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IAEA SAFEGUARDS

Preventing the spread of nuclear weapons

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IAEA

The International Atomic Energy Agency's mission is to 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: a vital contribution to international peace and security

By Yukiya Amano

Preventing the spread of nuclear weapons is a complex task. Seventy years after the destructive power of nuclear weapons was demonstrated in Hiroshima and Nagasaki, several international political and legal mechanisms are now in place to deter the spread of nuclear weapons. Key among these mechanisms are IAEA safeguards.

The IAEA is often referred to as the world's 'nuclear watchdog'. We have the technical competence, independence and objectivity to provide credible assurances that States are honouring their international obligations to use nuclear material only for peaceful purposes. Through the early detection of any diversion of nuclear material or misuse of nuclear technology, the IAEA can alert the world to potential proliferation. This makes a vital contribution to international peace and security.

IAEA safeguards are technical, scientifically based and make use of modern technologies — as our articles on pages 18 and 22 illustrate. The implementation of safeguards is based on legal agreements, both international treaties and bilateral agreements between the IAEA and States (see article page 4). Applying IAEA safeguards is therefore a legal obligation for the IAEA. We draw our safeguards conclusions independently.

Keeping pace with change

The world in which we implement safeguards today is very different from that in 1957, when the IAEA was founded. To meet evolving challenges, we need to remain agile and be able to adapt. We also need to take advantage of modern technology, for example, through the use of remote monitoring and satellite imagery. We have significantly improved our analytical capabilities by completely modernising our safeguards laboratories. Our safeguards inspectors travel the world seven days a week to conduct in-field verification activities.

This issue of the *IAEA Bulletin* provides a look behind the scenes. You can follow a safeguards inspector for a day in a nuclear power plant, and see how environmental sampling works. We also show you examples of our many types of safeguards equipment and explain how taking small samples of nuclear materials regularly helps us to check that nothing has gone missing.

It is my hope that this publication will contribute to an improved understanding of the IAEA's safeguards activities, both among our stakeholders and the wider public.

> "Through the early detection of any diversion of nuclear material or misuse of nuclear technology, the IAEA can alert the world to potential proliferation."
>
> — *Yukiya Amano, Director General, IAEA*

(Photos: D. Calma/IAEA)

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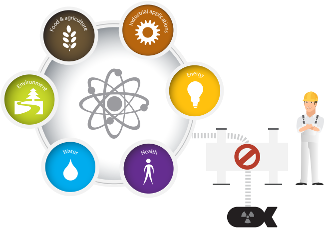

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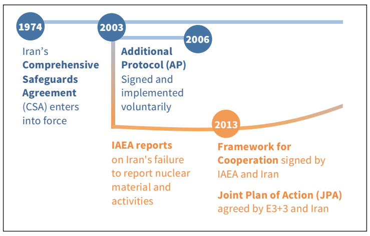

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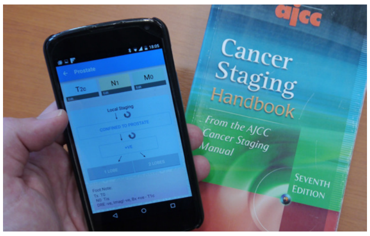

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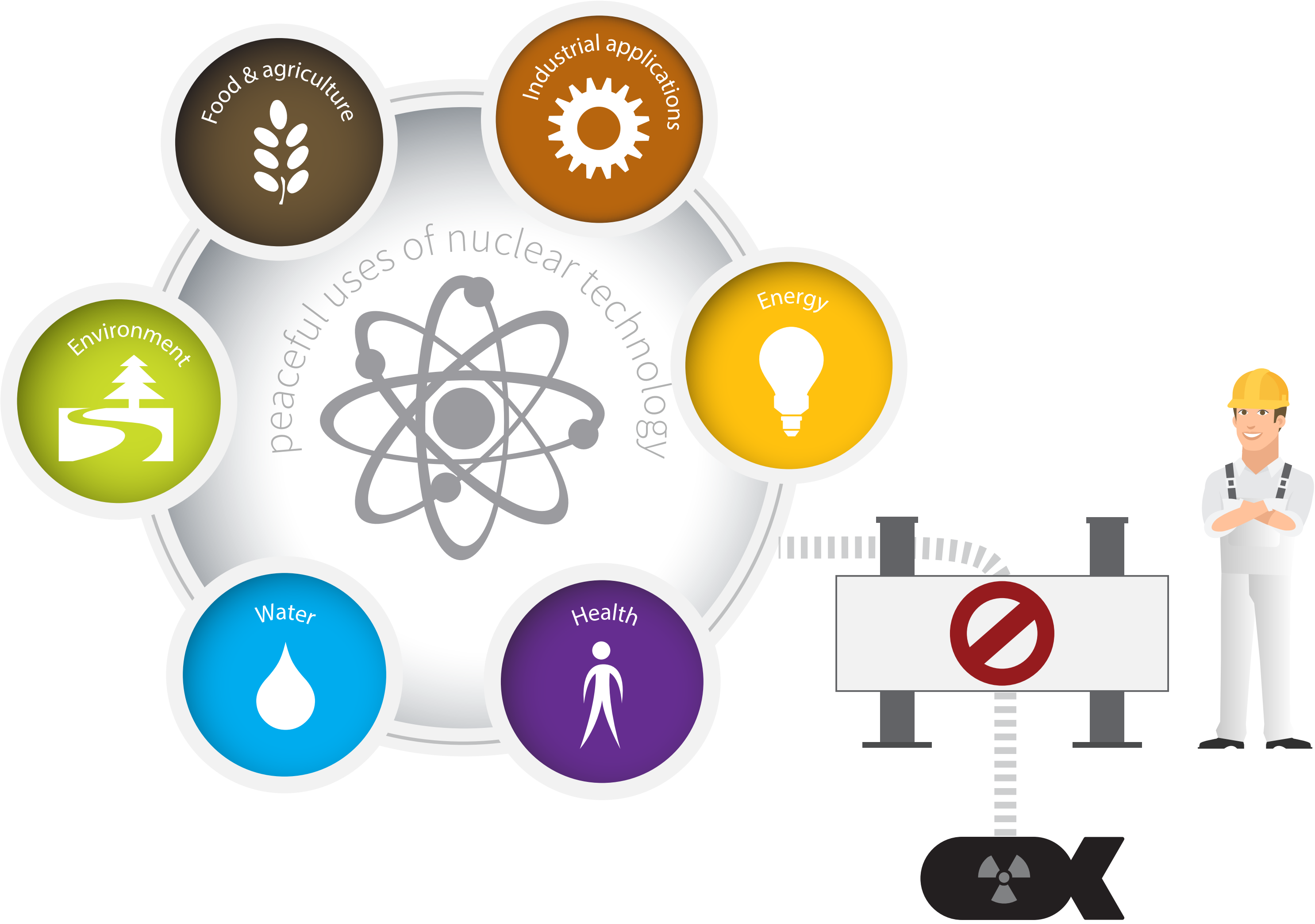
IAEA safeguards: serving



Through safeguards, the IAEA provides credible assurances that States are honouring their international obligations to use nuclear material and technology only for peaceful purposes.

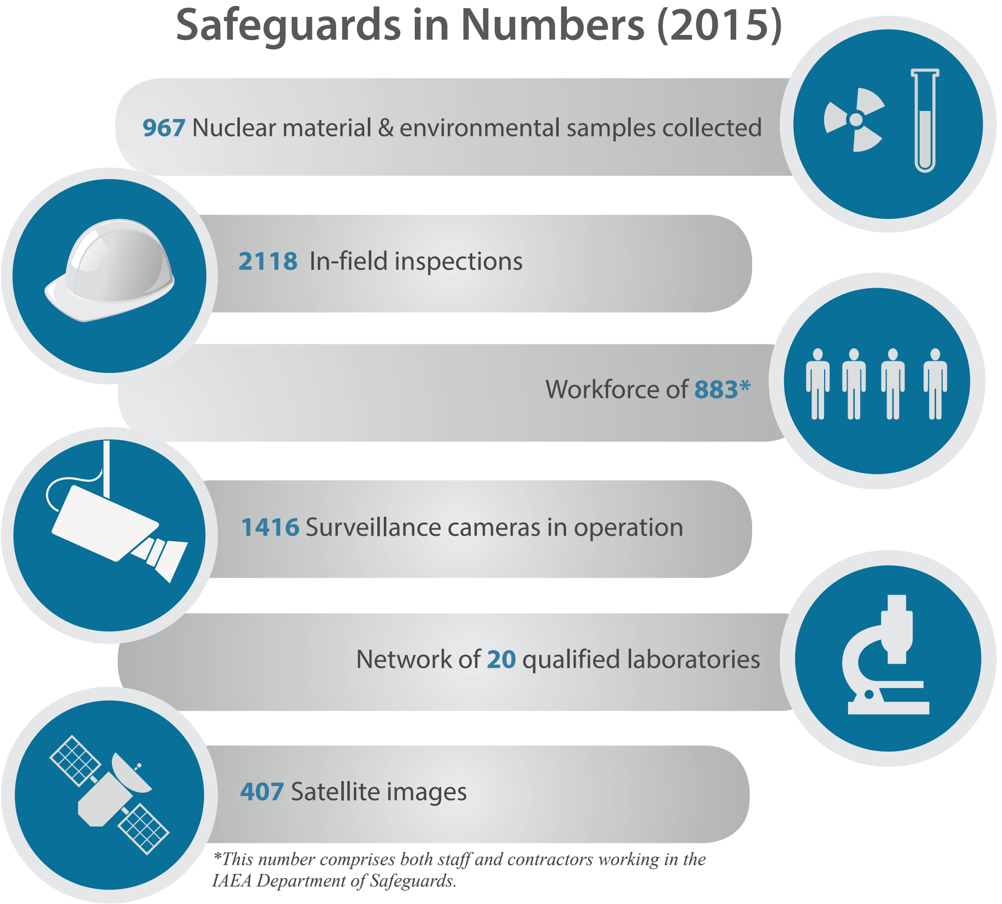
(Infographic: R.Kenn/IAEA)

nuclear non-proliferation

The objective of IAEA safeguards is to deter the proliferation of nuclear weapons through the early detection of the diversion of nuclear material or the misuse of nuclear technology and by providing credible assurance to the international community that States are honouring their safeguards obligations to use nuclear material and other nuclear-related items subject to safeguards only for peaceful purposes.

The number of nuclear facilities and the use of nuclear material continue to grow. With new nuclear power reactors under construction and a steady growth in the use of nuclear science and technology, the amount of material and number of facilities under IAEA safeguards is steadily increasing. In 2015, the IAEA safeguarded 1286 nuclear facilities and locations outside facilities, such as universities and industrial sites. IAEA inspectors carried out 2118 inspections in the field.

This article provides an overview of the legal framework for IAEA safeguards, their implementation and the safeguards conclusions the IAEA draws.



Safeguards in Numbers (2015)

967 Nuclear material & environmental samples collected

2118 In-field inspections

Workforce of **883***

1416 Surveillance cameras in operation

Network of **20** qualified laboratories

407 Satellite images

**This number comprises both staff and contractors working in the IAEA Department of Safeguards.*

The web of safeguards agreements

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) requires non-nuclear-weapon States (NNWSs) party to the Treaty to enter into legally binding agreements with the IAEA, known as comprehensive safeguards agreements (CSAs). Like the NPT, regional nuclear-weapon-free zone treaties also require their States Parties to conclude CSAs with the IAEA. Under a CSA, the State undertakes to accept IAEA safeguards on all nuclear material in all peaceful activities in the State, and the IAEA applies safeguards to verify that the nuclear material is not diverted to nuclear weapons or other nuclear explosive devices.

Under the NPT, there are also five nuclear-weapon States (NWSs) — China, France, Russia, the United Kingdom and the United States of America — each of which has entered into 'voluntary offer agreements' (VOAs) with the IAEA. Under a VOA, the IAEA applies safeguards to nuclear material in facilities that the NWS has 'offered' for safeguards and that have been selected by the IAEA for this purpose.

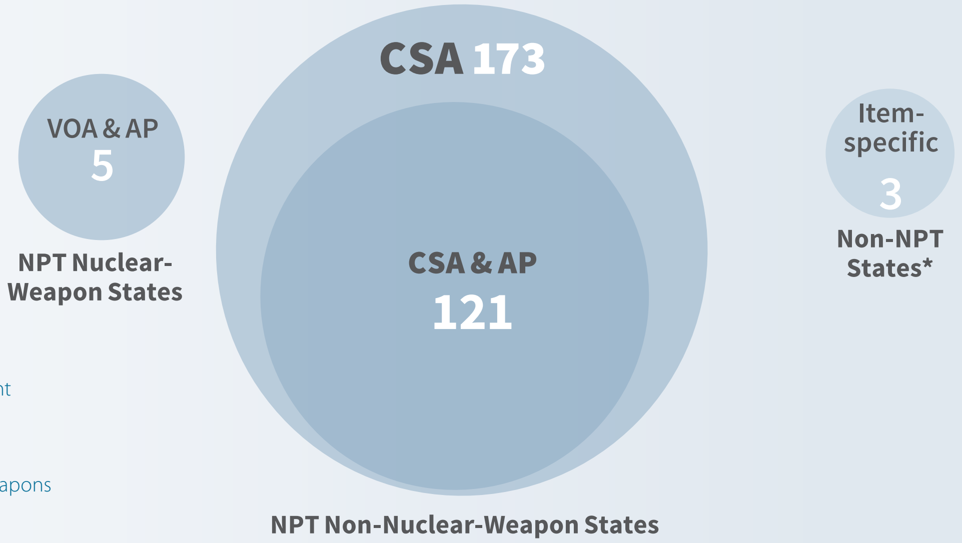
A third type of safeguards agreement is known as an 'item-specific safeguards agreement', under which the IAEA applies safeguards to nuclear material, facilities and other items specified in the agreement. Item-specific safeguards agreements are currently implemented by the IAEA in three States, which are not party to the NPT — India, Israel and Pakistan.

