The CTBT noble gas verification component

The International Monitoring System (IMS) and the International Data Centre were designed to be fully capable of monitoring compliance with the Treaty. New research and improved communication technologies continuously refine the detection capabilities of the IMS. This column introduces some of the latest developments in verification science.

The noble gas component of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) verification apparatus is at the same time the oldest and the most novel long range detection technology applied for the nuclear weapons complex. Already during World War II, Douglas A-26 Invader bombers descended over suspected atomic sites in Germany to collect air samples that were taken to a laboratory for analysis. The idea was to look for the radioactive isotope xenon-133, which would have been extensively produced in a plutonium production reactor, had there been one.

CTBT verification requires monitoring both particles and gases

Even though noble gas surveillance flights did continue through the half century of nuclear weapons testing, the technology was not advanced enough and did not provide the required sensitivity to be directly employed in the CTBT verification system. To help solve this, four countries, France, Russian Federation, Sweden and the United States have worked consistently during the last decade to develop reliable and sensitive new systems, which are fielded and tested primarily at noble gas designated International Monitoring System (IMS) stations. This endeavour is known as the International Noble Gas Experiment (INGE).

Nuclear explosions produce radioactive debris that is carried by the wind and can be collected far away. As the absolute majority of radionuclides that are formed in an explosion stick to microscopic particles, the “classical” method for long range detection of atmospheric nuclear explosions has always been to collect these particles by forcing air through a suitable filter medium.

The subsequent analyses of the filters then provide something like an open book for those who can read it. One can see whether an atom bomb or a thermonuclear bomb was tested, in what environment it was tested, what fissionable material it utilized and exactly when it was tested. Within the CTBT verification regime such analyses are planned at 80 stations to cover the atmospheric environment.

The CTBT, however, in addition requires a wider focus since it also has to cover the situation of a potential Treaty violator trying to do everything possible to evade detection. The explosion can for example take place in a rainstorm or in a big block of ice on a boat at sea with the intention to have most radionuclides washed out and deposited locally.

The comparatively few noble gas radionuclides, however, are not affected by washout because of their inherent quality, their nobleness, not to attach to other materials or atoms. For the same reason they are hard to contain in an underground explosion as they tend to be pushed out early on from the cavity by overpressure or sucked out later from cracks and faults in the ground by passing thunderstorms and low pressure weather systems. Half of the 80 radionuclide stations are therefore to be supplied with special equipment for sampling and analysis of noble gases, notably xenon.

Noble gas radionuclides of CTBT interest

The noble gases that can be found in nature are helium, neon, argon, krypton, xenon and radon. Among these, xenon provides the ultimate set of radioactive bomb products for long distance detection.

Most of these xenon isotopes are produced abundantly in the fission part of the explosion and have suitable half-lives; long-lived enough to allow for collection and analysis, but also short-lived enough to avoid building up a disturbing background reservoir in the atmosphere.

Many krypton isotopes are also abundantly produced, but they decay away within minutes or a few hours. One of them, however, krypton-85, is so long-lived that we are all currently exposed to about one Becquerel per cubic metre of it from past testing and reprocessing activities.

Argon has one isotope of interest, argon-37, that might be produced in the rocks surrounding an underground nuclear explosion. It has a life time of nearly two months, but is quite difficult and expensive to measure at low concentrations and is therefore not suitable for continuous surveillance. It can, however, be of great interest during an on-site inspection where higher levels can be anticipated and where the time scale of the operation quite well matches the life time of the isotope.

The xenon isotopes of interest are xenon-131m, xenon-133m, xenon-133

and xenon-135 with average life times of seventeen, three, eight and 0.5 days. Radionuclides decay to reach lower energy levels by emitting photons and/or material particles. Our xenon quartet does it with X rays, gamma rays and with electrons. These emissions can be measured in different ways and the amounts of the nuclides in a sample can thereby be determined.

New xenon analyzers

The four systems developed by France, Russia, Sweden and the United States utilize different parts of the radiations like X and gamma rays only or combinations of these with electrons where the detector systems make sure that the radiations were emitted at exactly the same time and therefore from the same individual nucleus.

