GEORGE DYSON

Strange Love

Or, how they learned to start worrying and love to hate the bomb.

Physicists love explosions. We owe our nuclear predicament to a quirk of human nature: designing, making, and testing nuclear explosives can be fun. "The sin of the physicists at Los Alamos did not lie in their having built a lethal weapon," physicist Freeman Dyson (my father) has explained. "They did not just build the bomb. They enjoyed building it. They had the best time of their lives building it. That, I believe, is what Oppenheimer had in mind when he said that they had sinned."

Eight years ago, I began interviewing retired (and semi-retired) nuclear weaponeers who had worked on Project Orion — the technically promising but politically unacceptable effort, begun in 1957, to build an interplanetary spaceship propelled by nuclear bombs. The project's leader, physicist Theodore B. Taylor (1925-2004), exemplified the conflict between love of explosions and fear of the results.

"I was given a chemistry set when I was 7 or 8 and that rapidly turned into a laboratory for making explosives, with one restriction set down by my mother: never, never under any circumstances was I allowed to make nitroglycerine," said Taylor. "So I didn't." He experimented with more explosive and less stable alternatives instead. "I was fascinated by explosions. I still am. Without any attraction to the damage. I hated to just fiddle around. I wanted to go to extremes."

Taylor promised his mother, in the aftermath of Hiroshima, that he would never work on nuclear weapons, but the temptation proved impossible to resist. After an unsuccessful first attempt at a Ph.D., Taylor with his wife, Caro, and four-month-old Clare, drove their 1941 Buick to Los Alamos from Berkeley in November of 1949. "Within 24 hours of our arrival at Los Alamos, I was deeply immersed in the nuclear weapons program. Within a week, I was hooked on understanding what went on at these enormously high energy densities, clear off any human scale."

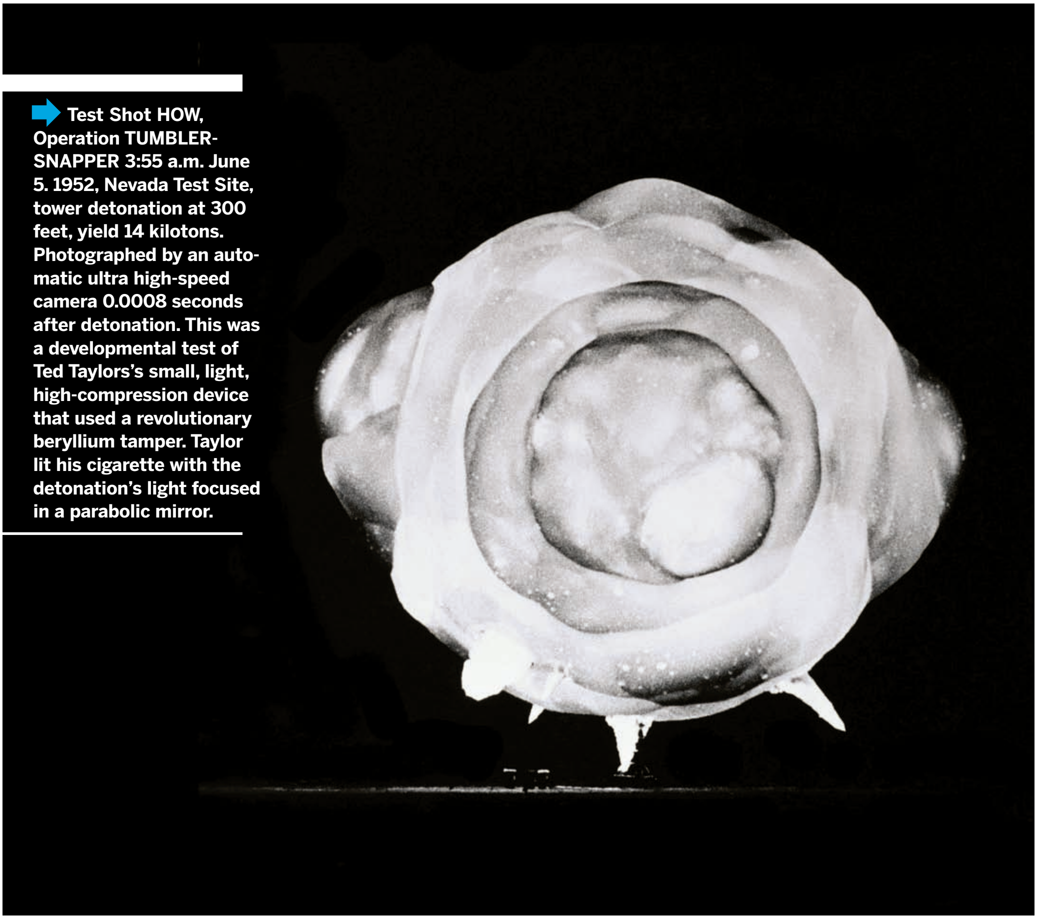
Within four years — but still without a Ph.D. — Taylor's designs included the largest, the smallest, and the most efficient fission devices ever exploded. The first of these records still stands. This was the Super Oralloy Bomb, which yielded 500 kilotons in the Ivy King test at Eniwetok on Nov. 15, 1952.

