

# IAEA BULLETIN

INTERNATIONAL ATOMIC ENERGY AGENCY

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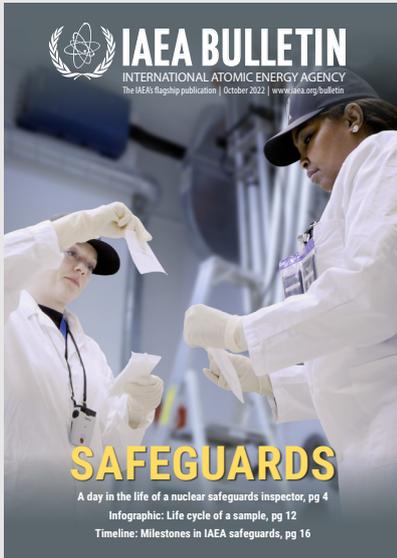


## SAFEGUARDS

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### IAEA BULLETIN

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Cover:  
IAEA safeguards inspectors collect  
environmental samples.

(Photo: IAEA)

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The International Atomic Energy Agency's mission is to help prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

# IAEA safeguards for international peace and security

By Rafael Mariano Grossi, Director General, IAEA

The IAEA was established in 1957, in response to the power of nuclear energy unleashed by the first self-sustaining nuclear chain reaction created by physicists 15 years earlier. The Agency has a dual mission to promote and to control the atom.

To the public, the IAEA is best known as the ‘nuclear watchdog’ for its crucial role in preventing the proliferation of nuclear weapons. As part of a robust safeguards system, our on-site inspections ensure that nuclear material designed for peaceful purposes is not diverted for military use.

IAEA safeguards are scientifically based and deploy state-of-the-art technologies. This *Bulletin* offers readers a glimpse into that work. For example, it describes how the instruments used to gather and process information are enhanced by technological developments, such as satellite imagery and artificial intelligence.

Around 870 staff from nearly 100 countries make up the IAEA’s Department of Safeguards, of which a core group of about 275 inspectors are regularly deployed for on-site verification activities. In this publication, inspectors share their experiences in the field and provide a glimpse into their toolbox.

The IAEA continues to rise to the challenge of inspecting ever greater volumes of nuclear material and an increasing number of facilities. Globally, more than 1300 facilities and other locations are under IAEA safeguards. In 2021 alone, IAEA inspectors verified about 27 900 seals applied for the containment of nuclear material or critical equipment.

The Treaty on the Non-Proliferation of Nuclear Weapons and regional nuclear-weapon-free zone treaties obligate non-nuclear-weapon States to bring into force comprehensive safeguards agreements (CSAs) with the IAEA. This year marks 50 years since the entry into force of the first CSA, and 25 years of the additional protocol. From peer review missions to training and advisory services, the Agency provides support to States so they can meet their safeguards obligations.

As the world’s nuclear inspectorate, the Agency works diligently to fulfil its duty to implement safeguards on every inhabited continent. Our independent, objective and technical verification work provides a critical contribution to the international non-proliferation regime and will continue, no matter the challenge, to help foster global peace and security.



**“The IAEA continues to rise to the challenge of inspecting ever greater volumes of nuclear material and an increasing number of facilities.”**

– Rafael Mariano Grossi,  
Director General, IAEA



(Photos: IAEA)



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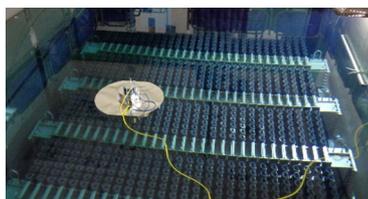
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# A day in the life of a nuclear safeguards inspector

By Patricia Musoke-Zawedde and Teodor Nicula-Golovei

Nuclear safeguards inspectors travel across the world, often to places such as nuclear power plants, uranium mines, nuclear fuel fabrication plants, enrichment facilities, research reactors and nuclear waste sites. Inspectors travel, sometimes at a moment's notice, to nuclear facilities and other locations to provide in-field verification of a country's nuclear material and technology. "Our job is very clear — we verify that nuclear material is used in peaceful ways," said Helly Diaz Marcano, Nuclear Safeguards Inspector at the IAEA.

The IAEA is the only organization with the mandate to verify the peaceful use of nuclear material and technology worldwide. It pursues this mandate through the application of IAEA safeguards; a series of technical measures to verify that States honour their international non-proliferation obligations.

In 2021, around 280 IAEA inspectors collectively spent over 14 600 days in the field. These trips often involve demanding logistics. Inspectors follow strict processes and procedures, but they must also adapt to the unexpected.

Team members — usually between two and ten inspectors, depending on the type

of facility — leverage one another's skills and abilities, sharing the knowledge and experience of those who have visited the facility before.

The following provides a glimpse of what an IAEA inspector may experience during a day in the field.

## Morning

The inspector ensures any necessary paperwork is in order and loads the inspection equipment into the team's vehicle. After a drive that could last many hours, the IAEA team reaches its destination. First, with the help of facility staff, the IAEA team must clear security, which typically takes around half an hour. Inspectors then meet the operator, facility manager and other State representatives. The group discusses safety and security regulations and establishes the day's agenda. After the meeting, the team begins to review the facility's nuclear material accountancy records.

## Afternoon

Accompanied by the operator, the team enters the facility. To do so, the team must put on personal protection equipment (PPE). Watches, jewellery or other accessories are



removed; and phones, keys and wallets are stored to avoid the risk of contamination. Depending on the type of facility, inspectors may put on protective suits or lab coats. Hair is tucked away in a net, hood or hard hat. Inspectors also wear a dosimeter around their necks to monitor radiation levels and ensure their individual safety.

The inspectors then prepare for the more strenuous part of the job: working for the next four to six hours while carrying up to 15 kilograms of instruments, tools and other equipment. The equipment and cases must be hand-carried during most of the inspection to avoid the risk of contamination.

“It’s a privilege to be inside a nuclear facility; you can see the wonders of nuclear science and technology right in front of you,” said Dinesh Sharma, Nuclear Safeguards Inspector at the IAEA. “However, it is also a job full of surprises. Each inspection is unique and comes with its own challenges.”

To verify nuclear material with a State’s declaration and accountancy records, an on-site facility inspection can include a variety of activities. Tasks may include checking IAEA surveillance cameras that are part of remote and unattended monitoring systems; examining IAEA seals for tampering; or attaching a new seal to a container, hatch or nuclear material cask.

Another task may require counting spent nuclear fuel assemblies in a spent fuel pond. The inspectors stand on a bridge that extends

across the pond and use customized cameras to verify the presence of the spent fuel. While one inspector identifies the spent fuel assemblies through a camera, a teammate helps ensure that what is identified matches what is reported. The IAEA team might request the facility operator to reposition a spent fuel assembly for further verification, with the help of the operator and facility staff.

Environmental sampling may also be conducted, during which the inspectors will use a cotton swipe to collect dust particles from surfaces in the facility. Anonymized samples are sent to the IAEA’s laboratory in Seibersdorf, Austria, and to other designated laboratories to look for minute traces of nuclear material (see page 12).

## Evening

The IAEA team meets with facility personnel to review the day’s work and discuss the next steps, which may include the activities planned for the following day, and to share the paperwork to be sent to the IAEA’s Headquarters. After this meeting, the coordinating inspector asks the other inspectors to provide a summary of the day and assigns parts of the inspection report to each of them.

Despite the demands of the job, safeguards inspectors agree that their work is important and rewarding. “I feel like a global citizen on a mission for peace and security,” said Amina Agbab Uthman, Nuclear Safeguards Inspector at the IAEA.

**Nuclear safeguards inspectors travel around the world to provide in-field verification of a country’s nuclear material and technology.**

(Photo: IAEA)



# What equipment is used for IAEA safeguards activities?

Equipping inspectors and facilities with the appropriate tools is key to effective nuclear safeguards. IAEA inspectors use over 100 types of equipment to verify nuclear material. Here is a look at some of the tools and equipment available for an IAEA inspector to carry out their verification activities.

**Personal protective equipment** includes clothing and equipment that is worn to protect against radioactive contamination and difficult environmental conditions. Such equipment includes:



Most equipment is transported in shock-resistant cases with IAEA staff, or as cargo shipment.



❶ **Unattended monitoring systems** record data from radiation, temperature or pressure detectors to provide a log of activities in a nuclear facility. Data are collected in an industrial computer, housed in a tamper indicating cabinet. These data may be collected remotely by the IAEA or stored locally until an IAEA inspector retrieves it.

❷ **Portable surface radiation monitors** are used to check for radiation contamination by measuring the levels of alpha, beta and gamma radiation. Surface contamination monitors can be used in most facilities, as well as at the IAEA's Headquarters, to check equipment and personal items that return from nuclear facilities.

❸ **Surveillance cameras** provide continuity of knowledge regarding nuclear material and facility operation between inspections. These cameras are equipped with data security systems and long-lasting batteries to prevent any disruption while in operation.



④ **Environmental swipe sample kits** may be used to take samples of dust that can reveal the presence of nuclear material particles. If found, these particles can indicate if any undeclared nuclear activities have taken place (see page 10).

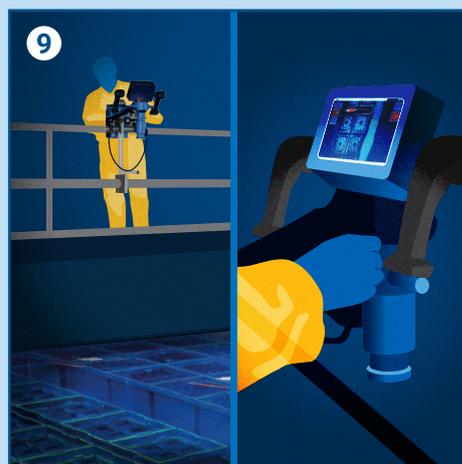
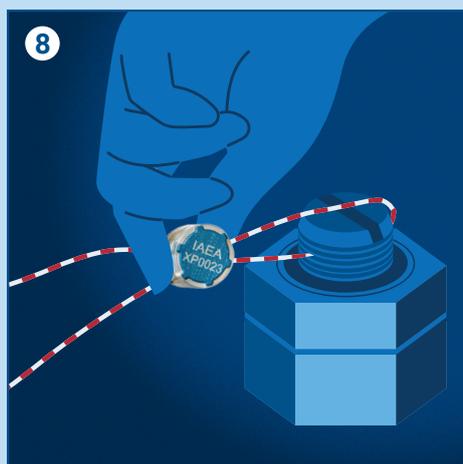
⑤ Inspectors use **destructive analysis vials** to collect and transport samples from the field back to the IAEA's safeguards laboratories. When analysed, these samples allow the IAEA to characterize the nuclear material, both quantitatively and qualitatively.

⑥ Most inspectors use **digital cameras or a laser-based system** to collect images to make comparisons with declared nuclear activities. This helps to maintain continuity of knowledge inside nuclear facilities.

⑦ A **spectrometric gamma hand-held monitor** measures gamma ray sources to identify radionuclides or uranium enrichment.

⑧ **Seals** are used to verify that containers or casks containing nuclear material, facility critical equipment, or IAEA monitoring and other equipment remain unopened. Seals can be passive, such as metal cap and wire seals, or active, meaning they can electronically record whether the seal has been tampered with.

