Living with Nuclear Weapons:
Sixty Years and Counting

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DYSON: **He began with a few paragraphs first on his relations with Oppenheimer at Princeton, and then he said something like, "And now to introduce Dick Garwin."** First of all, he's a scientist well known among his colleagues as a critic of unsound ideas, unsound experiments, unsound military projects. He's been enormously effective in demolishing all three kinds. That has been perhaps his major contribution to society, but he's done much more of course. To those of you who are physicists, there is a great tradition in physics for such people. We have in each generation, we have maybe one.

There was the previous scourge of God who was fulfilling Garwin's role in the early years of the century. It was Wolfgang Pauli, a famous Austrian physicist. Everybody who had a new idea, or a new experiment, went in fear and trembling at what Pauli would say to it. He was the conscience of physics and and I think that role has now been occupied by Dick Garwin for the second half of the 20th century.

I don't need to say much about what he has been doing. For most of his life he's been active as a scientist at IBM, but he's also been extremely important in advising the government. Whenever the government had any respect for truth and competence, Dick Garwin was there advising them. Unfortunately, that doesn't seem to be the case at present. Anyhow, here is Dick Garwin to speak for himself.

RLG: It is 50 years since the beginning of atomic power-- that is, propulsion of naval vessels; it's 55 years since my own involvement in the development of nuclear weapons and nuclear testing; it's 60 years almost since the first nuclear test.

You heard Oppenheimer's views. He had views on secrecy. He had views on the potential of the destruction of our civilization and much of the world by the use of nuclear weapons—not a few, but thousands, or tens of thousands in case of armed conflict in a world of nuclear weapons. So let's see how well we have done in the last 60 years.

I'll give you the conclusion. My judgment is that because people prize superiority more than they prize security, we haven't done very well at all. But the threat has changed and you'll see how the threat has changed. Between armed nations now there is a lesser threat of destruction; more probable, in my opinion, is the use of nuclear explosions by terrorists or individuals.

Slide 1. Here is the destruction of Hiroshima taken in October 1945. These are people walking. The city for miles is laid level. An analogy is that of the tsunami where a wave of water 30 meters high came in and swept everything away, except you can have this nuclear destruction anyplace—Philadelphia, New York, Berlin, Paris.

Nuclear weapons are made by people and nuclear war is conducted by people. Slide 2. Here is Paul Tibbets's copy of a photograph of Hiroshima. He was the pilot of the Enola Gay. The Hiroshima bomb was not well photographed. It was only by accident that there are any pictures from the air. Slide 3. Here is a picture of the Nagasaki mushroom cloud. Beautiful and terrible, 20 kilotons-- 20,000 tons of TNT equivalent.
Ten thousands trucks with 2 tons of explosives each, detonated all at the same point at the same time.

Slide 4. Here are the agents of such destruction. On the left, Little Boy which was a gun-type, gentle assembly of about 60 kilograms of highly enriched uranium, compared with the 0.7% of natural uranium. And on the right, Fat Man, a large also 4 ton weapon, but of the implosion-type needed in order to create a fission bomb from plutonium—an artificial element that was made in the nuclear reactor. The gun was 2% efficient; the implosion weapon was 30% efficient. The Hiroshima bomb released less energy than was put into it in the uranium enrichment plants in Oak Ridge. And this, somewhat less energy than was wasted to the Columbia River from the Hanford reactor used to produce the plutonium.

Slides 5,6. Immediately after the explosions, Henry De Wolf Smyth of Princeton published this work that he had prepared for the government which gave away the major secret of the nuclear weapon—namely that it could be done. And four years later the Soviet Union detonated their first nuclear explosion that turned out to be a carbon copy of the plutonium weapon exploded in New Mexico, July 16, 1945, and at Nagasaki. A carbon copy because their better version was not allowed to be tested. It wasn't prudent. If it had not worked the people who were involved in the development would have been shot.

