# BOOMTOWN

**Sheltered among the mountains of the Southwest, a group of researchers spend their days letting loose the destructive powers of explosives, all in the name of creation.**

BY RICHARD WOLKOMIR

Fifty miles outside Trinity, New Mexico, the spot where the world's first atom bomb was detonated, mangled warplanes lie strewn across the desert floor, their wings and tails torn off, their fuselages punctured. The vintage B-36's, B-57's, and F-86's are silent players in a tableau of frozen violence; from the look of the debris it's clear that these planes were intact when they got here, but that something since then has done them serious damage.

On a road that arrows in from the eastern horizon, where the town of Socorro sits like a smudge on the bank of the Rio Grande, a van jounces along, raising dust. Inside, the four men wearing hard hats ignore the mutilated jet carcasses. The van scuttles up into brown, sun-cracked mountains and disappears. After a while, from beyond the peak where it vanished, a siren wails. Minutes later it wails again. And then:

WHAM!

The blast from the mountains shivers the desert. In far-off Socorro the explosion shakes California Street, the town's main drag. But not an eye blinks. Socorrans are inured to

**A planned explosion in the New Mexico desert sends sand and soil 50 feet into the air. A blast this size can be harnessed to create a diamond half an inch in diameter.**

*kerpows, bams,* and *crumps*. They live in a literal boomtown.

This sunbaked Old West community and its adjacent mountain test site are home to the New Mexico Institute of Mining and Technology. The place has a fancy name, but the job they do here is simple: they blow up things. The institute is the nation's leading facility for explosions research, a laboratory settlement in which the science of explosives—the constructive and the destructive—is studied and unraveled.

Actually, the institute houses two facilities. The oldest, which tests cannon shells, armor, and missiles for the military, is the chillingly named Terminal Effects Research and Analysis Group. An offshoot of World War II ordnance research, the Terminal Effects Group was settled at Socorro in 1949, at a site that offered both the desert's emptiness and proximity to the White Sands Missile Range and the Air Force Weapons Laboratory. This is what created the warplane graveyard: the dismembered jets were targets used to measure the damage a given missile could do to a fuselage at a given range.

The other facility, the Center for Explosives Technology Research, does far tamer work. This branch of the institute was set up by the state in 1983 to use the power of explosions not to destroy but to build, to help industry create new materials and manufacturing techniques. Here chemists and physicists test the ability of explosives to weld ruptured seams inside nuclear reactors and resuscitate trickling oil wells. Like alchemists, they transform dusts and powders into new substances as they manufacture ceramic superconductors. Every month the builders and blasters of the institute set off dozens of explosions, ranging from modest popgun bursts to ground-shaking eruptions fueled by hundreds of pounds of explosive material. And though the purposes of their experiments vary, one thing remains constant: in the interests of science, the bruised mountains of Socorro take another licking.

It's early morning, but materials scientists Marc Meyers and Naresh Thadhani have already begun preparing for the day's explosion. Parking their van outside the Big Eagle firing bunker, a thick-walled concrete structure buried in the side of a mountain, they begin unloading the wires, fuses, and bomb cases that are the tools of their trade. Today's experiment is a rather routine one: using a volatile mixture known as ANFO—a combination of ammonium nitrate and fuel oil—they will try to transform a collection of elemental powders into a solid superconducting ceramic.

Traditionally, superconducting powders are fused into ceramics in powerful presses or ovens. The high temperatures are necessary for the powders to fuse, but if they overheat, the ceramic can break down and lose its superconducting properties. Moreover, the process is a slow one: to fuse properly, the powders must be pressed or baked repeatedly. Explosions, however, can do the job in a few millionths of a second. When the charge is detonated, the shock wave moves through the powders at more than 11,000 feet per second, squeezing the grains together violently. The surfaces of the grains melt and fuse, but the interior of each stays cool.

**An explosion can generate several million pounds of pressure per square inch. A sphere of TNT the size of a softball can deliver 6.7 million horsepower.**

Big Eagle is jammed with high-tech equipment. But the experiment Meyers and Thadhani rig up has an almost backyard look to it. A copper capsule a few inches long is filled with superconducting powders and set on a platelike base. Around the capsule the researchers place a shin-high section of black sewage pipe, which they fill with four pounds of ANFO. The stuff looks like coarse sand and smells of fuel oil. Meyers and Thadhani then attach a detonator to the pipe and run a cable to the bunker. Retreating inside, they seal the door behind them.

