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The National Ignition Facility: Management, Technical, and Other Issues

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Summary

The U.S. Department of Energy (DOE) is building a very large laser facility to provide scientific support for its program to maintain the safety, reliability, and performance levels of the nation's stockpile of nuclear weapons in the absence of nuclear testing. This National Ignition Facility (NIF), which is designed to simulate the behavior of nuclear explosions, is under construction at DOE's Lawrence Livermore National Laboratory (LLNL).

In August 1999, however, DOE announced that the project had run into some serious problems that would likely result in a significant increase in its cost estimate. The root cause of this problem was determined to be inadequate experience and capabilities in managing large, complex projects on the part of the LLNL NIF project team. Correcting these problems would require obtaining outside expertise and management that would significantly increase the project's cost. In addition, a review by the NIF Council of LLNL reported that substantial technical issues remained unresolved, although LLNL is confident that they can be resolved. In some cases, however, solutions do not appear to be obvious.

In its revised project baseline and schedule, DOE now estimates the project cost to be \$3.45 billion, 60% above the original estimate, and its completion date as 2006. A GAO report issued in August 2000 estimated the cost of the project at \$3.89 billion. In response to congressional direction, DOE submitted a letter to Congress on April 5, 2001, certifying that NIF should be built to the full 192 beams and that the September cost estimate and schedule would be met.

On June 1, 2001, GAO released a second report stating that the three DOE weapons labs do not agree on the value of NIF, as currently configured, for the stockpile stewardship program. GAO also noted that DOE has not set up an external, independent review of the project and does not intend to do so.

For FY2002, DOE requested \$245 million for NIF construction. Congress (H.R.2311 and S.1171, H.Rept.107-258) appropriated the full FY2002 request for NIF, adding \$7 million to the DOE inertial confinement fusion (ICF) program for NIF-related activities. The House (H.R.2586) and Senate (S.1438) each authorized \$245 million for NIF construction, adding \$10 million to the DOE ICF program for NIF-related activities.

In addition to the management and technology concerns, the NIF project raises other issues, including: the effectiveness of NIF in meeting the goals of the DOE program to maintain the nuclear weapons stockpile; the likelihood that NIF will reach its principal scientific goals; the potential effect NIF may have on nuclear nonproliferation; and uncertainty about NIF's contribution to the advancement of inertial fusion energy research. The management and technical issues, and the role of NIF in the stockpile stewardship program appear to be of particular concern.

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Introduction

As part of the U.S. Department of Energy's (DOE) program to maintain the nation's nuclear weapon stockpile, the DOE is building the National Ignition Facility (NIF), which is planned to be the largest laser ever built. DOE anticipates that NIF could achieve conditions of temperature and pressure in a laboratory setting that have only been reached in explosions of thermonuclear weapons and in the stars. It is hoped that NIF would be capable of achieving ignition of thermonuclear fusion of deuterium and tritium — isotopes or forms of hydrogen — for the first time in the laboratory.

NIF is to be a principal tool of the nation's Stockpile Stewardship Program (SSP) whose goal is to maintain the safety, reliability, and performance level of the nation's nuclear weapons in the absence of nuclear testing. It is one of several experimental facilities being built for that program and is expected to provide important contributions to the goals of stockpile stewardship and to contribute to the advancement of inertial fusion energy (IFE) and other civilian scientific research efforts. Recent problems with the construction of the facility, however, are likely to result in a significant increase in the project's cost. Also, technical problems remain unsolved that might compromise the ability of NIF to reach its goals. In addition to having implications for DOE appropriations and authorization, problems with NIF also could increase the difficulty of the Administration's continuing efforts to gain ratification of the Comprehensive Test Ban Treaty.

Stockpile Stewardship

Largely as a result of the end of the Cold War, the United States has initiated several steps designed to reduce the threat of nuclear weapons. On August 11, 1995, the President announced that the United States would pursue a zero-yield Comprehensive Test Ban Treaty (CTBT), which would institute a worldwide ban of nuclear weapons tests of any yield.¹ The treaty was signed by the United States at the United Nations in September 1996. At the same time, the nation is not abandoning

¹ For a discussion of the CTBT see, Congressional Research Service. *Nuclear Weapons Testing and Negotiation of a Comprehensive Test Ban Treaty*. CRS Issue Brief 92099. Regularly updated. On October 13, 1999, the U.S. Senate voted against ratification of the CTBT. While the Russian Duma recently (April 2000) ratified START II, other related actions must be taken by the U.S. Senate before it can enter into force. See, Congressional Research Service, *START II Debate in the Russian Duma: Issues and Prospects*, by Amy Woolf, CRS Report RL97-359, updated April 17, 2000.

its reliance on a nuclear deterrent as a key element of its national security policy. Under the terms of the Strategic Arms Reduction Treaty II (START II), which has been ratified by both the United States and Russia, the United States would retain a stockpile of about 3,500 weapons if and when the treaty is fully implemented.² The Administration and Congress have stated that a capability must be in place to maintain the safety and reliability of the existing stockpile.³

A program to carry out this mandate, the Stockpile Stewardship and Program, has been instituted by DOE.⁴ Because the SSP cannot rely on nuclear testing, a surrogate testing process based on laboratory experiments and computer simulation is being developed by the SSP, the research portion of the SSP. The goals of the SSP include enhanced surveillance of the aging weapons stockpile to detect aging-related defects, an improved capability to predict when defects will occur, increased understanding of the physics of nuclear weapons, and better computer simulation of nuclear explosions to assess the potential effects of defects. In addition, the program will explore means to simulate the testing of nuclear explosion effects. Finally, the SSP will attempt to help preserve the core expertise in weapons science and technology now in place at the DOE weapons laboratories.

Technical Description and Applications of NIF

An important component of the SSP is to be the National Ignition Facility (NIF), which will house the largest laser ever built. If completed, NIF will be capable of delivering light from an assembly of 192 laser beams at an energy level of 1.8 million joules (MJ) to a very small target.⁵ The energy will be delivered in a few billionths of a second, and the total power delivered on target will be about 500 trillion watts. The ultimate target is a tiny pellet of deuterium and tritium, two isotopes or forms of the element hydrogen. The laser beams, called drivers, are configured to compress this pellet to very high temperatures and pressures, forcing the deuterium and tritium to undergo nuclear fusion, releasing large amounts of energy. If all goes as planned, fusion ignition will occur, whereby the nuclear fusion reactions would release more energy than provided by the laser to cause the reactions in the first place.

NIF is designed to achieve, on a laboratory scale, conditions similar to those in a nuclear weapon explosion. It will be the only experimental facility that would be capable of attaining fusion ignition conditions. The pressure and temperature reached in an NIF laser-driven capsule that reaches ignition is projected to be similar to that

² U.S. Department of Energy, *Draft Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, DOE/EIS-0236, February 1996, p. S-10.

³ President William Clinton, "Statement on a Comprehensive Nuclear Weapons Test Ban," August 11, 1995, *Weekly Compilation of Presidential Documents*, August 14, 1995. Washington, U.S. Govt. Print. Off., p. 1433; and P.L. 103-160, Sec. 3138.

⁴ U.S. Department of Energy, Office of Defense Programs, *The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapon Stockpile*, May 1995, p. 3.