⑨ The **next generation Cherenkov viewing device** visually intensifies characteristics from the Cherenkov glow emitted during the cooling of spent nuclear fuel stored in a spent fuel pond. This device enables the inspector to verify the declared inventory of spent fuel while in wet storage.



# Small device, big effect

## Field verifiable passive seals

By Jennifer Wagman

One of the main tools that IAEA inspectors use to detect the diversion and misuse of nuclear material and technology comes in the form of a device no larger than a coin. This small but mighty instrument is called a passive seal. With it, an IAEA safeguards inspector can close a container, a hatch to a room or a nuclear material cask, and return years later to verify whether it was opened. In 2021, the IAEA verified over 17 000 passive seals applied to nuclear material, facility critical equipment or IAEA monitoring and other equipment at nuclear facilities.

“Seals are a simple and effective means to meet an important verification need. Used around the world, metal seals are an important part of an inspector’s toolkit when verifying that nuclear material and facilities remain in peaceful use,” said Joel Hoyt, seals modernization project lead and Senior Project Engineer at the IAEA.

A passive seal ensures continuity of knowledge regarding nuclear material. If the seal has not been tampered with, the inspector knows that the integrity of the equipment or

material it encloses is still intact. A passive seal is also used to ensure the integrity of the IAEA’s on-site verification tools and equipment, such as surveillance cameras.

The traditional passive seal, used since the 1960s, is a copper and brass device called the E-CAP metal seal (CAPS). CAPS is a general purpose, non-reusable passive loop seal. To close the seal, a double copper cap is snapped onto the base. Both the cap and its base have unique markings on the inside surface to ensure the authenticity of the seal. The metal base and its cap serve as the point of closure with a multistranded wire threaded between them. This wire encircles the item to be sealed. After an inspector confirms that the wire and the sealed enclosure have not been tampered with, they cut the wire and bring the seal, base and wire to the IAEA’s Headquarters for verification.

### Modernizing the passive seal

To identify the next generation passive seal, the IAEA considered advancements in materials, modern technologies and machining techniques to design and address

**IAEA inspector Georges Rubinstein applies an IAEA seal on a valve at the Nuclear Fuel Services plant in West Valley, New York, during the first IAEA safeguards inspection of the processing of spent fuel from a nuclear power reactor in August 1967.**

(Photo: IAEA)



the requirements of an effective seal. The prototypes of the new seal were subject to field conditions and extreme situations to confirm if the design could meet all requirements. The result was the adoption of the field verifiable passive seal (FVPS), which is made from aluminium and polycarbonate and requires no tools to apply, no maintenance while deployed, and no batteries or electronics to power.

Both the CAPS seals and the new FVPS have unique pattern designs etched onto their surfaces to ensure that they cannot be replicated or replaced, as well as other tamper-indicating design features. However, one of the main advantages of the new FVPS seals is that they can be verified in the field.

The device used to verify seals employs customized software and a specialized lens and light attachment housed in a bespoke case. When an inspector attaches a new seal, they use the dedicated software to input information about where the seal is installed and take three reference photos. These pictures and the related facility information are relayed back to the IAEA's Headquarters, simplifying the inspection reporting process. When an inspector returns to the facility at a later date, the verification device is used by the inspector to take photos for comparison with the reference photos. This allows the inspector to confirm the integrity of the seal and whether it was subject to tampering.



“Having an in-field verification technique for the seal means we have faster verification results, and we can reduce the administrative burden,” said Nicolette Seyffert, the new seal implementation project team member and Information Security Officer at the IAEA. “By having an in-field customized reader, it is immediately obvious if a seal was tampered with and removes the need to bring the seal back to the IAEA’s Headquarters in Vienna.”

The IAEA has produced the new FVPS for pilot use, with a planned expansion of deployment starting in 2023. Eventually, the new FVPS will replace all of the traditional CAPS seals.

**Metal seals are applied to nuclear material, facility critical equipment or IAEA monitoring and other equipment at nuclear facilities.**

(Photo: IAEA)

**The new field verifiable passive seal does not require any tools to apply or maintenance while deployed.**

(Photo: IAEA)



# Detecting nuclear material smaller than a pin

By Jennifer Wagman

The IAEA brings together analysts and experts to verify that nuclear material and technology are used only for peaceful purposes. The IAEA provides credible assurances based on information gathered from official State declarations, in-field verification activities and other safeguards relevant information. One activity that IAEA inspectors may carry out while in the field is the collection and analysis of samples — mainly nuclear material and environmental samples — from nuclear facilities and other relevant sites.

Since the 1970s, nuclear material samples have been collected for nuclear material accounting. Samples usually contain gram-sized amounts of uranium and milligram to microgram amounts of plutonium. These samples are packed in special vials and protective containers that are securely sealed and shipped to the IAEA's Nuclear Material Laboratory in Seibersdorf, Austria, for analysis. In 2021, the Agency collected over 700 nuclear material samples.

“From the collection of samples by IAEA inspectors to the analysis in the IAEA laboratories and then final evaluation of the results in Vienna, a rigorous, quality-checked process ensures the results are correct and appropriate conclusions are derived,” said Steven Balsley, Director of the Office of Safeguards Analytical Services at the IAEA.

In the 1990s, IAEA inspectors started to conduct environmental sampling, and this has proven to be one of the most important tools used to detect undeclared nuclear material or activities. An environmental sample consists of a 10 cm x 10 cm cotton cloth that an IAEA safeguards inspector swipes across a surface to pick up millions of tiny dust particles. This dust contains information, indicating not only if nuclear material is present, but also the type (e.g. separated plutonium or highly enriched uranium), the age of the nuclear material and the presence of other materials.

“By analysing the cotton swipes that inspectors collect in the field, the IAEA can detect nuclear material at weights below one trillionth of a gram,” said Todd Mock, Safeguards Information Analyst for Environmental Sampling at the IAEA.

In 2021, the IAEA collected over 470 environmental samples. About 80 per cent of the environmental samples were analysed by 16 external laboratories that are part of the Network of Analytical Laboratories (NWAL), with the remainder analysed in Seibersdorf at the IAEA's Environmental Sample Laboratory (ESL). Certified by the IAEA, the NWAL comprises external laboratories in IAEA Member States and at the European Commission, which supplement the work performed at the IAEA's own laboratories in Seibersdorf.



## How environmental sampling works

The analysis of environmental samples requires careful processing and highly sensitive instrumentation to not only detect trace amounts of nuclear material, but also ensure the samples contain particles only from the specified location. Before the sample collection, inspectors perform a pre-inspection check, in which they swipe their own clothing to account for traces of particles originating from the inspector collecting the sample during the sampling process.

Inspectors collect environmental samples in teams of two to reduce contamination as much as possible. One inspector handles the ‘dirty’ swipes, and the other takes care of the sampling equipment.

When the samples arrive at the laboratory, they are anonymized through a process that relabels each sample to ensure independent analysis. The samples are then screened for the presence of radionuclides. The screening results are sent to information analysts, who assign at least two laboratories to undertake more detailed analysis of the samples with specific instructions.

There are two basic types of analysis: bulk analysis and particle analysis.

Bulk analysis techniques can detect extremely small amounts of nuclear material and are used to determine the quantities of uranium and plutonium on a swipe, as well as the average isotopic composition. Bulk analysis has been used by the IAEA since the mid-1990s and is best for detecting the presence of trace amounts of nuclear material. This type of analysis requires the entire swipe to be dissolved in a solution, which can take days. Then, highly sophisticated equipment analyses droplets of the dissolved swipe solution. On average, bulk analysis takes three to four weeks per sample.

Particle analysis, which usually takes a few days, is used to determine the isotopic composition of uranium and plutonium in individual particles, revealing different materials and processes. This is done by vacuuming microscopic particles from swipe samples and placing them on a planchet to be analysed using precise instruments to determine isotopic information. The ESL has utilized mass spectrometers for particle analysis since 1999 and, in 2022, the IAEA installed a new large geometry secondary ion mass spectrometer to maintain its particle analysis capability at the highest level.

Following the analyses, results are uploaded to a secure database for further evaluation and analysis by information management experts at the IAEA. These results are then used, alongside all other relevant information, to support the drawing of safeguards conclusions.

**IAEA safeguards inspectors collect environmental samples.**

(Photo: IAEA)



# Life cycle of a sample

By Jennifer Wagman

Environmental swipe sampling is one method used by the IAEA to verify the correctness and completeness of a State's declaration of nuclear material and how it is used.

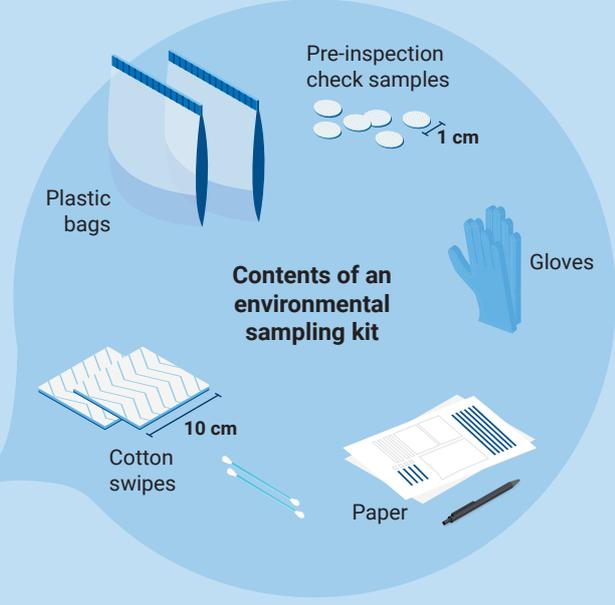


## PLAN FOR VERIFICATION ACTIVITIES

Each year, inspectors, analysts, specialists and other technical experts plan activities to verify a State's compliance with its safeguards obligations.

## EQUIPMENT COLLECTION

Inspectors pick up packaged environmental sampling kits along with other equipment, such as lead-coated vials and other specially designed tools and equipment.

