Part 6
Box 1663, Santa Fe, New Mexico

Los Alamos

The goal of the Los Alamos Ranch School was that "…pampered boys from the East would become men when they were separated from oversolicitious mothers and placed on the back of a horse…[1]" but by 1930, Billy Burroughs had come to hate it. He hated the cold, the short-pant uniforms, the strict schedule ("…they even timed you on the john"), and his horse, but he enjoyed for the rest of his life the irony that the school became the cradle of the Atomic Bomb.

Years before Billy Burroughs, Berkeley physicist, Robert Oppenheimer, then a frail teenager from Manhattan, visited New Mexico to regain his health. He and his family fell in love with the Sangre de Christo Mountains east of Santa Fe and bought a log cabin in the Pecos wilderness near Cowles. For years, Oppenheimer hiked and rode in the New Mexico high country. When asked by General Groves to choose a location for a laboratory to make an atomic bomb, Oppenheimer suggested the Los Alamos Ranch School, a place he had visited years earlier. The government purchased the property in February, 1943 and within months the scientists began to arrive and occupy the very rooms Billy Boroughs so hated.

There were few farmers to evict, no hordes of construction workers to house, no gargantuan factories to build or massive machines to tend, but, like Oak Ridge and Hanford, Los Alamos was a secret city. There were the ubiquitous barbed wire fences, armed guards on foot and horseback, and at the gates. In addition, Los Alamos was thirty-five miles down a poor dirt road. The name Los Alamos was classified and never mentioned; residents of Albuquerque and Santa Fe referred to the installation simply as the Hill.

At its war-time height, Los Alamos housed six thousand people, all of whom had the same address: Box 1663, Santa Fe, New Mexico. It was on their mail, their IDs, their tax returns and even their birth certificates. Their driver's licenses had a number rather than a name, "Special List" for an address and usually "engineer" or "housewife" as occupation. The "usual signature" was "not required." All the famous scientists had aliases, used whenever they left the base: Enrico Fermi was Eugene Farmer and Neils Bohr was Nicholas Baker. There was a Los Alamos radio station with no call letters.

Today in the heart of Santa Fe, on East Palace Avenue, a low block of adobe buildings — an old hacienda, dating from the seventeenth century — attracts tourists. The posts and lintels of the long porch are painted a vivid turquoise. Next to the doorway, marked 109, is a sign announcing the boutique, Chocolate + Cashmere; inside, a colorful array of soft wool scarves and boxes of designer bonbons. In 1943, Army security officers dressed in three-piece suits and wing tip shoes guarded 109 Palace Avenue. The small innocuous doorway was the gatehouse to the Los Alamos Atomic Laboratories; the gatekeeper, a curly-haired, bright-eyed woman named Dorothy McKibbin.

No one got to the Hill without first sitting down with Dorothy, as she issued the passes necessary to get through the gate. Dorothy was the concierge, oracle and mother of Los Alamos. If you needed a ride late at night, a reservation at a hotel in Albuquerque, a specific kind of thread, a goose for Christmas dinner, a new puppy or an abortion, she could make it happen quickly and discreetly. Dorothy was as much a key to the creation of the atomic bomb as Oppenheimer or Fermi.

The frail, hastily-built housing at Los Alamos had thin walls; heating was inconsistent and the houses were subject to fires. It was nearly impossible to light the coal-fired cook stoves, known as Black Beauties, at the 7,000-foot altitude. The elite scientists stayed on Bathtub Row, (the old Ranch School buildings were the only ones with bathtubs), but their accommodations were not perfect. Edward Teller complained that it was hard to sleep. "Feynman was beating his drum, which I did not like." but the food was not subject to rationing and there were plenty of alcohol-fueled parties.

[1] Ted Morgan, Literary Outlaw: The Life and Times of William S. Boroughs.

An Introduction to Nuclear Weapons: It's All About the Neutrons

While a nuclear power plant produces a constant amount of energy over a number of years; a bomb releases its energy in a millionth of a second. A reactor needs just enough fissions to maintain a steady chain reaction, and no more. If it has too many fissions, things melt, things explode and very bad elements are released, but for a bomb, no fissions are wanted until "just the right moment" and then they are needed by the billions. Even though it is not possible for a reactor to become a nuclear bomb, the consequences of lesser problems are enormous. If an atom bomb does not have the proper number of fissions at the proper time, it can go off prematurely or not at all.