⁵ The largest laser was the NOVA facility at Lawrence Livermore National Laboratory, which was capable of delivering 40 thousand joules. It was recently decommissioned.

in a nuclear weapon, although the total energy output would be at least a million times less than that of a weapon. The principal goals of NIF are to improve understanding of the physics of specific aspects of weapon behavior, to validate improved computer simulation codes,⁶ to evaluate the impact of defects discovered in the stockpile, to simulate the effects of nuclear explosions on systems, and to help maintain the core of “intellectual and technical competency” of the U.S. nuclear weapons program. NIF is also expected to have several civilian scientific applications. DOE hopes that NIF will be able to demonstrate fusion ignition as an important step toward harnessing fusion energy for the production of electric power (inertial fusion energy or IFE).

NIF Project Schedule and Cost Overruns – Chronology

When the NIF project first appeared in the DOE budget request for FY1996, its total project cost (TPC) — construction plus associated project costs — was reported as \$1.074 billion including construction and design costs (total estimated costs or TEC) of \$842.6 million. A completion date of the third quarter, 2002 was also given. In the FY1998 budget request, DOE reported the total project cost of NIF to be an estimated \$1.196 billion including construction and design costs of \$1.05 billion and \$146 million in associated project costs. The increase was a result of DOE’s decision to stretch the project out by one year to a completion date of the third quarter, 2003. These figures remained unchanged through the FY2000 budget request, and no mention was made of any possible difficulties in meeting those targets. A hint of some problems, however, could be seen in the detailed project description accompanying the FY2000 request. DOE reported that total construction and design cost estimates increased over the previous DOE estimate, but those changes were compensated by a decrease in contingency funds from 12.6% of the total estimated costs (the original contingency factor was 15%) to 7.6% of the total estimate. At this point, the project was less than 50% complete, and the size of the remaining contingency funds appeared to be quite low for a project this complex.

In March 1999, a preliminary assessment by NIF project officials at Lawrence Livermore National Laboratory (LLNL) determined that there were major potential problems with NIF construction that threatened to increase substantially project costs.⁷ LLNL staff attempted over the next several months to see if the additional cost could be accommodated within total project costs already approved, but did not notify DOE until June 1999, when it reported these problems to NIF project staff at DOE Headquarters. It was not until August 1999, however, that the Secretary of Energy was informed. At that point, LLNL reported that the project cost would increase by about 20–30% and completion would be delayed by 12 to 18 months. LLNL stated that the cause of the cost increase was that assembly of the laser system

⁶ As weapon codes are changed, they need to be validated to ensure that they are accurately modeling weapon processes. In the past, nuclear weapons tests were the primary means of accomplishing this validation. Without tests, the codes will have to be checked by seeing how well they describe the phenomena that occur during operation of the stockpile stewardship experimental facilities such as NIF.

⁷U.S. Department of Energy, *Energy Department Announces Major Changes to Improve National Ignition Facility Management and Accountability*, News Release, March 24, 2000, [<http://www.doe.gov/news/releases00/marpr/pr00084.htm>]

infrastructure was considerably more complicated than anticipated.⁸ An important contributor to this added complexity was the difficulty in maintaining NIF's stringent cleanliness requirements during assembly. Officials at LLNL determined that the lab did not have the capability to meet these more complex assembly requirements and must contract for them. According to LLNL, securing those services through the contract process was the primary source of the added cost and time to completion.

Upon learning of the potential cost overruns, the Secretary of Energy requested an internal review of the project to determine the source of the problems. A special task force of the Secretary of Energy Advisory Board (SEAB) was set up to investigate management and technical problems at the project. In addition, the University of California (UC), which manages LLNL under contract to DOE, also initiated a review by a special committee of the UC President's Council. The Council was set up to advise the UC President on matters about the three DOE labs managed by UC — LLNL, Los Alamos National Laboratory, and Lawrence Berkeley National Laboratory. A third study focusing on technical issues was carried out by the Technology Resource Group of the NIF Council, an advisory group internal to LLNL.

The SEAB⁹ and UC¹⁰ reviews both confirmed that the assembly and installation of the NIF laser system would be more difficult and rigorous, and would require a cleaner environment than originally anticipated. They both concluded that the original approach of having the assembly done by an operating contractor and LLNL personnel while relying extensively on LLNL management would not succeed. Rather, an outside contractor with experience in clean assembly of large, complex systems and management of large engineering projects would be needed.¹¹ As a consequence, a significant increase in cost and time-to-completion would result.¹²

The NIF technical review found a number of potential technical issues that if not resolved could seriously compromise the operation of NIF.¹³ Foremost is the possibility that the optics facing the laser target — the final optics assembly — would not be able to handle the laser energy intensities needed to achieve ignition. Both the UC and SEAB reviews agreed with that assessment.

⁸Personal communication, David Crandall, United States Department of Energy, Oct. 20, 1999.

⁹Secretary of Energy Advisory Board, U.S. Department of Energy, *Interim Report of the National Ignition Facility Laser system Task Force*, January 10, 2000. (Hereafter called the SEAB Laser Task Force.)

¹⁰University of California, *Report of the University of California President's Council National Ignition Facility (NIF) Review Committee*, November 18, 1999, [<http://labs.ucop.edu/internet/nr/nr112399.html>]. (Hereafter called the UC President's Council.)

¹¹UC President's Council, 3.

¹²SEAB Laser System Task Force, 3.

¹³Lawrence Livermore National Laboratory, Technology Resource Group of the NIF Council, *NIF Technology Review*, Nov. 4, 1999. [<http://www.nrdc.org/fpprog.html>]

In response to the management problems uncovered by the SEAB and UC reviews, the Secretary of Energy in March 2000, announced several changes in the project structure: an Associate Director of NIF reporting to the LLNL director was established; UC established a special panel of the President's Council charged with oversight of the NIF project; a headquarters NIF project office was established; the NIF project was made part of the DOE Project Management and Oversight function — mandated by Congress — that will provide an on-site DOE contractor with expertise in large, complex project management; and important decisions about NIF had to be approved by the DOE Deputy Secretary before funding is provided.¹⁴ In making this announcement, the Secretary reiterated his belief that while the NIF project has had serious problems with its management, the science underlying NIF “remains sound.”¹⁵

On May 3, 2000, the Secretary of Energy announced a new budget and schedule for NIF.¹⁶ He stated that DOE would increase funding for NIF by \$95 million for FY2001 to a total of \$169.1 million for construction. In addition, the NIF funding requirements would increase from \$100 million to \$150 million for FY2002 depending on the results of the new baseline, then scheduled for completion in August 2000. DOE did not ask for additional funding for FY2001, but proposed shifting funds from other sources within the department. It was further stated at the press conference accompanying the DOE announcement that most of the funds would come from LLNL.¹⁷ The new schedule announced by the Secretary would have the first batch of laser beams in operation by 2004 and the entire facility completed by 2008, nearly five years past the original date. That completion date would be well beyond the first estimates of the delay cited above.

On June 1, 2000, DOE delivered an interim report to Congress containing a new plan for NIF with a revised cost estimate and schedule.¹⁸ In this plan, NIF would have a total project cost (TPC) of \$2.12 billion, would provide first laser light at the end of FY2004, and would reach the full 192 -beam facility late in FY2008. Cost increments would be \$95 million for FY2001 and \$150 million for FY2002 over the original plan (\$74.1 million for FY2001 and \$65 million for FY2002). In addition to the TPC, DOE also included costs that are directly related to NIF that had not previously been counted as part of the NIF project but had been included in the Inertial Confinement Fusion (ICF) program. These costs, estimated to be \$833.1 million at the time of the FY1998 baseline, were now estimated to be \$1.137 billion. Therefore, the total NIF cost estimate in the June 1, 2000 document were \$3.26 billion compared to the original baseline estimate of \$2.03 billion, a cost overrun of \$1.23 billion or about 60%.

¹⁴U.S. DOE March 24, 2000, News Release.

