

The First Man-Made Nuclear Explosion



By L. Worth Seagondollar

American Center for Physics, Conference Room A July 24, 2007

Following is a transcript of the talk given by guest speaker L. Worth Seagondollar (pictured at left) during the Society of Physics Students 2007 Intern Presentations. Jim Stith, Vice President, Physics Resources, American Institute of Physics introduced Dr. Seagondollar.

STITH: You're in for a delightful treat this afternoon. We thought that it might be appropriate to cap the day off with a conversation with our senior intern. It turns out that in 2004 at the 2004 [Sigma Pi Sigma] Quadrennial Congress in New Mexico, Worth talked to us about the Manhattan Project, and agreed to come back and do it again. We're going to do something this time that we neglected to do the first time he did this, and that was, we're going to audiotape the presentation. The people, Victor Worth and his crew and Joe Anderson, will be transcribing it and it will eventually find its way into the Neils Bohr Library. Thanks, Worth, for allowing us to do that.

I have the pleasure of introducing Worth. I will keep it short so that we can spend most of the time listening to him tell the great story of the project. He earned his A.B. degree from Kansas State Teachers College in 1941, and his PhD in 1948 from the University of Wisconsin. Between '44 and '96, he worked for the Manhattan Project in Los Alamos. He worked on the critical mass experiment, and was nine miles away from the explosion when it went off. His career includes a number of academic appointments. I will not go over those. But his last position was at Northwest State University, where he was Chair of Physics from 1965-1975. He now has, he says, the best job in academia. He is Professor Emeritus at North Carolina State University. He is a fellow of the American Physical Society. And he continues as the Nuclear Radiation Safety Officer with the Triangle University Nuclear Laboratory in North Carolina. So please welcome Worth Seagondollar. [Applause]

SEAGONDOLLAR: Is the volume about right, or not? I'll get behind the podium. Maybe I'll feel safer when I put it between me and the audience.

In the spring of 1944, I joined the so-called W Group at what now is called the Los Alamos Nuclear Laboratory. At that time, it was a secret laboratory, a part of the so-called Manhattan District. The purpose of the laboratory there was to ultimately take the uranium-235 that was going to come from Oak Ridge, Tennessee, and the plutonium-239 that was going to come from Hanford, Washington, and devise and develop these into an explosive device which would be used against the Japanese in World War II.

I'll review very briefly what the situation was as far as physics was concerned when I went down there in 1944. For some time, it had been known that if you shoot neutrons—at that time, we were thoroughly convinced that atoms were made up of nuclei with electrons going around. And in the nucleus, we had positive charges, which are called protons, and we had neutral particles, which are called neutrons. The number of protons which were positive are equal to the number of electrons that are going around because they're negative. So each individual atom is electrically neutral.

For some time in the 1930s, people had been using machines that are popularly called atom smashers. They are electromagnetic devices which accelerate protons positive to the nucleus of the hydrogen atom at high speed, and shoot these into the nuclei of other atoms. The purpose for doing this is like a man who wants to know what's inside a certain henhouse. All he can tell in the early days was to sit on a nearby hillside and see what comes out. If only chickens and ducks come out, he's for sure there are chickens and ducks in there. The henhouse with the chickens and ducks corresponds to the very heavy elements in the periodic table, which are naturally radioactive. Some of them kick out alpha particles. Some kick out beta particles. Some kick out neutrons. And from what came out, they're trying to figure out what is inside.

Even with this technique, they would like to get more information. So what they do is, like Grandpa would do for the henhouse when he wanted to know what was inside, he'd get a load of buckshot and he'd put a load of buckshot in the henhouse. The buckshot would interact with

whatever is in there. Some of it gets excited and comes out and [recording skips]. [Audience laughter]. This is what atom smashers were doing.

One of the processes that was found to be important, right after the discovery of the fission of the uranium atom, which experiment Fermi did about in the late 1930s in Rome, it was found that if you shoot a neutron in, an electron comes out. And when that happens, the positive charge on the nucleus increases by a step of one. Suppose you take aluminum, which has 13 protons and 14 neutrons in the nucleus. If you shoot another neutron, things really get turned up inside. You get high energy. Then this energy has to be dissipated in some way. One of the most prolific ways in dissipating is by kicking out an electron, which is caused the inside of the nucleus by a neutron disintegrating into a proton and an electron. The proton is bound in there by the nuclear forces, and the electron is not. So the electron comes out.

You do this thing with aluminum. You shoot a neutron in. An electron comes out. You have an atom of silicon left. With aluminum, you had a positive charge of 13. It had 13 electrons. When it went up one step, you had 14 protons in there, and you now have silicon—a new type of atom. This was what Fermi used, this idea of going up in the periodic table, was what Fermi did to take uranium, which has the heaviest known nucleus at present, shoot a neutron in and he expected to produce plutonium. I won't go into the details; I haven't got the time to go into the details. But basically he found that he did get some more types of radioactivity. He interpreted this as a produced element neptunium, zirconium, and others.

He would soon discover the main thing that happened when the uranium nucleus had split into two. This is the process called fission. So he had gone into two fragments, which are back in the middle of the periodic table. In addition to this splitting of the uranium nucleus, a couple of things that were important were discovered. When you use $E=mc^2$ discover that there has been a very large amount of mass on a nuclear scale has disappeared and then appears in terms of energy, the amount of energy that comes out from a single fission process is roughly 100 million times the amount of energy you will get from completely oxidizing a big molecule of gasoline, completely oxidizing. That's good rocket fuel. Gasoline and oxygen make good rocket fuel. So here you would have a process and you can produce it on a macroscopic scale, which is giving you about roughly 100 million times as much energy for each individual event that is occurring.

Furthermore, if you could reproduce it on a macroscopic scale, you have to have something occur in the original fission process that will cause further fission. The point is, when you look in detail at what the radioactive fission fragments are, there are probably about three extra free neutrons that are given off. If you get one fission, then possibly there are three extra neutrons that continue to make more fission. That's where you produce a chain reaction.

