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Using Nuclear Technology To Boost Security

Any apparatus that makes use of nuclear radiation is typically thought about in terms of posing significant hazards. But such devices as particle accelerators, detectors, and even nuclear reactors can also serve to improve our safety and security.

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Poland's National Centre for Nuclear Research (NCBJ), situated in Świerk outside of Warsaw, has since its inception been engaged in building particle accelerators and detectors and developing methods for analyzing the data obtained from such devices. The first commercial particle accelerators were built here as early as the 1970s, and some of them are still in operation. Although in general particle accelerators are mainly used for scientific research – like the Large Hadron Collider (LHC), the world's largest such facility, built by the European Organization for Nuclear Research (CERN) – the technology is also frequently useful in industry and medicine. For instance, it can be harnessed to inspect transported goods, and thereby to boost security. Poland's only research nuclear reactor, named MARIA, is likewise involved in safety-oriented efforts: the research conducted using the reactor helps evaluate the safety of the structural materials used in nuclear installations, which are exposed to extreme conditions.


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NCBJ (2)

Exact X-rays

If you come to visit of the site of the NCBJ in Świerk, as you approach you may notice – against the backdrop of the surrounding buildings and the reactor's ventilation stack in the distance – a shipping container sitting near the parking lot. It houses the SOWA, the world's first relocatable X-ray vehicle scanning system, designed by a team of scientists, engineers, and designers from the center's Department of Nuclear Equipment and Techniques. The roof of the container contains an X-ray tube, while the walls and the floor are fitted with a system of detectors that capture the X-rays passing through the object being investigated, providing real-time images of the smallest details of the vehicle inside the scanner, even fractions of a millimeter in size. Supplementary software creates false-color images of suspicious elements and sharpens them, so the scan results can be analyzed immediately. It takes only a few minutes to scan a whole vehicle, which is moved through the scanner remotely so the driver does not get exposed to radiation. The device was designed for use by customs agencies, border guards, the military, and other security agencies, but it can also perform vehicle safety and technical inspections. The scanner is very accurate and can spot small hidden objects, modifications, and damaged technical components. The entire system is built inside a standard-sized shipping container, so it can be easily transported.

Photos 1, 2
The SOWA vehicle scanner is used to X-ray cars to detect contraband or technical damage, allowing immediate analysis of the resulting data

Smart safeguards

Other solutions developed at the NCBJ are capable of scanning shipments of significantly larger dimensions, such as whole sea and air containers and railroad cars. Such tasks can be performed by the Polish Cargo Control System (CANIS), the predecessor of the SOWA. At the heart of this device is a special electron accelerator that produces a beam of high-energy X-rays (with much higher energy than used in medical X-ray devices, for instance). Such radiation is a lot more penetrative, making it possible to create complete scans of structures and goods inside large shipments. One unique property of the accelerator driving the CANIS system is its ability to alternately produce a beam with two different energies. Such scans make it possible to more accurately identify materials of different densities. The NCBJ's Nuclear Equipment Division is one of just a few facilities in the world capable of producing such devices. The

Photo 3
The C-BORD non-invasive shipping container inspection system during tests in Gdańsk, Poland

Photo 4
The CANIS system scans railroad cars entering the European Union

Photo 5
The mobile ISWOT device uses photon backscattering to detect people hidden in vehicles

NCBJ (3)

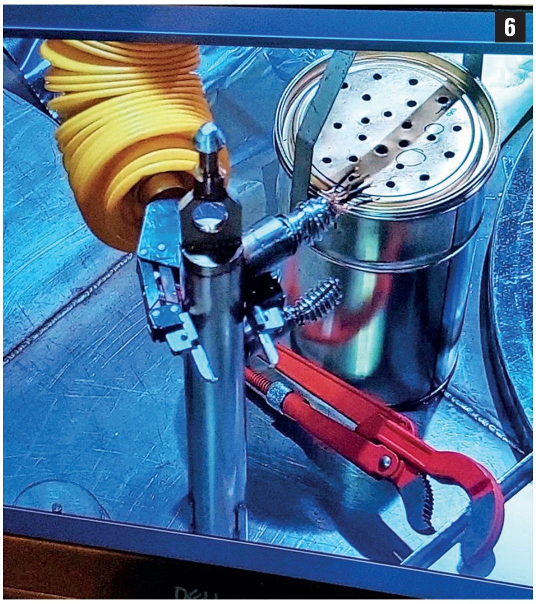
solutions used in the CANIS system make it possible to change the energy of the beam up to a thousand times per second and smoothly scan – for instance – railroad cars while the move. The Polish Cargo Scanning System has been commercialized in collaboration with the company PID Polska. A device based on this system is now being used at one of Poland's railroad border crossings, where it improves security by scanning railroad cars arriving from outside the European Union. The CANIS system also received the 2022 "Teraz Polska" Award in the category "Innovation."

