20121017 – Science - Technology Improving Detection of Nuclear Tests, Experts Say at AAAS Capitol Hill Event

17 October 2012
Earl Lane

There have been significant improvements during the past decade in the worldwide ability to detect covert nuclear explosions equivalent to only a few hundred tons of chemical explosive, experts told a recent AAAS-organized discussion on Capitol Hill. All but the most determined efforts at evasion likely would be spotted by a growing array of seismometers, radiation monitors, and other devices designed to detect nuclear blasts underground, underwater, in the atmosphere, and in space, they said.

In 2002, a panel of the U.S. National Research Council determined that an underground nuclear explosion with a yield of 1 to 2 kilotons (equivalent to 1000 to 2000 tons of TNT) could not be confidently hidden once a fully functional seismic monitoring system was in place as part of preparations for enforcement of the Comprehensive Nuclear-Test-Ban Treaty.

That treaty, adopted by the United Nations General Assembly on 10 September 1996, still is not in force because the United States and several other nations with nuclear technology have yet to ratify it.

But development of a sophisticated monitoring network has continued nonetheless. The International Monitoring System (IMS), operated by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna, Austria, is now about 80% complete—with more than 260 facilities certified—and is much more capable than the system in place when the National Research Council made its projections in 2002.

Richard Garwin

The system, when fully built, will consist of 337 facilities worldwide that employ four monitoring methods:

Seismic: 50 primary and 120 auxiliary stations for detecting shockwaves caused by such events as earthquakes, mining explosions, and nuclear blasts.

Hydroacoustic: Six underwater hydrophone stations and five land stations that monitor the oceans for underwater explosions. Sound waves associated with explosions can travel thousands of miles underwater.

Infrasound: 60 surface stations that can detect ultra-low-frequency sound waves (inaudible to the human ear) emitted by large explosions.

Radionuclide: 80 stations that measure airborne radioactive particles associated with nuclear explosions (half of the stations also detect varieties of a noble gas called xenon that are associated with nuclear explosions). The stations are supported by 16 radionuclide laboratories.

“Technical capabilities have improved significantly in the past decade,” said physicist Richard Garwin, an IBM Fellow Emeritus and member of another National Research Council study panel that recently updated the 2002 report and reviewed technical issues related to the test ban treaty. He and other specialists on nuclear test monitoring spoke at a 24 September Capitol Hill discussion organized by the AAAS

Center for Science, Technology and Security Policy.

The update from the Council (the principal operating agency of the National Academy of Sciences and the National Academy of Engineering) was released in March. It concluded there is now 90% confidence that the IMS seismic stations could detect an underground nuclear explosion well below 1 kiloton in most regions. The first-generation nuclear weapons that were used against Japan in World War II had yields of between 10 and 20 kilotons.

More than 2000 nuclear tests were carried out between 1945 and 1996, when the Comprehensive Nuclear Test Ban Treaty was opened for signature. The United States conducted 1032 tests, the Soviet Union more than 715, France more than 210, and the United Kingdom and China 45 each, according to the CTBTO. Three countries have broken the de facto moratorium on nuclear testing since 1996: India, Pakistan, and North Korea.

Under normal circumstances, a nuclear blast with a yield of 1 kiloton creates a seismic signal approximately equal to a magnitude 4.0 earthquake.

Lassina Zerbo

Lassina Zerbo, director of the International Data Centre for the CTBTO, said there now is a 90% probability that at least three seismic stations in the monitoring system will pick up an underground explosion in the northern hemisphere comparable to a 3.5 magnitude earthquake and an explosion comparable to a 4.0 magnitude quake in the southern hemisphere.

The detection capability will continue to improve as more facilities are added in the southern hemisphere and elsewhere. “We’re continuing to install stations and improving our processing method,” Zerbo said, “and then we’ll certainly be much better than where we are today.”

In addition to the IMS facilities, there are thousands of seismometers and other sensors worldwide that can help pick up signs of a nuclear blast, including “national technical means” deployed by individual countries (such as the U.S. Atomic Energy Detection System operated by the Air Force) and seismometers used by hundreds of academic and governmental research institutions.

Paul Richards

Data from the many seismometers worldwide can be combined to provide clues on the location, size, and character of various explosive events, said Paul Richards, a professor of natural sciences at Columbia University’s Lamont-Doherty Earth Observatory. Even a nation such as North Korea, which shares no seismic data with outsiders, is surrounded with detectors in nearby countries. There are 24 high-capability seismic stations in South Korea, Richards said, and more than 1000 stations have been installed in China during the past decade.