If you take a small chunk of—Well, theoretical calculations had indicated that in uranium, the isotope uranium-235 might be a suitable material for a nuclear explosion. The amount of mass that is required to make a nuclear explosion is called the critical mass. According to theoretical calculations as done by Bohr and Wheeler, the critical mass for uranium-238, which is the most abundant isotope for uranium, is infinite, and we ain't got that much. [Audience laughter]

Uranium-235 is another story. I have never seen what their calculation was. I read somewhere that critical mass for uranium-235 according to their calculations was somewhere in the neighborhood of 100 kilograms of uranium-235. I won't guarantee that; it's just a number that's stuck in my brain. This information was all known at Los Alamos when I went there in the spring of '44. Small quantities of separated uranium-235 had been made available. And the new element, plutonium-239, also was available. The thing that we wanted to calculate was the critical mass of uranium-235 and plutonium-239. Why did we want to calculate this? Richard Feynman put it very nicely in the colloquium that I handed you. He said what happens if we actually get the critical mass together unintentionally? What are we going to lose? We're going to lose a beaker? We're going to lose a laboratory room? We're going to lose the eastern half of New Mexico. That actually was the knowledge of the situation at that time.

The calculation of the critical mass, if you're going to really do it precisely, involves the probability of the fission process and other nuclear processes that can occur. One of the more significant of the other nuclear processes when you shoot a neutron in is the energy that is created in the nucleus and to be gotten rid of by the emission of gamma radiation. This is what makes uranium-238 totally unsuitable. There is a not-large probability of uranium-238 going by the fission, by the neutron-gamma reaction.

Unfortunately, the probability of any one of these reactions depends very highly upon the energy of the neutron that goes into it. The thing that was being done when I got to Los Alamos was two Van der Graaff generators from the University of Wisconsin—and I was also from Wisconsin. This is why I called W Group on our opinion. The one from Minnesota thought it was called W Group because John Williams was our group leader. They didn't know what they were talking about. [Audience laughs] Our job was to take the targets of uranium-235, targets of plutonium-239, bombard them—well, we bombarded lithium-7, and you get neutrons off from that. With those neutrons, you can control the energy of the neutrons by the energy of the protons you put into it with the Van der Graaff generator. So you can control the energy of the neutrons you're shooting in. We were measuring the probability of the various nuclear reactions as a function of neutron energy.

Well, we had enough information by early 1945 that the calculations of the critical mass were pretty trustworthy. They actually wanted experimental measurements of—Before you actually put together a large amount of this material, a critical mass, it would be highly desirable to have some experimental information to back up the theoretical calculations. I had nothing to do with the measurements of the critical mass of uranium-235. I was one of a three-man team that measured the critical mass—or very, very close to the critical mass, 98% of the critical mass—of plutonium-239. It was a three-man team. I think my importance in the team is well qualified by the hours I had to work. The group leader works from 8:00 a.m. till 4:00 p.m. A more senior graduate student worked from 8:00 p.m. till midnight, and I worked from midnight till 8:00 a.m. And this kind of defines where you are in this organization. [Audience laughs]

We had two of what are called long counters. They are... Incidentally, at my age you'd think one of the difficulties you have is the beginning, I presume, of Alzheimer's. I'm not sure. There's a certain word that you want. You know what it is, but you can't come up with it. These long counters were proportional counters, which made use of—and I can't think of the word. Beryllium, I think. Anyhow, these proportional counters by themselves, just bare proportional counters, had a very high efficiency for very low energy neutrons. Since we didn't know the energy of the neutrons that would come out of the fission process, we needed a neutron detector which has an essentially uniform efficiency over a wide energy of energy neutrons. These boron

[trifluoride] proportional counters were surrounded by large cylinders of paraffin, which had various calculated holes in them.

Basically what the paraffin around it did was moderating the energy of the neutrons, whatever they were, until they were back down to a region where the boron [trifluoride] was very efficient. The result was that these so-called long counters were essentially energy independent as far as the neutrons were concerned. There were theoretical groups at Los Alamos that didn't believe this. We spent days and days and days experimentally proving that even though they had theoretical reasons against it, we had experimental proof that they were essentially approximately 70 kiloelectron volts up to 10 MeV. The energy efficiency curve was essentially flat, from 93% to 100% and 97%.

We had two of these big, long counters. In between them, we had a place where we could put a neutron source. This neutron source was what was called a hot fission source. It was a source made up of various radioactive materials, which gave off neutrons for approximately the energy that comes out from the plutonium fission reaction. We had put this source in the middle and we had these two big detectors here, and we had measured the number of neutrons coming out per second from that source. Believe me, we knew how many neutrons came out per second. Then the thing that was going to happen is, as the amount of plutonium being shipped down from Hanford, Washington became large enough, we finally ended up with two hemispherical shells, which fit around this one-inch diameter source. The first one was an eighth of an inch thick.

What we wanted to do with these neutron counters was measure the number of neutrons per second that came out with these two shells around. If you were getting a significant number of fission processes, then you would get a larger number of neutrons coming out. We were measuring what we called the multiplication ratio. The multiplication ratio with an eighth of an inch-thick shell of plutonium was 1.0, as far as we could tell. There just wasn't enough fissions occurring in that eighth of an inch to be significant. Incidentally, plutonium is nasty stuff to handle. If you make a slice of plutonium or uranium and you have bare metal exposed to air, it oxidizes fast. You look at it, and under your eyes it turns from brown to black, and then fragments come off. In those days, the estimate was that if you had a microgram in your lungs, it should be surgically removed.

The hemispherical shells that we'd gotten were plated with some metal to prevent oxidation of the plutonium. I'm not sure, but I think the metal was silver. That's my recollection. I don't know where I got that idea. And as some of you have probably done some thermodynamic experiments in laboratories and as you let that thing sit there, due to alpha emission of the plutonium, the shell gets hot. We would start with a temperature about 30 degrees below room temperature. We'd run the experiment long enough until the temperature was up 30 degrees above room temperature. This was a standard undergraduate physics technique on taking temperature measurements.

We made this measurement with a multiplication ratio of 1.0. The function materials were sent back to the metallurgical laboratory, and meanwhile, more plutonium had come down from Hanford. Incidentally, when you do experiments like this, you have a guard watching you.