¹⁵U.S. DOE March 24, 2000, News Release.

¹⁶U.S. Department of Energy, *Secretary Richardson Settles on a New Budget Schedule for National Ignition Facility*, News Release, May 3, 2000.

¹⁷Tarun Reddy, “New NIF plan calls for delay in facility’s opening, more funding,” *Inside Energy/ with Federal Lands*, McGraw-Hill, May 8, 2000, 3.

¹⁸Letters to Senator Pete V. Domenici and Representative Ron Packard from Bill Richardson, Secretary of Energy, June 1, 2000. [http://www.dp.doe.gov/dp_web/news_f.htm]

As the basis for this interim report, on May 30, 2000, the Director of LLNL delivered a letter to the Secretary of Energy providing a certified estimate for a revised cost and schedule baseline for NIF.¹⁹ The letter noted that LLNL as directed by DOE had developed a detailed plan for completing the project as rapidly as possible. Under this plan, the first laser light (8 beams) would be obtained at the end of FY2003 and the full 192 beams would be operational at the end of FY2006. In each case, two years later than originally planned. The total project cost of this new plan was estimated at \$1.95 billion. Funding increases of \$150 million for FY2001 and \$240 million for FY2002 over the original plan would be required.

The LLNL Director noted, however, that such increases would likely have a “negative impact” on the rest of the stockpile stewardship program. As a result, he provided other estimates that would not require such large initial funding increases. Those estimates, however, were not developed in a detailed, bottoms-up manner, as was the plan noted above, but were determined by estimating the effects of stretching out that plan. When this stretched-out plan was presented to the NIF Program Review Committee (NPRC), a group formed as part of the management reforms instituted by DOE, the Committee expressed its dissatisfaction with the LLNL cost-estimate methodology. Further it was concerned about how well the stretched-out plan would meet the requirements of the stockpile stewardship program (SSP) to certify the readiness of the nation’s nuclear stockpile. As a result, LLNL created a new plan that meets the funding increase limits imposed by DOE for the next two years (as reported by the Secretary of Energy in March 2000) and would meet the SSP certification requirements. This plan was the basis of the June 1, 2000 interim report.

Because the June 1, 2000 estimate had not undergone a detailed, bottoms-up review, DOE did not consider that it was adequate to fulfill the congressional requirement for a revised baseline. This review was completed in August 2000, and DOE delivered the revised baseline to Congress on September 14, 2000.²⁰ The new cost estimate is \$2.248 billion for the TPC and \$1.2 billion for associated program activities giving a total of \$3.448 billion or \$1.42 billion above the original baseline. Of this amount, \$1.46 billion will have been spent by the end of FY2000. According to the new baseline, first light (eight of the planned 192 beams) would be achieved in FY2004 and the project would be completed by FY2008.

DOE also submitted to Congress on June 27, 2000, an FY2001 budget amendment requesting budget authority for FY2001 for an additional \$95 million for NIF to come from other Stockpile Stewardship programs and \$40 million to be reallocated from the FY2001 Readiness in Technical Base and Facilities originally planned for NIF operational support. This amendment, which would have added \$135 million in budget authority to the original FY2001 request of \$74 million, was rejected by the House and Senate authorization and appropriations committees. DOE, however, reiterated the request in the September 14, 2000 revised baseline. As

¹⁹Letter to the Secretary of Energy from the Dr. Bruce Tarter, Director, Lawrence Livermore National Laboratory, May 30, 2000.[http://www.dp.doe.gov/dp_web/news_f.htm]

²⁰Letters to Senator Pete V. Domenici and Representative Ron Packard from Bill Richardson, Secretary of Energy, September 14, 2000. [http://www.dp.doe.gov/dp_web/news_f.htm]

noted below, most of this request was approved by the House-Senate conference on the FY2001 DOE appropriations bill, although with significant provisos.

On April 6, 2001, the NNSA of DOE delivered a report to Congress responding to the certification request contained in the FY2001 Energy and Water Development Appropriations Act (see below for details).²¹ DOE was required to submit this report in order to receive the remainder of the FY2001 appropriation for NIF. In the letter accompanying the report, the Administrator of the NNSA recommended that the NIF proceed with the full complement of 192 beams. He also certified that the project was on schedule and budget as set forth in the revised baseline. The Administrator stated that a Workshop had been held to consider alternatives to a 192-beam facility and had concluded that full-scale NIF was the best course for meeting the Stockpile Stewardship program requirements. The Workshop concluded that any construction path that paused the project at fewer than 192 beams and then completed the project would cost more than proceeding directly to the full 192 beams. The Administrator also noted that a five-year plan for the SSP is currently under development and will be submitted to Congress after completion of the President's national security strategic review.

The Administrator also concluded that the High-Energy-Density Physics (HEDP) program within the SSP should not only include a 192-beam NIF, but also the Omega laser at the University of Rochester and the Z-machine at Sandia National Laboratory. As for the latter, the Administrator stated that the proposed refurbishment of that facility was promising but that it would not be a replacement for NIF. Finally, the Administrator emphasized the importance of NIF in attracting and training new scientific and technical personnel to the HEDP program.

In a related action, the Secretary of Energy announced on April 5, 2001, that DOE would not make any changes in the design, construction, or operation of NIF as a result of a supplemental environmental impact statement (SEIS).²² The SEIS was carried out as a result of the uncovering of capacitors containing PCBs during excavation for the NIF.

Congressional Actions – 106th Congress

In September 1999, the House Science Committee requested an investigation of the NIF project by the General Accounting Office (GAO). The GAO review, released in August 2000, concluded that

“NIF’s cost increases and schedule delays were caused by poor Laboratory management, which included weaknesses in planning, budgeting, and project

²¹Letter from John A. Gordon, Administrator of NNSA to The Honorable Dennis J. Hastart, Speaker of the House of Representatives, April 6, 2001. This letter and the accompanying documents were obtained at [http://www.dp.doe.gov/dp_web/news_f.htm]. At this time, however, the document is no longer on that website.

²²U.S. Department of Energy, National Nuclear Security Administration, “Record of Decision for the Final Supplemental Environmental Impact Statement for the National Ignition Facility,” *Federal Register*, 60, No. 66, (April 5, 2001) 18078.

control. DOE's oversight weaknesses contributed to cost and schedule problems, and coupled with no effective independent review of NIF, allowed NIF problems to go undetected."²³

The GAO report also noted that other factors contributed to the cost overruns and delays, including initial budgets that did not reflect project complexity and performance of major project construction in parallel with critical R&D.

In its report, GAO estimated total costs for the NIF project to be \$4.08 billion.²⁴ In addition to the TPC and costs for the associated program activities included by DOE in its revised baseline, GAO includes \$627 million for target-physics R&D and NIF support supplied by other DOE labs that are not included in the DOE revision. DOE disputes the inclusion of these costs arguing that they are part of the general inertial confinement fusion research program supported by DOE and support experiments in all of its ICF facilities. GAO claims that the target-physics work is essential to NIF and should be counted. No estimate of these disputed costs for the original baseline is given either by DOE or GAO. Assuming they would have been the same, the original baseline estimate would have been \$2.66 billion, leading to a cost overrun, as accounted for by GAO, of 53.4%. GAO did not attempt to make an independent assessment of the construction and supporting R&D cost estimates that DOE did acknowledge.

