

SPECIAL REPORT: Did Maridia Conduct a Nuclear Test Explosion? On-Site Inspection and the CTBT

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The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) Preparatory Commission launched a large-scale simulation of an on-site inspection in Jordan on November 3, 2014, to test the organization's ability to find a nuclear test explosion site. The exercise, involving two fictitious countries, lasted for five weeks and used 150 tons of equipment to comb a large swath of land next to the Dead Sea.

The inspection area encompassed 1,000 square kilometers, the maximum area allowed by the Comprehensive Test Ban Treaty (CTBT), although the 30-day inspection period for the exercise was much less than the potential 130 days that the treaty allows. Searching for clues of a nuclear explosion in such an expanse and in such a shortened time period was a daunting task. It required the international teams, comprising 200 scientists and experts in on-site inspection technologies from 44 countries, to focus on their respective tasks for 12- to 14-hour days.

The 40 inspectors employed 15 of the 17 techniques provided in the treaty, some for the first time. The on-site inspection began with less-intrusive techniques, such as visual observations (including satellite imagery), overflights, and seismic networks, and moved into more-intrusive techniques, such as magnetic field mapping and electrical conductivity measurements. The objective was to narrow down the areas of interest to one limited area where the inspection team found traces of relevant radionuclides, the "smoking gun" indicative of a possible nuclear explosion. The CTBT provides for inspection measures that are more intrusive than those of any other arms control treaty.

The purpose of the exercise in Jordan, called Integrated Field Exercise 2014 (IFE14), was to test the Provisional Technical Secretariat's ability to conduct the complex logistics, procedures, and techniques in a cohesive manner. The Preparatory Commission has been working on the key provision of on-site inspection for several years so that it will be sufficiently developed and operational prior to the CTBT's entry into force.^[1] Such an inspection cannot be requested until the treaty is in force.

The CTBT specifies 44 nuclear-capable countries that must ratify the treaty to bring it into force, and eight of those ratifications are still lacking (China, Egypt, India, Iran, Israel, North Korea, Pakistan, and the United States). All the countries that have signed but not ratified the treaty (China, Egypt, Iran, Israel, and the United States) participated in IFE14.

On-site inspection is a significant, final component of the CTBT's verification regime and is seen as a deterrent to noncompliance. The other components include the International Monitoring System (IMS), comprised of 337 seismic, radionuclide, infrasound, and hydroacoustic facilities, which transmit data from the stations to the CTBTO International Data Centre in Vienna. Under the terms of the CTBT, neither the inspection team nor the Technical Secretariat can make a judgment about the nature of an event or the measures to be taken in the case of possible noncompliance. That is the prerogative of the states-parties.

The Scenario

Did the fictional state of Maridia really detonate a nuclear device underground early in the morning of October 28? Its neighbor, the fictional country of Alluvia, certainly thought so, based on the discovery of telltale clues—a seismic event followed by unusual radionuclide isotopes detected by the IMS. Alluvia decided to request the ultimate verification measure, an on-site inspection under the CTBT. Thus began IFE14, which took place near the peak of Mount Nebo.

The scenario, which presumes that the CTBT has entered into force, began at 5:54 a.m., when the CTBTO recorded a magnitude 4 seismic event and then detected xenon-133 coming from the state of Maridia, located in the Middle East. To the trained analyst's eye, it did not look like an earthquake. In addition, Alluvia's national radionuclide station detected xenon-133 coming from Maridia. For its part, Maridia expressed its "outrage and grave concerns about the false and unfounded accusations" made by Alluvia in the request for an on-site inspection. Maridia said it had never violated its obligations and had always been a staunch supporter of the treaty.

The treaty requires the CTBTO Executive Council to decide within 96 hours whether to conduct an inspection, and on November 3, it voted to do so.^[2] Once the council had endorsed the inspection, inspectors had to arrive within six days in Maridia. The Technical Secretariat's On-Site Inspection Division and Operational Support Center began to mobilize immediately. All members of the inspection teams, which had been trained by the secretariat, were called to duty. The treaty provides for a roster of on-call inspectors rather than having them on staff because an on-site inspection is not likely to occur frequently. The secretariat arranged visas and air tickets for inspectors who assembled at the airport in Amman.

