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Report to the Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. Senate

April 2010

NUCLEAR WEAPONS

Actions Needed to Address Scientific and Technical Challenges and Management Weaknesses at the National Ignition Facility

GAO Accountability * Integrity * Reliability

GAO-10-488

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Accountability•Integrity•Reliability

Highlights

Highlights of GAO-10-488, a report to the Subcommittee on Energy and Water Development, Committee on Appropriations, U.S. Senate

Why GAO Did This Study

In March 2009, the National Nuclear Security Administration (NNSA), a separately organized agency within the Department of Energy, completed construction of the National Ignition Facility (NIF). NNSA considers NIF critical to its stockpile stewardship program to ensure the safety and reliability of the nation's nuclear weapons, absent live nuclear testing. NIF is intended to simulate the extreme temperatures and pressures of "ignition"—an atomic fusion event propagating a nuclear explosion—for the first time in a laboratory. GAO was asked to examine (1) the extent to which NNSA has addressed key scientific and technical challenges that could prevent ignition at NIF; (2) whether NNSA has an effective approach for managing the cost, schedule, and scope of ignition-related activities; and (3) potential impacts to NNSA's stockpile stewardship program if ignition at NIF is not achieved, as planned, between fiscal years 2010 and 2012. To conduct this work, GAO analyzed relevant budgets, reports, and plans, and interviewed NNSA and national laboratory officials and independent experts.

What GAO Recommends

GAO recommends that NNSA take actions to improve its effectiveness in (1) using outside experts to advise on scientific and technical challenges—by ensuring, for example, that the new committee reports to NNSA and advises on ignition activities early—and (2) managing NIC's cost, schedule, and scope. NNSA agreed with the recommendations.

View GAO-10-488 or key components.
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What GAO Found

Despite substantial progress, NNSA, its national laboratories, and the other organizations carrying out the NIF ignition effort face difficult scientific and technical challenges, which could limit the extreme temperatures and pressures that can be achieved using NIF's 192 lasers and, thus, delay or prevent ignition at NIF. As a result, successful ignition at NIF during the first attempt, scheduled for late 2010, remains unlikely, according to independent experts. In addition, Lawrence Livermore National Laboratory, which operates NIF for NNSA, waited 4 years to implement a recommendation to form a standing external review committee of experts to advise on the challenges. Although a committee met for the first time in December 2009, three factors could limit its effectiveness. First, the committee may not be able to give fully objective, candid advice, because the committee will take direction from, and report to, Livermore's Director, rather than to NNSA. Second, the committee will mainly review ignition activities after the fact, rather than advising on them sooner. Third, although its membership includes at least one scientist with significant nuclear weapons design experience, the committee may lack sufficient expertise to determine whether ignition-related efforts will meet the future needs of scientists conducting stockpile stewardship research at NIF.

Weak management by NNSA has allowed the cost, schedule, and scope of ignition-related activities to increase substantially, and further increases are possible. In 2005, NNSA established the National Ignition Campaign (NIC) to focus the management of ignition activities. Since then, however, NIC's costs have increased by around 25 percent—from $1.6 billion to over $2 billion—and the planned completion date has slipped by 1 year to the end of fiscal year 2012. Also, major new scope activities and milestones were added to NIC in 2008 to prepare NIF for stockpile stewardship experiments by the 2012 date. In addition, NNSA allowed tasks critical for the first ignition attempt—such as constructing concrete doors to protect personnel from radiation—to be removed from the NIF construction effort, which began in 1997, and deferred years later to NIC. Delays in completing the long-deferred tasks under NIC could delay, beyond 2012, ignition or other goals.

There would be no immediate impact to NNSA's Stockpile Stewardship Program if ignition at NIF is not achieved by the end of fiscal year 2012, according to NNSA and national laboratory officials. The consequences of not achieving ignition, however, would become more serious over time, possibly reducing NNSA's confidence in the data it uses to certify the safety and reliability of the nuclear weapons stockpile. In September 2009, during the first stockpile stewardship experiments at NIF, Livermore scientists began using NIF to validate NNSA's data and models on weapon performance under nonignition conditions. However, Livermore and NNSA officials said that only ignition experiments can help address some significant areas of uncertainty in predicting weapon performance, particularly as weapons in the stockpile age or are refurbished.

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Abbreviations

EP	Extended Performance
MJ	megajoule
NIC	National Ignition Campaign
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration

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The Honorable Byron L. Dorgan
Chairman
The Honorable Robert F. Bennett
Ranking Member
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

In March 2009, the National Nuclear Security Administration (NNSA), a separately organized agency within the Department of Energy, completed construction of the National Ignition Facility (NIF), a $3.5 billion research facility at the Lawrence Livermore National Laboratory in California.[1] In this stadium-sized laser facility, NNSA's goal is to produce extremely intense pressures and temperatures that may, for the first time in a laboratory setting, simulate on a small scale the thermonuclear conditions created in nuclear explosions, known as "ignition." If successful, NIF may improve scientists' ability to evaluate the behavior of nuclear weapons without explosive testing.

NNSA considers NIF a critical component of its multibillion-dollar stockpile stewardship program, which is responsible for ensuring the safety and reliability of the nation's nuclear weapons stockpile in the absence of underground nuclear testing.[2] Stockpile stewardship involves refurbishing or dismantling aging weapons, conducting advanced nuclear weapons research, and maintaining the nation's nuclear production capabilities. In addition to NIF, NNSA has other experimental research facilities to support stockpile stewardship in all three of its national nuclear weapons laboratories: Lawrence Livermore, Los Alamos National Laboratory in New Mexico, and Sandia National Laboratories in New Mexico and California. Although stockpile stewardship will be its primary mission, NNSA also plans to make NIF available to outside researchers for

[1]The $3.5 billion cost includes $2.2 billion to design and construct the NIF facility and $1.3 billion to assemble and install NIF's 192 lasers and their associated components.

[2]In 1992, the United States began a moratorium on testing nuclear weapons. Subsequently, the President extended this moratorium in 1993, and Congress, in the National Defense Authorization Act of 1994, directed the Department of Energy to establish a science-based stockpile stewardship program to maintain the nuclear weapons stockpile without nuclear testing (Pub. L. No. 103-160, sec. 3138 (1994)).

investigating basic and applied science issues, such as the physical properties of stars and planets and fusion energy production.

Lawrence Livermore was responsible for carrying out the design and construction of NIF, with NNSA oversight, in a capital construction project that began in March 1997.[3] At the same time, Lawrence Livermore and other institutions were conducting research and other activities—separate from the NIF construction project—to prepare for the first attempt at ignition that would take place sometime after NIF construction was completed. In 2004, Congress directed NNSA to develop a project management approach for controlling the cost, schedule, and scope of these separate activities.[4] In response, in 2005, NNSA established the National Ignition Campaign (NIC) to provide project management focus on the activities. The NIC participants, which include NNSA's national nuclear weapons laboratories and other research and industrial organizations, are responsible for planning and carrying out scientific experiments and related activities designed to set the stage for, and demonstrate, ignition at NIF, and for the completion of construction projects needed for the safe operation of NIF. In 2004, Congress also directed NNSA to enlist a group of outside experts, known as the JASON study group, to evaluate the NIC's initial plans and prospects for achieving ignition by the end of fiscal year 2010.[5] In its 2005 report, the JASON study group found that achieving ignition within this time frame would be unlikely and made a series of recommendations for addressing the many

[3]In 2000, we found that poor management and oversight of the NIF construction project had increased NIF's cost by $1 billion and delayed its scheduled completion date by 6 years. Among the many causes for the cost overruns or schedule delays, the Department of Energy and Lawrence Livermore officials responsible for managing or overseeing NIF's construction failed to plan for the technically complex assembly and installation of NIF's 192 laser beams. They also failed to use independent review committees effectively to help them identify and correct issues before they turned into costly problems. For more information, see GAO, *National Ignition Facility: Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays*, GAO/RCED-00-271 (Washington, D.C.: Aug. 8, 2000).

[4]Congress directed this in a report accompanying the Energy and Water Development Appropriations Bill, 2005, H.R. 4614, H.R. Conf. Rep. No. 108-554 (2004).

[5]JASON is an independent group of accomplished scientists that advises the U.S. government on matters of science and technology. The name "JASON" is not an acronym. Its sponsors include the Department of Defense, the Department of Energy, and the U.S. intelligence community. Congress directed the JASON review of ignition-related activities at NIF in the Conference Report to Accompany H.R. 4818 (Pub. L. No. 108-447 [2004]), the Consolidated Appropriations Act, 2005 (H.R. Conf. Rep. No. 108-792 (2004)).

scientific and technical challenges that could delay or prevent ignition at NIF.[6]

As they focus on achieving ignition and preparing for NIF's role in supporting the stockpile stewardship program, NNSA and the NIC participants face scientific and technical challenges that have the potential to keep them from meeting their goals within the expected cost and time frame. In this context, you asked us to examine NNSA's progress toward its ignition-related goals for NIF. Specifically, we reviewed (1) the extent to which NNSA has addressed key scientific and technical challenges for achieving ignition at NIF; (2) the extent to which NNSA has an effective approach for managing the cost, schedule, and scope for achieving ignition at NIF between fiscal years 2010 and 2012; and (3) the potential impact to NNSA's stockpile stewardship program if ignition is not achieved at NIF within that time frame.