If one fission produces one additional fission, a chain reaction will be sustained at a steady rate ($k=1$)[2]. In a properly-functioning nuclear power plant, operators adjust the number of fissions to maintain the reaction at a constant level and its "critical mass" is sustained. Less than one additional fission ($k<1$) and the same mass is "sub-critical", the rate of fission decreases and the chain reaction stops. If more than one additional atom is split (k>1), the mass becomes "super-critical" and the chain reaction will increase exponentially.

Neutrons are what cause fission[3] and their availability depends on many things. In nuclear reactors, rods made of boron, or other neutron-absorbing elements, are inserted into the pile to soak up neutrons and adjust the number of fissions they cause to k=1. In a bomb, an enormous number of neutrons are needed at "just the right moment[4]" to cause the maximum explosion. The success of a bomb depends on many things happening at "just the right moment."

The denser the nuclear material the greater the possibility that a neutron will encounter a nucleus and cause a fission. The same mass will be sub-critical at one density, but become super-critical as density increases. Likewise, as the material is heated and expands it becomes less dense until the chain reaction stops. In a millionth of a second, an atomic bomb goes from sub-critical to super-critical and back to sub-critical. It is this tiny piece of time that is most important to the success or failure of an atom bomb.

[2] k is called the effective neutron multiplication factor.
[3] Not all neutrons split an atom. Some simply miss the nucleus; some leave the pit before any encounter and some are absorbed by an impurity. The efficiency of a bomb depends on making it more likely that a neutron will split a nucleus.
[4] The timing of neutron availability is the most critical part of the process of successfully exploding an atom bomb. A part of a microsecond too soon or too late and the bomb does not work as planned. The duration of "just the right moment" is less than a millionth of a second.

How a Bomb Goes Boom

In 1940, the Frisch-Peierls Memorandum laid out the basics of how to build an atomic bomb and in 1944 their original ideas had hardly changed. One kilogram of U^{235} was still about the amount of fissile material needed and it should be made in two pieces. The parts should be assembled rapidly, but their idea that springs would do the job was a bit off the mark; the Los Alamos scientists determined that high explosives would be necessary. In the uranium bomb, half the nuclear mass would be a bullet fired down a gun barrel into the other half as a target. At the precise instant of impact, a neutron initiator[5] attached to the target would be crushed, releasing a torrent of neutrons and the first generation of fission would commence.

One generation of fission takes ten nanoseconds[6]. The time to complete eighty generations of exponential growth, the maximum number before expansion stops the chain reaction, takes less than one microsecond. In that time, heat increases to tens of millions of degrees and pressure spikes to billions of atmospheres, exploding and vaporizing the entire nuclear apparatus.

If the first generation of fission begins one tenth of a microsecond before the two spheres have completed their density-increasing collision, the bomb will expand before the last ten of the eighty generations occurs; the mass will become sub-critical, the chain reaction will stop; it will have fizzled[7]. One event that can cause a fizzle is spontaneous fission, a form of radioactive decay that releases neutrons. If this predetonation occurs at the wrong time, fission will begin too soon and the bomb will exude only a small fraction of its power. If fission begins at "just the right moment", it will grow exponentially for the entire eighty generations and the bomb will explode spectacularly[8]. Fortunately, U^{235} spontaneously fissions at a low rate so the relatively slow assembly using a gun barrel is possible.

Even with no predetonation, the expanding explosion must be retarded until all eighty generations of fission can occur. To achieve these few nanoseconds of delay, the core is encased in a strong jacket called a tamper. The tamper also reflects neutrons trying to leave the area, bouncing them back into the maelstrom so they can split more atoms.

[5] Neutron initiators, codenamed urchins perhaps because their size and shape resembled an echinoderm, are made of beryllium and polonium. When crushed, their components react releasing a thunder storm of neutrons at "just the right moment."

[6] Ten one-billionths of a second. This time was referred to by Los Alamos scientists as a shake as in two shakes of a lamb's tail. Eighty shakes take less than a millionth of a second.

[7] A bomb is said to have fizzled when a smaller number of fissions take place before the bomb is blown apart.

[8] Most of the energy in a nuclear bomb occurs in the last ten generations.