The inspection team developed an initial plan, and the support center checked that the 431 pieces of equipment, including seismic sensors, magnetometers, geophysical instruments, and radiation monitoring devices, were working properly. Each piece of equipment carries a bar code so that it can pass quickly through the loading and receiving area. All 150 metric tons of equipment were sealed in containers and sent off to Maridia within the six days.

The logistics of such an operation are complex. The Preparatory Commission keeps the equipment in a warehouse in Vienna. For IFE14, the Provisional Technical Secretariat devised plans, maps, routes, color-coded templates, and log forms. After arriving in Jordan, the inspection team set up a base of operations in a parking lot overlooking the Dead Sea and Jerusalem.

Although participants slept in a nearby hotel, the base became home for the experts serving in the exercise. It consisted of numerous inflatable tents that served as work spaces for representatives of the inspection team and Maridia, as well as management, communications personnel, and evaluation teams. A receiving area was designed to scan people and equipment with dosimeters for possible radiation exposure. A decontamination tent stood nearby with shower facilities and a 500-liter water tank. A doctor staffed a medical tent. Inspectors installed ultra-high-frequency and very-small-aperture-terminal (VSAT) antennas to ensure communication with the teams in the field as well as with Vienna. Portable laboratories consisting of tightly outfitted cargo transport containers analyzed samples brought back from the field to detect the possible presence of radionuclides.

Inspectors deployed the world's only portable laboratory designed to analyze argon. Inspection team and Maridian representatives were required to inspect each piece of equipment before leaving for the field and after they returned, when they reviewed together the data harvested. They analyzed three to five samples each day.

In addition to working in the field or analyzing data most of the day, the teams held multiple meetings in the morning and evening to review the day's activities and plan the next few days. Because IFE14 was an exercise, the inspected state-party had fewer staff in its contingent than it would have had in real life. With only about 25 people on its team, many of them had multiple functions.

"No one is being paid extra for this," said inspector Natalie Brely, chief of the Provisional Technical Secretariat's Monitoring Facilities Support Section. In the exercise, she directed the convoys each day, insisting that they stick together.

Revealing Signs

The first few days after a nuclear test are crucial because the telltale signs, called signatures, of a nuclear explosion are most pronounced during this period. When the cavity created by a nuclear explosion begins to collapse, it causes seismic aftershocks, which dissipate exponentially. So do radionuclides. Xenon-133 has a half-life of 5.24 days, and argon-37 has a half-life of 35 days. Therefore, the inspection team must act with great haste. It is looking for radionuclides, consisting of fission products and noble gases that are listed in the Preparatory Commission's manual for on-site inspections.

Thus, setting up the 18 seismic aftershock monitoring stations was a high priority. The positioning of this system is based on the location of the epicenter of the seismic event. Differentiating between normal radioactivity in any given area and radionuclides coming from a nuclear explosion can be quite difficult because the absence of radionuclides does not exclude the possibility that a nuclear test took place. If the explosion is fully contained, there might be no seepage through the rock fissures or cracks, although this would be unusual.

Safety and security were paramount during the exercise. To cope, five means of communication were available, from cellphones to satellite antennas. This combination provided coverage that was close to 100 percent, allowing the base to be able to reach the inspectors even in the deep canyons of the region.

The inspection area ranged from the Dead Sea, which lies 1,378 feet below sea level, to mountains reaching 6,083 feet above sea level. The terrain includes numerous valleys and sinkholes and is susceptible to landslides. The inspection team also needed to bargain with Bedouins herding sheep, donkeys, and camels and with private landowners whose permission was needed to install equipment or to conduct gamma surveys.

Further complications came from rain and the presence of scorpions and rodents. Almost every day, the rodents nibbled their way through cables, causing a certain amount of data loss.

The inspection teams snaked through the mountains in convoys of five cars, including one that carried a VSAT communications satellite rack on top, and always included one or more gendarmes supplied by the government of Jordan. In spite of the strains in the war-ridden region, Jordan was seen as providing an example for Egypt, Iran, and Israel, the nearby countries that are among the eight whose ratification is still needed for entry into force of the CTBT. Mohammad Hassan Daryaei, former counselor at the Iranian mission in Geneva who was an IFE14 observer, said he was "amazed by the level of maturity of the [on-site inspection] capability and component."