Sometimes it's a civilian, sometimes it's a man in military dress. You can tell these people always if you know what to look for. What to look for is a .38 revolver in their hand. They don't have a holster. Their job is to make sure that that plutonium stays where it's supposed to be. They don't care what happens to you, but that plutonium, they keep their eye on it. [Audience laughs] These were some remarkable individuals, but I don't have time to go into it. The first one I ran into was the first day that we started doing this experiment. I walked over to the equipment. I was the first person there in the morning. There was this deep voice behind me, "Will you please stand still." I don't know what your reaction is, but I turned around to look, and there's this guy with a big, funnel-shaped .38 pointing at me. He wasn't joking one bit. That was my first introduction to one of the security guards there.

Well, a few days later, it came back with thicker shells. We'd repeat the measurement, and we got a multiplication of 1.1. It goes back and comes back thicker. This procedure was duplicated over and over and over again. The final measurement we did with a chunk of plutonium which fit around this one-inch diameter core, which is about this big, about the size of a softball. I didn't know what the mass of it was at that time. That wasn't my business. We were making plots of the multiplication ratio as the radius of the shell. We got up to a multiplication ratio of 18. At that stage, it was decided that if you'd gotten to the critical mass, you'd know what the multiplication ratio was. It's infinite. If you get to that, you're—well, you're not in trouble;

you're not around anymore. [Audience laughs] We got up to 18. Our laboratory had been duplicated in a deep canyon nearby. The idea was that our laboratory was up on the main plateau or the town of Los Alamos. If there was a nuclear explosion, the town would go. So the 100% measurement was made down inside this deep canyon where they had duplicated our equipment.

When we finished that factor of 18 experiment, I was temporarily out of work, at which time I started looking at some other nuclear problems, which ultimately led to my PhD at the University of Wisconsin. But that's another long story. At any rate, I had come back from lunch and one of my friends said, "Fermi wants you to call him." Fermi was known as the Pope at Los Alamos. I remember making the remark, "I presume God is after me too." [Audience laughs] "No, the man wants you to call him." So I called him and he asked me to come up to his office. The point was, he wanted some more detailed information about fission experiments we had done. The other two guys were already down at a place in southern New Mexico where the first nuclear explosion was to occur. I was the best he could get a hold of. I still remember going into that office. I was absolutely terrified. I realized after about five minutes that he was asking me questions that any beginning nuclear physics student could answer. He was doing it to put me at ease. I had a high opinion of Fermi before that, and at that phase it just skyrocketed.

We were still talking when suddenly at the doorway was Louis Slotin He was the man who was in charge of the 100% measurement. He didn't say a word. He went over to the blackboard and wrote a number, six-point and two other digits at the end of it. There wasn't a question what he was talking about. This was the mass of plutonium-239 in a spherical geometry; that was 100% critical mass. Unfortunately, several months later, repeating this experiment, he was killed. There was a picture that I'd never seen before in your film here of something with a hemisphere above it and a screwdriver prying something apart. That's what I heard was the source for the accident.

At any rate, after my episode with Fermi, a few days went by. Suddenly we got a phone call from John Williams, who was down in southern New Mexico. He was number two man down there. He needed five of our group to come down if we were crazy or stupid enough to take the offer, to come down with all the good four-wheel drive vehicles we could bring down with us. As I was essentially out of work at that stage, I was assigned the job of going over to the tech motor pool and checking out four good four-wheel drive vehicles. The sergeant that was in charge just

laughed in my face when I asked him for them. He said, “We haven’t got four good-quality four-wheel drive vehicles. They’ve been siphoning all of them down here into southern New Mexico for some stupid reason. We just don’t have any.” [Audience chuckles] “What I can do is, I can furnish you two,” what are called four-by-four weapons carriers. These are oversized pickup trucks, which incidentally have dual rear wheels or single rear wheels. This is a critical thing, which I’ll come to later. And a Jeep.

Since I had never driven a Jeep before in my life and I had gone after those things, I was the first guy to drive a Jeep from Los Alamos down to this secret encampment. There was no windshield on the Jeep. The only instrument on it that worked was the battery charger. The oil pressure didn’t work. The gasoline tank didn’t work. And the agreement was the speedometer didn’t work and there was a 45-mile per hour wartime limit, I’m to drive it in between the two weapons carriers. I presumed they were going to go 45 miles an hour. I learned later that we went approximately 60 miles an hour all the way down there. I don’t know whose decision that was.

We were told that after we left Albuquerque at a certain number of miles we would see a track going off to the right, and there would be a sign there with a letter Y on it. We were supposed to turn off there, and we’d go and we would come to a checkpoint. We found the road, went that way, and suddenly there is an aircraft spotlight shining at us, and silhouetted is a three-man machine gun crew. You got the impression they really wanted you to stop and talk to them. [Audience laughs] Fortunately, we had the proper papers and they told us to go down so and so and we finally came to this base camp, which was originally the farm of a man whose name I cannot think of at present. We got there about midnight. At least I was shown into a bunkhouse and I climbed into an upper bunk. The next morning came around too early. I climbed out. I still had the same clothes on—getting in there at midnight, and the place was occupied with snoring people, I just went to sleep in my clothes. I got down from there and went over to a long military washhouse arrangement. Pinned to the wall was a tarantula, which had been pinned there with an ice pick, and a note behind it, “I found this in my boot this morning. What’d you find?” [Audience laughs] Public relations...

Soon thereafter, we found John Williams, and he told us what he wanted us to do. Three of us were to go with a meteorologist from Hanford, Washington and a GI guard—there were five of

us to go with—Oh, by the way, on the way down, the Jeep died. Unfortunately, I was driving it at the time it died. And I mean, it died. We saw it six months later still sitting in the same spot. [Audience laughs] That's U.S. engineers plight. But we got down there with the two weapons carriers.

