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Fusion Scientists See Promise Where Obama Shows No Ardor

By John Lippert - May 3, 2013
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Chris Bishop paces as he beams the world's biggest laser at a peppercorn-sized fuel pellet, a crucial step toward fusing hydrogen atoms to replicate the explosive power of the sun, stars and thermonuclear weapons.

With his blond ponytail, sneakers and jeans, Bishop looks more like rocker Gregg Allman than a lead operator at the National Ignition Facility. Here, 45 miles east of San Francisco, 1,200 scientists and staff are on a quest to create fusion energy, Bloomberg Markets magazine will report in its June issue.

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On this Tuesday in January, technicians gather in the control room of the NIF, where scenes in "Star Trek Into Darkness," scheduled for release on May 17, were shot last year. They rivet their eyes on 5-foot-high (1.5-meter-high) screen projections as the world's most powerful supercomputer sorts data in a system that rivals the U.S. air-traffic-control network for complexity. Panels turn green to show the laser is storing energy as it looms in the 10-story building above. In the blink of an eye, the laser unleashes its juice. Bishop, 42, gives a thumbs up.

"This looks like a control room for moon landings," he says. "We have the potential to do a lot more for humanity than that."

Laboratory Microbomb

Bishop is a fusion evangelist. He has devoted six years to this corner of the Lawrence Livermore National Laboratory, wielding a laser that delivers 1,000 times more energy than the U.S. electrical grid at any instant in time. If the laser can spark atoms to fuse in a self-sustaining reaction known as

ignition -- the equivalent of a laboratory-scale microbomb -- scientists may be on their way to rewarding the planet with unlimited and nonpolluting energy, Bishop says.

“Fusion is a rich source of power,” he says.

Edward Teller, father of the fusion-powered hydrogen bomb, would agree. When he co-founded Livermore in 1952 for weapons research, he also sought a peacetime perk: abundant electricity. Scientists say fusion could provide the foundation for both. It seeks to combine deuterium and tritium, two variants of hydrogen, to form the heavier element helium. As the atoms fuse, a small portion of hydrogen is converted to energy, as Albert Einstein’s famous E=mc2 formula predicted.

Power Plant

Edward Moses, the principal associate director for the NIF and Photon Science Directorate, wants to harness that energy for practical uses. He says Livermore could join with private companies to build an electricity-producing fusion power plant eight to 12 years after the NIF achieves ignition.

Mike Dunne, head of the NIF’s future plant designs, says a commercial-scale, 925-megawatt model could be built for about $4 billion. He estimates fusion-generated electricity would cost roughly the same as coal and nuclear power -- about $108 per megawatt-hour. That’s about $24 more than natural gas and $44 less than photovoltaic solar cells.

Moses, 63, wants to raise $1.5 billion, partially from utilities and suppliers, to get commercial fusion technology ready. In a possible prototype, Pacific Gas & Electric Co. (PCG) and others agreed in December to pay the Livermore lab $150 million to use its supercomputers for improving California’s electricity grid. Wealthy individuals may contribute, and some have expressed interest, Moses says, declining to name them.

Detractors say cost estimates are meaningless because they involve technologies not yet invented.

Ignoring Naysayers

“Moses is destroying his credibility,” says Burton Richter, a retired Stanford University physics professor.

Moses counters that people warned him about the impossibilities of just getting the NIF off the ground.

“I have a great responsibility to not be distracted by the naysayers,” he says. On May 1, Moses lost a portion of his direct oversight of the NIF when L. Jeffrey Atherton replaced him as the facility’s director.

NIF teams plug away at ignition on a 1.2-square-mile (3.1-square-kilometer) patch of Livermore Valley wine country. The Department of Energy, the facility's parent, periodically interrupts the bucolic setting with commando-style raids to check security.

After the U.S. banned real-world nuclear tests in 1992, the government turned to Livermore to create a small thermonuclear explosion for scientists to study so they could learn how to keep the nuclear stockpile up to date. The National Nuclear Security Administration broke ground in 1997 and completed the NIF complex in 2009.

Reduced Expectations

As scientists perform their weapons-related experiments, they haven't stopped exploring fusion electricity -- even as doubt and competition from labs pursuing other pathways have grown.

Many Americans dismissed such energy after researchers in 1989 labeled a tabletop method dubbed cold fusion as junk science. President Barack Obama, a backer of wind and solar, doesn't mention fusion in speeches. The National Academy of Sciences further doused enthusiasm on Feb. 20 by saying the NIF may be years from ignition.