When Meyers gives the signal, a warning siren sounds. After another signal, a technician presses a button sending 2,500 volts out to the detonator.

From behind the concrete walls comes first a flash of light, then a heavy thud, then a drizzle of black debris. When the ash and smoke settle, everything looks exactly as it did before—except the sewage pipe is utterly gone. Standing there alone is the blackened wreck of the copper capsule, now shaped something like a dumbbell.

Thadhani emerges from the bunker and begins poking at the sooty cylinder; it is still too hot to touch. "The last time we tried this we used eight pounds of ANFO," he says. "But the intense pressure generated by the explosion caused the ceramic to crack. This time we used only four pounds." Back in the lab the results of this experiment will be analyzed in order to fine-tune the next explosion.

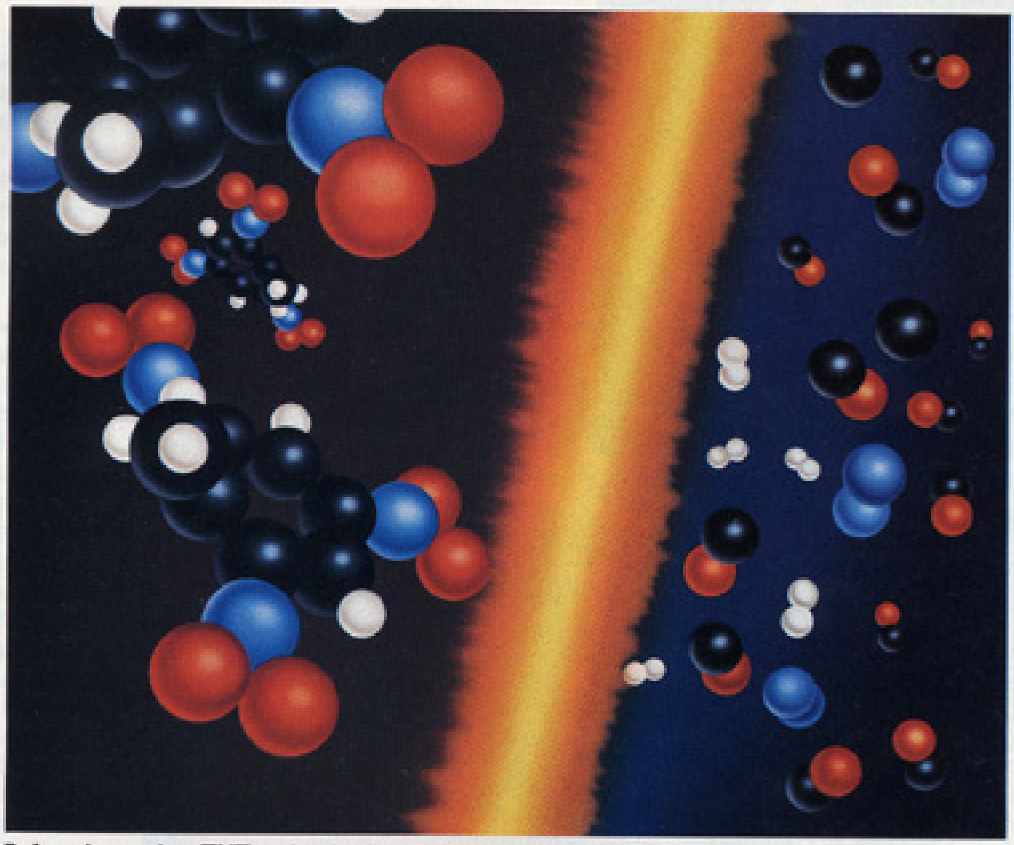
The violent molecular magic that went on inside the sewer pipe was just one of a number of forms an explosion can take. At its simplest, an explosion is mechanical, as when a balloon pops or an overly compressed gas bursts its container. At its deadliest and most complicated, however, it's atomic.

