BY THE NUMBERS

7
The number of years it took to produce the first refurbished W87 warhead under a Life Extension Program.

$312
The amount, in millions, requested for Life Extension Programs in 2007.

$88
The amount, in millions, requested for the RRW Program in 2007.

23
The number of subcritical tests performed at the Nevada Test Site since 1997.

146
The number of U.S. nuclear tests at the Nevada Test Site between 1982 and 1992, when U.S. nuclear testing stopped.

45
The number of focused physics and engineering experiments on weapons components at Lawrence Livermore National Laboratory in 2005.

2038
The year when the oldest W76 warheads that undergo a Life Extension Program are expected to be retired.

22.5
The average age, in years, of warheads in the U.S. nuclear arsenal.

SOURCES: FEDERATION OF AMERICAN SCIENTISTS, NATURAL RESOURCES DEFENSE COUNCIL, ENERGY DEPARTMENT, NATIONAL NUCLEAR SECURITY ADMINISTRATION, NEVADA SITE OFFICE.

At the workbench

Bruce Goodwin is the associate director for defense and nuclear technologies at Lawrence Livermore National Laboratory. He worked to design the W80 nuclear warhead and oversaw Livermore's winning RRW design team.

BAS: How did the RRW team proceed after it decided to go forward with a weapon based on previous designs?

GOODWIN: We had to figure out how to meet the new requirements: a different reentry body; different yield requirements; enhanced safety requirements; and essentially new security requirements. And you have to do this in the context of a future nuclear complex that's going to be very small. You'd like to eliminate as many of the unique, difficult, hazardous materials that used to be in these systems—materials nobody else in the world uses, other than people who build nuclear weapons. If you can get rid of them, you can avoid the multi-hundred-million dollar investments for each one of those materials. So you look at that design, and you start adapting it. To achieve all of those goals you really have to take a systems-level approach, because if you change one thing, something else may complain. The first part of the study was optimizing those combinations of requirements in order to get to a design that meets the majority of them well and is highly reliable, meaning that it will not require a nuclear test.

BAS: What are some of the frills that you removed from the design?

GOODWIN: I wouldn't call them frills, but they were things that made the previous systems much lighter and smaller for a given yield, for instance, beryllium. Beryllium is a remarkable material, it's very, very light and has extreme dimensional stability; it's a very strong metal in spite of the fact that it is so light. It has lots of properties that make it attractive for making very small, very high-yield weapons. Beryllium also happens to be one of the most dangerous substances on Earth. It causes lung disease, berylliosis, and is very nasty to handle. If you can avoid using it, if you can avoid exposing the people who have to deal with this weapon, manufacture it, handle it, and dispose of it some day, you have made a huge impact on the enterprise.

We removed a number of other materials which are harder to describe in an unclassified context. It's sort of funny, I can't tell you what we removed, and I can't tell you what we replaced it with, but I can tell you the impact. We removed a material that, again, nobody else uses. It's a material that doesn't want to exist. It's one of these combinations of materials that nature doesn't like, and it's very hard to create the factory to make this material. The production line is almost a mile long. When we produced it during the Cold War more than 90 percent of the material that went into the factory came out the other end of the factory as radioactive toxic waste, and that was the best you could ever do. With the new requirements, we were in a larger reentry vehicle, but we had the same military requirement as the W76 warhead. We had a much bigger weight budget, and we had a

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much bigger volume budget, and we could apportion that to nonradioactive material that happened to weigh a lot more. In fact, this material can be purchased commercially, and the waste stream now is about a tenth of the waste stream before.

BAS: What's the biggest design challenge post-Cold War weaponeers face? Is it vexing or exhilirating?

GOODWIN: How do you make a weapon perfectly reliable for when you need it, and also utterly uncooperative when it's not supposed to be operated? That's a huge technical challenge. Designers are really excited to be able to deliver something like that to meet the challenges of nuclear deterrence with a minimum number of weapons and a relatively small nuclear complex.

