities and expert support. Annex I provide further examples on different types of operations for expert support at State borders, within a State and at major public events.

2.20. . Depending on the type of operation, expert support personnel should, for example, be protected from all hazards (e.g. explosives, weapons) that could be present on-site. For this reason, training of experts should be conducted together with the relevant front line officers, such as with law enforcement agencies or security authorities. States should carefully consider all training opportunities, for instance through the coordinated system, as well as whether it is safe and operationally possible — depending on the operational situation and the threat assessment — to deploy subject matter experts on-site who are untrained in potential crime-scene hazards.

2.21. Joint exercises should also be carried out to ensure cooperation between expert support and front line officers deployed during field operations, and lessons learned should be used to develop, review and revise standard operating procedures, as well as to inform the content of future training (see Section 5).

2.22. Planning and organizing the nuclear security detection architecture within the national security regime helps to clarify the roles and responsibilities of each competent authority, including expert support. The instrument alarm and information alert assessment phase should be covered during this planning and organization exercise. The development of expert support capabilities could thus be based on a risk informed approach [4].

2.23. Figure 1 shows a flow chart of a generic process for detection (including the initial assessment). During the five stages presented in Fig. 1, expert support may perform the following tasks in the assessment of an alarm or alert:

(1) Stage 1: Primary detection by instrument alarm and/or information alert:

(i) Receiving a notification on an alarm or alert;

(ii) For an instrument alarm, if remote real time access to measurement data is available, carrying out an independent analysis of data.

(2) Stage 2: Confirmation of the primary detection:

(i) Checking the validity of the primary detection (upon the request of the front line officer);

(ii) Advising the front line officer on further measures (e.g. secondary inspection, additional measurements);

(iii) For an instrument alarm, if remote real time access to measurement data is not available, requesting measurement data from the front line officer and carrying out an independent analysis of data;

(iv) Deploying expert assistance to the scene, if the alarm(s) cannot be remotely adjudicated or additional investigation is required ;

(v) Advising the competent authority decision makers (if necessary).

(3) Stage 3: Confirmation of a radiation hazard:

(i) Advising the front line officer on the management of a potential radiation hazard.

(4) Stage 4: Collection and analysis of information, including radionuclide identification:

(i) Communicating with the front line officer on further data and information gathering;

(ii) Analysing all the gathered data and information;

(iii) Advising the front line officer and competent authority decision makers on the incident;

(iv) Characterizing the material (i.e. radionuclide and activity).

(5) Stage 5: Advising on an adjudication decision and declaration of a nuclear security event (if warranted); consultation with the competent authorities on next steps based on the outcome of the initial assessment.

(i) Proposing advice for alarm adjudication.

2.24. At the end of stage 5, the expert support team may still be requested to assess closed alarms in order to enhance inspection and detection efficiency. It may be beneficial for the expert team to conduct a periodic review of closed alarms to identify opportunities for improvement in the initial alarm assessment process.

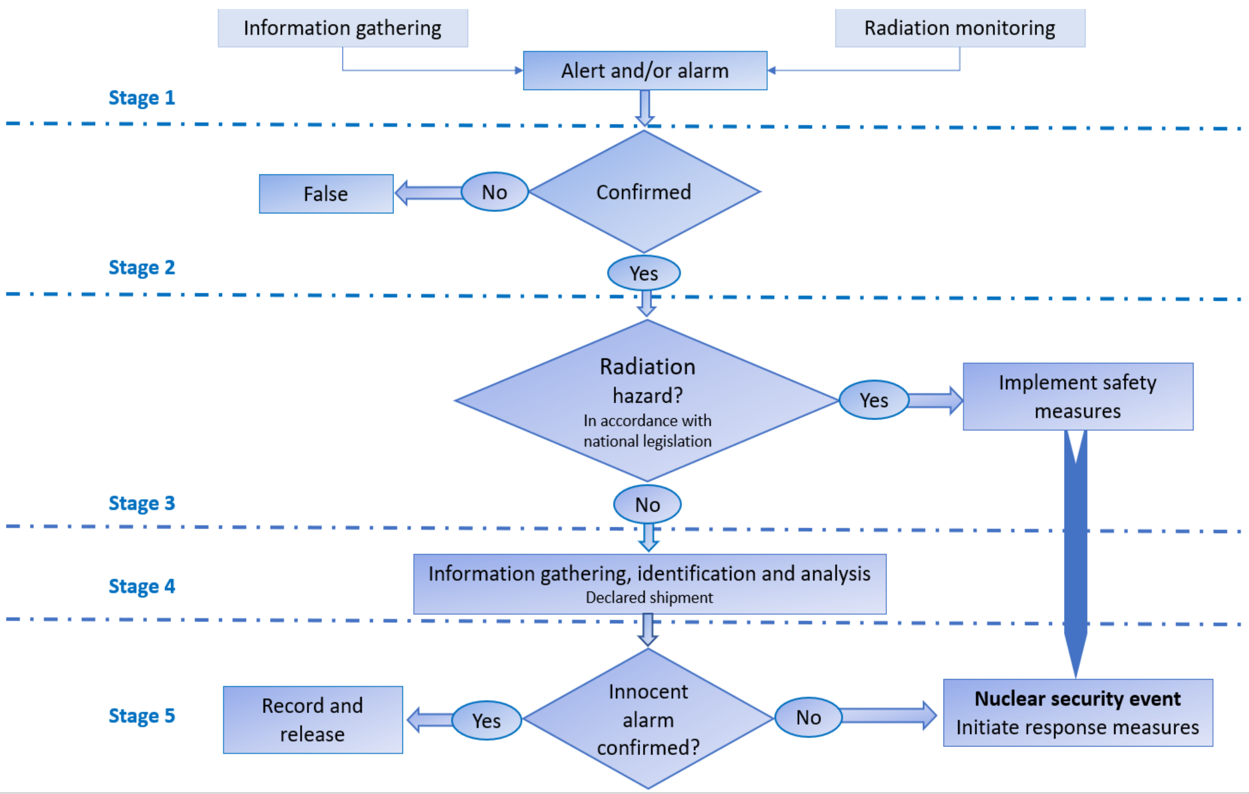

FIG. 1. Generic concept of operations flow chart (FIG. 1 of Ref. [7]).

ORGANIZATION OF EXPERT SUPPORT

2.25. Expert support can be organized at the local, regional or national level, and it can consist of human resources, material supplies, information processing, analyses and advice. Expert support may be implemented in diverse ways depending on the concept of operations. It could be a dedicated institution with specific nuclear security roles and responsibilities, or it could be a virtual network of subject matter experts who are available on call for specific tasks within the nuclear security regime.

2.26. Evolving nuclear security threats may motivate a State to establish or further develop the expert support mechanism, for example as a result of the identification of gaps and vulnerabilities in the national nuclear security regime, or as a result of changes to the operating environment, such as increased transport or use of radioactive material, or the operation of new nuclear facilities.

2.27. The establishment of an expert support mechanism is an effective way to sustain the national nuclear security regime and make optimal use of resources within the State. A feasibility study is nevertheless important to identify how to establish and organize such a mechanism, which will ensure optimization of human resources and financial investments.

2.28. Regardless of the organizational arrangements for expert support, the following key capabilities, security mechanisms and roles and responsibilities should be established, documented and communicated to all of the competent authorities within the nuclear security detection architecture:

(a) Legal basis for establishment of the expert support mechanism, including roles and responsibilities of expert support;
(b) Agreement on the concept of operations for providing expert support, designed to:
    (i) Offer advice on radiological aspects to responsible authorities;
    (ii) Verify the credibility of information from a radiological point of view.
(c) Technical basis for the operation of expert support including the following capabilities:
    (i) Identification of radionuclides in radioactive sources and radioactive material;
    (ii) Acquisition of a gamma spectrum;
    (iii) Analyses of gamma spectra;
    (iv) Detection of the presence of neutrons;
    (v) Assessment of alarms and alerts;
    (vi) Analyses of nuclear material (including determination of uranium enrichment);
    (vii) Use of computational codes, such as the Monte Carlo N-Particle code, for calculation of dose rates or to verify the presence of shielding.
(d) Information sharing and security protocols on the following activities;
    (i) Transmission of measurement data and information on the alarm or alert from the location where detection operations are conducted to expert support;
    (ii) Ensuring a reliable and secure information sharing mechanism between the competent authorities and expert support;
    (iii) Obtaining security clearance for expert support personnel.
(e) International assistance;
    (i) Establishment of a mechanism for receiving international assistance;
    (ii) Defining the role of expert support personnel in international assistance;
    (iii) Transfer of spectra to neighbouring countries or other Member States to assist with alarm assessment.

Establishing expert support

2.29. Radiological and nuclear expertise for the efficient use of national detection systems largely originate from government institutions, universities and the private sector. A State may decide to establish on-site expert support, and also to choose an additional expert support mechanism. A new capability within a certain government institution could be established, for example, to undertake work in cooperation with the competent authorities within the national security regime. This type of choice could be justified if the feasibility study did not identify any significant needs or gaps in the nuclear security regime. The State could also organize human resources and technical, scientific and operational support separately, without compromising the performance of the nuclear security detection architecture, and while also resulting in cost savings.

2.30. Threat and risk assessments and feasibility studies may indicate the need for dedicated on-site expert support or for a new expert support unit within an existing competent authority, for instance under the aegis of the national regulatory body. Each State should make the best use of its safety and security infrastructure, ensuring expert support within this framework. A State that establishes an expert support centre, for example, will allocate dedicated human and technical resources within this institution. Experts would therefore be available to support competent authorities through agreed protocols that define the timeliness of support. Support may also be initiated through a national point of contact. Alternatively, the details of the support mechanism could have been agreed formally between partners in the context of standard operating procedures or a memorandum of understanding.

2.31. States may also decide to take into account the possibility of combined attacks, where radionuclides are potentially used as part of larger scenarios that could lead to potential nuclear security events. In this case, expert support could be considered as an integral part of the broader national security framework, which would include national response arrangements.

2.32. In ideal circumstances, expert support should have the necessary equipment, analytical tools and capabilities for the analysis of alarms and/or alerts, and for the subsequent communication with front line officers regarding such alarms and alerts. Voice and data communication links are essential for exchanges between front line officers and expert support, particularly if a State has opted for remote deployment of expert support, or for both field and remote support in parallel.

INFORMATION MANAGEMENT AND EXPERT SUPPORT

2.33. Expert support deals with different types of information from various sources. Information on instrument alarms or information alerts can be of a technical or non-technical nature, and can often be categorized as follows:

(a) Information related to criminal or other intentional unauthorized acts, data and messages from detection systems, and technical and scientific assessments to determine if nuclear and other radioactive material out of regulatory control is present;

(b) Configuration information concerning the nuclear security detection architecture structure, which describes the concept of operations, human resources and the roles and responsibilities of the competent authorities, as well as the technical details of the detection systems;

(c) Status information consisting of specific details on the current state of detection systems.