The nuclei of most atoms are perfectly stable configurations of mutually repellent protons and chargeless neutrons. Some atoms, however—those with more than 83 protons in their nuclei—are unwieldy and easily unglued. If one of these unstable heavyweights, like uranium 235, gets beaned by a stray neutron from outside, it may lose its grip on itself. The nucleus can break in two, releasing energy. As it splits, it expels more neutrons that can split neighboring nuclei, and so on. One ounce of uranium undergoing such a chain reaction releases as much energy as 600 tons of TNT.

Most nonnuclear explosions—TNT, gunpowder, fireworks, ANFO—rely on similar mechanisms, but they take place one step higher, at the molecular level. Molecules, of course, are concatenations of atoms that bond to form chemical compounds. When the electron links holding these tiny confederations together are broken, the molecules instantly move about and remarry into other compounds.

There are thousands of types of explosives, but typically they involve fusing oxygen-nitrogen compounds with hydrogen-carbon compounds. When the two are mixed together in an enclosed space and nudged by heat or shock, the nitrogen breaks its electron bonds with the oxygen. Then the free oxygen mingles with the carbon or hydrogen, instantly forming intense heat, water vapor, and gas.

"An explosion's pressure can reach several million pounds per square inch," says Fred Sandstrom, an explosion specialist and one of the people involved in the superconductor studies, "and the gases can be one-and-a-half to two times denser than the original explosive. Anything surrounding that gas is going to get out of the way in a hurry—whether it's a piece of metal, a rock, whatever." A single kilogram of TNT—enough to fill a softball—delivers about 5,000 megawatts of power for a split second, the equivalent of 6.7 million horsepower.



**Before detonation, TNT molecules (left) form a ring composed of oxygen atoms (red), carbon (black), hydrogen (white), and nitrogen (blue). Afterward the atoms exist freely or in pairs.**

ILLUSTRATION BY GEORGE KELVIN SCIENCE GRAPHICS

Science's ability to fathom and control explosions was not come by easily. The New Mexico researchers owe what they know to a violent, centuries-long history of hit-or-miss discoveries. In the seventh century Byzantine Greek chemists found that a number of nasty compositions, including pitch, naphtha, sulfur, and petroleum, would burst violently when ignited. The empire's military got hold of the new materials, dubbed them Greek fire, and used them to defend Constantinople from invading Saracens.

For a few centuries this unstable material represented the state of the explosion art. But around the turn of the first millennium the world's workhorse explosive—black powder—was developed. The identity of just who discovered that a mixture of potassium nitrate, sulfur, and charcoal gets ugly when lighted is lost to antiquity, but most scholars credit the Chinese, who used the stuff in fireworks and signals. Whoever invented it, black powder started us down a long and bloody road. The new mixture found its way into cannons, muskets, bullets, and bombs.

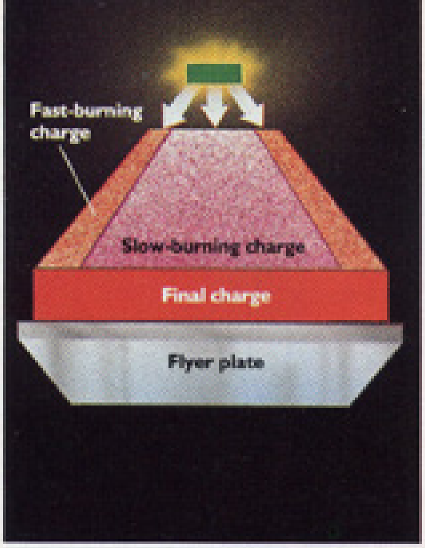
The next big breakthrough came in 1846, when an Italian chemist named Ascanio Sobrero added glycerol to a mixture of nitric and sulfuric acids and nearly obliterated himself in the ensuing explosion. Sobrero prudently decided that the stuff he called nitroglycerin was too dangerous to release to the world, and he tried to keep it a secret. He failed. Sweden's Nobel family obtained the formula and began manufacturing it as "blasting oil" for mining.

Some years later Alfred Nobel invented the less volatile substance he called dynamite, named for the Greek *dynamis*, or "power." By mixing nitroglycerin with a porous, siliceous material, he created a compound that he could drop, hammer, or even set afire without inducing it to blow. When subjected to the strong percussive shock of a blasting cap, however, it delivered as potent a punch as pure nitroglycerin. Dynamite caught on, and Nobel lived to see himself linked to the sobriquet "merchant of death." His later creation of the Nobel Prizes was an attempt to cleanse the family name.

