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SOME EXPERIENCES WITH ATOMIC WEAPONS

by

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It is mighty nice of you to invite me here tonight. I have followed the organization and growth of your chapter and indeed, except for a few coincidences, I would now be one of you, instead of being here to tell you of work taking place some fifteen hundred miles away. And, of course, what I will discuss are my own observations and in no way official.

Starting at the beginning, I am well aware that until tonight the name Sandia Corporation meant very little to many of you. I do not, in any sense, chide you for this, for our corporation is engaged in the development and production of atomic weapons, a highly secret project. Yet our scope is immense. It reaches into nearly every state of the Union; we have more or less permanent branches in Nevada, in California, and out in the Pacific - besides our main plant (5600 people) in Albuquerque, but the only advertisement we ever write appears in the help wanted columns in our never-ending search for scientists. I can't blame you for not knowing of Sandia until now, but I hope you will hear more of us in the future.

Any new science normally has repercussions in a wide number of related fields - usually more than the original inventors ever foresaw. A good example is television, which, besides revolutionizing the entertainment world, made visible a great number of chemical and industrial processes formerly hidden from the human eye, put the cabinet making industry back on its feet, and the cowboy back in every American home. A curious by-product, in this case, came to light when they recently filmed the "Spirit of St. Louis". There is something rather anachronistic about Lindy flying over a bunch of TV aerials.

The same widening of the field has also been true with the atom. I doubt if you could list the discoveries additional to weaponry on a single page. Indeed, it is its widespread effect that accounts for my presence here tonight. As an aerodynamicist, it would normally take a lot of courage to speak on atomic weaponry except that the field is so wide that aerodynamics - along with practically every other science - has a place in the new atomic world. I hope you will find its place interesting.

I suppose every speaker on the atom sooner or later gets around to July 16, 1945. I am going to follow the old routine - not because I can describe the great burst of flame that crossed the New Mexican desert a hundred miles south of my present home any better or as well as anybody else, but simply because for the past five years I have associated with many of the men who were there at that time and some of their experiences have rubbed off on me. Some of these men laid face down amongst the tumbleweed - following written orders to "prepare a suitable place to lie down on"; others were in the bunkers; still others sat in an Albuquerque hotel room and observed an explosion over a hundred miles away.

Possibly the most poetic description of "Trinity" was given by observer William L. Laurence when he said, "With the flash came a delayed roll of thunder heard, just as the flash was seen, for hundreds of miles. The roar echoed and reverberated from the distant hills and the Sierra Oscuro range nearby, sounding as though it came from some supramundane source as well as from the bowels of the earth. The hills said yes and the mountains chimed in yes. It was if the earth had spoken and the suddenly iridescent clouds and sky had joined in one affirmative answer. Atomic energy - yes. It was fascinating and terrifying, uplifting and crushing, ominous, devastating, full of great promise and great forebodings".

Mr. Laurence left out one thing -- hard work. For the blast, more than any other single achievement by man, was the result of the hard work of thousands of people; hard work, heartbreaks, and rarely, laughs.

For instance, to go back a few months more, some of my friends arrived at Trinity around Christmas, 1944. They lived in windowless barracks and ate at mobile kitchens for six months, many without ever leaving. They prepared the control points, installed instrumentation, and followed through every step short of firing the gadget so that they would be letter-perfect when the time came. For them, Trinity was almost an anticlimax.

Today, ten years later, much of the work they did remains unchanged; the blockhouses still remain, along with a few wires, and a stump of concrete and steel at ground zero. The area is still fenced. The ground is still radioactive, but no longer dangerous for short visits. The old farmhouse where the gadget was assembled is still there too. Things change slowly in the desert, unless man changes them in a millionth of a second.

One story that has never been told about the first explosion concerns a tank named "Jumbo"; probably the strongest tank in the world. It had steel walls over six inches thick. Its duty was to contain the chemical explosion if the uranium didn't fission; since in 1945 there wasn't a great deal of fissionable material in existence, and the prospect of spreading what little we had all over the desert was too horrible to contemplate. But the tank was never used. In the last few months it became a mathematical certainty that the bomb would fission. The hard work and heartbreaks that went into Jumbo were just necessary back-up to a program frequently operating on the boundaries of knowledge.