On October 30, 2000, the President signed the Floyd D. Spence National Defense Authorization Act for FY2001 (P.L. 106-398, H.Rept. 106-945). The Act authorizes \$209.1 million for NIF, \$135 million above the original request. Included in the funds are \$40 million to be transferred from the Inertial Confinement Fusion program. The Congress also included a provision in the Act requiring a report from the NNSA with a revised baseline cost and schedule estimate. The Act prohibited more than 50% of the authorized funds from being spent until this report was delivered. The Act also required the General Accounting Office to carry out a detailed review of the NIF program focusing on NIF's role in ensuring stockpile reliability and safety, its relationship with the rest of the stockpile stewardship program, and the possible effects further delays in the NIF project could have on the stockpile stewardship program. In addition, the GAO was to review the revised NIF baseline report. Congress expressed its continuing disappointment in the management and technical difficulties of the project, but also stated that it continues to believe in the importance of the project and that recent management improvements justify the funding increase.

On September 28 and October 3, 2000, the House and Senate respectively approved the Energy and Water Development Appropriations Act conference report

²³United States General Accounting Office, Report to the Committee on Science, House of Representatives, *National Ignition Facility: Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays*, GAO/RCED-00-141, August 2000, p.13.

²⁴GAO, *National Ignition Facility*, p. 10. The total reported by GAO was \$3.89 billion. That figure was based on an earlier DOE estimate for the TPC and associated costs. If the DOE estimate for these costs given in the revised baseline are used, the GAO estimate would increase to \$4.08 million.

(H.Rept. 106-907). The bill was signed by the President on October 27, 2000 (P.L. 106-377, H.Rept. 106-988). The Act provided an appropriations of \$199.1 million for NIF for FY2001.²⁵ Of this amount, \$25 million was to come from a reduction in other weapons activities funds allocated to LLNL, \$40 million from transfer of NIF operating funds to NIF construction, and \$60 million in new appropriations. Congress also included language in the bill stating that only \$130 million of the appropriation would be available at the start of FY2001 with the remaining funds becoming available after March 1, 2001, upon certification by NNSA that several requirements had been met. (See above for a discussion of that certification report.) Among those requirements are a recommendation from NNSA on the path the project should take based on an assessment of options including a smaller facility (48 or 96 beams); certification that the project is meeting its construction milestones and is on budget and schedule; completion of a study as to whether a full-scale NIF is needed to meet SSP goals; and a five-year budget plan for the SSP including how NIF will be paid for in the out years. Congress expressed its belief that NNSA had not adequately reviewed all options for NIF, particularly an assessment of a smaller facility. Congress also directed the NNSA to “fully reflect a balanced set of programs and investments within the stockpile stewardship program,” in its FY2002 budget request and to ensure that the \$3.4 billion NIF can be accommodated within these programs.

Congressional Actions – 107th Congress

The DOE budget submission for FY2002 requested \$245.0 million for NIF construction, 24.2% above the FY2001 level. In addition, DOE requested \$222.9 million for the remainder of the inertial confinement fusion program, much of which is directly tied to the NIF project. According to the budget submission, the request is consistent with the revised baseline described above. No changes were reported in the FY2002 budget submission in total cost, scope, or schedule of the project from the revised baseline.

On June 1, 2001, the GAO released its follow-up report as called for by the FY2001 defense authorization act (see above).²⁶ GAO concluded that the role of NIF in the SSP was uncertain because the three weapons laboratories were not in agreement on the contribution NIF would be able to make. In addition, GAO noted that DOE has not yet certified that completion of NIF at its full design level will have no negative consequences for the rest of the SSP. GAO further stated that any more delays in completing NIF could affect the weapons’ research program primarily by adversely affecting the programs ability to attract high quality scientific talent. GAO also noted that DOE has not set up an independent external review process for NIF and does not intend to do so.

²⁵For a discussion of the entire DOE R&D budget request for FY2001, see, Congressional Research Service, *Department of Energy Research and Development Budget for FY2001: Description and Analysis*, by Richard Rowberg, CRS Report RL30445, Jan. 5, 2001.

²⁶U.S. General Accounting Office, *Department of Energy: Follow-Up Review of the National Ignition Facility*, GAO-01-677R, June 1, 2001.

On June 28, 2001, the House approved funding the full request for NIF construction for FY2002 (H.R. 2311, H.Rept. 107-112). In addition, the House appropriated \$492.9 million for the ICF program, \$25 million above the request. The increase is to be used for R&D on high average power lasers. The House noted the recent GAO report about NIF and cited some of the findings including the lack of an outside, independent review group. The House stated its expectation that DOE would address the GAO concerns. On July 19, 2001, the Senate approved \$492.4 million for the DOE ICF program for FY2002 (S. 1171, S.Rept. 107-39). Included was the full request for NIF construction, and \$59.7 million for ICF/NIF experimental support activities. The latter is \$24.5 million above the request. Included in that increase are \$10 million to enhance NIF diagnostics and target development, and \$7 million for the base program. In approving the request for NIF construction, the Senate stated that despite the certification provided by DOE about the NIF cost and schedule, that a “high level of vigilance and extraordinary management attention is warranted” to ensure that the program remains on course. The Senate also noted its agreement with the recent GAO study. In particular, the Senate expressed its concern about the continuation of project oversight by the same people in that role before project costs began to grow in 1999.

On November 1, 2001, both the House and Senate approved the conference report (H.Rept.107-258) for the Energy and Water Development Appropriation Act, 2002. In that act, Congress approved the full request for NIF for FY2002. Congress also provided an additional \$7 million to the ICF program to enhance NIF diagnostics and target development. There was no language in the conference report about the cost overruns or other potential concerns about the project.

On September 25, 2001, the House passed its version of the National Defense Authorization Act for Fiscal Year 2002 (H.R. 2586, H.Rept. 107-194). The bill authorizes the entire request for NIF of \$245.0 million for FY2002. In addition, the House authorized an increase of \$10 million for the remainder of the ICF program to be used for NIF efforts to reduce risk and develop needed technology. The House argued that there was a funding shortfall in that part of the NIF program. The House also noted the improvements in NIF management and project oversight but expressed concern about the remaining technical problems facing the project. It directed DOE to inform it “expeditiously” of any future delays or cost escalation. The House noted that NIF offers many basic and applied research opportunities beyond its weapons mission, but directed DOE to ensure that the Stockpile Stewardship program be the facility’s primary focus.

The Senate passed its version of the defense authorization act (S.1438, S.Rept.107-62) on October 2, 2001. In that bill, the Senate authorized an appropriation of \$245.0 million for NIF construction, the requested amount. The Senate also authorized an additional \$10 million for the ICF program to support enhancements of NIF diagnostics and target development. In addition, the Senate directed the NNSA to report to the two Armed Services Committees when the NIF project has reached its level 1 and level 2 milestones. Noting the importance of the project to the stockpile stewardship program, the Senate directed these reports to ensure that Congress is kept apprised of the project’s progress in meeting the revised baseline. While expressing confidence that NIF’s budgetary and scheduling problems have been solved, the Senate still intends that Congress keep close tab on the project.

Issues

Project Management. Until the reports of cost overruns in early September 1999, DOE officials were quite confident of cost and schedule estimates for NIF. As recently as June 11, 1999, the Secretary of Energy publicly noted that the project was on schedule and budget. As noted above, the project's cost estimates were increased from the original estimates by about 11.6% during the Title I design phase, but no other changes were reported. The project had undergone several technical and management reviews and confidence was high that the estimates would hold. Clearly, that confidence was misplaced.