Ray Willemann

"Currently, access to them [the Chinese stations] is not as good as one would like," he said. "But certainly, to a subset of these stations, there is open access." Nearby, Japan is perhaps the best-monitored country in the world, with about 2000 seismic stations.

"So for the question of what assets are available to monitor North Korea," Richards said, "it's just quite an amazing variety."

Ray Willemann, director of planning for the Incorporated Research Institutions for Seismology (IRIS), noted that portable seismology instruments—provided by IRIS to scientists funded by federal agencies—give excellent baseline information on how seismic waves propagate through particular parts of the Earth. For example, use of portable instruments has allowed American researchers and their local partners to understand much better how seismic waves are distorted as they travel from sites in India and northwestern China to U.S. monitoring systems or the International Monitoring System, he said.

A state could try to elude detection by "decoupling" a small nuclear blast in a deep underground cavity where the amplitude of the vibrations through surrounding rock would be reduced. They also could try to mask the seismic waves from a nuclear blast by conducting the test near a working mine site where conventional explosions occur frequently. But the National Research Council study found that mine masking is a less credible evasion scenario now than it was at the time of its 2002 report because of improvements in monitoring capabilities.

With better regional seismic networks, improved understanding of the seismic background signals (from several hundred earthquakes and several thousand mine blasts that occur every day), and better calibration of seismic stations, the research council panel concluded that an evasive tester in Asia, Europe, North Africa, or North America would have to restrict a nuclear device’s yield to less than 1 kiloton—even if fully decoupled or mine-masked—to ensure no more than a 10% chance of seismic detection. Such evasion methods also would run the risk of detection by other means, such as human intelligence leaks by mine workers or cavity excavators.

At well-monitored locations, the yield would have to be even smaller—on the order a few hundred tons of TNT or less—to give hope of getting away with it, the study concluded. It did note that more work is needed to better understand the local geology in regions where seismic waves are strongly attenuated. Iran, much of Turkey, and other parts of the Middle East are regions of poorer propagation of seismic waves, according to the study.


Robert Werzi

Of course, seismology is only part of the international monitoring effort. Robert Werzi, senior expert on radionuclide technologies for the CTBTO, said about 80% of the radiation monitoring stations for the IMS are now operational, with sensors that can readily identify nuclear-related releases worldwide. Within one month after the tsunami-related nuclear disaster at the Fukushima power plant in Japan in March 2011, all of the IMS radiation monitors in the Northern Hemisphere detected radioactive particles from the plant and several stations in the

Southern Hemisphere, including one at Rio de Janeiro, also detected material, Werzi said. He said experts have made promising advances in their ability, using computer models, to pinpoint the origin of atmospheric nuclear releases (whether from power plants or bombs) and to predict where they will travel over time.

Even with the best technology, Garwin said, “there’s always a level at which a tester can confidently test and not be detected” by seismic instruments. He mentioned the possibility of carrying out tests with yields of only a few kilograms TNT equivalent inside an artificial pressure vessel sufficiently strong to contain the blast wave and other byproducts of the explosion. But Garwin said the National Research Council panel concluded that an evader wouldn’t benefit much from such a small-scale test.

He also noted that rogue nations may want the world to know they are nuclear-capable and take no steps to hide their tests. That was the case for North Korea, for example, which tested nuclear devices in 2006 and 2009, each of which was promptly detected.

Continuing improvements in the number and sensitivity of monitoring tools should make evasive testing of nuclear weapons a formidable challenge, Richards said. Only “at very low levels of yield” could a state or group hope to escape notice, he said, and “the chief goal of the monitoring effort is to drive ever downward the yields of anything that might go undetected or unidentified."

20130212 – Nature - Nuclear detectives sniff out North Korea

Radioisotopes may provide key details on nuclear test.

- Geoff Brumfiel

Corrected:

1. 13 February 2013

With this morning's announcement by North Korea that it has conducted its third nuclear test, experts are closely watching a network of seismic monitoring stations for hints of what sort of test it was. Ratios of radioisotopes could help to verify the explosion and perhaps even provide clues about the type of device detonated — but only if the radioactive gases can be identified before they decay.

Seismic stations detected the underground blast at 11:57 a.m. local time. The data, from the US Geological Survey and the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), showed a sudden, strong earthquake occurring at a depth of about 1 kilometre from the surface in the same region as North Korea's two previous nuclear tests. The blast, which registered on seismographs at around 5.0 in magnitude, was roughly twice the power of the country's last test in 2009. That puts it in the range of several kilotonnes of TNT, according to Tibor Tóth, head of the CTBTO in Vienna, which monitors globally for clandestine nuclear testing.

