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An Evening With Richard L. Garwin
Conversation with David Kestenbaum of National Public Radio

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Richard L. Garwin

KESTENBAUM (National Public Radio): Thanks for giving us an hour. I feel like an hour of Dick Garwin's time is very highly valuable.

When National Public Radio interviewed Edward Teller, when he was alive, he brought a stop-watch. He timed all his answers so that they would be exactly 20 seconds so no one would have to edit them (laughter). He was very afraid of being taken out of context. This will be unedited.

I actually wanted to start with Teller because before he died, he had a heart attack which apparently put the fear of God in him. He picked up the tape recorder and started dictating for history. One of the things he said is that you deserve credit for designing the hydrogen bomb. Will you tell the story of how that came about?

GARWIN: As you heard I was in Los Alamos for the first summer in 1950. I spent the first week in the classified library and learned all about nuclear weapons

KESTENBAUM: Just a week (laughter)?

GARWIN: A week, yes. Then I found that a lot of effort had gone into building a hydrogen bomb spearheaded by Edward Teller-- I didn't know all about that at the time, I learned much of it later-- and that it was based on cross sections that were ten years old from Tom Bonner of Texas. So I began an experiment to get some modern cross sections at low energy. The Laboratory picked that up when I went back to the University of Chicago in September and nice experiments were done. But when I arrived in 1951 I asked Edward Teller (who was also a Professor at the University of Chicago, but I didn't see much of him there, he was traveling) what I could do. He explained that he and Stan Ulam had had this idea of radiation implosion (that's a long story too). But everybody thought it would work, contrary to the classical super, and he wanted to be absolutely sure-- to have an experiment that would leave no shred of doubt. So he asked me to devise such an experiment. So I went away and I talked to people what they thought about this and came back in a little while with a detailed sketch of what turned out to be the MIKE device. I worked with liquid hydrogen and deuterium in my nuclear physics work at the University of Chicago and so naturally I could make this thing out of deuterium and hydrogen. It (MIKE) wasn't a problem at all. It turned out to be an 80-ton monster but it wasn't deliverable. I made another one that was deliverable because my work was done by August or so. It was taken up and fired less than 15 months after May 1951, which involved bringing together thousands of

people, a task force, manufacturers, getting all kinds of diagnostic equipment, to some of which I contributed. So that's the story of my part in the hydrogen bomb. I wasn't the inventor, I was sort of the architect.

DAVID KESTENBAUM: What was tricky about putting it together?

GARWIN: In all of these things there are many options and what's tricky about it is making decisions, finding your way through this thicket of options when everybody wants to do more research. Everybody wants to optimize what's going on. I'll give you another example. Fast-forward, not only did I help build nuclear weapons, but in 1953-54 I was detailed to work half-time in Cambridge, Massachusetts with Jerry Wiesner and Jerrold Zacharias and others on extending to the sea the air defenses of the United States against Soviet bombers and so we worked on this so-called Project LAMP LIGHT. And that's what introduced me to the Washington scene and to what was to become the President's Science Advisory Committee, for which I chaired many security oriented panels. And by 1965 I had been involved intensively for seven or eight years. {That year}, during the Vietnam War, we had a session at which one of my panels had in sequentially the Chief of Staff of each of the military services-- Army, Navy, Air Force, Marines. The MMarine Corps general said his greatest wish, greatest need in Vietnam, was rockets to transport his Marine squads to where they needed to be. And we asked him please to get real, what could be done before the war might end? And he said well he really needed to know where these squads were so that they could use artillery from fire bases and not destroy them. So we told him right on the spot, here is the answer; we can do it in a month.

Everybody has a high-frequency radio-- a PRC-25. We had LORAN-D {a 100-kHz navigation signal} over all of Vietnam but the receiver-computer was a box of about 70 lbs. But all you really need to do is with your high-frequency radio, take the little ferrite antenna out of a little transistor radio and put it on the front end, so the high-frequency radio (PRC-25) will radio to the fire base the raw LORAN signals themselves without processing them. You plug that into a standard LORAN receiver-computer at the fire base, they know immediately where the squad is. If they like to they tell them, but at least they don't lay artillery fire on them.

So, I told you about making decisions-- the Navy, which has a lot of technical laboratories, held a meeting. Six laboratories attended with eight concepts. By the time the Vietnam War ended seven or eight years later not one of them had been implemented. If they had just taken our approach which was eminently doable, maybe not optimum, they could have done it within two or three months.

KESTENBAUM: You were very young when you worked on the hydrogen bomb-- twenty something.

GARWIN: It was 1951, so I was 23.

KESTENBAUM: Did you have any concerns that it really would work?

GARWIN: Sorry?

KESTENBAUM: Were you worried that it... did you have concerns that it might not work?

GARWIN: No. That's the chance you take. Do your best, you check everything twice. People had looked at it very critically; it was an outside idea, {not} from the laboratory. In fact, the cryogenicists there refused to help because they were all worn out in providing the cryogenics tools for an experiment in the 1951 series. And so I gulped and I did the cryogenics engineering myself. And Ferdinand Brickwedde from the Bureau of Standards was tasked with developing the 500 liter per hour, 1000 liter per hour {deuterium and} hydrogen liquifiers.

I was only part-time. I was there three months, four months, a year so people didn't tell me much of what was happening in my off times and Brickwedde the next year said indeed they have built this thing-- hydrogen bomb-- and the thermal leak rate was less I had predicted.

KESTENBAUM: So it was November 1, 1952 the 11-ton MIKE test happened. Did you see it?

GARWIN: I haven't seen any nuclear explosion; I hope never to see one. I don't need it. I have a good imagination. I just look at the pictures, and I never did want to take the time to go out to the Pacific-- or even when they were moved to Nevada-- didn't see the point in seeing.

KESTENBAUM: I know that, because we had a short conversation yesterday or this evening, and I was thinking-- I can't imagine another-- I don't know another scientist ... .

GARWIN: I'm pretty calm.

KESTENBAUM: But it's something you designed and sort of helped put together. Wouldn't you want to go see if it worked?

GARWIN: No (laughter). I had done my part.

KESTENBAUM: And when you'd heard that it worked, did you feel Whew! or did you feel a bit of, you know, I am become death a destroyer of worlds?

GARWIN: Neither. And in fact really that same week or so another invention that I had worked on with Carson Mark-- and I think Ted Taylor-- was tested it; it worked too. I felt better about that because nobody else thought it would work.

KESTENBAUM: Do you feel like you are actually emotionally somewhat unaffected by it? It was just another problem to be solved, someone else would have done had you not?

GARWIN: That's exactly right. If I don't do these things somebody else will do it. It may take a lot longer; it will certainly cost a lot more (laughter).