The security provisions in those days were maintained at a very stringent level. However, personnel on a secret project sometimes forget that informing an outsider that something is secret, is a violation itself. For instance, there has always been a use for uranium; it was used by glass manufacturers to color glass yellow. Well, one day a scientist, who dared not whisper the word "uranium", called a glass dealer for some yellow glass tubing. He was told, of course, that they had "uranium glass". Forgetting himself entirely, and rising to the full height of great indignation, the scientist said, "If you're going to discuss classified information over the telephone, I can't do business with you", and hung up..

Many times I have wished that it had been my good fortune to have participated in the program in those years. It must have been a time of great excitement and frustrations. One of my friends told me of the early assembly problems, and how it was pointed out that a steel chain hoist was inadvisable as it might spark. My friend had the job of going to a chain manufacturer, and asking him to make a brass chain. Of course, the manufacturer pointed out that a brass chain was many times weaker, and many times more expensive, and there wasn't any sense in making one, but my friend stood his ground. He finally got a brass chain, along with a lot of looks that clearly questioned his sanity. Another fellow had to buy a square balloon.

There were many other human interest stories that occurred during the early days of the atom, and I would like to take time for just two more. The first is told by William L. Laurence in "Dawn Over Zero", and it concerns the great Danish physicist Neils Bohr. Bohr, it seems, had a small supply of heavy water, which, to keep from falling into Nazi hands, he had stored in a beer bottle in his refrigerator. When he escaped to Sweden he took the

bottle with him - only to discover that in his haste he had brought along just an ordinary bottle of good Danish beer. The proper bottle was finally rescued by the underground.

The second story concerns the loss of the cruiser Indianapolis - just four days after it had delivered the fissionable material to the assembly base at Tinian. One can speculate on the difference it would have made in the war had the cruiser been lost five days earlier.

But to return to the weapon itself, in 1945 nobody really cared about the quantitative effect of an atom bomb. There was going to be a hell of an explosion and the war would be over and our boys would come home. And this was exactly what happened. As General Groves so aptly put it, "We needed to fire one to show them such a bomb existed, and to fire a second to show we had more than one."

In the years that have followed, there has been a lot of speculation about the value of those blasts, both military and moral. I settled all this in my mind by studying a little Japanese history. Japan, in 1945, was in the grip of militarists, who, by custom, would have to commit suicide before surrender. One can infer that to them the war was going fine. The atom bombs furnished the excuse they needed to surrender with honor. The tragic deaths of Hiroshima and Nagasaki were, in fact, one of the great sacrifices of all time; saving not less than several million people at a cost of around a hundred thousand.

As well you know, the dropping of the atomic weapons presaged a period of peace; an era of great hope. And then, in September 1949, the Russians fired their first atomic weapon and the race was on. Now we had to look to

defense. While General Groves had told us in Atlanta in 1946 "that the only defense against an atom bomb is to be somewhere else when it goes off", we had to know how far off is "somewhere else". And we had to accelerate our research to keep ahead of all competitors. And from an offense standpoint we had to know how near we had to drop one to make certain a particular target would be destroyed.

In other words, besides weapon improvement, we had to increase our knowledge of weapon effects. Indeed, in that latter category, our knowledge was considerably less than you might guess after we had shot several bombs, but I think you will agree that conditions had not been exactly conducive to orderly research. What did we know? Well, we knew that the explosion released a great amount of radiation and heat, and made a great shock wave. What we didn't know was how far away was what dynamic pressure created? Or what radiation occurs how far away? Or how much heat? Or how much overpressure? And along with all this are the effects questions such as how much radiation is lethal? Or how much overpressure or dynamic pressure is needed for each of a hundred different type targets? Or what different effects occur high in the sky, or under the water or under the ground? I think you will agree that these problems certainly had to be solved before atomic weapons could join the other weapons of the military with any reasonable degree of intelligent use.

Another facet which I have not previously mentioned is the actual ballistics of the weapons. While you might argue that their destructive power is so great that you don't need drop accuracy, a little thought will reveal that that's just why you do. You don't want to destroy a city if all you really want is the airfield. So we had release, drop, and fuzing accuracy problems to add to all of the above.

Thus was initiated a great four-pronged program aimed at (1) developing better weapons, (2) measuring their effects, (3) determining the needed effects for particular targets, and (4) improving the ballistics of bombs in general. For testing the better weapons and recording their effects, a site was selected that is both remote and accessible, and off the airlines. This place is called the Nevada Proving Grounds. Where more remoteness is required, another base was set up at Eniwetok in the Pacific. And for the ballistic problems, a bombing range was developed at Salton Sea in southern California. The know-how and hardware for the whole program comes for the most part from Los Alamos and the Sandia Corporation in Albuquerque, with special problems worked out in laboratories all over the nation.

