NIF Ignites Changes at Livermore

Lawrence Livermore National Laboratory hopes that a $1.1 billion laser-fusion facility will change the culture of the nuclear-weapons lab and enhance its future

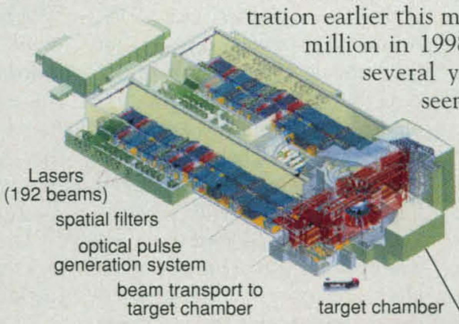
LIVERMORE, CALIFORNIA—Last year, physicist David Cooper was asked to be director of NASA's Ames Research Center, a fitting cap to 33 years spent in space science at the lab. But Cooper, 57, was concerned about declining budgets and Ames's uncertain future. So, he turned down the offer and left to run an exciting new venture in computing at an institution across San Francisco Bay, the prospects of which looked much brighter. No, Cooper didn't end up at some high-tech company in Silicon Valley. Instead, he cast his lot with Lawrence Livermore National Laboratory, another federal facility that only a few years ago seemed headed for extinction. Cooper's choice reflects a surprising paradox: A ban on nuclear-weapons testing, once seen as a threat to Livermore's survival, has instead given the 45-year-old product of the Cold War a new lease on life.

Livermore owes its turnaround to stockpile stewardship, a $4-billion-a-year federal program at the nation's three weapons labs to make sure the country's nuclear arsenal remains safe and ready to use if needed. The crown jewel of the stockpile-stewardship program is the $1.1 billion National Ignition Facility. NIF is a cluster of high-powered lasers that will focus in unison on a tiny target, blasting it with so much energy that it will undergo a miniature thermonuclear explosion. This spring, on a scruffy patch of land at a far corner of the Livermore campus, workers will break ground for NIF.

The stewardship effort has already reversed a sharp drop in the lab's budget and staff in the early 1990s, following the disintegration of the Soviet Union. Cooper, for example, was lured to Livermore to run the lab's computing organization, a vital component of the stewardship program. Together with a fresh generation of Livermore managers led by director Bruce Tartar, these new recruits are attempting to open up a once-supersecret facility created solely to design the world's most destructive weapons.

Officials at Livermore and the Department of Energy (DOE), which runs the stockpile-stewardship program, compare NIF to a fancy department store that anchors a successful shopping mall. "You've got to have something really high class that everything is built around," says George Miller, Livermore's national security chief. There is overwhelming political support in Washington for this notion: The Clinton Administration earlier this month asked for $900 million in 1998 to build NIF over several years, and Congress seems likely to endorse the request.

But not every scientist is pleased with what NIF is selling. Some lab researchers worry that NIF could dominate Livermore's scientific agenda, if not its $1.1 billion budget. And a few critics dismiss it as a high-priced toy that could doom the lab if it doesn't live up to its promise.



NIFty setting. Work is set to begin soon on Livermore's National Ignition Facility.

Hot topic

Even before the world's first thermonuclear explosion rocked a Pacific atoll in 1954, researchers have dreamed of igniting a fusion reaction under controlled conditions. Most such efforts have tried to use magnetic fields to corral superhot plasmas in huge donut-shaped machines called tokamaks. Members of an international team, for example, are struggling mightily to design a $10 billion tokamak that they hope will reach ignition by 2008 (*Science*, 31 January, p. 612). But Livermore and several other labs are taking a different path, called inertial confinement, and NIF is their best hope for triggering fleeting fusion reactions.

Planned for completion in 2002, the mammoth NIF complex will focus 192 laser beams on a tiny capsule of deuterium-tritium fuel confined in a target chamber. This colossal pulse of energy is expected to produce temperatures of 100 million degrees and ignite a small thermonuclear burn. Lab officials tout NIF as a boon for weapons researchers as well as civilian scientists—from fusion-power researchers to astrophysicists who want to explore the processes that power stars.

But NIF's primary goal is to help weapons researchers understand the basic physical processes that occur when a nuclear bomb goes off. This knowledge has immediate applications, says Miller, including making better judgments about the possible danger from a tiny crack in some portion of a nuclear device and whether that part should be replaced. But Tom Cochran, a physicist at the National Resources Defense Council, argues that NIF will be of little help in modeling important parts of a nuclear test, such as the fission portion. "It will give some data, but I don't believe NIF is needed to maintain the stockpile," he says. And a 1995 DOE analysis of NIF requested by Congress notes that "the physical processes for obtaining ignition and burn are different for [inertial confinement fusion] capsules and nuclear weapons." The study adds that NIF "will not be able to perform proof-testing of any nuclear device, nor can it substitute for an integrated test of weapon performance."