"I had complete freedom to work on any new weapon concept I chose," Taylor told me. "It's an exhilarating experience to look at what's going on inside something the size of a baseball that has the same amount of energy as a pile of high explosive as big as the White House. I went crazy over that. A big high. The highs needed fixes. And we got those twice a year easily. The fix was a combination of seeing one of these things go off — 'Aha! It worked!' — and seeing how the next one might be even more spectacular."

The first test witnessed firsthand by Taylor was Greenhouse Dog, at Eniwetok, yielding 81 kilotons on April 7, 1951. He was 15 miles away. "The explosion was every bit as awesome as I had expected — roughly five times as big as the one that destroyed Hiroshima. The countdown started close to dawn ... 1 minute ... 30 seconds (put on your dark goggles) ... 15 ... 4, 3, 2, 1: instant light, almost blinding through the goggles, and heat that persisted for a time that seemed interminable. The back of my neck felt hot from heat reflected off the beach house behind us. Goggles came off after a few seconds. The fireball was still glowing like a setting sun over a clear horizon, a purple and brown cloud rising so fast that in less than a minute we had to crane our necks to see the top. I had forgotten about the shock wave, a surprisingly sharp, loud crack that broke several martini glasses on the shelf of the beach house bar. I tried hard to shake off the feelings of exhilaration, and think about the deeper meanings of all this, without success."

The following year, at the Nevada Test Site, Taylor held up a small parabolic mirror and lit a cigarette with an atomic bomb. The fireball was 12 miles away. "I carefully extinguished the cigarette and saved it for a while in my desk drawer at Los Alamos," he remembered. "Sometime, probably in a state of excitement about some new kind of bomb, I must have smoked it by mistake."

What excited Taylor most were really, really small atomic bombs. "It was curiosity, wondering, 'What's the limit?' I wanted a panoramic view." Taylor was interested in low-yield explosions not because he anticipated a need for them — or a fear of terrorism — but because he was intrigued



Test Shot HOW, Operation TUMBLER-SNAPPER 3:55 a.m. June 5. 1952, Nevada Test Site, tower detonation at 300 feet, yield 14 kilotons. Photographed by an automatic ultra high-speed camera 0.0008 seconds after detonation. This was a developmental test of Ted Taylors's small, light, high-compression device that used a revolutionary beryllium tamper. Taylor lit his cigarette with the detonation's light focused in a parabolic mirror.

Photograph of HOW, 14 kilotons, Nevada, 1952, from *100 Suns*, by Michael Light, 2003

by the delicate balances involved.

"I said, why don't we build things with much less plutonium in there and see what's going on in the middle with much more sensitivity. We can do things at around a kiloton instead of what was then the predicted yield of a stockpile bomb, 80 kilotons — it was that for years. To make small yields with big implosion assemblies, that got fascinating. I was pushing things as far as one could go, never mind that you wind up in some cases with shells less than a millimeter thick. Who's going to make those? As it turned out, it was very worthwhile to find some way to make those."

