not inherently expensive. All the basic elements of such systems are contained in amateur radio transceivers, which sell in quantity for considerably less than $5000.

Reference

1. A. D. Hibbs et al., in *Detection and Remediation Technologies for Mines and Minelike Targets V* (Proc. of SPIE, no. 4038), A. C. Dubey et al., eds., SPIE, Bellingham, Wash., (2000), p. 564.

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Never before have I reacted so strongly to an article in PHYSICS TODAY. "The Evolving Battlefield" by John S. Foster and Larry D. Welch may be a reality that cannot be dismissed out of our wishes for a more peaceful world; however, my negative reaction stems from a moral element to the article.

Essentially 99% of the article pertained to changing technology needs for national security with a dubious amount of relevance to the physics that the reader is expecting. The conclusion, however, was a feel-good appeal to scientists who may decide to use their talents to "improve the human condition," as the authors put it.

Outside the ivory tower, many people don't believe it is a net positive to wage battles without offensive combatant losses or to have pinpoint accuracy destructive power hundreds of miles from the target. Perhaps the V-2 rocket was the first unmanned weapon to have long-range accuracy. This was considered a machine of terror, not just a weapon of war.

Certainly smart weapons kill fewer unintended victims, but that should never be confused with improving the human condition. If scientists wish to use their abilities to build more effective and efficient killing machines, then they should do so without cloaking it in some fabricated moral justification.

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It was sadly ironic that the true millennium ended with the special issue of PHYSICS TODAY (December 2000) featuring contributions on future challenges for physics and technology in warfare. Sidney Drell says that "history teaches us that new technologies have had a major influence on the structure, tactics, and strategies of military forces, and that technological advantage can prove decisive to the outcome of military conflicts." Although military battles clearly may be won with technology, history shows that military forces with extraordinary technological and economic advantages do little to end mankind's fundamental conflicts and that arms and violence beget arms and violence; consider, for example, the conflicts in the Middle East, Ireland, Chechnya, Sri Lanka, Yugoslavia, Vietnam, Indonesia, and Africa—and even the failed high-tech "war on drugs." Furthermore, history shows that the true end of conflict comes with interdependence, communication, education, and economic prosperity. These are not the present objectives of our national defense budget.

The continuing overwhelming focus on weapons and military technology ignores history and prevents interdependence. The cell phone and Internet will likely do far more to ensure future peace than any gadgets developed at seemingly unlimited expense by scientists working on secret defense projects. The biggest contributions that the scientific community can make for world peace are to encourage young scientists and engineers to shun military work; to focus on the challenges in energy, civilian communication, and the environment; and to promote leaders who recognize these priorities.

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DRELL REPLIES: The last section of my introductory article—A special responsibility—briefly touches on that very issue, asking each physicist to define his or her own response to the important challenges raised by applications of scientific advances.

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NIF's Value Questioned, Affirmed

The article by Jim Dawson on the NIF controversy (PHYSICS TODAY, January 2001, page 21) quotes Burton Richter as saying that it would take Lawrence Livermore National Laboratory (LLNL) two or three years to bring the National Ignition Facility (NIF) laser up to full performance, and that this was typical of projects of this kind. That viewpoint is not supported by the story of LLNL's previous laser, called Nova. In their 1980 laser program annual report,[1] LLNL researchers calculated an expected performance for Nova of 9–10 kJ/beam at the third harmonic. In their 1981 annual report (p. 2-28), at the start of Nova construction, they proposed operating criteria of 4–7 kJ/beam. The 1981 report also stated that the "primary programmatic objective for Nova," using an eventual 20 beam lines, would be "demonstrating the ignition of thermonuclear burn." The Nova laser worked poorly when it was completed. After several years of fixes and upgrades, the useful energy for laser-target hohlraum experiments at the third harmonic reached 3 kJ/beam. The ignition goal for Nova was discarded.

Ed Moses is quoted as saying that there has been no loosening in any way of the criteria for project completion of NIF. LLNL specifications for NIF had been 9.4 kJ/beam in a shaped 20-nanosecond pulse, with 98% of the energy focused to within a 600-micron spot size, with optical beam smoothing. LLNL scientists calculated that about 9 kJ/beam is needed to drive their target design to ignition; 20-ns-long pulse shapes are needed to create ignition conditions; the 600-μm focal-spot size is needed to fit the laser light through the entrance holes of their hohlraum target; and the optical beam smoothing is needed to control laser-plasma instabilities. This time, to reach ignition, there would be 192 beams. NIF would also use a different laser design than Nova.

The Department of Energy submitted draft NIF milestone definitions to Congress on 15 September 2000, and then to a NIF review panel on 16 November 2000. These milestones call for acceptance of the first eight beams in December 2004 with 5 kJ/beam of third-harmonic light in an unshaped 5-ns pulse. The full 192-beam system would be accepted in September 2008 with 5.2 kJ/beam in an unshaped 5-ns pulse. The draft includes no specifications on focusing or beam smoothing. This watering down of the NIF milestones is important because the scientific prototype of NIF, called Beamlet, was never operated simultaneously at full energy, full pulse duration, conversion to third harmonic, with focusing.