To conduct our work, we reviewed NIC project documents, relevant studies, and reports, and with assistance from GAO's Chief Scientist, analyzed scientific presentations and peer-reviewed articles by NIC or other scientists, as well as independent review reports by the JASON study group. We met with officials from the main organizations participating in the NIC, including Lawrence Livermore, Los Alamos, and Sandia National Laboratories; the University of Rochester's Laboratory for Laser Energetics in New York; and General Atomics in California. We toured NIF; facilities at the University of Rochester, Los Alamos, and Sandia for ignition-related stockpile stewardship research; and the target manufacturing facility at General Atomics. With assistance from GAO's Chief Scientist, we interviewed NIC participants to identify the key scientific and technical challenges for achieving ignition at NIF and their efforts to address those challenges. We also spoke with independent experts about the challenges of achieving ignition at NIF, including five members of the JASON study group, former NNSA laboratory scientists with expertise in fields related to ignition, and scientists from the Naval Research Laboratory's Laser Fusion Program. To assess the extent to which NNSA has an effective approach for managing NIC's cost, schedule, and scope, we examined NIC project execution plans, budget requests, progress reports, and other management documents. We also met with NNSA officials from the Office of Inertial Confinement Fusion and National Ignition Facility Project, responsible for formulating policy and

[6] JASON, *NIF Ignition*, JSR-05-340 (McLean, VA: June 29, 2005).

budget guidance related to NIC and monitoring the NIC participants' efforts to adhere to NIC's cost, schedule, and scope requirements. To evaluate the potential impact of not achieving ignition at NIF by the end of fiscal year 2012 to NNSA's stockpile stewardship program, we analyzed briefings and studies of NIF's role in addressing aging and weapons performance issues and met with the lead weapons scientists at NNSA's three defense laboratories, who plan or carry out research in support of the stockpile stewardship program. We also discussed, with the independent experts, NIF's expected contributions to stockpile stewardship.

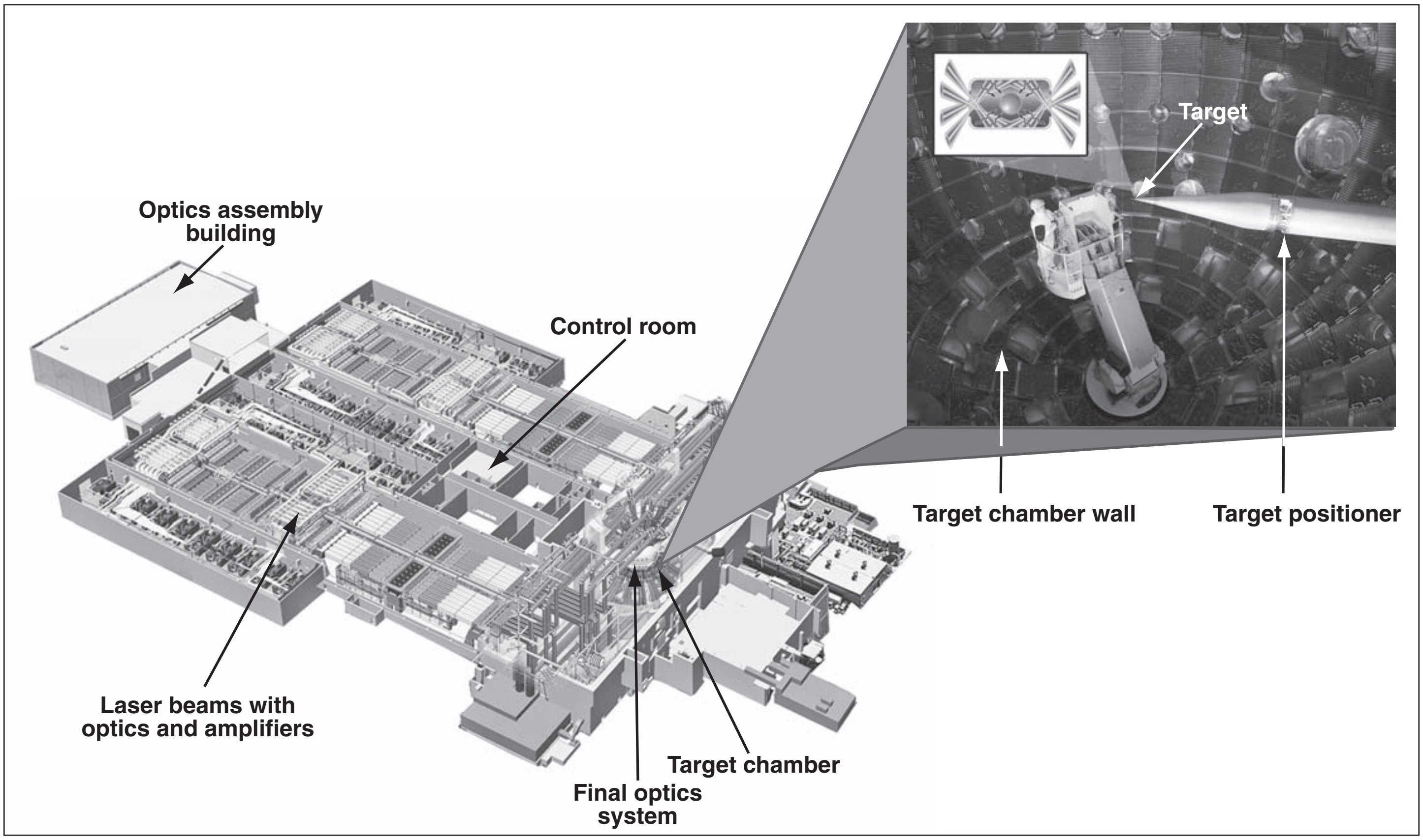
We conducted this performance audit from June 2009 to April 2010, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Nuclear fusion—the reaction that powers the sun—occurs when extreme temperatures and pressures force the nuclei of two or more atoms together. Scientists have previously achieved fusion during underground nuclear tests and in laboratory fusion experiments. Ignition—a fusion reaction resulting in a net gain of energy—has, however, only been recreated during nuclear tests. Scientists at NIF hope to use another man-made approach, laser-induced inertial confinement fusion, to recreate the intense temperatures and pressures under laboratory conditions necessary to fuse the nuclei of deuterium and tritium atoms (forms of hydrogen) and release helium atoms, neutrons, and a large quantity of energy. If ignition at NIF works as planned, the released energy would, in turn, fuse nearby atoms in a self-sustaining process known as thermonuclear burn.

To achieve ignition, NIF will focus energy from its 192 laser beams simultaneously to deliver as much as 1.8 million joules (more commonly referred to by its acronym, MJ, which stands for "megajoules") of laser energy onto a target smaller than a dime. In a process that takes about one millionth of a second, the laser beams pass through a series of glass optics that amplify the energy and focus it onto a target located inside of a large spherical target chamber 10 meters, or over 3 stories, in height (see fig. 1).

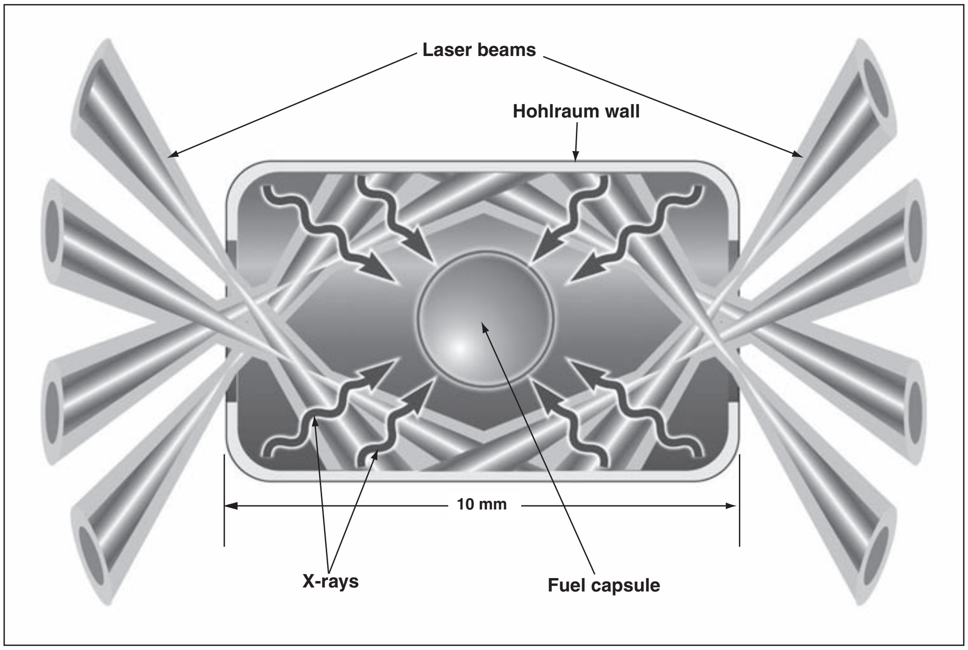
Figure 1: The National Ignition Facility



Source: GAO analysis of data provided by Lawrence Livermore National Laboratory.

