National Ignition Facility faces an uncertain future

David Kramer

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National Ignition Facility faces an uncertain future

As its budget declines, Lawrence Livermore's $3.5 billion laser fusion facility is refocusing on experiments in support of nuclear weapons science.

Last fall the two-year campaign at the National Ignition Facility to achieve a self-sustaining fusion reaction fell short. Now NIF stands to lose its academic basic research in high-energy-density physics—one of the three mission areas that were specified for NIF when the massive laser facility was approved for construction in 1996.

President Obama's fiscal year 2014 budget request calls for the end of NIF support for experiments proposed by university researchers. "NIF is going to have to focus on its principal missions, which are in support of stockpile stewardship," confirms an official at the National Nuclear Security Administration (NNSA), the Department of Energy agency that funds NIF. "We don't have the funds at this point to support additional operations and lower-priority work." Instead, the NNSA will continue to support academic research at the much smaller Omega laser facility at the University of Rochester, a contractor for the agency. As recently as last fall, an NNSA plan stated that fundamental science and other national security missions would make up about 10% of NIF's experimental program.

"It's an incredible long-term loss in my view," says David Crandall, a recently retired NNSA scientist who helped develop NIF, of the decision to end academic research there. "Some very good experiments have been proposed by external users, and the academic community is generally excited about NIF and developing the capability and people in the future that the stockpile stewardship program needs. It cuts off that enrichment and long-term development."

The proposal to end academic research at NIF is "driven by factors that have nothing to do with rational thinking," says Ricardo Betti, a professor of engineering at the University of Rochester and a member of NIF's proposal review panel. "Once you spend $3.5 billion to build the facility, the rational thing to do is try to get as much out of the facility as you can." A principal investigator cannot afford a NIF experimental shot, he says, which costs around $1 million.

The actual number of university-based experiments conducted at NIF is small—a handful, according to the NNSA official, who spoke on condition of anonymity. The original plan for NIF called for as much as 15% of its experiments to be devoted to research originating in academia. NIF has a 300-member user group, with 22% of its members coming from host Lawrence Livermore National Laboratory (LLNL). About 36% of users are from US universities, and 13% come from other DOE and Department of Defense labs. International users make up 22%, and 7% are in the private sector, according to LLNL.

Looking abroad for help

President Obama's budget request for FY 2014, released on 10 April (see the story on page 23), would cut funding for NIF to $329 million from the $379 million allocated in FY 2013 (next year's figure is likely to be reduced further by the budget sequestration process). In 7 May testimony to the Senate Armed Services Committee, LLNL director Penrose Albright said the proposed cut would result in the loss of 500 jobs and eliminate 70% of the experiments that had been planned for NIF in FY 2014. The 192-beam laser, which dominates the LLNL landscape, will consume nearly 30% of the lab's projected $1.1 billion budget next year.

Officials from LLNL recently announced they are looking abroad to supplement NIF's funding. In a 29 April announcement, Albright declared NIF to be transitioning to an "international science facility." Lab officials say that the change had been in the works since last fall and that the announcement's timing had nothing to do with the release of the budget.

William Goldstein, the lab's deputy director for science and technology, says managers have "reached out to scientists in the US and abroad to ask them about interesting things they might do in the science realm on NIF."

The French and UK governments have conducted experiments at NIF, and both have made contributions to the facility. The UK, for example, paid to install $50 million worth of cooling equipment to allow NIF to fire more frequently. France has collaborated with LLNL in building its own version of NIF, the Laser Mégajoule, and the US inertial confinement fusion (ICF) program has conducted experiments on an 8-beam prototype of the 240-beam French machine.

Albright also named Jeff Atherton to the newly created position of NIF direc-

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Seen from above, each of the National Ignition Facility's two identical laser bays has two clusters of 48 beamlines, one on either side of the utility spine running down the middle of the bay.

tor. In his new post, Atherton is responsible for determining how to allocate time among NIF's users, which include the NNSA's weapons and nonproliferation programs and DOD, primarily the Defense Threat Reduction Agency. Atherton assumed a portion of the duties that Edward Moses had as principal associate LLNL director for NIF and photon science. But Moses remains in charge of NIF operations and implementation of the experimental program, says Goldstein. Since the ignition campaign ended in September 2012, NIF's experimental program has been split roughly equally between experiments aimed at resolving ignition-related issues and experiments in support of the nuclear weapons and nonproliferation programs.