After dynamite came the deluge. Estimates of the number of explosives available today range up to 20,000. Many are variations on black powder or TNT. Many are wholly new compounds. All represent a simple effort to pack the greatest destructive wallop into the smallest possible space.

At a few research facilities efforts are still directed toward delivering more bang for the buck. Indeed, the researchers in the Terminal Effects group may be the leaders in this field, devoting their energies to building into each tablespoon of material the greatest plane- or tank- or soldier-smashing yield possible. But at their sister facility more constructive heads prevail.

In the same labs where the superconducting work is being done, Thadhani shows off a small square of metal only an eighth of an inch thick that, in appearance and weight, resembles nothing more exciting than a piece of aluminum. In strength, however, the seemingly flimsy sheet is closer to steel. It is a lightweight laminate composed of 15 alternating layers of aluminum foil and piano-wire mesh.



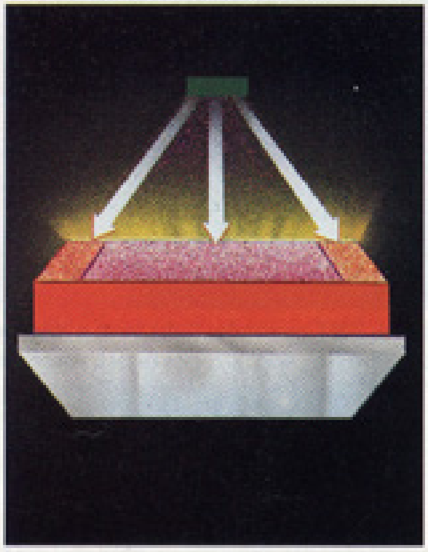

**Blast manufacturing often calls for a precisely focused explosion, produced by a cone made of a slow-burning inner charge and a faster outer one.**

To create the composite, the researchers stack thin layers of foil and mesh—each about four-hundredths of an inch thick—until they have a sandwich that's a quarter- to a half-inch high. On top of that they place a metal sheet called a flyer plate; and on top of that they place a layer of powdered ANFO. Only the upper surface of the explosive is exposed to the air; since the shock wave of the explosion moves faster through the solid material below than it does through the air above, when the ANFO blows, it blows mostly downward. This causes the flyer plate to compress the alternating layers instantly into a single, fused unit.

The new material can be used to construct armored tank bodies, aircraft, and spacecraft. It is manufactured much faster than any other existing laminates, most of which are either liquefied and poured into molds or welded together in hot presses. And this blast manufacturing is not only fast but also cheap. The explosives needed for the job cost a mere 15 to 20 cents a pound, and just a few pounds are needed for an explosion. What's more, there is no need for high-tech production plants or dust-free rooms. As the explosion blasts the sandwich, jets of vaporized metal shoot out from between the layers, scouring away any oxides or other particles that may be contaminating the surface.

Of course, blast manufacturing is not always as simple as merely spreading out some ANFO and letting it go to work. Often a much more precisely focused charge is needed if the explosion is to do its job. In these cases the researchers must rely on something known as an explosive plane wave lens, which is designed to deliver a flat, hammer-blow shock wave in just one direction.

Essentially the lens is a two-layer cone of detonating material: a solid inner cone molded out of a relatively slow-blowing explosive, and an outer layer of faster-blowing material. The two cones allow the material to burn evenly. If only a single explosive were used, the material at the periphery would take longer to burn down to the base of the cone than the material at the core, since it has a longer distance to travel. The outer charge helps ensure that the inner charge burns completely. When the cone is lighted at its



**The outer charge ensures that the inner one burns evenly and allows the two charges, traveling different distances, to arrive at the bottom simultaneously.**

apex, the two explosives begin burning together and reach the base at the same instant, producing a flat shock wave that slams across the entire face of the target.

"To get the most out of an explosion, you need to control this wave," says Thadhani. "Lenses let us get the entire wave to the target at the same time, which greatly increases the explosion's power."

With the force available through lens technology, Thadhani and his colleagues at the center are creating industrial diamonds of unsurpassed quality. Natural diamonds are formed when buried carbon deposits are subjected to slow but titanic pressure from surrounding layers of earth and rock. The researchers theorized that if they could get an explosion to apply the same pressure in a split second rather than an eon, they could imitate and accelerate the work of nature.