The Energy Department itself has trimmed expectations:

"Experience shows we didn't have as good an understanding of the physics as we thought," says David Crandall, who retired in March as the department's senior fusion adviser.

Congress is getting tougher, too. The NNSA has spent about $6 billion to build and run the NIF. Lawmakers were planning to press the NIF in May for measurable goals for reaching ignition, people familiar with the situation say.

Wrong Goal

In a 2005 Livermore newsletter, Moses said he hoped to achieve ignition in 2010. Now, he says the NIF is about halfway through a three-year set of experiments that may accomplish that goal.

Obama wants to cut the NIF budget to $329 million in the fiscal year that begins Oct. 1 from the prior $409 million. The NIF may close the gap by charging outside researchers to run basic science experiments, such as how elements like iron behave under extreme pressure. Moses is allocating time slots with the facility and its laser into 2022.

The NIF's fusion obsession amounts to a boondoggle, says Christopher Paine, director of nuclear programs at New York-based environmental group Natural Resources Defense Council.

"If we'd spent the same $6 billion to study energy storage, we'd have a massive deployment of solar

technology," Paine says.

Others say the NIF is chasing the wrong goal in keeping nuclear arms up to date.

"In the 21st century, weapons research should be geared toward disarmament," says Marylia Kelley, executive director of Livermore, California-based watchdog Tri-Valley CAREs.

True Believers

For true believers, fusion is too tantalizing to abandon for a simple reason: Fusing hydrogen atoms releases eight times more energy than a fission reaction that splits a similar amount of uranium, says Stephen O. Dean, author of "Search for the Ultimate Energy Source: A History of the U.S. Fusion Energy Program." Fusion is also more difficult, since such electrically charged particles as deuterium and tritium tend to repel each other.

"Fusion for electricity will work; the question is when and at what cost," Dean says. "Hopefully, climate change won't get completely out of hand before we find the answers."

Moses, who earned a Ph.D. in laser physics from Cornell University in Ithaca, New York, prides himself on keeping federal programs moving toward such complex and lofty goals. He supports big science, the government's ability to tackle grand challenges and win.

Oppenheimer Hero

Moses counts J. Robert Oppenheimer as a hero because when fission bombs were just theoretical possibilities, Oppenheimer was already wondering how big a plane would be required to drop them. For the next several years, the NIF will have the only laser with enough power to reach ignition, the National Academy of Sciences says. "Our facility is like a car driving 6,000 miles an hour," Moses says.

Fusion energy is more urgent today than ever, he says. Unlike fossil fuels, fusion wouldn't release carbon dioxide, which heats the planet. Low-level radioactive waste could go to a landfill, unlike the byproducts of fission, Moses says. Fusion is virtually unlimited, easing geopolitical conflict, he says. Unlike wind and solar, it could power cities day and night.

'Rocky Mountains'

Moses likens his job as fusion pioneer to that of Meriwether Lewis. President Thomas Jefferson tapped Lewis in 1804 to explore uncharted territory between the Mississippi River and the Pacific Ocean. Moses says that, like Lewis, he can't fully anticipate what he'll find. Tests may produce less energy than expected. Timetables may slip. His laser generates 1,000 times more pressure than anyone else has achieved in a lab, so he has no guideposts. Still, he's convinced of the ultimate goal.

Moses laughs when pretending to be Lewis reporting to Jefferson: "Our theories about the Pacific were correct; it's still there," he says. "I'm sorry we didn't know about the Rocky Mountains."

The NIF's slow progress hasn't deterred others from fusion fervor. Five U.S. national labs and several overseas research programs are taking competing routes. The biggest is a $19.8 billion test facility China, the European Union, India, Japan, Russia, South Korea and the U.S. are building in Cadarache, France, 46 miles northeast of Marseille.

In the fiscal year that begins Oct. 1, Obama wants to contribute $225 million to this project, called the International Thermonuclear Experimental Reactor. It's scheduled for completion in 2020, with the first full-blown experiments in 2027.

ITER's Price

For now, the ITER is the U.S. government's preferred path to civilian electricity compared with other fusion choices, says Chris Deeney, the NNSA's assistant deputy administrator.

ITER's construction price tag has grown to 15 billion euros ($19.7 billion) currently, up from 5 billion euros in 2001. Four U.S. senators, including Democrat Ron Wyden of Oregon, on Friday asked the U.S. Government Accountability Office to investigate whether the U.S. can absorb its portion of ITER cost overruns without being forced to cut other fusion research efforts. They didn't specify the other fusion programs.