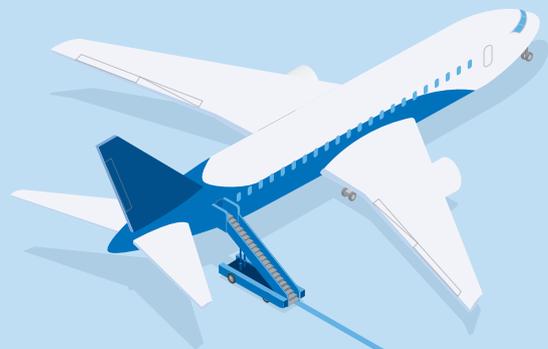
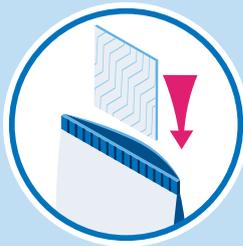
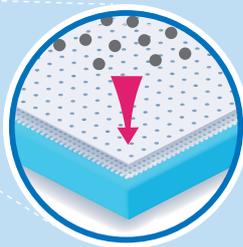


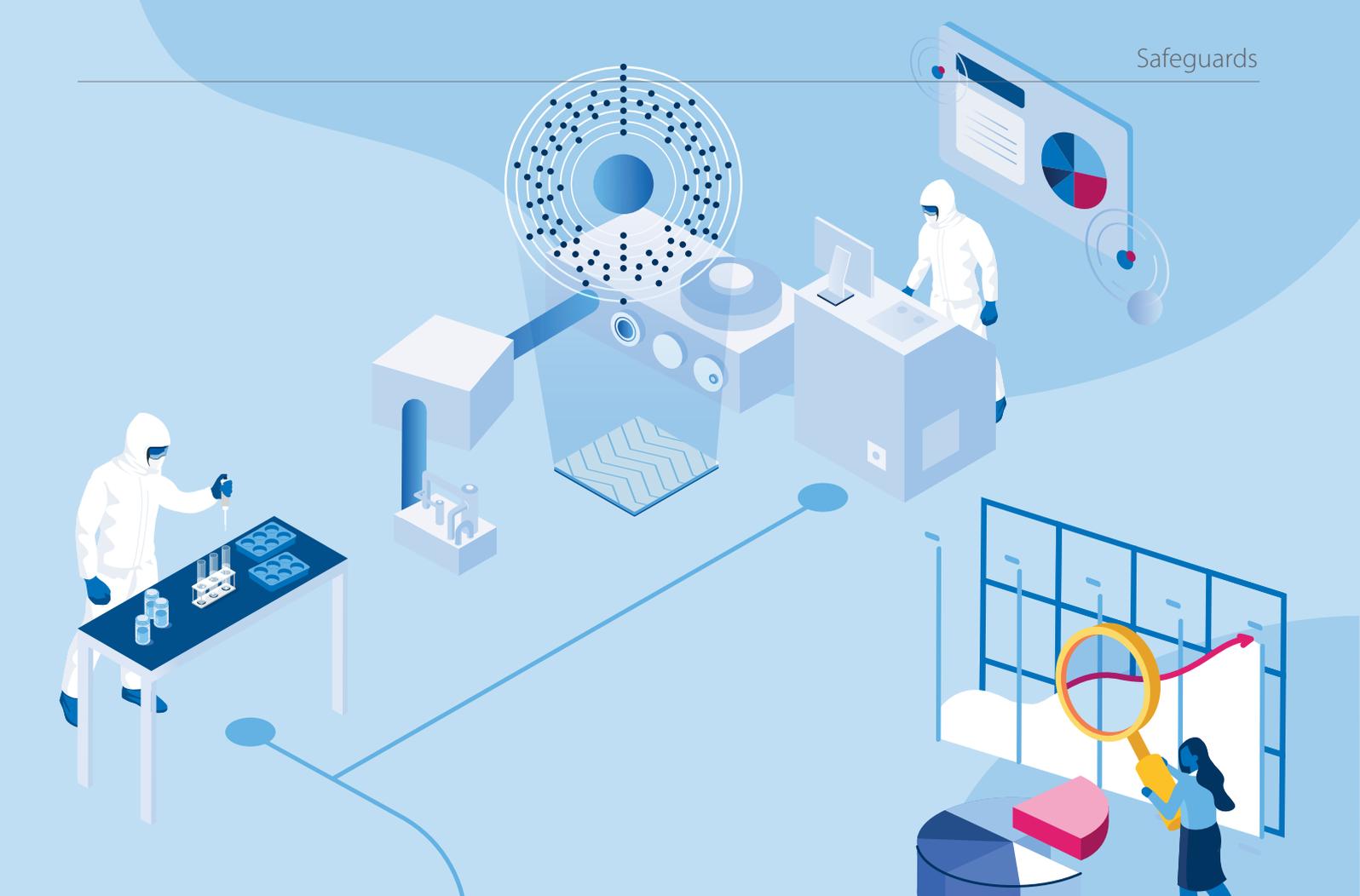
## SAMPLE COLLECTION

Once at the sampling location, the inspector collects samples by wiping a cloth on a surface. The cloth can pick up minute traces of particles.

## SAMPLE TRANSPORT

The cloth is individually placed in a plastic bag. All individually bagged cloth samples and paperwork are then stored together in a larger plastic bag, which is hand delivered to IAEA laboratories or shipped using a secure transport process.





### SAMPLE RECEIPT

Upon receipt, the IAEA laboratories screen samples for radioactivity and anonymize the samples using a special code. They are then distributed between the IAEA Environmental Sample Laboratory in Seibersdorf, Austria, and 16 laboratories across the world that are qualified for environmental sampling analysis.

### SAMPLE ANALYSIS

Through various analytical techniques, laboratories determine different characteristics of a sample, such as uranium and plutonium isotopic composition. This information is then uploaded to a secure electronic database.

### DATA EVALUATION

Analysts process and interpret the data to produce evaluation reports. Analysts compare these results with the State's nuclear material declaration.

### SAFEGUARDS CONCLUSIONS

State Evaluation Groups review the evaluation reports and all other safeguards relevant information available to the IAEA. These groups, which consist of inspectors, analysts, specialists and other experts assess a State's compliance with its safeguards obligations. These findings are published in the annual *Safeguards Implementation Report*.



# The evolution of safeguards technology

By Teodor Nicula-Golovei and Jennifer Wagman

IAEA safeguards are based on information provided by States, inspections carried out by Agency safeguards inspectors and other safeguards relevant information. The tools used to collect and process this information continually evolve, stimulated by technical progress. For more than 60 years, international endeavours to develop these technologies have allowed nuclear safeguards inspectors and analysts to verify that nuclear material and technology remain in peaceful use.

“Artificial intelligence, robotics and advancements in radiation detection and satellite imagery are some of the technological developments that are already starting to impact the implementation of international safeguards,” said Carrie Mathews, Safeguards Outreach Coordination Officer at the IAEA. “Technology allows inspectors to make better use of their time in the field, focusing on the inspections rather than on compiling reports or doing other repetitive tasks.”

The following are some examples of technological developments, which can increase the effectiveness and efficiency of the IAEA’s safeguards implementation.

## Satellite imagery

To implement safeguards, the IAEA collects and evaluates a range of safeguards relevant information to verify States’ non-proliferation obligations. This includes information

gathered from open sources, such as commercial satellite imagery. “Commercial satellite imagery analysis complements information provided by States and has become an important asset for verifying a State’s declarations,” said Marc Lafitte, Head of the State Infrastructure Analysis Section at the IAEA. Analysis of satellite imagery is routinely used in the following safeguards activities:

- to verify the accuracy and completeness of information supplied by States;
- to aid the planning of in-field activities;
- to detect changes and monitor activities at nuclear fuel cycle-related sites; and
- to identify possible undeclared activities.

In recent years, satellite imagery analysis capabilities have significantly expanded. In addition to a growing number of Earth observation satellites delivering optical imagery, commercial imaging radars, new infrared sensors and satellite-based video have all enhanced the analytical process. These sources of imagery associated with new techniques allow analysts to provide an in-depth assessment of nuclear-related facilities to support the State evaluation process and fulfil the IAEA’s verification requirements more effectively.

## Robotics

A Robotics Challenge was organized by the IAEA in 2019, leading to the development of the robotized Cherenkov viewing device

Left: Exhibit of IAEA safeguards equipment during the second Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons in August 1980.

(Photo: IAEA)

Right: The next generation Cherenkov viewing device.

(Photo: D. Calma/IAEA)



(RCVD) — an automated surface vehicle used to verify spent nuclear fuel rods stored in spent fuel pools. In 2022, the IAEA announced the first successful field test of the RCVD. Once authorized for safeguards verification, this floating robot will be able to propel itself across the surface of a spent fuel pool and provide high-quality images of the Cherenkov glow generated by the spent fuel. The RCVD will reduce the time taken to verify spent nuclear fuel in spent fuel pools and will make it easier to verify areas that are more difficult to access.

“We hope that this solution is going to not only improve the accuracy of the measurements, but also increase the efficiency of the verification — for the IAEA and also for the nuclear facility operator,” said Dimitri Finker, Technology Foresight Specialist at the IAEA.

## Artificial intelligence and machine learning

One of the latest examples of new technology utilized by the IAEA is learning-based algorithms, known as neural networks or more commonly referred to as artificial intelligence (AI) and machine learning (ML).

The use of AI and ML allows analysts and inspectors to focus on the highest value activities by automating routine processes, supporting human decision making and ensuring the quality and fidelity of data by identifying errors.

IAEA analysts review large quantities of data collected through multiple sources. One such source is video surveillance. In 2021, over 1300 surveillance cameras were maintained

by the IAEA at nuclear facilities around the world. These cameras operate around the clock to provide continuity of knowledge of nuclear material and installations and allow safeguards inspectors to verify that there is no undeclared access to the material and no misuse of the facility. In most cases, multiple surveillance camera systems are in operation, producing a large amount of data that require review by inspectors. AI provides the basis for the next generation of surveillance review software that allows for the efficient analysis of these data.

Beyond surveillance data review, AI and ML can strengthen the collection, integration and analysis of multiple information sources. State-declared information about facility design and nuclear material accountancy, information collected during inspections, as well as safeguards relevant open source information can all be more efficiently analysed with the help of AI. It can also detect and respond to information security events. The IAEA uses commercially available tools that have AI integrated in them to cope with cyberthreats, equipment tampering, and for authentication and encryption of sensitive information.

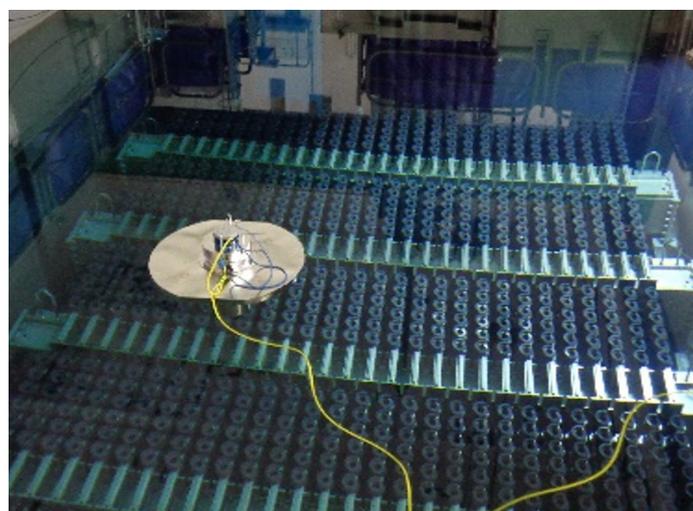
Along with advancements in nuclear technology, safeguards techniques are continuously evolving. New developments lie on the horizon, and the IAEA is proactively exploring how innovative technologies can help in its verification mission.

### Left: Satellite imagery analysis.

(Photo: D. Calma/IAEA)

### Right: The robotized Cherenkov viewing device in testing at a spent nuclear fuel pond.

(Photo: IAEA)





of Comprehensive  
Safeguards Agreements

**60 years**  
IAEA  
verification  
activities



of Additional Protocols

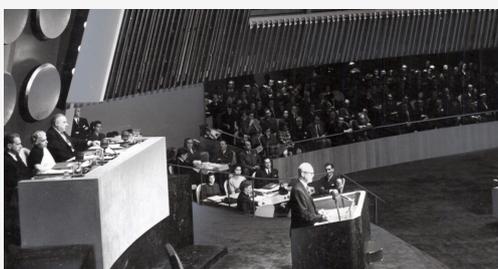


# Milestones in IAEA safeguards

## 1950s

1953

### Atoms for Peace



US President Dwight D. Eisenhower delivers the 'Atoms for Peace' speech, calling for the creation of an international atomic energy agency.

