UCRL-JC-129342
PREPRINT

Stewardship of U.S. Nuclear Weapons

Dr. C. Bruce Tarter, Director
University of California
Lawrence Livermore National Laboratory

This paper was prepared for submittal to the

National Security -- The Space Dimension
An Air Force Association National Symposium
Beverly Hills, CA
November 14, 1997

January 15, 1998

Lawrence Livermore National Laboratory

Stewardship of U.S. Nuclear Weapons*

Dr. C. Bruce Tarter, Director
University of California
Lawrence Livermore National Laboratory

It is a privilege to be here. If this is the first occasion where a lab director has appeared before one of these symposiums, I hope it isn't the last.

I come before you as director of the Lawrence Livermore National Laboratory, but I also view myself very strongly as a representative for all of the Department of Energy's national security laboratories: Livermore, the Los Alamos National Laboratory and the Sandia National Laboratories. Those three laboratories have historically been the centerpiece of creating the nuclear deterrent. We also have been involved in many activities to prevent nuclear proliferation worldwide.

My presence here has additional meaning because my laboratory and you are effectively bound together. When the Cold War ended and, in a sense, the music stopped, the three Livermore strategic warheads in the stockpile were all Air Force systems. Whether we like it or not, we are linked together. We have warheads on the Minuteman III and Peacekeeper and a modern Strategic Bomb. Those systems are our designs; a number of you in the audience are working with us on those systems in various ways.

My topic today is stewardship of U.S. nuclear weapons: Where we are. How we got there. And where we are going. Because of the congressional debates that are likely next year about a comprehensive test ban treaty and the interest in nuclear weapons reductions, I thought you would want to know how the Department of Energy and its laboratories are going to approach nuclear weapons in the coming decades.

I want to put you in the situation we were in the early 1990s and pose the problem that was posed to us -- what to do in a post-Cold War environment. Obviously every service has faced that issue as have defense industries.

Then I will tell you the solution we have crafted -- the stockpile stewardship program. It is a point solution, but it turns out to have a lot more dimensions than one point. It is still a work in progress. In fact, you will be part of the discussion and debate on how that work in progress evolves.

*An edited transcript of a presentation made at the Air Force Association Symposium, Los Angeles, CA, on November 14, 1997.

By way of background, I want to give you a short historical summary of the stewardship of nuclear weapons between 1945 and the early 1990s. You can't quite understand what we are doing now if you don't know what went on then.

This will be a very simplistic review of nuclear weapons during the 45 years between the only use of nuclear weapons at the end of the Second World War and the end of the Cold War. Not long after the atomic bombs were detonated in Japan, there was a large debate whether to develop hydrogen bombs, which are much more powerful than the atomic bomb. That debate produced two things: a decision to proceed with the hydrogen bomb and a decision to establish Livermore as a second nuclear weapons laboratory and increase the overall effort. That decision was strongly supported by then-Secretary of the Air Force Tom Finletter.

For the next 40 years or so, the system worked something like this. People at the labs, my laboratory and the Los Alamos laboratory, would come up with ideas driven in part by military requirements as they perceived them, and in part by technological advances. Combining those two factors, they would conceive of designs for new weapons. Every so often, those concepts would be tested with nuclear explosions in the Nevada desert.

Occasionally, a service would select one of those designs to enter into the stockpile of the United States. Then a rather large production complex would make various parts of the total warhead system. They would manufacture the weapons -- a few hundred, perhaps a thousand, perhaps several thousand. That build would enter and stay in the stockpile for about 10 to 15 years. In turn, that weapon would eventually be replaced by a new one with new kinds of characteristics, usually much safer, and perhaps more bang for the size.

That sequence of laboratories designing, testing, building, and then taking weapons out of the stockpile every 10 or 15 years in response to technology or military requirements characterized the Cold War period.