"Pursuing these limits became an obsession," Taylor admitted. "What is the absolute lower limit to the total weight of a complete fission explosive? What is the smallest amount of plutonium or uranium 235 that can be made to explode? What is the smallest possible diameter of a nuclear weapon that could be fired out of a gun?" The answers were surprising. "I was narrowing my focus, getting the quantities of plutonium that one could use to make nuclear explosions down to less than a kilogram. Quite a bit less."

The smallest tactically deployed nuclear weapon was the Davy Crockett, with a warhead weighing less than 60 pounds. It was not designed by Taylor. "I tried to find out what was the smallest bomb you could produce, and it was a lot smaller than Davy Crockett, but it was never built in those years," he said. "It certainly has been since then. It was a full implosion bomb that you could hold in one hand that was about 6 inches in diameter."

Taylor left Los Alamos in 1956 to work for General Atomic, first on the TRIGA research reactor and then on Project Orion, and then left General Atomic to work for the Pentagon's Defense Atomic Support Agency in 1961. He was surprised to learn how much fissile material was lying around. He began to think about do-it-yourself nuclear weapons, and became alarmed.

"The use of small numbers of covertly delivered

The Davy Crockett, ready to be deployed. It had a warhead that was less than 12 inches in diameter, had a weight of about 60 pounds, and yielded up to a kiloton.

nuclear explosives by groups of people that are not clearly identified with a national government is more probable, in the near future, than the open use of nuclear weapons by a nation for military purposes," he warned in November of 1966, in his privately circulated "Notes on Criminal or Terrorist Uses of Nuclear Explosives." Keeping fissile material out of the hands of foreigners might not be enough. "The group could be an extremist group of U.S. citizens who believe they are trying to save the U.S."

Although Project Orion was conceived as a way of expending our stockpile of nuclear weapons to explore the solar system, Orion's physicists soon found that to gain the support of the nuclear establishment they had to answer the question: could they launch Orion without depleting the stockpile? Fortunately or unfortunately, the answer was yes.

"One of the big questions, a large part of the whole project which I cannot talk about freely, is just how much plutonium you need," Freeman Dyson explained in 1999. "One of the things that made Orion very attractive is the trade-off between plutonium and high explosive. In the ordinary bombs we use for the stockpile, all kinds, it doesn't matter whether they are high yield or low yield. The military likes minimum weight and minimum volume, so you tend to use a rather small amount of high explosive because it quickly becomes the dominating mass. For what we wanted to do, it was an advantage to have a huge amount of high explosive because that would also absorb neutrons and be the shielding for the ship."

He added, "Then you need a lot less plutonium. And how much less I cannot discuss. The whole economy of the thing depended on that. These were all very nonstandard bombs, which meant nobody believed us; the numbers clearly didn't add up. This is also an interesting question from the point of view of the terrorist bomb problem. If you have a bunch of people wanting to blow up the World Trade Center or something, they might have no difficulty getting large amounts of high explosive. So it is important not to declassify all that stuff."

Consequences of the laws of physics can only be concealed for so long. "Scientific secrets do not keep," warned Edward Teller, cautioning us to acknowledge that we can never maintain a monopoly on secrets such as how little fissile material is required to build a bomb.

There were four main technical obstacles to building an implosion weapon the first time: accumulating fissionable material; performing the computations necessary to validate the physics underlying the design; machining the components precisely in space; and firing the detonators precisely in time. Computers have shifted the landscape, and only the first obstacle still looms large. The average notebook computer has more computing horsepower than all of Los Alamos did while the weapons constituting most of our present stockpile were designed.