1957

### Establishment of the IAEA

The Statute of the IAEA enters into force, establishing the IAEA as an autonomous international organization, authorized "to establish and administer safeguards".

1959

### First application of safeguards



The IAEA Board of Governors approves the first application of safeguards to three tonnes of natural uranium supplied by Canada to Japan.

## 1960s

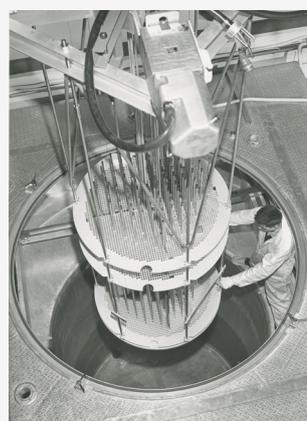
1961

### Safeguards for research reactors

The IAEA Board of Governors approves the first model agreement (INFCIRC/26) for applying safeguards to research reactors.

1962

### First IAEA verification



The IAEA conducts its first ever in-field verification activity, at a research reactor in Norway.

1968

### First safeguards agreement in an NWFZ

Mexico becomes the first country to accept IAEA safeguards on all of its nuclear material, in connection with the establishment of the first regional nuclear-weapon-free zone (NWFZ), in Latin America and the Caribbean.

## 1970s

### 1970

#### NPT verification mandate

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) enters into force, entrusting the IAEA with key verification responsibilities, under Article III, to verify the fulfilment of obligations assumed by non-nuclear-weapon States party to the Treaty.

### 1972

#### Entry into force of the first NPT safeguards agreement

The first comprehensive safeguards agreement (CSA), concluded between the IAEA and Finland in connection with the NPT, enters into force, paving the way for a significant expansion of the IAEA's safeguards activities in the following decades.



of Comprehensive Safeguards Agreements

### 1974

#### Safeguards Analytical Laboratory

The Safeguards Analytical Laboratory, dedicated to analysing nuclear material samples, is opened in Seibersdorf, Austria.

## 1990s

### 1991

#### Detection of undeclared nuclear material and activities

The discovery of a clandestine nuclear weapons programme in Iraq highlights the limitations of safeguards implementation that concentrates exclusively on a State's declared nuclear material and facilities.

### 1991

#### Confirming dismantlement

Following South Africa's accession to the NPT, the IAEA plays a key role in confirming the dismantlement of the country's former nuclear weapons programme; the experience demonstrates the benefits of a high level of cooperation between a State and the IAEA.

### 1993

#### Correctness and completeness of State declarations

After the IAEA's discovery of inconsistencies in the Democratic People's Republic of Korea's (DPRK's) nuclear material report, the Board of Governors confirms the importance of IAEA verification of not just the correctness but also the completeness of State declarations under CSAs.

### 1993

#### Strengthening of safeguards



Following the revelations about undeclared nuclear material and activities in Iraq in the early 1990s, the IAEA embarks on Programme 93+2 to further strengthen the effectiveness of safeguards.

### 1996

#### First environmental sampling

The IAEA introduces environmental sampling as a safeguards measure to detect indications of undeclared nuclear material or activities.

### 1997

#### Additional protocol

The Board of Governors approves the Model Additional Protocol, providing the IAEA with increased access to information and locations for verification; Australia becomes the first country to bring an additional protocol (AP) into force.



of Additional Protocols

## 2000s

### 2001

#### First State-level safeguards approach

The IAEA implements the first State-level safeguards approach (SLA) for Australia; the approach optimizes the implementation of safeguards by integrating safeguards measures available to the IAEA under the country's CSA and AP.

### 2002

#### Satellite imagery analysis



The IAEA establishes a unit for satellite imagery analysis to enhance its capabilities for detecting undeclared nuclear material and activities.

### 2003

#### Illicit nuclear supply networks

Libya's disclosure of undeclared nuclear weapons-related research heightens the IAEA's attention to the possible nuclear proliferation impacts of illicit supply networks and globalization.

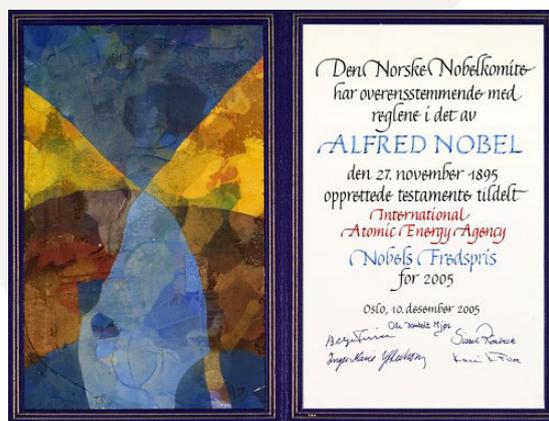
### 2005

#### Modified small quantities protocol

The Board of Governors addresses a weakness in the IAEA's safeguards system by approving a revised text and modified eligibility criteria for the small quantities protocol (SQP); the new SQP reinstates the State reporting requirement and the IAEA's right to perform inspections.

### 2005

#### Nobel Peace Prize



The IAEA and its Director General are awarded the Nobel Peace Prize "for their efforts to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way."

### 2006

#### The IAEA, Iran and the UN Security Council

Following the 2005 finding by the Board of Governors that the Islamic Republic of Iran was non-compliant with its safeguards obligations, the Director General transmits his report on the country's nuclear programme to the United Nations Security Council.

## 2010s

2016

### Expanded verification scope under the JCPOA

The IAEA begins to implement the monitoring and verification of Iran's nuclear-related commitments under the Joint Comprehensive Plan of Action (JCPOA), while continuing to verify the country's NPT-related obligations under its CSA.

## 2020s

2020

### Strengthening SSACs

The Director General launches a capacity building initiative – COMPASS – to help States strengthen the effectiveness of their national authorities and of their state systems of accounting for and control of nuclear material (SSACs).

2020

### The COVID-19 pandemic and safeguards

Despite unprecedented challenges posed by the COVID-19 pandemic, safeguards implementation continues; the IAEA carries out all necessary in-field activities and draws safeguards conclusions for all States with safeguards agreements in force.



# Supporting future nuclear safeguards professionals

By Teodor Nicula-Golovei and Farnaz Lyla Alimehri

To support the next generation of nuclear non-proliferation professionals, the IAEA engages students through youth competitions, provides fellowships and internships, and employs junior professionals as they start their careers in areas such as nuclear verification.

“The next generation must play an indispensable role in reinforcing non-proliferation and in promoting the peaceful uses of nuclear energy,” said Rafael Mariano Grossi, IAEA Director General, at the Advancing the ‘Youth, Non-Proliferation and Disarmament’ Agenda side event to the Tenth Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons in August 2022.

## Youth competitions

In 2022, the IAEA invited students to participate in a competition held in conjunction with the 14<sup>th</sup> Symposium on International Safeguards at the IAEA’s Headquarters from 31 October to 4 November. Students were given the task of producing papers on the subjects related to the evolution of safeguards to date. These included addressing contemporary challenges; anticipating and preparing for a changing landscape; leveraging innovations for safeguards applications; and identifying ways of engaging people and expanding partnerships. Around 40 submissions were received from around the world. After review by the IAEA selection committee, three winners were chosen from Australia, Romania and the United States of America. Authors of the winning papers were supported by the IAEA to attend the Symposium in person to present their papers and contribute to the dialogue on the past, present and future of international nuclear safeguards.

“With this year’s Symposium, we also wish to engage with new and previously unheard voices, in addition to seasoned safeguards practitioners,” said Jenni Rissanen, Team Lead of Safeguards Strategic Planning and Scientific Secretary of the Symposium.

## Fellowship programmes and internships

In 2020, the IAEA launched its Marie Skłodowska–Curie Fellowship Programme, which aims to help increase the number of women in the nuclear field and thereby support an inclusive workforce. Fellowships are awarded annually, with up to 150 female students selected per year, depending on the availability of funds.

The programme supports emerging professionals with scholarships and an internship opportunity, and provides young women with access, knowledge and insight into the IAEA and the broader nuclear field. The diversity of each cohort creates greater opportunities for learning, exchange and a community of support for continued engagement.

Inna Rodina, a current Marie Skłodowska–Curie Fellow, completed her master’s programme in non-proliferation and terrorism studies, and worked at the Rosatom Technical Academy, the Center for Energy and Security Studies in Moscow, and the Vienna Center for Disarmament and Non-Proliferation.

“My professional experience meant that I have keenly followed the work of the IAEA,” said Rodina who, as part of the Marie Skłodowska–Curie Fellowship, is undertaking an internship with the IAEA’s safeguards strategic planning team. “Being able to join the Agency, I’m now seeing first-hand how the IAEA uses technical measures to verify that nuclear material and technology remains in peaceful use, thus deterring the spread of nuclear weapons,” she added.

The IAEA offers internships to students and recent graduates to provide them with the opportunity to gain practical work experience in line with their studies or interests and learn about the work of the Agency. Furthermore, the Junior Professional Officer programme, based on an agreement between Member States and the IAEA, provides young professionals with an opportunity to acquire on-the-job professional experience.




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**“The next generation must play an indispensable role in reinforcing non-proliferation and in promoting the peaceful uses of nuclear energy.”**

– Rafael Mariano Grossi,  
IAEA Director General

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# Safeguards by design

## Designing nuclear facilities with safeguards in mind

By Jeremy Whitlock

As the latest innovations and technologies continue to present new possibilities, experience has shown that it is most effective to design nuclear facilities with safeguards in mind from the start. A concept known as safeguards by design (SBD) considers safeguards requirements during the planning phase — prior to embarking on the construction or modification of a nuclear facility.

“Acknowledging safeguards early in the design and construction process facilitates dialogue among stakeholders on how the facility will operate and the applicable safeguards measures,” said Traci Newton, Senior Safeguards Analyst at the IAEA. The aim of SBD is to facilitate the development of verification methods that will minimize the impact on the operator, without reducing the effectiveness of safeguards activities and IAEA access to the facilities for verification purposes. “SBD improves the efficiency of safeguards by helping the IAEA to optimize their application,” Newton said. By planning for expected verification activities, facilities can be designed to minimize

inspectors’ potential exposure to radiation, enhance access to safeguards equipment for maintenance, ensure capabilities for on-site remote data transmission and mitigate the impact of events that may disrupt the facility’s normal operation.

For example, when designing a spent nuclear fuel storage facility, it is important to consider the application of IAEA seals, so that safeguards activities can be carried out with minimal disruption to the operations of the inspected facility for years to come. Furthermore, early planning can incorporate flexibility into the facility’s infrastructure in order to support future technology innovations that may benefit both the operator and the IAEA in implementing safeguards.

SBD requires facility designers to have a detailed understanding of safeguards requirements. Therefore, one of the key goals of the IAEA in implementing SBD is to raise awareness about such requirements among nuclear regulators and the research and development community.



## SBD for future reactors

The IAEA has published a seven-part guidance series that reflects the application of SBD to all aspects of the nuclear fuel cycle, from initial planning and design through construction, operation, spent fuel management and decommissioning. The series provides advice for decision makers, designers, equipment providers and prospective purchasers, while also considering the economic, operational, safety and security factors related to designing a nuclear facility.