Information security in exchanges with expert support

2.34. When competent authorities transmit information pertaining to alarms and alerts to expert support, there should be a clear understanding of the level of sensitivity and classification of the information, when information pertaining to alarms and alerts are transmitting to expert support by competent authorities. (see Ref. [15]). Given the underlying risks involved in the unauthorized release of sensitive information, a means of protecting the confidentiality of information should be defined as part of the information management strategy, described in depth in Ref. [15]. Competent authorities may also solicit the advice of expert support regarding the classification and protection of sensitive information derived from the assessment of alarms and/or alerts. Integrity and availability of information should also be ensured, i.e. that the information is correct and that it is available to those who need it. Otherwise, the risk is that alarm adjudication will be incorrect or impossible

2.35. The competent authorities who are responsible for expert support in nuclear security detection should adhere to the established information strategy and protocols when handling sensitive information and should process information that could potentially be used to assist in legal proceedings. Failure to protect and secure sensitive information during the assessment of alarms and alerts might lead to ineffective adjudication and to potential risks to nuclear security. More detailed information on the protection of sensitive information can be found in Refs [1, 16].

3. THE ROLE OF EXPERT SUPPORT IN THE ASSESSMENT OF INSTRUMENT ALARMS

3.1. An instrument alarm is defined as “signal from instruments that could indicate a nuclear security event, requiring assessment. An instrument alarm may come from devices that are portable or deployed at fixed locations and operated to augment normal commerce protocols and/or in a law enforcement operation” [17].

ASSESSMENT PROCESS FOR INSTRUMENT ALARMS

3.2. There are three types of instrument alarms as follows:

(a) A false alarm: an alarm found by subsequent assessment not to have been caused by the presence of nuclear or radioactive material.

(b) An innocent alarm: An alarm found by subsequent assessment to have been caused by nuclear or other radioactive material under regulatory control or exempt or excluded from regulatory control. Examples of innocent alarms include:

(i) Legal possession or transport of nuclear and other radioactive material, and industrial devices incorporating radioactive material, accompanied by formal transport documents and appropriate labelling (as required);
(ii) People recently subjected to medical procedures involving radiopharmaceutical isotopes;
(iii) Cargo that contains naturally occurring radioactive material;
(iv) Consumer products containing radioactive material.

(c) A non-innocent alarm: An alarm found by subsequent assessment to have been caused by nuclear or other radioactive material out of regulatory control.

If an alarm is neither false nor innocent, it might indicate the presence of nuclear and other radioactive material out of regulatory control.

Primary detection

3.3. An instrument alarm might occur at any time during the operation of the following systems and measures within a State's nuclear security detection architecture:

(a) Fixed or mobile radiation detection systems;
(b) Radiation surveys and operations related to the search for nuclear and other radioactive material out of regulatory control;
(c) Measurements to confirm primary detection;
(d) Automated analysis pipelines.[3]

3.4. All instrument alarms should be followed by an assessment. The competent authority or other designated personnel carrying out the assessment should adhere to the appropriate procedures and protocols for alarm assessment (e.g. standard operating procedures).

3.5. An instrument alarm can also occur as a result of the investigation of an information alert. The role of expert support personnel is to give advice on the information acquired, and in particular on the validity of this information, as well as to recommend further detection efforts that could potentially lead to an instrument alarm.

Confirmation of primary detection

3.6. The confirmation of primary detection may be performed through the conduct of radiation detection measurements using the same radiation detection instrument or a different one. If the initial alarm is not confirmed by the confirmation measurement, it is likely that it was a false alarm. The assessment process may involve a determination of the isotope(s) that caused the primary alarm, as well as a non-technical assessment. This assessment process has two possible outcomes: the release of the

[3] An automated analysis pipeline uses algorithms to analyse in an automatic and continuous manner the data resulting from measurements of radiation detection systems and is usually situated in a centralized location.

entity that caused the alarm or; detention of the entity that caused the alarm for further investigation. The subsequent step of further investigation is often referred to as secondary inspection [2].

3.7. Expert support should investigate the causes of false alarms taking into consideration the following:

(a) Normal statistical fluctuations in the background radiation levels. During search operations or operations in a wide geographical area, an alarm can be generated by the local variability of background radiation. In fact, the environmental dose rate can vary by an order of magnitude, from 0.03 μSv/h to 0.3 μSv/h, and locations with elevated radiation levels are typical, particularly in urban areas where granite or other materials containing natural radionuclides (e.g. uranium, thorium) are used in buildings or monuments. Spectrometric analyses should be used to cope with this variability in background radiation. Expert support should organize and conduct site surveys to map natural radioactivity levels near critical infrastructure or other sites of interest from a nuclear security aspect.

(b) Radio-frequency interference caused by devices that emit radio waves and are operated near the radiation detection equipment. Expert support should check the surroundings to investigate whether any such devices are present.

(c) Electrical faults in the equipment. Expert support should check for any electrical failure in the equipment that could cause the false alarm.

(d) Environmental conditions. Sudden change in weather conditions can cause false alarms. Rain, for example, may lead to a radon 'washout' in the atmosphere, which would cause an increase in the false alarm rate near the beginning of the rainstorm. The instrument background will typically update as the rainstorm continues, and the false alarm rate will decrease as time passes. Expert support should consider environmental conditions during installation to minimize the impact that could lead to false alarm.

(e) Failure of equipment components. Front line officers and expert support should report equipment functionality issues immediately so that these can be resolved as quickly as possible and they should maintain a close working relationship with the assigned maintenance team. Expert support should remove faulty instruments from service until qualified personnel can diagnose the failure cause and carry out the appropriate repairs or replacement.

Evaluation of radiation hazards

3.8. Radiation safety should be taken into consideration for all detection operations for nuclear security. If the predetermined limits (based on national regulations) for the safe conduct of operations are exceeded, the appropriate response organizations should be notified, and immediate protective actions should be undertaken, as described in the standard operating procedures. Expert support should be informed to provide advice to relevant competent authorities in the most expeditive manner possible on further measures regarding safety and security.

3.9. The actions to be undertaken for the evaluation of radiation hazards, as well the related response procedures, are outside of the scope of the present publication. It should be assessed when it is safe to proceed with detection operations using the normal operating procedures developed in accordance with national regulations (e.g. a gamma dose rate exceeding 100 μSv/h at 1 m from the object or at 1 m above the ground is an indication of a possible radiological emergency). In the case of a radiological emergency, immediate protective action is required to be undertaken, including cordoning the area at risk, evacuating people from the area, notifying the competent authority (e.g. the national radiation safety authority) and activating the emergency plan [10].

Collection and analysis of information

3.10. During the assessment of an instrument alarm, expert support should gather technical and non-technical information concerning the entity that caused the primary alarm. Such information may be collected through examination or interrogation of persons, inspection of the objects involved, document verification, physical surveys, spectroscopic measurements and X ray imaging.

3.11. If nuclear or other radioactive material out of regulatory control is detected, gamma spectroscopy should be used as the primary means for radionuclide identification. Some types of spectrometers, radionuclide identification devices and backpack based radiation detectors are simple and robust enough to be operated by a front line officer. The presence of neutron radiation should also be confirmed through measurements using the appropriate equipment. An assessment of neutron alarms may necessitate analyses by expert support, particularly if the presence of neutron radiation cannot be verified by the front line officer using secondary inspection equipment after initial confirmation of a neutron alarm using radiation portal monitors or other primary inspection equipment.

3.12. The collection and reliable scientific analyses of data during an assessment may be accomplished remotely or on-site by expert support personnel. If the presence of nuclear and other radioactive material out of regulatory control is suspected, expert support should have the capability to deploy personnel to the site and carry out more detailed measurements with specialized radiation detection instruments (e.g. high resolution spectroscopy systems).

3.13. Innocent alarms may occur frequently at designated points of exit or entry as a result of shipments containing naturally occurring radioactive material, authorized shipments of radioactive material and transiting individuals who have recently undergone medical procedures involving medical isotopes. Expert support should be familiar with the standard operating procedure for adjudicating these alarms and provide guidance to front line officers for the resolution of innocent alarms when needed.

3.14. Expert support should have access to the national registry of radioactive material, which normally follows the categorization of radioactive sources presented in Ref. [18], and they should have the capabilities to identify the relevant radionuclides, especially those that can present challenges in gamma spectroscopic analyses.

3.15. A short list of the nuclides that are most likely to be encountered during detection operations as well as their application should be prepared by expert support (see Table 1 for an example list). Expert support should also develop rapid analysis methods to confirm the presence of these nuclides during the assessment of an innocent alarm (see para 3.45). Verifying whether the detected radionuclides are under regulatory control or out of regulatory control plays an important role in alarm adjudication.

TABLE 1. EXAMPLE LIST OF COMMON RADIONUCLIDES ENCOUNTERED DURING DETECTION OPERATIONS

Application	Radionuclide
Shipments of naturally occurring radioactive material	K-40, Ra-226, Th-232, natural uranium
Medical isotopes	F-18, Ga-67, In-111, Tc-99m, I-131, Lu-177, Tl-201
Industrial gamma sources	Co-60, Se-75, Ba-133, Cs-137, Ir-192
Industrial neutron sources	Cf-252, Am/Be, Pu/Be
Consumer goods[a]	Am-241, Kr-85, La-138
Nuclear material	Depleted uranium, U-233, U-235, U-238, Pu-239

[a]For example, ^{241}Am can be found in smoke detectors, ^{85}Kr in high intensity discharge lamps and ^{138}La in carbon arc lamps.

3.16. It is also possible that the adversary might use naturally occurring radioactive material or radioactive sources under regulatory control to mask the presence of nuclear and other radioactive material out of regulatory control. For example, ^{133}Ba is both an industrial isotope and a plutonium surrogate causing interference in low resolution spectroscopy. Ceramics, tiles, fertilizers, mine ore and other products containing natural radionuclides (e.g. ^{40}K, ^{226}Ra, ^{232}Th, ^{238}U) could be used to mask the presence of nuclear and other radioactive material out of regulatory control in shipments of naturally occurring radioactive material. The presence of shielding can also complicate analysing the results from spectroscopic measurements. Since low energy peaks could be absorbed by the shielding and not appear in the spectrum, the radionuclide identification process could be further complicated. Depleted uranium can be used to shield the radiation emitted by nuclear material. Radionuclide identification devices will often have difficulty identifying all the potential radionuclides present in large shipments of naturally occurring radioactive material. Therefore, expert support should obtain information from the front line officer such as information on declaration of cargo, spectroscopic measurements and X ray imaging. Further analysis should be conducted for the adjudication of complex and/or potentially non-innocent alarms.