As for the actual research, some could be and has been done on paper, and I would like to pay tribute here to the marvelous theoretical studies turned out by my associates at Sandia and, of course, the scientists at Los Alamos. Time after time, their theoretical efforts have been corroborated experimentally in the field.

Through about 60 tests, the data has been accumulated and the damage picture is becoming clearer so that we can help the military work out what yield they need with what accuracy of drop to do a given job.

I believe you would be interested in a few details about the full-scale test range and some experiences there. The Nevada Proving Grounds is some seventy miles northwest of Las Vegas, Nevada. A few years ago it was a pretty rugged place, but now you can get a steak there or see a movie, and while remote, it's not too bad for a short visit. The area includes Camp Mercury, a military installation, and Frenchman Flat and Yucca Flat. Near these two great flats or in the sky above, all of the atom bombs fired in the United States since Trinity have been shot.

Reaching out from ground zero for each shot are the lines of instrumentation which tell us what we got. And for some shots actual or simulated targets are emplaced.

A visit to, or I should say NEAR, an old blast site is quite awe-inspiring. The steel tower used to get a ground shot up so that less ground poisoning will occur and less fallout result, is usually gone with perhaps a couple of feet of the legs still sticking up, burned black and showing signs of having melted, and perhaps a burned and twisted piece of structure is somewhere about. The ground is littered with chunks of rock. Even though the shot took place years ago, the radiation danger signs are still up and occasionally you see a dead rabbit who decided to build too close to the site. General Groves' suggestion to "be somewhere else" comes clearly to mind. If the time of your visit is during a test series, the chances are that other towers are being constructed off in the distance. Looking at them, it is hard to imagine a steel tower high as a forty story building disappearing into thin air, but the evidence is inescapable as well as invisible.

The atomic burst itself is also pretty memorable. The big difference between how it really looks and what you've seen in the movies is that the real thing is silent from where you stand. The fireball sits there and the gases roll and tumble and grow without a sound. Then they turn red-brown and you think bromine? bromine? where'd the bromine come from? Someone says no, it's nitrogen dioxide. Then as you stand there the millions of cubic feet of brown gas turn into other oxides of nitrogen, some invisible, some white. Probably a few thousand cubic feet of laughing gas are manufactured in the process. As the great white cloud reaches into the stratosphere the loud speaker says "the shock wave will arrive in about thirty seconds", and

then you feel like somebody stuck two firecrackers in your ears and let them go. Then there's a long rumble as the wave bounces off the neighboring hills. It wouldn't be so bad except for the countdown which pulls your nerves into knots. If you're witnessing an air drop, rather than a tower shot, they give you a thirty-second count down to "bombs away", then, depending on the altitude there's about a 45-second count to burst, and later a thirty-second wait to shock wave arrival. You can get a lot of reminiscing and worrying done in 105 seconds. But the countdowns are necessary to give the times to turn on various instruments that can't be automatically set, and to alert observers without goggles to turn their backs or take other precautions for personal safety.

I have seen some ultra high speed movies that show the explosion to be fantastically different than what you might expect. First there is a blue flash, and then the whole cab of the tower is atomized into a ball of gas. Streamers of flame shoot down the legs of the tower, and out the supporting cables as the rate of propagation in steel exceeds that in air. Then a fireball forms and grows with a brilliance that defies description. Finally, a shock wave detaches itself from the fireball and travels outward. While all this has been going on the ground beneath the tower has exploded from the heat, and the fireball, lighter than air has been rising slowly. The human eye picks up the story about this time.

You turn away from the shot feeling pretty wrung out, barely conscious of the arrival of chase planes which will follow the cloud to keep airliners out of it.

What I have just described applies to small and medium-sized explosions. Shots too dangerous for the continental United States are fired out in the Pacific, in the Marshall Islands. Much publicity has been given to the radioactive fall-out experienced there, and suffice it to say, fall-out remains a great problem, especially from the defense standpoint.

Looking at the fall-out problem from a more technical point of view, the distribution of fall-out is a very real problem for the meteorologist and aerodynamicist. In turn, it influences the desired height of burst and many other military factors. Since there is such a thing as progress, the bomb mentioned above that caused damage and could have caused casualties 175 miles away, probably wasn't the biggest that could be built. So, to bring the problem home, a big burst over Birmingham might well chase you out of your homes here, or under the ground.