One emerging opportunity to apply SBD is in small modular reactors (SMRs), which present novel reactor designs, fuel processes and supply arrangements. SMRs offer significant potential for nuclear energy expansion thanks to their shorter construction timelines, greater adaptability and inherent safety features. Safeguards provisions are being considered throughout the development of these new reactors, thereby avoiding the need to make incremental changes once construction has already been completed.

“All nuclear reactors in a State under a comprehensive safeguards agreement with the IAEA need to be safeguarded — regardless of the size or technology — including SMRs,” Newton said. “By working with the IAEA at an early stage in reactor design, safeguards considerations can be embedded into the

design and planning of these reactors, so that nuclear verification can be performed in the most effective and efficient way with minimal burden to the operator.”

The IAEA is engaged in SBD discussions through its Member State Support Programme (MSSP). The MSSP allows for an open exchange of design information between interested countries, reactor designers and the IAEA. The IAEA also engages other stakeholders through the SMR Regulators’ Forum, which brings together nuclear safety and security experts to discuss challenges and share experiences related to the regulation of SMRs.

SMRs are under construction or planned in a number of countries, with many more expressing interest. In response to requests to address challenges and to facilitate the timely deployment of SMRs, the IAEA Platform on SMRs and their Applications was established in 2021. The Platform is a one-stop shop for the IAEA’s full array of support and expertise on SMRs, from technology development and deployment to nuclear safety, security and safeguards (see page 32).

“The IAEA’s SBD activities will ensure that the Agency is ready to implement effective and efficient safeguards in newly built or upgraded facilities, and in particular in SMRs,” Newton said.

**An IAEA nuclear safeguards inspector checks a surveillance camera, which is one type of measure considered during the design or modification of nuclear facilities.**

(Photo: IAEA)



# Safeguards during COVID-19

By Megan Porter

The COVID-19 pandemic affected every part of the world, with impacts reaching beyond the immediate concerns of public health and health care systems. During the time of the most heightened restrictions caused by COVID-19, the IAEA completed almost the same amount of verification activities as prior to the onset of the pandemic. To carry out its mission, IAEA inspectors and technicians had to adjust to, and overcome, the following measures around the world:

- **Travel restrictions:** Commercial flight restrictions and cancellations meant that many countries were hard to reach, and some not reachable at all, via commercial aviation. Immigration measures, such as allowing entry only to citizens and residents, also made access to some countries challenging.
- **In-country restrictions:** Restrictions on the movement of people and the availability of goods and services, such as hotel accommodation, posed logistical challenges.

- **Access restrictions to IAEA offices and laboratories:** In line with nationally imposed lockdowns, IAEA personnel in Vienna and Seibersdorf, Austria, worked from home for various periods throughout 2020 and 2021. Similar measures were imposed on the IAEA’s safeguards regional offices in Tokyo and Toronto. These restrictions caused delays and challenges, especially for performing work that needed to be done in a secure environment.
- **Access restrictions to facilities and sites:** Access restrictions at nuclear facilities and other locations meant that some in-field safeguards activities were difficult to complete.
- **Health and safety requirements:** Staff were subject to quarantine requirements, additional personal protective equipment (PPE) and compulsory polymerase chain reaction (PCR) tests.

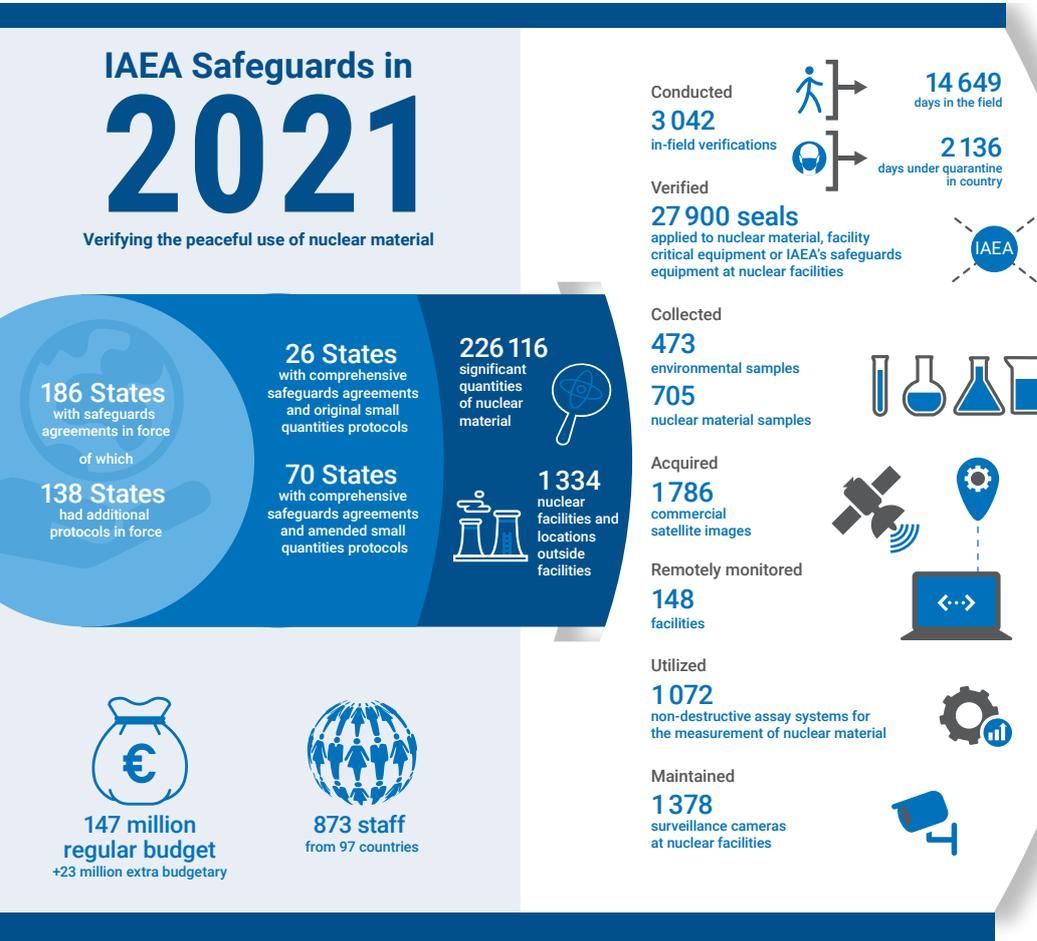
These measures had a significant impact on the Agency’s implementation of safeguards and on its ability to conduct in-field verification activities.

## Addressing the challenges

Close collaboration between States and the IAEA, and especially the IAEA’s host country, Austria, was essential to overcome evolving travel restrictions and operational obstacles.

“By adjusting to the circumstances and implementing specific solutions to address particular situations, the IAEA its ability to draw independent soundly based safeguards conclusions,” said John Coyne, Safeguards Business Continuity and Director of the Office of Information and Communication Systems at the IAEA.

Immediate actions taken by the Agency included prioritizing time-critical safeguards activities and verification efforts; storing equipment and PPE outside of the IAEA’s Headquarters to ensure access



for inspectors and technicians; establishing a temporary centralized office with a team to review and monitor in-field verification activities each day; and facilitating PCR testing with support from local medical services prior to and upon return from duty travel.

In the longer term, the IAEA implemented measures that included:

- **Charter flights:** For the first time in the Agency's history, aircraft services were chartered to transport inspectors and technical staff.
- **Re-focused planning:** Annual implementation plans (AIPs), which specify the in-field and Headquarters safeguards activities to be conducted for a State, were adapted to focus on the most time-critical and time-bound safeguards objectives.
- **Role of safeguards regional offices:** The availability of resident staff at the IAEA's regional offices in Tokyo and Toronto meant that there were fewer difficulties in safeguards implementation in Japan and Canada compared with other countries (approximately 24 per cent of all the IAEA's annual safeguards inspections are conducted in Canada and Japan).
- **Remote monitoring:** More than 1700 data streams continued to deliver images from facilities in 30 countries to the IAEA's Headquarters in Vienna.
- **Staff performance:** Agency inspectors and technical staff made extraordinary efforts to fulfil their duties. For example, staff isolated for up to 14 days prior to starting their work and embarked on their mission without knowing in advance how or when they would return to Vienna.
- **Support at Headquarters:** Staff at the IAEA's Headquarters also managed travel logistics and other challenges. Equipment engineers and technicians worked to source and supply PPE to ensure health and safety, while the Nuclear Material Laboratory (NML) produced hand sanitizer to overcome international shortages.

## Beyond COVID-19: Continuing verification activities

While the pandemic created unique challenges, the IAEA managed to carry out all of its critical on-site verification work. This was the result of a substantial adjustment of processes and workflows. Information analysis and associated interactive



teamwork by Agency staff have continued; the processing of country reports and declarations, and associated feedback, were performed; the evaluation of nuclear material balances and analysis of environmental samples were maintained at levels close to normal operations; and the IAEA continued to collect, process and evaluate other safeguards relevant information, such as open source information.

The IAEA conducted more than 3000 in-field verification activities and spent more than 14 600 days in the field in 2021. This represents a return to the pre-pandemic trend of increasing in-field nuclear verification.

“The IAEA successfully adjusted to the COVID-19 related restrictions and was also able to complete in-field verification activities carried over from 2020,” Coyne said. “While travel restrictions, including quarantine requirements, still applied in some countries, the Agency increased its verification effort to continue to deliver on its mandate.”

During 2021, the IAEA conducted verification activities at more than 1300 nuclear facilities and locations outside facilities around the world, while the amount of significant quantities of nuclear material under safeguards increased by 2.1 per cent to more than 226 000. A significant quantity is the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded.

The experience gained through the COVID-19 pandemic and the resulting changes in some of the IAEA's practices and procedures have allowed the Agency to continue delivering on its mandate during times of unprecedented challenges.

**During COVID-19, the IAEA chartered flights for inspectors and technical staff for the first time in its history.**

(Photo: IAEA)

# Fulfilling safeguards obligations with IAEA assistance

By Yoshiko Yamada

The IAEA provides assistance to support States in meeting their nuclear safeguards obligations. This assistance includes training, peer review missions, online learning and an encrypted portal to securely submit safeguards declarations and communicate with the IAEA.

Many of these activities support the effectiveness of State or regional authorities responsible for safeguards implementation (SRAs) and their respective State or regional systems of accounting for and control of nuclear material (SSAC or RSAC). The performance of national safeguards authorities and their SSACs has a significant impact on the effectiveness and efficiency of IAEA safeguards implementation. Under a comprehensive safeguards agreement (CSA), the State is required to establish an SSAC, which forms the basis of a State's reporting to the IAEA of its nuclear material.

“The existence of a strong partnership between the State and the IAEA is key to the successful implementation of safeguards,” said Rafael Mariano Grossi, IAEA Director General. “Under the assistance that the IAEA offers to States, it is inspiring to see the many and diverse activities successfully delivered to address States' SSAC-related needs.”

