

his Administration, they also concede that this budget contains a more modest and focused approach. Clinton's budget for 1998 has few big ticket items, in contrast to his early initiatives, which included the huge economic stimulus and health care packages that bombed in Congress in 1993 and 1994. But it also contrasts with the minimalist approach he took in 1995 after Republicans captured Congress.

Last November he declared his top priority was balancing the Federal budget by 2002. But in his State of the Union address on 4 February, he declared that his No. 1 priority is a "national crusade" to improve educational standards and performance, with the Federal government pitching in to help with everything from tutors to computers and a little brick and mortar to shore up dilapidated schoolhouses. He also

proposed \$51 million more for Pell grants and tax breaks "to open the doors of college education wider than ever before."

The President's budget is his opening gambit in the fiscal 1998 budget cycle. It will frame the policy debate, and with both sides pledging bipartisanship, the proposals are being taken seriously this year.

IRWIN GOODWIN

Without Explosions to Test the Aging Nuclear Arsenal, Bomb Builders Turn to Inertial Fusion and Supercomputers

With the end of the cold war, the nuclear arms race has run its course. And with it has come the end of test explosions. The Comprehensive Test Ban Treaty (CTBT) signed by President Clinton and leaders of more than 100 other nations last September (but still awaiting ratification by Congress and the other nuclear powers) has left nuclear weapons designers out in the cold. In fact, US tests ended in September 1992 when President Bush signed a bill funding the Superconducting Super Collider and containing an amendment by Senator Mark Hatfield, the Oregon Republican, to impose a nine-month moratorium on underground tests. After Clinton entered the White House in January 1993, he ex-

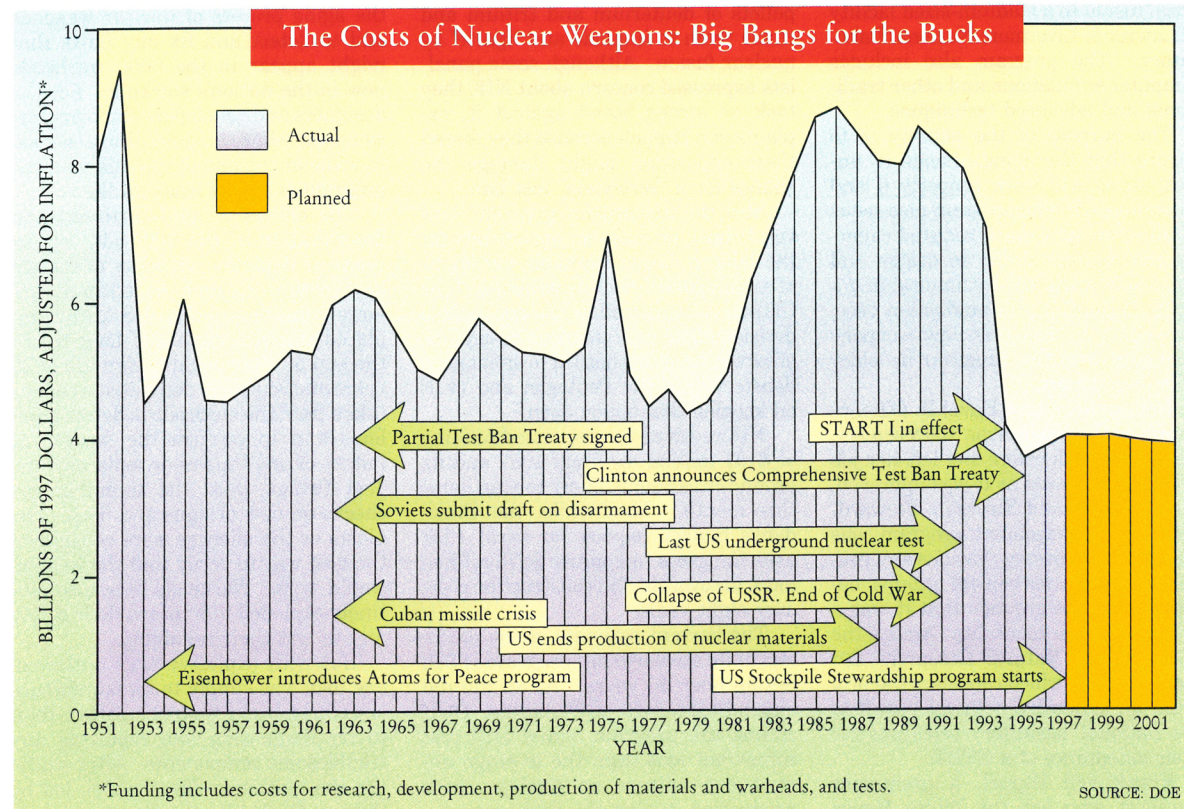
tended the ban year by year.