The vast majority of States in which IAEA safeguards are applied are NNWSs party to the NPT. For these States, safeguards are applied under their CSAs. In 2015, 174 NNWSs had a CSA in force with the IAEA. In 2015, 12 States Parties to the NPT had yet to bring into force CSAs with the IAEA as required under the Treaty (see illustration on page 6).

Among States with a CSA in force, 121 also have in force additional protocols to their CSAs. An additional protocol grants

Safeguards Agreements Implemented

(per State, as of December 2015)



CSA: Comprehensive Safeguards Agreement
AP: Additional Protocol
VOA: Voluntary Offer Agreement
NPT: Treaty on the Non-Proliferation of Nuclear Weapons
*India has an AP in force

the IAEA broader access to information and locations in a State, increasing the IAEA's ability to verify the peaceful use of all nuclear material in that State. An additional protocol may be concluded for all types of safeguards agreements.

Implementing safeguards

Safeguards implementation, based on safeguards agreements, is a continuing process involving four steps:

1. Collection and evaluation of safeguards relevant information about a State to verify its consistency with the State's declarations about its nuclear programme.
2. Development of a State-level safeguards approach consisting of establishing key objectives for identifying plausible paths through which nuclear material suitable for use in a nuclear weapon or a nuclear explosive device could be acquired and selecting applicable safeguards measures for attaining such objectives.
3. Planning, conducting and evaluating safeguards activities both in the field and at IAEA Headquarters through an annual implementation plan.
4. Drawing a safeguards conclusion for each State in which the IAEA has implemented safeguards.

While demands on IAEA safeguards are growing and becoming more complex, the Agency's budget for safeguards implementation remains largely static. Against this background, it is essential that safeguards implementation be cost-effective, productive and efficient, without compromising the credibility and quality of safeguards conclusions. Use of modern technology, smart and efficient work at headquarters and in the field, and increasing support and cooperation from States in safeguards implementation are three avenues through which the IAEA aims to maintain and strengthen the effectiveness of safeguards.

Safeguards conclusions

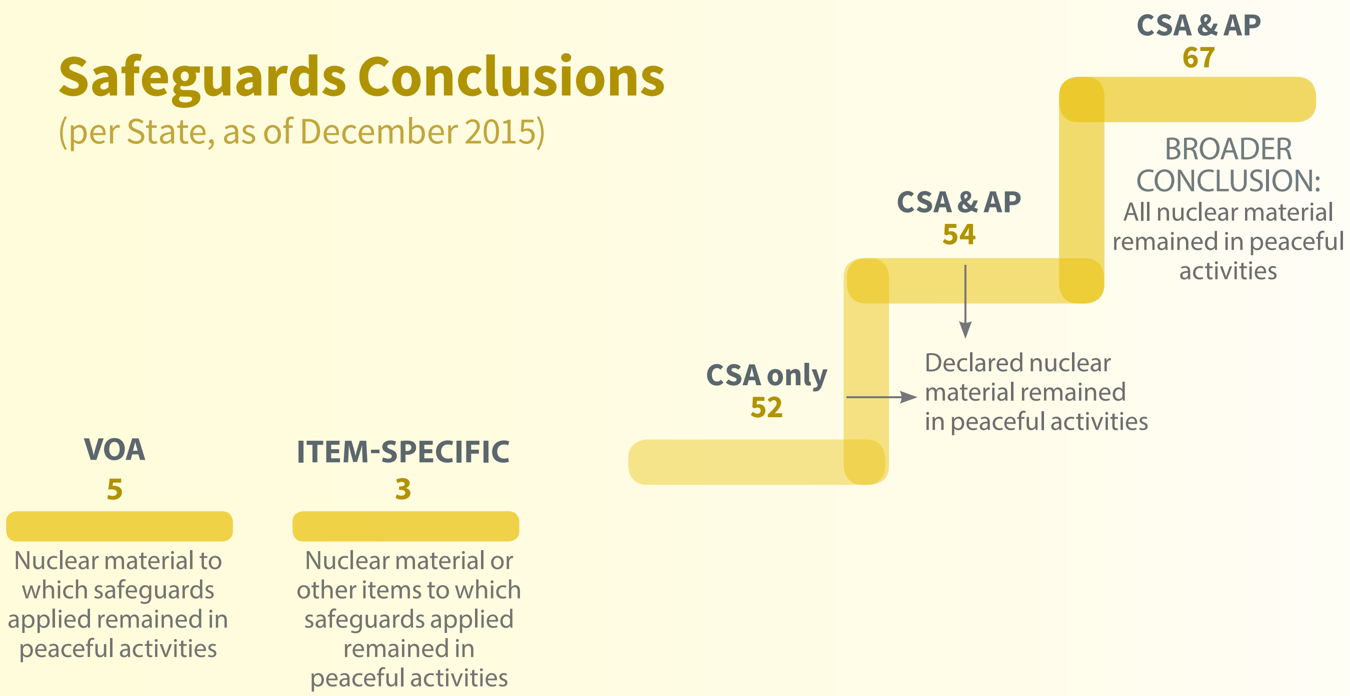
The IAEA draws safeguards conclusions annually for each State for which safeguards are applied. The conclusions are based on the IAEA's independent verification and findings, and are presented every year to the IAEA's Board of Governors in the Safeguards Implementation Report.

The type of conclusion that the IAEA is able to reach with respect to a State varies according to the type of safeguards agreement the State has in place with the IAEA, which specifies the State's undertaking and the IAEA's rights and obligations, including the level of access to nuclear material and information (see illustration on page 7).

States with both CSA and AP in force
In 2015, for 67 of the 121 States with both a CSA and an AP in force, and for Taiwan, China, the IAEA found no indication of the diversion of declared nuclear material from peaceful nuclear activities and no indication of undeclared nuclear material or activities in the State as a whole and concluded that all nuclear material in those States remained

Safeguards Conclusions

(per State, as of December 2015)



in peaceful activities. This is referred to as the ‘broader conclusion’. It is typically after a number of years of verification activities under the CSA and the AP that the IAEA is able to reach such a broader conclusion with respect to a State.

In States for which the IAEA has drawn a broader conclusion, the IAEA implements ‘integrated safeguards’ which leads to an optimization of verification efforts and, where possible, a reduction of in-field inspection efforts. Such cooperative and mutually trusting relationships can help to lower inspection costs, while also resulting in less interference with the operation of nuclear facilities. Of the 67 States for which a broader conclusion had been reached in 2015, 54 and Taiwan, China were already under integrated safeguards.

For the 54 CSA States that have an AP in force but for which no broader conclusion has yet been reached, the IAEA found no indication of the diversion of declared nuclear material from peaceful nuclear activities, while evaluations regarding the absence of undeclared nuclear material and activities remained ongoing. For these States, the IAEA drew the conclusion that declared nuclear material remained in peaceful activities.

States with CSA but no AP

As of the end of 2015 there were 52 States with a CSA, but no AP in force. For these States, the IAEA found no indication of the diversion of declared nuclear material from peaceful nuclear activities. This is because it is only for States with both a CSA and an AP in force that the IAEA has sufficient tools for broader access to information and locations to provide credible assurances that all nuclear material remained in peaceful activities.

States Parties to the NPT with no CSA

In 2015, for the 12 States Parties to the NPT that had yet to bring into force CSAs the IAEA did not apply safeguards and could not draw any safeguards conclusions.

NWSs and States with item-specific safeguards agreement

For the five NWSs, in 2015, the IAEA concluded that nuclear material to which safeguards were applied in selected facilities remained in peaceful use or had been withdrawn from safeguards as provided for in the agreements.

For the three States with item-specific safeguards agreement, the IAEA found no indication of the diversion of nuclear material or of the misuse of the facilities or other items to which safeguards had been applied and, on this basis, concluded that such items remained in peaceful activities.

Note: The designations employed and the presentation of material in this document, including the numbers cited, do not imply the expression of any opinion whatsoever on the part of the Agency or its Member States concerning the legal status of any country or territory or of its authorities, or concerning the delimitation of its frontiers. The referenced number of States Parties to the NPT is based on the number of instruments of ratification, accession or succession that have been deposited.

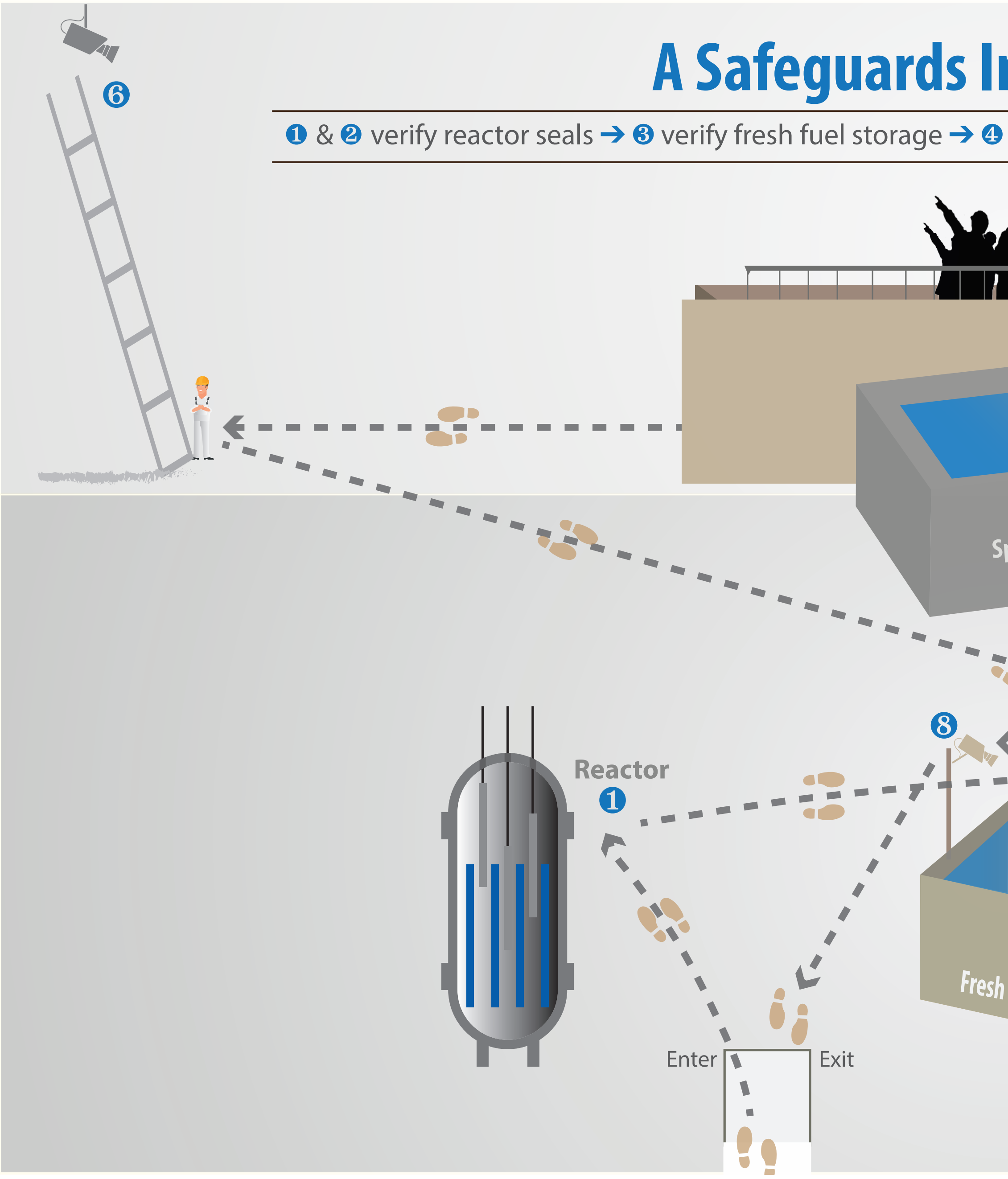
A day in the life of a safeguards inspector

By Sasha Henriques

Walking several miles through the winding, narrow corridors of a nuclear facility in protective gear while carrying heavy equipment, often escorted by facility operator personnel: welcome to the life of an IAEA safeguards inspector.

Safeguards inspectors are an essential part of the global non-proliferation regime, carrying out verification activities, so the IAEA can provide assurances to States worldwide that other countries are not diverting nuclear material from peaceful to military purposes or misusing nuclear technology. One important activity is the inspection of declared stocks of nuclear material: the IAEA is the only organization in the world with the mandate to verify the use of nuclear material and technology globally.

In 2015, 709 facilities and 577 locations outside facilities in 181 States were under IAEA safeguards, making them subject to verification by IAEA inspectors. IAEA inspectors performed 2118 inspections,



spending a total of 13 248 calendar days in the field.