The four systems also use somewhat different processes to extract the xenon fraction from the sampled air. All systems let the air pass through some cleaning stages before the xenon is slowed down and trapped in a column of activated charcoal. In two of the systems this charcoal is kept at a temperature of some -100 to -200 °C while the other two manage the process at room temperature. One system also makes use of a special membrane to initially enrich the xenon in the sample.

Understanding the xenon signatures

Several stations have already accumulated data on the background of the xenon isotopes. A special non-IMS station in Ottawa, Canada, has provided valuable benchmark signals of all four isotopes from a nearby plant for medical radionuclide production. Other stations have contributed to a general picture of xenon-133 backgrounds in central Europe, Scandinavia and in the Arctic. In broad terms we can say that central Europe displays a few mBq/m3 of xenon-133, and that that level is reduced a factor of ten into mid Scandinavia and further a factor of ten

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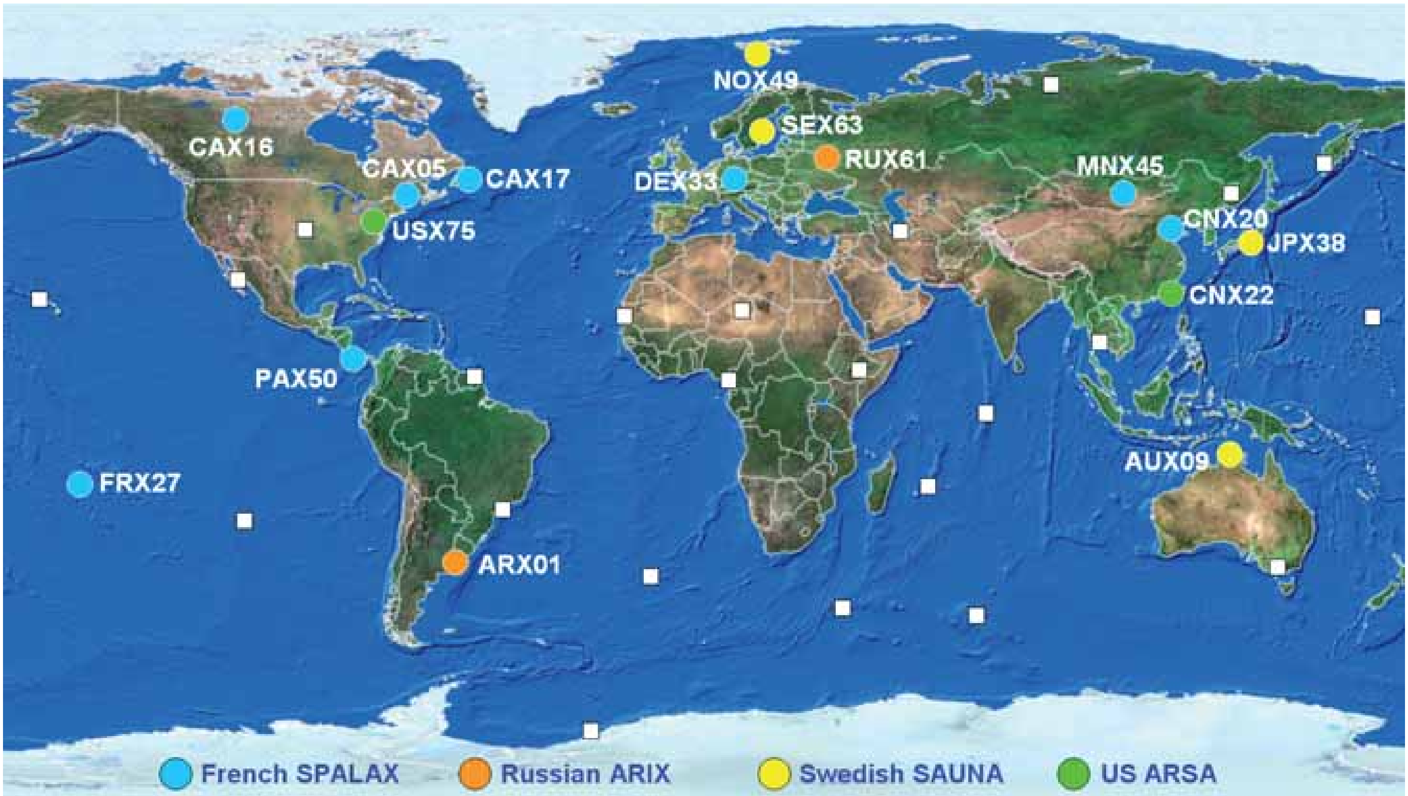