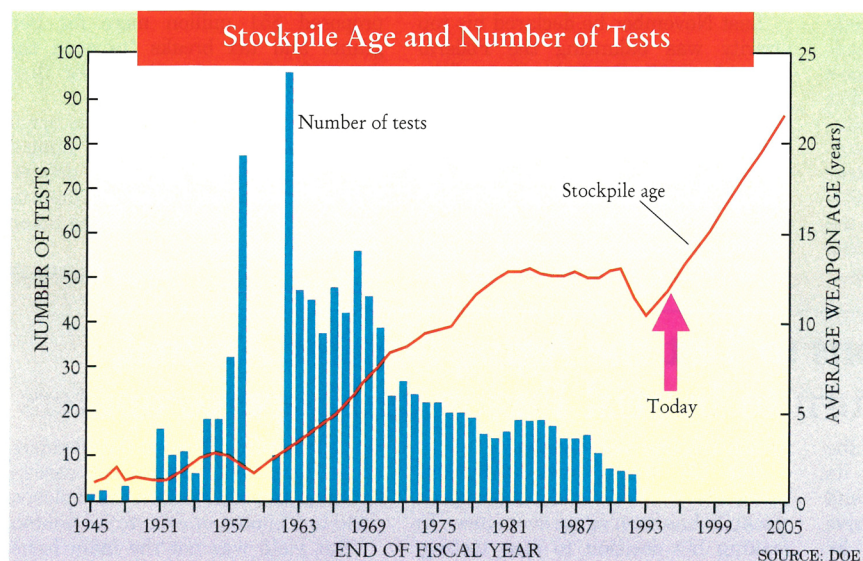
The US stopped making nuclear warheads in 1989 and its weapons stockpile has been aging ever since. In making his decision to stop testing, Clinton was under pressure from the Defense Department and its Joint Chiefs of Staff, as well as the Energy Department and scientists at its three nuclear weapons laboratories—Los Alamos, Lawrence Livermore and Sandia—to allow small subcritical underground tests. They argued that tests were the best way to know whether the weapons arsenal remained safe, stable and reliable. They also sought to conduct as many as 15 full-scale tests by 1996 and to extend low-level tests as much as ten years

into the future. The special pleaders, all of them with budgets and careers at stake, proposed to limit the explosive yield to 1 kiloton or even to 0.5 kiloton.

But yield was not the main issue. Continued testing, opponents of testing warned, would raise questions among the nuclear have-nots and wanna-bes that the US and perhaps other members of the nuclear club haven't really stopped developing nuclear arms to use when some threat arises.

True, banning tests can't guarantee that proliferation will be prevented. After all, Pakistan developed nuclear weapons without any test explosions—though suspicions linger that it conducted a test in China. And other countries, especially Iraq, Iran and North





NIF is only the largest and most expensive of a half-dozen machines the weapons labs will operate in the program. Other major projects include Los Alamos's Dual Axis Radiographic Hydrodynamic Facility (DARHF), which will generate flash x-ray images of shock waves traveling through exploding materials and simulate the first-stage detonation of a nuclear weapon, an upgrade of Livermore's Contained Firing Facility for non-nuclear high-explosive experiments, and Atlas, a pulsed-power machine at Los Alamos that simulates the implosion of a nuclear weapon trigger.

Despite the array of techniques, some of the program's most ardent advocates admit

that there is no guarantee that all the technical obstacles can be overcome to replicate in a virtual world what the CTBT prohibits in the real world. "We're in an area of significant unknowns," says Victor H. Reis, assistant secretary of DOE's defense programs and the program's architect. "We can't be sure what will happen to the weapons as they age, but we are sure they'll be expected to function way beyond their design lifespan."

The purpose of the new program is to achieve a better understanding of the aging process of nuclear weapons and to detect and fix any flaws that might appear in the 9000 warheads now in the nation's stockpile. For the designers and developers of the nuclear weapons, whose arcane culture seemed to wane at the end of the cold war, the program is a new lease on life.

The effects of age—corrosion and deterioration of the 6000-odd components or depletion or decay of certain key materials, such as tritium—are largely unknown. The US always replaced nuclear warheads long before the end of their usual design life of 20 years and routinely detonated weapons taken from the stockpile to detect problems and to confirm the success or failure of any repairs or replacements. Test firings were the unambiguous checks on new designs and fixes. The blasts or the silences were considered the best way to verify that the weapon would work. Warheads were also routinely exploded to improve their safety and to test their reliability.