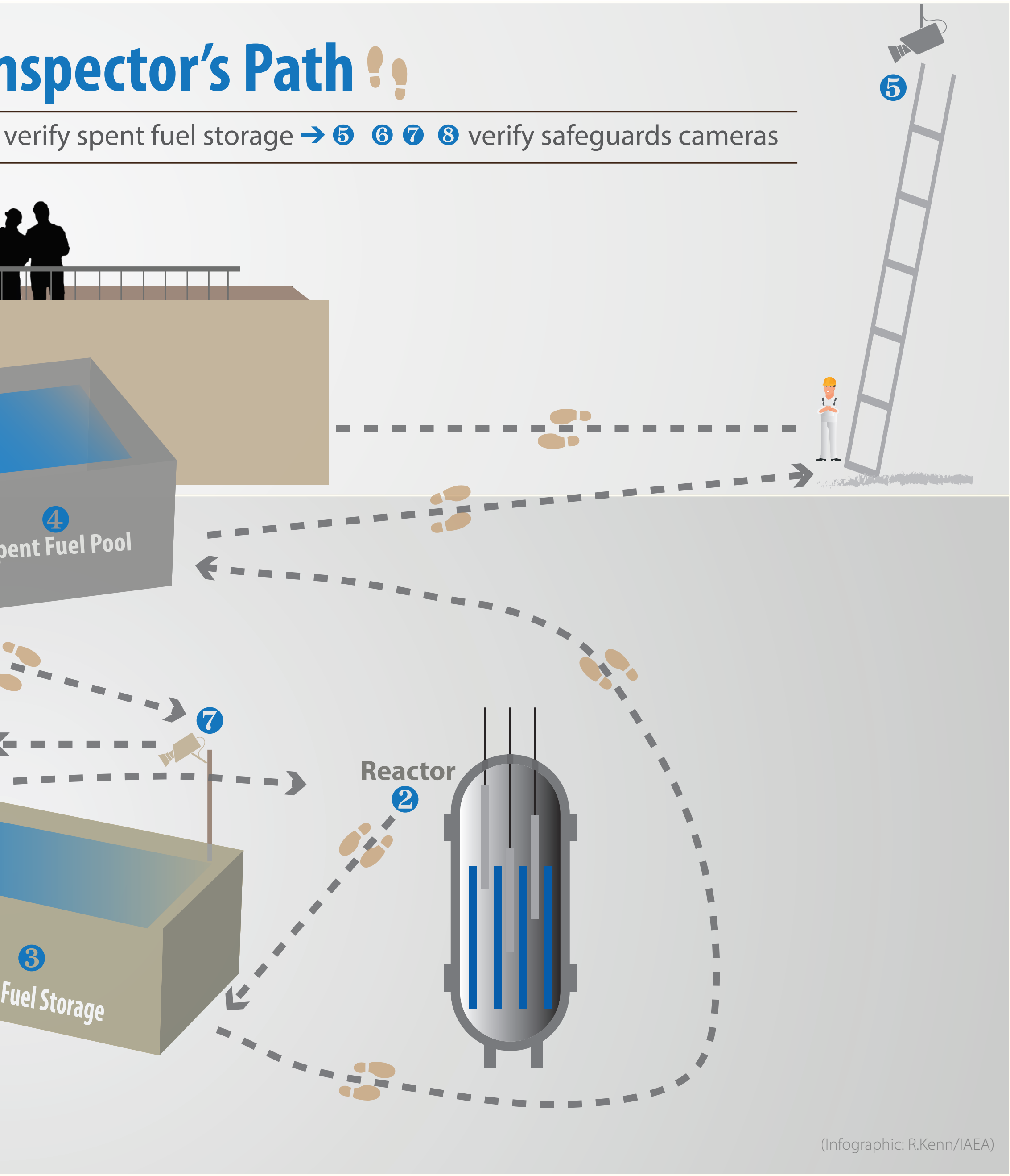
On average, safeguards inspectors are on the road around 100 days a year, but where they are going are not exactly coveted tourist locations. Power plants, uranium mines, nuclear fuel fabrication plants, enrichment facilities, research reactors and waste facilities are typically located in remote areas that are sometimes hard to access. Inspectors need to be mindful of security considerations in some locations.

Up and down

An inspector does about 5 kilometres of continuous walking and climbing during an inspection of the average nuclear power plant, dressed in steel-capped safety boots, safety helmets and coveralls. “It’s a very physical job,” said Abdellah Chahid, who has been an inspector for 16 years. “You really need to be fit and you need to have stamina.”

To add to the physical demands of the job, there are times when the weather refuses to cooperate. Chahid recalls protecting a gamma measurement device inside his jacket during a particularly brutal winter inspection in Kazakhstan where the temperature was -30 degrees Celsius. If the device had been out in the open, the liquid crystal display would have cracked and the entire instrument would have become useless.

An inspection of a nuclear power plant can last anywhere from four hours (if things



(Infographic: R.Kenn/IAEA)

Safeguards inspectors at work.
(Photo: D. Calma/IAEA)

go smoothly) to ten hours (if there are problems). The inspection of other types of facilities, such as those dealing with fuel fabrication, may require about a week to complete.

Precarious perch

Inside the reactor hall of a power plant, one of the key activities safeguards inspectors need to undertake is the verification of the spent fuel pond's contents. Inspectors use improved Cerenkov viewing devices (ICVDs) to determine the presence of the spent nuclear fuel assemblies stored inside the pool and to make sure that the plant operator has as much fuel as was reported. Depending on the size and age of the reactor, the total number of spent fuel assemblies can number in the thousands. Inspectors verify these by looking for the collimated Cerenkov radiation, the telltale blue glow, which emanates from a spent fuel assembly (see article, page 18). Most facilities provide

Walk a mile in the 'overshoes' of a s

The timeline of a routine inspection of an average nucle

Fly into the country the night before, arriving around **7 p.m.**

8 a.m.
the next day — leave hotel.

Drive one hour to reach the power plant, which is often located in a remote, sparsely populated area.

9 a.m.
arrive at the power plant. Wait for the escort provided by the plant.

30 minutes to 1 hour
for nuclear material accountancy: the inspector looks at the amount of nuclear fuel the facility has purchased, stored and used, as well as the capacity at which the facility is running to see if all this information adds up.

15 minutes
to meet with the representative of the national safeguards authority and plant operator to discuss the inspection and to agree on an 'activity plan' detailing the operator's plans for the facility's future.

the necessary equipment for inspectors to work in a safe environment. When this is not the case, inspectors take along and use IAEA equipment to ensure their safety. The job requires fitness, patience and adaptability.

Becoming an inspector

Of the around 250 applications received each year, only 15 to 25 inspectors are hired. New inspectors are trained and tested for five or six months before they are sent to facilities. Typically, their first assignments are supervised by a more experienced inspector, after which the new inspectors are finally ready to work on their own. All new inspectors also have a mentor for the first year. The IAEA employs around 385 designated inspectors from around 80 countries.

Because of the specialized skills required to do the job, mostly physicists, chemists and engineers (ideally with a background in nuclear physics or a related field) have been recruited as inspectors. “Safeguards inspectors need adaptability and good judgement. They need to learn quickly and pay attention to details,” says Hilario Munyaradzi, who worked as an in-field inspector for eight and a half years and has spent the past five years training new inspectors. They also need to show discretion, as much of the work they do and the samples they carry are highly confidential.

There are different kinds of verification activities — planned/routine inspections, unannounced inspections, complementary access, design information verification (to ensure that no modifications have been made to the facility and that it is being used as declared) and physical inventory verification (to verify the presence of the declared inventory of nuclear material — such as fuel — in the facility).

A physical inventory verification at a large facility can be so complex and time-consuming that it might take up to 10 inspectors 7 to 14 days to complete. During a design information verification, the inspector compares information about the facility’s design that the State has submitted to the IAEA with in-field observations to confirm that the information provided is correct and complete, and the facility has not been misused.

Both design information verifications and physical inventory verifications are conducted once a year in most of the 700 facilities that are under IAEA safeguards worldwide. Inspections are also carried out in a selected number of the almost 600 locations outside facilities under IAEA safeguards every year. Inspectors may also need to be present during major activities such as reactor refuelling at nuclear power plants and to work with a wide variety of complex equipment (see article, page 18).

afeguards inspector

ear power plant goes something like this:

1 hour
to undergo a whole body radiation scan, receive a dosimeter to track radiation dose received while on the premises, and put on special clothing and protective gear before entering the reactor hall.

2 to 4 hours
in the reactor hall for verification activities.

1 hour
for lunch

Discussion with national safeguards authority and plant operator about follow-up actions.

2 to 4 hours
Return to reactor hall

or move elsewhere in the plant for other verification activities

or continue with audits of the nuclear material accountancy records.

4 p.m.
leave the plant and drive for one hour back to the hotel.

5 p.m.
arrive back at hotel.

What’s in an inspector’s luggage?

A review of safeguards equipment

By Vincent Fournier

In-field inspections form the core of the IAEA’s nuclear verification activities, and equipping inspectors with the appropriate tools is key to effective nuclear safeguards. Over a hundred types of equipment are used by IAEA inspectors to verify the form, isotopic composition and quantity of nuclear material.

Inspectors typically select three to five hand-held pieces of equipment for each inspection. “There is no such thing as a typical inspection,” said Alain Lebrun, Head of the IAEA Non Destructive Assay Section that provides monitoring tools for inspector use. “Equipment is selected by inspectors on a case-by-case basis.”

Technicians prepare, calibrate and pack up the devices, which are carried by inspectors or — if they are too bulky — are shipped to their destination ahead of time. The most widely used hand-held equipment is non-destructive analysis instruments. These detect the presence of nuclear material (uranium, plutonium and thorium) and its specific characteristics. Specialized instruments assess physical characteristics — temperature, weight, volume, thickness and light emission/absorption — of nuclear materials.

“The equipment needs to be technologically advanced, versatile, rugged, and user-friendly,” Lebrun said. Equipment experts continuously review and optimize the instruments, keeping up with technological innovation and simplifying user interfaces.

Sometimes commercially available equipment can be used with minimal customization, while in other cases equipment is specifically developed for and/or by the IAEA. “Some of these tools cost more than a sports car,” Lebrun said.

Radiation detectors

One of the most commonly used pieces of equipment is the **HM-5**. It is a commercial instrument customized to safeguards verification applications. It is carried by inspectors to detect the presence of radioactive material. It emits a “beeping” sound if there is radiation above a certain level and identifies the nuclide emitting the radiation. It can also measure the enrichment level of uranium. With such versatility, the HM-5 is used in virtually all IAEA inspections.

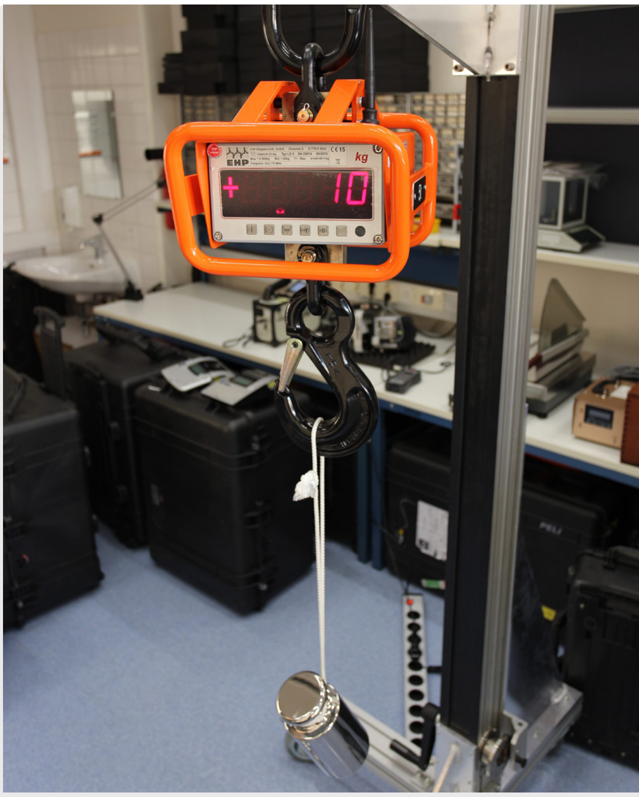
Enrichment matters

Uranium enriched in uranium-235 is required to sustain a nuclear chain reaction. However, the nuclear material and technology at enrichment plants can also be used to manufacture weapons-grade uranium. In facilities that process and/or store uranium, inspectors measure the weight and enrichment ratio of uranium in order to calculate the total amount of fissile material.

Inspectors use a big **load cell**, a sort of suspended scale, to weigh a cylinder to quantify the material it contains, such as uranium. It operates in two load ranges of up to 5000 and up to 20 000 kilograms.

To verify enrichment levels, inspectors often use high-tech detectors applying gamma spectrometry — a technique to monitor and assess gamma radiation released from a source — to take measurements. The **electrically cooled germanium system** (ECGS), for example, is a compact and portable high resolution detector that relies on an active germanium crystal, which, when cooled to -140 degrees Celsius, can detect gamma radiation released from uranium. It can be used in non-laboratory environments because, unlike conventional germanium detectors, it can be cooled using batteries, rather than with liquid nitrogen, which is difficult to handle and not always available.

As seen in the picture, the material that is analysed is sometimes contained in a bulky cylinder. To ensure that the ECGS — or other tools — can evaluate and analyse the data precisely, inspectors use an **ultrasonic thickness gauge** to adjust the detector’s sensitivity to gamma radiation based on the thickness of the cylinder walls.

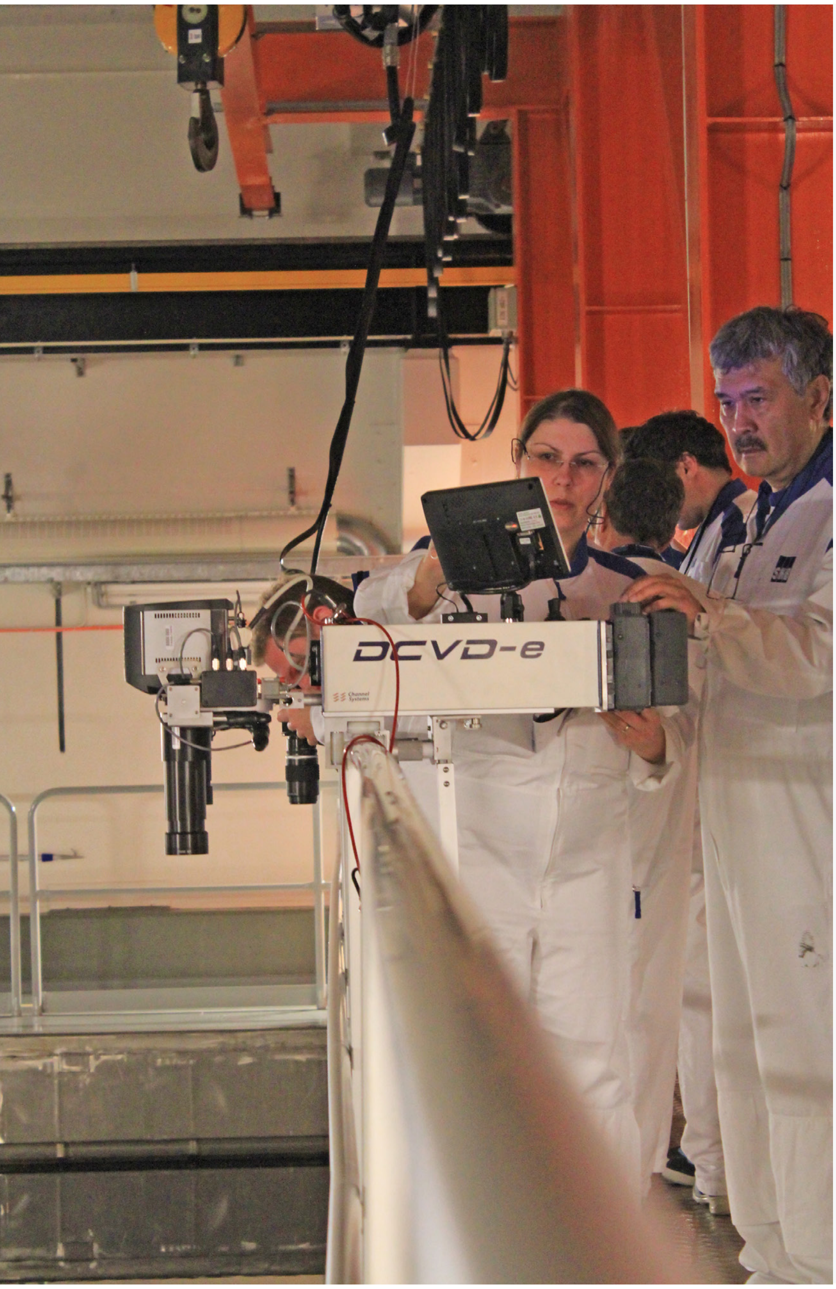


Under water

Inspectors use various types of detector systems to measure attributes of spent fuel, filters and waste in nuclear facilities.

