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The shots heard 'round the world

India conducted three nuclear tests on May 11 and two on May 13.

By David Albright

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India's underground nuclear tests on May 11 and 13 caught the world by surprise. Although intelligence agencies had monitored the Pokhran test site for years, they missed the preparations for these tests, resulting in a widely criticized intelligence failure.

"Weaponization is now complete," A. P. J. Abdul Kalam, scientific adviser to the defense minister and the leading figure in the development of India's ballistic missile, told a press conference in New Delhi on May 17. "Weaponization" refers to the process of turning a nuclear explosive into a militarily deliverable warhead or bomb. Both India's short-range Prithvi ballistic missile and the intermediate-range Agni are capable of carrying "any type of warhead," Kalam said. As for the warhead, "It can even carry flowers," he added with a smile.

But, said Kalam, the command and control systems for a nuclear weapons arsenal need to be consolidated. (It is ironic that Kalam, an observant Muslim, had to wait for the formation of the Hindu nationalist-dominated government of Atal Bihari Vajpayee to get the go-ahead to conduct the tests.)

India quickly announced a moratorium on further underground nuclear tests. Defense Minister George Fernandes said, "I can assure you that the tests have given us whatever inputs we needed and there is no reason why we should go in for more tests."

Confirming Fernandes's statement is difficult. It is not known how much India learned from the tests, or what exactly it wanted to learn in the first place. The tests have certainly provided India's nuclear weaponeers with important information. But if India actually deploys nuclear weapons, it may want to

conduct additional tests to answer new questions about existing designs or to develop more advanced ones. Pakistani actions could also spark additional Indian tests.

After the tests, Prime Minister Vajpayee declared to *India Today*: "India is now a nuclear weapon state." But will it decide to deploy a full range of nuclear weapons? And how many weapons will it decide to build? Gen. K. Sundarji, a former chief of staff, believes India needs a "minimum" deterrent of 30 to 40 nuclear weapons. Gen. V. N. Sharma, another former chief of army staff, believes that 50 warheads should do; nevertheless, he calls for "going whole hog" in developing delivery systems. Once India starts deployment, will inertia lead it to build an arsenal of hundreds of warheads, one that could challenge China's numbers?

India's tests sparked condemnation and inevitable questions about India's actual accomplishments. In particular, India's announcements of the explosive yields of its tests were challenged by several seismic experts. And its statement that it exploded a two-stage thermonuclear weapon surprised many experts who thought India's nuclear weapons program was less advanced.

"Shakti 1998"

On May 11, India conducted three simultaneous nuclear tests at the Pokhran test range, a desert site located about 350 miles southwest of New Delhi. Each shot was said to be in its own shaft, although some accounts said that only two shafts were used.

The test site, which was built in the early 1980s, had undergone extensive preparations during the last several years. However, a series of Indian governments had decided not to conduct tests, despite growing pressure from leaders of the nuclear weapons establishment to do so. In late 1995, however, U.S. intelligence agencies detected preparations for a test, which led the U.S. government to confront the Indian government of Prime Minister Narasimha Rao. Rao canceled the planned tests. When Vajpayee was briefly prime minister in 1996, he ordered the renewal of test preparations. But his shaky coalition lost power before the decision could be implemented, and the next government did not want to test.

The tests were organized by the Department of Atomic Energy (DAE) and the Defence Research and Development Organisation (DRDO), which develops advanced weapons for the military. The DAE, which operates the Atomic Energy Commission (AEC) and the Bhabha Atomic Research Center, is in charge of designing nuclear explosives and producing nuclear components.

DRDO is responsible for producing high-explosive components and weaponizing the nuclear devices.

Scientists at a May 17 Indian press conference said the three tests were a fission device with a yield of 12 kilotons, a thermonuclear device with a yield of 43 kilotons, and a third device of less than a kiloton. According to Rajgopala Chidambaram, DAE secretary and chairman of the AEC, the smallest device had a yield of 0.2 kilotons.

The 12-kiloton device (Chidambaram later said it had a yield of 15 kilotons) was said to have been an improved version of the device tested in 1974, being lighter and more compact. According to one Western scientific expert, a Bhabha scientist told him in the late 1980s that Bhabha had designed a fission device with a mass of about 200 kilograms--considerably lighter than the device India detonated in 1974.

India said that the 43-kiloton explosion was a thermonuclear device that used a fission explosion to trigger a fusion explosion. Chidambaram stressed at the press conference that the device was not a "boosted" fission weapon. He added that India had designed such a weapon, but had decided not to test it. He said the low yield of the H-bomb was deliberate, because of fear of seismic damage to nearby villages, the nearest of which was five kilometers from ground zero. Chidambaram later told an Indian TV station that India could have produced a 200-kiloton thermonuclear weapon.