Alarm adjudication

3.17. In accordance with standard operating procedures for detection operations, all radiation detection instrument alarms should be assessed. The assessment should be based on a thorough examination of the available information, and should result in the adjudication of the alarm and the determination of next steps. The instrument alarm may be triggered by the algorithm of the local detection system, or alternatively by the expert support alarm algorithm, in the case that continuous data transfer (see para. 3.29) is implemented. The information flow from front line officers to expert support relating to the instrument alarm will vary depending on the concept of operations, and the technical capabilities of the detection system and information management system.

3.18. Front line officers and expert support should cooperate for the assessment of an instrument alarm. The actions to be implemented for the assessment depend on the type of the detection architecture and can be summarized as follows:

(1) After the instrument alarm is triggered, the front line officer begins the assessment process, which involves localizing the source of the alarm, conducting a secondary inspection and gathering information relevant to the entity that triggered the alarm. If the alarm is resolved by the front line officer, no further steps are taken.

(2) If the alarm is not resolved, then the actions are as follows:

(i) In a detection architecture with no automated data transfer, the front line officer notifies expert support and sends all data relevant to the alarm to expert support. Expert support receives and analyses the data, and may request the front line officer to perform additional measurements or gather more information.

(ii) In a detection architecture with automated data transfer, the competent authorities share a central database or data storage system, which gathers in real time measurement data from radiation detection equipment as well as information on alarms generated by the instruments. Expert support personnel run an automated analysis software on the collected data, which can also trigger an instrument alarm. For the analysis, the expert support centre uses background radiation measurements gathered before and after the occurrence of the alarm. Expert support can also notify front line officers in the case of an alarm in accordance with standard operating procedures.

(3) Expert support communicates the results of the analyses to the front line officer, the operations centre and other competent authorities in accordance with the standard operating procedures.

(4) The front line officer and expert support make a joint decision on the adjudication of the alarm integrating all technical and non-technical information. Based on the assessment, the front line officer may proceed with releasing the entity that caused the alarm or with interdiction of the material and/or suspect. Expert support personnel may conduct further analysis on the data and document the results of the assessment.

When there is no automated data transfer, considerable delays might occur in the assessment of the alarm, as front line officers and expert support need to perform data transfer tasks and communicate continuously with each other.

Access to data and information

3.19. The level of data and information related to the alarm and the detection operations (e.g. equipment configuration) is an important factor in determining the speed and efficiency with which expert support can assess an instrument alarm, or to what extent expert support can assist in the assessment. Expert support can access and process instrument alarm data in different ways such as the following:

(a) Through immediate access to instrument measurement data through electronic transfer of data by the front line officer.
(b) Through real time access to instrument data and immediate automated real time analysis.
(c) By reanalysing the data using an automated analysis pipeline, managed by expert support personnel;
(d) Using information transfers (e.g. photos, descriptive details) between front line officers and expert support in the case that there is no direct access to instrument data.
(e) By interactive analysis[4] by expert support personnel.

3.20. If access to instrument data is possible, expert support should review all the relevant measurements and perform an independent analysis of all the data in order to complete the instrument alarm assessment. Expert support should also request that the front line officers provide any additional data available that might allow them to complete a comprehensive assessment and provide an adjudication recommendation.

[4] Interactive analysis of a spectrum, or many relevant spectra related to the case involved, is a strong tool implemented by expert support. It may take time, but if all support functions are in place, such as reliable data transfer, correct calibrations and event-specific axillary information, the analysis may provide conclusive evidence on the event.

3.21. In order for expert support to have the ability to assess instrument alarms effectively and as quickly as possible, real time access to instrument data and real time analysis of the data by expert support personnel or by an automated system (e.g. using algorithms or artificial intelligence) would be the optimal solution. However, this level of access necessitates a substantial investment in communication infrastructure and other technical resources, as well as adherence to procedures for the protection of sensitive operational information. In the case of automated analysis systems, subject matter experts should be available to validate the results, perform further assessments and support the adjudication of the alarms.

3.22. If direct access to the instrument data is not possible, the expert support may request information, such as photographs of an instrument screen showing the radionuclide identification results or other measurement results. In such cases, it may be possible for expert support to assess and verify the instrument alarms, particularly if the front line officer is able to provide other details pertaining to the instrument alarm. The assessment would nonetheless remain incomplete without an examination of the spectrum data.

ANALYSIS TOOLS FOR EXPERT SUPPORT

3.23. Operational constraints might limit detection operations in the field. Such constraints might be related to the time available for measurements, the safety hazards (radiological and non-radiological) or the minimum distance allowed between the target and the radiation detection equipment. A typical mobile field measurement provides data, counts or spectra in short time intervals (1–4 seconds). However, longer time intervals (i.e. several minutes) are preferred if the person or object of interest is not moving.

3.24. Many radiation detection systems use fixed radiation portal monitors. Other types of detectors can be carried by hand or transported by backpack, car, boat, drone or other robotic system, helicopter or aircraft. Several radiation detection systems may form a local radiation detection network, providing aggregated information on potential threats and their movements. Each radiation detection instrument and type of measurement poses its own unique challenges with respect to its operation and the measurements it carries out. The analysis of raw measurement data from detection equipment falls within the framework of the expert support’s scientific tasks, with the objective of ensuring a timely alarm assessment and rapidly informing operational units and the operations centre on the nature of the event.

3.25. The analysis of the data from nuclear security detection systems can be conducted using tools for spectrum analysis in three steps as follows:

(1) Immediate automated analysis using the built-in algorithm of the radiation detection instruments can be used for the assessment and adjudication of instrument alarms by front line officers. It would

represent a ‘first look’ at the data, which may underline an increased signal strength that cannot be explained by statistical variations or changes in natural background radiation.

(2) Automated pipeline analysis may generate an instrument alarm using an algorithm different than the algorithm of the instrument and could also lead to the assessment of the alarm.

(3) Automated analysis can be repeated with different algorithms or software, with a subject matter expert being notified to conduct further analysis, if necessary.

3.26. In addition to tools for spectrum analysis, expert support personnel should have an efficient and secure data management system to acquire data from, and communicate analysis results to, the personnel conducting detection operations. Data processing should be conducted on a secure computing system, which is able to manage measurement data arriving from multiple detectors in large quantities. The core of the computing system should be a database designed for storing raw data and analysis results.

3.27. Analysis of data from nuclear security detection systems may provide the following types of information:

(a) Indication of the presence of nuclear and other radioactive material;
(b) Location of nuclear and other radioactive material;
(c) Indication of a radiation safety hazard;
(d) Identification of radionuclides from the gamma spectrum;
(e) Characterization of the radioactive source and of any shielding material, if present.

3.28. Expert support should be able to acquire further technical and non-technical information in relation to the ongoing assessment of a non-confirmed alarm. A radiological safety assessment based on dose rate measurements is typically one of the first steps to be taken by expert support personnel, in coordination with the personnel conducting the detection operations. The front line officers may use a radiation detection device to measure dose rates or radionuclide identification devices or spectrometers to collect a gamma spectrum of the material; they should then transmit these data to expert support personnel for analysis. An expert support centre may have the capability to calculate dose rate directly from the spectrum. However, such capabilities should have been a planning priority in the detection system configuration, since this type of data processing necessitates mathematical modelling and specific calibration measurements. Expert support personnel may also have tools that allow them to determine if shielding is present through an analysis of the dose rate and gamma spectrum. For example, the activity of the detected material could be calculated (e.g. order of magnitude) and some properties of the shielding around the source could be estimated. Strict quality control requirements (e.g. functionality checks) are a prerequisite for successful measurements and analyses.

3.29. Natural background radiation is a major nuisance factor, and therefore every effort should be taken to minimize it, or at the very least to understand and characterize it. The location of a fixed radiation portal monitor should be optimized (see Ref. [7]). Continuous data acquisition during routine operation provides valuable information on background radiation, which can then be applied in the analysis of an alarm. When performing a radiation measurement on a conveyance, an object or a person who caused a primary radiation alarm, the initial background radiation level in the area should first be established. The instrument used to conduct the measurement should be powered on and the background radiation determined near the secondary inspection area, in similar surroundings but not directly adjacent to the conveyance, object or person. The spectrum of the background radiation, if available, should be provided to expert support, along with the files associated with measurements of the entity setting off the alarm.

Detection of radioactive material

3.30. Expert support should contribute to the detection of radioactive material by analysing data analysis from gamma spectroscopy for alarm assessment and by helping to answer the following questions: Does the measurement contain counts above the normal levels of background radiation? And if so, what are the levels and the nuclides present? Detailed information on analysing gamma spectroscopy measurements is provided in Annex II.

3.31. For expert support to be able to manage the data flow from fixed radiation detection equipment, one possibility is to reduce the number of reported measurements, for example by transferring to expert support only those measurements that can be interpreted as alarms by the on-site detection system. However, this way only direct instrument alarms are reported, and new findings cannot be generated and reanalysed by expert support. In addition, for reliable background analysis, it is important that data from both before and after the alarm are transferred to expert support.

3.32. Another possibility for expert support operations is to use the occupancy of the sensors of fixed radiation portal monitors that would normally accept data input only if a person, vehicle or object is passing through the detector. There is a possibility that the radiation portal monitor can record radiation levels above the background if radioactive material is in the vicinity of the detector without going through it and without the object passing through the occupancy sensor. If the occupancy sensor remains inactivated, the incident can be recorded only if the data from the detector are also being processed independently. If, however, another object is going through the occupancy sensor, an alarm will be triggered but the source of the radiation will not necessarily be identified during primary detection.

3.33. To reduce the burden on expert support, in routine operations at a location where fixed equipment is deployed, statistical tests on the presence of radionuclides of interest could be applied to all peaks potentially present in a spectrum at very low confidence levels. The rate of false alarms would otherwise be difficult to manage. When the occupancy sensor triggers a signal, more comprehensive analyses should be launched at a different confidence level. Another method for validating the detection of radionuclides is for the analysis to use two or more peaks of the same radionuclide, although this would not be possible for single-line gamma emitters (e.g. Cs-137).

3.34. If expert support personnel are seeing data in real time, they should be notified if an alarm is triggered and interactive analyses should be performed for further clarification, if necessary. As a result of the alarm assessment, the following actions should be taken:

(1) No further action needed other than documenting the alarm or;

(2) Front line officers are notified to launch further measures, such as the conduct of measures on-site, such as the conduct of secondary measurements (to improve the measurement statistics or using different detectors) or proceed with the interdiction of the person or material.

