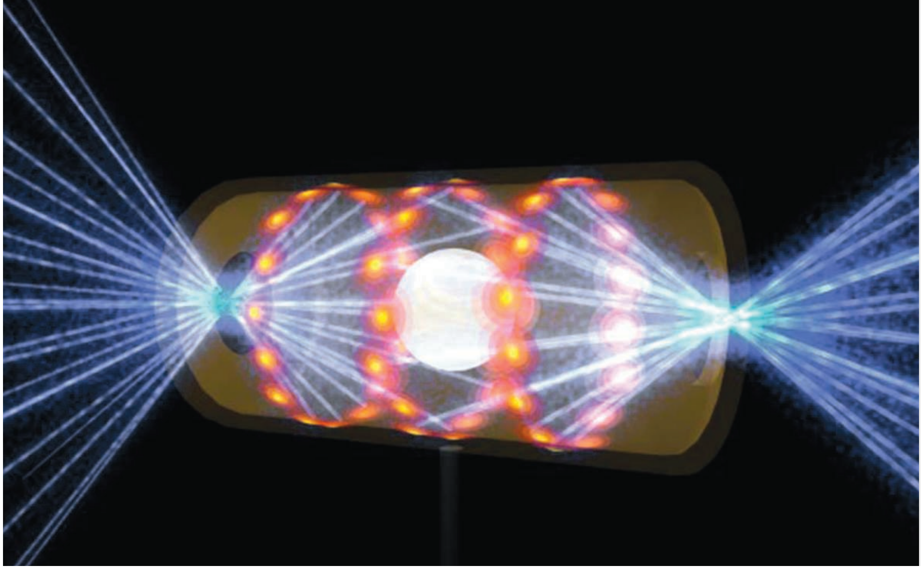

Hot zone. NIF's laser beams heat the inside of the hohlraum (illustration) to create an x-ray oven.

ENERGY

Laser Fusion Project Alters Goals, Fueling Concern Over Its Strategy

The hopes of fusion researchers worldwide are pinned to the fortunes of the National Ignition Facility (NIF), a $3.5 billion laser center at Lawrence Livermore National Laboratory in California, which is trying to show that it is possible to create a self-sustaining fusion reaction that could serve as a source of energy. But a change in its milestones, revealed in an internal NIF document *Science* has seen, has highlighted the concerns of some in the field that the path NIF researchers have taken may not be the right one.

Funded by the U.S. Department of Energy (DOE), NIF aims to use a huge laser, the highest energy laser in the world, to crush a tiny fuel capsule to temperatures and pressures higher than in the center of the sun. The goal is to spark a fusion fire in the center of the fuel to start it burning. But the fuel is not considered ignited until high-energy alpha particles produced by the fusion burn heat the surrounding fuel enough to keep the burn going until a significant fraction of the fuel is used.

Until last month, NIF was scheduled to show evidence of significant alpha-particle heating by the end of March, then prove by the end of June that fusion can produce as much energy as the laser provided (known as gain=1), and finally produce an overall energy yield of 5 megajoules (MJ) by the end of September—the end of NIF's initial research program called the National Ignition Campaign (NIC). But a document known as a Baseline Change Proposal, signed by NIF Director Edward Moses on 21 December 2011, would delete this third goal from the NIC schedule and push its two remaining milestones back by 3 months each.

Moses said this week that the changes were a scheduling, not a physics, issue. NIF has other priorities apart from fusion ignition: It simulates nuclear explosions to help ensure the effectiveness of the nuclear stockpile and is also used for basic science experiments. Moses says there is high demand from these other users. "People wanted more nonignition shots in [early 2012]," he says, so he had to negotiate a new schedule with NIF's funders in the National Nuclear Security Administration.

Moses also downplays the significance of eliminating the 5-MJ milestone. Gain=1 has, since the early planning of NIF in the 1990s, been the working definition of fusion ignition. Once NIF gets the fuel burning, it should just be a matter of finessing the implosion to increase the yield to 5 MJ, Moses says. Others agree that gain=1 is the key target, but some doubt even that milestone will be achieved by the end of the NIC in September. And that would be politically embarrassing for NIF because, as the campaign's name suggests, ignition is one of the key goals of the NIC.

NIF has been controversial from the start. Fusion scientists were only able to propose such a big and expensive machine because of its parallel role in nuclear weapon stockpile stewardship. But some argued that the experimental fusion program was too ambitious and too great a leap from existing techniques (*Science*, 17 April 2009, p. 326).

Since the facility's completion, many have hailed NIF as a technical triumph, but that hasn't stopped the controversy. One bone of contention is the schedule-driven NIC itself, which sticks to a set path in order to get to ignition as quickly as possible (*Science*, 28 October 2011, p. 449). The strategy chosen for the NIC is a technique known as indirect drive. The 192 laser beams are shot into the ends and onto the inside walls of a small gold cylinder called a hohlraum. The energy they deliver turns the hohlraum into a hot oven filled with x-rays. A plastic sphere the size of a peppercorn containing the deuterium-tritium fuel sits at the hohlraum's center, and the x-ray heating causes the plastic to explode, forcing the fuel inward and compressing it. Getting that implosion just right to cause ignition is hugely complicated and depends on many variables in the beam, hohlraum, and capsule.

Retired physicist Stephen Bodner, former head of laser fusion at the Naval Research Lab, is one of those concerned about the NIC. Based on presentations by NIF researchers at plasma physics meetings, Bodner concludes that indirect drive "is almost certain to fail." NIF researchers "have not really faced up to the problems they have," he says.

One of the strengths of indirect drive is that converting the laser light to x-rays in the hohlraum smoothes out imperfections in the laser beams, although this conversion does waste much of the beams' energy. That was expected, but critics point out that other processes in the hohlraum seem to be diverting more energy from the job of imploding the capsule. "Energy is going in places they don't want or in forms they don't want it," says a fusion researcher who asked not to be identified.

Even former DOE Under Secretary for Science Steven Koonin had doubts about NIF's progress. In a memo dated 8 November 2011, following his fourth review of the NIC, Koonin noted: "Surprises encountered on the path to ignition make it impossible to predict confidently the rate of progress on those issues of greatest concern to the NIC and so ignition by the end of [fiscal year 2012] is not assured."

Bodner and researchers in other laser fusion labs favor the alternative approach of direct drive: shining NIF's laser beams straight onto the fuel capsule. Although this demands higher beam quality, more beam energy goes into compressing the fuel.

The NIF team is making good progress, according to Moses. "It's a very hard problem," he says. "But we have the capability to do good experiments on the path to ignition." The team has carried out 15 realistic shots with damped-down fusion fuel, improving the quality of the implosion by a factor of 100, Moses notes. "There's another factor of 10 to go. If it's there, we'll get it."

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