India conducted two more tests on May 13, with yields between 0.2 and 0.6 kilotons, the government said. These later tests may have been conducted in a single shaft.

Although India's nuclear fission explosives are believed to have relied on the implosion of plutonium, the designs of the sub-kiloton devices are subject to speculation. Indian nuclear scientists have speculated that at least one test may have used highly enriched uranium. Some nuclear weapons experts have speculated that the low-yield tests may have included a "one-point" safety shot. Or they may have aimed to expand India's knowledge of nuclear weapons by testing a design with less plutonium, or by exploring the location in the yield curve (the "cliff") at which a fission design, intended to be part of a boosted fission weapon, would no longer work.

India has refused to say whether it used plutonium or highly enriched uranium, but most commentators believe the tests used plutonium, because India is known to have a large stock of unsafeguarded plutonium.

India also did not reveal whether the fusion material used in the thermonuclear device was lithium deuteride, tritium, or both. Bhabha started

producing lithium 6 almost a decade ago and began producing tritium even earlier. Bhabha also recently opened a tritium production plant, which can extract significant quantities of tritium from the heavy water irradiated in its CANDU power reactors.

What the tests achieved

Considerations of national security were an important factor in the decision to undertake the nuclear tests. According to Kalam: "When nuclear technology and defense technology meet, they get transformed into nuclear weapons technology. This is what the nations witnessed on May 11 and 13." India says the tests provided "critical data for the validation of our capability in the design of nuclear weapons of different yields for different applications and different delivery systems."

Earlier, Western analysts suspected that India's technical nuclear community was divided about whether India's nuclear weapon designs would work adequately as military weapons. According to the top Indian nuclear scientists, the latest tests were the culmination of a joint weaponization program started years ago by the DRDO and the DAE. These tests appear to demonstrate a range of weapons designs.

P. K. Iyengar, former chairman of the AEC and a key player in the development of the 1974 device, said in an interview that the tests show that India has three categories of nuclear weapon designs--a low-yield tactical weapon, a full-size fission weapon, and a thermonuclear weapon. He added that these three options should satisfy the military's interests.

The tests also allowed India to update the weapons design derived from its 1974 test. According to M. R. Srinivasan, former head of the AEC, "If we have to build up a credible nuclear deterrent, then we can't have a frozen design that is out-of-date."

India's official announcement also emphasized that the tests, particularly those conducted on May 13, provided data that would be useful in interpreting "subcritical experiments of zero yield." According to the official press statement: "These tests have significantly enhanced our capability in computer simulation of new designs and taken us to the stage of subcritical experiments in the future, if considered necessary." The DAE has probably validated or improved a complex software package that was used in the design of all the devices and in the estimation of their yields.

Yield estimates

Critics have taken issue with India's assertion that the measured yields of the explosions agreed with the devices' expected design values. The implication is that the tests did not work as well as India claims.

This controversy arises because the early seismic data, as measured by an international network of seismic detectors, suggested that the yields were smaller than India reported. Soon after the tests, seismic experts estimated that the total yield of the first day's tests was well below 20 to 30 kilotons; several estimated the total yield at 10 kilotons. As a result, many questioned whether a thermonuclear explosion had actually occurred.

But after the compilation of additional seismic data, several seismic experts increased their estimates of the total yield to 25-30 kilotons. Given the uncertainties in estimating yields, these newer figures cannot be used to directly challenge India's claim that it detonated an H-bomb.

India's credibility was attacked partly because of lingering uncertainties about the yield of the 1974 test, which India announced as 12 kilotons. Western experts have questioned that number, suggesting that it could have been as low as two kilotons--in other words, that the blast fizzled. Iyengar has been quoted as saying the yield was eight kilotons. But in a recent interview, he said that, based on a radiochemical analysis of samples of bomb debris taken from the shaft, the yield of the 1974 shot was closer to 10 than eight kilotons.

In any case, India is expected to drill back into the shafts to collect samples of debris. Analysis of these samples should provide more reliable information about the yield of the tests. Hopefully, India will make the results public.

A thermonuclear device?

Experts disagree about India's ability to build and successfully test a two-stage thermonuclear device with such a low yield. The many experts who believed that India had tested a boosted fission device were surprised by India's statement that it had instead detonated a thermonuclear device.