To do so, they pack diamond powder into square-inch stainless steel capsules, placing a dozen such capsules into a metal holder like eggs in an open carton. A flyer plate and an explosive lens are set up above that. When the charge goes off, the plate is driven into the capsules at about 1.5 miles a second and the powders are subjected to a pressure about one million times that found at sea level. When the capsules are opened, what is usually found inside is impressive indeed: jumbo industrial diamonds, half an inch in diameter and fully 85 percent as hard as those created by nature, a record for artificially manufactured diamonds. "They're dark and ugly," says lab manager Ed Roy, "but they're perfect for industrial jobs like slicing metals."

These sooty stones are known as polycrystalline diamonds, gems made up not of a single mammoth crystal but of many tiny ones held in place by shared electrons welded together in a sudden, shotgun wedding. They hold advantages over other manufactured diamonds in both quality and cost. "In theory," says Thadhani, "diamond presses could apply the same pressure an explosion does. But if you want to make them strong enough to do that you have to redesign the hardware completely. Explosives are cheap by comparison. And getting a more powerful burst may simply mean packing the material differently or using more of it."

Several of the center's other projects

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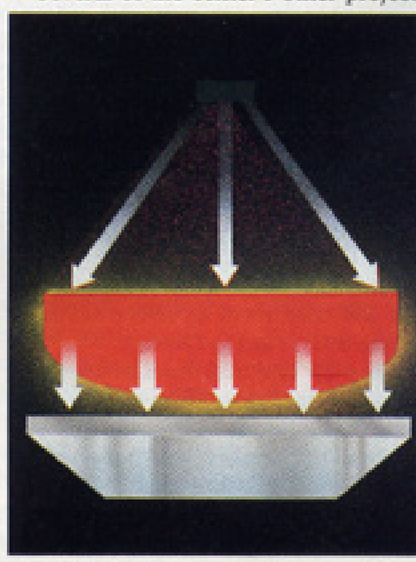


**There they ignite a single charge, which sends a flat shock wave across the entire face of a plate at the same time to generate enormous force and pressure.**

are already being used in a number of industries. One is explosion welding. Researchers have found that when one sheet of metal is slammed into another by an explosion-driven flyer plate, the two will adhere with a bond that is far stronger than any achieved by traditional methods. The pressure, stress, and heat generated at the site of the impact cause the two metals to liquefy briefly and swirl together in a microscopic, wave-patterned weld.

"Ordinary welding," says the center's assistant director, Pharris Williams, "leaves microscopic gaps that can lead to oxidation and corrosion. With explosion welding, the materials interlock so snugly that corrosion isn't possible."

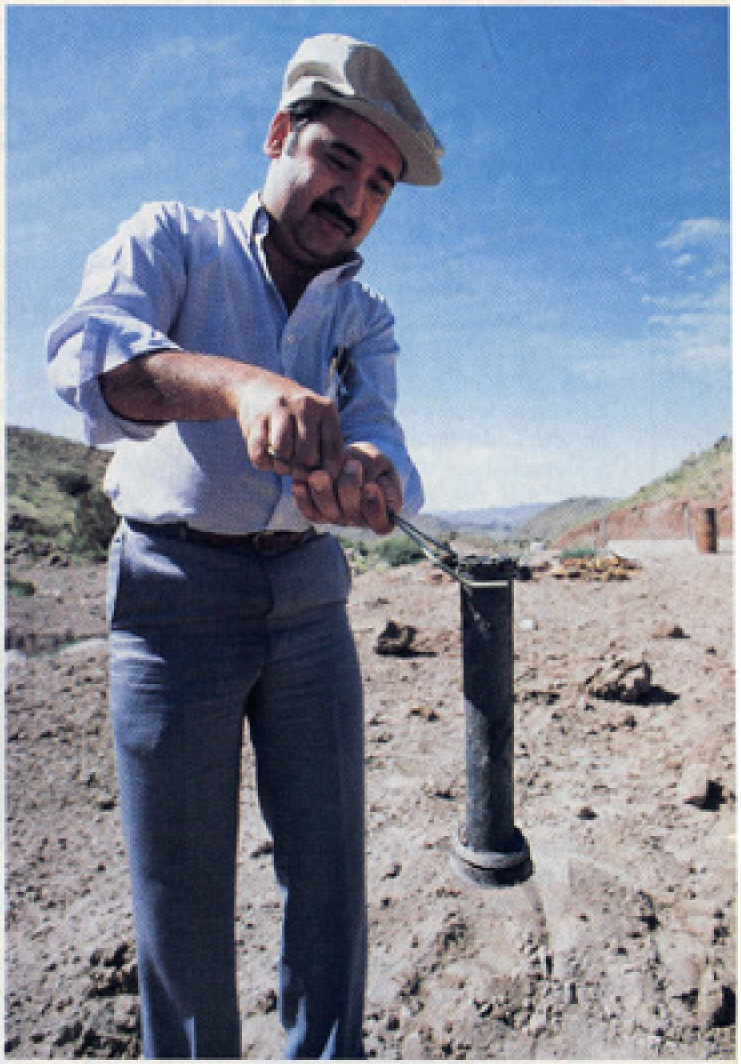
Explosive welding is now being used in the construction of nuclear power plants; explosive plugs are fitted into pipes and then detonated, sealing tiny leaks. The center has helped expand the technology into the transportation industry as well, developing blast-welding methods for European railroad designers seeking to weld tracks for high-speed electric trains.