Sidney Drell is quoted as saying that he supports NIF, independent of whether it achieves ignition, as a way of attracting bright young scientists to LLNL. Actually, over the past year, the LLNL laser fusion program has lost some of its best laser and target scientists. But if we assume that NIF is eventually completed, at some performance level, then we need to ask a fundamental question: What kind of scientist is needed to maintain an existing set of nuclear weapons, as compared to designing or improving these weapons? Maintenance requires different skills and attitudes than design. Is an entrepreneurial and risky undertaking like the laser fusion program[2] the appropriate vehicle to attract these scientists? Will laser fusion scientists be sufficiently cautious about making changes in the weapons stockpile, or will they be risk-takers? Will they make unnecessary changes in the nuclear weapons to justify, to themselves and to their sponsors, the high capital and operating costs of NIF?

References

1. Lawrence Livermore National Laboratory, *Laser Program Annual Reports*, rep. no. UCRL-50021-80 LLNL, Livermore, Calif. (1980; see figure 2-114) and rep. no. UCRL-50021-81 (1981); available from the National Technical Information Service.
2. S. Bodner, C. Paine, *Nature* **407**, 29 (2000).

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EDWARD MOSES REPLIES: We must respectfully disagree with the opinions of Stephen Bodner. His views of the National Ignition Facility, Nova, and the US nuclear weapons Stockpile Stewardship Program are well known. During the many reviews that preceded the authorization of the NIF Project, Bodner expressed his concerns to the committees. These committees, and those that succeeded them, have continued to support NIF.

Bodner's representation of Nova neglects to mention that, in addition to meeting its 30-terawatt performance goal, it completed 14 000 shots over its 14 years of operation. Nova was the world's premier high-energy density physics experimental facility, where the highest quality data in hydrodynamics, plasma physics, materials science, and inertial confinement fusion were generated and the first x-ray laser was demonstrated. Over 1000 journal articles were produced and a generation of laser and laser-plasma physicists was trained.

Bodner states that NIF's specifications have been "watered down" and the NIF prototype laser, Beamlet, never met its performance requirements. In fact, Beamlet demonstrated full energy, full power, temporally shaped ultraviolet laser pulses. All aspects of Beamlet design and operation were reported in 31 journal articles. Our Beamlet experience gives us high confidence that NIF will meet its full performance goals.

Bodner raises the question of whether NIF scientists will show good judgment as future stewards of the nation's nuclear stockpile. History speaks for itself. During the past 25 years, the very same people who developed and used similar facilities are now an integral part of the nation's Stockpile Stewardship Program, committed to maintaining its safety and reliability without weapons testing. State-of-the-art facilities like NIF are needed to draw and challenge the best-qualified scientists. NIF will play a vital role in our national security while pushing the boundaries of experimental and theoretical science.

Numerous reviews conducted by the NAS, DOE, and the University of California uniformly support the view that NIF can meet its technical and scientific goals. The NIF team is working to ensure this will happen.

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Accelerator Test Facility Hosts User-Oriented Research

Maury Tigner strikes a chord with accelerator scientists in his outstanding description of the science, technology, and culture of particle accelerator R&D (PHYSICS TODAY, January 2001, page 36).

Tigner refers to his recommendation in the report of the high-energy physics advisory panel's subpanel on accelerator research and development to devote intellectual and monetary resources to high-energy accelerator R&D. That report was instrumental in establishing, in 1982, the Advanced Accelerator Concepts R&D Program in the Department of Energy, Office of High Energy Physics. The program has, for several years, been supporting university, industrial, and national laboratory R&D projects on advanced accelerators. For the past decade, DOE funded, among other things, the Accelerator Test Facility (ATF) at Brookhaven National Laboratory (see http://www.atf.bnl.gov).

The ATF hosts exactly the user-oriented research that Tigner praises in the article section "Hope for the future." Fifteen graduate students have done their thesis research at the ATF since 1992, and the facility currently has 11 university users and 2 small business users. Another indication of the ATF's importance is the number of times it appears in the pages of high-impact journals such as *Physical Review, Physical Review Special Topics—Accelerators and Beams*, and *Science*. ATF users come from all parts of the US and from Russia, Japan, and Taiwan. The research covers advanced accelerator subjects, light-source science, diagnostics, lasers, and high-brightness electron sources. For nearly a decade, the facility has been a leader in accelerator-based particle and light-source research. I would like to think that the Orion project at SLAC, due to come on line in a few years, was inspired at least in part by the ATF.

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Radio Observatory at Maipú Completes Mission, Closes Doors

After 40 years of operation, the Radio Observatory of the University of Chile (ROM), located at Maipú, has closed down. The ROM came to life in 1959, 27 years after Karl Jansky's momentous discovery of cosmic radio waves. The facility was the result of two cooperative programs of the University of Chile, one with the department of terrestrial magnetism (DTM) of the Carnegie Institution of Washington and the other with the University of Florida in Gainesville. These efforts were initiated and encouraged by the late Federico Rutllant, director of the National Astronomical Observatory of the University of Chile, who wanted to have the university involved in radio astronomy. Rutllant's more ambitious interests led to the installation of large international observatories in northern Chile. At the DTM he met Merle A. Tuve, who was enthusiastic about developing radio astronomy in South America.

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