Speaking of homes, life in Albuquerque is so different from that which you enjoy that a few comments on desert life might be of interest to you. For instance, they tell me that the yearly average rainfall out there is seven inches. This reminds me of the colored pullman porter who was asked by a passenger what his average tip was. Being told "five dollars", he promptly tipped five dollars and the porter said, "Thank you, suh, we don't hardly ever get the average". It's the same way in Albuquerque - we don't hardly ever get the average rainfall. But the slope of the land and the lack of vegetation is such that even a little shower finally runs down to the valley and all too frequently floods some homes. Daily sunshine is the eternal rule some 355 days a year, and the air, being devoid of moisture doesn't give you much protection so that a real bad sunburn is an easy thing to get. I know you won't believe it, but Albuquerque is one of the coolest summer spots in

the country. Get out of the sun, and the relative humidity of from 8 to 15% just won't let you get hot. Of course, we water every living plant a couple of times a week, and a three-week vacation without providing for somebody to water your place might result in every tree, plant and blade of grass being dead when you return. The dryness permits easy home air-conditioning with a fan and some wet pads. You might think that all this dryness would be uncomfortable, or bad for your skin, but the body seems to be able to readjust quite easily.

North of Albuquerque some 60 air miles is the famous Los Alamos, a city of about 12,000 people where most of the wage earners are scientists. You can't own your own home there, but living accommodations and social life are very nice. A private airline connects the atomic work in Albuquerque with that of Los Alamos. Its 25-minute flight is the world's shortest, but offers some of the most spectacular scenery. Speaking of Los Alamos reminds me of our security and how it backfired a couple of years ago. It seems that if a city can qualify as a "prime target" or such, a certain government agency will stand half the cost of a fire engine. Accordingly, Albuquerque put in for one. Now, mind you, the Sandia Corporation is right in Albuquerque, Los Alamos is 60 miles north, Sandia Base (home of the Armed Forces Special Weapons Project) is in Albuquerque as is Kirtland Air Force Base (home of the Air Force Special Weapons Command). Well, such was the security that the agency wrote back that since Albuquerque was not within 100 miles of an important target, they couldn't have the fire engine! I assume that the decision was reversed. But it shows that our negative publicity was in high gear.

Security hurts us when we try to hire people, too. In the old days of the Manhattan Project, they'd get you up on a rooftop (no microphones) and ask you to come out to New Mexico to work on--a "secret project"). Then when you got here you learned you were an atomic scientist, and your new address--along with thousands of others, was P.O. Box 1663, Santa Fe. This was so your mail could be censored. Your magazines came via General Delivery, Los Angeles, as even the simplest mail clerk would get alarmed at sending 500 copies of, say, the "Physical Review" to one box number.

We suffered part of the same security when I arrived five years ago. We had to use fictitious addresses when we traveled. Believe it or not, the word "aerodynamics" was then classified when used in conjunction with Sandia. This was based on an "association theory" that an enemy agent might figure we had aerodynamics problems if he found we needed aerodynamicists. Well, if they don't know, I'll tell them; we do have aerodynamics problems along with Lockheed, Douglas and any other company that makes products that fly through the air.

Fortunately, the association theory has been fairly well discredited, and I'm able to say we want and need aerodynamicists, physicists and just about any kind of engineer. But we still can't get very specific about duties until the candidate has been FBI investigated, and the results of the investigation accepted by the AEC. We call it a "Q" clearance.

In connection with our work, you might wonder what training is necessary for A-bomb aerodynamicists. I guess the answer doesn't exist. The aerodynamicists do weapon static and dynamic stability, shock wave work, unsteady aerodynamics, and any other type of aerodynamic problem that arises. If it

can't be solved on paper, we use sleds, wind tunnels, shock tubes, drop tests, rockets, or rocket-boosted drops. Since we don't have all the facilities we need, necessarily we contract a lot of work out. This in turn requires a rather large amount of traveling compared to most jobs; in fact, I noted the other day that I had crossed the country 48 times in five years.

In connection with research, you might think that rather than shoot off atom bombs, we could use some sort of scaled-down test, and to the greatest extent possible, we do. Normally, this is so successful that our full-scale tests are just check-outs for the small scale work. But some of the fundamental work has required atomic explosions.

Scaling of the shock wave seems pretty remote. It develops that you can scale the overpressure, but when you do, the duration of the shock is all wrong. And, as it turns out, the duration is a very important parameter. For instance, when you compute the simple gust loading on an airplane, you have some empirical factors that take care of the gust gradient, but there is little in the literature that covers the case when there isn't any gradient and when the gust dies out in a fraction of a second.