Some of the technological advances I think you know about and I won't belabor them. Of particular interest to you, we developed the first MIRV [Multiple Independently-targetable Re-entry Vehicle] with the Air Force. That was for Minuteman, back in the early 1960s. We also developed the first warhead that made submarine-launched ballistic missiles feasible and practical. Those are the kinds of advances that happened. Roughly speaking, we moved from the initial nuclear explosive device, roughly the size of this stage, to create weapons that fit into something the size of this podium. Through advances in physics, materials science, and a broad range of other technologies, we reduced size so you could deliver weapons in a missile. And the weapons became vastly safer in their transportation delivery and sequence.

That is what the 40 to 45 years was all about. Then the Cold War ended. I think by any definition, it ended with a victory.

At that moment, each of the components of the defense complex -- the military, defense industries, laboratories like Livermore, and the relevant parts of the government -- tried to sort out their futures. Each of you have been involved in that. The Nuclear Posture Review, the Quadrennial Defense Review (QDR) are pieces of this effort. For us, once the Cold War ended, the Department of Energy entered into a major dismantlement program and began to close production plants. Budgets were slashed by a factor of two to three. So were personnel levels. This was done without much advanced planning.

A few years after the events that defined the end of the Cold War, it was clear we had to structure a new logical framework for thinking about the future of the nuclear weapons complex. A key early driver for the effort -- and an important pegpoint -- was the first Strategic Arms Reduction Treaty (START I), which set stockpiled warhead levels at about 10,000 weapons, compared to the 30,000 or 40,000 that had been extant during the peak of the Cold War. That set a goal and a milestone and it defined the systems that were going to be in the stockpile for some time.

At that time, another event happened. Vic Reis was given responsibility for the national security nuclear programs at the Department of Energy, which was a very demanding assignment. Many of you may have had experience working with Vic during his tenure in the Department of Defense as head of the Advanced Research Projects Agency (then Defense Advanced Research Projects Agency) and as Director, Defense Research and Engineering.

Vic quickly assessed the situation and a few months later, in the 1993-94 time period, assembled a group of us in a windowless room and said, "We have the following challenges: We have a stockpile which will be reduced to 10,000 warheads (now, to a couple thousand if the START treaty process is successful) and we have a production complex that is not functioning. We have no manufacturing capability left to retrofit or make real changes. We have weapons, most of which are already near the end of their 10- to 15-year nominal design lifetime and, in effect, we've been asked to design no new weapons and to extend the lifetime of these weapons for decades, if necessary. We have a group of people who designed the weapons who are also aging. *And* we have to transfer their expertise to their successors while we still can. And finally, by de facto decision from Presidents Bush and Clinton, you won't be allowed to field test your final systems any more. So, what are we going to do to ensure that these weapons will be safe and reliable for the indefinite future?

That was not a bad place for an exit line. To say the very least, it was a challenging tasking and that is what my last several years have been about. Specifically, to work with Vic Reis, the other two laboratories, the Nevada Test Site, the remaining production complex, and, obviously, our primary customer in the Pentagon to sort through this system of problems. What I want to do in the remaining time is try to describe what we decided in that room, what the results have been, and where we are.

In that room, we began at the obvious point anyone would start in a situation like this -- you take stock of where you are. First, there was some good news -- the 10,000 or so weapons in the stockpile, depending upon how you count active and inactive stockpiles, all had good pedigrees. It was as if those weapons developed at Los Alamos had a Harvard degree, and those from our laboratory had an MIT degree. They went into the stockpile with blue chip credentials. The weapons had a good testing history and they were well honed. They had actually been fielded long enough so the initial bugs had been fixed. That was the good news.

The bad news was what I have already mentioned. We had no manufacturing complex to speak of in case we needed to make changes. We had design experience which was going to evaporate with time. We had, as you have had, incredibly tight budgets and the sense that those budgets would decrease even more. We had this very peculiar task of dealing with weapons that were going to age in ways that would be completely new to us -- we have no data base or historical experience with this. Finally, we were not going to be able to test the final product.