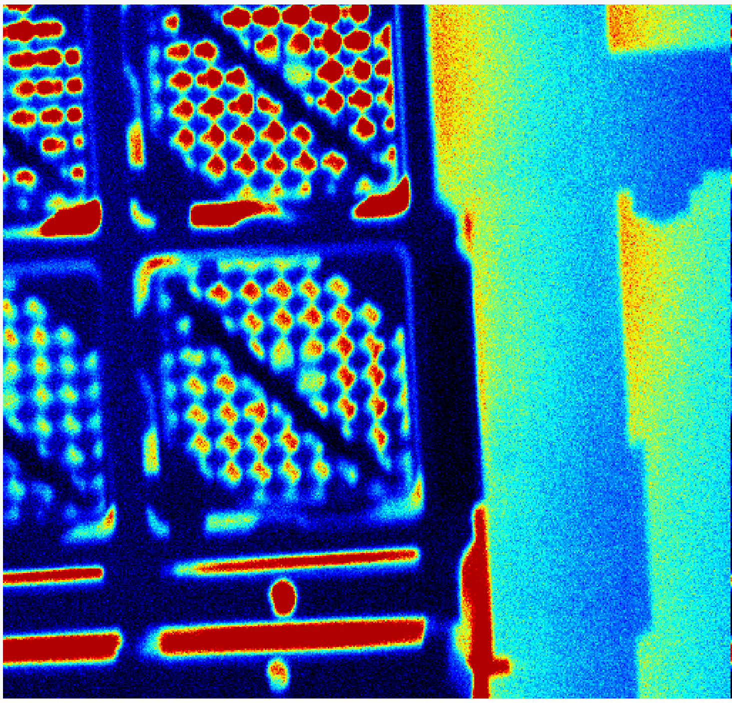
For instance, the **Irradiated Item Attribute Tester** is comprised of a small but sensitive gamma ray detector — the size of a small gemstone — contained in a protective tube, which is lowered into the spent fuel pond to measure items stored there. Cables connect it with an analyser that remains on the side of the fuel pond.

The device measures the intensity of gamma radiation at distinct energy levels. Each isotope of each atom has a characteristic gamma ray emission, so gamma spectrometry can be used to verify the contents of items in the spent fuel pond. If spent fuel had been removed or replaced in the pond, the spectrometry information will reveal this to the inspector.



Looking in spent fuel ponds while staying dry

One alternative to the Irradiated Item Attribute Tester for the verification of spent fuel is the **digital Cerenkov viewing device**, which is based on an ultra-sensitive camera detecting ultraviolet light. The camera is connected to a computer that uses specialized software to analyse the image. This device was custom-developed for the IAEA from astronomy equipment. But instead of looking at the stars, this camera's specialized lens and sensor capture ultraviolet light emitted from spent fuel assemblies, and the light patterns reveal key details about their characteristics. This is used to verify spent fuel ponds, ensuring that spent fuel was not diverted and substituted with a non-fuel assembly. Importantly, this device does not get immersed in the fuel pond, so it does not get contaminated with radioactive elements.



Additional protocol in action

The additional protocol grants the IAEA expanded rights of access to information and locations, helping to provide greater assurance of the absence of undeclared nuclear material and activities in those States with comprehensive safeguards agreements in place (see article, page 4).

To assess the completeness of States' declarations under the additional protocol, inspectors may perform complementary access visits with the **complementary access kit**. The toolkit equips them with multiple tools to collect information and verify declarations. The items include a camera, a laser distance meter, a GPS tool, a voice recorder, a flashlight, a general purpose radiation measurement system such as the HM-5, and an environmental sampling kit (see article, page 14.) These tools help the IAEA to confirm the absence of undeclared nuclear material and activities in those States.

Planning for the future

Technological progress continues to offer new opportunities and efficiency gains for monitoring and verification work. Equipment has an average life span of about ten years, after which its reliability decreases. The IAEA, with critical support from several Member States, works to keep pace with the evolution of new technology.

"Improving inspection efficiency is a priority for the IAEA. We are aiming to do what we do today faster and better without disturbing the workflow," said Dimitri Finker, technology foresight specialist at the IAEA. "We are doing this by implementing incremental changes and by customizing tools and technologies that already exist on the market."

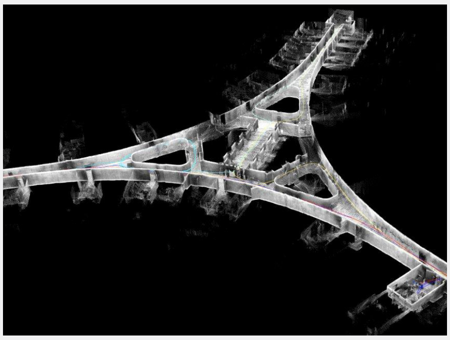
For instance, improvements to the complementary access toolkit will allow the inspectors in the near future to work faster, more accurately and generate reports with less effort upon their return to Vienna.

They will use an **electronic pen** to take notes in the field, an **autonomous positioning system** based on an inertial unit fixed on the foot of the inspector to keep track of where the inspector has been, different cameras including **infra-red cameras** combined with a **range-meter** and a new **miniaturized radiation detector** able to both detect and identify various sources of radiation. The data collected in the field is uploaded into a software and the information is put together to create a highly accurate geo-localized inspection report with the time, radiation value, picture and exact location of sampling throughout the duration of the inspection.

"Instead of having the inspectors spend half their time compiling information for the report, we provide them with technological solutions that then free up most of their time for analysis instead," said Finker.

The IAEA is also evaluating the benefit of using 3D laser technology for verification, as it can quickly map out buildings when the inspector walks through them with the tool in hand. The resulting 3D plans are more efficient than standard photographs for verifying States' declarations of facilities.

Photos: IAEA



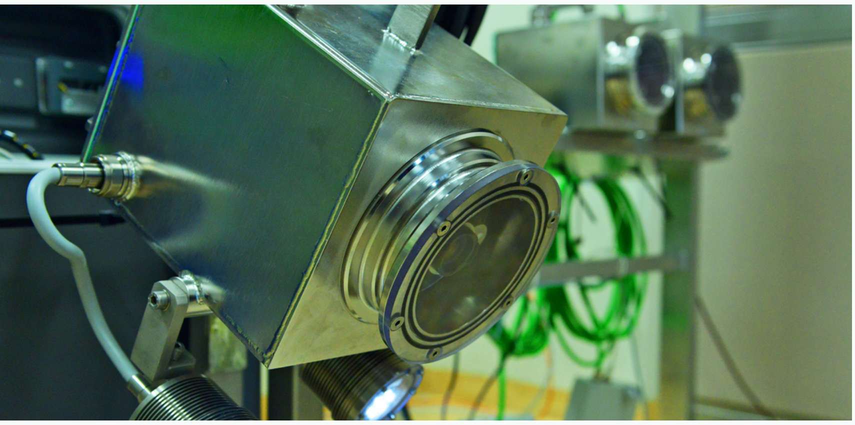
Surveying safeguarded material 24/7

By Vincent Fournier

While inspections are at the heart of the IAEA's verification activities, they are increasingly supplemented by surveillance technologies that operate around the clock. This allows the IAEA to strengthen the effectiveness of its safeguards while increasing its efficiency.

Such monitoring of nuclear material and facilities provides continuity of knowledge, the ultimate assurance that material is not diverted from peaceful use. Instead of requiring the presence of inspectors, cameras and radiation detectors record long operations, such as refuelling a light water reactor, which can take weeks. Data are either securely transmitted to the IAEA in real time or inspectors can review them on location during an inspection, and check whether activities have been performed as declared.

Over a million pieces of encrypted safeguards data are collected by over 1400 surveillance cameras, and 400 radiation and other sensors around the world. More than 23 000 seals installed at nuclear facilities ensure containment of material and equipment.



Watchful eyes

The IAEA's **next generation surveillance system** (NGSS) consists of cameras housed in tamper-indicating containers and equipped with long lasting batteries that can provide electricity for extended periods without access to external power. The authenticity and confidentiality of surveillance data acquired by the NGSS is maintained by three different layers of cryptographic data protection and multiple layers of physical, passive and active tamper-indication technology. At the heart of the NGSS camera, a secure surveillance core component protects the critical electronic components and the optical sensor, as well as the cryptographic secrets by an active tamper-indication mechanism.

The cameras are installed in storage areas, in and near spent fuel ponds, and at all transit points through which nuclear material can pass. The cameras may be equipped with a "fish eye" optical lens, enabling them to take panoramic pictures. They take images at pre-determined intervals of between one second and ten minutes or more, depending on verification needs. For example, in an enrichment facility, the cameras record activity more frequently, while in a storage area the intervals are longer. "If you need to install a crane to move material, as in storage facilities, we can detect suspicious activity even if images are captured less frequently," said Gabor Hadfi, head of the IAEA Safeguards Surveillance Team.

Taking pictures rather than continuous filming is advantageous for several reasons: it conserves battery life, and images are easier to process and analyse than films, Hadfi explained.

The surveillance data is pre-processed for review with the help of specialized software that detects movement, and inspectors examine the data and evaluate whether they are consistent with normal and reported operations of the facility.

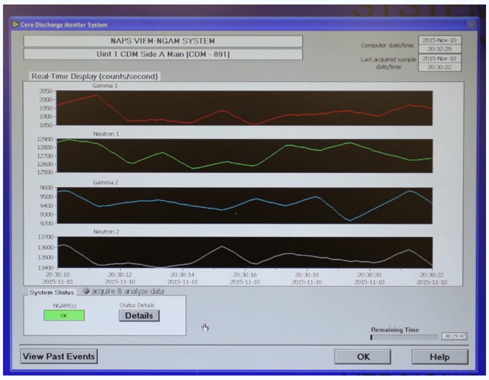
Remote radiation check

The surveillance cameras can see movement but cannot detect radiation levels. To this end, the IAEA uses unattended non-destructive assay monitoring systems that include radiation detectors to measure neutron and gamma radiation and various sensors to monitor temperature, flow and other parameters. “These are installed at specific locations to characterize and verify nuclear material, monitor the movement of spent fuel, and collect and transmit encrypted data round the clock,” said Thierry Pochet, Head of the IAEA Unattended Monitoring Systems Team.

These systems can be installed and collect data in areas inaccessible to inspectors due to high amounts of radiation. Around 160 systems with a total of 700 detectors and sensors are installed in over 40 countries, Pochet said. A typical CANDU pressurised heavy water power reactor, for instance, has around 20 sensors installed.

Different types of unattended systems are used for various types of facilities from enrichment to reactors to spent fuel storage to reprocessing. The data collected from radiation monitoring are often analysed in conjunction with video surveillance to track the movement of nuclear material in the facility: the photos enable the inspector to remotely observe what caused a variation in radiation levels.

The **VXI integrated fuel monitor** tracks and counts discharged fuel from the core of pressurized heavy water reactors, including CANDU reactors. In these types of reactors fuel bundles need to be replaced several times a day. The monitoring system tracks these bundles as they are loaded, shuffled in the core and discharged to the spent fuel pond using a number of neutron and gamma radiation detectors.



NAPS VIFM-NGAM SYSTEM

Uint 1 CDM Side A Main [CDM - 891]

Computer date/time: 2015-Nov-10 20:32:29

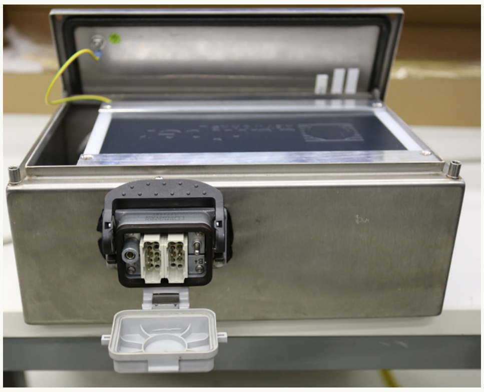
Last acquired sample date/time: 2015-Nov-10 20:30:22

NGAM(s): OK

Status Details

Remaining Time: 00:29:47

After around five years of cooling in the spent fuel pond, the fuel is ready to be moved to a storage location — normally within a few kilometres of the reactor site. For transport, the spent fuel is transferred into special casks on which a **mobile unit neutron detector (MUND)** is mounted to measure the level of radiation to make sure its content is not altered while in transit. This device is based on a neutron detection system and can collect and store data on battery power for up to eight weeks without being serviced.