Every day, four or five teams inspected different sites. In the early phase of the inspection, one team used helicopters to cover the entire inspection area of 1,000 square kilometers with handheld cameras. Later, the helicopters would carry equipment capable of multispectral imaging, which can provide additional information about changes in surface and subsurface features, and gamma spectroscopy, which assists in identifying elevated levels of gamma radiation. Inspectors relied initially on visual observations to detect anomalies on the surface, such as fresh landslides, scraping of earth, new roads, and roads leading to nowhere. They also used satellite imagery to look for changes in order to focus on specific areas and eliminate others.

The inspection team started the initial phase (November 11-20) with the least intrusive techniques and proceeded to more-intrusive techniques during the so-called continuation period (November 22-December 4). In the treaty, the initial phase is to last 25 days, after which the teams must send a preliminary report to the Executive Council. The council could then vote to end the inspection; otherwise, the inspection would continue. For IFE14, the initial phase was compressed into 10 days.

Parsing the Polygons

Based on visual observations on the ground and from the air, inspectors found a number of areas of interest, which they blocked on maps in areas known as polygons. By November 20, the team had

created 29 polygons. Within days, however, it began to eliminate some in the southern part of the inspection area where the team found no interesting evidence of nuclear testing. The objective was to narrow down the territory to be inspected so that the team could focus on a smaller area with more-sophisticated inspection techniques to identify or confirm the possible nuclear nature of an underground explosion.

As part of this process, inspectors took samples of earth, plants, and debris on top of rocks or even on the tires of vehicles. Although most of the detection equipment is very sophisticated, the inspectors resorted to using small shovels to dig up the dirt, small plastic bags to hold the plant material, and plastic wrap to rub against rocks to remove debris for a sample. They divided each sample into two, one for the inspection team and one for Maridia, and immediately labeled them with barcodes for chain of custody and identification purposes back in the laboratory.

Within 10 days, the inspectors were focusing their search on two polygons of high interest (numbers 18 and 29), where they began to take samples of soil, plants, and soil gas. Mysteriously, in polygon 18, newly laid stones forming a staging area appeared at the end of a short dirt road that ended at a locked grated door on the side of the hill. The inspection team suspected that the door might lead to a tunnel under the hill. The team asked Maridia if it could sample the air from the top of the door and then sucked air from behind the door with a tube leading to an air sampler mounted on a pickup truck. The sample was compressed into what looked like a scuba tank and taken back to the base of operations for analysis.

One of the inspectors walked up the hill above the locked door and began to swipe a pipe sticking out of the ground. When he reached the cap on the top of the pipe, he tried to swipe around under the cap, but it fell off into his hand. This caused quite a stir because he was supposed to ask permission before swiping anything.

“Inspectors don’t manipulate things without asking first,” said the senior representative of the Maridian team at a subsequent meeting with the inspection team. “I will, of course, give you a chance to explain, but my government is not happy about this and expects an explanation. You will not go back to the site if this happens again.”

He also suggested that the inspector might be asked to leave. The inspector in question replied, "Believe me, no one was more surprised than I that the cap fell off into my hand." He explained that as he swiped the pipe near the lid the cap fell off. "The hinge on the cap was broken," he said.

It was a crucial time in the inspection, as the inspection team wanted to introduce two large geoprobes into polygons 18 and 29 the following day. These large machines, which poke holes up to about five meters into the ground, had to be delivered by large flatbed trucks. The senior representative of the Maridian team said that it would usually take three weeks to obtain permission to enter the requested area with such equipment, and he would get back to the team the following day about further action. When the team asked to visit another location, he said that there were local landowners who did not want inspections on their land, so he would have to get permission.

The inspection team leader later told his colleagues that Maridia "shows interest in getting us out of the area sooner rather than later, so it is worthwhile to begin continuation-period techniques." These inspection techniques assist in locating features of possible nuclear explosions conducted underground, such as certain tunnel infrastructures. They are employed when the inspectors conclude the initial inspection period of 25 days and have narrowed down the search to a number of limited areas of interest that are roughly the size of a soccer field.