## COMPASS

In September 2020, the IAEA launched the IAEA Comprehensive Capacity-Building Initiative for SSACs and SRAs, known as COMPASS. The initiative further enhances the Agency's support to States in their effort to strengthen and sustain their SSACs and SRAs. COMPASS uses a tailored approach to provide multidisciplinary assistance designed to address a State's specific needs, whether in legal, administrative or technical areas. Building on the IAEA's existing safeguards support to States, COMPASS assistance is delivered in the forms of outreach among stakeholders; procurement of equipment; expertise sharing; IT support;

fellowships and scientific visits; training and coaching; and assistance in developing safeguards legal and regulatory frameworks. COMPASS brings these activities together into a single, streamlined and multifaceted mechanism for increased effectiveness and coordination.

During the two-year pilot period, seven recipient States have worked with the IAEA, with the support of 14 States and the European Commission, in COMPASS implementation: Guatemala, Jordan, Malaysia, Rwanda, Saudi Arabia, Türkiye and Uzbekistan.

In COMPASS's next phase, the Agency will conduct an IAEA Safeguards and SSAC Advisory Service (ISSAS) mission for each COMPASS-supported State.

## Advisory services and review missions

Upon request, the IAEA conducts an ISSAS mission to advise on establishing and strengthening SSACs or RSACs. ISSAS provides a peer review to understand needs and develops an agreed action plan to enhance the technical capabilities and effectiveness of SSACs and RSACs. ISSAS enables in-depth discussions between representatives of the State, a team of IAEA staff and external experts. From these discussions, recommendations and suggestions are compiled in a confidential report to the State and provide the basis for setting national goals to enhance the performance of the SSAC.

In 2021, the ISSAS guidelines — IAEA Service Series No. 13 (Rev.1) — were updated to include criteria for countries to conduct a self-assessment. This allows countries to be more proactive in assessing their SSAC in preparation for the advisory service mission. The first mission using this self-assessment approach was conducted in Bangladesh in 2022.

## Training

IAEA safeguards training courses are provided at the national, regional and interregional level. In 2021, the IAEA hosted 16 training courses (in person and virtual) for over 200 experts from 50 States. Training courses can range from targeted webinars to address a specific activity, to two-week international training courses hosted by a partner State. At these two-week courses, all aspects of safeguards implementation are covered. For example, States will learn about their legal obligations, the verification activities that the IAEA undertakes and the types of information that the State is required to provide to the IAEA. The training is specifically designed to ensure more effective implementation of safeguards by the SRA and SSAC.

The IAEA hosts an annual Safeguards Traineeship Programme for young graduates and junior professionals from developing countries. Nominated to participate by their government, participants expand technical skills and competences with hands-on training, mentoring, workshops and nuclear facility-based learning. For the first time, in 2022, the IAEA also offered an additional two-week course, ‘Introduction to the IAEA and Safeguards’, for young professionals from countries with limited or no nuclear fuel cycle. The course provided a broad understanding of IAEA safeguards, other areas of the Agency’s work and related initiatives that the IAEA offers to support States.

Integrated Nuclear Infrastructure Review (INIR) missions are designed to assist countries in evaluating the status of their national infrastructure for the introduction of a nuclear power programme. These missions cover 19 infrastructure topics, one of which is safeguards. Safeguards assistance to these and other embarking countries include strengthening the SSAC to accommodate the safeguards requirements associated with the operation of nuclear power plants.

## Web-based resources

Since the start of the COVID-19 pandemic, the IAEA has expanded its outreach and training through its dedicated online portal, the Cyber Learning Platform for Network



Education and Training (CLP4NET). The portal, which has over 1000 registered users, provides access to a variety of learning opportunities, including five recent webinar recordings, four self-study courses and 19 virtual classrooms on safeguards related topics, as well as downloadable instructional materials and guidance documents.

The IAEA also continues to expand and promote the State Declarations Portal (SDP), a web portal for the submission of safeguards declarations and reports. SDP provides efficient and modern information exchange that saves time and effort for both the States that use it and the IAEA. SDP uses multiple security layers to guarantee the confidentiality and security of data and offers a digital historical log of all communication exchanges.

“The IAEA offers many outreach and capacity building programmes to countries, and has a vision for expanding efforts,” said Rebecca Stevens, Team Leader for Member State Training at the IAEA. “We’re focused on the future for further cooperation with authorities and always welcome their input on how we can support them.”

**The ISSAS mission in Bangladesh was the first to use a new self-assessment component.**

(Photo: IAEA)

# Legally bound

## Safeguards agreements and protocols

By Joanne Liou

**N**on-proliferation treaties and agreements, as well as safeguards agreements concluded with the IAEA, provide the legal basis for IAEA safeguards and its verification activities. The IAEA serves as the international safeguards inspectorate under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The objective of the NPT, which came into force in 1970, is to prevent the spread of nuclear weapons, to promote cooperation in the peaceful uses of nuclear technology and to further the goal of achieving nuclear disarmament.

With 191 parties — 186 non-nuclear-weapon States (NNWSs) and 5 nuclear-weapon States (NWSs), namely China, France, the Russian Federation, the United Kingdom and the United States of America — the NPT is the most widely adhered to treaty in the field of nuclear non-proliferation.

The IAEA plays an indispensable role in the implementation of Article III of the NPT, which requires each NNWS to conclude a comprehensive safeguards agreement (CSA) with the IAEA to enable the IAEA to verify the fulfilment of the State's obligation under the Treaty.

### Comprehensive safeguards agreement

Safeguards agreements concluded before the NPT entered into force were known as item-specific safeguards agreements, under which the IAEA applied safeguards to specified nuclear material, facilities and equipment. Under a CSA, a country is required to

declare to the IAEA all nuclear material in all peaceful activities — not only specific items — and the IAEA is obligated to ensure that safeguards are applied to verify that such material is not diverted to nuclear weapons or other nuclear explosive devices.

In 1971, the IAEA Board of Governors approved document INFCIRC/153 and requested the Director General to use it as the basis for negotiating CSAs between the IAEA and NNWSs. The document — which outlines the structure and content of CSAs — specifies the rights and obligations of the parties; details the safeguards measures and procedures to be applied (e.g. the provision of information and inspections); and provides for the establishment of State systems of accounting for and control of nuclear material, the designation of IAEA inspectors, and the privileges and immunities for the IAEA and its inspectors. Finland became the first country to conclude and bring into force a CSA in 1972, and Guinea-Bissau is the most recent country to bring into force a CSA in 2022.

### Additional protocol

Among the 181 States with a CSA in force, 135 also have additional protocols (APs) in force. In May 1997, the IAEA Board of Governors approved the Model Additional Protocol to strengthen the effectiveness and improve the efficiency of the safeguards system as a contribution to global non-proliferation objectives. The AP expands the IAEA's access to information and locations in States with CSAs in force.

IAEA Director General Rafael Mariano Grossi delivers his remarks at the opening session of the Tenth Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), held at the United Nations Headquarters in New York in August 2022.

(Photo: C. de Francia/IAEA)



Under the AP, the IAEA has short notice access to any building on a nuclear site, as well as access to all parts of a State's nuclear fuel cycle and related research and development activities not involving nuclear material. The IAEA can also collect location specific environmental samples.

The Model Additional Protocol contained in INFCIRC/540 serves as standard text for the conclusion of APs to CSAs. This year, 2022, marks 50 years since the entry into force of the first CSA and 25 years since the approval of the Model AP and entry into force of the first AP.

### Small quantities protocol

The IAEA introduced the small quantities protocol (SQP) in the 1970s for States with minimal or no nuclear activities to minimize the burden of safeguards implementation in such States. The protocol was revised by the Board of Governors in 2005 in recognition of the fact that the original SQP constituted a weakness in the safeguards system, as the IAEA could not receive declarations on nuclear material and facilities or conduct in-field verification activities in such States.

The revised SQP reinstates the obligation of the State to provide the IAEA with an initial report on all nuclear material and the IAEA's right to conduct in-field inspections. In addition, a country with an existing or planned nuclear facility can no longer have an SQP to its CSA.

At the Tenth Review Conference of the Parties to the NPT in August 2022, IAEA Director General Rafael Mariano Grossi

urged all countries that had not yet done so to bring into force their CSA, amend their SQP and conclude an AP enabling the IAEA to carry out effectively its nuclear verification mission. "A safeguards regime, reinforced by the additional protocol and the amended small quantities protocol, can give us all the trust and confidence we need that States using nuclear energy for the wellbeing of their people are not hiding anything," Mr Grossi said.

### Voluntary offer agreement

The five NPT NWSs are not required to conclude safeguards agreements with the IAEA under the NPT; however, these five States have concluded voluntary offer agreements (VOAs). Under a VOA, the State voluntarily offers a list of eligible facilities, which may be selected by the IAEA for the application of safeguards. VOAs also contribute to nuclear non-proliferation objectives. In the United Kingdom, for example, the IAEA applies safeguards to large amounts of plutonium. For nuclear material shipments from an NWS to an NNWS, it is also more efficient to verify the material and apply seals at the point of origin in an NWS.

### Item-specific safeguards agreement

Item-specific safeguards agreements are in place today for three States that are not party to the NPT: India, Israel and Pakistan. Like the agreements that predated the NPT, these agreements cover only nuclear material, facilities and other items specified in the agreements.

## Key figures

(as of September 2022)

- **181 States** have comprehensive safeguards agreements in force
- **141 States** have additional protocols in force
- **5 States** have voluntary offer agreements in force
- **3 States** have item-specific safeguards agreements in force



# Industry engagement

## Safeguarding a changing nuclear landscape

By Wolfgang Picot

As global demand for nuclear power continues to increase, engagement between the nuclear industry and the IAEA is becoming more important. Facility designs are significantly changing, with the introduction of new reactor types such as liquid-fuelled advanced reactors or transportable microreactors. The emergence of these new reactor designs, along with the increased interest shown by more countries in nuclear power, requires changes in the industry's approach to safeguards, industry experts say.

“Industry supports safeguards; it knows safeguards are important. Companies take responsibility for nuclear material in their facilities,” said Sama Bilbao y León, Director General of World Nuclear Association. “However, beyond those who deal with them directly, safeguards are not very well known to the average nuclear industry employee. In contrast to safety, not everyone has safeguards on the top of their minds.”

While safeguards may not be at the forefront for some, international affairs are placing the role of the IAEA and safeguards into the spotlight. Staff across the nuclear industry are becoming more aware of international nuclear safeguards, said Jo Anna Bredenkamp, Director of Global Nuclear Safeguards and Strategic Export Programs at Westinghouse Electric Company. “News in the field of non-proliferation makes people more aware,” she added.

The growing interest in nuclear energy in many parts of the world is also contributing to the increased awareness of safeguards. “This is a very timely discussion,” Bredenkamp said. “More States have become interested in nuclear power. As we look at export opportunities to these countries, we see that we have to address potential

customers' concerns about safeguards from the start of the bidding process.”

Economics and the ‘bottom line’ are a primary concern for corporations when it comes to new reactor designs. Vendors are integrating safeguards early in the design process for novel reactor types in order to avoid costly adjustments later — something commonly referred to as ‘safeguards by design’ (see page 22).

“As a company, we have to look at the most economic view for designing a power plant based on a novel concept,” Bredenkamp explained. “If you build a demonstration plant and have not thought about safeguards from the start, retrofitting it gets costly. Microreactors, for example, are so small that there is not much space for additional wiring or sensors after a unit has been built. As a company, we need to have a role in safeguards because the new business models do not fit the previous regime of ‘retrofitting’ safeguards in existing facilities.”