Slide 7. You've already seen this picture with the (unoccupied) ships in the lagoon for the Bikini Test in 1946. Note the ships standing on end in the stem of the mushroom cloud. But there was more to come, as Oppenheimer indicated. Those were fission weapons, in which one neutron produces two, produces four, then eight, ..., in a time of the order of a hundred millionth of a second. In less than a microsecond the magic of compound interest involved 2% of the uranium in the Hiroshima bomb; 30% of the plutonium in the Nagasaki bomb.

There is another way to release nuclear energy-- the way that is done in the stars. And that is through the fusion of light elements. Slides 8,9,10. Here was our first test– Mike. A 40 ton monster on the left. A fission bomb in one end and a mass of liquid deuterium at the other with experimental apparatus-- two-mile-long lightpipes for diagnosis. I worked a good deal on Mike and on the tests.

You could not take a picture of Mike's mushroom cloud from the same distance where you photographed that of Nagasaki or Hiroshima. A cloud of 11 megatons is ten times as large in every dimension. You would be engulfed. You would be destroyed, but, of course, the cameras could have recorded.

Slide 11. Here is a modern nuclear weapon. Instead of 4 tons, this weighs a few hundred kilograms. Each of these three mounted on a Minuteman III missile has about a 300 kiloton yield. Each would destroy a large city and kill half a million people.

Here is one difference between little weapons and big weapons. The 10 kiloton weapon here took about a tenth of a second to give 30% of its energy released in the form of heat-- thermal radiation that burn people and sets fires. A big weapon, 10 megatons, takes about four seconds. People who have observed such tests are impressed that the explosion of a big weapon is so "slow" because the whole timescale for a bigger weapon also goes like the cube of the yield. Slide 12. You can find these data on the Web, "The Effects of Nuclear Weapons," latest version 1977.

Mike represented a factor thousand growth in weapon yield, and there were even bigger weapons tested and deployed.. There was a Russian thermonuclear weapon planned for a hundred megatons and detonated at half-scale. But it turned out that the most practical use of thermonuclear weapons was to make smaller ones, but very many more of them. For the investment of a few kilograms of plutonium one could have a weapon of any energy release. And that's why the General Advisory Committee and some of its members at their meeting in 1949 called the hydrogen bomb an evil thing when they advised against its construction. And for GAC members Rabi and Fermi, because of its unlimited power, it was "inherently evil."

Slide 13. We had as many as 33,000 nuclear weapons at the time Oppenheimer died in 1964 and the Soviet Union ultimately over 40,000.

There were efforts to control nuclear weapons. 1970 was an important date as you will see for the Nonproliferation Treaty which did more to prevent the spread of nuclear weapons among states than to control the number within a state. Slides 14,15,16. So Article 1, mandates no transfer from a nuclear weapon state; Article 2, no receipt from a non-nuclear weapon state party to the Treaty. Of course, these were voluntary; a state had to sign in order to be influenced by the NPT. And in order to persuade non-nuclear weapon states to sign, they were guaranteed their otherwise inalienable right. But this did not take away, even voluntarily, their inalienable right to development and research to produce and use nuclear energy for peaceful purposes. Furthermore, in this the nuclear weapon states undertook to help the non-nuclear weapons states.

We have something new, though. We had *states* with nuclear weapons. We had, in fact, pretty well controlled the nuclear threat by the realization that although we could not defend, we could deter the use of nuclear weapons. And a very modest number of nuclear weapons would serve for deterrence. In the Kennedy Administration, Secretary of Defense McNamara defined for planning purposes 400 one-megaton nuclear weapons as effective deterrence against the Soviet Union. This would destroy 30% of the population and 50% of the industrial potential and, of course, it would cause terrible problems for the society which already had terrible problems. Slide 17. By 2002, almost a year after the 9/11 attacks, I happened to write a paper on nuclear and biological megaterrorism, and here is a website where you can find a lot of other papers by me: www.fas.org/RLG/.