The target at the center of this chamber is a hollow gold cylinder, known as a hohlraum, which contains a tiny, peppercorn-sized fuel capsule consisting of a frozen deuterium-tritium layer surrounding cooled deuterium-tritium gas. As shown in figure 2, NIF's lasers rapidly heat the interior wall of this hohlraum, which converts the lasers' energy into X-rays. These X-rays then rapidly heat the outside surface of the fuel capsule. After sufficient heating, the capsule's outside surface blows off with rocket-like force, driving the remaining capsule wall and deuterium-tritium fuel layer within to implode. If this implosion occurs symmetrically, and at a sufficient velocity, it is expected that the deuterium and tritium atoms will be forced together in a fusion reaction, lasting about 10 trillionths of a second, and the fuel in the capsule will be ignited to temperatures greater than approximately 100 million degrees Celsius—hotter than the center of the sun. As the reaction is occurring, diagnostic instruments placed inside and around the target chamber are to take measurements and provide data on the reaction.

Figure 2: NIF's Approach to Achieving Ignition



Source: GAO analysis of data provided by Lawrence Livermore National Laboratory.

To prepare for the first ignition attempt, NIC participants have been conducting experiments at various NNSA-funded facilities, including, very recently, NIF. The participants have also, among other activities, been developing many of the diagnostic instruments for NIF, including instruments to determine whether ignition has occurred. For purposes of NIC, ignition is being defined as a reaction in which the fusion energy output is greater than or equal to the laser energy used to create the fusion reaction. Currently, NIC's budget totals around $2 billion and covers activities from fiscal year 2006 through NIC's scheduled completion date at the end of fiscal year 2012 (see app. I).

NNSA's Office of Inertial Confinement Fusion and National Ignition Facility Project—which is part of the Office of Defense Programs, the organization responsible for maintaining the nation's nuclear weapons stockpile—has oversight responsibility for NIF and NIC. Lawrence Livermore National Laboratory in California manages and operates NIF for NNSA and has the lead role in managing and coordinating NIC activities and receives most of NIC's annual funding. The other partners in the NIC campaign, listed in order, from highest to lowest, of the share of annual NIC funding they typically receive include the following:

- University of Rochester's Laboratory for Laser Energetics (New York): This laboratory's OMEGA and OMEGA Extended Performance (EP) laser systems are considered to be NNSA's workhorse for ignition-related research due to the high number of experiments conducted at the facility. Prior to the completion of NIF, OMEGA and OMEGA EP were capable of the world's most powerful laser pulse. For NIC, this laboratory performed target implosion experiments and developed diagnostic instruments.

- General Atomics (California): A private company that manufactures NIF targets, including the hohlraum and fuel capsule, as well as targets for other NNSA research facilities.

- Los Alamos National Laboratory (New Mexico): Los Alamos scientists have developed nuclear diagnostics for NIC, conducted target design research, and worked on-site at NIF to lead or assist with experiments.

- Sandia National Laboratories (New Mexico and California): Sandia's pulsed-power "Z Machine," which converts electromagnetic energy into X-rays to create conditions of extreme temperature and pressure, supports NIC by conducting ignition-related stockpile stewardship research. Also, researchers at Sandia have developed diagnostic instruments for NIC experiments and worked at NIF during experiments.

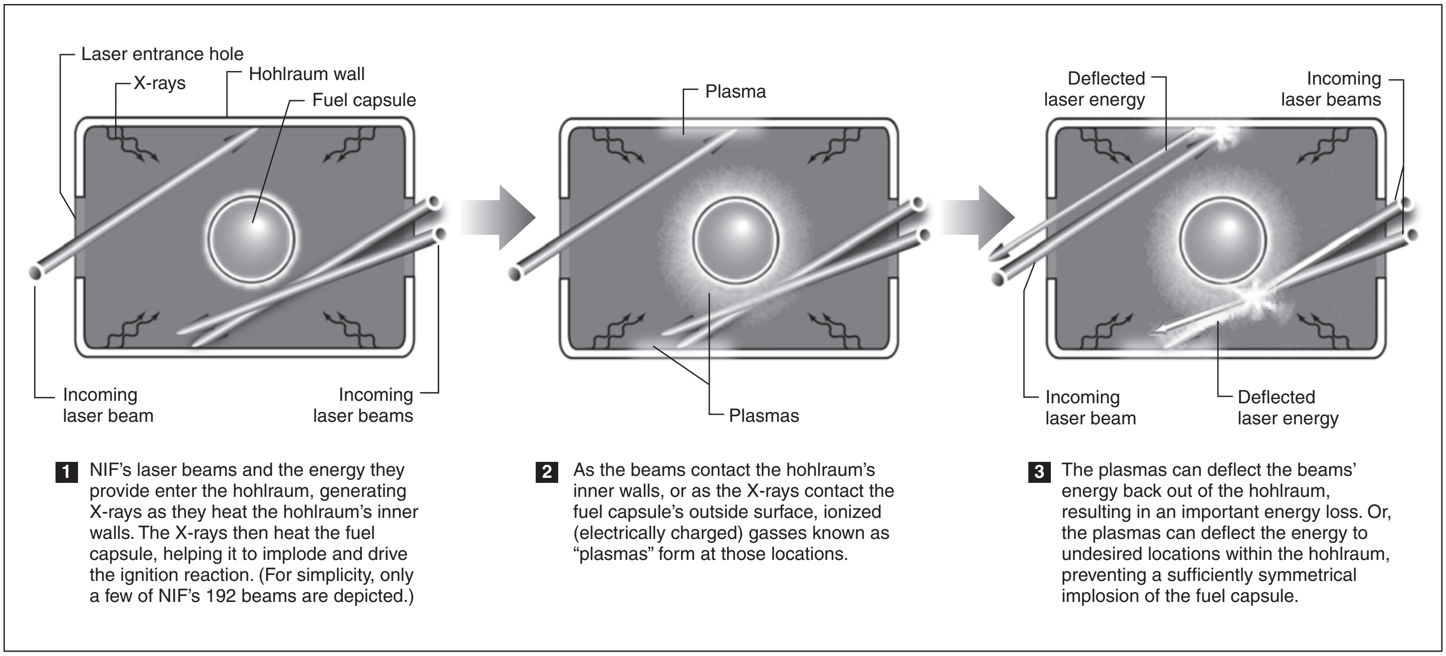
NNSA Has Made Progress Toward Achieving Ignition at NIF, but Key Scientific and Technical Challenges Remain

Despite progress, difficult scientific and technical challenges are likely to affect NIF's ability to achieve the temperatures and pressures needed for ignition. Furthermore, a newly established committee to evaluate NIC's progress toward achieving ignition may not be as effective as the JASON study group intended.

Scientific and Technical Challenges Could Hinder Efforts at NIF to Achieve Extreme Temperatures and Pressures Needed for Ignition

While NNSA and the NIC participants have made substantial progress toward achieving ignition, two key scientific challenges, and a technical challenge, may affect NIF's ability to create the extreme temperatures and pressures needed for ignition. According to NIC scientists and independent experts such as the JASON study group, a key scientific challenge is to minimize the amount of laser energy that is reflected out of, or misdirected within, the hohlraum. Reflected laser light reduces the amount of energy available to heat and compress the fuel capsule, while misdirected light can negatively affect the symmetry of the resulting compression, thus risking the desired ignition reaction. As NIF's laser beams heat the inner walls of the hohlraum, a plasma, or ionized (electrically charged) gas, is created. While crucial for generating the X-ray energy needed for the implosion of the capsule, this plasma can also deflect incoming laser light out of the hohlraum, resulting in an important loss of energy. Scientists refer to the interaction between laser light and this plasma as laser-plasma instability. Alternatively, this instability can misdirect a portion of the laser energy from one beam into the pathway of another beam. If enough of this energy is misdirected to undesired locations on the hohlraum's inner wall, the fuel capsule might not implode symmetrically. Rather than maintaining its spherical shape as it compresses, the fuel capsule could instead flatten, lowering the probability of ignition (see fig. 3).