THE COLOURED CIRCLES MARK NOBLE GAS STATIONS THAT ARE EXPECTED TO DELIVER DATA BY THE END OF THIS YEAR. THE WHITE SQUARES INDICATE STATIONS THAT THEN REMAIN TO BE ESTABLISHED TO COMPLETE THE 40 STATION NETWORK (ONE STILL TO BE DETERMINED). THE STATION CAX05 IN OTTAWA, CANADA, IS A NON-IMS NATIONAL CONTRIBUTION.

process, the chairperson of the Preparatory Commission as well as bureaus of geographical and political groups, with a view to advancing the cause of the Treaty in those Annex 2 States that have yet to ratify the Treaty;

- Promoting the universality of the Treaty, as an effective instrument for international peace and security, providing assistance to States to move forward with the signature/ratification process as well as supporting States which, after ratification, need assistance in implementing the Treaty;
- Cooperating and creating synergies with international organizations by establishing cooperation frameworks with relevant international organizations. Furthermore, forging linkages with other international and sub/regional instruments, in order to ensure more visibility of the Treaty in the concerned organizations and their relevant programmes;
- Featuring the potential benefits of the verification technologies as a distinctive asset of the CTBT verification regime in external relations activities and;
- Supporting and assisting Member States to promote the Treaty in a specific country or group of countries. ■

Training

In order to assist Member States to fulfil their verification responsibilities under the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and to enable them to benefit fully from participating in the work of the Treaty regime the CTBTO Preparatory Commission has emphasized the importance of training and capacity building since its establishment.

In order to complement traditional training methods, the Provisional Technical Secretariat (PTS) has developed an e-learning project, which will provide electronic, interactive access to training courses and technical workshops to authorised users as well as continuous access to training modules.

The e-learning project will include training for national officials involved in the development and operation of verification system elements of the CTBT, International Monitoring System (IMS) technologies and station installation processes; for station managers and operators on the function and operation of station equipment and the interaction with the International Data Centre (IDC) on the function of the IDC and the analysis of IMS data; for national data centre staff on the utlization of and access to IMS data and IDC products and services; and for on-site inspection (OSI) experts and potential future OSI inspectors.

The e-learning project, which will be implemented in two phases over a period of approximately 15 months, will be financed by a Joint Action of the European Union in the magnitude of 1,133 million Euros. A pilot phase is currently in progress and is being financed by the Netherlands and the Czech Republic in the amounts of € 180,000 and € 15,263.55, respectively. ■

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into the Arctic. The main sources of this are nuclear power plants in Europe.

As the quartet of xenon isotopes is also produced and disseminated by civilian applications it is very important for CTBT verification purposes to be able to provide data that enables States to interpret the signatures as indicative of either a nuclear explosion or of some other event. It is therefore necessary to understand very well the dynamics of civilian sources like reactors and the two major radioxenon plants (Chalk River in Canada and Fleurus in Belgium). As the composition of the quartet varies in the emissions from different sources, forming ratios between the four relevant isotopes can provide insight into the origin of a given sample. Research is zealously pursued to improve the understanding of these relations.

Xenon and the waveform technologies

The waveform networks (seismic, hydroacoustics and infrasound) are able to geo-locate suspicious events, but they cannot provide evidence of the 'smoking gun' of a nuclear event. With the radionuclide technologies it is quite the opposite. They are informative on the character of the event but cannot pinpoint the location with a corresponding exactness. The answer to this is data fusion; first, a meteorological analysis to conclude from what areas of the globe radionuclides could possibly emanate and second, a comparison with waveform detections from the same area and time. It is possible, however, that in a well designed evasive scenario a nuclear event is solely detected by the noble gas system. The noble gas component is therefore of very special importance to the CTBT verification regime. ■