Nuclear waste repositories are another area where industry should consider integrating safeguards by design, Bilbao y León said. “We are not only now starting to consider safeguarding nuclear waste in the implementation of deep geological repositories. Any such project has included safeguards from the start. We have thought about this for a long time.”

As the industry proactively considers safeguards, the IAEA plays an essential role in helping implement safeguards by design. The IAEA regularly hosts ‘safeguards by design’ workshops with representatives from regulatory entities, industry and IAEA staff, focusing on themes such as decommissioning, waste, spent fuel and small modular reactors.

**The emergence of new reactor designs requires changes in the nuclear industry's approach to safeguards, industry experts say.**

Photo: (D. Calma/IAEA)

# IAEA safeguards

## Reflecting on the past and anticipating the future

By Massimo Aparo, IAEA Deputy Director General and Head of the Department of Safeguards

For over half a century, IAEA safeguards have served to effectively verify the peaceful use of nuclear material and activities. This year marks two notable anniversaries for safeguards: the 50th anniversary of the entry into force of the first comprehensive safeguards agreement (CSA) in connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), and the 25th anniversary of the entry into force of the first additional protocol (AP). These important anniversaries provide an opportunity to reflect on the evolution of the safeguards system and to consider its future direction.

The earliest safeguards system was ‘item-specific’, meaning that safeguards were only applied to the nuclear material, equipment and facilities that a State chose to submit to safeguards. A shift towards a comprehensive safeguards system occurred in 1967, when countries in Latin America and the Caribbean reached agreement on the first treaty outlawing nuclear weapons in a populated region of the world. This treaty, the Treaty of Tlatelolco, opened a new chapter by requiring parties to accept IAEA safeguards on all nuclear material and activities. Mexico was the first State to conclude an agreement pursuant to the Treaty of Tlatelolco.

One year later, in 1968, the NPT opened for signature. Article III of the NPT requires each non-nuclear-weapon State to conclude a safeguards agreement with the IAEA covering “all source or special fissionable material in all peaceful nuclear activities”. To meet this requirement, CSAs were established. Finland was the first State to bring into force a CSA in connection with the NPT, in 1972.

During the early 1990s, the discovery of undeclared nuclear material and activities in

Iraq demonstrated that the IAEA safeguards system needed to be strengthened. The IAEA embarked in 1993 on Programme 93+2 to further strengthen safeguards implementation under CSAs and enhance the IAEA’s ability to verify not only the correctness but also the completeness of a State’s declaration of nuclear material subject to safeguards. This programme led to the adoption of the AP in 1997. An AP provides the IAEA with expanded rights of access to information and locations. Australia was the first State to bring into force an AP.

The IAEA started developing and implementing State-level safeguards approaches (SLAs) for individual States with a CSA in the early 2000s, gradually moving away from generic facility safeguards approaches. As part of efforts to allow the Agency to make full use of the flexibility provided by SLAs (within the scope of the relevant safeguards agreement), in 2011 the IAEA began to update and customize existing SLAs based on State-specific factors. In 2019, a project was launched to further improve SLAs through the definition of performance targets.

As we look to the future, the demand for IAEA safeguards is likely to continue to increase, and novel technologies will pose both opportunities and challenges. We must deploy modernized safeguards infrastructure and equipment, and further develop and align safeguards approaches, tools and methodologies. With the support of our Member States, I am confident that we will rise to meet the challenges we face and ensure that IAEA safeguards remain a key element in global non-proliferation efforts in the decades to come.




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**“As we look to the future, the demand for IAEA safeguards is likely to continue to increase, and novel technologies will pose both opportunities and challenges.”**

— Massimo Aparo, IAEA Deputy Director General and Head of the Department of Safeguards

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## SMR Platform: New web portal facilitates technical support



The SMR Platform provides support to countries working to introduce small modular reactors.

(Photo: A. Tarihi/IAEA)

Countries looking to accelerate small modular reactor (SMR) deployment with the help of the IAEA Platform on Small Modular Reactors and their Applications — launched in 2021 to provide support on all aspects of SMR development, deployment, licensing and oversight — can take their first step through a new online portal (<https://smr.iaea.org>) to access all IAEA services as well as the latest information related to this emerging nuclear power technology.

With more than 80 SMR designs under development in 19 countries and the first SMR units already in operation in China and Russia, SMRs, including microreactors (MRs), are expected to play an increasingly important role in helping to ensure the security of energy supply as well as the global energy transition to net zero. The technology, its safety and economic competitiveness must be fully demonstrated before SMRs can be more widely deployed — and the SMR Platform is already helping governments, prospective operators and regulators in countries such as Brazil and Jordan to address these and related challenges.

The portal covers technology development and deployment (including non-electric applications); nuclear safety, security and safeguards; and fuel, the fuel cycle and waste management. The portal's navigation bar features ten selectable topics that allow users to filter the news, events and publications per subject matter. The portal will be further expanded to incorporate additional features, such as areas for technical working groups, information on national and international SMR projects and programmes, and a version for mobile phones and tablets.

“The portal is designed to serve as a centralized source of information for both external and internal IAEA stakeholders, with different levels of information and data access,” said Stefano Monti, Chair of the SMR Platform Implementation Team and Head of the IAEA's Nuclear Power Technology Development Section.

SMRs will use prefabricated systems and components to shorten construction schedules, and offer greater flexibility and affordability than traditional nuclear power plants. They have the potential to meet the

needs of a wide range of users and to be low carbon replacements for ageing fossil fuel fired power plants. They potentially offer enhanced safety features and are suitable for non-electric applications, such as cooling, heating, hydrogen production and water desalination. SMRs also offer options for countries with smaller electricity grids as well as regions with less developed infrastructure and for energy systems that combine nuclear and alternative sources, including renewables.

The IAEA has in place several activities related to SMRs, which the platform helps to coordinate and on which it provides information. The platform also interfaces with other important IAEA initiatives. For example, the new Nuclear Harmonization and Standardization Initiative (NHSI), which held its kick-off meeting in June 2022, is helping to facilitate the deployment of safe and secure SMRs by harmonization and standardization of regulatory and industrial approaches.

“The IAEA is undertaking important activities on the safety and security of SMRs. For example, we have recently

completed the review of applicability of the safety standards to SMRs and other technologies,” said Paula Calle Vives, Senior Nuclear Safety Officer at the IAEA coordinating SMR safety activities. “We have also developed a programme of work to progressively adjust the safety standards so that they better capture the specificities of these new technologies. The platform will enable us to better disseminate this work to Member States.”

The SMR Platform includes information on activities on SMRs and their applications, with a focus on the technologies closest to near-term deployment, including supporting industrial preparedness for SMRs and their applications; promoting, supporting, and developing SMR research and innovation; supporting the establishment of institutional, legal, and regulatory frameworks for the deployment of safe and secure

SMR operation and decommissioning; and supporting international cooperation on SMRs. In September, the IAEA released a new booklet in connection with the platform, SMRs: A New Nuclear Energy Paradigm, which examines the factors to be considered when deciding whether to adopt SMRs and ways to enable their safe, secure, peaceful and sustainable deployment. The 2022 edition of the biennial booklet entitled Advances in Small Modular Reactor Technology Developments was also published in September.

Countries are already receiving assistance through the SMR Platform and several cross-cutting task forces have been established to address their needs. One of these task forces is helping to organize an expert mission to Jordan to analyse the economics of using SMRs for electricity generation and water desalination.

The IAEA is also supporting Brazil in analysing SMR technologies and market readiness, regulatory issues and requirements for SMR siting, and in April took part in a three-day course on SMRs and MRs organized by the Brazilian Association for the Development of Nuclear Activities (ABDAN).

“Amid the energy and climate crises, more and more countries are looking at SMRs as an option to improve energy security and reduce greenhouse gas emissions,” Monti said. “The IAEA can help them on this journey, which can begin with a visit to the new portal of the IAEA SMR Platform and then, if desired, by lodging a formal request for Agency assistance.”

– By Nicholas Watson and Jeffrey Donovan

## IAEA launches early warning notification system to protect nuclear installations from natural hazards

Natural hazards and disasters, such as earthquakes, floods or wildfires, may seriously challenge nuclear installation safety. Therefore, it is crucial not only to predict such events and calculate their magnitude, but also to effectively assess the potential impact on the safety of nuclear installations to utilize appropriate response mechanisms in time. To this end, the IAEA launched the External Events Notification System (EENS) during a side event at the 66th regular session of the IAEA General Conference in September 2022.

EENS is a web-based tool that provides real-time information on external events and hazards, such as earthquakes, tsunamis, volcano eruptions, river and coastal flooding, rotational winds and wildfires that have occurred or are expected to occur, including on their severity and location, as well as estimations of their potential effects on nuclear installations and major population centres. The system collects relevant data and sends it directly to the IAEA’s Incident and Emergency Centre (IEC)

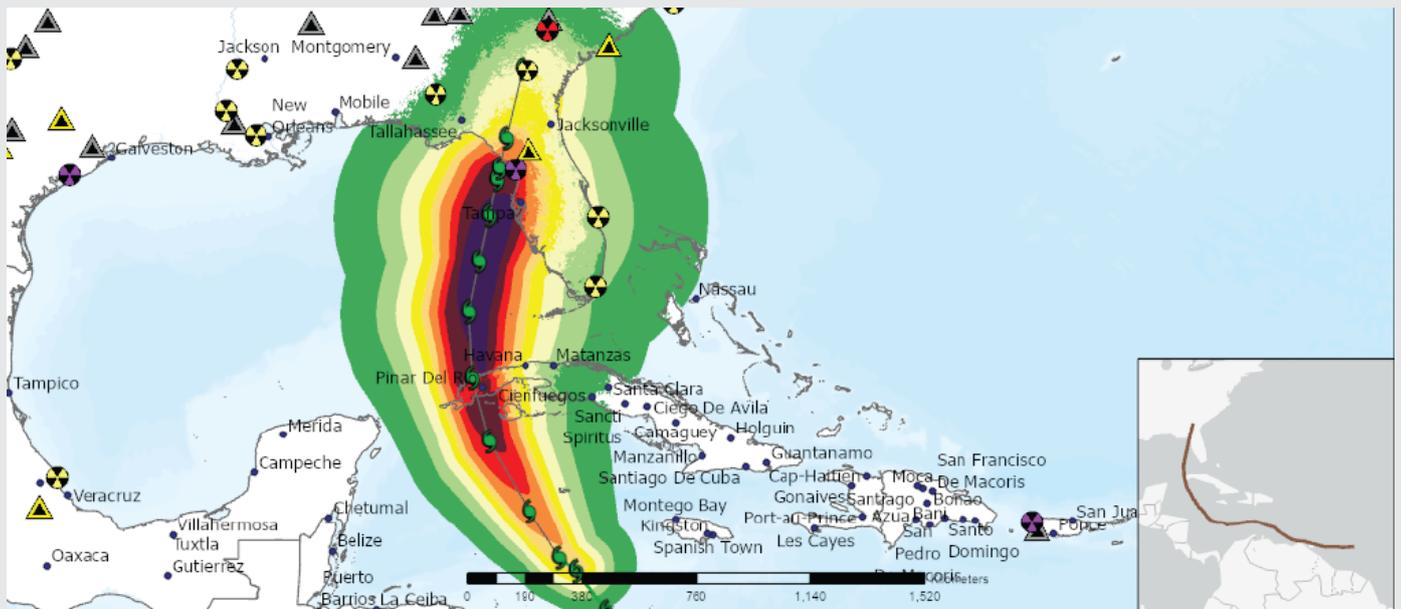
and External Event Safety Section (EESS) for assessment.