Upon arrival at the storage location, the MUND is removed and the cask’s content is transferred into a silo. A **silo entry gamma monitor** is installed before the transfer, and its gamma detectors monitor the loading process. The device is linked to a cabinet where the data is stored. This system works in conjunction with camera surveillance to additionally capture all movements of the transfer process.

Monitoring the power of research reactors

Specific systems are used to monitor the power of nuclear research reactors. The **advanced thermohydraulic power monitor** is used to monitor the power output of research reactors by measuring the temperature and water flow in the reactor's cooling circuit. If the power calculated based on the monitoring is above a certain threshold the inspector can investigate to determine if the reactor is operating as declared. A higher than declared thermal output power could indicate that plutonium may have been produced, posing a proliferation risk.

Reprocessing

During nuclear reprocessing of spent uranium fuel, fissionable plutonium is recovered from irradiated nuclear fuel. This reprocessed plutonium is recycled into MOX nuclear fuel for thermal reactors. The reprocessed uranium, which constitutes the bulk of the spent fuel material, can also be re-used as fuel. The presence of plutonium represents a particular proliferation risk, and the different processes involved in reprocessing plants are monitored using unattended equipment. More than 20 specific systems including hundreds of neutron and gamma detectors have been designed for the Rokkasho Reprocessing Plant in Japan, for instance. This plant, one of the world's largest, has the annual capacity to turn into fuel 800 tonnes of uranium or 8 tonnes of plutonium per year. All the monitoring data collected are transmitted in real time to the IAEA Inspection Centre at the plant through a dedicated and secure network.

Tracking U-235 in enrichment plants

In 2015, the IAEA developed an online enrichment monitor, dedicated to measuring the enrichment level of uranium in gas centrifuge enrichment facilities. Such facilities enrich uranium by gradually increasing the proportion of uranium-235 isotopes (U-235), which can sustain a fission chain reaction.

The monitor measures the characteristics of gaseous uranium — uranium hexafluoride (UF6) — flowing through the processing pipes out of the cascades of centrifuges of the enrichment plant. The main connection node, a gamma ray detector based on a sodium iodide crystal, measures the amount of U-235 in the pipe, while pressure and temperature sensors enable the machine to determine the total quantity of gaseous uranium. From the two, the device can calculate and store or transmit to IAEA headquarters the enrichment level in real time. The device can be installed in a configuration to monitor the enrichment levels of the material coming in and out of the gas enrichment centrifuges cascades.

All the components are contained in sealed boxes that are connected by special tubing and all enclosures are sealed. A special paint is used to ensure that any attempt to tamper with the device will be noticed.

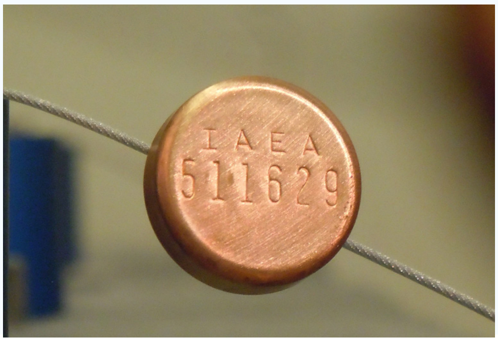
Following its debut in Iran at the Natanz Fuel Enrichment Plant in January 2016, the IAEA intends to gradually roll out the online enrichment monitor to gas centrifuge enrichment plants in other countries. Since the new technology provides continuous measurement, sample taking and environmental sampling will be reduced, resulting in efficiency gains and cost savings.

The IAEA's seal of approval

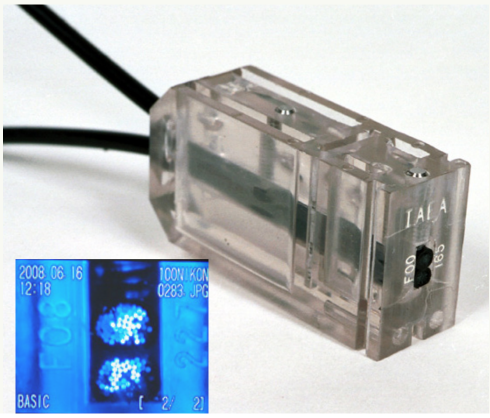
The IAEA seal is the most famous, and also the most frequently used, safeguards equipment. Although simple, these tamper-indicating devices are very efficient in deterring unauthorized access to safeguarded materials and IAEA safeguards equipment. They also provide a means of uniquely identifying secured containers. Seal verification consists of carefully examining an item's enclosure and the seal's identity and integrity for any sign of tampering.

The IAEA uses several types of seals as appropriate. Some are designed for use under water or in extreme environments.

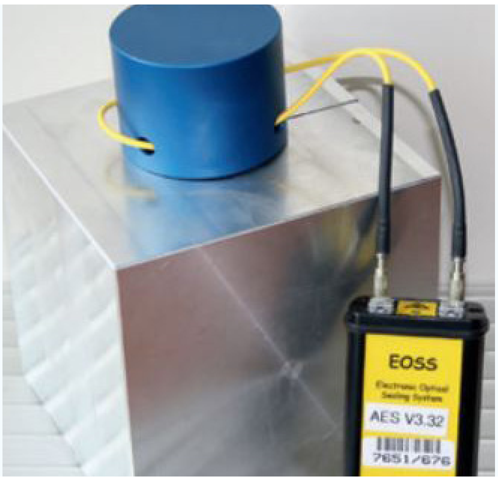
The single-use **metal cap s**eals have been in service for more than 30 years — and about 16 000 of these seals are distributed and verified every year. For identification, each seal is numbered and has unique markings on its inner surfaces, which are recorded before they are issued to inspectors. During inspections, seals are replaced and brought back to IAEA headquarters to verify their effectiveness and their authenticity by checking that the markings are the same as the original.



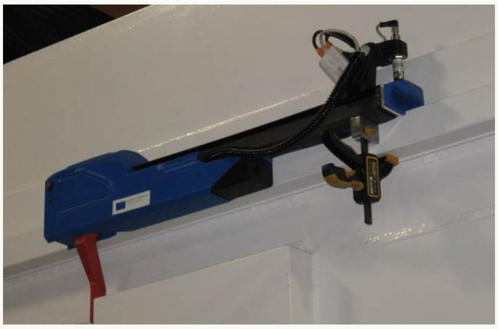
Other types of seals are verified by IAEA inspectors on location. The **COBRA seal**, for example, includes a multicore fibre optic cable with its ends enclosed in the seal body. Some of the cores are randomly cut during the closure of the seal to form a unique optical pattern. Cameras are used to record this unique signature by shining a light through the cable. During verification, the inspection image is compared with the installation image to ensure the seal's identity and continued integrity. Approximately 2000 COBRA seals are deployed per year, typically in conjunction with metal cap seals to further improve reliability.



The IAEA also uses electronic seals, such as the **electronic optical sealing system**, which can be remotely interrogated by inspectors and are linked to video surveillance systems. These seals consist of a fibre optic loop and an electronic unit, which keeps monitoring the status of the loop by sending a pulse of light through the fibre at short intervals. The time, date and duration of any opening and closing of the fibre optic loop are recorded in an encrypted internal memory. Active electronic seals allow for cooperation with national authorities and operators, who are allowed to attach or detach them. These modifications are recorded and inspectors can compare them with activities declared.



The **laser mapping for containment verification system** is the newest seal technology in use. Based on laser surface mapping technology, its scanner generates a high resolution map of a container's closure weld when containers are placed in service. Identification and tamper detection are achieved by re-scanning the weld and comparing the new map with the corresponding reference.



Photos (unless noted otherwise): IAEA

Revealing facts through science for nuclear verification

By Nicole Jawerth

> **"We use highly sensitive equipment to evaluate samples collected by safeguards inspectors, sometimes even down to the nanogram."**
>
> *— Steven Balsley, Head, Nuclear Material Laboratory, IAEA*

Keeping track of the facts is an important part of nuclear verification. Receiving hundreds of samples each year, staff at the IAEA's safeguards laboratories verify data through spot checks and analysis of the uranium and plutonium content of nuclear material samples.

"We use highly sensitive equipment to analyse samples collected by safeguards inspectors, sometimes even down to the nanogram," said Steven Balsley, Head of the IAEA Nuclear Material Laboratory. "It's a highly accurate process that plays an important part in the IAEA's work to verify whether nuclear material and facilities are being used peacefully."

The laboratory scientists analyse environmental swipe samples and samples of nuclear material from various points of the nuclear fuel cycle collected by safeguards inspectors during physical inspections of nuclear facilities. The samples are screened, processed, distributed to laboratories in the IAEA network of laboratories, and analysed and archived by scientists at the IAEA's laboratories in Seibersdorf, Austria. These laboratories consist of two modern facilities: the Nuclear Material Laboratory (NML), which handles samples of nuclear material, and the Environmental Sample Laboratory, which receives and screens all environmental swipe samples for traces of nuclear material. (see article, page 14).

Once the samples are recorded and distributed to the labs in the IAEA network, scientists use instrumentation such as gamma spectrometers and mass spectrometers (see The Science box on page 15), to determine the amount and type of uranium or plutonium in a given sample.

"Uranium and plutonium are the two main fissionable elements used for generating power in nuclear power reactors, but are also the fissionable elements most commonly used in producing a nuclear weapon," explained Balsley. "We're most interested in keeping a very close eye on where the fissionable isotopes of those two elements are moving around in the nuclear fuel cycle."

On average, more than 600 samples of nuclear material are received and analysed each year. They are kept in small containers labelled with anonymous barcodes to ensure confidentiality throughout the evaluation process. The sample sizes can vary from as small as an eyelash to several grams. The information they contain may help uncover clues about past and current activities at the site where the sample was taken.

"While the samples collected by safeguards inspectors may just be a tiny fraction of the tonnes of material in a facility, we can look at certain characteristics of the atoms in a given sample to evaluate its overall nature," Balsley said. "By extrapolating data from the analysis of a small sample, scientists can determine the composition of tonnes of material — and improve the accuracy of nuclear material accounting."

Samples for verification

The main purpose of collecting nuclear samples is to verify the declared quantities and isotopic composition of material in facilities under safeguards. The IAEA then compares the declared values with its own independently measured values.

"A small discrepancy is normal when working with large inventories in any sector, be it banks, grocery stores or nuclear facilities. There is either an excess or deficit when book values are compared to physical items," explained Balsley. One of the main goals of safeguards is to make sure the discrepancies are small compared with what is known as a 'significant quantity', the amount of material required to develop a nuclear explosive device, he said.

Significant differences between declared and independently measured values are known as defects and come in three types: a gross defect, when one or more bulk items of nuclear material cannot be accounted for; a partial defect, when a significant portion of a bulk item is siphoned off; and a bias defect, when a small fraction of a bulk item is shaved off periodically over time.

Unlike gross and partial defects, which are more easily spotted by an inspector at the facility due to the larger quantities involved, the small-scale nature of a bias defect requires high-precision chemical and physical measurements to improve nuclear material accountancy.

With homogenous bulk material, like barrels of uranium oxide, for example, this is done by first carefully and precisely weighing the original, randomly selected bulk item using a specialized system called a load cell (learn about this and other equipment on page 18). Then representative gram-sized samples are taken from the bulk item by the operator, under the watchful eye of an IAEA inspector. These gram-sized samples are then also carefully weighed at the facility.

Once delivered to the NML, the samples are re-weighed and then analysed to reveal the percentage of uranium, as well as its isotopic composition. By measuring the percentage of uranium in the sample and the weight of both the samples and of the original item, IAEA specialists can calculate precisely the quantity of uranium in the bulk item. They then compare these findings to the declared information from the facility and also to the historical record of analytical results from samples taken from the same physical area where nuclear material quantities are overseen, known as the material balance area.

For some products that cannot be easily sampled, or inhomogeneous materials from which representative samples cannot be taken, other methods are used to verify their chemical or isotopic composition.

Accuracy, quality, confidence

Quality control is essential to maintaining confidence in analytical findings used for safeguards verification. Being part of an internationally certified laboratory, staff use validated analytical methods to perform analyses. Certified reference materials are used to monitor the quality of measurements in the labs, and participation in inter-laboratory comparison programmes ensure that standards of measurement and instrument calibration are on point. Lab staff also train safeguards inspectors in procedures to properly collect and handle samples, from how to avoid cross-contamination to sampling nuclear material items in such a way so as to achieve representative samples.

Experts in the Nuclear Material Laboratory use specialized tools to carefully analyse samples of nuclear material as part of the safeguards verification process.

(Photo: D. Calma/IAEA)

Staying up-to-date with the latest technological developments also contributes to higher levels of accuracy and precision for ensuring quality. The laboratories keep pace with these developments through frequent consultations with experts in the field, support from Member States, and continually improving methods and upgrading instrumentation.

Modern facilities

A major modernisation project, costing around 80 million euro at the Seibersdorf laboratories was completed on time and on budget at the end of 2015. The ‘Enhancing Capabilities of the Safeguards Analytical Services’ project included a new Clean Laboratory Extension for the Environmental Sample Laboratory and a new Nuclear Material Laboratory that replaced the Safeguards Analytical Laboratory built in the 1970s.

This project, among other things, increased the laboratories’ sample capacity, improved the sensitivity of analytical methods, and provided more infrastructure for training inspectors and staff from Member State laboratories.

“Successfully completing this project underlines the IAEA’s readiness to cope with the increasing workload of safeguards,” said Balsley. “Being up-to-date and modern will enable the IAEA to continue to meet safeguards’ analytical requirements for decades to come.”

Swipe check: collecting and analysing environmental samples

By Aabha Dixit

> **“No matter how much you clean a kitchen, a speck of material dust always remains. This is also true in a nuclear facility. This enables environmental sample swipe analysis to detect what elements have been used.”**
>
> *— Stephan Vogt, Head, Environmental Sample Laboratory, IAEA*

The air is pressurized, carefully filtered and closely monitored. Scientists and technicians pass through air showers before entering. Welcome to the IAEA Environmental Sample Laboratory, or ‘clean laboratory’, in Seibersdorf, Austria, where more than 300 samples are analysed every year to verify that nuclear facilities have been used as declared.