The debate is clouded, however, by the lack of information about India's progress on its entire range of nuclear weapons. Until May 11, India successfully hid its program from prying Western eyes. Although important

questions remain about India's progress on thermonuclear weapons and the explosive's yield, the available information suggests that India had been working on thermonuclear explosives for more than a decade, adding credibility to its claim that its two-stage thermonuclear test was a success. At the least, India's claim cannot be disregarded. India may have carefully designed a low-yield two-stage fusion explosion, and one motivation may have been a concern that a significantly larger explosion would damage nearby villages or vent dangerous amounts of radioactive material into the atmosphere.

Some information about India's efforts to make thermonuclear weapons has been discovered over the years by various members of the intelligence community. For instance, a 1985 West German intelligence document cited one agent's unconfirmed report that the "leadership of [Bhabha] had been given the assignment by the Indian Defense Department, after consultations with the highest cabinet officials and Prime Minister [Rajiv] Gandhi, to continue working on the development of a nuclear fusion weapon (hydrogen bomb)." According to this report, Bhabha's job was to be sure that "within two months of a Pakistani test, the second Indian test could be carried out. Such an Indian test should simultaneously be used for the development of a fusion explosion."

During the 1980s, India established an inertial confinement fusion program at Bhabha--useful for studying the high-energy, high-density physics associated with thermonuclear explosions; the improvement of elaborate weapons-design computer codes; and the development of sophisticated diagnostic techniques and instrumentation.

In 1989, William H. Webster, the director of the CIA, told the U.S. Senate that India had several programs that demonstrated its interest in developing thermonuclear weapons. India was purifying lithium, producing tritium, and separating lithium isotopes. Webster also said that West Germany had illegally re-exported a shipment of U.S.-supplied pure beryllium metal, which is used to produce smaller, lighter, fission explosions.

In the same year, a senior U.S. nonproliferation official said in an interview that although "we do not really have a good handle on what India knows" about thermonuclear weapons, "India has the basic scientific expertise" to build them. He added that if India "made a decision" to build an H-bomb, it could do so.

In the 1980s, India conducted theoretical work on both boosted fission and two-stage thermonuclear weapons. Theoreticians evaluated the compressions needed, the pressures generated during explosions, and "flying-plate" designs.

Even with all of these activities, India would likely have encountered problems in developing an H-bomb--and Indian officials recently implied as much. Chidambaram said that the computer programming for the thermonuclear device was "particularly complex." A former head of the AEC said in a recent interview that if the test had occurred in the 1980s or early 1990s, it would probably have involved a large-yield boosted fission weapon, not an H-bomb.

One Indian nuclear expert said that the H-bomb had a fission trigger of about 15 kilotons, with most of the remaining yield coming from a fusion secondary. He speculated that the secondary may have been a solid composed of lithium, deuterium, and perhaps, tritium. He was unsure about whether the secondary would have contained a "spark plug" of fissile material, because the use of a kilogram of plutonium would have added significantly to the yield. But, he said, Indian scientists had learned enough to pursue many variants of a standard, two-stage thermonuclear weapon.

India's abilities

The recent tests undoubtedly mean that India can deploy reliable fission weapons on a wide range of delivery systems, including ballistic missiles. Whether India could deploy a two-stage thermonuclear weapon or a boosted fission weapon on a ballistic missile is less clear. However, India might be able to drop a thermonuclear weapon from a bomber.

Although India is thought to have assembled 20-30 nuclear devices or weapons before the tests, it is not believed to have deployed these weapons on ballistic missiles or attack aircraft. Moreover, their reliability and readiness for deployment are questionable. It is not clear whether India plans to disassemble these earlier devices and build new, more capable nuclear weapons.

New information released following the tests makes clear that the responsibility for producing nuclear warheads and bombs is divided equally between the DAE and the DRDO. The DAE focuses on designing and developing the weapons, and DRDO concentrates on making and testing the high-explosive components and on weaponizing the designs.

Bhabha designs the nuclear explosives, produces the fissile material, and converts it into weapons components. Bhabha has designed and developed fission, boosted fission, thermonuclear, and low-yield devices. As part of this effort, it has also developed sophisticated computer codes, worked out ways for long-term storage of components, and optimized the devices' yield-to-weight ratios.

Chidambaram told Indian TV that the nuclear program has been constantly upgraded in the areas of explosive ballistics, high-pressure physics, neutron physics, neutron kinetics, and the physics of the "secondaries" of thermonuclear weapons.