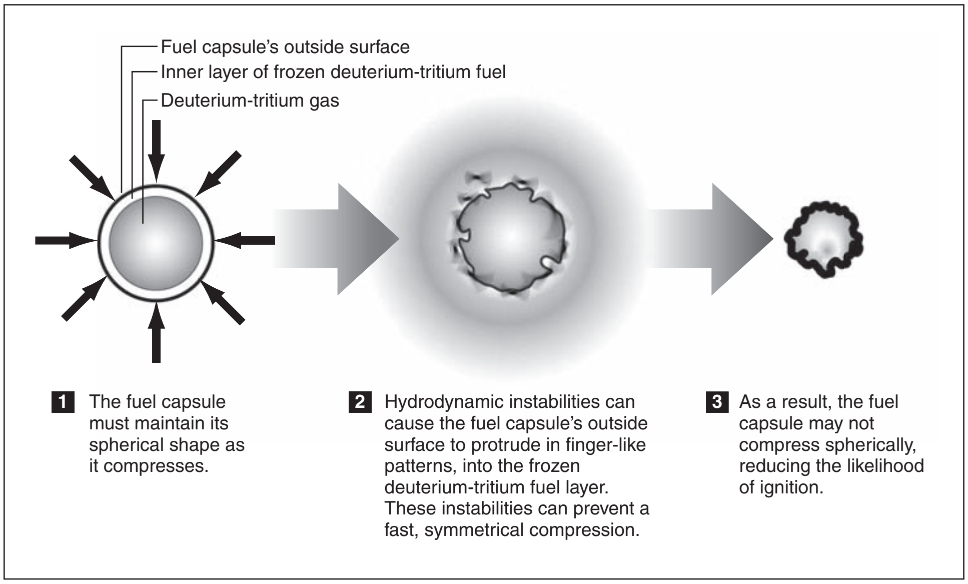
Figure 3: How Laser-Plasma Instabilities Can Prevent Ignition at NIF



Source: GAO analysis of data provided by Lawrence Livermore National Laboratory.

Another widely recognized key scientific challenge is achieving a fuel capsule implosion with sufficient velocity for ignition, according to NIC scientists and independent experts. For ignition to occur, NIC scientists believe that the fuel capsule has to shrink to a size that is about 40,000 times smaller than its original size. During this compression, the capsule must not only maintain its spherical shape, but it must implode at an extremely fast velocity in order to achieve the pressures needed for ignition. However, if the capsule's outside surface is not sufficiently smooth, or the X-rays produced in the hohlraum strike the capsule unevenly, the capsule's outside surface can protrude inward into the fuel capsule rather than blow away from the capsule with rocket-like force. The resulting protrusions are the result of "hydrodynamic instabilities," which occur when a material of lower density (i.e., the outside surface of the fuel capsule) makes contact with a material of higher density (i.e., the capsule's inner layer of frozen deuterium-tritium fuel). Having too many of these protrusions can prevent ignition, because they lower the temperature inside the fuel capsule, potentially reducing the compression velocity below that which is needed for ignition (see fig. 4).

Figure 4: How Hydrodynamic Instabilities Can Prevent Ignition at NIF



Source: GAO analysis of data provided by Lawrence Livermore National Laboratory.

In addition to these two scientific challenges, NIC scientists face a technical challenge: controlling damage to NIF's glass optics—particularly, the optics leading into the target chamber—caused by NIF's laser beams as they pass through the optics on their way to the target. Though the damaged areas on an optic initially may be few in number or very small in size—about the width of a human hair—they can increase in number or size the more the damaged optics are exposed to energy from NIF's lasers. According to the 2005 report by the JASON study group, if optical damage is beyond expected levels, the time and cost of repairing or replacing damaged optics could make it difficult or impractical to operate NIF at higher laser energy levels, including the 1.8 MJ-capability for which NIF was originally designed.

Since NIF's construction, NIC scientists have taken steps to address these scientific and technical challenges, such as the following:

- To minimize the amount of laser energy that is deflected out of, or misdirected within the hohlraum, NIC scientists have made several modifications to the hohlraum's original design and composition. For example, they removed the laser entrance hole liner, originally put in place to allow for more laser light to enter the hohlraum, after learning that it led to increased laser-plasma instabilities. NIC scientists also chose a new width for the laser entrance holes, allowing them to deliver less-intense laser energy into the hohlraum. Finally, they decided to fill the hohlraum with pure helium gas, rather than a mixture of hydrogen and helium, as originally designed. Following the completion of NIF's construction in March 2009, NIC scientists were able to test these modifications during the initial phase of their experimental campaign. As a result of these experiments, NIC scientists report that they are now able to limit laser-light deflection and misdirection due to laser-plasma instabilities to acceptable levels.

- To improve their understanding of fuel capsule implosions, NIC scientists used two- and three-dimensional computer simulations to help predict how the fuel capsule's outside surface might mix with the frozen deuterium-tritium fuel layer during an implosion. They have also used other laser facilities, such as OMEGA, to study hydrodynamic instabilities, although, at lower velocities and pressures than are expected at NIF.
- To address the challenge of optics damage caused by NIF's lasers, NIC scientists have developed a process to address routine damage by quickly repairing or replacing damaged optics so that the facility can seamlessly continue operations. During the first series of experiments, they have been slowly and methodically increasing the levels of laser energy delivered to the target, in part, to prevent optical damage. Laser energies during the first series of experiments, which were completed in December 2009, were gradually increased from laser pulses with 660 kilojoules (or less than a megajoule) of laser energy to pulses with laser energies as high as 1.2 MJ.[7]

While NIC scientists have made progress in addressing the scientific and technical challenges, independent scientific experts told us these challenges could still impede efforts to achieve the extreme temperatures and pressures needed for ignition. They also cautioned that, despite some early experimental successes, NIF will likely encounter unexpected or confounding scientific results or technical problems that are common in cutting-edge research and development. In 2005, the JASON study group recognized the uncertainty of resolving these complex challenges and

[7]Although less than NIF's 1.8 MJ design capability, the 1.2 MJ of laser energy achieved during a December 2009 NIC-funded experiment, using all 192 lasers simultaneously, is the world's most powerful laser pulse to date. When operating at 1.8 MJ, NIF will be able to deliver 45 times more energy to a target than OMEGA. In addition, prior to producing the 1.2 MJ pulse using NIF's 192 laser beams, Lawrence Livermore produced a 78-kilojoule pulse using 8 of the beams, which Lawrence Livermore officials we spoke with said they considered to be equivalent to achieving nearly 1.9 MJ of laser energy, if the 78-kilojoule value is applied to all 192 beams.

reported that achieving ignition at NIF in 2010, while possible, would be unlikely.[8] In its 2009 follow-up report, the JASON study group recognized the NIC participants' substantial progress since 2005 but cautioned that substantial scientific challenges remained.[9] According to the 2009 JASON study group report, even after 4 years of additional research, the likelihood of achieving ignition at NIF in 2010 still remains unlikely. In particular, NIC scientists have not been able to fully resolve each scientific challenge because computer simulations, while important for developing an understanding of the science involved, are not sufficient by themselves to predict the results of actual ignition attempts or other experiments at NIF. And while the scientists have recently begun getting data from experiments conducted at NIF, questions remain that will require further investigation at NIF. For example, NIC scientists have not yet conducted any experiments at NIF testing the effects of hydrodynamic instabilities under ignition-like conditions. Until they begin using deuterium-tritium capsules in experiments at NIF, instead of the plastic surrogate capsules currently being used, NIC scientists cannot be certain as to how well the deuterium-tritium capsules—planned for use during the first ignition attempt—will compress and whether a sufficiently symmetrical implosion will be possible.

Additionally, independent experts are concerned that NIC scientists, for the first ignition attempt that is planned to take place at NIF at the end of fiscal year 2010, may not use enough of NIF's laser energy to compensate for inevitable energy losses out of the hohlraum. NIF was designed with the capability of delivering 1.8 MJ of laser energy to the target chamber. However, NIC scientists said they plan to conduct the first ignition attempt using laser energies between 1.2 and 1.3 MJ. They predict that, at this level, there would still be enough energy left over for the capsule to reach ignition conditions, even after losses due to laser-plasma instabilities and other phenomena are taken into account. The scientists told us their innovations in target design, among other factors, will make it possible to achieve ignition with considerably less laser energy than NIF's 1.8 MJ designed capability. As a result, they do not plan to fire NIF's lasers at 1.8 MJ until the first half of fiscal year 2011, after the first ignition attempt. Moreover, during experiments in early fiscal year 2010 at NIF, months before the planned ignition attempt, energy losses due to laser-plasma

[8] JSR-05-340.