KESTENBAUM: I spoke with your daughter and I said what was it like you know being the girl whose Dad designed the hydrogen bomb-- because I know a friend of mine whose Dad designed the trash can he has done

quite well. And she said "I had no idea until I read it in the New York Times."

GARWIN: Well that's right. There was just never any opportunity to talk about (laughter).

KESTENBAUM: Do you mean no time or it just didn't come up over breakfast?

GARWIN: No. For a long time it was very secret. And I had plenty of things to talk about at the breakfast table. Actually at the 40th anniversary of Los Alamos, which was 1983, where the fact of hydrogen bombs was not secret anymore, I did speak about my work. Most of the people then, and certainly at the 50th anniversary in 1993, had no idea that I had been involved in these things. I was at Livermore one day and somebody there had been recognized for his contribution to stable isotope tracers in nuclear explosions and I commented that I had written a paper about that in 1950 at Los Alamos. And they were incredulous, but they got on the classified FAX and within half an hour they had my paper. But there are a lot of these things. They are just little things that come and you do them and you move on to something else.

KESTENBAUM: You have said that if you could wave a wand and make it so bombs were impossible, you'd do it. On the other hand, in this very room not long ago I saw Sig Hecker put up a slide showing by some measure that wars had generated less fatalities since bombs are available, and that they have helped keep the peace. What do you make of that.

GARWIN: I think both are true. But the problem is that devastation when nuclear war comes, with tens of thousands of nuclear weapons that we and the Russians have, will be the end of civilizations. And we've worked very hard and I hope with some success at preventing that. Maybe it's been just dumb luck but a lot of people in this room have worked hard too, and now I think what needs to be done is to reduce from tens of thousands to hundreds of nuclear weapons in the world.

One of the secondary but very important -- in physics you know you have the first order of things, then you have second order, and in many types of physics second order is less than first order. But that's only because those are the ones you can calculate. In a lot of the real world the second-order effects are even more important than the first-order effects. One of the most important aspects of reducing from 10,000 or more to a couple hundred nuclear weapons will be the motivation of our Administration, our Congress, and our people to make sure that other people don't acquire even a few nuclear weapons. Now it's all too frequent to hear that it's okay let them have a few; we have 10,000, we are superior. But we don't have a lot more cities than other people. Our people aren't more proof against nuclear explosions than other people. It's a real problem.

KESTENBAUM: You have worked with Pugwash for a number of years. Their goal is the elimination of all nuclear weapons. Do you think that's achievable?

GARWIN: Well in fact the United States is a signatory to the Non-Proliferation Treaty and that has right up front nuclear disarmament, but in the context of general and complete disarmament which I never thought was feasible. People put too much emphasis on nuclear disarmament {alone}. So I don't think that is going to happen in the near term. If we could have a security system that would make the elimination of nuclear weapons possible, I would favor it. But I put my effort on greatly reducing the number of nuclear weapons and restraining them perhaps with a multi-national, maybe international hand on their use.

KESTENBAUM: So maybe you have the U.N... hand them over to the U.N. or some organization like that?

GARWIN: Yes. I've written about these things and, of course, when you do such an important thing it has to be worked out in great detail. It can't be everybody in the United Nations votes on it. It has to be an Executive Council. The Security Council... the present form of the Security Council isn't right. There are a lot of details there. But let's get down to a few hundred nuclear weapons in national hands and see what we can do about regional security, about getting other people involved and that may in fact reduce the incentive that non-nuclear nations have to acquire nuclear weapons. But at the same time we have to do a lot more in prohibiting terrorist nonstate acquisition of nuclear weapons which becomes all more and more feasible because there is all this weapon usable material around especially in Russia but also in Pakistan and in the civil nuclear power sector.

KESTENBAUM: So actually you said in an interview recently that you thought we had been lucky that there hadn't been a nuclear bomb go off in an American city and that you thought-- that terrorists hadn't gotten hold of one-- you thought that that would probably happen in the next few years.

GARWIN: Yes, I think there is 50% probability to have such a nuclear explosion in the next four or five years. We ought to be doing what we can to prevent it. We ought to be doing what we need to do to keep the damage that it causes localized rather than destroying the whole society because of the foolish concentration of fundamental elements...

KESTENBAUM: Those aren't great odds. I'd move to the suburbs.

GARWIN: I don't like it, but that's my view.

KESTENBAUM: Can I ask you another hypothetical, which is suppose you can change the laws of physics so that nuclear weapons were not possible and neither was nuclear power and the rest of the world wouldn't get screwed up by changing all this. I saw you working thought the alpha, the fine-structure constant.u

GARWIN: Well, to give up nuclear power, yes we could give up nuclear power. It provides something like 16% of American electrical power and it's about the same amount worldwide. France has 80% or so. It's potentially competitive. It has its own problems. I'm in favor of nuclear power so long as it's technically feasible which it is. But it needs constant care and I don't know that we always provide that. Certainly other people don't. So the more recent version of the book

that Norm Neureiter showed "Megawatts and Megatons," published in France in October titled "De Tchernobyl en tchernobyls" says unless the nuclear industry shapes up as it says it has to, the Tchernobyl accident is going to be replicated. In addition you have the problem of terrorist acts against reactors that needs to be faced. So there is a lot that needs to be done and that runs up the cost of nuclear power-- not so much, but it means that you have look at it.

KESTENBAUM: I want to talk a bit about your role as a Science Advisor to just about everybody. I was reading through an interview you had done and you talked about this nuclear test which was technically, I suppose, done in space-- Starfish Prime-- above the atmosphere. I didn't realize this, but it is my understanding is that it was expected that the electrons would return sort of quietly to Earth and in fact a lot of them got stuck up in the Van Allen Belt. And President Kennedy was upset about this because he had a plan for putting astronauts on the Moon and this was going to send them through a very dangerous radiation field. And you got called in to explain to him what was going on. Could you tell us about that story.

GARWIN: The Starfish test was 400 kilometers-- it's well into space-- fired from Johnston Island, July 1962, 1.4 megaton yield, so a hundred times the Hiroshima bomb-- it was a hydrogen bomb actually. And people had reviewed it. I hadn't been involved in the planning simply because I was doing other things. And it was expected that because of the relatively low altitude the fission products that would come out and decay into electrons would be at a sufficiently low altitude so that even though they would get out (there wasn't any atmosphere there) they would follow the magnetic lines, they would come back on the other side, they would be mirrored and come back, but they would be at a low enough altitude that the turning point would be such that they would be lost in a few weeks. And it was realized that astronomers might see some radio noise, but it wouldn't provide a lot of radiation to astronauts.