One of DRDO's laboratories had the task of "weaponizing" proven nuclear-explosive designs. As for nuclear warheads for India's Agni and Prithvi missiles, Kalam said: "We have tested the size, weight, performance, and vibrations." He added: "We have been doing that kind of task for some time." DRDO is also in charge of "interface engineering, systems engineering, and systems integration to military specifications" for the weaponized designs.

DRDO has also designed, tested, and produced advanced detonators and "ruggedized" high-voltage trigger systems. It has also conducted a series of trials and achieved the necessary operational clearances.

Press reports imply that the DRDO is playing an increasingly important role in creating the Indian nuclear arsenal, and India may be shifting from a largely scientific endeavor to a military program. The situation may be similar to that of South Africa in the early 1980s, when South Africa's armaments corporation, Armscor, was assigned the task of producing deliverable nuclear weapons based on nuclear core designs and fissile material that had been produced by South Africa's Atomic Energy Corporation.

How much fissile material?

India's capacity to produce unsafeguarded weapon-grade plutonium and highly enriched uranium has been developed over a period of 35 years. Weapon-grade plutonium production is centered at Bhabha, which houses the 40-megawatt Cirus reactor, the indigenous 100-megawatt Dhruva reactor, and a plutonium separation facility.

The Cirus reactor, which was supplied by Canada in the early 1960s, has been operating poorly during the last few years and is currently shut down for repairs and renovation. Although Canada's supply agreement required the reactor to be committed to peaceful uses, India has interpreted the "peaceful uses" clause to mean that it can use the plutonium from Cirus in "peaceful nuclear explosives." (The 1974 test used Cirus plutonium.)

Because the Cirus reactor has not been subject to any type of Canadian or international inspection, India may have switched an equivalent amount of lesser quality plutonium from power reactors for plutonium already produced in Cirus. If so, the weapon-grade plutonium produced in Cirus may have already been assigned to India's nuclear weapons program.

I estimate that India possessed a stock of about 370 kilograms of weapon-grade plutonium by the end of 1997, generated by the Cirus and Dhruva reactors. Assuming the use of about five kilograms of plutonium per weapon, this was the equivalent of about 74 nuclear weapons, of which about 40 could come from Dhruva plutonium.

Although Cirus plutonium has probably been mixed with Dhruva plutonium in the past, it may not be once Cirus restarts in a few years.

If the estimated current growth of India's plutonium stockpile is based on Dhruva plutonium alone, then the supply should grow by about 20 kilograms per year. This amount corresponds to four nuclear weapons per year. At that rate, in 2005 India would be expected to have enough weapon-grade plutonium for more than 100 nuclear weapons.

India could produce significantly more weapon-grade plutonium by using its unsafeguarded CANDU power reactors and civil reprocessing facilities, although these facilities could suffer significant operating penalties. Although the civil plutonium separation plant at Tarapur has not operated well, India expects to start processing irradiated power reactor fuel this summer in the new Kalpakkam reprocessing plant. This plant is expected to operate better than the Tarapur plant.

India enriches uranium at a small gas centrifuge facility near Mysore. Although the plant has reportedly been plagued with problems, it is believed to have produced at least some highly enriched uranium.

With its May 11 and May 13 tests, India's nuclear establishment has come of age, albeit in a highly controversial manner. Since the time of Pandit Jawaharlal Nehru, all of India's prime ministers have supported that country's indigenous research and development in the nuclear field. According to Vajpayee, "What we are doing today is to build the superstructure on that solid foundation."

However, that superstructure is likely to be expensive. On June 1, declaring that there can be "no compromise on defense preparedness," the Indian government approved budget increases of 14 percent for the military, 68 percent for the Atomic Energy Commission, and 62 percent for the Department of Space, which helps develop both civilian rockets and the military's ballistic missiles. Although these increases represent some of the largest India has ever approved in peacetime, they are only a downpayment

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on the cost of fully deploying a nuclear arsenal.

David Albright is president of the Institute for Science and International Security (ISIS) in Washington, D.C., and a Bulletin *contributing editor.*

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Sidebar: Pakistan: The other shoe drops

Pakistan responded to India's five nuclear tests with tests of its own on May 28 and 30, 1998. Adding to the suspense, Pakistan had said on May 27 that it feared an Indian air attack on its nuclear installations. After the tests, Prime Minister Nawaz Sharif declared a state of emergency, suspended many civil rights, and froze foreign exchange accounts.

Unlike India's tests, Pakistan's tests were advertised in advance by U.S. intelligence agencies--the more than 100 Pakistani scientists and technicians who prepared the tests over a seven to eight day period had apparently taken few steps to disguise their activities.