Other products being developed could find application in the business of strip-mining, supplementing the excavation equipment that coal-digging companies currently use. "Say you've discovered a lode of coal under a hundred and fifty feet of earth, sandstone, and shale," says Roy. "Ordinarily you'd have to dig it all up with bulldozers. But newer compounds can put out more heave over a longer period of time. This can expose millions of tons of coal and keep a mining company busy for months."

Such disquieting applications notwithstanding, most of the facility's future work appears geared not toward muscling up explosives but toward taming them. Explosives are already used in the oil industry to clear sand-blocked oil channels at the bottoms of deep wells. But a problem arises when ordinary explosives are lowered the necessary 15,000 feet into the ground: the hellish temperatures at those depths often cause the blasts to go off before they are properly positioned, doing far more harm than good. The center is hoping to correct this problem by developing "insensitive" explosives.

"An insensitive explosive," says Roy, "is essentially a buffered explosive. We've developed a way to bond a plastic compound to each crystal of an explosive material. This serves to stabilize the explosive chemically, physically, and thermally. Insensitive explosives go off only when you want them to go off."

Of course, the same properties that make the compounds so valuable to the oil industry also make them attractive to the military. "A Navy ship may be filled with missiles, aircraft, and fixed ammunition," says Roy. "That's a very dangerous vessel. If it takes a hostile strike, an entire ordnance magazine can be set off. As a result, the military has its own drive on to develop insensitive explosives. What they learn they're transferring to us, and what we learn we're transferring to them."



**Naresh Thadhani lifts a cylinder in which titanium aluminide powder has been explosively compacted to form heat-resistant skin for the experimental space plane.**

"We're working on explosives that don't accidentally do anything," says the center's director, Per-Anders Persson. "Some already have the qualities of a block of wood unless they're detonated by a charge of the right size and power." He also looks forward to the development of intelligent detonators—microchip fuses with the silicon smarts to distinguish between an intentional firing signal and stray electric cracklings. This would allow them to pass only the right signal on to an explosive and would virtually eliminate accidental detonations.

Persson was recently summoned to help diagnose what went wrong at a Nevada chemical plant, where an explosion in the spring of 1988 killed two people, injured more than 100 others, and destroyed a substantial portion of a key ingredient used in the space shuttle's solid fuel. His role in this has helped drive another of the center's research efforts: finding ways to store volatile materials for long periods with minimum risk.

"We're learning how to handle these materials better and feel safer around them," says chemist Jimmie Oxley. "They're really nothing more than constructive tools."

Indeed, Oxley believes that, despite their ominous image, even the most powerful explosives aren't really so different from everyday objects. "Many physical things release energy," she says. "I once had my students analyze the energy in a Snickers candy bar; it turned out to be equal to a couple grams of TNT. The only difference between the dynamite and the candy is that the dynamite releases its energy a little faster." ❑

*Richard Wolkomir wrote about hypothermia in the February 1988 issue.*