These techniques are more intrusive than those used in the initial period of the inspection. One such technique is gravitational field mapping to measure changes in the earth's gravity. Another is magnetic field mapping from the air and the ground to measure the deviations in the earth's magnetic field that could indicate the presence of pipes, cables, and shafts.[\[3\]](#)

According to the preliminary inspection report of November 22, during the initial period, the team conducted 137 field missions, including sampling and laboratory activities at the base of operations. The team identified 29 polygons of interest, triggering 35 ground visual observation field missions and numerous radionuclide missions.

Maridia strongly condemned Alluvia's "malicious act" of calling for an on-site inspection and provided an explanation of the nature of the event. Maridia is located in a part of the Middle East where three tectonic plates meet, providing active seismicity in the "Palestine-Sinai subplate." This complex tectonic setting produces frequent earthquakes. Indeed, the location of the suspected event that triggered the on-site inspection is in an area of known seismic activity, consistent with the fault lines shown in a map that Maridia produced. Thus, Maridia said, the event was an earthquake.

In addition, Maridia contended that the xenon concentrations detected at the radionuclide station of the IMS originated from a medical isotope production facility southwest of Maridia where molybdenum-99 is produced from the fission of uranium targets. Maridia was aware that molybdenum-99 was being produced for 12 days (October 20-31) prior to the IMS radionuclide detections. For the same reasons, Maridia dismissed the radioxenon signals from Alluvia's radionuclide station. The report noted that seismic aftershock monitoring had detected four local seismic events. One was identified as an explosion and at least one as a potential aftershock.

The report concluded that there was "a discrepancy" between the clarification provided by Maridia and the inspection team findings within the inspection area. Therefore, "the collection by the inspection team of facts as are relevant to the...inspection has not yet been concluded."

At the beginning of the continuation period, one of the inspection teams returned to polygon 18 to begin the laborious process of gravimetry, measuring the changes in gravity in the field above the locked door to determine if there was a tunnel below. This technique involves dividing the area into quadrants of four square meters, using stakes, tape, and orange spray paint to mark where the gravimeter should take measurements.

Another inspection team set out for a second visit to polygon 29. A Bedouin accompanying his large flock of sheep occupied the road, so experts waited in the car, listening to the famous Lebanese singer Fairouz on the Palestinian radio station. This polygon was located in an old quarry, and noting the interest of the inspection team, Maridia quickly established a restricted access site. According to

the treaty provisions on managed access, an inspected party can delineate an area of four square kilometers as off-limits to inspectors in an on-site inspection.

Citing security risks, Maridia said the team could not enter the area. In the area, inspectors saw a pipe sticking up from the ground with wires coming out of it. This could be a strong clue of instrumentation underground. They also saw that buildings were fractured, which could have been caused by the ground motion from an explosion or earthquake. In addition, the inspection team observed freshly plowed land next to the site. Satellite photos showed that the road leading to this part of the site had been upgraded since September.

The inspection team ordered that large geoprobes be placed in polygons 18 and 29 to sample the subsoil for radiation. Maridia managed to delay the deployment of the geoprobes for a few days, but they arrived on November 26. At polygon 29, the geoprobe drilled some holes in the ground, and the inspectors placed tubes into the holes to draw air overnight into a large yellow balloon. They compressed the air from the balloon into a scuba tank so that they could bring it to the portable laboratory at the base of operations to analyze it. As the machine probed the earth, one member of the Maridian team kept repeating, "You will find nothing. My country is innocent."

In a November 21 interview, Peter Sankey, a senior scientist at the United Kingdom's Atomic Weapons Establishment who helped create the IFE14 scenario, said he thought the exercise, as a whole, was going well. "We need to quicken the uploading and processing of information, and [fix] a few other kinks, but it is demonstrating an integration of techniques and procedures," he said. The 2014 exercise showed "dramatic progress" over the one in 2008, he said.

Multiple Missions

The teams planned the work of each day two days in advance. Each day, the teams set out on various missions, including overflights, visual observations, gamma radiation monitoring, and environmental sampling with equipment to monitor air particulate and noble gas. Gamma radiation monitors were mounted in airplanes, cars, and even backpacks to trace the possible presence of radionuclides. Each team comprised a color-coded representative from the inspectors (light blue), Maridia (red), a control team to monitor that the teams operated within the limits of the scenario (bright blue), an evaluation team (green), and a management team (black).