In a way, there was a simple solution. In this room, you might say "Why not let them sit there?" You've got the weapons; they've got this good pedigree. They will do their deterrent job and we are done. The trouble is, everything ages to some extent, but nuclear weapons age in very dynamic, not necessarily predictable, ways. Let me give you a very simple example. If your car sits in the sun for a few years, the dashboard will crack. That is because plastic cracks when you expose it to the ultraviolet radiation from the sun. It just happens. That is very similar to what occurs inside a nuclear weapon, because you have radioactive material and a lot of plastic. That material is subject to radiation from the radioactive components just as your car dashboard is damaged by sunlight.

Almost every component of a nuclear weapon system has limited life. The plutonium ages. All other components age. When we dismantle weapons retired from the stockpile we sometimes find cracks and corrosion because that is the nature of this very toxic radioactive environment inside a weapon. To keep weapons in the stockpile a long time, we have to find out which changes happen and when. Should we care about a change in the weapon? Does it matter for the safety or reliability of the device? To fix it will cost a lot of money. If we simply ignore it the weapon may not perform as designed. We've got to have an affordable program to deliver to the customer what we promised -- safe and reliable weapons. Stewardship of the stockpile is not as simple as saying, "Put it on the shelf."

That is the job that we took on. We think we have come up with a workable plan. I will give you a brief summary of what the program to maintain the stockpile looks like. A couple dozen of us devised it in a series of very intense sessions, at least on paper and in planning, well enough that, in meetings in August 1995 with General Shalikashvili and then Anthony Lake, the national security advisor, we effectively told the President that we thought we could do this job under the constraints I have mentioned. Let me now describe what we said we would do.

The stockpile stewardship program has four components. First: We are going to do a lot more surveillance, and better surveillance. We have to because these weapons are going to age well beyond their design lifetime. Put in my terms, once you're past 50, the physicals get increasingly intrusive and extensive -- that is what we are going to do to the weapons. We are going to take a lot more x-rays. We are going to develop better endoscopes to go in every little place we can find. We are going to sample a much larger number of weapons in stockpile. We need to find out what is happening in great detail to be able to understand the aging process and do preventive maintenance. We don't understand the aging process very well -- neither we the laboratories nor industry. Step one in our program is surveillance -- to anticipate problems, to identify them and then to try to find research and development solutions or system solutions.

Second: We have to create a manufacturing program to actually build parts and make the retrofits. We have to put in new plastic for the old plastic; however, the original tools and the materials, in many cases, don't exist. And I have mentioned the problems we have with production capacity. But even more constraining, you cannot rebuild exactly the same components with the same materials. In some of the older weapons, it is not quite tubes instead of transistors, but it is close. You don't want to replace tubes with tubes; you want replacements to be something newer. We need a manufacturing complex that provides modern technology, not ancient technology. And for each change you make, you have to certify that it doesn't reduce safety or reliability.

Worse yet for planning purposes, you have to design a manufacturing capability for a stockpile expected to be a couple thousand deployed units, but might be much larger than that in an adverse future security environment. We need a capability that can go way up again, while at the same time aiming for something low, and to do that within budget. The approach is to create a modular manufacturing capacity, where you build the capacity to produce the amount you need, but can expand it in a reasonably straightforward way.

Third: Assess all changes that happen within the weapons as the stockpile ages, find out whether they matter, and take necessary corrective actions. Each year, we are required to certify to the President that the weapons are safe and reliable. That is now a much more formal process. I've signed the letters the last two years to the Secretary of Energy and Secretary of Defense which make that statement.

To support these certifications, what we've done is create a program that replaces the full-scale nuclear explosive test by a series of component-level tests. One of the dilemmas is how to do those component-level tests in a way that produces sufficiently relevant scientific information. This requires investing in the scientific experimental facilities to do that testing. When we are done with the component-level testing, we are then going to tie all the information together with what will be the world's biggest computers. We are aiming to go far in advance of teraflop level computing capability that General Ryan already mentioned.

Fourth and finally: <u>We've got to have a source of tritium</u>. I won't get into program details, but we need a constant supply because tritium radioactively decays away in roughly 10 years. Tritium gives weapons the punch in a lot of complicated ways. It makes bombs much more powerful than the bombs that exploded in 1945.