What Williams wanted us to do was that they knew the direction—The thing was supposed to be set off about 4:30 in the morning. Originally it was going to be set off—this is an implosion-type device. There were two ways known then, and as far as I know these are still the same two basic techniques. You handle the fact that what you've got to do is take uranium-235 or plutonium-239 somehow in a subcritical assembly and do something to it so that it becomes critical. One method is the so-called "gun assembly". What they do is, they take a reproduction of a German .88-millimeter anti-aircraft gun. It turned out to be very good and shoots out bullets at 3,000 feet per second. And basically, on the nose of the shell in the gun is roughly half of the uranium they're going to use. It's subcritical. Screwed onto the end of it so that you won't miss is the other half of the critical assembly. Somebody had the intelligence to realize you'd better evacuate the gun barrel; otherwise the thing will go down and then get back due to compressed air. At any rate, it was evacuated.

The basic idea was you would shoot these two things together and it would become supercritical. At this time, you have what's called a certain type of neutron source, which is fractured by the crush—it'd be crushed by the assembly of the two things. You'd shoot neutrons in and the thing would go off. This is the so-called gun assembly. It is relatively very simple. Unfortunately, plutonium, in addition to the isotope 239, has another isotope called 241, which is a spontaneous neutron emitter. In the length of time that you take to assemble the gun assembly, it probably will shoot some neutrons off. So if you're using the gun assembly on plutonium, it's going to self-detonate at the time of the assembly. There are reasons why you would like to be able to—this is not a healthy property. [Audience laughs]

This led to the concept of the so-called "implosion device". In the implosion technique, basically what you do is, you surround a sphere of the material. This sphere is a subcritical assembly. Plutonium is very unusual in that it has six different metallurgical phases. The one that is most common is a metallurgical stage where the density is sort of minimal. So this critical

assemblage—what will be a critical assemblage when you compress it—is still subcritical. Basically, you surround this with explosives. These are shape charged explosives, so that when it is detonated, there will be a spherical compressing force, which will compress this plutonium. I do not know how much, what the size of it is actually. My guess is maybe it was something like this. But I don't know; it's a guess. I know that 98% of it was about this size.

The difficulty with this is that these compressive shockwaves are developed by individual high explosive, so-called lenses. These lenses are made by a combination of different velocities of explosive materials. They have to be detonated at just precisely the right time, I mean within a microsecond of the same time. If you do this, you get all of them fired at the same time, then you get this compression and you will get a critical mass. This is what the first plutonium device exploded, how it was supposed to work.

Originally, the possibility that there would not be a nuclear explosion was so great that they decided to set them off inside a big steel tank. There was a picture of that big steel tank being pulled up on that big tower. It's roughly eight-inches thick. There was also another picture. After the war, some general's tank was still lying there. Some general had them put 500-pound explosives in it and blew the ends off of it. The thickness of the steel is about this thick, and the tank itself, the diameter was something like this. It was so heavy that it had to be shipped from the Brooklyn Navy Yard where it was built by a special boat, and then by a special trailer, like the trailer that goes on semi trucks. Except those usually have four wheels on the back, and this had not just two axles. It had an axle that is all wheels, and then another axle that was all wheels, and then another axle which was all wheels and another axle which was all wheels. And they had towed this down into the desert area. There was a picture there of it being lifted into position.

I think a few weeks before the detonation of the device down there, which is July 15, 1945, a few weeks before that, a decision was made that the complications of getting all the electrical leads into this steel tank, the possibilities for trouble were so great that they decided to do it out in the air. Furthermore, doing it out in the air, they could put it up 100 feet. The reason for doing that was that thinking in terms of using it as a weapon, if you drop this thing, say, on a Japanese city and if you set it off right on the surface of the ground, the devastation right near it for a certain long distance, it's just simply going to vaporize everything. If you set it up higher, then the

shockwave that comes down will actually do more damage to the ground and the people beneath it than the damage that would be done if it were set off right on the ground. That one over Nagasaki where the first plutonium device was used was actually set off about 2,000 feet up.

So the decision was made to put this device up in this 100-foot heavy-duty oil well tower. There was a picture there of the heavy-duty oil well tower. There was also a picture of this spherical device, which was completely covered in a tremendous number of wires. Actually, a few weeks—maybe one week—before this thing was set off, a final critical test was done to see about the timing of the electrical pulse, and it failed miserably. I know the guy and his name I cannot think of now. He's a professor emeritus from the University of New Mexico, who at that time was a sergeant in the Army. He was the guy actually doing the electrical tests. The day that the thing was to go off, they thought that the electrical testing had worked fine. One measurement. That was the condition under which they were going to set the thing off. If the compression did not work, then you probably would not get a nuclear explosion, but you would get a big chemical explosion, and two billion dollars worth of plutonium would be scattered over the desert floor. There would have been the darnedest surface mining operation you ever saw to get that back. [Audience chuckles]

Well, at three o'clock in the morning, the GI guard came in and got us out of the bunkhouse so that we could see what was going to go on. The GI, by the way, still really had no idea why they'd been down there in these miserable conditions for about six months, and they really wanted to be overseas fighting. They were a rather disgruntled group. They came around at three o'clock in the morning and got us all out. And the rancher, whose central headquarters we were using as a base camp, had bulldozed out a couple of areas about three feet deep and about the size of a football field to catch surface runoff water in the few times when it rained down there. I don't think I even had a close friend with me. But I went up, and there was a bank about this high, which was perpendicular to the line of sight for this oil well tower out there nine miles away. There was a big light bulb on top of it, so even at nine miles you could see the glimmer of this big light bulb. I was leaning up against this bank along with a large number of other people. Apparently, in the next one over, Fermi and Hans Bethe were also leaning up against the side. I can still remember what the co-sign of the angle must be of the dirt between me and that tower out there, and it was a rather reassuring amount of dirt.

Come time for the thing to be set off, it was supposed to be set off I think at 4:30 in the morning while it was still dark for aid in photographic techniques. There were two Air Force planes that were supposed to get at a certain distance from the explosion to take aerial photographs. There was a most interesting argument, conversation, that went on between a colonel who was in charge of those two planes. They were new B-29 planes and there was an Air Force regulation: you do not take them into storm clouds. Where they had to come there were storm clouds. In fact, the night before had been a rather stormy night. Two friends of mine had repeated Ben Franklin's experiment nine times: they put meteorological devices up on balloons with thin steel cables, and the cable would flash white when it got hit with lightning. Believe me, they had them well grounded.