3.35. The response to the alarm should be planned and documented in advance, according to the standard operating procedures. Joint training and exercises are also essential between expert support and front line officers so that the response is prompt and proportionate to the findings of the detection and the potential risk.

Detection of nuclear material

3.36. Uranium and plutonium are nuclear material. The nuclear security detection architecture should contain special arrangements for the detection of nuclear material, keeping in mind that the adversary might attempt to shield or mask the nuclear material through use of surrogate materials. One of the aims of detection is to recognize the indicators of illegal activities where uranium and plutonium are present. The challenges associated with the identification of nuclear material using instrument automated analysis software (e.g. in radionuclide identification devices) include the following:

(a) False negative assessment (i.e. nuclear material is not identified when it is present);
(b) False positive assessment (i.e. nuclear material is identified although it is not present).

Expert support should pay particular attention to inconclusive results, in particular when nuclear material is suspected (e.g. as a result of information alerts) and/or when neutron radiation is also present.

3.37. The presence of nuclear material can be revealed through means other than radiation detection systems, which may include insufficient documentation for the shipment, nervous behaviour on the part of the shipper, use of an X ray scanner to detect the presence of shielding material, or an information alert. The presence of uranium and plutonium indicators should lead to more detailed radiation measurements of the material. Active neutron interrogation could be applied on occasion to investigate a suspect object, but this would necessitate specialized equipment and specialized on-site expertise or expert support.

3.38. For the detection of uranium, expert support should use spectroscopic analysis and detailed measurements to specify the chemical state and the isotopic composition of uranium. It should be specified whether uranium is present as depleted uranium, natural uranium, reactor grade uranium or highly enriched uranium. Such analysis may require the use of laboratory facilities beyond the capabilities present on-site.

3.39. Detection of plutonium is based on neutron counting and gamma spectroscopy. The detection of neutrons is always considered an indicator of suspicious material and should lead to more detailed investigation. Expert support should have special algorithms for the detection of plutonium.

3.40. Neutron sources, such as Am/Be sources, are widely used in industry and research. For example, the oil and gas industry are an extensive user of neutron sources all around the world, and such sources are frequently shipped internationally. Algorithms to distinguish these neutron sources from nuclear material should be incorporated.

3.41. To ensure proper alarm adjudication processes, neutron sources can be used during training and exercises focusing on the detection of nuclear material. For example, in exercises simulated measurement data for the instrument alarm could be used.

Detection library and artificial intelligence

3.42. Spectroscopic measurements can be interpreted using past experience. Expert support should have a detection library of innocent alarms due to common medical and naturally occurring radioactive material that can be used as reference for alarm assessment. The content of these libraries may differ depending on the material in use or transport in the country. Establishing such a library can speed up the adjudication during secondary inspections if certain sources are commonly encountered. A reference library can also be used for automated data processing using artificial intelligence.

3.43. To make the best possible use of detection data gathered in the most efficient manner, careful planning of the detection library is needed. The detection library should contain detailed information on the source, the distance between the source and the detector, and any packing or shielding material around the source. Depending on the specifics of these data, these libraries may need to be developed for certain detector configurations. Software tools used by expert support should be designed to allow comparisons of two or more spectra. The detection library could also contain spectra of individual radionuclides measured in well characterized environments. These data sources would be valuable in the identification of radionuclides rarely seen at a particular site.

3.44. A detection library is useful not only for alarm assessment but also for training, exercises and research. A national data repository contains sensitive information, and therefore it is important to categorize such data accordingly and at an early phase. Use of actual measurement data in local or national training and exercise programmes for authorities involved in the response to nuclear security events would also be advantageous. The analysis of realistic data and scenarios during training and exercises greatly improves both the results of training and the quality of lessons learned from such exercises. In addition, research and development efforts would benefit greatly from having the possibility to test new data processing algorithms on library data.

The ability of artificial intelligence to quickly process large amounts of data has enabled the development of machine learning algorithms that can help expert support with assessing instrument alarms and potential non-innocent alarms. Artificial intelligence is an additional tool that allows expert support to more efficiently deal with the large number of alarms due to the presence of naturally occurring radioactive material that are encountered while screening shipments with radiation portal monitors. Using existing measurement data and shipment documentation, artificial intelligence can be taught to classify alarms into different categories, such as ‘typical background’, ‘alarms due to the presence of naturally occurring radioactive material’ and ‘potential non-innocent alarms’. In this way, finite human resources can be focused on the assessment of potential non-innocent alarms and the efficiency goals (i.e. the extent to which systems and measures serve the detection needs) are improved, and the impact of detection measures on the regular flow of goods and people is simultaneously reduced. Expert support plays an important role in the development of artificial intelligence, and in helping to customize and improve the performance of machine learning algorithms over time. At the same time, artificial intelligence has limitations that will not enable it to replace expert support. It can, however, be applied to large volume screening, such as legal shipments of medical radionuclides, air cargo, mail, luggage and passenger flow.

CHALLENGES FOR EXPERT SUPPORT

3.45. Innovations in detection technology is producing detectors with higher sensitivity, faster and more versatile means of data processing and novel algorithms that can solve problems encountered during detection for nuclear security purposes. However, while source localization methods and list-mode data acquisition are among innovations offering new capabilities for nuclear security, these might represent a challenge for expert support (See Section 3.51-3.55 for the discussion on list-mode data acquisition)

3.46. Confirmation of a non-innocent alarm through alarm adjudication is the starting point for nuclear security response. Further detection efforts should be initiated to understand the nuclear security risk and to support the implementation of detection operations. More resources — both in terms of equipment and human resources — should be deployed. Expert support may have a key role in information processing and in further measurements on-site.

Source localization

3.47. If the alarm resulted from a search operation in a certain area, the source first has to be localized before interdiction can take place. In general, the source could be anywhere, even hundreds of metres away from the site of the initial detection.

3.48. Source localization is key for more detailed analyses to follow that are designed to determine the activity of the source attributes and the presence of shielding) in order to assess the risk that the source might pose for nuclear security. A systematic scan of the area in which an alarm was triggered should be conducted using, for example, a backpack, drone or vehicle mounted detector. However, this might not be possible for several reasons such as the following: (1) limited resources; (2) operational needs for the conduct of discreet operations; (3) area that needs to be covered.

3.49. Other localization based on gamma or neutron imagers that provide visual information in augmented reality where a glowing source is added to a normal photograph. The segmented detector array and rotating anti-collimator (i.e. rotating small shield covering the visibility of the source) are other examples of novel source localizers that provide the direction of the incoming radiation. Two or more measurements should be made at different locations, and the expert support can then analyse the directional vectors for source localization. Another method is to localize the source directly from three spectroscopic measurements without using any additional instrumentation. The peak count rate would depend on the distance from the source detector, the attenuation of photons in the air, and the presence of shielding between the source and the detector. Mathematical models have also been developed to locate a source, but these still remain at the research and development stage.

3.50. The role of expert support is further enhanced in such cases, because the analyses will rely on a fusion of data from various measurements at different locations, potentially made with different instruments. Expert support can develop the capabilities to manage such information flows and to support the teams operating on-site in real time by providing advice on operational information relating to interdiction, safety and security aspects.

List-mode data acquisition

3.51. The typical operating mode of nuclear security detection instruments is to ensure the acquisition of data over a fixed period. A more efficient and reliable measurement system would be based on recording the time stamp for the arrival of each photon or neutron. This kind of measurement is called list-mode data acquisition. Today, state of the art equipment can propose a nanosecond time resolution for these events, which is a more than sufficient time resolution for instrumentation in nuclear security.

3.52. The greatest advantage of list-mode data acquisition is that none of the information provided by the detector is lost, meaning that event dynamics can also be analysed. It is impossible to know in advance the statistically optimum data acquisition time (i.e. when to start and when to stop data acquisition). In list-mode, such problems are avoided in the measurement phase and are addressed in the subsequent analysis.

3.53. Depending on the measurement geometry, an instrument may provide a considerable number of counts in a short time interval, for example < 0.1 seconds. These counts could be the result of a malfunction in the detector, external electromagnetic disturbance, X ray imaging nearby or a spallation neutron source induced by cosmic rays. An ordinary instrument with a data acquisition interval of a few seconds would generate an alarm. However, the time profile in the list-mode data acquisition would reveal the true nature of the event, and no alarm would be triggered.

3.54. Nuclear security equipment operating in list-mode data acquisition mode and their operation relating standards are commercially available. [19].

3.55. List-mode data acquisition can create challenges for expert support, given that additional data needs to be processed and new analysis algorithms have to be designed. However, the benefit of this type of data acquisition is that it reduces the false alarm rate. The operational impact is more reliable with less work on-site, and the detection capability for nuclear and other radioactive material out of regulatory control is improved.

4. THE ROLE OF EXPERT SUPPORT IN THE ASSESSMENT OF INFORMATION ALERTS

4.1. An information alert is defined as “Time sensitive reporting that could indicate a nuclear security event, requiring assessment, and may come from a variety of sources, including operational information, medical surveillance, accounting and consignor/consignee discrepancies, border monitoring, etc.” [17]. A policy should be implemented at the national level to clarify the protocols for the use of information as an essential part of detection systems and measures within the established framework of the nuclear security detection architecture.

4.2. Information alerts may contain information that involves multifaceted expertise for their assessment and the adjudication. An effective nuclear security detection strategy relies on a well established and coordinated national system involving the identified competent authorities. Assessment and adjudication of information alerts may dictate that multiple competent authorities be made aware of the various types of information influencing the ability to assess and adjudicate alerts.

4.3. Information alerts include reports of operational information, medical surveillance, regulatory non-compliance and loss of regulatory control. Information provided by the public or the media, as well as reporting from intelligence or information agencies or any other credible source of information should also be considered. Depending on the source of the information alert, expert support may be called upon to provide input and analysis of information.

SOURCES OF INFORMATION

Operational information

4.4. When competent authorities need to assess the presence of potential nuclear and other radioactive material out of regulatory control, they may transmit operational information to expert support. Operational information includes information from indicators of suspicious activity during detection operations, information related to the suspicious presence of radiation protection equipment; labelling, packaging and documentation; or indicators of the presence of shielding or masking.

4.5. Expert support should be conducted in accordance with the defined national protocols on acquiring operational information. The proper assignment of roles and responsibilities to expert support should be determined by the State.

4.6. The expert support organization should establish and maintain protocols for sharing operational information with competent authorities. An expert support organization should protect operational information in such a manner that does not compromise the operations of competent authorities.