Slide 18. This terrorism was not unexpected. In 1999 there was a report by the Hart-Rudman commission. "There will be a greater probability of catastrophic terrorism," they said. "Terrorism will appeal to many weak states as an attractive option and there will be ad hoc cells and individuals moved by religious zeal and seemingly irrational cultist beliefs, or seething resentment, and the United States will be vulnerable to such strikes. We are still vulnerable to such strikes."

Slide 19. So we survived 60 years of potential annihilation, initially by nuclear monopoly that people hoped would persist, but in four years the Soviet Union had their own nuclear weapon. We tried defense. We spent many billions of dollars on air defense. We never succeeded to destroy more than 15% of the Soviet bombers in exercises that we conducted ourselves. And finally we fixed on "deterrence by assured destruction"—that is by having our weapons capable of retaliating even if our country was destroyed. Those enormous stocks of 10,000 strategic nuclear weapons are in part irrational. But they are rationalized (or were at that time) by the needs of assured destruction in the face of air defense that might be able to destroy 90% of our weapons on the way in, and destruction of many of our weapons before launch. So a factor 5, and a factor 5-- a factor 25 in this example-- gives you 10,000 nuclear weapons instead of 400 and you "need" additional weapons for other countries that might have antipathy to the United States.

Slide 20. The United States and the Soviet Union had a joint interest in survival and nonproliferation. So what are the barriers to the spread of nuclear weapons? There are political barriers-- people may not want them; intellectual barriers—they may not understand how to build them; and material barriers—not having access to the highly enriched uranium produced in the United States by gaseous diffusion. This is one of the least efficient processes known to humanity; it takes 5 million electron-volts of energy to separate one uranium-235 nucleus, instead of the tenth of an electronvolt that it would it ideally take. Gas-centrifuge enrichment plants now require only about 2% as much energy as gaseous diffusion for the same product, and the original electromagnetic separation required even more.. In any case, 25 kilograms of highly enriched uranium is formally judged by the International Atomic Energy Authority as a Significant Quantity-- SQ. With one SQ you can make an implosion bomb out of highly enriched uranium, and the first Chinese weapons were uranium implosion bombs. Our first test, July 16, 1945, was a plutonium implosion bomb.

Plutonium is an element that comes either from production reactors which are a lot simpler, or power reactors where it is undesired byproduct.

Our interest in survival was broadened by nonproliferation concerns. We have the pact such as the 1970 Nonproliferation Treaty and the 1972 US-Soviet Antiballistic Missile Treaty where we agree not to deploy effective defenses.

How about the states that are not deterrable? For a long while influential voices in the United States claimed the Soviet Union was not deterrable and we needed more and more nuclear weapons for actually destroying them, maybe preemptively. There is not much of that heard these days. We need to bar access to weapon usable material—highly enriched uranium and plutonium. But there is the problem of the civil plutonium that is produced by every power reactor—about a quarter ton a year--30 bombs worth a year from each reactor. A relatively new problem is terrorists and nihilists, a threat that cannot be resolved by deterrence. Slide 21.

According to General George C. Marshall, solving a problem depends on the shape of table. He said that the key is to have all the participants on one side and the problem on the other. But it's difficult enough to get Republicans and Democrats sitting on the same side of the table, let alone the leaders and people of Iran, North Korea, India, Pakistan, Israel, and Syria. And yet we must try and have been trying.

The problem now is the enormous stock and flow of weapon usable materials. In Russian and the United States we have hundreds of tons of excess highly enriched uranium from weapons or that was never put into weapons. But this exists also in many other states and facilities, some of it safeguarded-- that is, accounted to and audited by the International Atomic Energy Authority which has no power except to report violations of the accounting process.

There are some tools and progress. In 1992 Senators Nunn and Senator Lugar initiated a very important program. About a billion dollars a year has been spent to consolidate and secure weapon usable material in the former Soviet Union. Consolidation is truly important because securing many small amounts is much more difficult than securing a large amount all in one place. We've had now 12 years of a 20-year program, to purchase from Russia 500 tons-- 20,000 nuclear-weapon equivalents--of highly enriched uranium. They blend it down to nuclear reactor grade, 4% uranium-235. But at least 700 tons more exist.