The SEAB, UC, and GAO reviews found the NIF project to suffer from severe management problems. The principal source of the problems was LLNL's inexperience with managing large, complex engineering projects.²⁷ The SEAB Task Force concluded that the management structure in which the DOE weapons labs (LANL, LLNL, and Sandia National Lab) operate encourages a self-reliant attitude that inhibited LLNL's willingness to seek help from outside for activities in which it did not have adequate competence, in particular management of large engineering systems.²⁸ This conclusion was also arrived at by the UC review. A particularly egregious example of this inexperience, according to all three reviews, was the setting of the original contingency factor at 15%. They all argued that this was much too low for a project this complex. The fact that the contingency level had dropped to less than 8% with the project less than half done appears to corroborate this conclusion. GAO noted that LLNL failed at the outset to appoint a project manager with the "management and technical expertise" required of such a large and complex project. It also stated that LLNL did not install a reporting system that could have effectively noted technical and other issues that would put the project at risk.²⁹

The SEAB and GAO reviews also concluded that all three participants in the process — LLNL, DOE, and UC — must share in the blame for allowing this cost overrun to occur. The UC report stated that the project was far more complex than any ever attempted by the LLNL and required management capabilities it did not possess. LLNL was not capable of identifying those management weaknesses, and neither were DOE nor UC.³⁰ The three assessments also noted that the project was not adequately reviewed and monitored by either DOE or UC. The SEAB Task Force stated that independent reviews are a necessity, a view concurred with by UC. All three reviews pointed out the absence of effective communications throughout the entire NIF project. The UC review suggested that success in solving earlier problems on the project led to a reluctance to report problems to anyone outside the immediate project staff. GAO concluded that DOE's historic reliance on contractors was at the

²⁷SEAB Laser System Task Force, 9.

²⁸SEAB Laser System Task Force, 5.

²⁹GAO, *National Ignition Facility*, p. 15.

³⁰UC President's Council, 5.

“core” of its oversight weakness. GAO stated that DOE did not have staff with “adequate management and technical skills” to provide effective oversight.³¹

The GAO report elaborated on the absence of effective DOE oversight.³² GAO concluded that the monthly and quarterly reports prepared by LLNL did not indicate the growth and extent of cost and schedule problems as they appeared. Further, the chain of command between DOE and LLNL was confusing leaving ambiguous at best questions of to whom laboratory officials should report. GAO also argued that DOE did not act expeditiously when problems were first suspected.

DOE has taken many steps to implement the recommendations of the SEAB and UC reviews. The announcements — noted above — that were made by the Secretary of Energy indicate that substantial management changes have been made at both LLNL and DOE. The May 30 LLNL letter also notes substantial changes in project management.³³ In particular, the letter says that the external review process has been “completely revamped” including the establishment of the NIF Programs Review Committee. The LLNL director also noted that every attempt is being made to coordinate the activities of all of the new review groups. The committee established to validate the revised baseline of the NIF project concluded that DOE has made the management changes necessary to ensure successful completion of the project.³⁴ It stated that the “management approach is appropriate for the project with the size and complexity of NIF” and “that the proposed NIF scope, cost, and schedule baselines are reasonable.” The committee also agreed that the new contingency level of 25% of remaining costs was reasonable. The Chairman of the SEAB review team also concluded that the management concerns raised in its interim report have been addressed and that he was “confident” that the responsible parties could perform their tasks “properly.”³⁵ It is apparent that changes have been made that suggest a shift from science to engineering expertise has taken place within the project management hierarchy.

It remains to be determined, of course, whether these changes will guide the project to a successful completion within the new baseline. A particularly crucial issue is the degree of outside, independent review. GAO noted that the “absence of effective independent reviews” was a major reason that problems were not recognized and dealt with in a more timely manner.³⁶ As noted above, the latest GAO report

³¹GAO, *National Ignition Facility*, p.16.

³²GAO, *National Ignition Facility*, p.16.

³³LLNL, May 30, 2000, letter, 7.

³⁴U.S. Department of Energy, *Department of Energy Rebaseline Validation Review of the National Ignition Facility Project*, August, 2000, [http://www.dp.doe.gov/dp_web/news_f.htm], ii.

³⁵Letters to William B. Richardson, Secretary of Energy, from John P. McTague, Chairman, SEAB NIF Laser System Task Force, September 7, 2000. [http://www.dp.doe.gov/dp_web/news_f.htm]

³⁶GAO, *National Ignition Facility*, p.18.

repeated the observation that DOE has not yet formed an external independent review, and further noted that DOE does not intend to do so.

While new oversight panels have been established by UC, DOE, and LLNL it is not clear how effective these reviews will be. In addition, while coordination among these review groups is important to avoid duplication and minimize the burden on the NIF project team, care must be taken to ensure the independence of the review groups. Without an effective outside review mechanism, there is increased risk that the project will continue to run into significant problems even with the new management structure in place.

The revised baseline validation committee also pointed out a number of potential problem areas.³⁷ It concluded that a single NIF review process that satisfies NNSA, UC, and LLNL was necessary to avoid excessive demands on the NIF project. The committee also recommended strengthening the NIF project office within NNSA headquarters. In addition, it argued for strong support from LLNL in terms of getting and retaining the right personnel for the project. The committee also found that a system for measuring progress and performance using earned-value techniques was critical for the project and should be put in place. The committee also noted that the separation of most R&D activities from project control was a significant contributor to the problems encountered by NIF. While recognizing the steps taken to integrate R&D into the project, the committee stated that the scope and cost of R&D necessary to complete NIF needs to be identified and incorporated into the project's schedule.

In connection with this last point, the June 2001 GAO report noted that about \$700 million of R&D that is supporting the NIF project is not managed by the project and is not included in the monthly reports issued by NIF.³⁸ While the report notes that DOE is currently reviewing how to integrate those activities within the NIF project.

A critical aspect of these management issues is the degree of involvement of industry in the project. As noted, one of the major contributors to the cost overrun was the substantial underestimate of how difficult it would be to assemble the 192 beamlines to the required degree of cleanliness. According to the May 30 LLNL letter, the project, after consultation with the semiconductor industry, has taken two steps to correct this problem.³⁹ It is asking industry to provide a higher level of component integration than originally planned. Component integration by laboratory personnel will be greatly reduced. Also, installation of the mechanical and electrical infrastructure for the beampath will be done by one contractor. These actions will place much of the installation of the beam assembly in the hands of industry with more experience in large, complex project management. In August 2000, DOE completed these actions by awarding a \$230 million contract to Jacobs Engineering for integration management and installation.

³⁷DOE, Rebaseline Validation, p.39.

³⁸GAO, *Department of Energy*, 4.

³⁹LLNL, May 30, 2000, letter, 8.

Because of the unique nature of NIF, however, it is not clear whether these steps will ensure successful construction of NIF within the revised budget. In particular, care will be needed to ensure a close and cooperative working relationship between industry with the project management expertise and LLNL staff with expertise in large laser systems. The revised baseline evaluation committee also argued for close management, communications, and monitoring by LLNL of the industrial contractors obtained to perform beam hardware integration.⁴⁰

Another important management issue is the rate the NIF should be completed given the extent of the cost overruns. A number of options were considered by LLNL at the direction of DOE.⁴¹ Two options were described in a review carried out by the Target Physics Program Review Committee at the request of the NIF Program Review Committee on the impact of NIF construction delays on the DOE SSP.⁴² The first option called for the first laser bundles to come on line by the end of FY2003 and final project completion by the end of FY2006. The other option (labeled option 3) called for the first bundles by the end of FY2004 with final project completion by the end of FY2009.