The seismic signature, together with North Korea's open declaration of having conducted a test, are strong evidence for a nuclear detonation. But "the smoking gun will be the potential radionuclide release”, says Lassina Zerbo, who oversees the CTBTO's data centre. In particular, researchers will be looking for radioactive isotopes of xenon produced in the explosion.

Plutonium or uranium?

Xenon, a noble gas, interacts only weakly with the environment and can thus slip unimpeded through the rocks and backfill that North Korea's scientists will have used to seal the entrance to the test tunnel. Once airborne, it can drift towards the CTBTO's monitoring stations, which are located in countries including China, Japan and Mongolia, where it can be detected using a specially developed gas chromatograph. The US Air Force also has special aircraft that can search for xenon from above, although it does not share its data openly.

Xenon data would provide strong evidence of a test and could give details about the type of nuclear weapon used, says Anders Ringbom, a researcher at the Swedish Defence Research Agency in Stockholm. Ratios of various xenon isotopes can point towards whether North Korea's latest weapon was made of plutonium or uranium, he says. Both the 2006 and 2009 tests were believed to have been conducted using plutonium, but the country is suspected of having a uranium-enrichment programme and may have developed a uranium device. A uranium bomb would be particularly worrying because, until now, North Korea has been forced to rely on its limited supply of plutonium for weapons.

The ratios of xenon isotopes might even be able to reveal whether North Korea tested a weapon that was 'boosted' with tritium and deuterium, two hydrogen isotopes. Such a device would release more energy than simple fission and would thus be smaller and more powerful than a conventional atomic bomb. "It looks like boosting will also affect the ratios, but it might be more complicated," Ringbom says.

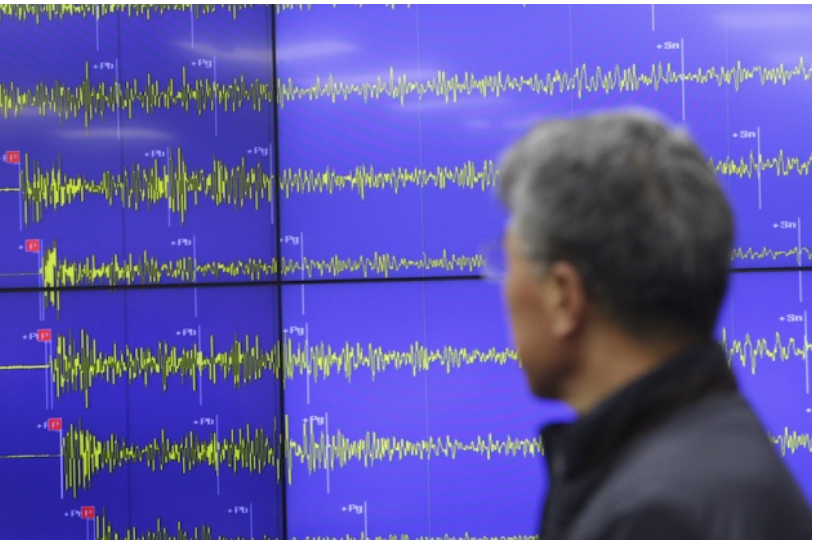
The detection of xenon might not be able to say that much, however, warns David Keir, programme director at the Verification Research, Training and Information Centre, a London-based non-profit organization. Other civilian nuclear facilities also produce xenon, and such releases could trigger a false detection or muddy the result. "The thing is, a nuclear weapon and a nuclear reactor are substantially the same thing," Keir says. "The real smoking gun is if you can get inspection on the ground."

And it may be that monitoring stations will see nothing. Although a station in Canada detected xenon after the first test in 2006, its monitors failed to see anything following the country's larger test in 2009. This may have been partly due to the fact that North Korea's scientists had become better at sealing their tunnels, but "there's also a certain amount of luck involved" in detection, Ringbom admits.

Whatever detection is achieved, it will have to be obtained fairly quickly if it is to provide substantive insight: xenon-133m, a metastable isotope needed to pin down the type of weapon, has a half-life of just 2.2 days. But Ringbom remains optimistic that a signal will appear in the coming days. "If our measurement is good then we might be able to say something," he says.

20160108 – Nature - What kind of bomb did North Korea detonate?