Pakistan's first test series was conducted in a tunnel dug into a mountain in the Ras Koh range in the Chagai region of desolate southwestern Baluchistan. The test on May 30 is believed to have been conducted in a vertical shaft about 100 kilometers from the first test site. The history of these sites is unclear, but the test site was selected and prepared "years ago," according to Samar Mobarik Mand, a key official at the Pakistan Atomic Energy Commission who headed the nuclear test program.

A. Q. Khan, father of both the Pakistani uranium enrichment program and the Ghauri missile, said at a May 31 press conference that mass production of the missile had started and that Pakistan can deploy nuclear warheads on the Ghauri within days.

Given Pakistan's rapid test preparations, a rash of confusing and contradictory statements is not unexpected. But at press time, many questions remain--about the types of devices, their yields, plans for future tests, the number of nuclear weapons Pakistan could build, and Pakistan's intentions about deploying nuclear-tipped missiles.

The tests. According to Pakistani officials, the May 28 tests involved the successful detonation of five devices. The sheer number led many in the West to believe the claim was too convenient--chosen to match the number of tests India conducted during its recent tests.

Khan said on May 30 that the yield of the largest explosion was 30-35 kilotons, and that the other four tests were of small, low-yield weapons ideal for missile attack against troops. Mobarik said that the total yield of the first day's tests was 40-45 kilotons.

Preliminary assessments of international seismic data led others to estimate the total yield--or the yield of the largest--as 2-15 kilotons. Those estimates led to widespread suspicion that Pakistan was exaggerating both the number and yield of the tests.

On May 30, Pakistan tested a smaller, lighter device that could be mounted on a missile. Mobarik put its yield at 15-18 kilotons; Western seismologists estimated it as two kilotons. Pakistani Foreign Minister Gohar Ayub Khan said initially that two tests had been detonated on May 30, but a spokesperson said later that only one device had actually exploded. Khan explained the next day that two tests were originally planned, but after the results of the first day's tests were evaluated, it was decided to conduct only one test.

Pakistani officials said all the tests were of fission devices. Khan, however, described the largest test on the first day as a boosted fission device.

No official claimed that the tests included an H-bomb, but several said that Pakistan could explode such a device if it decided to. Mobarik said, "Technically, we can do it. We have everything ready to test the device, but the program requires massive funds."

Were the tests a success? If Western yield estimates hold, they would raise questions about whether Pakistan's nuclear weapons work as well as expected. Although the tests were prepared rapidly, Pakistan has probably been ready to test for some time. According to Mobarik, "We wanted to do it [test] earlier, but the government did not allow us."

Whatever the yields, it is reasonable to assume that Pakistani scientists

increased their knowledge. They were probably able to check their computer software, gain confidence in existing designs, and gain useful information for future designs.

Khan said the tests went "exactly as we had planned and the results were as good as we were hoping." He said that Pakistan has collected all the relevant data from the tests and does not need to conduct any more tests. He also emphasized the importance of the data for future computer simulations. Khan and others also implied that the tests may have helped Pakistan achieve its long-term goal of reducing the size of its weapons, increasing their yield and storage life, and making them more effective.

Pakistan's nuclear weapons abilities. Before the tests, Pakistan was viewed as capable of producing a fission bomb for its attack aircraft and probably a warhead for its ballistic missiles. This assessment was strengthened by the oft-stated mantra that China had given Pakistan nuclear weapons design assistance. It was no surprise when Pakistan said after the tests that "a number of successful cold tests were carried out to finalize the design of the weapon systems."

Considerable uncertainty surrounds estimates of how much weapon-grade uranium Pakistan possesses. Nevertheless, I concluded in a recent Institute for Science and International Security assessment that Pakistan started producing weapon-grade uranium at least several months ago, breaking a moratorium on production that it established in 1991.

Although Khan said recently that Pakistan never stopped making highly enriched uranium, his statement contradicts several other Pakistani officials and must be viewed skeptically. Former Army Chief Gen. Mirza Aslam Beg said in a TV interview in late 1997 that Pakistan had acquired nuclear capability in the late 1980s and, he added, "Of our own free will we decided to put a restraint on it by lowering the enrichment of uranium."

The middle range of my preliminary estimate is that through the end of May 1998, Pakistan had produced 335-400 kilograms of weapon-grade uranium (excluding the material used in the nuclear tests). This estimate reflects the rapid growth in Pakistan's uranium stockpile during the first part of 1998--a result of enriching the low-enriched uranium it produced during the moratorium. At 20 kilograms per weapon, Pakistan could have enough weapon-grade uranium for 16-20 nuclear weapons.

--D. A.