The Grand Challenge of Thermonuclear Ignition

SCIENTISTS often refer to formidable scientific and technological hurdles with far-reaching consequences as grand challenges. One of the enduring grand challenges is achieving nuclear fusion—the power source of the Sun and stars and the physical process at the core of Livermore's national security mission—in a laboratory environment.

Since our founding, Lawrence Livermore National Laboratory has been one of the world's centers for fusion research. Immediately after the laser was invented in 1960, Laboratory scientists understood the possibility of using coherent light to ignite a fusion microexplosion. Since then, Livermore researchers have led the world in the goal of achieving controlled thermonuclear burn in the laboratory using laser light.

Ignition and thermonuclear burn will release more energy than is required to initiate the reaction and may offer an environmentally sound method to supply energy. Ignition in the laboratory will be a key capability for stockpile stewards to help ensure the safety and reliability of the nation's nuclear weapons. It will also provide new insights into the world of high-energy-density physics, recently dubbed by the National Academy of Sciences as the "X-Games of Contemporary Science."

An overarching goal of the National Ignition Facility (NIF) is to attempt to achieve thermonuclear burn in 2010. NIF is the most recent in a long line of increasingly more powerful solid-state lasers constructed at Livermore. It is nearly 100,000 times more energetic than the first system. In working to make NIF a success, our scientific and engineering team has achieved breakthroughs in laser architecture, developed new optical materials and target designs, and devised innovative diagnostic systems. In many ways, these technological and scientific advances have received all the glory.

However, no breakthrough has been more important, no undertaking more challenging than finding a way to control the more than 60,000 components that make up NIF. This integrated computer control system (ICCS) is the linchpin that makes NIF operations and experiments possible. It is the most complex real-time control system ever designed for a scientific machine. Described in the article beginning on p. 4, ICCS will ensure that all of NIF's 192 laser beams arrive at a tiny target within a few tens of microseconds of each other and that a host of diagnostic instruments record data in a few billionths of a second.

We've designed an extremely complex system whose pieces operate individually but, at the time directed, work in unison. The NIF control system uses an innovative architecture that allows 24 bundles of eight laser beams to be aligned and prepared for a shot independently. With this modular approach, scientists can design experiments so that individual bundles have different energy and waveform characteristics. In response to an input command, ICCS software calculates the required configuration of the laser beams, aligns them on target, fires the laser, and collects the data. NIF is thus an unusually flexible user facility that will provide scientists the wide experimental regime they need in the decades ahead.

ICCS demonstrated its effectiveness during the 18-month-long experimental campaign called NIF Early Light, which was completed in October 2004. This campaign used the first four lasers beams to conduct more than 400 shots. It validated the modular architecture while performing unique experiments in high-energy-density physics supporting stockpile stewardship.

As we continue to complete NIF, we will be refining and replicating the software that controls each bundle. We are now turning from a build-and-test mode to one of activating equipment and planning for a full-scale shot schedule for ignition in 2010.

NIF is a grand-challenge machine. We are confident that it will allow us to meet the goal of thermonuclear burn—a goal that scientists at Livermore and throughout the world set nearly a half-century ago. Experiments conducted on NIF will make significant contributions to national security, could lead to practical fusion energy, and will help the nation maintain its leadership in basic science and technology. This goal is a grand challenge that only a national laboratory such as Livermore can accomplish.

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