Well they missed the point-- I probably would have too, had I been involved-- that when you have a nuclear explosion in space you get a large conducting region, a plasma. And it's in a converging region of magnetic field so it squirted up like toothpaste from a tube. And so it goes up to a thousand kilometers and there, after some seconds, the fission products decay and so you get energetic electrons ejected into the Van Allen Belt and their turning point is way up there where there isn't any air at all and they last forever so far as their behavior as individual particles in a magnetic field is concerned.

But people who had approved the test from PSAC were on vacation and so I was called in (PSAC-- the President's Science Advisory Committee) for two weeks to analyze what was going on. And really there was not a lot of science known. So I discovered Carl McElwain in California and learned about L-shells and such things and tried to make policy sense of it. Russian cosmonauts were up and the first thing we needed to do was to determine what the likely radiation exposure would be so that we could tell the Soviets to bring these people down if they could prematurely before they were destroyed by radiation. But we managed to figure that they would have a measurable, but tolerable, radiation dose. In fact, when the cosmonauts came down they actually read their dosimeters on the reviewing stand as I recall.

That was okay, but several satellites died because of the high energy electron exposure. That wasn't in the plan. And indeed there was so much radiation that passing through the Van Allen Belt would have given astronauts a lethal dose on the way to the Moon and back. And so Jerry Wiesner, the President's Science Advisor, took me to see President Kennedy. Carl Kaysen came along, he was Deputy National Security Advisor, and I think the head of the Atomic Energy Commission, Glenn Seaborg. So I explained what was going on.

KESTENBAUM: In the Oval Office?

GARWIN: I think so. Kennedy was most concerned. I told him well, you know, I was working on orbiting uranium foil to scatter this stuff out of space, and whatnot, which is entirely feasible. But it turned out that there are lightning and other natural phenomena that excite the electrons and dump them out of the Van Allen belt a lot faster. So it took only months instead of years and so they vanished all by themselves.

Carl Kaysen tells the story that Kennedy had asked me a question and I said well, you know, order of magnitude. He had never heard that so he rolled it around his tongue for awhile and said to Glenn Seaborg, "So Glenn, when you tell me I should believe something, I should believe it to the order of magnitude. Right?" (laughter).

KESTENBAUM: Was that your first time speaking to a President of the United States.

GARWIN: No. I think that I had spoken to Eisenhower.

KESTENBAUM: You've done some research on the Kennedy assassination tapes over the years. How come?

GARWIN: Well, President Kennedy was assassinated in Dallas, November 22, 1963, and The Warren Commission said he was killed by Lee Harvey Oswald acting alone. But a lot of people felt there was a conspiracy and that it was so unlikely that all these things would happen, that it couldn't be possible. Now, of course, everything is unlikely. What was the likelihood of your interviewing me tonight with all these people here? Zero. It happened (laughter). And then in 1978 and 79 the House of Representatives convened a Special Committee on Assassinations and toward the end of its tenure it asked Bolt, Beranek and Newman to look at the Dallas Police Department radio communication recordings that had been known to exist, to see whether perhaps the shots were recorded on these recordings-- on office dictation equipment. One channel on a Dictabelt embossed in plastic and the other channel on a Gray Audograph disk, again embossed in plastic like a turntable-- like a record.

Well, Bolt, Beranek and Newman found what they felt were imprints of the shots, and using a technique that had been pioneered-- time difference of arrival-- in the Kent State shootings by the National Guard, they located the microphone that recorded this in the motorcade with reflections from the various buildings in Dealey Plaza. And that was confirmed by Weiss and Aschkenasy of Queens College in New York. The Justice Department and the FBI didn't believe this was true so they

asked the National Academy to convene a committee to study this. Norman Ramsey, a physicist of Harvard University, was our chair. Luis Alvarez and I, and Paul Horowitz were some of the members of the Committee and we began to study the statistics-- how likely is it that all the noise on the tape (there was a lot of noise on these recordings) could by accident conspire to give you nice results.

In the middle of this we heard by letter, before the days of Email and FAXes, from Steve Barber, a rock musician in Mansfield, Ohio. He had a report of the House Committee on Assassinations published in Parade, or something like that, with a little flexible plastic disk of the relevant five minutes of each channel the police department recordings. And he says, you know, where the shots are supposed to be, just in those few seconds, I hear a little faint voice saying "Hold everything secure" and when I listen to the other channel I hear very clearly, "Hold everything secure until homicide and other detectives can get there." Obviously if somebody is broadcasting "Hold everything secure" as a result of the assassination, it can't be at the time of the shots. So we dropped our statistical efforts and we worked on trying to determine whether there was in fact this imprint of the "Hold everything secure" there. First we did it by looking at voiceprints and studying them by hand and eye and then I and two IBM colleagues did a computer analysis-- really making computer images of the voiceprints and stretching them and sliding them. We found enormous peak of a few tens of milliseconds wide at an appropriate 5% offset in speed, because these two dictation machines were not running at the same speed, and we compared that with other images that were clearly on both channels.

We said, you know, it can't be that these are shots and it was very likely this microphone that was stuck open for five minutes was not in Dealey Plaza at all. Just recently somebody {D.B. Thomas} published in Science & Justice, a British magazine, an attack on our work claiming that there were some things said on other copies of these tapes that weren't on our copies-- so impugning our efforts.

KESTENBAUM: So it's not as if you have been obsessive, it's other people have been.

GARWIN: Other people. Norman Ramsey picked this up and he started responding. We finally did some really nice work. We looked at the details, we used the so-called Cepstral analysis-- not spectral analysis, (I make mistakes, but I didn't make a mistake in speaking there.) Cepstral analysis was invented-- oh, probably in the 1950s-- by John Tukey of Bell Labs, a member of the President's Science Advisory Committee.

Anyhow, we found that throughout these recordings on the Gray Audograph disk there was a pre-image-- a distortion of the groove by the following groove. That was the key to let us understand exactly the speed of all the recordings and to find this image and others and to show that a word called Play (that Thomas said we missed because it was on one of the other recordings and not on the two that we chose to use) didn't exist at all. It was the elision of 3.60 seconds precisely, by a skip-ahead of the needle in the playback. Really Play came from "Get those trucks out of the way." Cutoff the "ay" and start implosively, "ay" sounds like Play. So anyhow we have put this thing to bed again, I hope. Our report is just about to be published in Science & Justice,

five authors. Four of the original panel (many of whom have died) and also Ralph Linsker.

KESTENBAUM: You mentioned PSAC, the President's Science Advisory Committee, and you are a member of the Institute of Medicine, and the National Academy of Science, and the National Academy of Engineers, and you've worked with JASON forever. How well heard is your advice these days in government?