The May 30, 2000, letter from LLNL to DOE suggests that LLNL favored an aggressive completion path described by the first option. As noted, that path would have required an increase in FY2001 funding of \$150 million and an increase of \$240 million for FY2002.⁴³ This option was also the one apparently favored by the Target Physics Review Committee (TPRC).⁴⁴ It argued that the first option would provide the “earliest benefit” from NIF because it would allow operation of a partially completed facility — 48 beams — well before the other options (the end of FY2004) while the facility was being completed. The TPRC stated that operation of a 48-beam cluster would be very beneficial for DOE’s SSP. The TPRC also expressed its belief that if deployment of NIF took too long, the project might not be completed.

DOE has chosen a path about mid-way between the two options. As argued in the May 30, 2000, LLNL letter to DOE, the large increases required by the first option could have serious consequences for the rest of the SSP. Therefore, DOE has chosen to limit those increases. Presumably, DOE hopes that its path will balance budget concerns with the technical and programmatic concerns of the Target Physics Review Committee. The DOE-selected path would reach the 48-beams bundle in FY2006, about one and one-half years later than the LLNL choice, and result in a completed NIF about one to 1.5 years after the LLNL choice. This path was

⁴⁰DOE Rebaseline Validation, p. 20.

⁴¹U.S. Department of Energy, Memorandum for Dr. Bruce Tarter, Director, Lawrence Livermore National Laboratory, Options for National Ignition Facility, March 9, 2000.

⁴²U.S. Department of Energy, Lawrence Livermore National Laboratory, *Report of the National Ignition Facility Target Physics Program Review Committee*, Draft, April 13, 2000, 3. The NIF Program Review Committee is the successor to the NIF Council. The Committee along with the Target Physics Program Review Committee are made up of individuals outside the NIF program and, for the most part, outside of the DOE labs.

⁴³LLNL, May 30, 2000, letter, 2.

⁴⁴Target Physics Review Committee, 4.

confirmed in the revised baseline presented on September 15, 2000 and in the March 2001 certification report to Congress.

A final point concerns project milestones. One result of the management problems has been the establishment of detailed milestones for the project including a comprehensive work schedule. The June 2001 GAO report, however, noted that none of the major milestones take place until after 2004.⁴⁵ As a consequence, GAO recommended that earlier milestones be set up in order to track more carefully the progress of the project.

Technical Concerns. In addition to the management issues uncovered by the reviews of the NIF program, several technical concerns were highlighted. These included the high degree of cleanliness required during assembly of the laser system infrastructure and optics, and some potentially serious limitations of key optical components.

The NIF design has always incorporated the need to maintain stringent cleanliness requirements during construction and operation. As noted above, however, the degree of cleanliness required was greater than anticipated. As pointed out by the SEAB Task Force, maintaining the necessary level of cleanliness while assembling the laser infrastructure and optics is a major challenge. In addition, budget constraints early in the project constrained the size of the laser building, limiting clean air flow below the levels needed.⁴⁶ Further, because the infrastructure is to be completed before the first optical elements are installed, any cleanliness-related lessons learned during installation cannot be used to modify the infrastructure.

As noted by LLNL and the SEAB Task Force, the size and cleanliness requirements of NIF are similar to those of semiconductor fabrication, and the lab plans to make use of that expertise. There are, however, some differences.⁴⁷ Unlike a semiconductor manufacturing facility, the NIF infrastructure will lack adequate air flow, which, combined with the constrained height of the building, will make it impossible for the laser bay to be a truly clean room. Also, unlike semiconductor manufacturing, there can be no period of operation at less than optimal cleanliness conditions because an NIF laser bundle cannot be operated with any particulate contaminations. Also, nonvolatile organics — used to clean optical components prior to installation — must be at a much lower concentration for NIF than for a semiconductor plant. Therefore, it is not clear that using industrial expertise to manage the installation of the laser assembly will by itself ensure that cleanliness requirements will be met. If NIF had constructed an engineering prototype beam, some of these problems might have been addressed earlier. Construction of such a beam does not appear feasible at this point and it is likely that the first bundle will have to serve in that capacity. The SEAB Task Force, however, stated that if adequate care is taken and it is understood by NIF project management that assembly

⁴⁵GAO, *Department of Energy*, 4.

⁴⁶SEAB Laser System Task Force, 15.

⁴⁷SEAB Laser System Task Force, 16.

of that first bundle will necessarily require a steep learning rate, the cleanliness issue should not stop NIF from achieving its goals.

The review by the revised baseline validation committee did not explicitly address the cleanliness issue. It did, however, comment on beamline assembly and installation, and on the beampath infrastructure systems, all of which are critically coupled to the cleanliness issue. The committee found the personnel involved in these activities to be of high quality and experienced.⁴⁸ It further noted that the Integration Management and Installation (IMI) contract was an “innovative solution” to the problem of installing the beamline in the NIF building with adequate cleanliness. The committee cautioned, however, that the contract must be well-managed and monitored closely to ensure success. This is particularly true because the contract does not contain allowances to correct problems that might arise during installation. It is clear that DOE is depending critically on the IMI contractor to resolve the cleanliness issue.

Also problematic are the issues about the laser optics. The report of the Technology Resource Group (TRG) of the NIF Council noted that major technical advances in eight areas were needed from the start of the project to reach NIF’s goals. In other words, substantial research and development (R&D) to develop key project components remained even while NIF was under construction. Furthermore, the original NIF budget and program did not adequately account for that R&D, and the technology development budget associated with the NIF project was exhausted by the end of FY1998.⁴⁹ The TRG noted that the deployment goal, which assumed that the required technology and associated manufacturing processes were complete and available, was unrealistic. It went on to say that the original plan, to begin operation as soon as the facility was complete, was not possible because of the technical uncertainties and required technology development.

While the TRG reports that significant progress has been made in these eight areas, substantial technical challenges remain.⁵⁰ The TRG identified four specific technical areas of special concern. The most important of these, as noted above, appears to be the potential for severe damage to the final optics assembly (FOA) because of NIF energy intensity requirements.⁵¹ To reach the design level of 1.8 million joules (MJ), a fluence — beam energy per unit of area — of 8 to 9 joules per square centimeter (J/cm²) is required. This level is a result of an original design compromise that reduced the number of beams from 240 to 192. At that fluence level, it was discovered, unexpectedly, that the fused silica optics when operated in a vacuum with light at the wavelength at which NIF would operate — conditions that

⁴⁸DOE Rebaseline Validation, p. 20, 25.

⁴⁹Technology Resource Group, 6.

⁵⁰Technology Resource Group, 5.

⁵¹The final optics assembly is that portion of the beam path that fronts on the target chamber. That portion of the beam path operates in a vacuum.

would occur in the FOA — are subject to “catastrophic” damage in that the damage grew rapidly with each pass of the beam.⁵²

At this point, there is no obvious technical solution to this problem. The TRG stated that design alternatives for the FOA are likely to be needed. It proposed that the NIF project “get out of the box” in addressing the FOA problems.⁵³ Further, the TRG noted, it is possible that fused silica may never be able to permit full-fluence operation of NIF, and that such operation is likely to need a superior optical material. Without a solution, NIF would be forced to operate at either fluence levels of about one-half the design level, reducing laser output below one MJ, precluding achieving ignition, or the optics would have to be changed at a rate 10 times greater than now planned, significantly increasing NIF operating costs.⁵⁴ Indeed, GAO argues in its June 2001 report that DOE may have significantly underestimated the annual operating cost of the completed NIF because those cost estimate assume solution to the FOA problem. DOE claims that it has developed a theoretical solution, but it has not been tested in the laboratory.⁵⁵

Another of the four areas concerns the quality of laser glass produced by the continuous melt process. That process was selected by the NIF project team because of the large quantity of glass required for the facility. The first batches produced in this manner showed higher levels of water vapor trapped in the glass and greater variations in the optical quality (measured by the index of refraction) than could be tolerated. The laser glass is where the physical phenomena that produces the laser beam takes place, and the two problems would result in beam energy intensity below the design level. LLNL believes that it has found solutions for these problems. It intends to use special furnaces to heat the laser glass material prior to its introduction into the continuous melt process to reduce its water content. Recently, LLNL announced that continuous-melt laser glass produced by one of its principal vendors using this preheating technique met specifications for water content.⁵⁶ As a result, it appears that water content, at least, will not prevent the laser glass from being able to support the design fluence of 8-9 J/cm².⁵⁷ The laser glass from this run, however, still did not meet optical quality specifications. For this purpose, LLNL proposes using special polishing techniques called “small tool” polishing. Such methods, while appearing straightforward, have not yet been tested for NIF laser glass design parameters.