The clean laboratory conditions are necessary so that the smallest traces of uranium and/or plutonium can be identified in the swipe samples taken by inspectors at research reactors, enrichment plants and other nuclear facilities for analysis. The machines used are so sensitive that they can pick out uranium and plutonium at weights below one trillionth of a gram in a sample.

Inspectors taking a swipe sample at a nuclear facility.

(Photo: IAEA Department of Safeguards)

“No matter how much you clean a kitchen, a speck of material dust always remains. This is also true in a nuclear facility. This enables environmental sample swipe analysis to detect what elements have been used,” said Stephan Vogt, Head of the IAEA Environmental Sample Laboratory.

While many safeguards verification methods aim to check and confirm the type and quantity of nuclear material declared by a State, environmental sampling is used to verify the absence of undeclared nuclear material.

How IAEA swipe sampling began

In the 1990s, a nuclear facility in Iraq was bombed and there was no way for IAEA inspectors to perform conventional verification activities at the destroyed site. Instead, the inspectors innovated. They used cotton cloths to ‘swipe’ items from the damaged facility and analyzed them to determine what elements were used in the facility prior to its destruction. An entire spectrum of uranium — from depleted to highly enriched — was identified. The contaminated cloths were able to reveal important information about the history of the destroyed nuclear facility. The notion of using swipe sampling as part of IAEA verification activities was born.

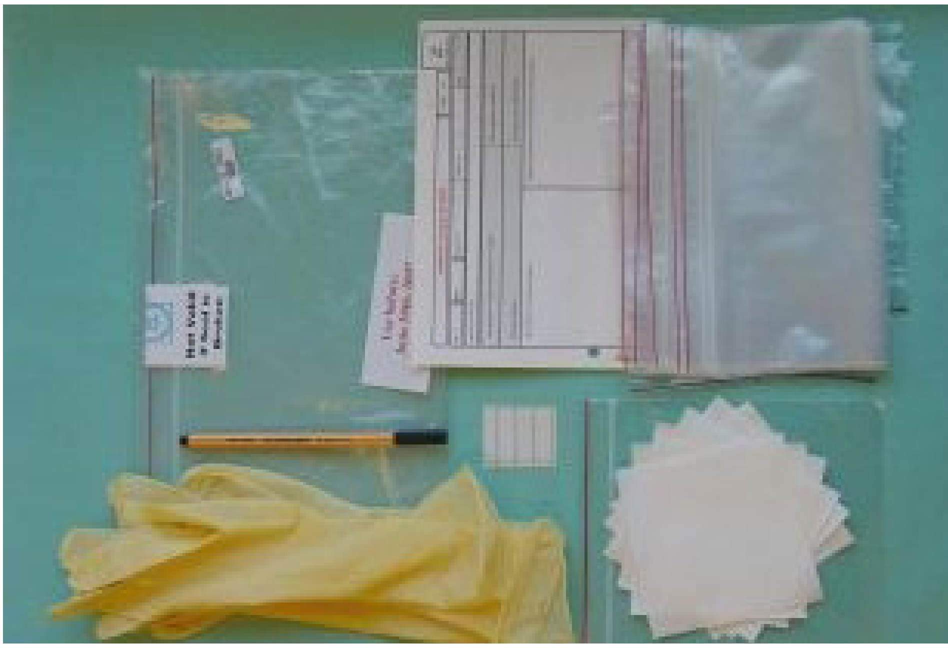
Environmental sampling is now part of the IAEA’s standard processes. The environmental sample kits for inspection purposes are all prepared in the laboratory’s ‘clean room.’ The sealed packaged swipes are only opened at the designated area of inspection. The package contains two pairs of latex gloves, 6 to 10 cotton swipes, as well as additional ziplock packets for the swiped samples. These are then placed in an outer sealed bag until they reach the IAEA.

Surfaces at various locations at a nuclear or related facility are swiped a number of times. Back at the laboratory, these samples are subject to highly sophisticated analyses using advanced technology (see box).

Samples are analysed at the IAEA laboratory as well as at the 19 accredited laboratories in eight IAEA Member States and the European Atomic Energy Community (Euratom). Labs in Australia, Brazil, France, Germany, Japan, Russia, the Republic of Korea, the United Kingdom and the United States are part of the IAEA’s network of affiliated laboratories.

To maintain the confidentiality of the process, all collected swipe samples are subjected to a rigorous labelling system that removes the identity of the country and the place of collection. Anonymized samples undergo an initial investigative screening for radioactive signatures and major elemental composition and are then sent to the designated laboratories in Member States, Vogt said. Among the samples the IAEA sends are also blind quality control samples so that measurements can be assessed against the standards set by the IAEA and a consistent high quality maintained.

Careful collection and thorough analysis of environmental samples is now an essential element of the IAEA's safeguards work. "These activities enable the IAEA to verify that nuclear facilities have been used as declared and to build confidence in the peaceful uses of nuclear technology," said Tero Varjoranta, Deputy Director General and Head of the IAEA Department of Safeguards.



Sample kit for environmental sampling.

(Photo: IAEA Department of Safeguards)

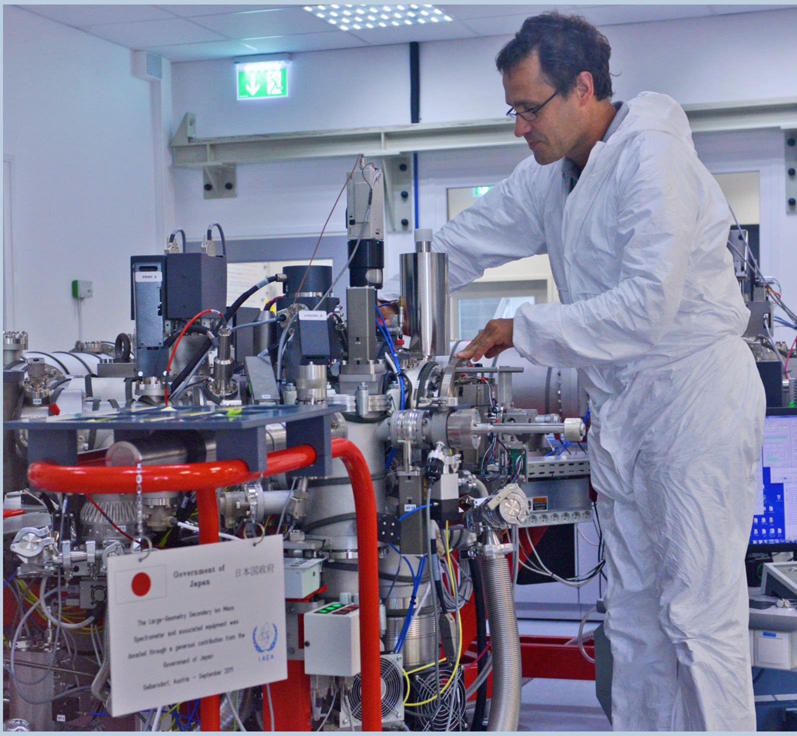
THE SCIENCE

Tracking signature elements and isotopes

All swipe samples are screened using gamma and X-ray spectrometry that can detect the type of element and radioisotope present. "The methodology for the swipe screening is non-destructive, which means that the samples are not destroyed or decomposed prior to screening and they do not get compromised throughout the examination process," Vogt said.

Mass spectrometers are used to determine the isotopic composition of uranium or plutonium contained in the swipe samples. The method is so sensitive, it can identify a single particle that is 100 times smaller than the width of a strand of hair.

The large geometry secondary ion mass spectrometer measures the uranium isotopic composition in micrometre-sized particles. It provides a powerful analytical tool for 'isotopic fingerprinting' of individual uranium particles. Another method to analyse samples is bulk analysis, looking at the uranium and plutonium content and the isotopic composition of the combined material on a swipe. Typically samples are sent out simultaneously for bulk and particle analysis, Vogt added.



Swipe samples being analysed at the IAEA Environmental Sample Laboratory in Seibersdorf, Austria.

(Photo: D. Calma/IAEA)

Completing the picture: using satellite imagery to enhance IAEA safeguards capabilities

By Rodolfo Quevenco

Satellite imagery is used to create site plans to capture information on buildings and structures on a site. In this photo, analysts are discussing the site plan.

(Photo: D. Calma/IAEA) Satellite

In the implementation of safeguards, the IAEA collects and evaluates a wide range of safeguards relevant information in order to verify States' international obligations to only use nuclear material and technology for peaceful purposes. This includes information gathered from open sources, including commercial satellite imagery.

"Imagery analysis complements information provided by States and can be an important component of verifying a State's declarations," said Karen Steinmaus, Head of the State Infrastructure Analysis Section at the IAEA. "Commercial satellite imagery has become a very important information source for the IAEA's Department of Safeguards, especially regarding places where the IAEA does not have access," Steinmaus added.

Analysis of satellite imagery is routinely used in the following safeguards activities:

- to verify the accuracy and completeness of information supplied by States;

Satellite imagery during the Fukushima accident

The importance of satellite imagery goes beyond simply verifying States' declarations, planning and supporting verification activities, and detecting and investigating undeclared activities. It also plays a significant role in monitoring nuclear fuel cycle activities. The Fukushima nuclear power plant accident serves as an example.

When a magnitude 9.0 earthquake struck off the coast of north-eastern Japan on 11 March 2011, it set off a chain of events that eventually led to a nuclear accident. That same afternoon, the IAEA Department of Safeguards began to collect satellite imagery to assess the possible damage at a wide range of Japanese nuclear sites.

The IAEA was able to receive and analyse imagery on a daily basis. Between 11 March and the end of May that year, the IAEA acquired 157 commercial satellite images of Japan, 130 of which were donated through the Crisis Event Service.

An initial assessment of the satellite images detected damage at several nuclear sites, but it soon became apparent that the crisis was centered on the Fukushima Daiichi nuclear power plant. Commercial satellite imagery thus served a critical role in supporting the IAEA's Incident and Emergency Centre to inform Member States as well as communicate with the wider public in the days and months following the accident.

- to aid the planning of in-field and inspection activities;
- to detect changes and monitor activities at nuclear fuel cycle-related sites; and
- to identify possible undeclared activities.

The value of satellite imagery to safeguards: the case of the DPRK

Satellite imagery helps the IAEA to remain abreast of developments in the nuclear programme of the Democratic People's Republic of Korea (DPRK), even though it is unable to carry out physical verification activities there. Monitoring developments at the Yongbyon site are particularly important.

Use of satellite imagery allows the IAEA to prepare and update a detailed plan for the implementation of monitoring and verification activities in the DPRK in the event of inspectors returning to that country.

Future challenges and opportunities

In recent years, both challenges and opportunities for satellite imagery analysis have expanded dramatically. New, high spatial and spectral resolution sensors with significantly improved 'revisit times' provide unprecedented opportunities to monitor sites and activities.

In addition to optical imagery, commercial imaging radars, new infrared sensors and satellite-based video have the potential to enhance the analytical process. These capabilities provide analysts with different techniques to get additional information that support the IAEA's operational verification requirements.

> "Commercial satellite imagery has become a very important information source for the IAEA's Department of Safeguards, especially regarding places where the IAEA does not have access."
>
> *— Karen Steinmaus, Head, State Infrastructure Analysis Section, IAEA*

Optimizing IAEA Safeguards

By Tero Varjoranta, Deputy Director General and Head of the Safeguards Department

IAEA safeguards make a vital contribution to international security. Through safeguards, the IAEA deters the spread of nuclear weapons and provides credible assurance that States are honouring their international obligations to use nuclear material only for peaceful purposes. Its independent verification work allows the IAEA to facilitate building international confidence and strengthening collective security for all.

The field of nuclear technology does not stand still. In the past five years, 7 new safeguards agreements and 23 new additional protocols entered into force. The quantities of nuclear material under safeguards have increased by 17% and the number of nuclear facilities under safeguards by 5%. As civil nuclear programmes continue to expand, these trends are set to continue.

While the demands on the Safeguards Department – driven by our legal verification obligations – continue to grow, our budget does not increase in a proportionate way. If we are to continue strengthening our effectiveness, therefore we must become more efficient. In other words: achieve greater productivity.

There are three ways in which we are doing this. First, we are making full use of available modern technologies. Second, we are streamlining our internal processes. Third, we are encouraging States, where necessary, to improve their cooperation to implement safeguards with us.

Moreover, the nuclear agreement between Iran and major powers in July 2015 has shown the importance of the Department of Safeguards in being able to respond effectively and promptly to new verification demands from IAEA Member States.

I am positive about the future of IAEA Safeguards and their contribution to global security. We have a strong legal mandate, widespread political support and the technical capabilities to enable us to provide assurances to the world that all nuclear material is in peaceful use.

My vision for safeguards is one in which States and the nuclear industry see the IAEA as value added; in which we continue to draw independent and credible safeguards conclusions; and in which any issue of safeguards concern continues to be firmly addressed.

Tero Varjoranta, Deputy Director General and Head of the Safeguards Department

(Photo: IAEA)

Iran and the IAEA: verification and monitoring under the JCPOA

On 16 January 2016, IAEA Director General Yukiya Amano announced that Iran had completed the necessary preparatory steps to start implementation of the Joint Comprehensive Plan of Action (JCPOA). This ushers in a new phase in the relations between the IAEA and Iran, and represents the start of an increased effort of the IAEA's verification and monitoring activities in Iran.

The JCPOA was agreed last July between Iran and China, France, Germany, Russia, the United Kingdom, the United States and the European Union, the so called E3/EU+3. The IAEA, which is not party to the JCPOA, is undertaking a wide range of verification and monitoring of nuclear-related commitments set out in the document.

