SCIENCE DESK

How to Listen For the Sound Of Plutonium

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WASHINGTON, Jan. 30 - In March 2004, the science and technology directorate of the Central Intelligence Agency called a secret meeting of hundreds of the government's top experts in nuclear intelligence to address a problem that had bedeviled Washington for decades: how to know, with precision, when a country is about to cross the line and gain the ability to build an atomic bomb.

The aim of the two-day conference was to reinvigorate the nation's atomic espionage efforts, not with spies on the ground or satellites in space but with a new generation of advanced technologies meant to detect the faintest clues of nuclear activity.

The meeting, said an official who attended, "was to galvanize people to say, 'We recognize this is a big problem and we need to get everybody thinking about it.' "

"There was a hope that, out of this, promising new approaches might be identified," the official continued.

The experts discussed a range of potential tools, including new ways to monitor electric power lines for the signature of high-speed centrifuges as they purify uranium and lasers that can track radioactive dust. Also on the agenda were more fanciful items, like robotic butterflies that can monitor an atomic site while appearing to flutter by innocuously.

Nearly two years later, federal officials and scientists say that meeting and other secret actions have accelerated the government's efforts to develop new atomic espionage technologies. The research focuses on better detection of four basic, but inconspicuous, signatures that covert nuclear facilities and materials can emit: distinctive chemicals, sounds, electromagnetic waves and isotopes, or forms of the same element that have different numbers of neutrons, a subatomic building block.

Now, the Iranian crisis could pose a big test of how far that technology has come. On Thursday in Vienna, the board of the International Atomic Energy Agency is to consider what to do about Tehran's recent decision to restart its enrichment of uranium, which many Western nations see as a major step toward the acquisition of nuclear arms.

American officials say better remote monitoring -- some of which appears to have already begun-- could prove crucial if Iran follows through on its threat to limit cooperation with international inspectors.

At a minimum, the crisis is putting more pressure on intelligence agencies to find out if Iran harbors secret nuclear sites. And after Iraq, there is huge pressure to get it right.

It is hard to say which, if any, of the new ideas have come to fruition because the work is highly classified. So too, it is unclear how well an improved generation of monitoring devices are yet helping American intelligence officials see into Iran, North Korea or other states suspected of trying to build atomic weapons. The C.I.A. declined comment.

However, officials say that the program has become a high priority and that the work is now spread across the C.I.A.,

the Energy Department and the Defense Department, as well as government laboratories, military contractors and universities.

One participant in the C.I.A. meeting characterized the effort as a bureaucratic overreaction prompted by a string of recent intelligence failures. "We're throwing money at it," he said. "We've created a whole business of people looking for needles in haystacks." That participant, like many other scientists and officials, spoke on the condition of anonymity because of the effort's secrecy.

One topic at the C.I.A. meeting was tiny monitoring devices that can fly. Federal researchers are creating new classes of such remote-controlled aircraft, pushing the art of miniaturization in what are known as microflyers. Discussion focused on whether such devices could carry minuscule sensors to sniff out atomic activity.

That effort is embryonic, experts say. The government's research program centers more immediately on developing larger but still stealthy sensors that can detect the making and manipulation of such key atomic ingredients as uranium hexafluoride gas, which is fed into centrifuges as part of the enrichment process.

One way to track the gas is to detect atmospheric rises in radioactivity as well as the uranium 235 isotope, which is unique to enrichment. Federal experts say research on that goal is under way at the Oak Ridge National Laboratory as well as the Los Alamos and Livermore weapons labs. Steve Wampler, a Livermore spokesman, said the California laboratory could say nothing "beyond that the work is an important element for proliferation detection."

Another goal, officials say, is to develop remote means of tracking plumes from clandestine sites that leak the chemical byproducts of uranium hexafluoride, revealing the presence of the toxic gas. "That's the smoking gun," a nuclear expert said.

Sidney Drell, a Stanford University physicist who has long advised the federal government on national security issues, lauded the overall effort. "It's important to get, as early as possible, reliable evidence on what may be clandestine facilities," he said. "Being able to develop better ways to do things like this is a high-priority issue."

Tehran's acts have given sudden prominence not only to research meant to improve atomic espionage but, in less classified forms, to aid the nuclear inspectors of the United Nations' I.A.E.A.

Even the less secret versions of such technologies can be quite exotic, including sensors that track ghostly particles known as antineutrinos -- a kind of antimatter.