GARWIN: Advice is never very well heard because you may have somebody who wants to hear but they are quite limited in what they can do with it, even if it's the President. What we did in PSAC, which I thought was very good and very effective, was to have an 18-person committee which met two days every month. It had a dozen or more panels some of them standing, some of the ad hoc, which typically met two days every month also. The panels had the very best people we could get, leading specialists in the field, plus a few young people we tried to bring in to the PSAC process, and a couple of people from PSAC. At half-time, when the panels were half-way through their work, they might report to the Committee for a sanity check, and then the reports were issued as reports of the Committee. They had to satisfy not just the panel but the Committee itself.

KESTENBAUM: Was there an example where you felt you waited{worked} on something and it really made a difference?

GARWIN: Well it made a difference in the Supersonic Transport even though that was particularly gory. That wasn't a PSAC {panel, but one of the Office of Science and Technology Policy.}

KESTENBAUM: And that got your Committee eliminated.

GARWIN: Well, it might have. Lee Dubridge, who was President Nixon's first Science Advisor when he took office, explained to the Press that he was creating two panels-- one under Marvin Goldberger to look at ballistic missile defense and one to look at the supersonic transport, to chair that. The panels would report in a month and he looked forward to sharing the results with the Press. Well, nobody else in the White House looked forward to sharing the results with the Press. So it's really very awkward to have the Press asking what was the result... But our SST panel-- supersonic transport panel-- very good people, had a very negative report. We said that we could not at the same time satisfy the goals of the government contracts-- Boeing and General Electric-- to make an aircraft that was at the same time safe, environmentally acceptable, and profitable and so the government should admit that it's not going to satisfy those goals or it ought to cancel the program. That isn't what President Nixon wanted. Congress, of course, had to provide money. Congress knew all about this panel and asked for the report which it didn't get. But after a year or so I decided I would testify to the Congress on the basis of the information Congress already had. The White House didn't like that even though PSAC had asked President Nixon specifically about the question of testifying in regard to the ABM system--- anti-ballistic missile system-- question. And he said go ahead everybody should have the benefit of this expertise. He didn't really mean it. Haldeman and Erhlichman probably even less...

KESTENBAUM: Do you feel like it would be nice if there was a thing like that around now or do you feel like that advisory role is being filled by JASON and the National Academies and the Defense Science Board?

GARWIN: Oh no, absolutely not. The more scientific advice you have at lower levels the more advice you need at the higher level in order to compete. In fact, PSAC, the President's Science Advisory Committee, early on was successful in creating assistant secretaryships for research and development, or for science and technology in the various government entities, but too often these were captured by a particular department and they became adept at making proposals in which the difficulties were concealed. So it got harder and harder to find out where the bodies lay and so ...

KESTENBAUM: A solution would be to put a physicist in the presidency?

GARWIN: No. I recommend against it (laughter). There are too few such people....

KESTENBAUM: It would be a waste of their time?

GARWIN: I didn't say that. However, you need really more horsepower than that. And you need a whole committee. That's a pretty good structure, maybe not the best. You need the panels. Need the Office of Science and Technology to staff it, not just an Office of Science and Technology Policy and a kind of commission on science and technology that meets a few times a year.

You need a powerhouse to identify problems. And even if they can't be solved to explain what the problems are and how one has to adapt to them. And some of them can be solved but they won't be solved unless we do what's required. One example is this flu pandemic which is certainly in the works. Whether it's avian flu or just plain old influenza such as the 1918 pandemic, it's going to come sometime and it will overwhelm hospitals and medical supplies. We will be left, in my opinion, with public health, hygiene, and things that could very well ... not just reduce the deaths from 30 million to 15 million but prevent a pandemic altogether. Because if you can get the reproduction rate from an index case-- the first person gets the disease-- if instead of infecting 2 or 5 more in the next generation, 2,4,8,16, and so on, you can get it down below one, like 0.8, you have one case, then 0.8, then 0.64 cases, and so on..

KESTENBAUM: There is a direct analogy here to a nuclear reactor I think.

GARWIN: Exactly. Just because a nuclear reactor isn't doing anything because it's shut down-- it has its control rods inserted-- you don't pull out the control rods to use them someplace else.

KESTENBAUM: We don't have any control over how virulent. That's up to nature.

GARWIN: Well, no. But if it has normal virulence and so the R-naught (R0) as they call it is 2 or 3, it's perfectly reasonable to reduce

that by a factor 3 or 5. Now if you are a health care worker and you have to deal with ...

KESTENBAUM: by quarantine and things like that.

GARWIN: Not quarantine. Hand washing, improvised masks, not seeing people when you don't need to see people. But in fact go ahead, go about your daily life. Scorn people when they come to work when they are sick when we have a pandemic. It's okay when we don't have a pandemic. We don't get germs when there aren't germs to get.

KESTENBAUM: Do you have advice for people in the audience out that who are scientists who are interested in advising the government in the capacity in being involved in technology issues. You've advised both democratic administrations, democrats and republicans. Do you have a strategy for the sort of tone that you use or... I have a sense of your valued because you're a compulsive problem solver and compulsive truth teller. So that I think they feel like in you they know exactly what they are getting. They're not getting a sort of political opinion. Do you have advice for how people should approach this?

GARWIN: That somewhat limits the number of people who want to tell you their problems. Many of them really don't want their problems solved. They want their approach to solving the problem endorsed. But I certainly support what Norm Neureiter said is the goal of the MacArthur folks and that's probably a better approach than suggesting that somebody copy me, because I had this unique position. The only really political (perhaps a couple of other things) thing I did in my life was to negotiate with IBM as a condition of employment that I have one third of my IBM time free to work with the government on national security matters.

KESTENBAUM: I was going to ask about that. Why did they allow you to do that?

GARWIN: Because I wouldn't have gone there.

KESTENBAUM: Because they figured if you just used one hand to help them that would be enough. They would be grateful for that and you could go do what you want.

GARWIN: It came up a couple of times during my 40 years there.

KESTENBAUM: They would have liked your full attention.

GARWIN: Yes, and I told them that wasn't in the cards and they just had to decide (which is what they knew) whether what they were getting from me was worth what they were paying me. And I explained to them that probably I helped the overall government to the tune of a billion dollars or something like that ... And IBM was ...

KESTENBAUM: Did you calculate that?

GARWIN: Yes (laughter). IBM was a fraction of a percent of the government and that fraction {of the benefit} was a lot more than they were paying me. But I didn't push it; I didn't insist that they ...

KESTENBAUM: That's a heck of a raise.

GARWIN: What I do is really try to help. If anybody has a problem, working for the government, or for a government contractor, and what they are doing is legal, then if they tell me their problem I'll tell them right away what I think about it. Sometimes it catches my attention and I will try hard to solve it.

KESTENBAUM: Well you know that means I'm going to have to skip this next question and go right to ..

GARWIN: And at the same time I will use that information if I manage matters to see their bosses or the Congress or whatever to give my views on the program to which their problem is attached. So if they are working on something that even though it can be solved or can't be solved and its on a program for which there is a better approach or if it isn't worth the money, I'll tell them that.