[9] JASON, Letter report addressed to the Office of Inertial Confinement Fusion, JSR-09-330 (McLean, VA: Feb. 13, 2009).

instabilities were found to be within NIC's acceptable levels, according to NIC scientists. Even at laser energies of 1.2 MJ, the amount of total energy lost to laser-plasma instabilities was 6 percent, meeting NIC's goal of keeping these energy losses below 15 percent.

Furthermore, optical damage remains a concern. In March 2009, for example, NIC scientists noticed that some of the laser light moving toward the optics around the target chamber was being reflected back into the laser pathway, causing unexpected damage to the mirrors that direct NIF's laser light to the target chamber. Though the impact was limited, affecting only about 4 percent of NIF's mirrors, the damage occurred even at low laser energies. Additionally, according to NIC scientists, NIF's optics cannot, at present, adequately withstand routine exposure to higher laser energies, including the 1.8 MJ of energy for which NIF was designed. Despite major improvements in NIF's optics over the years, when NIF construction was completed in 2009, NIF's optics were incapable of withstanding repeated shots at 1.8 MJ without experiencing extensive damage. To improve the optics' performance under increasingly high energy levels, Lawrence Livermore recently began resurfacing certain optics with newly developed coatings, designed to provide better protection against high laser energy levels. Lawrence Livermore will take advantage of a 4-month pause in experiments at NIF, which began in December 2009, to continue resurfacing NIF's optics and complete other critical tasks. NIC scientists expect that NIF's optics will be prepared for 1.8 MJ operations in December 2010.

Effectiveness of Committee Established to Evaluate NIC's Progress Toward Achieving Ignition May Be Limited

The committee formed by Lawrence Livermore National Laboratory to review the NIC may not be structured in such a way that will allow it to be fully effective in evaluating NIC's progress toward achieving ignition. In 2005, the JASON study group recommended the formation of a standing review committee that would advise top NIF leadership on the allocation of scientific resources and provide peer reviews of critical scientific efforts, such as designing ignition targets. The JASON study group also suggested that the committee should hold regularly scheduled meetings and reviews, where proposals for scientific work, target designs, and the ignition shot plan could be discussed. Four years later, the NIC responded to this recommendation by stating that its activities had, in fact, been broadly examined during the intervening period, including semiannual reviews by a committee that reports to the Lawrence Livermore National Laboratory Director, as well as occasional internal and external reviews of its target design and experimental plan. The JASON study group, however, determined that the narrow focus and ad hoc nature of these reviews made them insufficient to evaluate NIC's progress in addressing the complex scientific and technical challenges facing NIF.

In February 2009, the JASON study group again recommended that NNSA and Lawrence Livermore establish a standing review committee of subject-matter experts to help manage technical and scientific risks and recommend the best course of action to achieve ignition. In response, Lawrence Livermore National Laboratory then established a NIC review committee that first met in December 2009. Chaired by a former national laboratory Director, the 13-member committee consists of scientists with recognized credentials and expertise in plasma physics, materials science, inertial confinement fusion, and other related fields. The laboratory's charter asked the committee to review scientific and technical issues, such as NIF laser performance, planned ignition experiments, and target designs.

However, several issues could reduce the committee's effectiveness. First, the committee may not be structured in a way that will allow it to objectively analyze and render candid judgment on NIC's scientific progress. For example, Lawrence Livermore officials selected and appointed the committee's members. The committee will also report to, and take direction from, the laboratory Director. Reporting to the Lawrence Livermore Director, rather than to NNSA, may limit its members' ability to report honestly and frankly on any findings related to the scientific and technical progress of the NIC participants. In contrast, the Fusion Energy Sciences Advisory Committee—a standing Department of Energy review committee established in the early 1990s—reports its findings to, and takes direction from, the Department of Energy's Office of Science, which has broad oversight responsibility over much of the department's nonweapons-related scientific research, or from NNSA's Administrator, if the findings are applicable to weapons scientists. This advisory committee is not limited to reporting to the organizations most closely tied to fusion energy research, such as the Office of Fusion Energy Sciences, which more directly manages fusion energy research for the Office of Science, or the national laboratories and other organizations that carry out the research. Second, the NIC review committee may not be as extensively involved in reviewing the NIC's scientific progress as the JASON study group intended. For example, officials at Lawrence Livermore told us they do not plan on asking the review committee to review experimental results until mid-2010, following the next series of experiments focusing on hydrodynamic instabilities. These plans do not meet the intent of the JASON study group recommendation or the general purpose of a standing review committee. According to the JASON study group, the review committee should be involved in making decisions on what experiments to conduct and what approach to take before experiments are completed. Further, the 2005 JASON study report called for the establishment of two separate subcommittees for the NIC: one to review laser-plasma instabilities and the other to review ignition fuel capsules. This recommendation signals the JASON study group's recognition that NIC's complicated ignition experiments should be reviewed with a high level of detail. Third, the committee may not have adequate representation from each of NIF's primary users, including those with significant experience in nuclear weapons design. For example, the committee has only one scientist with significant experience in nuclear weapons design. Since NIF's primary mission is stockpile stewardship, the committee might not have sufficient experience to determine whether NIC's approach is appropriate for creating a platform for future stockpile stewardship experiments.

Management Weakness Has Extended the Schedule and Increased the Cost of Achieving Ignition and Could Delay the Fiscal Year 2012 Ignition Goal

The cost, schedule, and scope of ignition-related activities at NIF and supporting facilities have expanded substantially because NNSA officials and NIC participants failed to follow required processes. In addition, weak oversight by NNSA has allowed the lead NIC participant, Lawrence Livermore National Laboratory, to defer critical performance requirements, construction activities, and key equipment acquisitions needed for ignition experiments at NIF, which could delay ignition or other NIC goals beyond 2012.

NNSA Officials and NIC Participants Did Not Always Follow Required Processes for Controlling Cost, Schedule, Scope Increases

The cost, schedule, and scope of ignition-related activities at NIF and supporting facilities have expanded substantially, in part, because NNSA and the NIC participants did not always follow the required procedures for controlling cost, schedule, and scope increases. To better manage NIC's cost, schedule, and scope, NNSA designated NIC as an "enhanced management program," requiring more rigorous standards and project-management practices than typical NNSA programs. In particular, NNSA's program management policies require that enhanced management programs follow an execution plan, which identifies the program's mission and establishes its cost, schedule, and scope. NNSA's policies also require that participants in enhanced management programs adhere to a formal process for approving any changes to the established cost, schedule, or scope.[10]

To meet these requirements, NNSA and the NIC participants adopted an execution plan in June 2005, formally establishing both NIC's total cost at $1.6 billion and its completion date at the end of fiscal year 2011. The execution plan also defined NIC's mission and major scope elements for achieving ignition at NIF by the completion date. Furthermore, the plan outlined a process for controlling cost, schedule, and scope changes, which requires the NNSA Administrator's written approval for changes that would affect NIC's total cost, extend its completion date by more than 6 months, or change the scope in ways that would impact the overall mission. The plan requires approval from lower-ranking NNSA or NIC officials for less significant changes to cost, schedule, or scope.

Despite NIC's enhanced management designation, the NIC participants did not consistently follow the more rigorous standards, and NNSA failed to ensure that the standards were being followed. Since NIC's cost, schedule, and scope were established in June 2005, its total costs have increased by around 25 percent—from $1.6 billion to over $2 billion—and its planned completion date has been extended by 1 year to the end of fiscal year 2012. At the same time, NIC's mission and scope have expanded significantly. For example, in addition to achieving ignition once by NIC's planned 2012 completion date, the participants will need to achieve ignition repeatedly and reliably, as well as understand and control the results of ignition experiments. Moreover, within this same time frame, under the enhanced management program, the NIC participants must create a reliable "platform" for future ignition and stockpile stewardship experiments at NIF. To create such a platform, the NIC participants plan to, among other things, develop and install special diagnostic instruments and optics for future ignition and stockpile stewardship experiments, in addition to the ones for NIC experiments.

[10]Standards for NNSA program management, including "enhanced management programs," are found in NNSA's *NA-10 Defense Program–Program Management Manual*, November 2005. Enhanced management programs share many of the requirements of programs and projects carried out under Department of Energy Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*, including an execution plan and a formal process for approving changes. However, requirements under the Department of Energy order are generally more rigorous than for enhanced management programs. For example, independent peer review and formal departmental or NNSA approval is required before programs and projects managed under the department's order can proceed through various stages of planning, design, and implementation.