Indeed, NIF proponents are walking a fine line in arguing for the facility's ability to model nuclear explosions. During test-ban treaty negotiations, developing nations such as Iran and Indonesia unsuccessfully proposed banning any experiments related to nuclear-weapons maintenance, fearing that programs such as NIF could lead to the development of new weapons. The topic remains a sensitive one, but Livermore officials say NIF is no threat to world peace. "It can't give you the confidence you need to put a new weapon in the stockpile," says Miller.

Even if NIF works as planned, some critics question whether the stockpile-stewardship program makes sense. Livermore astrophysicist Hugh DeWitt, for example, argues that it would be easier and cheaper to remanufacture weapons according to exact specifications when they wear out. But Livermore officials say such an approach wouldn't satisfy another important goal for NIF: to develop a cadre of scientists who know how to design new weapons before all the old hands retire or leave.

Civilian Lab Grabs NIF's Coattails

BERKELEY, CALIFORNIA—Officials at Lawrence Berkeley National Laboratory (LBNL) used to go to great lengths to distinguish their civilian research agenda from the nuclear-weapons work being done at nearby Lawrence Livermore National Laboratory. But the imminent arrival of the National Ignition Facility at Livermore (see main text) has made them change their tune. Now, LBNL officials are touting the opportunity for collaboration between the two labs as a major selling point in a campaign to secure funds from the Department of Energy (DOE) for a $150 million heavy-ion accelerator.

For LBNL, the accelerator would be a big step forward for its small, 20-year inertial-confinement fusion (ICF) program. Unlike magnetic fusion, which uses magnetic fields to contain hot plasma, ICF focuses a vast amount of energy on a small capsule, which then ignites and sets off a miniature fusion reaction. But the lasers or light-ion accelerators currently used as power sources cannot provide the energy, durability, or fast repetitive rates that would be needed to generate power commercially. Accelerators using mercury or xenon ions are a better bet, say fusion researchers, because they eliminate the fragile lens needed for lasers and pack a greater wallop.

LBNL officials see NIF as a powerful ally in their campaign, thanks to a 1995 decision by the government to declassify ICF work. "It opens up an opportunity for a vigorous civilian program," says LBNL director Charles Shank. NIF's lasers are expected to provide vast amounts of information on indirect heating and other technologies, while Berkeley's machine would provide essential data on heavy-ion drivers. "You've got to do that experiment at some point," says Bill Hogan, Livermore's deputy ICF chief. Despite the substantial collaboration between the two labs, neither expects Livermore to help fund the proposed accelerator.

LBNL officials admit that the odds of winning DOE funding are long, and that any new money for ICF research will most likely have to come from other parts of DOE's strapped $220-million-a-year fusion budget. "At this point, there is no way we can even contemplate doing this," says Ann Davies, DOE's fusion chief. "And there's a lot to do before we build a new accelerator."

But hitching their wagon to NIF may be LBNL's best chance to build a machine that can imitate the stars. And that strategy highlights one of the ironies facing DOE's network of national labs: In a post–Cold War era, the government weapons labs are doing much better than their civilian counterparts at winning support for big new projects. Says Livermore's director, Bruce Tartar: "We have done a little bit better than the civilian R&D world in coming to an understanding of what the post–Cold War rationale and programs are going to look like." –A.L.

Culture clash

Lab officials freely admit that one of NIF's important missions will be to attract new scientific talent. Cooper and the 96 scientists and engineers who have joined Livermore since 1994 are part of that vanguard. This rationale has led DeWitt and other critics to dismiss stockpile stewardship as a jobs program, but Tartar says there's nothing wrong with wanting to improve the quality of the staff. "It's an old comment that there are a lot more smart people outside than inside the fence," he says. Adds Miller, "There's nothing altruistic here. We need help."

To succeed in attracting and keeping new talent, however, Livermore must overcome a psychological barrier higher than the fence surrounding the lab. For 4 decades, a small group of nuclear-weapons designers, seen as a priesthood and referred to as "monks," stood at the apex of the lab's hierarchy. The last, John Nuckolls, was forced to resign in 1994 over differences with the lab's operator, the University of California, which wanted to shift the lab's focus away from weapons design.