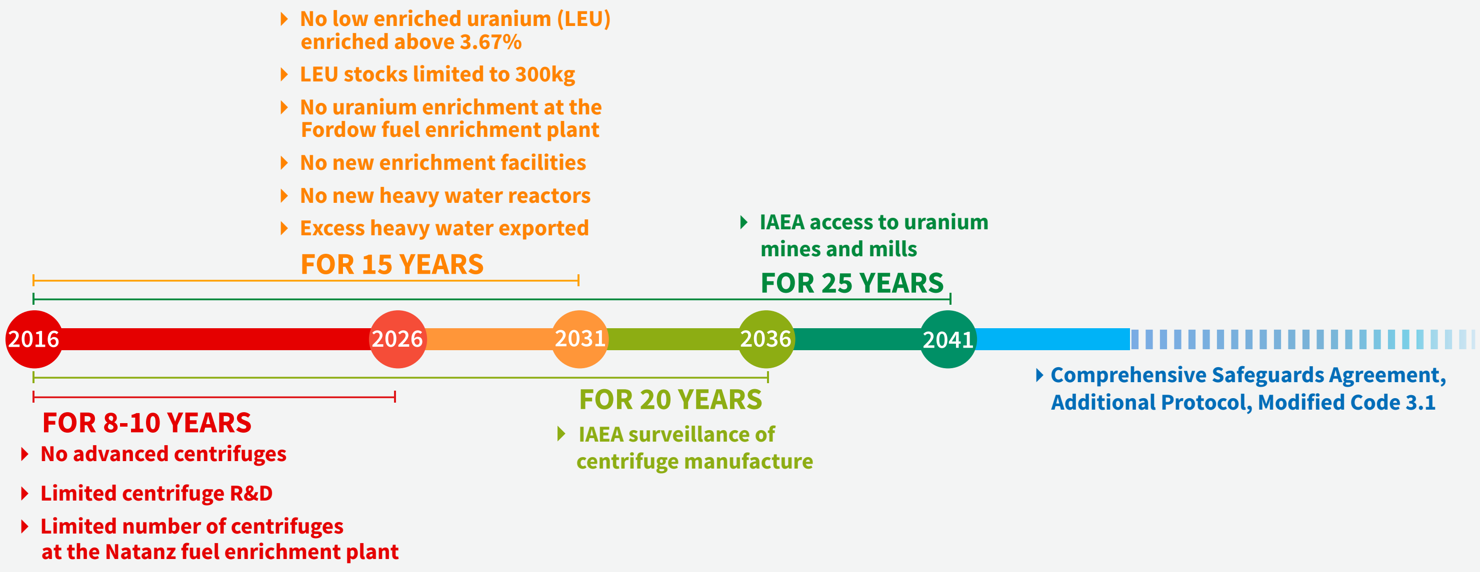
In the JCPOA, Iran has committed to reduce by about two-thirds the number of its enrichment centrifuges and not to enrich uranium above 3.67% uranium-235. It has also agreed to provisionally implement the additional protocol, a legal agreement granting the IAEA broader access to information and locations in a State, beyond declared nuclear facilities and materials. This increases the IAEA's ability to verify the peaceful use of *all* nuclear material in that State.

Under the JCPOA, Iran has also agreed to implement voluntary nuclear-related commitments — known as 'transparency measures' — which include enhanced access for IAEA inspectors to uranium mines and mills, and continuous surveillance of centrifuge manufacturing and storage locations (see figure below for an overview of Iran's key nuclear commitments and their timing under the JCPOA). These measures go beyond the scope of the Additional Protocol and will help the Agency to better understand Iran's nuclear activities.

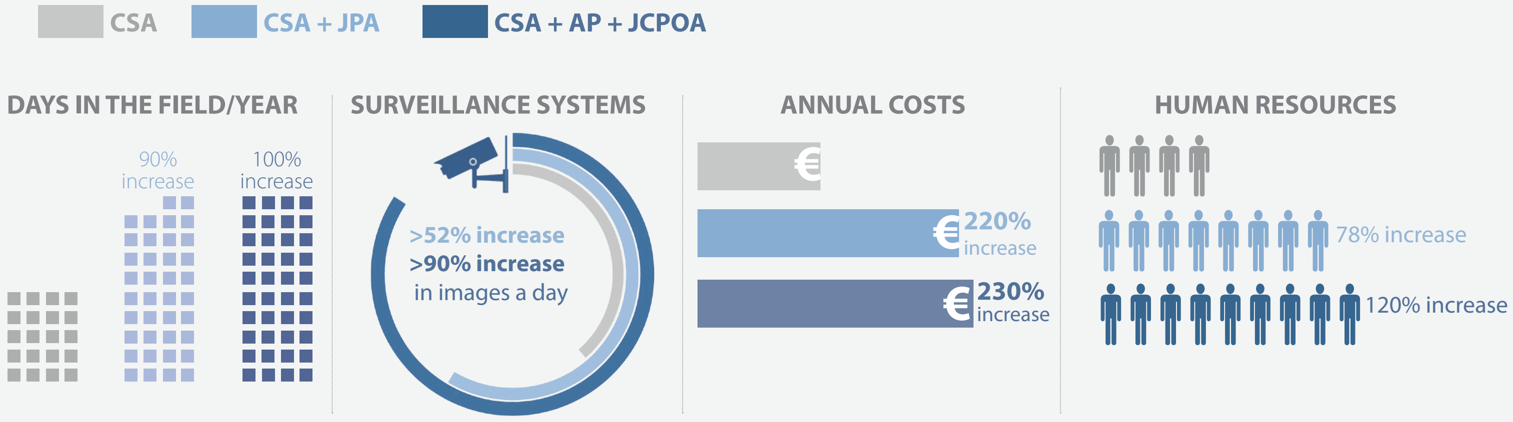
Higher commitment

As a result of the implementation of the JCPOA, IAEA resources devoted to verification and monitoring in Iran have increased considerably (see chart above). For instance, remote surveillance systems (see article, page 22) are now transmitting 25% more images and nuclear data to the IAEA each day as before the implementation

KEY COMMITMENTS OF IRAN UNDER THE JCPOA



INCREASE IN RESOURCES REQUIRED



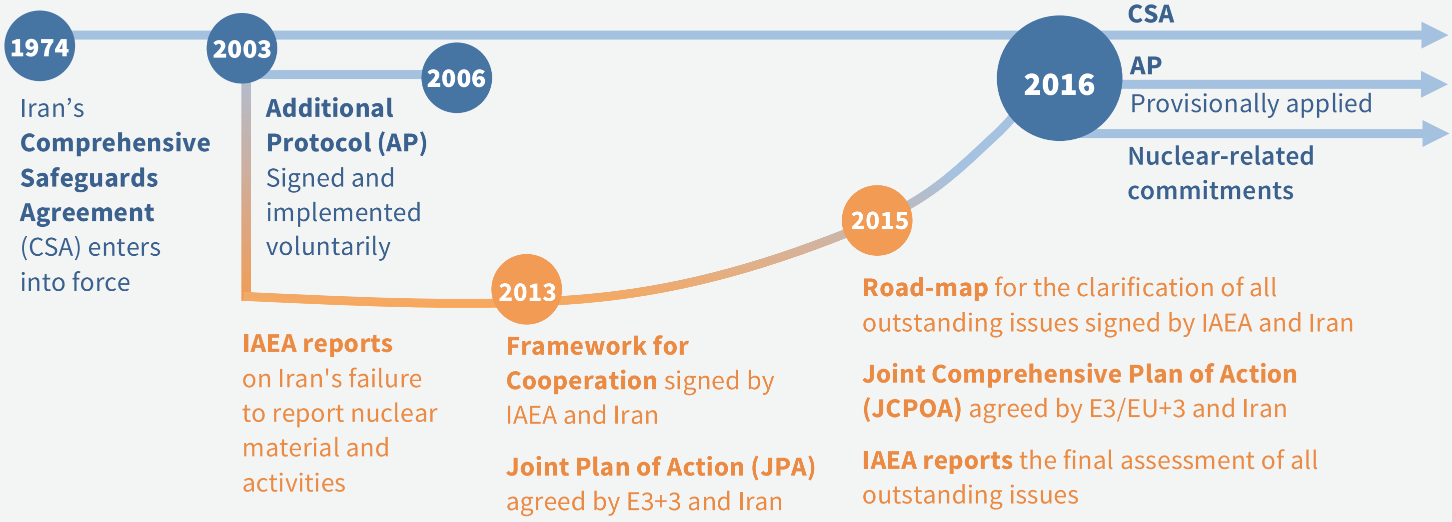
of the JCPOA, and almost twice as many as before 2014, when the IAEA started the verification and monitoring of an interim framework, the Joint Plan of Action, that was agreed between Iran and the E3+3 in 2013.

The number of IAEA personnel devoted to verification and monitoring in Iran has increased by almost a quarter since last year, and has more than doubled since before 2014.

Implementation of verification and monitoring by the IAEA under the JCPOA will require additional expenses of €9.2 million per year. The IAEA's budget devoted to these activities is 2.3 times higher than before the implementation of the JPA.

"While much work lies ahead, the IAEA has the expertise and experience to do the job," said Tero Varjoranta, Deputy Director General and Head of the Department of Safeguards. The combination of Iran's CSA, additional protocol and the nuclear-related commitments under the JCPOA represent a clear net gain from the verification view point.

IRAN AND IAEA SAFEGUARDS: KEY DATES



1974

Iran's **Comprehensive Safeguards Agreement** (CSA) enters into force

2003

IAEA reports on Iran's failure to report nuclear material and activities

2006

Additional Protocol (AP) Signed and implemented voluntarily

2013

Framework for Cooperation signed by IAEA and Iran

Joint Plan of Action (JPA) agreed by E3+3 and Iran

2015

Road-map for the clarification of all outstanding issues signed by IAEA and Iran

Joint Comprehensive Plan of Action (JCPOA) agreed by E3/EU+3 and Iran

IAEA reports the final assessment of all outstanding issues

2016

CSA

AP Provisionally applied

Nuclear-related commitments

How the IAEA contributes to the Sustainable Development Goals

By Nicole Jawerth and Miklos Gaspar

The 17 Sustainable Development Goals (SDGs) are a range of objectives agreed on by the United Nations General Assembly in September 2015. They aim at stimulating action over the next 15 years in areas of critical importance for humanity and the planet. They balance the three dimensions of sustainable development: the economic, social and environmental.

The IAEA makes peaceful nuclear technology available to its Member States in many fields including energy, human health, food production, water management and environmental protection — all important areas recognized under the SDGs.

To shed light on the role of nuclear science and technology, and in turn the IAEA, in some areas covered by the SDGs, here is a look at how the IAEA is providing support to countries in using nuclear and isotopic techniques. This work is expected to intensify in the light of the SDGs, and will help to bring the world closer to achieving the relevant targets.

2 ZERO HUNGER

Hunger and malnutrition are often rooted in food insecurity and agricultural challenges, causing well-being to suffer and economies to grow strained. Through the IAEA, and its partnership with the Food and Agriculture Organization of the United Nations (FAO), several countries around the world are improving food security and agriculture by using nuclear and isotopic techniques to protect plants from insect pests and to breed new plant varieties that show improved crop yields, disease resistance and/or drought tolerance. Others use these techniques to protect the health of their livestock and enhance reproduction. For example, the IAEA assists countries like Senegal to use the sterile insect technique in eradicating tsetse flies, which used to decimate livestock.

As foodstuffs are prepared for consumption, irradiation helps to ensure quality and safety. With IAEA assistance, some countries use irradiation to eliminate potentially harmful bacteria and unwanted insect pests, while others benefit from their use in extending food shelf life.

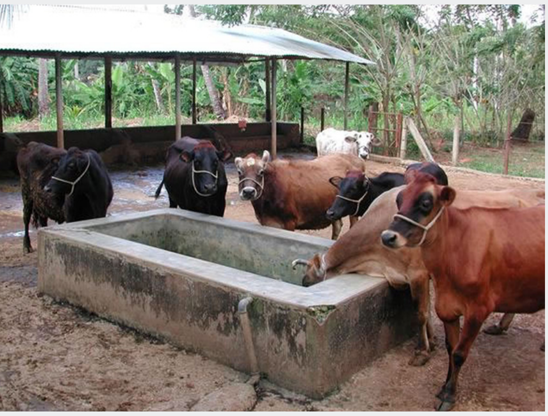
Food insecurity and agricultural challenges often lead to hunger and malnutrition. Using stable isotope techniques, health professionals can monitor body composition and food intake and absorption to better understand the complexities of malnutrition and whether treatment and prevention measures are effective.

3 GOOD HEALTH AND WELL-BEING

Achieving sustainable development is not possible if health suffers due to debilitating diseases and health conditions. To help achieve the SDGs target of reducing deaths from non-communicable diseases by one third, the IAEA is well-positioned to assist countries in tackling cancer by helping them to devise comprehensive cancer control programmes, establishing nuclear medicine, radiation oncology and radiology facilities, as well as supporting education and training for specialized health professionals. The IAEA's work contributes to improved cancer management and access to care worldwide.

The IAEA also works to improve the utilization and reliability of facilities, including research reactors, that produce life-saving radioisotopes and to support countries in limiting patients' overexposure to radiation during medical procedures.

With greater access to radiation and nuclear medicine technologies, countries are also able to more precisely diagnose and manage diseases, like cardiovascular disease, as well as monitor and evaluate health


(Photo: IAEA)


(Photo: IUCNweb/flickr.com/CC BY 2.0)


(Photo: Philipp P Egli/CC BY 3.0)

conditions, such as tuberculosis and other infections.

With the help of nuclear techniques, for example, scientists and health workers in Guatemala are now able to identify the causes and consequences of malnutrition in the country’s children, enabling policymakers to devise strategies to combat obesity and stunting. The IAEA also supports countries in developing capabilities for the early detection of diseases that spread from animals to humans, such as Ebola.

6 CLEAN WATER AND SANITATION

Water is essential to life. As populations grow and economies expand, access to clean and safe water is imperative. Isotopic techniques shed light on the age and quality of water. Some countries, such as Brazil, use this to implement integrated water resource management plans to sustainably use resources and to protect water and water-related ecosystems, while others use the data to address scarcity and improve freshwater supplies.