NNSA officials and the NIC participants implemented these cost, schedule, and scope changes without following the required processes. Because the changes were extensive—affecting NIC's total costs, extending its completion date by more than 6 months, and changing its scope in ways that impacted the overall mission—the participants were required, under the provision of the enhanced management program, to obtain the NNSA Administrator's written approval before implementing the changes. On three separate occasions, however, the NIC participants revised the cost, schedule, or scope in the execution plan and implemented the revised plan without the NNSA Administrator's written approval as follows:

- *May 2006:* The first revision to NIC's execution plan called for reducing NIC's total costs by around $14 million (1 percent) in response to a directive from an NNSA official in the Office of Inertial Confinement Fusion and National Ignition Facility Project, the office responsible for overseeing NIC. According to officials from that office, the revised plan was never submitted to the Administrator because Sandia National Laboratories, one of the NIC participants, did not agree with the changes. The NIC representative from Sandia told us the plan did not include detailed criteria for completing NIC's scope.

- *July 2007:* In the second revision, NIC's costs were increased by $74 million (4.5 percent) over the $1.6 billion total cost figure cited in the original June 2005 execution plan. Also, NIC's planned completion date was extended by one quarter through December 2011. NNSA officials from the Office of Inertial Confinement Fusion and National Ignition Facility Project said they did not seek formal approval for the revisions because NNSA did not know, at the time, whether funding would be available to cover the cost increase.

- *August 2008:* In the third and most recent revision, NIC's costs were increased by $404 million (24.8 percent) over the original costs, and the planned completion date was extended to the end of fiscal year 2012. Furthermore, NIC's mission and scope were expanded to include the aforementioned effort to achieve ignition reliably, as well as the platform for future ignition and stockpile stewardship experiments at NIF. NNSA officials told us that achieving ignition reliably at NIF was always planned as a follow-on effort, but NNSA decided, instead, to include this work in the NIC. The officials said they did not seek the NNSA Administrator's approval for the changes because, at the time, the increased costs for NIC exceeded NNSA's overall budget for ignition-related activities in fiscal years 2011 and 2012, of which NIC is a major component. Similarly, the NIC representative from Sandia said he did not sign the revised plan because it was not budget compliant, and he felt it increased NIC's scope too far beyond the goal of achieving ignition at NIF. In the absence of a formally approved execution plan the NIC participants have been using the August 2008 revision to plan and prioritize their activities.

In January 2010, officials from the Office of Inertial Confinement Fusion and National Ignition Facility Project told us they were considering further changes to NIC's scope but that these changes would not impact the overall mission. They also said that efforts to revise the August 2008 NIC execution plan, which were previously under way, have been put on hold, until the fiscal year 2011 budget is in place. In addition, they said that NNSA plans to end the NIC enhanced management program at the end of fiscal year 2012, even if the NIC participants have not achieved ignition or a reliable platform for future experiments. Work on any remaining NIC scope, as well as routine operation of NIF, would continue beyond 2012 as a standard NNSA program, rather than an enhanced management one.

Deferral of Key Activities Could Delay Ignition or Other NIC Goals Beyond 2012

Weak oversight by NNSA has allowed the lead NIC participant, Lawrence Livermore National Laboratory, to delay critical performance requirements, construction activities, and key equipment acquisitions needed for ignition experiments at NIF, increasing the risk that ignition or other NIC goals may not be completed by the end of fiscal year 2012. In particular, NNSA has allowed Lawrence Livermore to defer constructing major aspects of NIF's safety infrastructure, initially required under the NIF construction project.[11] The infrastructure will be needed to protect personnel and the environment from exposure to radiation and hazardous materials during the first and subsequent ignition attempts. Without the infrastructure, the NIC participants would have to delay ignition experiments because they involve using tritium, a radioactive material that is key to an ignition reaction. Although NIF construction was officially completed in 2009, construction and installation of the safety infrastructure is currently under way as part of NIC.[12] The work is expected to cost around $50 million, including

[11]*National Ignition Facility System Design Requirements*, *Conventional Facilities*, April 1996; *National Ignition Facility Subsystem Design Requirements*, *Laser and Target Area Building*, August 1996; and an addendum to the NIF project completion criteria dated Feb. 27, 1997.

[12]According to NNSA, the NIF construction project, upon its completion in March 2009, complied with the project completion criteria, as revised by NNSA in 2000. Furthermore, in February 2009, a committee of outside experts verified that the project completion criteria related to the performance of NIF's lasers had been met or surpassed.

- $16 million for facilities and equipment to handle the radioactive tritium left inside of NIF's target chamber during ignition shots and other experiments with tritium-laced targets;

- $13 million for concrete doors and other target-area shielding to contain radiation from neutrons generated during an ignition (or near-ignition) reaction; and

- $21 million for ventilation, filtration, detection, and decontamination systems and other safeguards.

Deferring this work from NIF could delay completion of ignition or other NIC goals. As of September 2009—several months before the scheduled ignition attempt—construction of this safety infrastructure was considered to be behind schedule and over budget, in part because NIC's fiscal year 2009 funding was uncertain, according to NIC officials from Lawrence Livermore. According to NIC progress reports, by November 2009, satisfactory progress had been made, and the construction was no longer considered to be behind schedule and over budget. To speed progress, in December 2009, Lawrence Livermore halted all NIC experiments at NIF for an expected 4-month period, focusing instead on the safety construction and other critical tasks to prepare for ignition experiments. But, even if the safety construction is completed on time, the Lawrence Livermore officials told us that further delays are possible. Before ignition experiments can take place, the Department of Energy will need to inspect and approve the construction, and NIF staff will need to be trained and certified to work in exposed areas and handle dangerous materials. A delay in these or subsequent activities could threaten the NIC participants' schedule for the first ignition attempt or other NIC goals, thus increasing the risk of not completing NIC's goals by the fiscal year 2012 deadline.

Similarly, NIC participants expressed concerns that a key diagnostic instrument would not be completed in time for the first ignition attempt. Known as the Advanced Radiographic Capability, the instrument would dramatically improve NIC researchers' ability to observe the fuel capsule as it implodes and reaches ignition-level temperatures and pressures. According to NIC officials from Lawrence Livermore, the need for such a capability had been identified long before NIC began, but NNSA instructed them to defer working on the instrument until 2009 due to budget constraints. As a result, the NIC officials do not expect to complete the instrument—which is expected to cost nearly $42 million—until fiscal year 2011. Officials from NNSA's Office of Inertial Confinement Fusion and

National Ignition Facility Project said they did not specifically instruct the NIC participants to defer the instrument, but given budget constraints, encouraged them to defer activities that were not absolutely necessary for the first ignition attempt in fiscal year 2010. Although the participants could attempt ignition in 2010 without the diagnostic instrument, the Lawrence Livermore officials said it will be more difficult to determine why ignition succeeded or failed without data from the instrument.

Failure to Achieve Ignition in Fiscal Year 2012 Would Not Immediately Impact NNSA's Stockpile Stewardship Program, but Further Delays Could Limit NNSA's Options for Maintaining the Stockpile

While there would be no immediate impact, the consequences to the stockpile stewardship program of not achieving ignition at NIF would become more serious over time—from delaying nuclear weapons research, to ultimately, reducing NNSA's confidence in its ability to certify the safety and reliability of the stockpile. NIF was designed to support nuclear weapons research and obtain additional data about nuclear weapon performance to increase confidence in the long-term safety and reliability of the nuclear weapons stockpile. As weapons age, cracks, corrosion, and the decaying of materials may affect weapon performance. Through the stockpile stewardship program, NNSA has assessed weapon performance by relying on data from past nuclear tests, sophisticated computer simulations, and routine surveillance of nuclear weapons in the stockpile to spot signs of deterioration as the weapons age.[13] When the United States stopped underground nuclear testing in 1992, scientists did not fully understand all of the important details of how a nuclear weapon works. NNSA scientists told us that scientific knowledge and computational capabilities acquired in the meantime are still inadequate to understand all of the impacts on weapon performance and safety as nuclear weapons age. According to NNSA officials, when ignition has been achieved, and NIF is fully operational, scientists will be better positioned to address many significant gaps in their knowledge, as well as maintaining the skills of nuclear weapons designers.

Despite the eventual importance of achieving ignition, there would be no immediate impact on the stockpile stewardship program if ignition is not achieved at NIF by the end of fiscal year 2012, according to NNSA and

[13]A key component of the stockpile stewardship program is annual surveillance testing, in which active stockpile weapons are randomly selected, disassembled, inspected, and portions tested—either in laboratory tests or in flight tests—to identify any problems that might affect a weapon's safety or reliability. Problems identified during surveillance testing can result in a "significant finding investigation" to determine the problems' cause, extent, and effect on the performance, safety, and reliability of the stockpile.

national laboratory officials. Most of the planned stockpile stewardship experiments at NIF between fiscal years 2010 and 2012 do not require ignition. According to NNSA officials, scientists will be able to obtain key weapons physics data by achieving temperatures and pressures just short of ignition, known as nonignition experiments. These nonignition experiments will, among other things, test the strength of materials inside nuclear weapons as they are exposed to intense radiation, temperatures, and pressures approaching those found in a nuclear weapons explosion.