But at any rate, the conversation between the colonel and some character that we could tell by his voice was J.R. Oppenheimer: Oppenheimer was speaking in a very calm, authoritative method, "You've got to get to this point," and the colonel was repeating the Air Force regulation that he can't go up because of so and so. Oppenheimer was telling him that this was a matter of national security and so forth, "You've got to get up there." I don't think they ever got them to where they were supposed to be, but one of them, at least, got to a point where a decision was made to go ahead and set the thing off.

It was set off some time after 5:00 in the morning. We'd spent the previous three days in the mountains because Williams had told us that he wanted the G.I. guards and the Hanford meteorologist to go up the other side of the so-called Osceola Mountains and set off some smoke puffs in an Army portable smoke generator. To generate smoke problems, you go up at six in the morning, and a plane would come over and photograph them. The reason was that they knew the normal direction of the airflow over at the place of the tower towards these mountains. There were towns on the far side of the mountains, which they maybe, if the air current were appropriate, then maybe we'd have to evacuate those towns, and they didn't want to do this.

We had the two weapon carriers blowing smoke puffs, each of which was marked "Reject," and this portable smoke generator in the back, and water and oil and provisions and so forth. As we were going across the desert while I'm driving, one of the weapons carriers died. An informal vote was taken, which was four to one. I was on the losing end. I had been driving two of the

three vehicles we started out with. I wasn't to drive another vehicle until we got back to base camp. [Audience laughs] We found a place where the meteorologist had been a few weeks before and had picked out this particular ridge. They also had had terrible experience with rattlesnakes. They shot 14 of them in a half a day. We were extremely worried about rattlesnakes.

We started up this ridge, and we lit off the smoke generator about halfway up. The smoke generator—this is portable. Do you know what the Army's definition for portable is? It's got handles. [Audience laughs] It was kind of heavy getting it out of the truck, but we got it there and left it there. We headed on up. And we only had one weapons carrier. Unfortunately, we'd not thought to bring any hand radios with us, so we didn't have any correspondence back to base camp. We'd gone just a little bit further, and we ran into a sharp outcropping of rocks, which cut the tires completely to the rim. We had spare tires, but we decided that what we would do at that stage is that where that truck was going to be, we were going to replace the tires tomorrow morning. Meanwhile, we would take smoke pots to the top of the mountain. Smoke pots weighed 14 pounds apiece; they were about that of a gallon can of fruit, something like that, with a handle over the top, a striker device to set them off, and this big, heavy mark on them, "Reject." We assumed that they would not go off. Actually, all of them did go off and we used them. Unfortunately, we took some of them back to Los Alamos. Only a couple of weeks later, another group was using them and one of them exploded and blinded a man. But we didn't have any trouble with them at all. They weighed 14 pounds apiece. We were on a New Mexico mountainside, which is, oh, 30 degrees, something like this. So what we had to do is carry as many of these smoke pots up to the top of the mountain. We never did get to the top of the mountain. The way of carrying them, we hooked our belts through four of them and they had to be slung over your shoulders. The fifth one you carried in your hand just to throw at the rattlesnakes. [Audience laughs]

By the time it was dark, we were not anywhere near the top of the mountain ridge. So we left them on a rocky outcrop and went back to the base where the truck was. We had supper. We were a rather constipated group. Rattlesnakes really confined us to base camp. Also, there were questions about our sleeping arrangements. Nobody was going to sleep on the ground. So there were five of us. Two people were asleep in the seat of the weapons carrier, and the three

lucky guys got to sleep in the truck bed. I was one of the two that got a straw that led me to one of the seats. You might not think this was too bad, but the truck was so old there was no upholstery on the springs whatsoever. I didn't get much sleep that night.

The next morning, we got up. I don't know how we got up before 6:00, but we did. I and another guy went up to the smoke pots and we set them off before 6:00. And there came an airplane that we thought was ours. We hoped it was. Meanwhile, there was a column of smoke down below where we'd left off the portable smoke generator. Presumably he got the photographs that he wanted.

Meanwhile, we came back where the truck was. I was hearing language from a man who was an elder in the Mormon Church and one of the finer gentlemen I've ever known in my life. The words that were coming out were not words I thought he would even know. We had a single rear wheel weapons carrier, and we had a lug wrench. This is the lug wrench that kept the nut for the dual rear wheel. We had a big crescent wrench, so we tried to take the nuts off with the big crescent wrench. This is during the peak of World War II, and the alloys that went into iron were kind of skimpy in those days, and that wrench just unfolded. You may find it hard to believe, but if you were sufficiently motivated, you can take the lug nuts off of a truck with a ball peen hammer. [Audience laughs] We got the other wheels on it.

Meanwhile, the man from Hanford had decided the next ridge over would be better. So we decided to go back down. We had to go back to the other weapons carrier and pick up some more stuff. We didn't have any more smoke pots. We were going to open and pickup the portable smoke generator; it was down, and we did get halfway up the next ridge over. The decision was made that two people would carry the smoke generator. There were two handles on the front and two handles on the back. The remaining three people would carry five-gallon cans of oil and water, which were necessary to feed this thing. That was supposed to be a rest period when you were doing that. So we start back down, and I'm one of the ones carrying a can of water, which unfortunately leaked, but that's another matter.

We'd gone just a few feet, and there's a wild yell, "Come on back up!" The reason was that two people could pick this thing off of the ground. So we ended up with four people carrying the

smoke generator down that mountainside, and the single person that was left carried ten gallons of oil down. We had some water in the other truck. We got this thing down in the valley floor. And then the question about carrying it halfway up met with the unanimous vote, “It sits right there in the valley floor.” [Audience laughs] We carried smoke pots as high as we could up there.