The problem is not the first 99%. It's not the problem of securing gold. If you have $100 billion in gold and are successful in securing 99.9% of that, well the rest you can afford to lose. It's only a one week's interest. But it's that tenth percent, or that one percent, which can make a nuclear weapon, or 10, or 100 nuclear weapons that will ruin that number of cities and destroy tens of millions of people.

Slide 22. in 2005 the knowledge barrier to the terrorist nuclear explosion has eroded or vanished . There is the general progress of technology. There is all the information that was provided because our key hope in the United States was to prevent the Soviet Union from learning about our advanced nuclear weapons. And we were not so careful about protecting information about the elementary nuclear weapons. Nor could we have been because they are really so simple. As Oppenheimer said, there is very interesting physics involved, but you bypass the interesting physics in making practical nuclear weapons.

The political barrier is absent for terrorists. Terrorists not only want to sow terror, but some of them want to kill people. They don't mind whether they are terrified, they just want them dead. And that makes it very hard to counter. Suicide warriors were always a problem. They were a rare tool, but now we see suicide warriors everyday. The remaining barrier is to the acquisition and transport of the material—either a stolen nuclear weapon, or improvised nuclear device, or the uranium or plutonium required to build them.

Slides 23,24,25. Here's what we need to do. We need to expand the Nunn-Lugar program. But now we need to spend the money with the people who will do the work—not on American contractors, where it costs ten times as much and does not motivate the other side. The purpose is to consolidate and secure weapons and weapon usable material. We need to spend the money for national security, not for votes. This is truly a matter of life and death.

We can accelerate the blend down of highly enriched uranium without spoiling the world market for reactor fuel. We would blend it down to the upper limit of low-enriched uranium, so that it is not immediately weapon usable. The existing capabilities could thus accept highly enriched uranium at five times the present rate and do the job in a couple of years. It would need a subsidy to be repaid on ultimate blend down.

People don't understand what nuclear explosions do, and therefore I think it would be useful to have a nuclear explosion simulator. Of course, at some time in the nuclear explosion simulation you have to cut it off before the shockwave reaches the person and you carefully arrange that it doesn't fry them. But it would give a little bit of feeling for what it really means to have a weapon explode.

More generally recognized is that one needs universal accounting and security for the uranium, for the reprocessing of reactor fuel, and for the capability for enrichment. We have two important problems right now. Iran's nuclear power program. Iran has an inalienable right to nuclear power and to enrichment, imperiled a bit by the fact that they haven't been honest in their accounting to the IAEA over the last 20 years. What we should do it to safeguard Iran's commitment not to acquire nuclear weapons.

North Korea has separated from its small reactor several weapons worth of plutonium and has probably incorporated it into functioning warheads or bombs . What we need is a muscular extension of the Nonproliferation Treaty with universal enforcement of a new provision that states not later use materials or facilities that they acquired with the cooperation under the NPT. And we need to erect serious barriers to the transfer and transport of (weapon-usable) material.

Slide 26. It's not true that we have nothing to fear but fear itself. For our country to lose a third of a million people is likely to happen. It. must not be the end of our history. We must plan and invest to prevent this and then to live with this loss. But even though there is now a finite probability of such an attack each year, such a loss is not a certainty.. People often ask, "Well, can you say that we have no likelihood of this happening this year." No, I say, we have ten percent. But you still have hope because if the ten percent is reduced by half the next year, and to one-quarter in the next year, there is only two years of peril equivalent. So this is the magic of compound interest in reverse. If you could reduce the hazard by even ten percent per year then the total hazard is only ten years of hazard at the existing peril. And we have already lived through that. So if we are working hard to reduce the probability that this will happen, it may happen, but it very well may not happen. That may be the only encouraging word that I leave with you today. Thank you.

Applause.

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