KESTENBAUM: There are a lot of Garwin stories and there is at least one Garwin joke which I assume you know.

GARWIN: You're asking me?

KESTENBAUM: Yes (laughter).

GARWIN: You mean the guillotine joke?

KESTENBAUM: I mean the guillotine joke (laughter). The joke is something like it's the French revolution and you're there for some reason and two other people about to be executed with the guillotine. They put the first man under and pull up the blade and they let it go and it stops. They say the law says we only have one chance to kill you so you can go free. They put the second man under and the pull it up and it sticks also and he gets to go free. And then Richard Garwin goes in and they pull it up and Richard Garwin looks up and says, "I think I see your problem" (laughter). It was told to be just out there over hors d'oeuvres.

Do you, and I think the point of that being that sometimes you will solve problems that maybe you wish you hadn't or maybe it would be in your best interest not to have solved. What do you make of that story.

GARWIN: Well, you know it's true (great laughter). I never was about to be guillotined, although I am sure it occurred to some people (laughter). But it's just too hard to decide in advance. So I really do try to help people with their problems. If that leads to further problems, I try to solve them later.

KESTENBAUM: Maybe I can cause you some problems here. One thing I wanted to do is if you had a budget authority and could kill a program or change the budget I want to know what you would do to each of these. The first one is missile defense.

GARWIN: Well, it's not ready. We're spending much too much money on missile defense ....

KESTENBAUM: It has to be a short answer because I have a list. Kill it, keep it going a little bit?

GARWIN: Kill it and bring it back later.

KESTENBAUM: Bunker-buster?

GARWIN: Oh, that's a nonsense program (laughter). The Congress felt that the weapons could somehow go underground and destroy the thing down there and the fallout would be snuffed by the earth. In fact, there was just an Academy panel which showed that wasn't so and a lot of independent ... anyhow it was a totally misguided program.

KESTENBAUM: Reliable replacement warheads.

GARWIN: People don't know what it is. Of course we need reliable warheads. Reliable replacement warheads will be the remanufactured warheads of the kind we have. Anything new has to compete with those.

KESTENBAUM: How about R&D for nuclear reprocessing?

GARWIN: I'm in favor of that. I think that we eventually will deploy families of fast neutron reactors-- breeder reactors-- we need the kind of reprocessing that's suitable for that. But it would be a great mistake to go ahead with reprocessing of the lightwater reactor fuel the way the French and British have done for the Japanese and Germans and that the Japanese have invested in Rokkasho.

KESTENBAUM: Because it doesn't help you?

GARWIN: Because it doesn't help the problems; it costs a great deal of money and makes, in fact, the problems worse. Because you could have problems in a reprocessing plant much more readily than with the {direct} disposal of spent fuel.

KESTENBAUM: Human space flight.

GARWIN: I don't want to pay for it. People are going to the edge of space commercially, that's fine with me. We fought very hard in the mid-1960s against the Defense Department manned-orbiting laboratory. Don Hornig, the President's Science Advisor, and McNamara, the Secretary of Defense, would discuss this. The manned-orbiting laboratory was really a euphemism for space reconnaissance and we did much much better, much faster, without people in space.

KESTENBAUM: DARPA?

GARWIN: DARPA is a fine organization. Always hope it will do the right thing. We need more high-risk investments in science and technology, not only in the classical realm.

KESTENBAUM: In the last section here I want to talk a little bit about problem solving. Is there something from your time at IBM, your work there, that you are particularly proud of? Probably all of it but is there something that stands out?

GARWIN: I did a lot of work on many, many things. For instance, in the mid-1950s I invented a whole technology of planar superconducting computing elements. That never was a product. It worked fine. Quite a few other patents and inventions. For instance, in 1993 I invented the little accelerometer-controlled hard disk so when you drop the thing-- now your Ipod, or whatever-- it strikes and damages the recording medium the head reads the magnetic spots, it has moved over and parked itself.

KESTENBAUM: Is that a part of them now?

GARWIN: Yes.

KESTENBAUM: Oh, thank you.

GARWIN: IBM brought that out about three years ago. I don't know that they know that I invented it (laughter). I know exactly ...

KESTENBAUM: Is that a problem for you that some of your coolest inventions are secret and you can't talk about them?

GARWIN: No. Hardly any of them are really secret. There is one I mentioned that's secret and many of the other things. But there is so much to talk about that isn't secret so why would I worry about talking about the other things.

KESTENBAUM: So you coauthored, by our count, 500 papers I think.

GARWIN: I wrote them myself. The books are coauthored.

KESTENBAUM: Matt Bunn at Harvard said often he would ask you a question and you would say "Well, I wrote a paper on that and here's the reference." I actually looked at your patents and I was particularly interested in U.S. patent 4,324,020. Do you know which one that was?

GARWIN: Was that the mussel washer?

KESTENBAUM: That is the mussel washer, yes. I'd like to know about the mussel washer (laughter).

GARWIN: Our late friend, Harold Friedman, a chemist at Stony Brook, worked for awhile for IBM, whom I knew him from my graduate student days at Chicago, had a house with his family across the road from Conscience Bay. So Lois and I would go there and he would put on his wetsuit and get an enormous pot of mussels and Lois and Edie Friedman would spend time scrubbing them, taking off their beards, getting the sand out. But there was always sand in the pot after we had eaten the mussels.

So Harold and I (it was a co-invention; both our names are on the patent) decided that what we needed was a device that would wash the mussels. So it's a dual-purpose device; we took a five gallon plastic can, glued Styrofoam floats to its end, put in a crank. We put holes in it (and a trap door)... So you put the mussels into it and then let it float on the surface of the water and turn the crank. Black water would come out for about a minute, then it would get clear; you take

the mussels home {in the drum} and cook them up. You didn't have to do anything to them-- no sand!

KESTENBAUM: You built one of these?

GARWIN: We built half a dozen in order to refine the design. We tried to sell them. Very few people are in this business of gathering the mussels (laughter).

KESTENBAUM: IBM was not interested.

GARWIN: Mussels are grown on strings these days.

KESTENBAUM: Can you talk a little bit about the work you are cited for in that CIA award-- some of the reconnaissance? What were your contributions there?

GARWIN: Some of this ... there was a 1996 CIA award-- the R.V. Jones Award- and some of it was toward imaging satellites beginning with contributions to the film-return CORONA system that began to fly in 1960 and it flew until 1972.

KESTENBAUM: What did you do for that?

