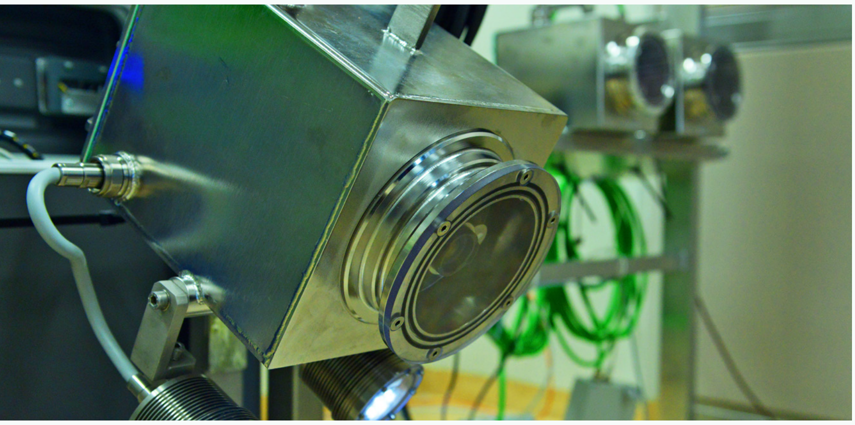
Surveying safeguarded material 24/7

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.

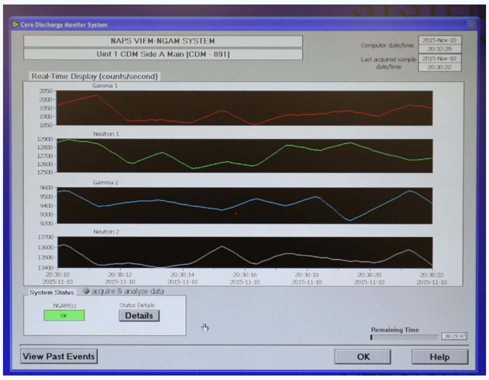
Remote radiation check

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.

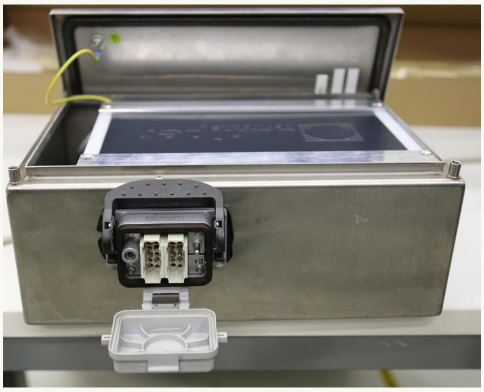
These systems can be installed and collect data in areas inaccessible to inspectors due to high amounts of radiation. Around 160 systems with a total of 700 detectors and sensors are installed in over 40 countries, Pochet said. A typical CANDU pressurised heavy water power reactor, for instance, has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



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.

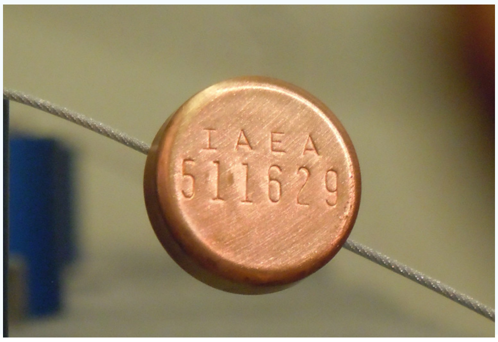
Following its debut in Iran at the Natanz Fuel Enrichment Plant in January 2016, the IAEA intends to gradually roll out the online enrichment monitor to gas centrifuge enrichment plants in other countries. Since the new technology provides continuous measurement, sample taking and environmental sampling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

The IAEA's seal of approval

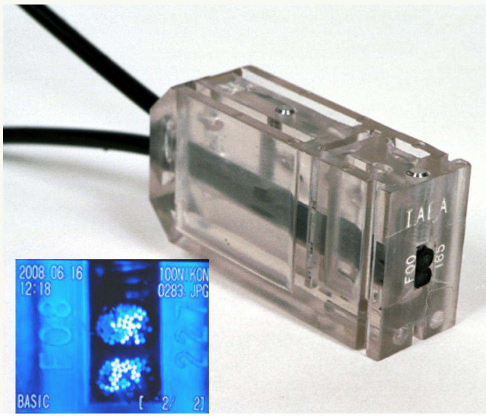
The IAEA seal is the most famous, and also the most frequently used, safeguards equipment. Although simple, these tamper-indicating devices are very efficient in deterring unauthorized access to safeguarded materials and IAEA safeguards equipment. They also provide a means of uniquely identifying secured 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.

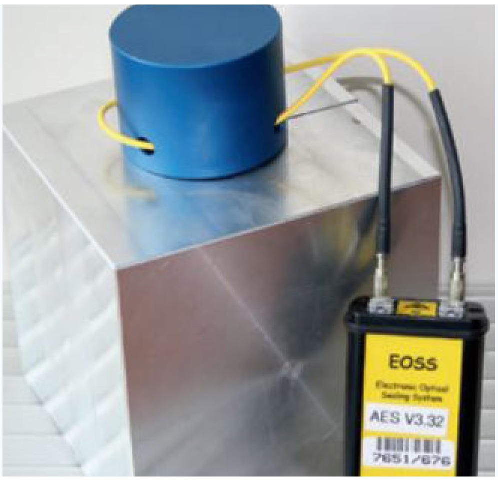
The single-use **metal cap s**eals have been in service for more than 30 years — and about 16 000 of these seals are distributed and verified every year. For identification, each seal is numbered and has unique markings on its inner surfaces, which are recorded before they are issued to inspectors. During 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.



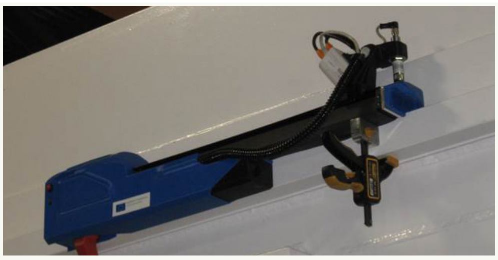
Other types of seals are verified by IAEA inspectors on location. The **COBRA seal**, for example, includes a multicore fibre optic cable with its ends enclosed in the seal body. Some of the cores are randomly cut during the closure of the seal to form a unique optical pattern. Cameras are used to record 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