Presence of radiation protection equipment

4.7. Expert support may be called upon to advise the competent authorities on the potential implications of persons having in their possession supplies that can be associated with unauthorized criminal acts involving nuclear and other radioactive material out of regulatory control. Equipment, tools and medical products such as those listed below are uncommon in day to day usage, and it is not likely that these goods be found in the possession of individuals without cause:

(a) Potassium iodide tablets that can be used for prophylaxis;
(b) Prussian blue tablets;
(c) Glove boxes, with or without gas bottles (i.e. common gases, such as helium and argon, used for purging);
(d) Tools that can be used to handle radioactive material, such as tongs, ropes, hooks and pulleys;
(e) Personal protection equipment, such as gloves (lead or chemical), lead aprons, coveralls, respirators, filtration masks, protective suits, goggles or laboratory coats;
(f) Dosimeters, used to measure radiation dose, and particularly dosimeters with real time indicators.

Labelling, packaging and documentation

4.8. Nuclear and other radioactive material is required to be appropriately placarded, labelled, packaged, and documented during use or transport. Competent authorities may call upon expert support to identify potential errors and inconsistencies in the relevant documentation. Expert support can therefore contribute to the identification of forgeries or the interpretation of damaged labels, and can advise and assist in the handling of damaged packaging [20].

Indicators of shielding and masking

4.9. Adversaries might use shielding and masking techniques to prevent the detection by instruments of nuclear and other radioactive material. As a result, the presence of shielding and masking materials might indicate suspicious activity, involving assessment by expert support. The expert support should analyse the appropriateness of the material's presence for legitimate purposes. For example, use of the following elements should be examined:

(a) Dense materials, such as lead, tungsten, steel, iron or concrete;
(b) Materials that contain hydrogen, such as water, plastic or wax;
(c) Large amounts of naturally occurring radiological material, such as ceramics, fertilizer or cat litter.

Medical surveillance report

4.10. Expert support should have an understanding of medical conditions related to radiation exposure to advise competent authorities on matters related to the possible source of exposure when assessing information alerts and providing adjudication recommendations.

4.11. Information alerts on the following health symptoms that might have been reported by medical experts could lead to the detection of nuclear and other radioactive material out of regulatory control:

(a) Nausea;
(b) Skin burns or erythema;
(c) Vomiting;
(d) Dizziness and disorientation;
(e) Weakness and fatigue.

4.12. Information on certain medical circumstances, such as a patient requesting a complete blood count test and displaying other signs of radiation sickness, might indicate the need for further assessment.

Reporting of regulatory non-compliance or loss of regulatory control

4.13. Regulatory requirements set out the minimum security measures that authorized users of nuclear or other radioactive material are required to implement to prevent the loss, sabotage, illegal use and illegal transfer of the material. Reporting of regulatory non-compliance and loss of control by the authorized user or the regulatory body to the competent authorities aids expert support in assessing information alerts in relation to any potential nuclear and other radioactive material out of regulatory control found within the State. Assessments of such information alerts also help the competent authorities to detect nuclear and other radioactive material out of regulatory control, or to determine whether the deployment of additional detection equipment is needed. Examples of reporting regulatory non-compliance and loss of control are the following:

(a) Report of missing or stolen nuclear and other radioactive material;
(b) Report of unauthorized use, possession or transfer of nuclear and other radioactive material;
(c) Report of unauthorized disposal of nuclear and other radioactive material.

Public or media reporting

4.14. Competent authorities may receive information alerts from the public (e.g. from a dedicated call line) and the media (e.g. social media, news media).

4.15. Matters pertaining to nuclear security are an issue of substantial public concern given the perceived negative impact on health, society, the environment and the economy. As such, accuracy when communicating with the media and the public is essential to maintain the credibility of, and trust in, the competent authorities. Expert support should be capable of advising competent authorities on matters related to technical and scientific accuracy when competent authorities are communicating with the media and the public.

4.16. Increasing use of social media provides both a platform for competent authorities to communicate with the public as well as to collect information that has potential nuclear security implications. Competent authorities may choose to collect information directly from the public (e.g. through public reporting using an established hotline number), or to monitor information shared by social media users and analyse that information in order to detect information alerts pertaining to the following:

(a) Theft, sabotage or loss of nuclear and other radioactive material;
(b) Illicit movement of nuclear and other radioactive material;
(c) Environmental contamination;
(d) Recovery or discovery of nuclear material and other radioactive material that is considered missing, lost or otherwise out of regulatory control;
(e) Unreported closure of a business with potential nuclear security implications, such as one authorized to use radioactive sources;
(f) Accidents involving the transport of nuclear or radioactive material;
(g) Adversary activities with nuclear security implications; or activities by non-adversarial groups that might have nuclear security implications.

Intelligence reporting

4.17. Intelligence agencies within the State, and agencies with whom mutual understandings have been established in other States, may obtain information related to nuclear security events. Intelligence sources may provide information pertaining to the planning of a nuclear security event, the knowledge transfer relating to the use of nuclear technologies, or the transport of nuclear and other radioactive material. Some intelligence data may consist of official correspondence, as well as videos or photographs of different activities and materials, but such data might not always provide clear information.

4.18. Expert support should have the capability to assist competent authorities in analysing any information collected that might involve nuclear security aspects. The following elements should be considered when evaluating the credibility of an alert based on intelligence reporting:

(a) The accuracy of the report in relation to available knowledge and awareness inventories, availability and uses of nuclear and radioactive material in the State;
(b) The source of the information alert;
(c) The potential public perception of the information reported.

PROCESS FOR ASSESSMENT OF INFORMATION ALERTS

4.19. The general process for collecting, analysing, disseminating and using information alerts to inform nuclear security detection operations is outlined in Fig. 2. Expert support should be capable and available to analyse information alerts and advise the competent authorities with respect to the technical and scientific aspects related to assessment and adjudication within nuclear security detection operations. Expert support can in fact assist competent authorities in the assessment of information collected from a variety of open and closed sources.

4.20. Raw data collected by competent authorities should be sorted, evaluated and interpreted by expert support so as to produce an analytical report of key findings relevant to assessment and adjudication. Additionally, these analytical reports may be disseminated to the relevant competent authorities, as appropriate, considering confidentiality principles, in order to inform the planning, implementation and evaluation of additional detection operations.

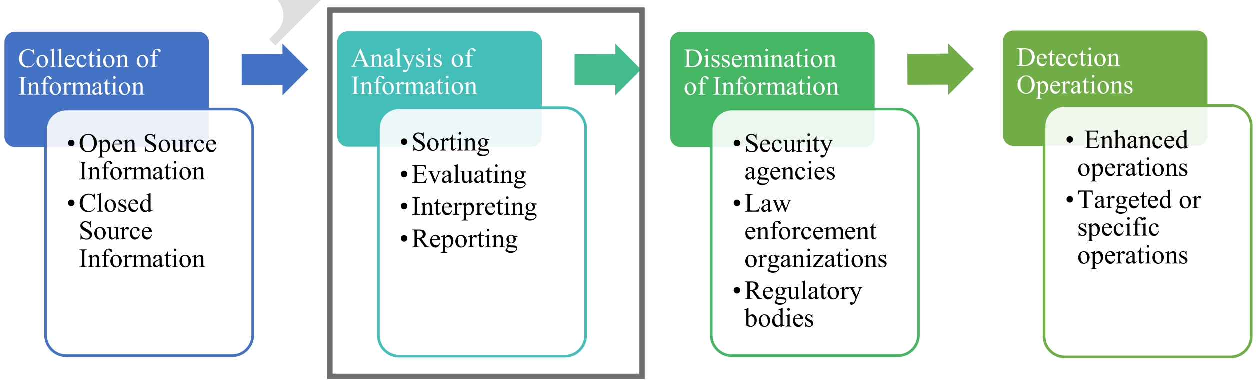

FIG. 2. Information handling process for conducting detection operations. (reproduced from Ref. [7]).

4.21. Competent authorities may also request that expert support analyse information alerts that, following assessment, have proven to be a hoax or a scam. It is important that expert support personnel consider whether the information provided is related to a plausible nuclear security event with radiological consequences or whether the information is meant to distract or otherwise mislead authorities into reaching a false conclusion about the potential nuclear security risk.

4.22. Expert support should be able to provide timely, easily accessible, accurate and concise advice that contribute to the effective assessment and adjudication of information alerts.

5. SUSTAINABILITY OF EXPERT SUPPORT

5.1. Sustainability is a key consideration for the nuclear security detection architecture and includes the planning of human resources to operate and maintain equipment, assess instrument alarms and information alerts and ensure the life cycle management of equipment [2].

5.2. For expert support to be effective, proper planning on matters related to logistics should be in place, and an education, training and exercise programme should be implemented. Expert support personnel may also be requested to assist with verifying functionality of radiation detection instruments and performing some types of corrective maintenance on these instruments.

5.3. The different roles of expert support within the nuclear security detection architecture should be appropriately assigned to the identified competent authorities within the defined concept of operations. The assignment of these roles should be accompanied by the establishment of policies and procedures regarding the way in which expert support performs functions within the nuclear security detection architecture framework.

5.4. Detection operations either within the interior of the State or at the State's borders involve the timely and accurate assessment of alarms and alerts. Access to, and functionality of, expert support should be supported by the efficient operation of detection instruments, including their communication and network systems. Detection systems and measures should provide reliable results that can be used as evidence if legal action is pursued in the case of the detection of criminal or intentional unauthorized acts involving nuclear or other radioactive material out of regulatory control.

5.5. A thorough understanding of the behaviour and limitations of radiation detection instruments can facilitate the proper development of an operation and maintenance plan. Factors such as the type of detection operations, the local climate, the site and geographical conditions, and the availability of relevant infrastructure, such as the electrical power supply and the data transfer network capability, provide input to the development of a plan for the management of radiation detection instruments during their life cycle.

5.6. The operating mechanism of a radiation detection instrument generally begins with a power supply that allows the detector to record radiation signals, which are later converted into a pulse signal produced by a processing device. The processed signal is further converted into a value that can be read by the operator, via the computer workstation, as an alarm. This alarm is then sent to a data collection centre through a communication device using an internet connection. In the case of an interruption in the operation of the detection instrument, technical expertise should enable the identification of the cause, which could either be related to damaged components in the detection instrument's auxiliary systems or in the network that supports the transfer of alarms. Expert support should have information on the detection instrument's operating mechanism to perform root cause analyses in the case of equipment failure and assessments to establish a life cycle management plan, resulting in sustainable detection systems and measures for expert support.

CAPACITY BUILDING

Human resources for expert support

5.7. An important component in setting up expert support is the human resources involved. Depending on detection operations in a State, expert support personnel may need to be made available either via shifts on-site or through on-call procedures.