In connection with damage due to blast, every target has its own characteristics. Some are affected most by gust, some by overpressure, some by shock diffraction. With some, the heating is important and must be figured in with the above aerodynamic effects. And, of course, if living humans are involved, radiation is important too. It's just impossible to stay a pure aerodynamicist or physicist or pure anything else. An important phenomena of shock waves from atomic explosions is the manner in which they are bent by the winds aloft and the upper atmosphere temperature structure to return to earth, focused and far stronger than one could reasonably expect from distance

considerations alone. Without going too much into technical details for the reasons, damage claims have been put in from points as far away as St. George, Nevada, and Cedar City, Utah, - cities 130 to 150 miles away from Frenchman Flat. Due to this refraction - reflection phenomenon, these cities have actually heard many more A-bomb bursts than has Las Vegas, 60 miles away. But when Las Vegas' turn comes, it comes! For instance, on February 2, 1951, the atmospheric structure was such that a blast skipped across the desert, striking at distances of 11, 22, 33, 44, 55 and 66 miles from the shot. On that sixth hop, it cracked or shattered many large display windows in downtown Las Vegas. To guard against a repetition of this pattern, the AEC later that year moved the shot site out to 80 miles from Las Vegas. This time the winds created two foci, one at 6.6 miles and the second at 40 miles Southeast from the shot point. The larger one socked Las Vegas on its first bounce, and eleven big windows succumbed. Typically, and perhaps invariably, windows withstand the overpressure, but due to their method of installation, are sucked out by the underpressure.

Of course, every effort has been made to get an understanding of the refraction-reflection phenomena; and to this end, the following procedure has been adopted:

A few days before a shot, microbarographs and operators are spotted throughout the Nevada-Utah-California area. Two hours before a scheduled shot, and again an hour before a shot, a stack of TNT is detonated at the proving ground. The sensitive microbarographs record the comparatively puny blast waves, and the operators radio-telephone their readings to the control point. Here the data is compared with readings from other TNT and atomic explosions, and a decision to postpone the proposed atomic blast is considered.

According to theory, the blast pressure at a given distance from an explosion should vary according to the square root of the size of the shot for constant weather conditions. Nature's modification to this law may be judged by the fact that blast pressures from a given charge of TNT as recorded at Indian Springs (about half-way between Frenchman Flat and Las Vegas) have varied by a factor of 3000 to 1 under different weather conditions! Accordingly, a 2-pound shot on one day hits with as strong a blast as a 10-thousand-ton shot on another day!

From a defense standpoint, while adequate weather data and time will not be available to judge reflection-refraction phenomena, a simple rule is to remember that shock waves focus in corners, and are weaker in the middle of the room. We've had this demonstrated many times. Again, from the safety standpoint, even the simplest clothing will go a long way to protect one from flashburn, and a couple of feet of dirt will reduce radiation by a large amount. Time also reduces the residual effects - the radiation goes down by a factor of ten every seven hours.

Besides aerodynamics effects, we do a fair amount of weapon shape and bomb bay aerodynamics. We've taken some interesting movies of drops in wind tunnels that show there are plenty of troubles associated with dropping bombs at very high speeds. Missiles, too, have received some of our attention, in what might be called routine design work. In respect to drop work, the base previously mentioned at Salton Sea, California, is believed to be one of the finest drop facilities in the world. Here the path of a bomb is followed to the nearest foot by cameras, sighting stations and radars, so that its performance can be exactly determined. This base and its associated apparatus might be useful in determining the drag of airplanes.

At Sandia itself we have a couple of small tunnels, a sled track, and what I believe to be the world's largest centrifuge - plus a lot of electronic equipment which is pretty well outside of my field so that I'd rather not attempt to comment on it. Personally, I have never been hurt by lack of equipment, since if we do not have it, we borrow or rent it. The above statement presupposes, of course, that the equipment exists, and it is true that we have to design and build a lot of our own.

In closing, President Eisenhower summed up our job and our success in his State of the Union message last year when he said:

"As we enter this new year, our military power continues to grow. This power is for our own defense and to deter aggression. We shall not be aggressors, but we and our allies have and will maintain a massive capability to strike back." Then the President added: "While determined to use atomic power to serve the usages of peace, we take into full account our great and growing number of nuclear weapons and the most effective means of using them against an aggressor if they are needed to preserve our freedom."

I know that the world of so-called atomic scientists seems strange and remote, perhaps a little long-haired, and reminiscent of the cloak-and-dagger boys.

I hope my discussion has helped to bring it out of the closet.