GARWIN: I helped. But mostly I helped on the later generations which haven't been declassified yet. And so in 2000, on the 40th anniversary of the formation of the National Reconnaissance Office, I was named one of the ten founders of national reconnaissance. There are a couple of citations and one of them is thermal and mechanical properties of satellites. Another refers to persuading President Nixon and Henry Kissinger to build the electro-optical near-real-time reconnaissance systems that fly today. Like the electronic digital cameras that you have. So instead of returning film they take pictures, they store them, they send them back via radio. So that's what is done. So I did a lot of things there ranging from speed control of film in some things. Really very interesting things. We had very good people working on these programs and sometimes they were extremely cooperative in picking up ideas.

Mostly when I talk about my work with the government, most of it is frustration. Because if you add up all the days that I was doing something, mostly it's repeating the advice that was given long before. So you forget the successes which happen right away. In one case, for instance, I used a technique that I had used in some of my nuclear physics work, that I used again in gravity wave detection, and that I used in the IBM supermarket scanner. The government contractors were quite proud of the work they had done on an imaging focal plane like that in your digital camera, and they had gotten the electronic noise down to the thermal noise-- down to kT. Couldn't do much better. Just the way the noise figure of an amplifier at 0db has gotten right down into the thermal noise. But I realized-- I had done this work 20 years before in another context-- that you could go far below kT at room temperature.

All you really need to do is to read the charge on the capacitance that's fed by each of these photo diodes (or the CCD) twice. You read it before you let the light in and you read it after you let the light

in, but you don't reconnect it to ground. Measure it's charge. And so whatever energy that capacitor has-- kT typically, it retains. It doesn't change and so we were able to get to less than a tenth of kT. And that's like multiplying the area of your lens by a factor ten. So that's the sort of thing with which I am most proud. But there are little things. It's not that I make bombs, or satellites, or planes, I make them possible.

KESTENBAUM: That runs into advertising {?}..

GARWIN: Cribbing a slogan.

KESTENBAUM: I was told that you once got a case of tennis elbow and that it had nothing to do with tennis and everything to do with carrying around a gigantic briefcase, and that that was a major form of exercise-- lugging this thing around. What was in it?

GARWIN: Well, I would testify, especially in the Supersonic Transport days, and it was before the days of Rolaboards. I can't imagine how long it took to connect the wheel to the suitcase (laughter)-- I was not responsible. So I would have this big suitcase and I'd come into the Senate hearing room and pull up a chair next to me and open the suitcase. So if there was a question about something, I could pull out the document. And, of course, in those days I think in testifying you had to bring along a hundred copies of whatever it was you were going to present. So I was fortunate in working for IBM, even in the 1950s and 60s, we had the chain printers with fan-fold paper, and burster-trimmers. So I would bring home many pounds of such stuff and the children and my wife and I would go around the dining room table and collate these things (laughter) and staple them so I could have a hundred copies.

KESTENBAUM: And was the idea that it was incredibly powerful to have the actual document there-- if you would be in some argument and you would actually, you could say, "No, actually I have that here in my suitcase"?

GARWIN: Well it seemed only responsible to do that.

KESTENBAUM: Like a library of sorts.

GARWIN: Right. So nowadays, of course, you have it in digital form.

KESTENBAUM: Right. So you know have a backpack which is somewhat smaller.

GARWIN: Yes. The backpack comes because I hurt my elbow and my wrist by carrying these things.

KESTENBAUM: So what's in the backpack?

GARWIN: Well it has my computer and has typically 15 or 20 lbs. of paper that most of that I want to get to read, or I haven't finished working on.

KESTENBAUM: I am told that you type sort of constantly during meetings and people wonder how it is you also manage to offer advice at the end.

GARWIN: That keeps me awake. If I'm not typing I fall asleep (laughter).

KESTENBAUM: What do you think is the longest you've been away from a keyboard is?

GARWIN: And so the main reason for typing actually is not ... sometimes its typing other things, but mostly it's really to find out more about what's going on, or to do little calculations or to write up responses so that I could show them. These days it's very convenient to snatch the lead that goes to the projector and connect your computer, and show the response to whatever has been said. But in cases where you can connect your computer to the Internet, there is just so much that can be found with search engines that can go far beyond what people are talking about. That's what I do.

KESTENBAUM: I have another policy question I want to ask you. You did a lot of sort of what I might call back-channel communications with I think Russian nuclear scientists and you've also been involved with the Chinese. What have those sessions been like and do feel they were productive in securing ...

GARWIN: Yes. Thanks for mentioning it. My involvement in such things began with the Harvard group led by Paul Doty. The Doty group that met in conjunction with the Pugwash meetings because the Soviet scientists would get permission to go to Pugwash meetings, which organization began in 1958.

KESTENBAUM: Where did you have these meetings?

GARWIN: Well in the United States or in ... well the Pugwash meetings were wherever they were. And sometimes they were in Sweden or Vienna or small towns around and occasionally in the Soviet Union or the United States. But there are a lot of other countries in the world-- England. And so the day before, or two days before, or two days after we would meet with the Soviet delegation (not all Pugwash were involved in this) on international security-- particularly the control of nuclear weapons.

KESTENBAUM: Were there other government officials there sort of who were watching over your shoulder ...

GARWIN: There weren't government officials, but when this began Jerry Wiesner and Paul Doty were very well connected in Washington. So they talked to the people first and they talked to them afterwards and much later when Henry Kissinger was National Security Advisor or Secretary of State in the Nixon Administration we would go see him. I remember I led a delegation to see Jim Schlesinger when he was Secretary of Defense. He spent 45 minutes with us before we went to the Pugwash meeting and talked to the Russians. But this had been going on for a long time-- essentially 15 years or so-- by 1983. And then we had a group of Soviet counterparts that included Evgenii Primakov, Evgenii Velikhov, Georgi Arbatov, and Roald Sagdeev. We were continuing to talk about {nuclear weapons and missile defense}.

KESTENBAUM: What were those conversations like? Were they cordial? Were they technical?

GARWIN: Oh technical. Yes, they were very technical. We tried to keep them technical because there is only so much you can say on the ideological plane, so I didn't like that. As John Holdren ... but by that time it was the National Academy Committee on International Security and Arms Control {CISAC} carrying on these conversations. CISAC was founded in 1980 just for the purpose of meeting twice a year with the Soviets. In fact, the MacArthur Foundation was a principal source of support.

KESTENBAUM: And was that a useful channel? Can you look back and say concretely this treaty came ...

GARWIN: Oh absolutely. For instance with the Soviets when Gorbachev came in we had had very good relations with these four people I named and another six on the delegation. We had discussed in 1983 just before President Reagan announced his Star Wars program the merits of space weapons-- it didn't seem to be very sensitive at the time. DARPA people were testifying in Congress ...

KESTENBAUM: That was just before Star Wars?

GARWIN: ... that there was no prospect for having these things effective, so we tried to get a mutual understanding of what went on. And I think there was at first some resentment on the Soviet side about this that we had known about this and hadn't talked to them about it just a couple of weeks before. But Nobody knew about it except the President and few of his closest advisors.