But with explosive tests outlawed, one idea was simply to remanufacture or refurbish old weapons rather than to try diagnosing and repairing any troublesome components. After studying the matter, a Jason panel, led by Sidney D. Drell, deputy director of

Korea, are seeking such weapons of their own.

For its part, the US has embarked on the most sweeping change in its nuclear weapons program since it built and tested its first atomic bomb in 1945. Ironically, a week after signing the CTBT (see *PHYSICS TODAY*, December 1996, page 37), Clinton authorized a huge increase in funds for testing nuclear weapons. But instead of exploding the weapons underground, the new program calls for generating miniature thermonuclear explosions by inertial fusion in a stadium-sized facility at Lawrence Livermore National Laboratory. The program also includes computer simulations and other traditional and advanced techniques.

The purpose of the activity is to ensure that the aging arsenal of nuclear arms will work properly if and when needed. The program also seeks to preserve, at a much reduced capacity, the nation's ability to design and build new warheads by maintaining a limited scientific and production base, as well as by bringing new weapons scientists into the program as older scientists depart.

Energy Secretary Hazel R. O'Leary approved the program on 19 December, just one month before she left her job at DOE. But even as it was approved, the Science-Based Stockpile Stewardship and Management program was mired in controversy. Various environmental and arms-control groups opposed it on the grounds that it was a relic of cold war mentality. Among the critics is the Natural Resources Defense Council, which considers the program an expensive political payoff to the national laboratory scientists for their acceptance of a CTBT.

Frank von Hippel, a prominent physicist who left the White House

Office of Science and Technology Policy in 1994 to return to science policy studies at Princeton University, has also criticized the program as gold-plated. "Stockpile stewardship is a misnomer," he says. "It's not so much preserving the stockpile as preserving the weapons-designer community." Von Hippel served on a DOE panel that reviewed the security implications of the National Ignition Facility (NIF) at Livermore, a \$1.1 billion laboratory that will house a laser with 192 beams, whose light will converge on minuscule pellets of deuterium and tritium and cause them to implode and "ignite" by nuclear fusion. Although some panelists expressed concern about NIF, they took no strong stand against it, explains von Hippel, because they feared their opposition might damage the chance for a "zero-yield" test ban.

Still, the stewardship program, says von Hippel, provides an opportunity for the labs to design workable variations of contemporary nuclear weapons. "The Clinton Administration has not made a decision about new weapons design," he observes, "and this has led to an internal debate within the Pentagon and DOE on keeping that option open."

NIF received the requested funding of \$191 million for fiscal 1997 and its ground-breaking is likely to start later this month. Meanwhile, the President's budget request for fiscal 1998 asks Congress to approve \$876 million more to cover the full construction costs over eight years.

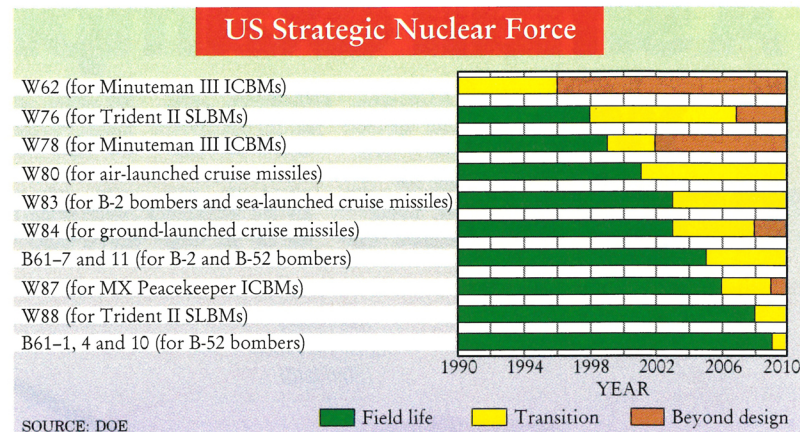
The current estimate of the entire stockpile stewardship program is \$40 billion over 10 years. At an annual expenditure rate of \$4 billion, DOE claims the program would still cost somewhat less than the average annual expenditure on nuclear arms production during the cold war.

SLAC and a physics professor at Stanford University, reported that remanufacturing and refurbishing existing weapons, while still necessary in the stewardship program, would not be enough. "In order to maintain high confidence in the safety, reliability and performance of the individual types of weapons in the enduring stockpile for several decades under a CTBT," the Jasons stated in an earlier report, DOE needed "a focused, multifaceted program to increase understanding of the stockpile; to detect, anticipate and evaluate potential aging problems; and to plan refurbishment and remanufacture." In addition, said Jason, a "significant industrial infrastructure" would need to be maintained in a state of manufacturing readiness.