That is the program. Give weapons intensive physicals. Recreate a manufacturing complex, including a supply of tritium. And then assess the changes to know when we do or don't spend money for refurbishment, or at least give us the option of deciding to spend money under which criteria.

Let me mention a few pieces of the technology to do the job we've signed onto. There are a number of component-level testing facilities. I'll focus on a couple of examples where my lab has special responsibilities. One example is a set of plutonium experiments, which we and Los Alamos are carrying out at the Nevada Test Site. Plutonium is a fascinating element. As an astrophysicist, I'm not comfortable with plutonium because stars don't make it. It is an artificial element, manmade. But plutonium is obviously at the heart of devices; it is what makes them go bang -- initially. Also it turns out that plutonium ages. We don't have much that's aged because it was never made before 1940.

The bad news is that plutonium is very complicated. For those of you who vaguely remember your chemistry class, and I've repressed most of that, there are things that describe material properties called phase diagrams. As an example, for water it includes a triple point where ice, water, and water vapor can coexist. Plutonium has the worst-looking phase diagram you have ever seen. There are many sections on it. When it ages, those sections begin to shift so we actually don't know how aged plutonium behaves. So below the desert in Nevada we are conducting experiments on plutonium with no nuclear yield, which we can do safely. These are called "subcritical experiments." They begin to help us understand the aging of plutonium.

Let me mention another piece of the technology. In my laboratory, we are building lasers that are leading the technology in the United States. The world's biggest laser is under construction at Livermore. It is called the National Ignition Facility. It costs a lot of money, $1.2 billion, but it is the only capability we will have in the country to create miniature thermonuclear explosions in a laboratory environment. The way it works, a guy in the basement throws a switch and he starts a little tiny laser pulse. By the time it's done, that pulse will have been split into 192 separate laser beams and each is greatly amplified. Those 192 beams are brought together and hit a target about the size of a marble, simultaneously, within about a tenth of a billionth of a second. When we do that, we create in the marble the conditions that exist in the center of the sun or in a nuclear weapon.

Engineers are very clever people. They can create nice round targets for the laser to study what part of a bomb might look like when it explodes. What is more important is that they also can simulate a target with cracks in it to actually watch what happens as you reach the thermonuclear conditions. You can see whether the crack opens or closes and disrupts the way the weapon works. Not only can you get a baseline understanding of many weapons, but you can test a lot of special situations you might encounter in surveillance of weapons in the stockpile. That is what this big laser is supposed to do.

We are vastly improving our component-level testing capabilities in other areas as well, which I won't talk much about, such as hydrodynamic testing, where new facilities will provide much more detailed experimental data on the implosion phase of nuclear weapon operation. What ties all this component-level testing together, is something called "ASCI", which stands for Accelerated Strategic Computing Initiative. What we are trying to do with ASCI is outperform Moore's law over the next decade. Gordon Moore, the chairman of Intel, coined Moore's law which says that computing capability doubles about every year and a half or so, just because of the way the industry creates chips. Let me tell you why we need ASCI and why we are working with industry to create so much computing power so quickly.

You are back in that room without windows. We ask: how much computing power do we need? Calculate it. The first thing you need to realize is that bombs were designed as two-dimensional objects. They are symmetrical. You don't see them in odd shapes or with odd appendages, they look two dimensional.

But bombs don't age in two dimensions any more than you do. This part of you doesn't age like that part does. You age a little piece here and a little piece there. So do weapons. For an aging stockpile, you need three-dimensional computer codes, not two-dimensional computer codes. That adds about a factor of 1,000 to the capability you need because it is a different job. We are examining aging effects, not designing something that is symmetric. Another factor of 100 comes from science; we've got to better model the science in our physics simulations. The best estimate is that we need between 10 and 100 times more information and resolution in the way you compute. You put those two factors together and you need about 100,000 times more capacity than you have in the current computers.