Tartar, his successor, is an astrophysicist, and by the time he took charge, the influence of the designers was already waning. In the past decade, their number has shrunk from 67 to 45. Meanwhile, the 1800 scientists and engineers that a decade ago were responsible for conducting nuclear tests in Nevada have largely been dispersed, as have the coterie of technical and support staff associated with bomb work. Some retired, some left, and others found jobs in booming areas like stewardship and nonproliferation. At its peak, in the late 1980s, Livermore had 10,500 employees, more than a third of them scientists and engineers. That overall figure now stands at 8240, and the percentage of scientists and engineers is roughly the same.

As their numbers dwindle, some of those wedded to nuclear-weapons design fear the lab will lose its traditional strengths. They see their job as ensuring that the pendulum doesn't swing too far. "It would be irresponsible for the lab to walk away from its nuclear-weapons responsibility," says Nuckolls, now associate director at large. At the same time, they worry about becoming isolated or superfluous in an operation focused on civilian research.

PHOTOS BY LLNL

Open up. Livermore's Tartar, left, and Campbell would like to increase the lab's contacts with outside, civilian scientists.

NIF gives Livermore's current managers, both outsiders like Cooper and veterans who are not part of the nuclear priesthood, a concrete tool with which to transform the lab's culture. "NIF is part of a social experiment as well as a scientific one," says Michael Campbell, a Livermore veteran and laser-program chief who recalls first seeing the lab on his way to the quintessential counterculture experience, a rock concert. "NIF will not have a fence around it."

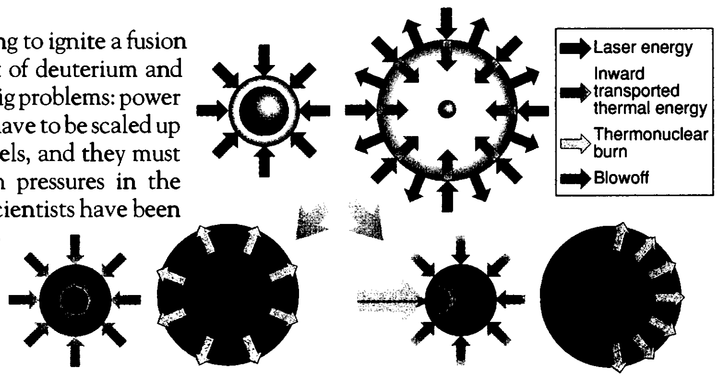
Livermore has already begun to test this new philosophy with Nova, a $176 million laser lab completed in 1984 that packs one-fortieth of the power planned for NIF. Last year, Nova was opened to civilian outsiders for the first time, and managers have reserved 10% of its time for academic researchers of all stripes, whether astrophysicists, nuclear physicists, or fusion researchers. "We're all interested in physics under extreme states of compression," says Bruce Remington, a Livermore physicist who divides his time between stockpile issues and astrophysics.

Remington is also trying to drum up interest in Nova among academics. "People haven't thought about using these laser facilities for astrophysics experiments," says University of Virginia astrophysicist Roger Chevalier, who has dreams of creating miniature supernovas to understand stellar processes. "It's a matter of coming up with experiments that are doable." Even DeWitt, the skeptic of the stewardship effort, says he backs NIF for its potential contribution to astrophysics.

NIF's value to civilian researchers hinges on how much time Livermore managers set aside for academic researchers. The lab has

Laser Fusion With a Fast Twist

TOKYO—Researchers hoping to ignite a fusion reaction by blasting a pellet of deuterium and tritium with lasers face two big problems: power and consistency. The lasers have to be scaled up to unprecedented power levels, and they must generate extremely uniform pressures in the pellet. For the past 5 years, scientists have been quietly working on a way to ameliorate both problems by delivering very fast laser pulses to an already compressed fuel pellet to spark a burn. This year, the technique, known as fast ignitor, will be put to the test at new facilities in Japan and the United States. If it succeeds, the results could be applicable to the planned National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) (see main text).



Burning issue. Both conventional and fast-ignitor inertial-confinement fusion (ICF) rely on lasers or particle beams to heat the target and form a plasma. But conventional ICF, lower left, relies on a steady pressure to ignite the core and trigger a burn, while fast-ignitor ICF, right, sends two laser pulses to the core, causing the burn to spread from the point of ignition.