Early in the continuation period, an additional overflight, along with updated information from the International Data Centre on the area of the epicenter and ground-based missions, resulted in most polygons in the southern part of the inspection area being moved lower on the list of sites of interest or eliminated from it. Others, in particular numbers 18 and 29, continued to elicit high interest, requiring the more sophisticated inspection equipment that is used in smaller areas of concern.

Mounting Evidence

By December 2, the noose seemed to be tightening on Maridia. "We have now had several significant detections of xenon in polygon 29 from analyses of soil gas samples," said Charles Carrigan, who played the role of a key member of the Maridian team. (Carrigan is a physicist at Lawrence Livermore National Laboratory, where the soil gas sampling system used by inspectors was developed.) It would be a significant challenge to explain the presence of xenon as resulting from something other than an underground nuclear explosion. "There are a lot of technologies to potentially deploy and only a small amount of time to really use them, given the compressed nature of the field component [of the exercise]," Carrigan lamented.

Nevertheless, the inspection team found enough evidence to press its case. It detected xenon-133, xenon-131m, and argon-37 in subsoil gas samples taken at polygon 29 at a level that "could be considered as strong evidence of a nuclear explosion," according to an expert. As noted above, however, the CTBT gives the states-parties, not the inspectors or the secretariat, the right to make a judgment about the findings of an inspection.

On December 6, members of the inspection team and Maridia met to sign and formally exchange the Preliminary Findings Document on the inspection. Maridia held to the position that no test had

occurred in this seismically active part of the world and that the xenon gases detected were not of weapons origin. The iodine-131 detected came from a spill of a radiotracer used in a groundwater study at the quarry in polygon 29, Maridia argued. In the end, the main evidence against Maridia was noble gases. Although the high level of observed argon-37 might be expected in a limestone quarry location, Maridia had a difficult task in explaining the xenon. Experts quietly noted that the findings were indicative of an underground nuclear explosion in polygon 29.

Methodology

Senior experts from China, France, Germany, Israel, Russia, the UK, and the United States created the scenario for this simulation. A number of them had worked on nuclear testing for many years. Other experts commended their ability to design a clever, challenging, and plausible exercise. Only the control team, comprising individuals involved in the elaboration of the scenario, knew the scenario in advance, and they kept it quiet. As there has not been any nuclear testing in Jordan, it was essential to create a convincing scenario so that the inspectors could collect credible data.

As part of the exercise, the control team injected variables to ensure that the inspection operated within the boundaries of the scenario and that the objectives of the exercise could be accomplished. The designers of the scenario actually detonated three chemical explosions in order to create the seismic signals and injected radioactive noble gases into some samples before they underwent analysis in the laboratory so that it would appear that a nuclear explosion might have been conducted.

Ward Hawkins, project leader at Los Alamos National Laboratory, chaired the task force set up in November 2012 to create the event. He said the group studied 150 potential locations, using maps and aerial photos, to determine which would be the best place to test the 15 on-site inspection techniques. "The exercise needed to be technically realistic, rationally coherent, temporally logical to narrow the search area, and intellectually motivating," he said in an interview on November 24. He said the inspection team was more or less where it should be at that point and that he thought the exercise would demonstrate that it is possible to catch a noncompliant state.

The exercise in Jordan was the second and largest IFE conducted by the Preparatory Commission. The first took place in 2008 at the former Soviet nuclear test site of Semipalatinsk in Kazakhstan. In that exercise, the Preparatory Commission learned a great deal about how to test crucial aspects of the various phases of an inspection as well as the gaps to be filled. A robust evaluation process revealed the areas that required more work and refinement.

What has changed since 2008? North Korea has conducted another two tests (2009 and 2013), both of which were detected by the Provisional Technical Secretariat. The IMS is now more than 90 percent complete. Communications and data analysis systems have been improved. In addition, the Preparatory Commission had conducted a number of build-up exercises and field tests to test various individual on-site inspection techniques and prepare for IFE14. As noted above, the IFE14 inspection team employed 15 of the 17 on-site inspection technologies provided in the treaty, whereas in Kazakhstan it tested 10. Drilling and resonance seismometry were the only two not employed in Jordan.