Again, the next morning, we set the smoke pots in both places. A plane comes over, and we go back and we pick up our weapons carrier, which now has four operating wheels. We go back to where the other one was. We had a field cable with us. We tow it and we get back to base camp. We had not had our boots off since we left base camp—rattlesnakes. The main thing we wanted was a shower. We got back there about 12:30. We were ready to go into the shower, and here comes a young lieutenant, an M.P., and said, “Everybody is supposed to be over at the Mess Hall. There are important talks going on over there.” We explained we had been in the field. We were filthy. We’d probably heard everything they were going to say over there anyhow. We were going to take a shower. And he explained to us what we were going to do, so we put our clothes back on and went back to the place where the talks were going to be. [Audience chuckles]

Sure enough, most of the talks were things we’d heard before. One of them was that Hans Bethe, who was head of the theoretical division, had made an estimate that the explosive power he thought was going to be about the equivalent of 5,000 tons of high explosives. That was the place where you got [inaudible] and a handle on how big they were was going to be.

The other thing we heard was from Col. Stafford Warren. Why do I remember this name? His talk was extremely impressive. He was head of the medical division of the Manhattan District. He said, “What’s going to happen when that thing goes off tomorrow morning?” Assuming it does go off properly. He said he strongly recommended that you have some kind of eye protection. We thought of this, and brought back a whole case of welder’s goggles of the type that were used for acetylene torch welding. The more he talked, the dimmer those goggles got. He strongly recommended that you be looking in the opposite direction. From the reflected light, you decide if and when you want to turn around and look.

That afternoon, I’d seen that there was a welding shop there. I went over and I traded the whole case of goggles for five pieces of blue glass that they put in an electric arc welder’s hood. We got

some 18-inch square pieces of cardboard and cut a little rectangle in them and scotch taped this blue glass over it. This is what we were going to look through. I tried it out that night on a 100-watt bare light bulb that was there, and all I could see was the blue glow where the filament was, nothing else. It was really dark.

Comes the morning when they get us out of there. I'm looking in the opposite direction and he's counting down—seven, six, five, four. When he gets down to zero, I'm looking in the opposite direction. The amount of light that I saw there was the most intense light I have ever seen in my life, and I hope to God I never see another thing like that. There were mountains in the distance, and they actually seemed to mechanically jump forward. Like looking into a photographer's light bulb, except this is absolutely everywhere. I counted 1001, 1002, to 1015 and turned around and looked, and my first reaction was, "You forgot the blue glass." But I hadn't. I was looking through it, and what I was seeing out there was a ball of fire. You saw pictures of it there. When I saw it, it was about a ??? diameter above the valley floor, and it simply went up through the clouds. I do not know how long we watched that thing. I know it was full daylight before we gave up watching it. There was that familiar mushroom cloud. Somebody remarked that the top of it was about 78,000 feet, but I do not know whether this was correct.

This is what I saw down there on this first explosion. I sincerely hope I never see anything similar to it again. I was one of the first people to leave the camp there and go back to Los Alamos. There was a debriefing session by a sergeant who was attached to General Groves. Since I was apparently the first one, it was not a group discussion. He was talking directly to me. "When you get back to Los Alamos, you were not to say whether you saw anything. What you saw, you just don't say anything about it. It's classified. I don't care what the clearance is of the person you're talking to. You don't say anything, period."

I get back to Los Alamos and go to our apartment, and there's a note on the door. My wife had gone with friends to the cafeteria. If I got back in time, come join them. This is just about six o'clock at night. So I go back over to the cafeteria, and I'm going through the line. There's this group of women—my wife is one of them—who are sitting across the cafeteria. They start yelling questions at me. "Was the ball of fire really as big as so-and-so?" "Did it really go to 78,000 feet?" [Audience laughs] Me, I'm afraid to open my mouth. Somebody had talked. You

probably know there are several means of communication—the telegraph, tele-this, tele-this, and tell a woman is one of them. It really had gotten around.

Well, that's what I saw. Thirty days later, a friend of mine who'd been one of the people that did Franklin's experiment, wanted to go down and look for some of the ???. There wasn't a chance in Hades that those things survived that explosion—they were only about 100 feet away. But it was a good excuse to just go down there and see what had happened. He asked me if I wanted to go along. Sure, I wanted to go along. This was about 30 days later. The M.P.s had set up a system whereby you had to go in on a Jeep that one of their people was driving, and he had radiation measuring chambers. He had orders that when he got to 15 [rems], which was the standard unit at that time, he was to leave. So if we came with him or not, that was up to us.

When we got there, I saw what had happened. The hole in the ground, I was very surprised at how small it was. My recollection—and I can't verify this—but my recollection was maybe 30-40 feet in width and a little bit longer. How deep was it? Eight, nine, ten feet, filled with powdered earth, just powder. This was much less than I anticipated. Apparently, dirt is very resistant to compression. Outside of that crater, though, it was really horrifying. The desert floor had simply melted and was green glass. It had begun to break up into chunks about so big, and it was quite radioactive. One of the things we'd found, and we'd been told to look for this, about 1,000 yards out there were some little glass spheres. Two or three of these little glass spheres were as radioactive as a whole bucket full of the stuff right close to the crater. What had happened was that some of the safe material in the crater had been liquefied and thrown into the air as liquid, and then due to surface tension had gone into a surface shape and then it hit up there about 1,000 feet. This was these highly radioactive little spheres. We brought back a bucketful of this stuff, including some of the spheres. There was a story that went around—and I don't know if it was true or not—that somehow a woman had gotten hold of one of these spheres and had it mounted in a ring, and she lost a finger as a result of it. Whether that's true or not, I don't know.

Well, that's what I saw; I hope I never see anything like it again. I think I'd feel better if you'd let me talk a little bit more. One of the things at Los Alamos was there were lots of secret colloquia showing photographs of what had happened at Hiroshima and at Nagasaki. They are not pleasant at all. There was a concrete wall that has a silhouette of a man. Inside the silhouette,

there is a concrete color. Outside of the silhouette is his hand. In other words, the intensity of the light that hit that concrete wall was such that it caused a change in the color of the wall. The man stopped the light. He probably was incinerated. I saw a picture of a woman's back. She had been wearing a bright kimono, which was apparently a black kimono with pretty yellow lines going across the fabric. Where the yellow lines were, there was still skin. Where the black was, it had been burned about three-quarters of an inch thick. I have been told that there were over 100,000 people drowned in the river there in Hiroshima. The drowning was caused by people trying and getting into the river to try to get away from the ??? burns.