Goldstein and Moses say they hope the university research will continue despite the budget directive. Moses says the budget "is a work in progress" and could well change before enactment. The academic research component is a "hallmark of the national labs" and was aimed at "bringing the best and brightest academic institutions and researchers to the lab," he says. "Our reading of the request is, I don't think it rules out science," says Goldstein. "It does envision that that use is paid for by users or some other entity." It's not likely, however, that universities would pay for experiment time at NIF. "It is important to note that the fundamental science community simply cannot afford to pay, so their research will simply not get done," Albright told the Senate panel.

One of a kind

"There's no question NIF is a unique facility with unique capability in terms of the energy densities it can produce and the pressures it can achieve," says Raymond Jeanloz, a planetary scientist from the University of California, Berkeley. Jeanloz, who has collaborated with LLNL research teams for 15 years, studies materials conditions at the centers of large planets and substellar objects such as brown dwarfs. "We can get into the few tens of millions of atmospheres at a place like Rochester, depending on the specific material. For a comparable experiment, we could get 10 to 50 times higher pressure at NIF." Moreover, he explains, NIF allows the duration of experiments to be extended to as long as 20 nanoseconds, compared to a more typical 2–4 nanoseconds at Omega and other laser facilities. That allows more precise measurements and larger sample sizes.

Paul Drake, a professor of space sciences at the University of Michigan, has participated in experiments at NIF that will eventually "create unstable fingers of fluid amidst shocked matter so hot that radiation ablates the fingers away." Such conditions are found in exploding stars, and "no other machine on Earth" can replicate them, he says.

Drake and Betti worry about a separate FY 2014 proposal to terminate the DOE Office of Science's support for academic research in high-energy-density (HED) laboratory plasmas. Housed in the Fusion Energy Sciences office, that program has provided grants to investigators for HED experiments at various laser and other facilities, including NIF, Omega, and Z—a pulsed power accelerator at Sandia National Laboratories. The overall Office of Science HED program would be slashed to $6.6 million from $25.3 million in FY 2012 and would pay only for experiments at SLAC's Linac Coherent Light Source.

Jeanloz is hopeful that some alternate funding mechanism, possibly user facility funding from other DOE programs or in collaboration with other agencies like NASA and NSF, will be devised to keep the academic program at NIF alive. He notes, for example, that NSF has paid to build beamlines at DOE synchrotron light sources.

Weapons applications

In addition to its ignition efforts, NIF contributes to the scientific underpinnings, largely through equation-of-state experiments, of nuclear weapons. That kind of work is also performed at both Z and Omega. But LLNL senior scientist Robert Kauffman says that with NIF's higher pressures, "we can start looking at the dynamics; we can provide pressure pulses at time scales that are shorter than Z can do." That, he notes, enables scientists to see how atoms rearrange in near-real time. Researchers currently have papers in review on carbon and iron equations of state, with heavier elements to come, he says.

Other types of weapons experiments to be performed at NIF involve measuring opacities and hydrodynamics in materials under high pressures. "The rate of change of pressure causes strain rates that are incredibly high—very important issues for the weapons program and understanding basic science," Moses notes. "When materials are moving rapidly, they act differently than when they are treated adiabatically. . . . We can not only reach extreme pressures but reach extreme strain rates and do that in a precision manner."

Ignition-related experiments still account for about half of NIF's operating time, but recently attention has been focused on improving the understanding of the phenomena that have interfered with ignition. Another attempt at an integrated deuterium–tritium capsule experiment is expected to take place in the next few months, says Moses.