In September 2009, NNSA completed the first series of stockpile stewardship nonignition experiments at NIF. These experiments exposed materials to intense radiation, and scientists used the data to compare the predicted results with the actual results and make changes to computer models, as necessary, to predict weapon performance. To obtain these data, scientists used 700 kilojoules of laser energy—less than half of NIF's full laser capability but more than 20 times the energy of OMEGA. According to NNSA scientists, understanding how these materials behave under extreme temperature and pressure, especially as the materials age, is crucial to understanding how a nuclear weapon will perform. Because models to accurately predict the behavior of materials in nuclear weapons are too complex for even the most state-of-the-art supercomputers, weapons scientists have long made predictions using less complete models that cannot precisely account for all performance factors. The inexact performance data provided by the current models raises uncertainties about the accuracy of predicting a weapon's performance as it ages or as changes are made to the weapon. Nonignition, as well as ignition, experiments at NIF are intended to allow scientists to improve these models and reduce some of this uncertainty.

According to NNSA and Lawrence Livermore officials, however, some of the significant stockpile stewardship issues, and areas of uncertainty, can be addressed only with ignition experiments. According to NNSA officials, only NIF will be able to achieve the temperatures and pressures needed to study in a controlled laboratory setting the conditions that approach those found in a nuclear weapons explosion. The extreme temperatures and pressures that will be used to compress targets at NIF will help scientists simulate the conditions of actual nuclear explosions, providing them better data with which to predict the performance of similar implosions in actual weapons—particularly in the presence of design irregularities that are sometimes found in those weapons as they age. New data from NIF on the nuclear reactions observed in imploding targets will be used in the annual assessment and certification of the U.S. nuclear weapons stockpile. According to NNSA officials, the closer NNSA can get to nuclear weapons conditions, the less extrapolation is required, and the greater the confidence in its understanding of weapons physics. As a result, many of the stockpile stewardship experiments will require ignition reactions that, much like a nuclear detonation, produce significant energy gains—releasing 10 times the amount of energy, or more, than was used to initiate the reaction. According to NIC officials, achieving these high energy gains could require that NIF operate reliably at 1.8 MJ, although operation at lower laser energies may be sufficient.

A long-term failure to achieve ignition, among other factors, could limit NNSA's options for refurbishing and making design changes to nuclear weapons to improve their safety and reliability. Although experts believe that current weapons refurbishment activities, which include replacing aging components, may be sufficient for extending the lives of deployed nuclear weapons for 20 to 30 years, doing so without ignition could constrain NNSA's options for ensuring a safe and reliable nuclear stockpile. An August 2009 review by the JASON study group found that life extension programs have not increased the risk of certifying the safety and reliability of currently deployed nuclear weapons. The JASON study group concluded that the lifetimes of currently deployed weapons could be extended for decades, with no anticipated loss in confidence, by using approaches similar to those employed in life extension programs. However, NNSA officials told us that this approach necessarily requires manufacturing the same materials used in the original weapons and maintaining the same designs, because assessing a weapon's safety and reliability is partially tied to historical data from live nuclear tests. Changing the original design of the weapons increases the uncertainty about its potential performance, because the refurbished weapon cannot be tested using live detonations, and NNSA's ability to simulate similar conditions is limited. Furthermore, NNSA is finding it increasingly difficult to manufacture the same materials made 20 to 30 years ago and would, therefore, like to introduce some design changes to increase the safety and reliability of currently deployed weapons. If ignition is achieved, experiments at NIF could be used to study the potential effects of design changes, possibly giving NNSA greater confidence to make changes to weapons in the stockpile. But, without ignition at NIF or some other facility, NNSA's options for doing so would likely remain limited.

In addition, according to NNSA in a March 2006 letter to Congress, a failure to achieve ignition may reduce NNSA's confidence in certifying the safety and reliability of the nuclear weapons stockpile, according to NNSA and national laboratory officials, depending on the reason for the failure. These officials told us that as weapons continue to age or are refurbished, the risk and uncertainty about predicting weapon performance increases, and only ignition experiments at NIF can fully address those uncertainties. A long-term failure to achieve ignition could signify problems with NNSA's models and computer simulations and call into question some aspects of NNSA's knowledge about weapon performance. However, these officials also told us that a failure to achieve ignition would not necessarily signal a need to return to underground nuclear testing. Nonignition experiments could continue to validate certain models for predicting weapon performance, and NNSA could continue to rely on other stockpile stewardship tools, such as supercomputing facilities, to maintain the safety and reliability of nuclear weapons. The Secretaries of Defense and Energy have certified stockpile safety and reliability for the past 15 years without NIF or underground nuclear testing and could continue do so.[14]

Conclusions

Given the significant scientific and technical challenges that NNSA faces before it can achieve ignition at NIF, NNSA's ability to fully use NIF to generate new data in support of stockpile stewardship depends on achieving ignition. Although NNSA and the NIC participants have made significant progress toward ignition at NIF, it could take them longer than expected to reach this milestone, and any long-term failure to achieve ignition and produce significant energy gains could erode NNSA's confidence in its ability to certify the safety and reliability of the nuclear weapons stockpile. In light of this, we are concerned that NNSA and the NIC participants have been slow to solicit help and ideas from outside experts with knowledge in inertial confinement fusion. In particular, we question NNSA's and the NIC participants' decision to wait 4 years—only months before the first ignition experiment is expected to take place—to implement the JASON study group's 2005 recommendation to form a standing external review committee of experts that could provide expert advice on the scientific and technical challenges.

In addition, we are concerned that the committee currently in place falls short of meeting the intent of the JASON study group recommendation. In

[14]In 1995, the President established an annual stockpile assessment and reporting requirement to help ensure that the nation's nuclear weapons remain safe and reliable without underground nuclear testing. Subsequently, Congress enacted into law the requirement for an annual stockpile assessment process in section 3141 of the National Defense Authorization Act for Fiscal Year 2003 (Pub. L. No. 107-314 (2002)). Specifically, section 3141 requires that the Secretaries of Energy and Defense submit reports to the President providing their assessment of the safety, reliability, and performance of each weapon type in the nuclear stockpile.

particular, we believe that the committee might not be as effective as it could be, given its reporting structure, its limited involvement in NIC's decision-making process, and the possibility that it may not have adequate representation from each of NIF's primary users. Committee activities, such as closely reviewing detailed experimental plans, could help create the needed level of committee involvement. Though the NIC has taken a positive step in forming the committee, we believe that an unprecedented, complex endeavor such as ignition requires a more effective external review component that can better evaluate whether NNSA and the NIC participants are in fact taking the correct approaches in their experimental campaign. Otherwise, NNSA and the NIC participants may be missing a valuable opportunity to draw on and implement the advice of recognized experts—and their contacts throughout the United States—who may be able to provide fresh perspectives on such a challenging scientific experiment.

Furthermore, because NNSA has not approved the most recent NIC execution plan, including its cost, schedule, and scope, as required by its own guidance, NNSA, in our view, has not been executing its oversight responsibilities as effectively as it should. Especially problematic is NNSA's failure to follow the processes required for making important changes to NIC's cost, schedule, or scope—as evidenced by the fact that NNSA's Administrator was never asked to formally approve major scope changes, which made the NIC participants responsible for achieving ignition repeatedly and reliably by the end of fiscal year 2012. Confidence in achieving ignition at NIF, and financial support for this expensive endeavor, could be jeopardized if the NIC participants do not achieve ignition at NIF by the end of fiscal year 2012 or complete these more ambitious goals within the proposed time frames and budget.

Recommendations for Executive Action

We are making six recommendations for addressing the scientific and technical challenges and management weaknesses. To enhance the NIC review committee's effectiveness, we recommend that the Administrator of NNSA direct the Director of the Office of Inertial Confinement Fusion and National Ignition Facility Project to take the following three actions:

- Have the NIC review committee report to, and receive direction from, NNSA's Director of the Office of Inertial Confinement Fusion and National Ignition Facility Project on its review activities, instead of reporting to Lawrence Livermore's laboratory Director. Alternatively, the Director of NNSA's Office of Inertial Confinement Fusion and National Ignition Facility Project could appoint a separate review committee, serving a substantially similar function as the NIC review committee, to advise and report to that office's Director.

- Involve the NIC review committee, or the separately appointed review committee, in NIC's critical decision-making, such as evaluating experiments planned on NIF, identifying potential weaknesses to the experimental plan, and recommending, if necessary, alternative approaches to address scientific and technical challenges.

- Ensure that the review committee adequately involves nuclear weapons scientists that can help evaluate whether NIC's approach is appropriate for creating a platform for future stockpile stewardship experiments. This can involve increasing the number of nuclear weapons scientists on the NIC review committee or sharing information with weapons scientists at the national laboratories.