In World War II, it has been discovered that if you have an intense artillery barrage and then the troops go in afterwards, they find that amazingly, they find that the enemy troops that were where the barrage-type exposure had been, they came out of holes, and the conclusion was that the artillery barrages are done by large numbers of cannons which are set out maybe a mile across, something like that. So that the time of delivery of the shells, the ones that are closer get there faster. The ones that are farther away take longer to get there. When the first shell goes off, the enemy troops head for the hole. So they had developed a technique called the serenade, where you have a long string of artillery, and the guys out on the far end fire, and then in and in and in, so that all of the shells arrive there at the same time. It is much more effective in terms of an artillery barrage than the older artillery barrage. A similar thing happens when there's a nuclear explosion. If you have a bombing raid like was on London, on Dresden and so forth, the bombs fall and fall and fall. A lot of people get under cover. If it is a nuclear explosion, it is one bomb, and everything happens right there.

I was told at one of these colloquia later that there were 94 fire stations in Hiroshima. In 92 of them, there was nobody left alive. In two of them, people were found still alive, but their equipment was dead. And also another thing that happened is the blast of the bomb on the Earth caused potentially the problems of an earthquake. Gas lines were lit, and fires break out everywhere. Medical facilities under these conditions, there just aren't any. So here you have a city the inner portion of which is just demolished. If you go further out, the density of the damage is considerably left. There's nobody there to come in and take care of you. This was done at Hiroshima with a 235 bomb, and that was a gun assembly. Then they dropped a 239 device on Nagasaki a week later. The purpose of doing that on a weekly basis was to impress the

Japanese that we have these things; we're going to continue to use them on city after city if you don't give up. And the Japanese gave up. So it cut World War II off.

And I've often been asked, "Do you regret your participation in this?" Well, first of all, I was a rather low man on the totem pole. But on the other hand, I was involved. It's not pleasant to think that you [inaudible] at Hiroshima, you were involved in the killing of 100,000 people—men, women, and children. On the other hand, the United States and its Allies were ready to invade Japan. Many times, when I've given this talk, there's somebody come up from the audience—I have no regrets for my participation. People would come up to me and say that they strongly agree. They were on one of the ships that were ready to go into Japan. As I recall, Churchill made a statement that if the Allies had invaded Japan, there probably would have been 250,000 deaths of Allied troops, and over a million deaths of Japanese people, defenders and civilians. So from that point of view, maybe we saved some Japanese lives in cutting off the war when we did. That's my position on it.

I was made particularly uncomfortable one time when I gave this talk in a department at MP [?] State University. Afterwards, I see a man that I know is a Japanese professor in the mathematics department coming up to me. I was a little uncomfortable. When he got up to me, he rapped his leg with a cane, and it was obviously a wooden leg. He said, "I got this at Hiroshima." He said, "I agree with your feelings about you've probably saved more Japanese lives than you've taken." It was a real feeling of relief.

Well, that's what I saw. Being at Los Alamos was probably the most fortunate thing that could happen to a graduate student at that time. One other thing, nobody was shooting at me. My draft board had told me, "Sure. Go on to New Mexico. We can get you down there just as well as we can get you here in Wisconsin." They were wrong, but they didn't know that at that time. So anybody that had been in Los Alamos, they did not want to get them anywhere near any enemy lines. So every time I got a draft card, I'd take it to this certain Major and he'd say he'd take care of it. And I'd get a ???, and he'd say, "Don't worry. They can't get in to get you." And that was his story. [Audience laughs]

In addition to the security of being there working on it, working on it was extremely interesting. Was there a feeling of pressure? We knew the Germans were working on this. We had a feeling—the usual statement was, “We’re probably a year and a half ahead of them.” If the Germans got it before we did, London would go and World War II would be over very soon thereafter. It would not have been very pleasant.

The other thing about it was the opportunity to work with some of the outstanding physicists that existed in the world at that time. I worked personally with many outstanding [inaudible]. For instance, at colloquium, we had seven different speakers, all of them Nobel Laureates. At another colloquium, we had Niels Bohr as the speaker. I’m sure you know who Niels Bohr is. He had a lapel microphone with a cord on it. They didn’t have the FM jobs. So he talked to the audience and turns around and writes on the blackboard. Then he turns around, and [inaudible; audience laughter] him all wound up. [Audience laughs] This business of coming back and Enrico Fermi wants you to call him. I was petrified. But on the other hand, it was an experience that I would never... I was very happy when it was over and I ???.

There were other people. First day I was there, going down the hall towards where we worked with the two Wisconsin Van der Graaff generators, I hear bellowing out of the laboratory across the hall, “[Shouting in German].” That’s kind of unusual in World War II, at that stage. Turns out it was a very prominent Swiss physicist, and German was his natural language.

That’s it. Thank you very much. [Applause]

STITH: Worth has agreed to take some questions.

SCHEWE: You very eloquently described your experiences there. Could you say a few more words about the moment when the Trinity Test went off? Did you have a visceral feeling that you or you and your colleagues had created some new force, some new phenomenon? What kind of physics, change in the universe was happening at that moment, in your mind?

SEAGONDOLLAR: The main thing in my mind at that time was, “You forgot the blue glass.” [Audience laughs] No, I did not have this feeling. Oppenheimer apparently did. There are some recorded statements of his about, “I have seen something vast [?].” No, I’m afraid I was too young

and too inexperienced to have such feelings. One of the things I remember was the reception. When I first ran into a G.I. guard, this guy had been there for months, and he had no idea what he'd been working on. Man after man as I was walking by wanted to buy me a drink. They were extremely relieved to at last realize that their relatively unhappy experience there had been for some reason. But that's about all I can do to answer your question.

JONES: What were you told when you were asked to come to work at Los Alamos? And what, in turn, did you say to your parents or friends or your loved ones about what you were about to do and how long you would be gone and why?