KESTENBAUM: Were you talking with him about the things like suppose we were to do an arms reduction and here's how we can do it with mutual confidence?

GARWIN: No, no it was more technical than that. We would talk about properties of lasers; how you might discriminate a laser from a laser weapon. You can't do it necessarily on the basis of power because even a tiny laser that is designed to ablate samples off the moon for analysis, can have a power as big as the 20 megawatts of a laser weapon. But it's not continuous, it's just a tiny short burst. And so we would try to have a mutual understanding on these things. And I had written long before about space arms control, decoys, and missile defense, so we recycled these and tried to see what the Soviets could bring us. When Gorbachev came in, like President Eisenhower, he distrusted the formal military advisory system. Eisenhower's response to Sputnik was to bring the President's Science Advisory Committee from the Office of Defense Mobilization into the White House. He called these people "His scientists." Gorbachev took on as informal advisors the afore mentioned, gang of four-- Arbatov, Primakov, Sagdeev and Velikhov. And they were very important in explaining to Gorbachev a moderate response to the Star Wars program.

KESTENBAUM: Is that sort of back channel communications as relevant today? Because it seems like in some ways what you were doing happened to have something to do with science, but it was also just diplomacy. Is there some reason, you know academics do these sorts of things, is

there some special reason why you think scientists can be particularly useful.

GARWIN: Because they can talk about these things without being constrained by national policy. If you work for the State Department you may be a very good technical person, but your job is not to go out there and inform the Chinese of the realities of space weapons. It's to persuade everybody that there is not a threat; that it's premature to try to control space weapons before there are any. And you know discussions have the opposite effect. You're not going to survive very long in government employ. And yet that's only one view. We don't negotiate, we discuss.

KESTENBAUM: So the idea is that it's a dispassionate discussion of the facts and somehow...

GARWIN: Yes. And, for instance, with the Chinese, CISAC has been talking with the Chinese since about 1988 and there we had very important discussions with them, as did others from the Natural Resources Defense Council, about the Comprehensive Test Ban Treaty. The Chinese were very emphatic about the requirement for peaceful nuclear explosions-- that you could ban nuclear weapons tests but you can keep peaceful nuclear explosions.

KESTENBAUM: Being for mining or something.

GARWIN: Mining for storage, propelling space ships, who knows? The communists ideology is that the mind of people is unlimited that you can do everything with technology. But when you open the door of such technologies and any of these nuclear explosives can be used for nuclear weaponry it really to too much a hazard. So in fact the Comprehensive Test Ban Treaty which the Chinese signed permits peaceful nuclear explosions but only after ten years with unanimous agreement by the parties. Which is unlikely to happen unless the parties unanimously agree, it won't. If there is some real opportunity and potential threat that can be solved by nuclear explosions, then the people of he world can get together and agree.

KESTENABUM: Let me close with this and I think we'll have some time for questions. I read, at the end of an interview someone had done with you, you were asked did you ever wish you had done things differently with the career? And you said, "No, but, of course, I had wished the world would turn out better.

GARWIN: Well that's certainly true. Quoting our President, "There is a lot of evil in the world." We're not going to end evil but we can hope to limit its effect and preserve our country at the same time. I remember a long time ago-- 50 years ago-- trying to get my priorities straight and they were really family and preventing nuclear war. But the next was to preserve a system of government that would enable the other things to happen. That's one of my primary worries because we do not have a lot of effective democracy. Congress does not do the job that it is supposed to be doing. If people came to work every day and tried to solve the country's problems instead of putting down the other party and ensuring their own election. And it's not just I, it's many members of Congress, the House, and the Senate who say the same thing. And one of their principal jobs is oversight of the federal government.

To take a nontrivial example this Medicare Part D is designed by people who hate people (laughter) or who hate government involvement. It couldn't be worse, and I encourage you to write your Congress person and tell them that you are holding them responsible either for creating this monster or for not supervising the government to make sure that they do a job that is in the interests of the populace.

KESTENBAUM: Here's to a better world. Thank you. (Applause).

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February 13, 2006

An Evening With Richard L. Garwin
Conversation with David Kestenbaum of National Public Radio
Questions and Answers

American Association for the Advancement of Science
January 10, 2006
Richard L. Garwin

QUESTIONS & ANSWERS:

MARK GUBRUD: Dr. Garwin, if there is one person that I would trust with the power to re-legislate the laws of physics, you might be that person. But short of that, I'd like to know your perspective on the potential of today's frontier technologies-- computers, biotechnology, nanotechnology-- to transform this world, or our world, in fundamental ways in decades to come.

GARWIN: Well, it's been largely transformed in the last two decades by information technology, especially the Internet and the search engines that I mentioned. We have a lot of other possibilities especially in biotechnology. They're obvious. But I don't think that we will realize the benefit under the current system. I think that what needs to be done is to engage entrepreneurs and scientists in China and India particularly in making vaccines in exploiting the frontiers of biotechnology for the benefit of everybody in this country as well as elsewhere. That's all I want to say about it.

WHO??: To the extent that some of these solutions have a technical underpinning what advice would you give the current Administration and Congress with regard to the emergence of widespread proliferation starting in Iran and North Korea?

GARWIN: They should have taken the advice of the various commissions beginning in 1999 and put a lot more effort into reducing the proliferation potential. That is in securing the weapon usable materials in Russia and working with Pakistan and elsewhere and in taking more measures so that instead of a billion dollars a year, {we would be spending} $3 billion, $5 billion a year, easily affordable. But we have, in fact, instead we've been more interested in spending money in this country with U.S. contractors rather than spending money over there where it would go much farther and motivate people to get the job done. So we have now the Nuclear Threat Initiative, courtesy

of Ted Turner's initiative which is very good, and the Carnegie Endowment for International Peace. There is no shortage of advice and programs to be undertaken. I think reducing our own nuclear weapon holdings and those of Russia would go a long ways toward increasing the motivation to limit the acquisition of nuclear weapons by others. So take it seriously-- act as if we had already had a nuclear explosion in an American City.

WHO??: Thank you.

BILL FULKERSON: Dr. Garwin, I would like to ask what your opinion is of the Norm Augustine Rising Above the Gathering Storm report is which seems to be perhaps something that could be bipartisan and is critically important.