To better manage NIC, we recommend that the Administrator of NNSA direct the Director of the Office of Inertial Confinement Fusion and National Ignition Facility Project, with assistance from the NIC participants, to take the following three actions:

- Develop an execution plan to establish NIC's cost, schedule, and scope.

- Ensure that all NIC participants and appropriate NNSA officials have formally approved the execution plan.

- Ensure that all changes to NIC's cost, schedule, and scope receive formal written approval from appropriate officials, as required.

Agency Comments and Our Evaluation

We provided the National Nuclear Security Administration with a draft of this report for its review and comment. In commenting on the draft report, NNSA's Acting Associate Administrator for Management and Administration said that NNSA agreed with the recommendations and, overall, found that the report was fair and properly reflected the progress at NIF. NNSA's comments are reprinted in appendix II.

NNSA also provided clarifying comments related to NNSA's oversight of NIC's cost, schedule, and scope, and the potential impact to NNSA's stockpile stewardship program if ignition is not achieved at NIF by the end of fiscal year 2012. We have incorporated these comments with one exception. We did not incorporate NNSA's proposed revision related to our statement on pages 22–23 of the report that scientific knowledge and computational capabilities, acquired since the United States stopped its underground nuclear testing, are inadequate to fully understanding the safety and performance impacts to nuclear weapons as they age. NNSA expressed concern that such statements would be misconstrued as meaning that NNSA's current stockpile certification methods are not adequate. We disagree since NNSA's own documents state that, as the stockpile continues to age and weapons are refurbished, existing stockpile assessment methods, without NIF—and, hence, without the capability to reliably and repeatedly demonstrate ignition—may become inadequate. Our report cites a 2006 NNSA letter to Congress, and NNSA has made similar statements to help justify NIF. For example, in its fiscal year 2008 Congressional Budget request, NNSA stated, "Without the NIF, the nation's computational capabilities and scientific knowledge are inadequate to ascertain all of the performance and safety impacts from changes in the nuclear warhead physics packages due to aging, remanufacturing, or engineering and design alterations."

In addition, NNSA provided detailed technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate Congressional Committees, the Secretary of Energy, the NNSA Administrator, and other interested parties. The report is also available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact Gene Aloise at (202) 512-3841 or Tim Persons at (202) 512-6412 or by email at aloisee@gao.gov or personst@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Gene Aloise
Director, Natural Resources and Environment

Dr. Timothy M. Persons
Chief Scientist

Appendix I: National Ignition Campaign (NIC) Budget, by Major Scope Activity, for Fiscal Years 2006 through 2012

Dollars in millions

NIC scope activity[a]	Total cost of NIC activities during fiscal years 2006 through 2012[b]	Description
Target development and manufacturing	$195.9	Design and fabrication of targets—including hohlraums, fuel capsules, and related components—for NIC target physics experiments at the National Ignition Facility (NIF).
Target physics experiments	504.0	The experimental campaigns to be conducted under NIC, including the first ignition attempt, which is scheduled for the end of fiscal year 2010.[c]
Cryogenic target system	55.7	Equipment and processes for positioning targets for ignition experiments and keeping cryogenic targets frozen at extremely low temperatures.
Target diagnostic instruments	216.7	Design, fabrication, and operation of a suite of diagnostic instruments to detect and measure various physical phenomena during experiments, including ignition.
Personnel and environmental protection systems	49.5	Equipment, infrastructure, and processes for protecting personnel from the effects of radioactive and hazardous materials that may be released during experiments, including the first ignition attempt.
NIF operation and maintenance	575.6	Personnel, equipment, and other expenses for day-to-day operation and maintenance of NIF, as well as efforts to prepare for routine operation at peak laser energy (1.8 million joules) in fiscal year 2011.
All other activities	446.8	Includes such activities as management and administration of NIC, development and acquisition of laser optics and systems for acquiring data from target diagnostic instruments.
Total	**$2,044.2**	

Source: GAO analysis of National Ignition Campaign Execution Plan, Revision 3.1, August 2008, and other data provided by Lawrence Livermore National Laboratory.

[a]We grouped the scope activities in the table for purposes of the discussion in this report. The groupings do not necessarily reflect those that NNSA or the NIC participants use for budgeting, reporting, or other purposes.

[b]Data on the total cost of NIC activities is current as of August 2009.

[c]NIC's budget for target physics experiments includes around $5.9 million for experiments using "direct drive" ignition, in addition to the "indirect drive" approach for which NIF was primarily designed. Under direct drive, NIF's lasers would directly strike an ignition target rather than indirectly "driving" the target to ignition by striking a hohlraum to create X-rays. According to NIC participants, NIF will need significant facility modifications in order to field direct drive experiments.

Appendix II: Comments from the National Nuclear Security Administration

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

April 2, 2010

Mr. Gene Aloise
Director
Natural Resources and Environment
Government Accountability Office
Washington, D.C. 20458

Dear Mr. Aloise:

The National Nuclear Security Administration (NNSA) appreciates the opportunity to review the Government Accountability Office's (GAO) report, *NUCLEAR WEAPONS RESEARCH: Actions Needed to Address Scientific and Technical Challenges and Management Weaknesses at the National Ignition Facility,* GAO-10-488. In response to a request by the Senate Subcommittee on Energy and Water Development, Committee on Appropriations, we understand that GAO performed this review to determine (1) to what extent has NNSA addressed key scientific and technical challenges for achieving ignition at the National Ignition Facility (NIF); (2) to what extent does NNSA have an effective approach for managing the cost, schedule, and scope of achieving ignition at NIF between fiscal years 2010 and 2012; and (3) what is the potential impact to NNSA's stockpile stewardship program, if ignition is not achieved at NIF within that time frame?

Overall, NNSA believes the report is fair and properly reflects the significant progress NIF has made. For the sake of clarity and correctness, below are some specific comments that, if accepted, would make a more balanced report.

1. Page 17 – Second full paragraph
NNSA believes there might be a misimpression that "achieve ignition repeatedly and reliably" is a new assumed burden for the ICF Program. This could be corrected by replacing sentence, "For example, ...ignition experiments." with the following sentence:

> "Achievement of repeatable and reliable ignition was always planned as a follow on to NIC in order to prepare ignition for weapons program requirements. It was decided that it would be efficient to include this essential work in the body of the NIC effort."

2. Page 19 – First paragraph
NNSA does not recall saying anything about an implicit action by the Administrator. We believe that it would be more accurate to replace the second sentence with the following:

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"The NNSA officials said they allowed the NIC participants to continue FY 2009 activities without a revised directed change because of the FY 2009 budget being consistent with the proposed revised NIC Execution Plan."

It was in the FY 2011 and FY 2012 budgets where we had concerns of major shortfalls. Also, NNSA officials did not move the proposed NIC Execution Plan Rev. 3.1 forward because it was not budget compliant. This is the reason it was not signed.

3. Page 20 – First full paragraph
NNSA believes that adding the following sentence to the end of this paragraph will enhance both clarity and accuracy:

"The NIF Project was completed according to the completion criteria of the rebaseline of 2000, as confirmed by reviews from the Laser Performance Review Committee in a letter to the NIF Project Manager signed on February 25, 2009."

4. Page 23 – First paragraph
NNSA is concerned with the use of the terms like "inadequate" regarding nuclear weapons. An unequivocal term like "inadequate" might imply that our current weapons assessment methods are not adequate for certifying the stockpile when in fact they are. Our scientific advances will improve the assessment and certification process and meet the future needs of an aging stockpile. Replace "… mean time are still inadequate…" with "…mean time still need improvement…".

Now on p. 23.

5. Page 26 – First paragraph
NNSA believes the sentence beginning with; "A long-term failure …weapons physics." is too strong and implies a broad lack of understanding of weapons performance. Thus, in a similar concern to the item above, NNSA suggests replacing this sentence with: "A long-term failure to achieve ignition might limit the options that could be included for future weapons life extension programs. However officials…".

Now on p. 24.

6. Page 27 – Last paragraph
NNSA believes it would be more accurate if the last sentence is deleted and replaced with:

"If ignition is not achieved by the end of fiscal year 2012 then confidence in achieving ignition at all at NIF and financial support for this endeavor could be jeopardized."

I am also enclosing general/technical comments for your consideration.

NNSA agrees with the recommendations. We recognize that even good programs can improve, and we are committed to quickly and effectively addressing GAO's recommendations for further improvement.

If you have any questions concerning this response, please contact JoAnne Parker, Acting Director, Policy and Internal Controls Management at 202-586-1913.

Sincerely,

Gerald L. Talbot, Jr.
Acting Associate Administrator
for Management and Administration

Enclosure

cc: Deputy Administrator for Defense Programs
NNSA Senior Procurement Executive

Appendix III: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

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