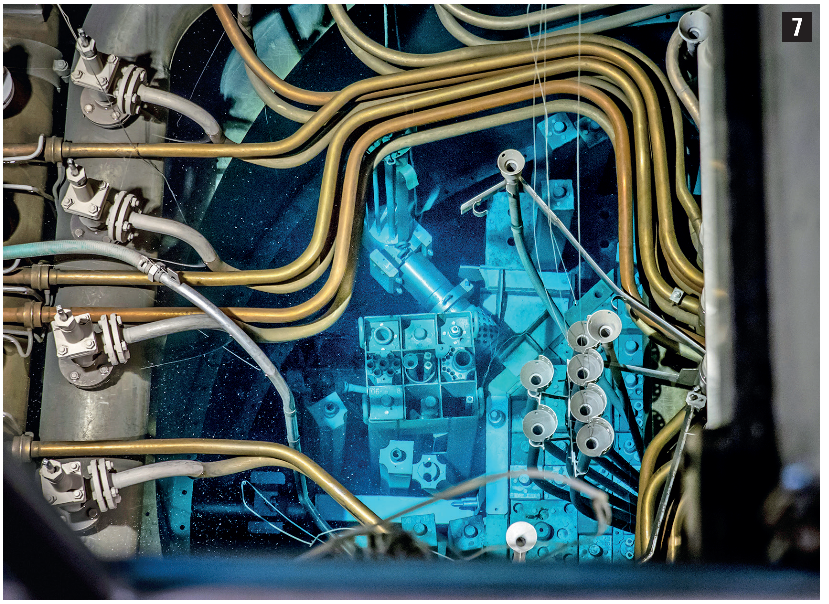
Scientists from the NCBJ were also involved in developing methods for rapid and non-invasive inspection of containers at seaports and land border crossings as part of the C-BORD project. The system integrates five different physical and chemical methods to inspect cargo: neutrons, gamma radiation, an industrial X-ray scanner, gates for detecting radioactive isotopes, and a system for chemical air composition analysis. The NCBJ has developed a detection system that searches for characteristic signals from neutrons and gamma radiation. C-BORD has been tested in the container ports in Gdańsk and Rotterdam, as well as at a roadside checkpoint in Hungary. The system proved to be effective and user-friendly for the inspectors who operated it.

Brilliant backscattering

Most procedures that use X-rays are performed using the transmission method. On one side is a source that sweeps a beam of radiation around the object being scanned; on the other are detectors that catch the photons passing through the object, allowing the obtained signal to be interpreted in terms of the properties of the objects being scanned. Such a solution is effective, but it requires separate modules (a source and a detector) and therefore more space to scan objects from both sides. An alternative solution harnesses a phenomenon called backscattering, whereby the generated particles or radiation are reflected back in the direction from which they came. This way, both the source of radiation and the detectors collecting it can be located at the same point, and it is enough to access the object being scanned from just one side.

A device using this technology has been developed by scientists from the NCBJ's Department of Nuclear Equipment and Techniques, who created a mobile scanner for finding people hidden in vehicles. It can be used for other purposes, such as scanning composite aircraft components in search of accumulated water. The innovative design also applies a unique collimation method (known as the *spinning line* or *flying line* technique), instead of the traditional (*flying spot*) method. The new technique scans an entire slice of the plane, so the source of radiation can be





NCBJ (2)

less intense because it is used more efficiently, which is crucially important in devices meant to be used to detect human beings. The device consists of an electric cart with a support arm, a head containing the source of radiation and a portable collimator, a set of scintillation detectors, plus the operator's computer with software that facilitates wireless control of the scanning process. The project is expected to be continued using an even more mobile backscattering system, meant to fit inside a van.

"Time travel" inside a reactor

The NCBJ's research aimed at improving safety in the broadest sense also involves MARIA, Poland's only nuclear research reactor. Scientists can place materials inside MARIA's core, alongside the targets for producing radioisotopes, in order to analyze how they are affected by intense neutron radiation. In recent years, this type of research has been done to investigate components that could be used in the design of future nuclear and even thermonuclear facilities. One unique feature of the MARIA reactor is the very intense neutron flux in its core, several magnitudes greater than in nuclear power reactors, neutron generators, or isotope sources. Materials placed in the dense neutron flux could be said to experience a kind of "time travel" – in just a few weeks or months, they are exposed to conditions that correspond to years or even decades spent inside a typical nuclear reactor. Scientists can therefore observe how such elements react to prolonged exposure to extreme conditions and what types of damage they sustain. Such damage, especially to the structural materials used in nuclear and thermonuclear facilities, is an important issue in safety analyses.

A major success in this area was achieved with the high-temperature capsule called ISHTAR (Irradiation System for High Temperature Reactors), developed by scientists from the NCBJ's Reactor Research Division as part of the GoHTR project. As the name suggests, the capsule was used to irradiate samples of structural elements of a high-temperature gas-cooled reactor (HTGR) and was designed to reach temperatures of up to 1,000°C in a helium atmosphere (the kind of conditions that are present in a high-temperature reactor). The capsule spent several irradiation cycles in the reactor's core, and the effects on the materials inside it continue to be analyzed.

Research using thermostatic irradiation devices is not limited to nuclear reactors. The MAKARONI irradiation rig, which contained components of the IFMIF-DONES device for irradiation and testing, was also placed inside MARIA's core. The device, which is being developed in Granada, Spain, will be used for the final testing of the components of the world's first nuclear fusion plant named DEMO, the successor to the ITER research device, which is currently under construction. The designed rig is unique in that it allows three different operating temperatures, from 300°C to 550°C, to be achieved simultaneously. Also, its construction involved the use of 3D printing in nuclear technology – a pioneering move in Poland and the region. The thermostatic irradiation rig program continues to be developed. Its creators have received a badge of honor in the field of innovation.

Constructing and operating various types of devices harnessing nuclear radiation certainly demands technical expertise, but it is not as scary and mysterious as is sometimes portrayed. The contribution of such devices to improving safety and security is plainly evident and widely recognized. ■

Photo 6
Manipulator pulling the ISHTAR high-temperature capsule into the hot cell

Photo 7
View of the core of the MARIA research reactor and its components, where materials to be irradiated can be placed

Further reading:

The MARIA research reactor, https://www.ncbj.gov.pl/en/o-nas/maria-research-reactor