GARWIN: This is a report of the National Academy of Engineering and it says the United States really does not have an upcoming generation interested in science and technology and not only is production moving abroad but also research and engineering. When I received from President Bush in 2003 the National Medal of Science, during the photo opportunity, which was less a fraction of the meeting than this recent meeting with former Secretaries of Defense (laughter) Secretaries of State, I managed to stand next to President Bush and I told him two things. One was that we had a disastrous problem in the visa program for foreign scientists and that if we didn't solve that they would go elsewhere for training; that when they came here and stayed instead of going back, that was to our benefit, not a problem for us. And, in fact, as the Gathering Storm indicates, there are a lot of people who wanting English go to Canada or Australia or England now which are much more welcoming than we are. If we're interested in countering terrorism we can do it much more effectively than by the procedures that we have. You might need to spend more money, but it would be worth doing because these are very valuable exchanges, very valuable contributions that are made by people coming here and setting up business, doing research here. But in fact we have to really be concerned. It's not clear that the free market is going to solve these problems for us because the lower wages abroad and the much more competition among their larger populations for such leadership scientific roles will mean that we have very serious problems and we will not be able to have a critical mass over here to do things in the semiconductor industry, in information technology and biotechnology and the like.

RHYS PRICE JONES, George Washington University: The concentration of nuclear weapons in two camps has actually been used as an argument against proliferation because, for example, during the Cold War Britain and France-- the proponents of unilateral disarmament-- could say that the mere possession of a small number of nuclear weapons by those countries made them a natural target for both sides if there were ever a confrontation between the two big ones. Is there anything to this argument and if there is does it color your idea about reducing the nuclear arsenal.

GARWIN: I think there was during the Cold War. We certainly didn't need to have such vast numbers of nuclear weapons. We had a maximum of some 35,000 and the Russians maybe 47,000 nuclear weapons at the peak and totally unnecessary. We could have had 2000 and it would have been

plenty. But it wasn't the monopoly on nuclear weaponry, it was the rest of the power of the United States and the Soviet Union-- really the ability of the Soviets to exercise their power that would keep people from taking lightly the decision to acquire nuclear weapons. Still some did. Britain because we had shut them out of the nuclear program after it was created there and here and they were full partners during the war; France because they felt that the British had nuclear weapons and France needed nuclear weapons. And besides after Suez when we stopped the French and British military operation in Egypt they vowed never to be in the position where that could happen again. How the possession of nuclear weapons would keep it from happening again, I don't know. But those days are long past. Our nuclear weapons, Russian nuclear weapons, are not useful in preventing proliferation. A modest number of nuclear weapons would serve to counter any number of nuclear weapons elsewhere.

But in fact we will have a very interesting test case in Iran. North Korea, I think we know about, has probably half a dozen plutonium weapons. But Iran may have in addition to 18 years of secret programs-- where Iran says all they did wrong was not to reveal them to the IAEA and the reason they couldn't was that the United States was violating its obligations under the NPT to help them get peaceful applications of nuclear energy. But if indeed they have been populating their centrifuge hall at Natanz with centrifuges, all the while discussing with the IAEA, that's going to be a very serious problem. I'm not clear what will happen as a result. However our nuclear weapons are not a solution to that problem.

FRED SINGER: Since you are a recognized expert on nuclear proliferation issues and you have a very distinguished record as a government advisor, what advice would you give on the current situation with respect to Iran where you have a government that appears to be not quite rational and where you also have the additional problem of leakage of nuclear material, or even nuclear weapons, to terrorists who have no particular national location. How do you deal with a problem like that?

GARWIN: There are two problems that you mention and take the terrorists first. They can't get nuclear material from Iran because Iran doesn't have any. But they can get it from Pakistan and Pakistan does have nuclear weapons and nuclear materials and they did have this one man proliferation machine, Dr. AQ Khan, who took it on himself to sell the technology and even weapon designs to a number of countries. And that's a terrible thing. We ought to be talking with Pakistan-- maybe we are, I'm not involved with that; I'm not talking to them-- about the necessity for them to effectively control nuclear weapons and in case there is a coup against the government to do something so the nuclear weapons do not fall into military hands in usable form. Now that's a tall order and we may not be able to solve that problem.

In Iran, I think, if Iran proves to have been cheating on their undertakings in the last two years, as I said, it's going to be a very serious problem. It may not only go to the Security Council for sanctions-- and of course Iran is a big oil producer so that's a problem there too-- but it may require empowering individual countries to take military action. We could bomb Iran for a long time together with some colleagues in order to prevent the development of such a

capability, but we'd rather not. They have every right to civil technology but they have to behave according to their undertaking in the NPT. Now our role in enforcing people's word, people's obligations, has been weakened by a lot of playing close to the margin on our part, when we have had international undertakings, but that's a different story. It's a very serious problem. I cannot give you the answer here. It requires a lot of people to work on it full time.

KESTENBAUM: One final question.

ARTHUR?? TURNO??, Interactivity Foundation: I've been working on a project here in town on exploring contrasting concepts of science-- a project that I have been working on here in town with some people. And the idea has come up in some of the discussions of-- the claim would be something like this-- that work that is classified, or that is based upon data that is classified, somehow is something else, ought not be regarded as science. And I'm wondering if you would have, I mean you've dealt with this type of work over the years, and I'm wondering what you would say to that. I'm also wondering what you would say to how this issue of secret data, secret information within science, has effected the ethics of science say over the past 50-60 years in which you've been involved in it. It seems that if this idea were to be taken seriously a lot of the greatest achievements that we would think of as being scientific would somehow be off the board. But the people in the discussions I've been involved with seem to take it seriously so I'm wondering what you would have to say to it.

GARWIN: Well, I'm trying to respond to your question. And I guess in the nuclear energy area there was for a considerable period a lot of scientific-- where a lot of scientific data that were secret-- and so people were inhibited in the design of reactors, for instance. But this was not so much scientific, it was technical and engineering data. Now commercial firms, of course, try to keep secret their ideas especially in the biotechnology area. They're working on particular drugs and in fact there are many pharmaceuticals that could be used to counter a particular target. And so it's very important to the firms to keep secret not only the drugs that they are working on but the target of these drugs. Now it's hoped that in the patent system when a drug comes to market it will be patented and people will not be able to use that particular drug for 20 years. But they may be able to invent something else to attack the same target. It may be possible to patent the target-- that is the drug that attacks a particular target. And some of these things need to be worked out. But the secrecy vanishes at the time the patent is issued. So most of science, maybe somebody else can help me, there is hardly any science that is classified. It may be that you have a government program which is highly advanced and not only the technology but a lot of supporting science may have been done under cover.

I suppose oceanography is one like that. Yes, oceanography is such a case and it's of the greatest importance commercially and in understanding climate change. But I've worked a little bit in oceanography and at the beginning of ocean tomography where one uses acoustic paths through the ocean in order to determine the temperature and there was never any question about classifying that. Some things are born secret-- that is under the Atomic Energy Law nuclear information is born secret and cryptography is the other approach,

which is not quite so constrained as nuclear information. But for the rest of scientific information one has to make an argument to classify it rather than having it born classified at the beginning.

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