5.8. Establishing and sustaining expert support capabilities produces synergies that are beneficial, and may include:

(a) Expert support working together with experts from other organizations to take into account all factors contributing to assessment of alarms and alerts;
(b) Training and exercises encourage knowledge transfers between organizations;
(c) Documentation of explicit or tacit knowledge and exercises contributes to the retention of knowledge over time.

Workforce planning

5.9. Workforce planning is essential for sustainability of expert support. Real data feedback on the skills derived from operational changes and challenges in relation to alarm and alert assessment activities contributes to workforce planning, enabling the proper preparation of different talent sets to establish the necessary expert support. Assessments should also be made against the backdrop of advancements in the detection instrument technologies that support predictive supply analytics, demand planning, task planning and the identification of potential gaps.

5.10. Such an approach enables effective gap analyses to be undertaken at all levels of expert support in the organization, and contributes to better planning and responses to changes in the nuclear security detection environment at the decision making level. The appropriate workforce planning programme would, moreover, offer benefits in terms of financial planning, budgeting and recruitment, as well as development, redeployment and transition programmes for expert support personnel. Expert support organizations should monitor their effectiveness in meeting the overall needs and objectives of the nuclear security detection architecture.

Expert support capabilities

5.11. The development of suitable human resources for expert support should be an important consideration to sustain capabilities for the assessment of alarms and alerts. Allocation of human resources to expert support should be commensurate with results from life cycle management analyses that support the operation and maintenance of detection instruments. Investment in training is also important for the development of expert support. Appropriate training and financial investment should be determined according to the actual needs of expert support in assisting with alarm and alert assessments.

5.12. The State should conduct a needs assessment to identify the expert support capabilities (and the type of expertise) needed for alarm and alert assessment taking into consideration detection systems and measures and priorities defined at the national level. The State should design its own human resources development programme for capacity building in relation to the assessment of alarms and alerts for expert support. An adequate pool of experts should be created which will in turn contribute to knowledge retention and succession planning for expert support.

5.13. The existing training facilities of competent authorities within the State's nuclear security detection architecture can be leveraged to conduct training for expert support on alarm and alert assessment. Training experts can also make use of detection instruments for the purpose of demonstration, development and delivery of the training programme. A formal instructor training programme could be designed and implemented in order to develop the human resources needed to support a capacity building programme for the assessment of alarms and alerts.

5.14. Assessments of the operability and effectiveness of the overall components of the State's nuclear security detection architecture can be performed through targeted exercises. Each element within the State's nuclear security detection architecture should be properly assessed through the following:

(a) Evaluating and validating strategies, procedures, operations, equipment, training levels and awareness concerning alarm and alert assessment.
(b) Testing new approaches, scenarios, techniques and technologies for nuclear security.

Gaps can be identified in operating procedures, detection instrument operation and many other areas of interest.

Training and exercise programmes for expert support

5.15. The knowledge, skills, attitude and behaviour necessary to perform a specific expert support function should be identified and communicated clearly before training begins. The training, and the assessment of the training progress (e.g., identification of training gaps), should be based on the knowledge, skills and behaviour defined as necessary for the specific expert support function.

5.16. It is important that the expert support component of assessing alarms and alerts be included in exercises. Lessons learned from exercises, in particular the determination of capability gaps, will then be used to inform and prioritize training for expert support. States should also take advantage of existing capabilities related to human resources so as to strengthen expert support.

5.17. Expert support personnel should have knowledge of the nature of nuclear security events to effectively carry out alarm assessments. Expert support receive training to be able to deliver the appropriate information to competent authorities, allowing them to make timely and accurate decisions on the implementation of further detection and radiation safety measures. An expert support team should have adequate training in the following areas:

(a) Nuclear security culture [21, 22], including the nature of nuclear security events;
(b) Operational structures of relevant national competent authorities, as well as of the standard operating procedures for the detection and assessment of alarms and alerts for material out of regulatory control;
(c) The use of secured communication channels between expert support and competent authorities, including secured methods of sharing information;
(d) Equipment used by front line officers, including the type and mode of use;
(e) Radiation detection instrumentation and methods, and in particular gamma spectroscopy for nuclear security applications;
(f) Radiation safety;
(g) Regulations for the transport of radioactive material;
(h) Country specific (or site specific) training on handling radiation alarms or alerts;
(i) Specialized in-house training for the expert support team on standard operating procedures;
(j) Joint exercises with other competent authorities and organizations.

5.18. Learning on the job is one means of ensuring that training takes place. A rotation system could be used, for example, in order to ensure that a larger pool of subject matter experts is made available during such training. The training of expert support personnel in the assessment and adjudication of alarms and alerts should be made a priority for nuclear security.

5.19. Each deployment of expert support on the site where detection operations are taking place should be thoroughly reviewed and the lessons learned documented. In the case of frequent deployments of expert support teams, exercises on deployment could be considered as low priority. Lessons learned from deployments and exercises should be used to develop, evaluate and revise the procedures for expert support. More detailed information on the preparation, conduct and evaluation of exercises can be found in Ref. [23].

5.20. Expert support can also play a role in the planning and development of exercises for other competent authorities. Exercises can be further used to raise general awareness on nuclear security, and more specifically on radiation protection fundamentals and radiation detection operations, both of which are useful skills for competent authorities. Moreover, the general steps involved in radiation detection and radiation protection should be described in standard operating procedures. Given the potentially significant variations between detection operations at different locations, systematic job training and related exercises should be tailored to the location. Training should target both the competent authorities and expert support.

5.21. Radiation safety measures should be included in the training programme (i.e. training and exercises on the use of personal protective equipment, radiation detection equipment, the conduct of measurements), as well as on the protection of instruments from contamination, and the decontamination of people and instruments. All training and exercise programmes should be included in the concept of operations, and the role of subject matter experts should be central when planning and conducting all these activities.

Resource management

5.22. Resource management and financial planning are important considerations for capacity building in relation to expert support and should be addressed well in advance. Considerations with regard to the operational costs of assessing alarms and alerts should be taken into account in the context of the management of resources. To ensure cost effectiveness, existing resources and capacity within a State could be leveraged to optimize the needs and operations involved in expert support assessments.

5.23. Operational arrangements between organizations within a State should also be in place before the deployment of expert support. Such arrangements should include, as appropriate, response times, defined data formats for exchanges and communication mechanisms for expert support. Consideration for the needs of both remote and on-site expert support should be included in the concept of operations to ensure effective operational arrangements and overall resource management.

Maintenance of detection instruments

5.24. Knowledge about the type of measurement equipment deployed for detection operations, and detailed information about quality assurance checks performed on the equipment, are of particular importance for expert support in the case of alarm assessment and adjudication. The sustainability of technical detection capabilities and the management of the instruments' life cycles involve the development of a maintenance programme. Expert support should maintain a complete record of instruments used within a States, including the configuration management of deployed detection systems. Continuous measures to maintain and improve the information integrity and security of communication and information systems should be implemented.

5.25. All operational detection systems should be user friendly and should always be accompanied by the operating manuals. Such manuals need to include simple procedures for quality assurance and quality control (QA and QC) testing. Expert support can help develop basic checklists and minimum standards for the QA and QC of a given detector. QA and QC testing should be carried out frequently and always prior to deployment of equipment for detection operations. In addition, the instruments' data transmission capabilities, if available, should be tested as part of the QA and QC process. If data can be transferred, then remote expert support may directly contribute to QA and QC testing. A subject matter expert may also support QA and QC on-site.

5.26. Expert support should be familiar with the technical specifications of operational detectors, should have access to information on their calibration and should have the proper software tools for data analysis.

5.27. After deployment of equipment on-site for detection operations, the detection instruments should be returned to their storage locations and have their batteries recharged, with spare batteries also recharged on a regular basis. Problems with the detectors should be immediately reported to all users and to expert support.

Life cycle management

5.28. Expert support plays a vital role in life cycle management by providing technical and scientific information when nuclear security detection architecture is being designed. To ensure that decision making on asset investments is effective, and to achieve sustainable results in nuclear security detection, a holistic approach needs to be developed, addressing not only infrastructure assets but also supporting resources, processes and procedures, as well as data and enabling technologies that are critical to success [24]. This holistic approach to life cycle management enables vast amounts of detection instruments and information to be effectively managed and leveraged to ensure efficient detection operations. Through such an approach, expert support authorities can institutionalize the management of detection equipment and treat it as part of the operation. Only by incorporating asset management into routine detection operations can a State achieve optimum performance of the equipment and use all the instrument capabilities that will contribute to an overall high quality nuclear security detection architecture.

5.29. Practical applications of life cycle management could be used to determine the allocation of costs for essential spare components. These applications would need to be prepared based on the results of analyses emanating from detection system operations. Being aware of the right components, the life span and the needs of the detection system will support market selection in determining products that have the best value for money. Expert support knowledge will facilitate the decision making process when acquiring spare components. The advance preparation of spare components should be complemented by the accurate allocation of labour costs that will be needed to carry out a maintenance programme, avoiding interruptions in detection activities that might result from maintenance and budget issues. Given that detection instruments are commonly deployed at remote locations, far from expert support authorities, proper planning will also be vital in this area.

6. INTERNATIONAL ASSISTANCE FOR EXPERT SUPPORT FOR THE ASSESSMENT OF ALARMS AND ALERTS

6.1. Information on alarm and alert assessments that has been verified as accurate should be exchanged in accordance with relevant international obligations, and in line with national legislation. This exchange of information can be achieved through international cooperation arrangements. For the purpose of the assessment of alarms and alerts, the State may inform the IAEA, and/or any other relevant international organization, as stipulated in Ref. [2]:

> "This is the (often remote) capability to assist those at the detection site in the assessment of radiation alarms or information alerts or on the discovery of suspicious or unauthorized material that could be used to manufacture an IND, RED or RDD. Technical support relies heavily on radiation analysts and subject matter experts who can identify specific isotopes and potential threats based on data collected from the detection site, either remotely or in person. International technical support capabilities may be available on request (e.g. through organizations such as the IAEA and other incident reporting channels)".

6.2. In the case of technical cooperation and assistance, States should consider bilateral or multilateral cooperation initiatives that might include developing joint protocols, coordinating capabilities, implementing joint training and exercises, and providing expertise and equipment for major events. In addition, States are encouraged to ask for assistance from other States, as well as from international organizations [1].

6.3. The main challenge associated with international cooperation in alarm and alert assessment is that States may need to consider sharing sensitive information. Measures can, however, be taken by States to build trust so as to preserve the confidentiality and ownership of information during such assessments. In nuclear security, critical information processing during alarm and alert assessments occur at the expert support level. Bilateral agreements are often used as formal mechanisms, allowing subject matter experts to request or receive help from another State in resolving instrument alarms or information alerts. Other mechanisms may also be used and are to be determined by the individual States.