Another significant difference between the 2008 and 2014 exercises was the role of the United States. The country did not participate in any on-site inspection activities during the administration of President George W. Bush and therefore did not participate in IFE08. Now it is contributing fully, which makes a substantial difference as the United States has extensive experience and expertise in this field. Washington sent a number of experts from its national laboratories and the Defense Threat Reduction Agency to take part in the exercise.

In addition, some participants said they believed that the recent IFE was based on a scenario that was more plausible and technically credible than the one in 2008.

The Provisional Technical Secretariat spent \$10 million on the exercise; the European Union and 10 countries^[4] contributed another \$10 million in voluntary funding and in-kind contributions. As a finale to the 2014 exercise, a South Korean Ministry of Defense representative told the observers

that his country is thinking about hosting the next IFE.

An Assessment of IFE14

IFE14 will provide a wealth of information, scientific findings, and recommendations. The Preparatory Commission expected to obtain information about the preparedness of the inspection team in a number of areas, in particular radionuclides; multispectral imaging, including infrared equipment; continuation-period technologies; documentation; and shortcomings. This will entail a lengthy evaluation period.

In the first stage of the evaluation process, the Provisional Technical Secretariat will hold a two-part workshop, one near Tel Aviv in April and one in Vienna in June, to obtain reactions from the participants, examine the functioning of the equipment, assess procedures and management, and make recommendations. In addition, the participants will review the observations of an external evaluation team. All of these elements will be integrated into a new On-Site Inspection Action Plan to be submitted to the signatory states of the Preparatory Commission by the end of 2015 for further action. According to the commission, the plan will address achievements, progress made since IFE08, capabilities requiring further development or training, and recommendations to be approved by signatory states.

Although it is too early to draw conclusions about IFE14, some of the experts shared a few preliminary observations. While expressing a strongly positive view of the exercise overall, they noted some flaws. They found that some members on the inspection team missed seeing some obvious indications. In some instances, the inspection team underestimated the time it would take to go to proposed deployment sites and did not sufficiently review the data in advance to determine that some seemingly suitable locations might be out of the question as sites for a nuclear test. Some of the equipment malfunctioned (a high-resolution camera on an initial overflight, some radionuclide detectors, other equipment that resulted in delays of additional overflights).

The equipment likely should have been operated or tested more often while in storage in Vienna, the experts said. It took the inspectors longer than expected to find the iodine-131 at polygon 29, and in general, they should have taken more samples than they did, according to the experts. Undoubtedly, these and other criticisms will be aired at length in the workshops in 2015, and experts will be provided opportunities to find ways to rectify the problems.

Countries are expected to honor their legal commitments to treaties they have signed, and they usually do so. Thus, an on-site inspection under the CTBT will be an unlikely although very significant event. Nevertheless, it is valuable to test the provisions of a regime that has been so arduously developed over the years.

Although many countries that have ratified the treaty have expressed frustration that the treaty has not entered into force because certain countries have not ratified it, only one country, North Korea, is not abiding by it. Russia, the UK, and the United States have not conducted a nuclear test since 1992, France and China since 1996, and India and Pakistan since 1998.

The CTBT has established a norm against nuclear testing. Nevertheless, countries cannot request an on-site inspection until the treaty enters into force.

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ENDNOTES

1. The Comprehensive Test Ban Treaty (CTBT) stipulates that until it enters into force, the organization is to be called the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), which has a Provisional Technical Secretariat. Thereafter, these will be

the CTBTO and the Technical Secretariat.

2. The CTBT requires the support of 30 of the 51 members of the Executive Council for this measure. As the exercise began after the vote occurred, a tally was not provided.

3. Other examples are electrical conductivity measurements to identify metallic objects near the surface and disturbances deeper underground, ground-penetrating radar to locate buried objects, and active seismic surveys to identify anomalous areas.

4. The 10 contributing countries are Canada, China, the Czech Republic, Hungary, Italy, Japan, Jordan, Sweden, the United Kingdom, and the United States.

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