During the event, Head of the IAEA’s External Events Section Paolo Contri and Senior Safety Officer Ayhan Altinyollar showcased how the EENS works in practice, while IEC Response System Officer Günther Winkler explained the role it plays both within the IEC’s specific work and global nuclear safety and security more broadly. “The EENS is designed to provide initial assessments of the severity of external events on nuclear facilities, which can lead to activations of the IAEA’s Incident and Emergency Centre,” Winkler said. “This tool will help us to promptly identify natural hazards that can affect nuclear or radiation safety in order to exchange information or to coordinate international assistance between Member States.” The event was concluded with a round table, with the participants discussing the data sources for EENS, the on-call process of the IEC and issues of cybersecurity.

The EENS is based on a multi-hazard monitoring and early warning platform and has been developed in collaboration with the University of Hawaii’s Pacific Disaster Center (PDC) and Tenefit, a supplier of risk and impact intelligence to enterprises. “It is a system that will be permanently available to provide 24/7 support to the IAEA, forming a database which can be used for further assessments,” said Chris Chiesa, Deputy Executive Director at the PDC. The customized version, tailored to the needs of the IAEA, has been modified to focus specifically on the impact of hazards on nuclear installations. It consists of two components: the Alert System and the External Event Damage Forecast.

### Monitoring and analysing threats in real time

The Alert System monitors — in real time — situations in the vicinity of nuclear installations, and is based on carefully selected indicators, which determine the severity of the event. It



**EENS is a web-based tool that provides real-time information on external events and hazards that have occurred or are expected to occur, including on their severity, location and estimations of their potential effects on nuclear installations and major population centres.** (Image: PDC)

alerts the IAEA's IEC when hazards could potentially affect nuclear sites.

The External Event Damage Forecast receives information from the Alert System and produces a preliminary estimation of potential damage to nuclear installations and population centres. This estimation is called an Event Notification Report (ENR), which consists of the basic information about the event, such as magnitude, timing and location, as well as impact projections. This report is essential for evaluation of the lessons learned from recent external events and for assessment of the robustness of nuclear installations, for periodical dissemination to all Member States.

“In case of a cyclone, for example, the ENR would include the basic information on the cyclone, with maps, expected storm surge at coastal sites, the possible arrival time and the estimated wind speed at nuclear installation sites. This information is vital for the IEC to be able to swiftly offer its assistance to support an affected country,” Contri explained. “The EENS allows us to monitor the global natural hazard situation in the vicinity of all nuclear installations, not just nuclear power plants, including large cities where radioactive sources may be affected by the hazard. This system is an integral part of IAEA's work, allowing us to evaluate the situation and help countries mitigate

the associated risks. In the years to come, the severity of natural hazards is expected to increase because of climate change. We must be prepared for this.”

The EENS launch includes its first two modules — focusing on earthquake and cyclone prognosis. An additional four modules, on river floods, tsunamis, volcano eruptions and wildfires, are under development and are expected to be operational by mid-2023.

The development of the system has been financially supported by France, Japan and the United States of America.

— *By Vladimir Tarakanov*

## After a 34-year gap, the Philippines has a nuclear facility again

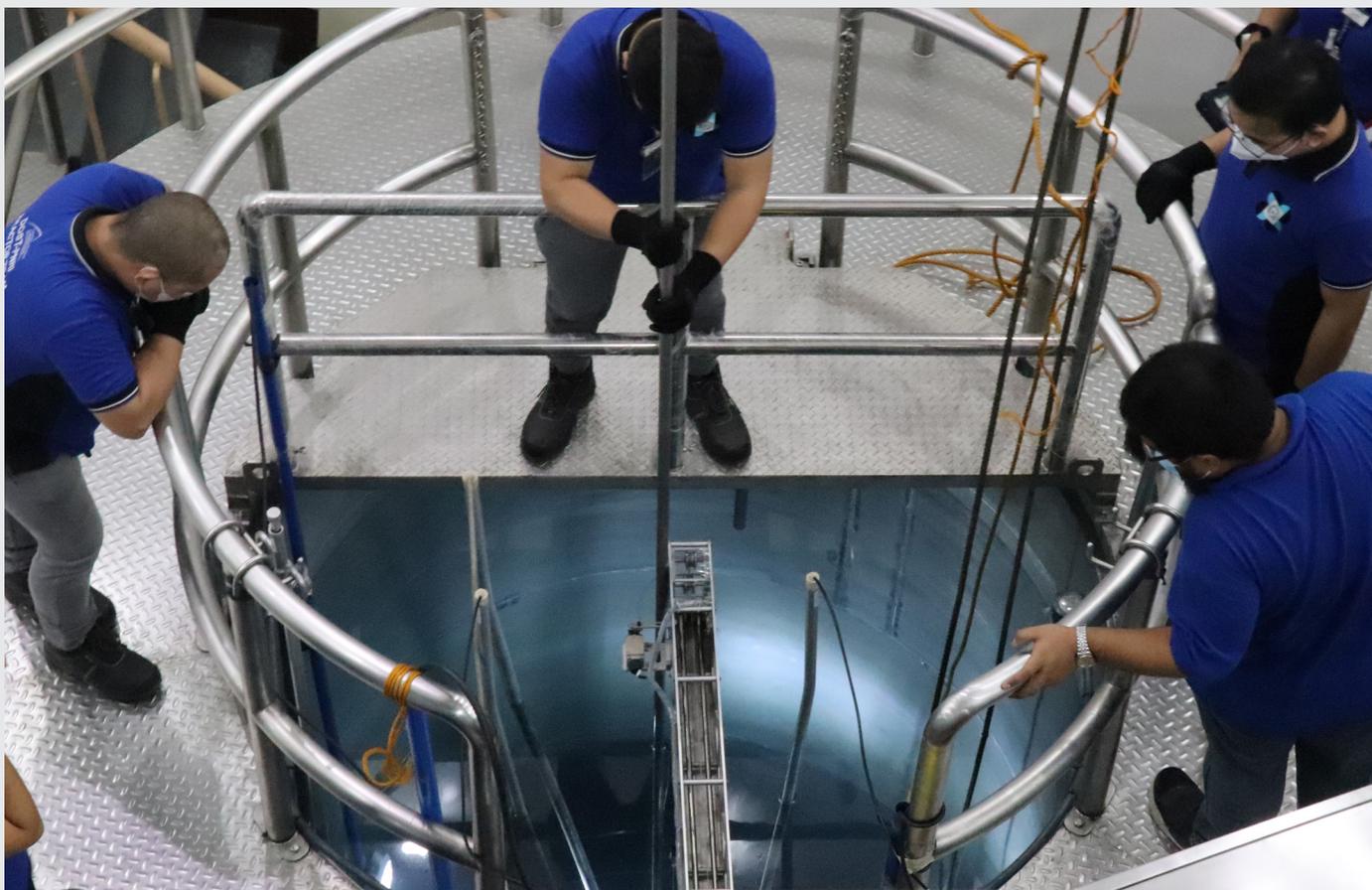
After more than three decades, the Philippines is again operating a nuclear facility. In 2014, a proposal was accepted to utilize fuel elements of a shutdown research reactor for training and education, which the IAEA has been supporting through a series of technical cooperation projects. In the first project, launched in 2016, the IAEA assisted the Philippine Nuclear Research Institute (PNRI) in building

capacity in reactor design, neutron dosimetry and regulatory matters related to research reactors.

A second cooperation project followed in 2020 and is ongoing to further build capacity, particularly in reactor engineering and operation, reactor utilization and development of a reactor training programme to sustain local capacity-building activities. “With

nuclear power in consideration for the country's future energy mix and a demand for nuclear technology in different sectors, it is essential to build capacity and develop a new generation of scientists and workforce in this field,” said Syahril Syahril, IAEA Programme Management Officer for the Philippines.

A presidential executive order from earlier this year outlines the



**A fuel rod is loaded into the core of a subcritical assembly.**

(Photo: PNRI)

Government's position on the inclusion of nuclear energy in the Philippines' energy mix. The Philippines built a nuclear power plant in the late 1970s, but the project was stopped in 1986, and fuel was not loaded into it.

### Revitalizing nuclear capacity

In June 2022, the PNRI loaded 44 nuclear fuel rods into the core of the newly constructed tank of the Subcritical Assembly for Training, Education and Research (SATER). The fuel rods had been previously stored unused for more than 30 years. The new SATER facility is housed at the Philippine Research Reactor 1 (PRR-1) building and will remain in a subcritical state, which means the nuclear fission chain reaction is dependent on neutrons from an external source. PRR-1 SATER is designed not to reach a critical state, which is when the chain reaction is self-sustaining, under any operational or incidental condition, providing a

safe and versatile tool for researchers and students.

The 1-megawatt PRR-1 research reactor had reached criticality in 1963, but it was in extended shut down since 1988. "The activation of PRR-1 SATER is a milestone for the Philippines, as the facility will provide significant support in re-establishing nuclear capabilities in the country," said Alvie Asuncion-Astronomo, Associate Scientist and former Head of PNRI's Nuclear Reactor Operations Section. In the past two years, the IAEA assisted the local regulatory and operating staff by providing recommendations on licensing and commissioning PRR-1 SATER. IAEA and international experts participated in various on-site missions.

Subcritical assemblies, such as PRR-1 SATER, are valuable educational and research tools. It will support recently launched nuclear education programmes at the University of

the Philippines Diliman and Mapua University. In the field of research, PRR-1 SATER will be used for reactor physics experiments, as well as a demonstration facility for neutron irradiation and neutron activation analysis.

"PRR-1 SATER is expected to be a training reactor for research reactor operators, regulators and users. It also aims to increase the research reactor stakeholder base in the country," Asuncion-Astronomo said. "The facility is projected to open the whole scientific field of reactor physics and engineering for Filipinos and to pave the way for the Philippines to strengthen its niche in the nuclear field."

PRR-1 SATER is expected to conclude commissioning tests and become fully operational by 2023.

— *By Joanne Liou*

**New Edition**

# IAEA SAFEGUARDS GLOSSARY

2022 Edition



## IAEA Safeguards Glossary: 2022 Edition

Since the last edition of the IAEA safeguards glossary in 2001, IAEA safeguards implementation has continued to evolve, including greater emphasis on ‘State as a whole’ considerations in the development of State-level safeguards approaches and reflecting a myriad of technological advancements.

This new edition reflects these developments and contains terms that are either specific and unique to IAEA safeguards or those that may be used in other domains, but which have a specific meaning or application relevant to IAEA safeguards.

New terms that have come into common use over the past two decades have also been introduced. Each term includes a definition and, where applicable, further explanation or examples. Each section addresses a specific subject area relevant to IAEA safeguards, and the terms are arranged in relation to the subject area.

Within each definition, terms that are defined elsewhere in the glossary are italicized, and an index referring to the term numbers has been provided for ease of reference. The terms have been translated into Arabic, Chinese, French, Russian and Spanish, as well as into German and Japanese.

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