PREREQUISITES FOR INTERNATIONAL COOPERATION

6.4. Considerable resources are required for the development and operational implementation of advanced alarm and alert assessment capabilities. States may need to develop technical, scientific and operational capabilities to face a wide range of nuclear security risks. In most instances, certain detection instruments are used only during specific nuclear security events. In such cases, States may seek international assistance only when the need arises. However, the provision of this more specific detection capability may require accompanying external expert support. Careful planning and agreements may therefore be necessary between the parties involved in these cooperation initiatives. The IAEA facilitates and/or extends support to States upon request for assistance.

6.5. Arrangements for information sharing should also be agreed in advance. It should be acknowledged, for example, that the owner of the data is the State in which the measurement is performed, regardless of who owns the measurement instrument. The owner can decide who has access to the data on a need-to-know basis.

6.6. The roles and responsibilities in the coordination for provision of international assistance should be clarified and documented. An example mechanism for requesting and obtaining assistance can be summarized as follows:

(a) Receiver – a designated national organization prepares the necessary arrangements, such as logistics and the point(s) of contact to receive external expert support;
(b) Provider – an expert support organization from a different State prepares the capabilities that can be deployed during the defined time frame;
(c) International organization – facilitates and extends support to States involved.

6.7. The development of joint formats and protocols concerning data management may be considered for the purpose of assessing alarms and alerts. To this end, the sharing of assessment analysis software and resources through international cooperation initiatives may ultimately contribute to reinforcing the efficiency of a State’s alarm assessment capabilities.

APPENDIX I: INFORMATION TO BE PROVIDED TO EXPERT SUPPORT FOR THE ASSESSMENT OF ALARMS AND ALERTS

A.1. This appendix provides examples of incidents where front line officers may request assistance from expert support and the type of information to be provided by the front line officers to expert support for the assessment of alarms and alerts.

A.2. Expert support personnel should have an understanding regarding when front line officers may request assistance. They should also be fully aware of the type of information that should be collected by front line officers when investigating nuclear and other radioactive material out of regulatory control. Front line officers are trained to initiate their established response protocol when nuclear and other radioactive material out of regulatory control, or a radiation hazard, has been confirmed or is suspected following an information alert or an instrument alarm. The circumstances in which the front line officer may request assistance include in the following cases:

(a) Potential or confirmed non-innocent alarm;
(b) Illicit trafficking of nuclear and other radioactive material out of regulatory control;
(c) Presence of nuclear and other radioactive material out of regulatory control (suspected presence of gamma radiation or neutrons);
(d) Presence of a radiological dispersal device, radiation exposure device or improvised nuclear device;
(e) Detection of a contaminated product;
(f) Detection of an abandoned source;
(g) Scam or hoax with nuclear security implications;
(h) Gamma dose rate at least 100 μSv/h at 1 metre from the source;
(i) Suspected surface contamination.

EVIDENCE

A.3. If the presence of nuclear and other radioactive material out of regulatory control is suspected or confirmed, all the information gathered and all the materials handled should be treated as potential evidence. Expert support may request front line officers to provide the following information:
(a) Personal details, such as an identification card(s);
(b) Interview statements;
(c) Manifest (cargo information);
(d) Photographs/videos that use descriptive file names, and show:
    (i) A common item within the photo as a reference for size;
    (ii) Instruments (e.g. radionuclide identification devices) in use;
    (iii) Details of potential evidence;

(iv) The surrounding scene.

(e) Personal effects;

(f) Radioisotope identification device (spectroscopic) data: Background measurements and saved files, as well as a record of the instrument identification number, file name, location of measurements, date/time, isotopes identified and the name of the front line officer.

(g) Radiation portal monitor data files;

(h) Other data associated with the assessment and proceeding investigation;

(i) Thorough records on people, objects and places involved in the investigation.

COMMUNICATION AND COORDINATION WITH COMPETENT AUTHORITIES DURING A NUCLEAR SECURITY EVENT

A.4. If the presence of nuclear and other radioactive material out of regulatory control, or of a radiation hazard, is suspected or confirmed, expert support may request front line officers to provide the following information:

- Description of the suspicious or unknown item;
- Type of detector (including name and/or manufacturer) used for performing the radiation measurements;
- Gamma spectrum of the suspicious or unknown item;
- Background spectrum, including collection time;
- Gamma spectrum of a known source (check or calibration source) using the same detector;
- Descriptive names for spectra files;
- Dose rates measured at specific distances from the suspicious or unknown item;
- Neutron count value, if available;
- Description of any materials located between the detector and the material;
- Any photographs of the material or the measurements;
- Information on the instrument file name and a description of the object being measured;
- Contact information of the person or organization submitting the information.

A.5. The data will assist the competent authorities in confirming a nuclear security event and in developing the response measures. The more information that is submitted to expert support, the easier it will be for them to assist front line officers.

A.6. Table I-1 summarizes the information that should be collected by the front line officer and submitted to expert support to ensure an accurate and timely adjudication of the instrument alarm or information alert.

TABLE I-1. INFORMATION TO BE SUBMITTED TO EXPERT SUPPORT

Item	Information to be submitted
Detector used for the conduct of radiation measurements	Manufacturer of detector and/or detector name, including model and/ serial number Type of detector Detector size Detection efficiency Maintenance history Date of last calibration
Suspicious or unknown item	Spectrum of suspicious or unknown item Distance between the detector and the suspicious or unknown item Distance of the detector from the ground Estimated location of elevated radiation levels within the suspicious or unknown item (for containerized cargo) Estimation on whether the source of radiation is located or distributed within the suspicious or unknown item Duration of initial measurement Duration of any additional measurements (usually with longer count time)
Background	Background spectrum of the area where the spectrum of the suspicious or unknown item was collected, using the same Duration of measurement Measurement geometry (including distance of the detector from the ground) Background spectra collected before and after the measurement of the suspicious or unknown item
Known source (i.e. check source, calibration source)	Spectrum of known source using the same detector; ideally using a multiple line check source (e.g. Na-22, Ba-133, Th-232) Distance between the known source and the detector Known source activity and calibration date Duration of measurement
Dose rate measurements	Measurements of dose rate at two different distances between the detector and the unknown or suspicious item (e.g. on the side where the highest dose rate is observed and measurement at a distance where the count rate is approximat¼ 1/4 of the count rate of the highest reading)
Neutron measurements	Neutron count value, even if it is zero Indicating whether there is the capability to conduct neutron measurements Detection instrument(s) used Distance between the detector and the suspicious/unknown item Neutron background count values If a significant number of neutrons is measured, indicate whether a moderator (e.g. hydrogen) was used to moderate neutron counts Description of the environment, including material types and the distance from the suspicious/unknown item
Intervening materials	Exact material type Measured thickness of materials Order of materials
Incident information	 Descriptive information that 'sets the scene' of the incident (i.e. situational information describing what, why, where, when, who) Details about the item
Photographs	Photographs of the suspicious or unknown item Photographs of the instrument location and readings Use a fiducial or common item to indicate size of unknown or suspicious item Photographs of the surroundings Photographs showing details of the item (e.g. nameplates, openings)

Naming convention for instrument file names and photographs	File names including a description of the suspicious or unknown item being measured Descriptive names for photographs
Contact information	Phone number and email of the person submitting the information Phone number that can be used in the field or at the scene Contact information for other competent authorities who need results

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ANNEX I: EXAMPLES OF EXPERT SUPPORT AT STATE BORDERS, WITHIN A STATE AND AT MAJOR PUBLIC EVENTS

I–1. This annex provides examples of expert support for different types of operations at State borders, within a State and at major public event.

STATE BORDERS: DESIGNATED POINTS OF EXIT OR ENTRY

I–2. Expert support can be located at centralized locations where they rely on front line officers to conduct secondary inspections. If expert support is located at the point of exit or entry or if a mobile expert support team has been deployed on-site, personnel may directly use secondary inspection instruments in the assessment process. Tasks for expert support may include one or more of the following:

(a) Analysis of radiation detection instrument data and provision of expert support to the front line officers;
(b) Conduct of secondary inspections upon request by front line officers with spectroscopic radiation detection instruments if radiation data associated with the primary detection alarm is insufficient to make an adjudication determination (i.e. it appears as if the primary detection relates to a typical naturally occurring radioactive material shipment and does not represent a significant nuclear security risk;
(c) Coordination with front line officers and other competent authorities with respect to detaining people, vehicles or commerce that might have caused a radiation detection instrument alarm that needs further inspection;
(d) Undertaking of research on declared commodity information and analysis of gamma spectrum data to assess radiological risks associated with the instrument alarm;
(e) Maintaining of a database of instrument alarms, assessment and adjudication results;
(f) Liaising with other competent authorities and organizations on adjudication decisions.
(g) Liaising with international partners in the case of an interdiction of nuclear and other radioactive material out of regulatory control;
(h) Initiation of response measures, if necessary, and provision of expert support during the response to a nuclear security event.

STATE BORDERS: UNDESIGNATED POINTS OF EXIT OR ENTRY

I–3. Detection operations and alarm assessments need to be carefully planned, with preliminary training and exercises being carried out for expert support. Since detection sites at undesignated points of entry might not be staffed with permanent personnel, covert and secure installations of detection systems may be needed. Cooperation between front line officers and expert support, including reliable and secure communication capabilities, thus remains important.

I–4. Expert support for alarm assessments may also involve supporting data, such as videos or photographs. Given that successful assessment by the expert support involves expeditive action, joint data formats and secure protocols should be developed for data transmission.

STATE’S INTERIOR

I–5. The assessment of an instrument alarm or information alert within a State’s interior may initially be conducted by an internal security or law enforcement official, a front line officer, competent authority or industrial facility operator. If the instrument alarm or information alert is assessed to be non-innocent or potentially non-innocent, those who carried out the assessment should follow the relevant standard operating procedures and contact expert support for further assessment and adjudication support.

I–6. During covert operations or other sensitive operations, it might not always be possible to share operational information with expert support personnel. During these types of operations, prior discussion between competent authorities and expert support is necessary to determine the degree of information needed by expert support personnel to complete a meaningful assessment of an instrument alarm or information alert. In such circumstances, expert support personnel may provide limited analysis results to the competent authority, and may also play a minor or no role in the adjudication process.

I–7. While conducting operations within a State’s interior, competent authorities may need the assistance of expert support to help in the assessment and adjudication of instrument alarms. The personnel carrying out detection operations needs to provide expert support with all the relevant data. Testing of data transfer channels and procedures (including the types of information to be transferred and points of contact) between competent authorities and expert support need to be established in advance, thus improving the efficiency of coordination and supporting timely assessment of data provided to remote expert support personnel.