SEAGONDOLLAR: First of all, when I was working in the nuclear physics group in '43 and I was asked if I would be willing to go down to somewhere in the Southwest, it became apparent that graduate school was falling apart, and I wanted to go. Two hours before train time, a guy named Oppenheimer, who I'd never heard of, told the guy who was in charge of our group to cancel the last two jobs that he had offered. When my job was cancelled, I was offered a job at Chicago or on the West Coast. I had done some considerable changes in my life, and I was not happy. I refused to go down to take either of those jobs. That was in April, I think. In October I got a telegram from Los Alamos offering me a job to come down there. What had happened was, apparently General Grove [?] had gotten worried about the number of physics students that had been hired to come to Los Alamos at the beginning, and that's where their reduction in force occurred at that stage. Then the thing was expanding more and they wanted me to come down. And I was still mad, and I would not go.

But then in the spring of 1944 I was teaching in the Army Specialized Training Program, and that was the basis for my draft deferment. Suddenly, the Army Specialized Training Program was cancelled overnight. A decision had been made on June 4 or June 6 of 1944 was coming up. They were going to be going into France, and they'd better start emphasizing their military training rather than their classroom training. So that was cancelled overnight. I took a train to Chicago and talked with some people in that lab and was offered a job there. I had also sent a telegram to Los Alamos asking if their original offer was still open. I was offered a job at the Met Lab, and I asked if I could defer my answer for 24 hours. When I got back to the hotel, my

wife had called, and Los Alamos had said to come ahead, and that's when I went down there. So that's how I got there in the spring of '44.

WHITE: I remember a story about the plutonium sphere being dropped at some point. Could you remind me the details of that?

SEAGONDOLLAR: Where did you hear that? I had the midnight till 8:00 a.m. shift. Basically what you had were these two hemispheres which were about this big when put together, with a one-inch spherical hole in the middle for the source in there. I do not know what happened, but I bumped it and knocked it over. One piece fell about six inches onto a steel table, and the other piece I caught like this [in straining voice]. I don't know what you do when you are really scared, and I mean really scared. I want to throw up. The piece I caught was not damaged in the slightest. The piece that fell over onto the steel table had a dent in the side, and the two pieces would not go back together. You couldn't continue the experiment. This was coated with, I think, silver. The question was, with this dent, had the silver been broken? Because if it was, I was in severe danger because the stuff would oxidize and go into the air. We had an ionization chamber there for this kind of purpose. I checked very quickly, and there were no alpha [?] particles coming out of this damaged hemisphere.

Looking back, what I did, I'm not sure if it was the most intelligent thing in the world. But at Wisconsin when you had problems, you were told to solve them yourself. So I went and told the guard to stay there, which he obviously was going to do. And I went to the big maintenance building next door, to which we had a key for emergencies. I got a gas mask and a new ball peen hammer. I went back to the ball, put the gas mask on, put the guard out in the hall, and gently tapped this thing. I took my time with it, until it was back into a shape where it would fit back together, and went ahead with the experiment. I told Al Hanson, who was the number one man—he was the 8:00 a.m. to 4:00 p.m. guy—what had happened. I don't remember him making any derogatory comments about it. I went home and went to bed.

The next night there I was midnight till 8:00 a.m., about 2:30 in walks Oppenheimer. He introduced himself, and that wasn't necessary—I could sure tell [inaudible; audience laughter]. I had a very uncomfortable feeling he had heard my name and the reason why. [Audience laughs]

After talking for a bit in a very polite manner, he said, and I can remember the words, “We are all exceedingly fortunate that you were so successful.” And he left, and that was it. That’s one of the two times at Los Alamos that I really, seriously thought about the possibility of death, though I didn’t know it.

STITH: Do you have a question?

JONES: When you saw the bomb go off, did you feel at that point that the end of the war was now within grasp, that that would change it all?

SEAGONDOLLAR: I suspect I did. I can’t honestly answer that I specifically thought of it. I remember specifically thinking that this is the culmination of a tremendous amount of experimental research work, and it worked. I remember that feeling. It was not long after that that I began to think in terms of, “This will stop the war.” But I don’t remember whether I had it within the few minutes after the thing went off. I just don’t remember.

STITH: I’ll ask one. While you were at Los Alamos, how much did you know about what was going on at other places?

SEAGONDOLLAR: At Chicago, at Hanford, at Oak Ridge, not only to get the white badge number, which meant that you had the highest level of security except for administrative stuff, there you also had to have the “need to know.” If you didn’t have a need to know to do your particular job, you were not supposed to know. A decision was made at Los Alamos, this is a place where everything is going to be talked about. So if you had a white badge card, which I did, you had a right to everything except administrative reports. I remember at one of the secret colloquia, Urey, who got the Nobel Prize for verifying the mass ??? of isotope hydrogen, Urey was at that time at Los Alamos. He was there at one of the secret colloquia. I think he was one of the seven Nobels that I was talking about. At one of his talks he said at Oak Ridge, they had this gaseous diffusion system separating uranium-235 and uranium-238. In these tall, gaseous diffusion columns, there are certain filters. And he said the content of those was classified, and he went on. A few minutes later, Oppenheimer said, “Here at Los Alamos, all the people that are in this audience are cleared for all classified information. Would you please describe what these

filters hold.” Urey was just shocked. He went down and he talked to some guy on the front row. He came back, and he said, “I apologize. The constituency of these filters is so-and-so.”

Incidentally, I think you’re all familiar with Teflon on cooking utensils. Teflon was developed during World War II as packing material for valves at Oak Ridge. In the early stages, you could get a gram of Teflon for the same difficulty and the same cost as a gram of gold. Obviously, the situation has been changed.

STITH: Worth, on behalf of AIP, on behalf of all the interns in the audience, thank you for thrilling us with the events of that time. And we hope that when we get this transcribed, you could take a look at it and tell us those things that you meant to say and those things that we still need to know. Let’s give Worth a hand. [Applause]

We thank Dr. Richard Dyer for pointing out several errors in the original transcript.