SOURCE: UNIVERSITY OF CALIFORNIA/LLNL

The fast-ignitor approach starts out much the same as conventional laser fusion, using a barrage of lasers to compress a fuel pellet. Then, two additional intense, short laser pulses are directed at the core. The first, lasting about 100 picoseconds (trillionths of a second), blasts a path through the plasma surrounding the pellet. Then, a second pulse, even shorter and more intense, follows that path to the edge of the compressed-fuel core. That pulse generates hot electrons, which ignite the fuel. The burn then spreads through the fuel, releasing the fusion energy. "It's similar to a gasoline engine, where the fuel is compressed and then the combustion reaction starts from the heating of the spark plug," says Yoshiaki Kato, a physicist at Osaka University's Institute of Laser Engineering.

In theory, the fast-ignitor method would require far less energy than is needed for conventional inertial-confinement fusion because it triggers a burn at lower compression. And because uniform compression of the fuel would not be as critical, the confinement laser system could be made simpler. But the physics involved is not well understood. "Fast ignitor, although extremely promising, is based on a lot of untested physics," says Livermore physicist Michael Perry.

Perry and his team are now putting the finishing touches on an ultrashort-pulse Petawatt laser system that should provide a critical test of the physics. In experiments planned to begin in April, nine of the 10 beams of Livermore's Nova laser, which deliver relatively long pulses, will compress the fuel, while the Petawatt—which set a peak power-output record in a test firing last May—provides the ultrashort ignitor pulses.

At about the same time, scientists at Osaka's laser institute expect to start experiments with a new 100-terawatt ultrashort-pulse laser in conjunction with the institute's GEKKO XII 12-beam laser system. While Livermore's Petawatt has the edge on peak power, the GEKKO XII system holds the record for recorded fuel densities, at 600 grams per cubic centimeter. Neither group will actually achieve ignition. But they do expect to replicate the conditions necessary to explore whether the fast-ignitor approach warrants further work.

If the results are promising, a fast-ignitor capability might be added to NIF. But scientists are cautious about claiming too much too soon. "We're just at the starting point for this concept," Kato says. "It's probably too early to say [whether] fast ignitor can replace the standard approach."

–Dennis Normile

organized a NIF user council, similar to ones used by civilian DOE labs, to ensure that a broad range of disciplines has a say in the facility's operation. "We've got to learn how to engage civilian researchers," Campbell says. Cooper adds that his stewardship computer effort, which will be fully operating by the end of 1998, will allot at least 20% of its capacity for unclassified research.

But being unclassified isn't enough. Some of the work will relate to specific experiments and, therefore, be of little interest to civilian researchers. And while Campbell says he hopes NIF will at least match the 10% share that Nova now devotes to outside scientists, he and other managers say that national security will remain NIF's number-one priority. "I don't want anyone to get illusions that this is a science sandbox we're trying to sell through defense programs," Campbell cautions.

Another potential sticking point is access by foreign-born scientists. While common on U.S. campuses, graduate students from countries with active nuclear weapons programs, including China, India, and Pakistan, are not now welcome at NIF. "What if [a faculty member] wants one of his Chinese students to have access on a Sunday morning?" asks one lab scientist. "It's a big problem."

The hippopotamus effect

In spite of such concerns, even skeptics of the stewardship program say Tartar has begun to change the lab's cloistered image. Increasing numbers of graduate students from Europe and Canada are working at the lab, and some areas no longer require visitors to carry a badge. But the presence of NIF has led some Livermore researchers to worry that other efforts will be pushed to the sidelines. "NIF has the potential to be a hippopotamus in the bathtub," complains one official. He notes that NIF will offer few opportunities for those engaged in biomedical, environmental, and chemical-engineering work at the lab. And Cochran's organization and a local citizens group remain opposed to NIF, seeing it as unnecessary or unsafe.

Even some who would benefit directly from the facility fear its costs may eat up money better spent on science (*Science*, 24 May 1996, p. 1092). So far, the money for NIF—its construction budget will peak at $229 million in 1998—has been added to the lab's overall budget. But it's too soon to tell whether the lab will have to curtail other programs to pay for operations.

Critics like Cochran say Livermore managers should be worrying about the long-term effects on the lab if NIF is not a useful tool to study nuclear explosions. "Then, you are not going to attract a lot of top scientists," he says. "And it would be very damaging to the inertial-confinement fusion community." But top lab officials are confident of NIF's success, and they see few other ways to draw new talent like Cooper. Attracting outsiders is essential for survival in this new era, they say, and new facilities, they add, are a key ingredient. Says Tartar: "We don't have to live behind a fence anymore."

–Andrew Lawler