The question is, why not wait? We can't wait because all the people with hands-on experience in designing weapons, which is still art as much as science, won't be around much longer. We have to get these new capabilities into the hands of the people who did the original job so that they can develop and test the tools and train those responsible for the job in the longer term.

I also mentioned the manufacturing component of the program. Redoing our manufacturing complex is a very tough business. Every decision has jobs at stake, not unlike military base closure decisions. As many of you appreciate, it is a much harder transition than technology or systems. Nonetheless, I think we can make inroads on creating a modern technological complex.

Let me provide one example of how we are modernizing manufacturing. One of the problems we face in surveillance is taking things apart and rebuilding them -- you want to cut material, look inside the part, and put it together without damaging it. We can now effectively do that with a laser. It is the work of some very clever people at our lab who created a table-top-sized laser with the world's shortest pulse and highest power level -- more power than produced by the entire U.S. electrical grid for an extremely short time. This ultra-short-pulse laser is able to cut atom-by-atom -- quickly and precisely. The surrounding material is not damaged because it doesn't have time to heat up. This laser technology, which started out as a scientific research project at the lab, is now being introduced into the production complex to cut weapon parts with effectively no waste and no significant remanufacturing burden. It has lots of other potential applications, too, which I don't have time to mention.

Another serious problem I alluded to was that as the systems are aging so are the people. In the early part of the next century, most of the current warheads will be beyond their design life. But, more importantly, most of the people who created those weapons will also be beyond their design life. They will have retired. They go away, too.

One of the biggest problems we have is trying to transfer the art and the expertise that created the stockpile into a group of people who you can trust as suppliers of a safe and reliable nuclear deterrent force. Their judgments, which are not going to be formed out of designing and testing in Nevada, will have to be credible to you, themselves, the administration, and to the world. The plans we devised include new facilities that have to come on line, like the computers, in time for our experts to map their experience onto those new facilities and the people who will rely on them in the future.

We are working to manage these issues in a number of ways. For the people with limited experience and new people, we are going to try to steep them in the archives of our nuclear test data so they can understand what we did and why we did it. We are taping people who designed the weapons. In a series of video tapes, these experts will step through each of the design features of the warhead and try to jog their memories as to why they did what they did. We are archiving that whole level of experience.

We will also have our people perform experiments on the new component-level testing facilities to apply them to issues encountered in the past and to the types of problems that might be faced in the future. A key part of this approach is that we've got to give them situations under which they can fail. We don't want them to fail on your systems, we want them to fail on the component-level trials, so they can learn their limitations and, in the process, improve capabilities. We'll give them previously encountered problems to solve, where we have a historical record including nuclear test data. We'll make them design and test laser targets, using the same computer codes used for nuclear weapons, and get the right answer. Or, if not learn the science that will lead them to the right answers.

Of course, we must be certain that success in transferring skills to the next generation of experts translates into operational successes as well. We have to do well with warhead surveillance and needed component refurbishment. But if we don't properly develop the people's judgments, and don't build skills in using the scientific tools to address real world problems, you won't have a product you can believe. This is probably the hardest part of our job, because this one involves humans and culture and who you believe when.

Where we are heading with nuclear weapons in the much longer term is an important issue. A number of very senior officers have expressed differing views on the long-term role of nuclear weapons as a deterrent. My own perception, as a pragmatist, is that U.S. interest and involvement in world events for the next several decades means that some level -- perhaps in the few-thousand range of nuclear systems -- will be important to the national security of the United States.

Wherever the debate about the nuclear force posture in 2030 or 2050 leads, my concerns and responsibilities are more near term. The President says that safe and reliable nuclear systems are a supreme national interest of the United States. He has asked us, your department and my department, to assure him that the job can be done without nuclear testing. We have said we think so, but we wanted safeguards -- and we have those safeguards. And we've got to have reasonably bipartisan support to make this work. I would add that I hope that our partnership with the services remains strong, even in difficult budget times. If so, we can deliver on the job I've described to you. We can't do it alone, we'll need your help, your feedback and your confidence. Thank you.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.