⁵²Technology Resource Group, 17. This problem is also referred to as the 3 ω problem because the frequency of the laser light is increased by a factor of three as it enters the FOA region. It is this higher frequency that creates the problems with the FOA optics.

⁵³Technology Resource Group, 18.

⁵⁴SEAB Laser System Task Force, 21.

⁵⁵GAO, *Department of Energy*, 4.

⁵⁶Lawrence Livermore National Laboratory, “National Ignition Facility and Glass Vendors Achieve Continuous Melt Milestone,” NR-00-03-13, March 31, 2000.

⁵⁷Beam conditions for the laser glass and the laser glass itself are different than the FOA glass, and the ability of the former to support the design fluence will not affect the problems described about the FOA glass.

The TRG offered a number of recommendations to address the concerns it raised. It estimated the cost of implementing these recommendations to be about \$50-80 million over the next eight years. The Group concluded that by following these recommendations, “NIF can reach its original performance goals, although with some delay and at higher cost than projected.”⁵⁸

The MAY 30 LLNL letter also addressed the technical issues. The LLNL Director reported that all of the external reviews concluded that NIF is “technically sound and based on good engineering design.”⁵⁹ Addressing the FOA issue explicitly, the LLNL Director noted that it was not yet completely resolved. He stated that the current plan is to operate NIF at fluence levels below the damage threshold for the initial experiments. For those experiments that require higher levels, such as for achieving ignition, it would be possible to replace the optics more frequently although operating costs would increase. The NIF project team, however, expressed its belief that the optics current limitations with the FOA will be overcome and that NIF will be able to operate economically at the higher fluence levels.⁶⁰

The revised baseline evaluation committee also addressed the FOA damage issue. It concluded that existing technology would allow NIF to meet its goals but at a very high damage rate that would adversely affect operating costs.⁶¹ At the same time, the committee, expressed confidence that the problem would be solved provided sufficient resources are made available. It stated, however, that while progress towards a solution appears to be promising, the relevant R&D program described in the NIF project, now estimated to cost \$27 million, appears to be underfunded and the committee recommended an increase of \$30 million.⁶² The DOE certification report of April 2001 did not address the FOA problem. On a related issue, the committee recommended that LLNL contract with a second vendor for the critical optics to ensure that a single-point production failure situation would not occur. Such an occurrence is possible with just one vendor producing all of the critical optics.

While the cost estimate of the TRG and the revised baseline evaluation committee are relatively modest compared to estimates of \$3.5 to 4.1 billion for the total NIF project cost, it should be emphasized that the issue with these technology concerns is not cost but whether they can be solved at all. Solutions will likely require basic research for which the outcomes cannot be predicted and success is only weakly dependent on funds available. This is particularly true of the FOA concerns. Therefore, while the TRG, the NIF Laser Task Force, and the revised baseline evaluation committee all appear confident that the technical problems can be solved, there remains considerable uncertainty, and success is not assured. Underscoring this concern is a finding of the GAO study that criticized DOE for starting construction of the project in parallel with critical R&D. GAO noted that results of that R&D have

⁵⁸Technology Resource Group, 5.

⁵⁹LLNL, May 30, 2000, letter, 4.

⁶⁰LLNL, May 30, 2000, letter, 6.

⁶¹DOE Rebaseline Validation, p. 19.

⁶²DOE Rebaseline Validation, p. 18-19.

forced changes in the project that were difficult to make and contributed to the cost overrun because construction of the infrastructure had advanced so far.⁶³

The SEAB Task Force also argued that LLNL should consider a different approach to installing the full 192 beams. Currently, plans call for installation of two bundles of 96 beams, the second to follow immediately upon completion of the first. The Task Force suggested that an extended pause between the two bundles would be preferable. While adding costs to the facility, such a pause would allow the NIF team to commission the first 96 beams and determine if any modifications need to be made in the second bundle before it is installed.⁶⁴ Such a process could save a significant amount of time in installing the second bundle. In essence, the first bundle could act as the prototype which was not constructed earlier in the project. The Target Physics Review Committee, however, did not favor a pause. It stated that there did not appear to be any “programmatically reason” as far as the SSP was concerned for any pause.⁶⁵ The Committee noted, however, that if technical or budget reasons required a pause, it should be done at a point where enough beams were available to do important stockpile stewardship physics. It recommended that 120 beams would provide the best opportunity for this situation.

The LLNL director in his May 30 letter argued that the path proposed by DOE would have the same effect as the pause recommended by the SEAB Task Force.⁶⁶ He stated that while there is no “distinct” pause in the preferred schedule, the fact that it is stretched out would give the project team time to carry out the testing recommended by SEAB. He noted that the completion dates in the preferred schedule are the same as those recommended by SEAB including the pause. The revised baseline evaluation committee did not make an explicit statement about phased beam installation. Rather, the report appeared to assume a full 192-beam facility.

Contribution to Stockpile Stewardship. The potential contribution of NIF research to the Stockpile Stewardship program (SSP) is substantial and diverse. It could be a valuable platform for investigating a range of scientific and technical problems about nuclear weapons performance and reliability that could be significant for the long-term security of the nation. All outside review groups setup by DOE to date agree that these capabilities are critical for the success of the DOE SSP.⁶⁷

Some other groups, however, believe that nuclear weapons safety should be the primary concern of the SSP, and oppose NIF because its contribution to verifying

⁶³GAO, *National Ignition Facility*, p.14.

⁶⁴SEAB Laser System Task Force, 11.

⁶⁵Target Physics Review Committee, 8.

⁶⁶LLNL, May 30, 2000, letter, 6.

⁶⁷ See, for example, JASON, The Mitre Corporation, *Science Based Stockpile Stewardship*, JSR-94-345, McLean, VA, November 1994. This study was performed under DOE contract.

weapon safety would be relatively small.⁶⁸ In addition, a few critics argue that the level of reliability and performance that DOE is trying to maintain for the stockpile through NIF and other elements in the program is excessive and not needed for a credible deterrent. Others, however, believe that the level of confidence desired by the DOE program cannot be achieved without nuclear testing.

Recent advances in pulsed-power research at Sandia National Laboratories (SNL) have also raised questions about whether other, lower cost technologies might be able to achieve many of the goals of NIF. Based on successful experiments completed in 1998 on the SNL's Z accelerator, a new machine, called the X-1, is being proposed at a cost of about \$300 million. That machine might be able to explore important conditions needed for the SSP.⁶⁹ As currently envisioned, NIF would still be able to reach temperatures greater than those likely for the X-1 allowing NIF to investigate conditions not otherwise attainable. It is possible, however, that the X-1 could also achieve ignition, although that is uncertain at this time. If so, it might be able to achieve a large fraction of NIF objectives. Currently, no decision has been made whether to proceed with the X-1. For FY2001, DOE is requesting funding to continue experiments on existing pulsed-power devices in order to assess such devices for a high yield. DOE, however, did not request any funding for development of advanced pulsed-power devices, suggesting that any decision about the X-1 remains on hold. The Target Physics Program Review Committee recommended that the Z accelerator, along with the Omega laser at the University of Rochester, be used extensively to explore important SSP scientific issues as both a supplement to NIF and to mitigate some of the consequences of the delay in completing NIF.⁷⁰ The Committee, however, said nothing about the X-1.