Little Boy, The Gun Bomb

Eighty-five pounds[9] of enriched uranium (80% U^{235}) configured as nine doughnut-shaped rings made up the bullet which was fired down a six-and-a-half-inch gun barrel at 2000 miles per hour onto a fifty-six-pound stack of six similar rings on a steel pin. A tungsten carbide tamper surrounded the target and backed the bullet so when the two collided, the enclosure was complete and a super-critical mass was formed. When the two came together, the mass of one hundred and forty pounds of uranium completely enclosed with a tamper was more than twice the critical mass.

By the summer of 1945, the supply of U^{235} was only enough for one bomb, but the idea was so simple that no test was required. On August 6. 1945, Little Boy exploded two thousand feet above Hiroshima and killed 100,000 people.

[9] They used more than Frisch and Peierls estimated, but still led to a bomb that could be carried in an aircraft.

The Gadget and the Fat Man

The gun-type was also planned for the plutonium bomb, named Thin Man[10], but there was a problem. Until spring of 1944, all experiments and calculations had used very pure Pu^{239} made in the Berkeley cyclotron, but when the plutonium from the X-10 reactor arrived from Oak Ridge, it was found to contain a significant amount of Pu^{240}. $Plutonium^{239}$ produces eighteen spontaneous fissions per kilogram per second, an acceptable level for a gun-type bomb, but Pu^{240} has 10,000 times more. If plutonium from a reactor were used to make a bomb, it would predetonate and fizzle. In July of 1944 the Thin Man project was dead and the focus of Los Alamos was how to make a bomb with this contaminated plutonium. Unless the scientists at Los Alamos could figure it out, the Hanford plant would be useless.

In a gun-type bomb, the two sub-critical masses are assembled to super-critical in about one thousandth of a second. This is too slow for reactor-produced plutonium, but since the summer of 1944, John von Neumann and George Kistiakowski had been experimenting with a method where a solid sphere is compressed by encircling explosives. This inward collapse, called an implosion, acted over a distance one hundred times shorter and in a time one hundred times quicker than the gun bomb. What had been a backup method in 1943 was suddenly the main focus of research at Los Alamos.

Implosion doubles the density of a sub-critical mass and makes it super-critical before spontaneous fission causes a fizzle, but the details of how to create a perfectly-timed, symmetrical crush were daunting. It was decided to encircle the core with a number of separate high-explosive charges. The shapes of the explosives and the timing of their detonations would have to be precise to create a uniform compression.

Complex mathematics could only take them so far and much of the development was by trial and error. Solid spheres of iron, then copper and finally cadmium were crushed by explosives in a remote canyon near the Rio Grande. Kistiakowski and von Neumann tried out many combinations and shapes of fast and slow explosives, until they finally had a combination that exerted a force of six-million atmospheres and crushed the plutonium pit to double its density in five microseconds. Once the experiments had produced a perfect implosion, Los Alamos was ready to build a plutonium bomb. The implosion bomb project was nicknamed the gadget and the bomb was called the Fat Man[11].

One of the men making measurements of these experiments was a nineteen-year-old physicist named Ted Hall. The different shapes of high-explosive lenses[12] were cast using molds machined to thousandths of an inch by skilled craftsmen, one of whom was David Greenglass. One of the theoretical physicists who worked on the problem of implosion was Klaus Fuchs who came over with the British Tube Alloys scientists. They were all Soviet spies[13].

On July 1, 1945, the chemical and metallurgy department at Los Alamos completed the forging of the hemispheres of plutonium that formed the core of the gadget. The bomb components less the core and the explosive lenses were put together at Los Alamos on July 7 and five days later, the explosives package was assembled. The next day, the pit was placed in the back seat of an army sedan and driven, at high speed, to the test range at Alamogordo, known as Trinity. The rest of the bomb went the same day in the back of a five-ton army truck at a much slower speed.

[10] The slender Thin Man bomb was named for Nick Charles, played by William Powell in the Dashiell Hammett movie of the same name and the Fat Man for Sr. Ferrari, played by Sidney Greenstreet in *Casablanca*.

[11] Due to the size of the explosive lenses, the plutonium bomb was quite rotund; it could barely fit in the Bombay of the B-29.

[12] Shaped explosives can be made to focus shock waves, just as lenses focuses light.

[13] I will tell the stories of the three spies in more detail in the section on the Russian bomb.