Within hours of North Korea’s fourth nuclear test on 6 January, data pouring from seismic monitoring stations had shown that the explosion was almost certainly not a hydrogen bomb — contrary to claims made by the totalitarian, isolated state. Scientists are now relying on luck — and prevailing winds



A South Korean official examines the seismic signature of a nuclear test from North Korea on 6 January. Chung Sung-Jun/Getty Images.

— to find out more about the design of North Korea’s device.

They hope that radioactive gases leaking from the underground explosion will be picked up by a global network of monitoring stations managed by the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), based in Vienna.

By comparing the ratios of various isotopes of xenon, an unreactive gas that can permeate the rock that sealed the blast, researchers might be able to determine whether the bomb was made from uranium or plutonium, and whether it was a conventional fission device, or a smaller, more-efficient "boosted" fission bomb.

But speed is of the essence: detectors would need to precisely measure xenon isotopes before some of the radioactive gases decay.

Not a hydrogen bomb

North Korea claimed to have produced a hydrogen bomb, but the small explosive yield of the blast probably rules that out. The seismic event it caused was estimated by the CTBTO at magnitude 4.85, much the same as the 2013 test. Its explosive yield is likely to have also been similar, at the equivalent of around 10 kilotonnes of TNT, says James Acton, who studies nuclear policy at the Carnegie Endowment for International Peace in Washington DC.

A hydrogen bomb would have created a blast hundreds or thousands of times more explosive. In this kind of bomb, energy released from a fission-based device is used to trigger a separate secondary nuclear fusion reaction, in which hydrogen isotopes fuse together, typically releasing energy equivalent to megatonnes of TNT.

But it is possible that by “hydrogen bomb”, North Korea was referring to a boosted fission device that contains hydrogen, Acton says. This is a conventional fission bomb that contains a small quantity of the hydrogen isotopes tritium and deuterium, which fuse to release extra neutrons that greatly boost the fission reaction and explosive yield.

Experts have speculated for years that North Korea might be working on such a device. Boosted devices are smaller yet can be just as powerful as fission bombs, making them more suitable for use in missile warheads. The research involved in developing them is also a step along the way to developing thermonuclear weapons.

Boosted fission?

Xenon isotope ratios might be able to help determine whether the device was boosted in this way, says Hugh Chalmers, a senior researcher at VERTIC (the Verification Research, Training and Information Centre), a non-profit organization in London.

“If the test device was boosted, it would have consumed much more of its fission fuel than if it hadn’t,” he says. “If states can get strong and accurate measurements of fission products released from the test, the isotopic ratios may provide clues as to how efficiently the fission fuel was burnt, and whether this fuel was consistent or inconsistent with a boosted device".

Those ratios could also reveal whether North Korea’s weapon was made of uranium or plutonium. Past bombs are believed to have been built using the country's limited domestic supply of plutonium; North Korea is widely suspected of having a uranium-enrichment programme, but that hasn’t yet been proved.

Little time to tell

But xenon isotopes must be detected quickly and in sufficient amounts to distinguish them from the signals generated by sources such as civilian nuclear-power reactors. As time passes that gets harder: some isotopes decay very rapidly. The half-life of one isotope called xenon-133m, needed to pin down the type of weapon detonated, is just 2.2 days.

Although the CTBTO detected xenon two weeks after North Korea’s first test in 2006, it detected none after the country’s 2009 test, and only spotted xenon more than a month after a third nuclear test in 2013. That was too late for useful forensics.

And as the radioactive gases are transported through rocks and air, adds the CTBTO’s Martin Kalinowski, some isotopes of xenon become more enriched than others. This can blur the signatures of the original explosion.

Without other sources of intelligence, the chances of reliably determining what kind of nuclear weapon North Korea did detonate are low, he thinks.

20170906 – Nature - North Korea's nuclear test

North Korean nuclear test is biggest yet

North Korea carried out its sixth nuclear-bomb test on 3 September. The explosion at an underground site in Punggye-ri had a yield equivalent to around 120 kilotons of TNT — six times greater than the country's previous test in 2016 — said NORSAR, a geoscience research foundation in Kjeller, Norway. As with previous tests, North Korea claimed it had detonated a hydrogen bomb, which uses a conventional nuclear-fission device to trigger

North Korean leader Kim Jong-un, second right, inspecting an alleged nuclear device. KCNA via REUTERS

a secondary, more powerful fusion reaction The event had an estimated seismic magnitude of 6.3 — bigger than previous tests — but the bomb type cannot be determined from seismic data alone. The larger blast makes North Korea's claim more credible, says NORSAR. [Leakage of radioactive particles] from the test site could reveal whether the blast was from a hydrogen bomb.

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