Since the first nuclear explosion on July 16, 1945, at Alamogordo, the growing club of nuclear powers have conducted approximately 2,000 nuclear tests: in the atmosphere, in space, underwater, and underground. Surely we are safer now that atmospheric testing has stopped? Maybe not. The risk from fallout has dropped. But we may owe the restraint that kept us away from the nuclear precipice over the past 60 years to nuclear policy makers who had actually seen bombs go off. All the weaponeers I interviewed, no matter how convinced of the need for overwhelming nuclear force as a deterrent, prefaced their statements by describing the effects of being an eyewitness to a nuclear test.

"I was there at the big one on Bikini," retired Air Force Col. Donald Prickett told me, over pancakes made from a sourdough culture he had nurtured uninterrupted for 54 years. This was Castle Bravo, exploded on Feb. 28, 1954, with a yield of 15 megatons, almost three times what had been

Photograph courtesy of U.S. Army, National Archives expected, producing a fireball more than three miles across.

"I had seen up until that time maybe 50 shots at least, atmospheric shots out at the test site, so I wasn't really startled," said Prickett, describing how, with Navy Capt. George Malumphy, he maneuvered a remote-controlled merchant ship into the path of the fallout to test an automatic wash-down system being developed for decontamination of surface craft. "I knew it was going to be big, but Malumphy and I were at least 30 miles from ground zero. And so when the order came on for countdown, we put on our dark goggles. And sure enough it went off, and it was a full two minutes anyway before we took off our goggles, and then it was so awesome that all Malumphy could say was, 'My God, my God, my God!'"

Prickett, who died in 2004, wants us to remember what he could not forget. "I wish people could understand what would happen if one of these megatons ever got over to these cities. I wish to hell these people could see something like that. You're going to have to keep indoctrinating people to what these things are. Or they will forget."

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On May 28, 1998, I was spending the day with Ted Taylor when news came in that Pakistan had conducted a series of nuclear tests. I expected a somber response. But Taylor was unable to conceal the old excitement: "Aha! It worked!" Over dinner, he kept drifting away from the conversation and coming back with some new insight, based on the sketchy news reports that had come in during the day, as to what his Pakistani colleagues had tested, and what they might do next.

Pakistan wanted to show the world (and India) that they had joined the nuclear club. Before the countdown, they disconnected all seismographs, not to conceal a successful test but to conceal their failure in the event the devices fizzled out.

The latest advance in the United States nuclear arsenal is the stockpile stewardship program, which claims to predict, purely from computer simulations and non-nuclear tests, whether our stockpile weapons will work or not. The next step in this arms race is a new generation of weapons whose designs are so simple, and so completely modeled using powerful computer simulations, that we do not have to test them to be sure that they will explode. But this favors potential adversaries as much as it favors us. The danger of not testing nuclear weapons is that we no longer know who has what.

"I had a dream last night, about a new form of nuclear weapon, and I'm not telling anybody what this is, because I'm really scared of it," Taylor told me in 1999. "I have tried, I thought successfully, to hold on to a vow of just not thinking about new types of nuclear weapons any more. And what's happened, to put it simply, is that it has gone from my conscious to my unconscious, and it's emerging as a dream; I cannot shut it off. I woke up at 2 a.m. and went back to bed at about 6 o'clock, and wound up filling up a page with notes. It makes me think of the prototypical example of what directed energy can do, making the transition from a pile of high explosive to a gun, as the Chinese did, after they invented it. What I am afraid is in the offing is people figuring out how to make a transition that's as spectacular as trying to kill a deer at 200 yards with a pile of high explosive, or by shooting at it."

Taylor had the time of his life designing bombs, and spent the remainder of it trying to get the madness of threatening to use them stopped. His final words to me: "I am searching for the truth as long as I can."

We are now relinquishing control of our nuclear arsenal, for the first time, to a generation that has never seen a nuclear explosion firsthand. There are no more Ted Taylors. The new generation of nuclear weaponeers grew up with video games, but was not allowed to have chemistry sets. Are we any safer as a result?

Further reading: *Curve of Blinding Energy* by John McPhee, and *Project Orion* by George Dyson.

George Dyson, a kayak designer and historian of technology, is also the author of *Baidarka* and *Darwin Among the Machines.*