I–8. A mobile expert support team may be jointly deployed with competent authorities to support the instrument alarm assessment and adjudication on-site with instruments, equipment or advice. Whether support is on-site or remote, real time advice from a subject matter expert can provide valuable input to the personnel of the operations centre. If a mobile expert support team is not deployed to assist competent authorities on the site, a direct communication link between expert support and decision makers could be established to improve coordination, facilitate decision making and allow competent authorities to adjust operations. The type, extent and timeliness of information necessary for expert support to interpret measurement data should be agreed upon before deployment. The mechanism for information exchange should be tested and documented. Expert support involves close coordination with law enforcement officials on-site and an understanding of the related procedure before deployment.

MAJOR PUBLIC EVENTS

I–9. Depending on the nature of the organizations involved in the implementation of nuclear security measures for a major public event, expert support personnel may be requested to assist in the planning and the operational implementation of nuclear security measures. Expert support may be requested to provide advice and support for a range of activities related to the implementation of nuclear security systems and measures at major public events, including the following:

(a) The development of nuclear security plans and procedures for the major public event;
(b) The development of the nuclear security concept of operations during the major public event;
(c) The implementation of pre-event preventive measures, such as a radiation survey (mapping) of event venues and strategic locations before the event, using mobile or relocatable detectors;
(d) The selection and deployment of suitable radiation detection instruments for the major public event;
(e) The assessment and adjudication of instrument alarms and information alerts at the major public event;
(f) The response to criminal acts involving nuclear and other radioactive material out of regulatory control during the major public event;
(g) The provision of technical, scientific and operational expert support during the major public event.

I–10. During a major public event, remote and mobile expert support teams conducting assessment and adjudication support for instrument alarms and information alerts would benefit from clearly established communication protocols with the relevant competent authorities, including the personnel in charge.

I–11. Details on the implementation of nuclear security systems and measures at major public events are provided in IAEA Nuclear Security Series No. 18, Nuclear Security Systems and Measures for Major Public Events [I–1].

REFERENCES TO ANNEX I

[I–1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Security Systems and Measures for Major Public Events, IAEA Nuclear Security Series No. 18, IAEA, Vienna (2012).

ANNEX II: INFORMATION ON DETECTION OF RADIOACTIVE MATERIAL USING GAMMA SPECTROSCOPY

II–1. This annex provides further details on analyzing gamma spectroscopy measurement for the detection of radioactive material.

II–2. All measurements have random and systematic uncertainties. Measurements of radioactivity contain fundamental and additional uncertainties, which have their origins in the radioactive decay process. All such uncertainties have to be considered in nuclear security detection systems, including in the context of the analysis of alarm assessments.

Single-channel analyser

II–3. If the radiation detection system is a single-channel analyser (e.g. a plastic counter), the answer to the above question will be based on statistical considerations comparing data of interest with data from background radiation. The detection capability of an instrument refers to detecting the presence of radioactive material, including through analysis methods. The mathematical formulation for detection is based on hypothesis testing that defines the following two limits:

(1) Critical limit (L_C): knowledge that proceeds from observation, and it is used to decide whether a measurement contains a signal of interest;
(2) Detection limit (L_D): quantity used to characterize the sensitivity of the measurement process prior to any measurement being taken.

II–4. A measurement system based on a counter gives a single number as a result of a measurement. Background counts refer to a measurement with no source present, and gross counts refer to a measurement with a source present (i.e. the sum of the signal and the background). The key question is therefore: when is the signal significant enough to be interpreted as an alarm?

II–5. Making decisions about the existence of an alarm signal is subject to inherent risks, and these risks can be classified into two categories. The first category, a type I risk, refers to the risk that the assessment process accepts the detection of the radioactive material involved when in fact it is not present (false positive). Type II risks refer to cases where an assessment process has concluded that no radioactive material is present when in fact it is present (false negative).

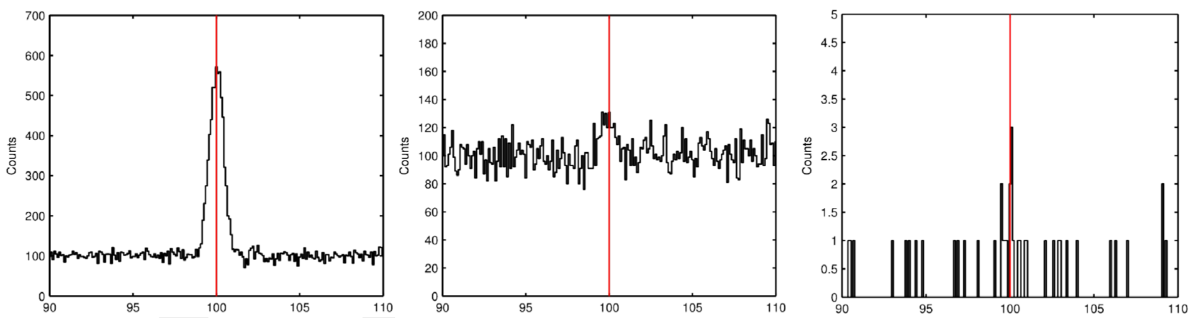
II–6. The instrument alarm assessment process in nuclear security determines whether there are reasons to believe that the object of interest truly contains radioactive material when a measured signal is higher than the critical limit. Expert support plays a key role in correctly setting the alarm threshold for every instrument in use.

II–7. The detection limit is used to calculate the minimum detectable quantity of the detection system. The minimum detectable quantity acts as the basis for the selection of a nuclear security detection instrument. It is also used to report the capability of the detection system in a given measurement.

II–8. The exact mathematical formulation of the critical limit and the detection limit is beyond the scope of the present publication. Although the classical Currie formulation is commonly used, extremely low signals should be processed using more sophisticated statistical methods [II–1].

Spectroscopic radiation detection equipment

II–9. The analysis of a radiation spectrum necessitates technical expertise. Figure II1 presents three gamma spectra obtained during the assessment of an item suspected to be radioactive. In this example, a clear peak can be seen in spectrum (a), in which case its area can be analysed with high accuracy and precision, while in spectrum (b), a small peak may be present, however analytical tools such as fitting and the least squares method are needed. Spectrum (c) shows a questionable peak with very low statistics. A summation algorithm works well for a measurement with good statistics: simply add the counts within the peak and then subtract the sum of the counts of an equal number of channels in the neighbourhood of the peak. A small peak is a more difficult case. First the peak has to be located using a specialized search algorithm, and then its area has to be quantified by fitting a Gaussian function above the baseline. A statistical analysis should be carried out to accept or reject the identification of the peak based on the confidence level chosen (i.e. the amount of acceptable false positives and false negatives).



Energy (keV– kiloelectron volt) Energy (keV) Energy (keV)

Spectrum (a) Spectrum (b) Spectrum (c)

FIG. II-1. Statistical analysis of the presence of a peak in a gamma spectrum.

II–10. Such a fitting algorithm is today a straightforward mathematical tool, providing not only estimates for the parameters involved but also for their uncertainties (covariance matrix). Low statistics, on the other hand, are a particular challenge that necessitate the use of special non-Gaussian mathematical tools.

II–11. Radionuclide identification should be performed to determine innocent alarms and to understand the possible threat from nuclear and other radioactive material out of regulatory control. The spectrum may contain a large number of peaks originating from several radionuclides; for example, see

Fig. II-2. Some peaks in Fig. II-2 are multiplets, containing counts from two or more nuclides. Expert support should have the tools to handle overlapping peaks because in smuggling or other criminal acts surrogate materials might be used to mask the radioactive material.

II–12. While in-house and commercial software have been developed for spectrum analysis — including for radionuclide identification — these software tools were initially designed for interactive work. Their ability to manage, in an automatic fashion, a large number of acquired spectra might therefore be limited.

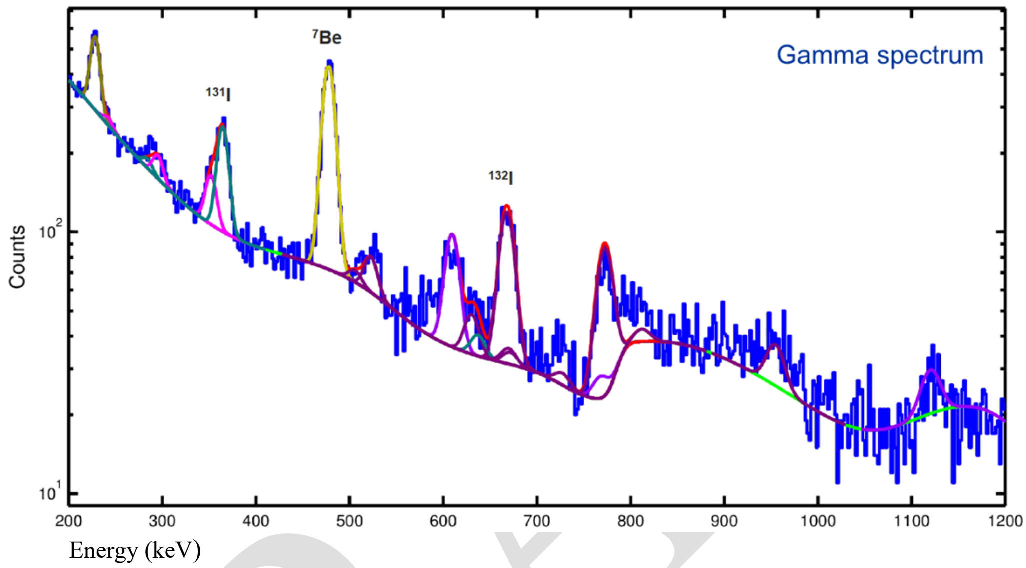


FIG. II–2. A complex gamma spectrum.

II–13. If an information alert is received on suspect material, expert support can set up the analysis pipeline, giving priority to the assessment of this alert. An analysis method based on hypothesis testing is a powerful tool as it assumes that a spectrum contains the nuclide of interest, and then, using analytical and statistical methods, it can show that the hypothesis is wrong or right at the confidence level chosen. In practice, expert support should prepare a list of suspect radionuclides in advance, based on a national threat assessment, to use for hypothesis testing. In addition to hypothesis testing, the software should warn of the presence of unknown peaks, which should then be analysed interactively.

II–14. Spectroscopic systems for nuclear security produce large amounts of data. Each spectrum may contain tens or even hundreds of peaks. For example, a detection site with a network of ten detectors and each of them providing a spectrum every two seconds, would produce 10 x 24 x 1800 = 432 000 spectra per day. Therefore, it is important to design a dedicated data management system to handle such large flows of data.

REFERENCES TO ANNEX II

[II–1] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, International Standard, Determination of characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation – Fundamentals and application, ISO 11929:2010, ISO, Geneva (2010).