BAS: How can you maintain confidence in the design without testing?

GOODWIN: Take when somebody builds a suspension bridge. Every suspension bridge is a brand new design, and, if you do your job right, one never tests a suspension bridge to failure. How do you have confidence? The answer is engineering safety factors. You design that bridge to have a much larger margin to failure than it could ever encounter, whether it's an earthquake or a hurricane or corrosion over the next 100 years. You do subcomponent testing: You test the bolts, you test the cables, you test the beams, you test the concrete. You make sure that what you specified is what you've put in there. You even do some subassembly testing, but you never ever test the entire bridge until the day that either the people or the trucks go out on it. We use the same principles here.

BAS: What are the limitations of computer simulations that Livermore uses to evaluate nuclear performance?

GOODWIN: The fundamental limitation to any computer simulation is the data you input; it's the old saying, "Garbage in, garbage out." You have to have confidence that the components, the physics subcomponents, of the coupled, large-scale simulation are validated. Then you have to validate the entire ensemble, and you do that in a very formal way using regression testing on a daily basis. The simulation has to be validated against experimental data.

BAS: As a designer, what's wrong with stockpile stewardship? Why won't it sustain the arsenal for as long as its needed?

GOODWIN: I don't think there's anything wrong with stockpile stewardship. The issue that we face is the extremely low margins in the legacy stockpile. The margins were basically just big enough to ensure that the weapon would work because the premium was on yield to weight. To be honest, if you were in a catastrophic nuclear war, and you were exchanging 10,000 weapons, did you care if 4 percent of them didn't work? Nobody would ever have known.

BAS: Describe the current generation of weapons designers.

GOODWIN: The current weapons designers refer to me as a "graybeard," which is probably fairly accurate even though I don't have a beard. I refer to them as the "young ones," but that's ironic because to become a nuclear weapons designer you typically have to have a PhD in physics or engineering, and then it takes a while. The young ones are in their early thirties to early forties, and graybeards like me are in their late fifties.

BAS: What's different about the class of RRW designers?

GOODWIN: Designing a warhead is very much a team process, and there is a continuous cohort in age up to the cranky old guys like me. For instance, the primary designer is a young woman in her late thirties, who's a very, very sharp astrophysicist from Berkeley. And she works with people who have been doing this for 5, 10, 20 years longer than her. And then the design team itself is red-teamed or criticized. We bring in a separate team. Generally those are fairly old people. Many of them are retirees who are not involved in the design process. They come in independently and try to rip everything apart to find out what's wrong with it and then deliver that—politely, I'd call it a peer review—to the original design team to defend themselves and, if necessary, change their design. It's a continuous process. We continue this process, even after a weapon is in the stockpile. We have a red-teaming process on an annual basis where we examine the health of each weapon.

BAS: What are the rewards of being a weapons designer?

GOODWIN: It's intellectually fascinating. The complexity of physics is amazing. Some of the people who review us from the university community refer to it as multi-physics. I started as an astrophysicist out of the University of Illinois, where I worked on neutron-star collapse. The complexity of physics involved in the operation of nuclear weapons far exceeds astrophysical explosions, neutron stars, or supernova.

BAS: By designing very reliable warheads, are you designing yourself out of a job?

GOODWIN: I don't think so. Nuclear weapons prevent large-scale war. That doesn't mean that they prevent all war, but the worst is prevented through deterrence. Nuclear weapons will be required certainly beyond my lifetime, and I intend to live a long time, and somebody's going to have to take care of them.

BAS: Will this require a replacement RRW?

GOODWIN: Well, I don't know what the requirements will be in the year 2040 or 2050. Do I believe that we will have nuclear weapons until the year 2050? Absolutely. Will these weapons have to be remanufactured, rebuilt, or replaced? There's a good chance. Nothing lasts forever. Probably only the pit's going to last more than 100 years. The rest of it will have to be replaced just like components in a car.