Two Approaches

Deeney's thinking puts Moses's work at odds with the prevailing U.S. sentiment.

The NIF approach, called inertial confinement, uses lasers to create conditions that make fusion possible. In two-millionths of a second, they heat deuterium and tritium to at least 100 million degrees Celsius (180 million degrees Fahrenheit) and crush it with enough pressure and at sufficient velocity to release energy.

The ITER plans to utilize magnetic confinement, which doesn't use a laser. Andrei Sakharov, who led the Soviet Union's hydrogen bomb research before becoming a dissident, helped formulate the idea in 1950. The project will seek fusion inside a plasma or cloud of deuterium-tritium fuel that's heated to 150 million degrees Celsius and is held in place by magnets as tall as a small apartment building. The density is one-millionth of an Earth atmosphere, and scientists hope to sustain the plasma for 16 minutes, compared with a fraction of a second at the NIF.

"We need long-range thinking about energy and about how we're going to survive as mankind," says Osamu Motojima, 65, the ITER's director-general. "It's very important that fusion be recognized as

one of the frontiers that humans are now trying to conquer."

A smaller version of an ITER-style machine, in Culham, England, produced 16 megawatts of power after consuming 24 megawatts to get the reaction started.

Thermonuclear Bombs

The NIF's role in updating U.S. nuclear weapons explains why Moses is chasing a type of fusion resembling thermonuclear bombs.

Holding up a Plexiglas tube, he shows how the so-called indirect drive method starts with a hohlraum, or canister, the size of a pencil eraser. The canister is coated on the inside with gold. Laser light enters the hohlraum, heats the gold and generates X-rays that converge on a fuel pellet, similar to the one Bishop tested in January. Inside the pellet is a layer of deuterium and tritium that's frozen in place as the experiment begins and then imploded by heat and pressure.

Elusive Ignition

To achieve ignition, NIF scientists say they need to implode the fuel at a rate of 360 kilometers per second and crush it with pressure equal to 350 billion Earth atmospheres. In April 2012, they reached 330 kilometers per second and 202 billion atmospheres. Since then, the NIF has targeted its experiments at determining what could be robbing the microbomb of power, Moses says.

Laser beams entering the hohlraum are generating fewer X-rays than expected, meaning there's less energy to implode the fuel, he says. The implosions, intended to be symmetrical to reduce energy loss, are shaped more like apples or pears. Misdirected energy melts the frozen fuel before fusion takes hold.

Scientists are experimenting with longer hohlraums to reposition laser beams and increase symmetry. They're using fuel pellets that are thicker, shaped like rugby balls and coated with boron carbide. They're revamping computer simulations. Moses hopes such measures will boost pressure to 250 billion atmospheres, a move he likens to taxiing down a runway toward ignition rather than being parked in a hangar.

Public Support

On a larger scale, Moses is confronting the inefficiency of the indirect drive method. During a typical test, less than 2 percent of laser energy reaches the fuel; most heats the hohlraum. Moses says he can overcome this situation partly by expanding to 3,000 kilojoules of energy with upgraded laser lenses.

In the meantime, the National Academy of Sciences is calling for continued experiments with a process called direct drive, in which laser light is beamed straight at the fuel.

Jeff Wisoff, Moses's deputy, says achieving ignition would decrease the questions about science and money that surround fusion -- and help the NIF avoid the loss of public support that hurt the U.S. space program.

"The moment of opportunity for talking about fusion energy will come when we get ignition, and we'll be ready," says Wisoff, a veteran astronaut of four Space Shuttle flights.

For commercial fusion, Moses would need laser diodes made of silicon or germanium crystals that conduct electricity and that can fire 10 times a second. Heat would be captured in a lithium blanket surrounding the reactor and used to create steam, which would generate electricity in a turbine.

Unreasonable Men

Crandall, the retired DOE fusion adviser, calls a power plant eight to 12 years after ignition preposterous, because it would require so many new technologies. The Energy Department has other options: ITER-style fusion, fission, natural gas and renewables.

Still, he's not turning his back.

"All great progress is made by unreasonable men," Crandall says. "I wish Ed luck."

Moses, for his part, says he feels close to a promised land where fusion provides unlimited, carbon-free energy. Setbacks such as the disappointing fuel implosions haven't made him despair. Nor have they shaken his belief in big science and pioneering exploration like that of Meriwether Lewis.

A fusion stalwart in a field of doubters, Moses is convinced the NIF has the tools and people to harness the power of thermonuclear weapons and to use it for peaceful purposes that benefit the Earth.

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