Jason also considered another approach, which was to keep talented weapons scientists on call at the labs to diagnose and fix any flaws in the weapons and to make informed decisions about substituting or changing any materials to maintain the explosive potential of the array of warheads. While the Jason panel accepted DOE's intention to scale back the weapons labs and the assembly plants, it argued for retaining "core intellectual and technical competencies" in nuclear arms. To sustain a dynamic scientific and technical base, the program must possess an experienced cadre of capable scientists and engineers to anticipate, find and solve any problems and defects in the stockpile.

"The idea of making something last forever is complicated enough with even the most exceptional scientists and engineers," says Reis. He explains his dilemma with an apt metaphor: "Think of a classic Model A Ford that over the years is rebuilt piece by piece but is never souped up to become a Taurus, let's say. Some of the parts no longer can be found, so we would need to rebuild them to keep the old car as it was in its heyday. It will take ingenuity and persistence to do that, and that's why we need experts."

One way of attracting more talent and ideas to the program is to engage universities, says Reis. "We need stronger ties with universities to help solve the complex problems we face in creating computer simulations and other scientific methods of evaluating the nuclear stockpile. So we've decided to support two to five new academic centers of excellence this year." The centers would receive about \$5 million in each year of the five-year program. In addition, DOE plans to spend another \$3 million this year on a new collaboration between academic researchers and all three weapons laboratories. The work by the centers and



researchers would be unclassified and multidisciplinary. It will not be expected to deal directly with nuclear weapons problems. Instead, Reis says, DOE is encouraging universities to propose topics with important civilian applications that may also be relevant to the problems that the weapons laboratories want to solve. The problems might include earthquake and weather prediction or astrophysics modeling. "In selecting the proposals, we'll use peer review," Reis says.

While some scientists applaud the concept, others object to it as inappropriate for universities to become involved in weapons work. "It's a little like giving free samples of a narcotic to kids," says an MIT physicist who opposes nuclear weapons for moral and ethical reasons. "It's tempting because universities and graduate students are hungry these days and the offer sounds so innocent."

"The labs have been downsizing for some time," says Robert Seidel, professor of the history of technology at the University of Minnesota. "This sounds to me like they've gone to the next level, which is 'outsourcing' work to universities."

Ray Kidder, a retired Livermore scientist who was a pioneer in laser fusion, believes NIF and its associated facilities will benefit the weapons program indirectly "by providing challenging research in the kind of physics that happens to be the kind of physics of nuclear weapons" and universities will find the work exciting.

The stewardship program also will challenge computer scientists. Computer simulation of nuclear explosions is where the Accelerated Strategic Computing Initiative (ASCI) comes in. The first of these complicated number crunchers is the massively parallel ultra computer using 9200 of the same Intel Pentium Pro processors that are installed in desktop computers and servers around the world. The

\$46 million machine, installed in Building 880 at the Sandia lab in Albuquerque operates at 1 teraflop—cyberspeak for 1 trillion calculations per second. Sandia's computer experts believe the system's peak speed could be as high as 1.8 teraflops. From now until 2002, DOE will invest \$940 million in its supercomputer program. By the end of 1998, the department expects to have an IBM supercomputer operating at 3 teraflops at the Livermore lab. It will cost \$90 million. And late in the year 1999, a \$100 million machine now being designed by Silicon Graphics and Cray Research, the two companies that merged last year, is expected to run at 4 teraflops and to be installed at either Los Alamos or Livermore. If all goes according to ASCI's schedule, a 10-teraflop computer may be running at one of the labs in late 2000 or early 2001, and still faster and more powerful machines are planned in 2002 or 2003.

Some scientists claim throwing money at universities and computer makers to support the nuclear stockpile program may be self-defeating. William Happer, a Princeton physicist who once ran DOE's energy research office, worries that although the department may be able to convince Congress to support the program for a few years, stewardship will fall prey, as the public purse is tightened, to charges that it is sheer indulgence. "If it begins to look to Congress like support for National Public Radio or the arts endowment, it's going to be funded at the same level they are," he warns.

Serious misgivings also prompted the Joint Chiefs of Staff to insist that the military be allowed to conduct an annual review to certify that the stockpile stewardship program is on track and the arsenal is secure and reliable. The program now requires the directors of the three weapons labs to certify to the President each year that the stockpile is safe, secure and reliable.

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