There are signs that atomic espionage is already aiding Washington's hunt for clandestine Iranian sites. Late last year, Iran publicly complained to the United Nations about two unmanned American aircraft that it said crashed on its territory. In interviews, two federal intelligence experts said such drone aircraft, launched from Iraq, periodically spy on suspected nuclear sites.

"They look for all kinds of emissions," said a senior intelligence official.

The United States has practiced various forms of atomic surveillance since the earliest days of the cold war, flying jets around the globe to pick up radioactive dust from atomic testing, or to detect faint emissions from plants harvesting plutonium for bomb fuel.

In 1991, the research began focusing more intensely on uranium, the other main path to building nuclear weapons. This came about when United Nations inspectors discovered, after the gulf war, that the United States and its allies had vastly underestimated Iraq's progress on developing a uranium bomb.

In the mid-1990's, the I.A.E.A. conducted studies to investigate the monitoring of air, water and land for clues. A 1999 agency report found that uranium releases might be detected at distances of up to 64 kilometers, or 40 miles, but cautioned that, over wide areas, pinpointing the source would be difficult.

"The conclusion was, 'Yes, it's technically feasible,' " recalled Jill Cooley, a senior I.A.E.A. official. "However, it was seen as being extremely expensive to implement," requiring dense arrays of detectors to monitor target areas successfully. "For us, it didn't seem like the bang was worth the buck."

The landscape changed drastically by early 2004. After invading Iraq, the United States came to realize that it had overestimated Saddam Hussein's efforts to make unconventional arms. At the same time, intelligence officials saw that they had seriously underestimated the damage done by Abdul Qadeer Khan, the Pakistani nuclear engineer who had secretly supplied nuclear know-how to Iran, Libya, North Korea and perhaps other countries.

The twin failures produced a surge of interest in improving the methods of atomic espionage.

The C.I.A. meeting, held on March 18 and 19 of 2004 at the Virginia offices of Science Applications International Corporation, a federal contractor, came just two months after Dr. Khan's arrest. Its speakers included Dr. Duane F. Starr, an expert on nuclear proliferation at Oak Ridge in Tennessee, a federal complex that specializes in how best to gather intelligence on the use of uranium abroad.

A recommendation of the meeting was that the United States build a secret center where scientists could practice monitoring the kind of first-generation centrifuges sold by Dr. Khan.

"The notion of a test bed was really pushed," a participant recalled, using the phrase to describe a centrifuge facility where American researchers could conduct surveillance experiments. "The problem was that it was seen as expensive, really expensive."

Although the United States obtained some of these centrifuges from Libya after it agreed to end its nuclear program, it is not known whether the government has used them as part of a testing facility.

Several intelligence experts said they believed Iran was well aware of the range of remote sensors trained on its corners, even if it did not know their specific technical capabilities, and was probably engaged in devising countermeasures. It is a kind of technological intelligence race.

Robert Joseph, the under secretary of state for arms control and international security, who has led the drive within the administration to find new ways to pressure Iran and North Korea, called the research vital.

"There is an urgency and imperative to invest in the technology to determine which approaches are best," he said in an interview. While declining to discuss specific methods, he added: "Some will work. Some will not. But it is the geopolitics that makes this urgent."

Experts inside and outside the Bush administration agree that the new technologies, even if successful, are no substitute for the human inspectors of the International Atomic Energy Agency, who have the right, at least on paper, to examine closely suspect facilities.

The Iranians, say I.A.E.A. inspectors, are acutely aware that many if not all detection technologies work best in close proximity to nuclear facilities. That is one reason Iran's recent threat to stop cooperating with inspectors worries Western nations that are trying to negotiate limits on Tehran's nuclear efforts.

"There is a lot we can now do with remote sensing," a senior government official said recently. "But it is very hard when you talk about activities going on in buildings that don't generate a unique signature. There are real limits to what you can do."

Chart/Diagram: "Faint Clues of Hidden Acts"
Technologies that may help determine if a country is developing nuclear arms focus on these "signatures" that can emanate from conversion and enrichment facilities.

CHEMICALS -- The enrichment process includes the making and refinement of uranium hexafluoride. Chemical byproducts from this work can leak into the atmosphere, where they can be tracked.

ACOUSTICS -- Uranium gas is purified in centrifuges at extremely high speeds, giving off a telltale whirring.

ISOTOPES -- Elevated levels of uranium 235, the form of the element used in reactors and bombs, are a sign that work is under way to enrich ore so it can sustain nuclear reactions.