Direct versus indirect drive

To date, all of the ignition experiments have taken what is called the indirect-drive approach. Up to 2 MJ of laser light have been directed with great precision into the ends of a cylindrical hohlraum that contains a peppercorn-sized sphere of D–T fuel. Inside the hohlraum, the 351-nm light is converted to x rays, which cause the fuel pellet to implode. The NNSA says that indirect drive, which resembles the radiation implosion process that occurs in the secondary fusion state of thermonuclear weapons, is most relevant to its needs. But in its report to Congress, the agency also noted that inadequate modeling of hohlraums and laser–plasma instabilities within the hohlraum have been part of the problem. In his testimony, Albright noted that ignition will help weapons scientists resolve remaining uncertainties with the physics of boosted fission—a process that occurs in the primary stage.

One area of concern is the shape of the imploding fuel; Moses describes the D–T fuel as compressing into a diamond shape rather than the desired sphere. But recent experiments have demonstrated an ability to manipulate the shape, he says.

Crandall says ignition simulations used in designing NIF failed to foresee the deleterious changes in hohlraum radiation that take place during experiment runs. He now estimates that NIF has less than a 50% chance of reaching ignition with indirect drive. That compares with the 75% probability reported to Congress at the time NIF was given the green light, he notes.

Stephen Bodner, the former head of the Naval Research Laboratory's (NRL's) ICF program, predicted asymmetries and other trouble with the NIF hohlraum design nearly 20 years ago. The symmetry might be improved by increasing the size of the hohlraum, he said, but that would require a laser with as much as five times the energy of NIF.

Other ICF devices, including Omega and the NRL's Nike, have pursued a direct-drive approach to fusion, in which laser beams impinge directly on the fuel target. Those, however, are far too small to approach ignition. Omega has been performing experiments using a modified symmetry approach known as polar direct drive, which NIF was built to accommodate. According to Crandall, extrapolations of experimental results at Omega indicate that if performed on NIF, polar-direct-drive shots could get somewhat nearer to ignition than has been attained with indirect drive.

Moses stresses that LLNL has no prejudice against direct drive, but he notes that the Omega extrapolations have not been peer reviewed. Modifying NIF to do polar-drive experiments would cost $200 million or more, he says. But Betti says that Rochester estimates those costs at $40 million to $50 million and that indirect-drive experiments could run in parallel with those using polar direct drive. The NNSA's current plan is to evaluate the polar-direct-drive option on NIF in FY 2015.

Meanwhile, though, NIF's struggles with ignition might dim prospects for all ICF. Stephen Obenschain, who now directs NRL's $6 million Nike program, worries what might happen if indirect drive doesn't pan out. "Do you kill off everything? Do you kill off all the other options? We have a lot of concern about that."

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Budget gains for physical sciences will be uncertain at best

The administration's spending blueprint for 2014 finds room for a new space mission and increases for the physical sciences, but R&D budget decreases are looming.

Although President Obama's proposed fiscal year 2014 budget almost certainly won't be enacted as written, his request reaffirms the administration's commitment to science and technology. But with the sharp partisan divide over how to reduce budget deficits, and with sequestration's across-the-board spending cuts scheduled to increase, it appears likely that next year's science and technology budget will decline.

The White House plan puts total spending for basic and applied research at $68.1 billion, an increase of $4.8 billion, or 7.5%, over FY 2012 levels. (Comparisons are to FY 2012 because the FY 2013 budget process remained incomplete as the request was finalized.) Overall, nondefense R&D would increase 9.2%, to $69.6 billion, but defense R&D would fall 5.2%, to $73.2 billion. By far the largest component of defense R&D consists of weapons systems development. The request would add a total of $1 billion, or 8%, to the budgets of three key federal supporters of basic physical sciences research: the Department of Energy's Office of Science, NSF, and the laboratory programs of NIST. Obama has carried forward an initiative begun under President George W. Bush to double the budgets of those three agencies.

The FY 2014 budget request, submitted to Congress on 10 April, more than two months late, exceeds the cap on discretionary spending established under the 2011 Budget Control Act. The president has proposed a combination of tax increases and cuts to entitlement programs to pay for the increased spending. Leadership of the Republican-controlled