The IAEA’s work includes helping farmers in Africa to use their scarce water resources efficiently through nuclear and isotopic techniques, establishing isotope laboratories in the Middle East for studying groundwater resources, and assisting in the development of water use and management policies in the Sahel region.

As society leaves its mark, water pollution is also a challenge. With IAEA support, some countries are now turning to radiation technology to treat industrial wastewater, reducing contaminants and improving water quality, making water safer for reuse.

7 AFFORDABLE AND CLEAN ENERGY

Access to clean, reliable and affordable energy is a precondition for sustainable economic growth and improved human well-being, affecting health, education and job opportunities. The IAEA fosters the efficient and safe use of nuclear power by supporting existing and new nuclear programmes around the world, catalysing innovation and building capacity in energy planning, analysis, and in nuclear information and knowledge management. The IAEA helps countries meet growing energy demands for development, while improving energy security, reducing environmental and health impacts, and mitigating climate change.

The IAEA supports countries considering and planning the introduction or expansion of their nuclear power generation capacities, assisting and guiding them through all stages of the process towards the safe and secure use of nuclear power.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Cutting-edge industrial technologies underpin the success of strong economies, in developed and developing countries alike. Nuclear science and technology, in particular, can make a major contribution to economic growth, and have an important role to play in support of sustainable development.

With the IAEA’s help, some countries have increased the competitiveness of their industries by using these technologies for non-destructive testing in safety and quality tests, and irradiation techniques for improving product durability, from car tyres to pipelines and medical devices to cables.

Industrial testing using nuclear technology has contributed to the competitiveness of Malaysia’s manufacturing sector, for example. The country has built itself a niche in South-East Asia, offering non-destructive testing with nuclear devices to manufacturers in neighbouring countries.

Irradiation also improves industrial sustainability by helping to lower environmental impact through treatment of flue gases at coal-fired power plants and through the identification of pollution pathways in the air.

13 CLIMATE ACTION

Nuclear science, including nuclear power, can play a significant role in both climate change mitigation and adaptation. Nuclear power, along with wind and hydro, is one of the lowest-carbon technologies available to generate

(Photo: A. Nassir Ibrahim/Madani NDT Training Centre)

(Photo: FAO/IAEA)

(Photo: P. S. Hai/Dalat Nuclear Research Institute) electricity. The IAEA works to increase global awareness of the role of nuclear power in relation to climate change, in particular to try to ensure that the role that nuclear power can and does play in assisting countries to reduce their greenhouse gas emissions is properly recognized.

Nuclear power forms an important pillar of many countries' climate change mitigation strategies, and an increasing number of countries are considering nuclear power within their national energy portfolios.

Nuclear science and technology can play a vital role in assisting countries to adapt to the consequences of climate change. With the IAEA's support, the use of nuclear techniques has led to better flood control in the Philippines, to the development of new irrigation techniques in increasingly arid regions of Kenya, and to the creation of new wheat seed varieties in Afghanistan that thrive in harsh environmental conditions.

14 LIFE BELOW WATER

Oceans contain vast ecosystems brimming with marine life, and are a vital resource for people that rely on the sea for their livelihood, day-to-day nutrition, or both. To sustainably manage and protect oceans and, in turn, support coastal communities, many countries are using nuclear and isotopic techniques, with support from the IAEA, to better understand and monitor ocean health and marine phenomena like ocean acidification and harmful algal blooms.

The IAEA assists Member States in the use of nuclear techniques to measure ocean acidification, and provides objective information to scientists, economists, and policymakers to make informed decisions.

National, regional and international laboratory networks established through IAEA coordination also offer several countries an avenue for scientific collaboration, and are key resources for analysing and monitoring marine contaminants and pollutants.

15 LIFE ON LAND

Desertification, land degradation and soil erosion can jeopardize lives and livelihoods. Isotopic techniques provide accurate assessments of soil erosion and help to identify and trace erosion hot spots, providing an important tool to reverse land degradation and restore soils. These include using fallout radionuclides, which help to assess soil erosion rates, and compound specific stable isotope analysis, used to identify where eroded soil originated. Furthermore, the IAEA is supporting Member States to fulfill their obligations to combat desertification.

The IAEA's support in these areas helps many countries to gather information using these techniques to shape agricultural practices for more sustainable land use. This contributes to higher incomes, while also improving conservation methods and protection of resources, ecosystems and biodiversity.

Farmers in developing countries such as Viet Nam use these tools to identify the source of soil erosion afflicting their plantations, allowing them to save their farms and earn extra income.

17 PARTNERSHIPS FOR THE GOALS

Partnerships with Member States are at the heart of the IAEA's activities. Close collaboration between the IAEA, United Nations organizations and other international and civil society organizations also helps to maximize the impact of the IAEA's support towards the achievement of Member States' development priorities.

In 2014, the IAEA provided support to 131 countries and territories through its technical cooperation programme.

In cooperation with its partners, including a global network of regional resource institutions and collaborating centres, the IAEA promotes science-based policy making and access to technology and innovation.

Longstanding partnerships, such as the ones with the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), allow international organizations to combine their skills and resources in their respective areas of expertise and mandate to support Member States.

To ensure that the IAEA's assistance is tailored to the specific needs and priorities of its beneficiaries, and is sustainable in the long term, activities are based on consultations with Member States. Over 90 Member States already have in place Country Programme Frameworks that identify areas of cooperation with the IAEA in support of their national development priorities.

IAEA Member States also share their knowledge, technologies and best practices through regional technical cooperation projects – including regional/cooperative agreements – coordinated research projects and projects involving the IAEA's specialized laboratories. The IAEA promotes and facilitates bilateral, South–South, sub-regional and topical collaboration among countries, regulators and institutions.

Nuclear-derived techniques improve cattle productivity and milk quality in Cameroon

By Aabha Dixit

Increasing agricultural production and improving the quality of milk and meat are key to combating poverty and increasing food security in Africa. Countries such as Cameroon are increasingly turning to innovative, nuclear and nuclear-derived techniques to control and prevent diseases among livestock, and boost cattle and milk production.

"Nuclear techniques are important tools in practically all fields of animal science when the objective is to advance the productivity and health of economically vital domestic animals," said Abel Wade, Head of Cameroon's National Veterinary Laboratory (LANAVET). "Our country will face an unprecedented animal-product supply crisis if we don't use all the available scientific tools to ensure good breeding and increase the healthy cow head count." Cows are the main livestock in Cameroon: the country has 5.8 million cattle, compared with 4.6 million goats and 4 million sheep. Cattle are also regarded as a symbol of wealth.

Since the early 1990s, the IAEA has assisted Cameroon through its technical cooperation programme to use nuclear and nuclear-derived procedures such as radioimmunoassay (RIA) and enzyme-linked immunosorbent assay, molecular diagnostics and genetic screening in reproduction and breeding, artificial insemination and disease control programmes for livestock. Nuclear techniques for artificial insemination were introduced in Cameroon eight years ago. "If we don't have healthy cows, we will not have good meat to eat or nutritious milk to drink," said Wade.

Focus on productivity

In collaboration with the IAEA and the Food and Agriculture Organization of the United Nations (FAO), LANAVET and the country's Institute of Agricultural Research for Development are training veterinarians, veterinary extension services and breeders on disease control and artificial insemination to improve cattle productivity, breeding management and animal health control. Artificial insemination allows scientists to improve the genetic make-up of the offspring, leading to up to five times more milk produced per cow, said Mario García Podesta of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

The methodology assists technical staff in improving the reproductive management of cattle farms and in obtaining more calves, meat and milk than with traditional farm management. The application of progesterone RIA in artificial insemination helps to identify 20–40% more cows for breeding than conventional methods that involve watching behavioural signs. It can subsequently increase the conception rate by between 5% and 50%, depending on the effectiveness of the traditional method and management previously used, said García Podesta.

Improving livestock also involves tracking and preventing diseases such as contagious bovine pleuropneumonia, brucellosis, tuberculosis, peste des petits ruminants and African swine fever. LANAVET is performing surveillance to detect infectious diseases in northern Cameroon, where the seasonal movement of people with their livestock between summer and winter pastures poses disease risks to livestock, Wade explained. Mobile labs using isotopic, nuclear and nuclear-derived techniques also help to identify these risks early and rapidly, which results in an effective response.

Reaching out

Crossbred cows in a dairy farm in Cameroon. (Photo: M. García Podesta/IAEA)

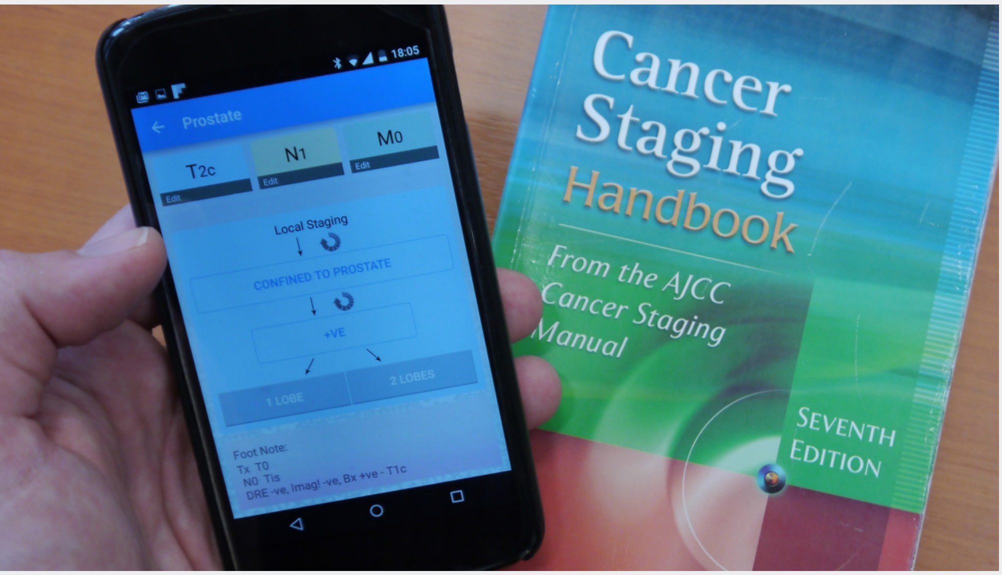
To extend awareness of the benefits of artificial insemination among rural farmers, who depend on traditional methods of cattle rearing, the Institute's regional centre in Bambui works with them directly in getting across the message, and provides access to the tools required for artificial insemination. "The proactive efforts by the Institute to successfully convince our farmers will assist in meeting the rising demand for meat and milk production," said Victorine Nsongka, Head of the Animal Production and Health Section of the Institute of Agricultural Research for Development in Bambui.

A related project, currently in its preparatory phase, will lead to the artificial insemination of 70 000 cows over the next six years in northwestern Cameroon, Nsongka said. Sponsored by the Islamic Development Bank, this initiative will also use the IAEA-supported techniques and will lead to the development of an artificial insemination and reproduction network in the region, she added.

Cameroon's government is reaching out to extend support to breeding centres in Benin, Burkina Faso, the Central African Republic and Chad to increase the number of dairy animals through artificial insemination using semen from genetically superior animals.

Towards optimal cancer treatment: the IAEA's new smartphone app for cancer staging

By Miklos Gaspar and Omar Yusuf



(Photo: IAEA)

Identifying cancer stages quickly and accurately will become easier for healthcare professionals in developing countries, thanks to an IAEA-developed smartphone app launched in September 2015 during the IAEA's 59th General Conference.

Staging cancer is a complex process, involving the integration of the results of a wide range of tests. Based on this diagnosis, physicians decide on whether surgery, radiotherapy, chemotherapy or any other form of treatment is most appropriate.

Reflecting the IAEA's commitment to building capacities in human health, the new smartphone app, available for iPhone and Android devices, will "enable cancer staging to be accessible and easy to use, and will be absolutely free of charge," said Najat Mokhtar, Director of the Division for Asia and the Pacific in the IAEA's Department of Technical Cooperation.

Typically expressed in stages ranging from one to four, with several sub-stages, the cancer staging system provides a common language for doctors and facilitates the development of a treatment plan.

The staging system, called TNM, uses the size and location of the tumour (T), whether cancer cells have spread to the lymph nodes (N), and whether the tumour has spread to other parts of the body (metastasis or M). There is a complex system to determine each of these variables particularly when the main tumour and its spread are evaluated in the entire body.

"This information will now be at their fingertips, and much easier to use through this interactive application," said Ravi Kashyap, a diagnostic radiologist at the IAEA. The app will be operational offline as well, so doctors will be able to use it in remote locations without internet access, he added.

While physicians in developed countries have had access to handbooks and sometimes computerized staging tools for years, healthcare professionals in many developing countries have until now had to resort to the handbook. "This is a small contribution, but an important step in narrowing the global divide in access to quality cancer care," Mokhtar said.

From diagnosis through staging to treatment planning: the role of the IAEA

The IAEA contributes to improved cancer management worldwide by assisting Member States in devising comprehensive cancer control programmes, implementing nuclear medicine, radiation oncology and radiology facilities, as well as supporting education and training for medical staff.

Invaluable information on the extent of cancer spread can be obtained through nuclear medicine and radiographic imaging like positron emission tomography (PET)/computed tomography (CT) scans. Knowledge of the stage of cancer based on these results then allows doctors to devise the appropriate treatment plan.

The new staging app is a reflection of the use of technology to facilitate the dissemination of information to support cancer management worldwide, said May Abdel Wahab, Director of the IAEA's Division of Human Health, adding that access to radiation medicine for early detection, diagnosis and treatment is a key step towards cancer management, an area in which the IAEA plays a pivotal role.

The app was developed by the IAEA in collaboration with the Tata Memorial Centre under the Government of India's Department of Atomic Energy and supported by the IAEA technical cooperation project 'Improving Cancer Management Through Strengthening the Computed Tomography Cancer Staging Process.'

Android

iPhone

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Commitments and Actions

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