The May 30, 2000, LLNL letter repeats the arguments made at the projects inception in support of the need for NIF.⁷¹ It states that the completed NIF (with the full 192-beam assembly) is the only instrument capable of reaching the conditions of temperature and density necessary for greater understanding of the physics of nuclear explosions. Further, it is stated in the letter that NIF will be necessary to help validate the codes being developed for the Accelerated Strategic Computer Initiative whose goal is to simulate the nuclear explosion as a substitute for nuclear weapons testing. In both cases, the letter's author notes that ignition is essential, and the potential of NIF to reach ignition is one of the most important features of the project.

The delay in construction and cost overruns have raised the question about whether NIF should be completed to its original design level of 192 laser beams. In particular, could NIF still make a significant contribution to the SSP if it were built

⁶⁸ See the National Resources Defense Council web site for an extended critique of NIF and SSP [<http://www.nrdc.org/nrdcpro/fpprog.html>]; and Unpublished memorandum to Marylia Kelly, Tri-Valley Citizens Against a Radioactive Environment, from Greg Mello, May 13, 1994.

⁶⁹James Glanz, "Will NIF Put the Squeeze on Sandia's Z Pinch?" *Science*, v. 277, July 18, 1997.

⁷⁰Target Physics Review Committee, 8-9.

⁷¹LLNL, May 30, 2000, letter, 4.

with only a fraction of the beams, say 48 or 96? The Target Physics Program Review Committee argues that the facility should be completed to the full 192 beams.⁷² In particular, the Committee states that ignition is very important if NIF is to be of maximum utility, and it very likely will require all 192 beams to reach ignition. At the same time, however, the committee noted that important contributions to the SSP can be made with a 48-beam laser, and it recommended that experimentation begin as soon as that level was reached. The committee also argued that operation of 48 beams could help resolve several of the operational issues and ease attainment of the 192-beam goal.⁷³

A report issued by directors of the three weapons laboratories also argued for completing the laser to the full 192 beams.⁷⁴ In order to study critical physical phenomena in the laboratory in regimes that permit extrapolation or the results to the behavior of actual nuclear weapons, minimum laser energy levels are needed. The report notes that the energy threshold for some of these phenomena will be crossed at the 48 to 96 beam level. Others will require 96 beams or more, while still others will require the full 192 beams.⁷⁵ Furthermore, the report's authors argue, the full 192 beams are likely to be required to reach ignition and to provide enough energy to test the computer models being developed to simulate nuclear weapons behavior.⁷⁶ The April 2001 certification report reiterated the need to develop the full complement of beams. As noted above, the report cited a study by the High-Energy-Density Physics Workshop that examined alternatives to a 192-beam facility and concluded the SSP requirements were best met with the full 192 beams.

It appears that a critical factor in this debate is whether all 192 beams are needed to reach ignition. While some scientific issues of stockpile stewardship can be addressed if NIF did not reach ignition, many observers believe it is critical to do so. In particular, the authors of the Foster report concluded that it "is very important that the NIF produce ignition in order to address a new range of stockpile issues" They argued that "a half-power NIF without ignition is not worth the investment for stockpile stewardship."⁷⁷ If ignition could be reached with a smaller number of beams, it is possible that a smaller facility could be built or that NIF can make a greater contribution to the SSP before it is complete than now seems to be the case. The studies requested in the conference report along with the FY2001 DOE appropriations appear to ask for a DOE justification of building the full-scale NIF.

Another aspect of this issue is how the delays in completing NIF and paying for its cost overruns will affect the remainder of the SSP. GAO concluded that the

⁷²Target Physics Review Committee, 4.

⁷³Target Physics Review Committee, 7.

⁷⁴U.S. Department of Energy, *The National Ignition Facility and Stockpile Stewardship White Paper*, April 24, 2000, [http://www.dp.doe.gov/dp_web/news_f.htm].

⁷⁵White Paper, 6.

⁷⁶White Paper, 7.

⁷⁷John S. Foster, Jr., et.al., *FY2000 Report to Congress of the Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile*, February 1, 2001.

consequences for the program could be substantial.⁷⁸ In particular, GAO reported that construction delays will mean that some of the experiments needed to reach the SSP milestones for 2010 could be delayed by three years. The budget consequences could be much more serious. GAO argues that if the cost overruns are taken from existing programs as is now DOE's plan, "significant portions of the weapons program could be affected."⁷⁹ Further, GAO reports that the three weapons labs — LLNL, LANL, and SNL — are not in agreement about how to proceed with NIF to minimize the potential budgetary impact. At this point, according to GAO, DOE has not sought to resolve these differences and the new baseline decision was made without adequate consideration of its effects on the rest of the SSP.⁸⁰

The revised baseline evaluation committee also raised this issue, although somewhat obliquely.⁸¹ It noted that NNSA and DOE Defense Programs should take steps to ensure a balance between the long-term NIF operating costs and the resources needed for other facilities and activities "essential" for the stockpile stewardship program. The committee stated that a plan for governing NIF as a user facility must be in place before research begins on the facility.

The June 2001 GAO report noted that there appears to be difference of opinion among the three weapons laboratories about the potential usefulness of NIF to the SSP.⁸² In particular, it stated that Los Alamos National Laboratory believes that NIF will be limited in its contribution to the SSP unless it can use plutonium and can achieve ignition. The former is currently not planned and the latter, as discussed below, is uncertain. Sandia National Laboratory argues that NIF's contribution will be limited because it will not be able to certify whether weapons can exist in a hostile (radiation) environment. GAO notes that the two labs reportedly have recommended that NIF be limited to a smaller number of beams until its performance can be assured.

In any case, the potential contribution of NIF is a matter of dispute. The increased cost of the project has revived these concerns. Although Congress at this point appears to have agreed that a full-scale NIF is necessary for the program, it has asked DOE, through the NNSA, to certify this conclusion in light of the cost increases. It may be difficult, however, to verify whether the several contributions of NIF, combined with those of the other elements of the SSP, are effective in helping to maintain performance and reliability without some kind of nuclear test validation.

NIF and Ignition. NIF is being designed to reach thermonuclear ignition — the condition where energy released by the fusion reactions is sufficient to sustain the reaction. Nearly all scientists who have reviewed the project believe that ignition will

⁷⁸GAO, *National Ignition Facility*, p.25.

⁷⁹GAO, *National Ignition Facility*, p.26.

⁸⁰GAO, *National Ignition Facility*, p.27.

⁸¹DOE Rebaseline Evaluation, p. 48.

⁸²GAO, *Department of Energy*, 2-3.

be reached at the design level of 192 laser beams.⁸³ Some critics have argued that certain physical conditions concerning the interaction of the laser beam and the plasma that is generated when the target is vaporized will prevent attainment of ignition. They have said that more analysis is needed before a decision to begin physical construction is made.⁸⁴ Recent experiments on the NOVA laser at LLNL, however, showed that some of those concerns might not be warranted. Other improvements in target design have also raised confidence that ignition can be achieved. Indeed, some have suggested that combining all of the advances could result in ignition being reached with as few as 96 beams, although there would be virtually no margin in terms of laser performance.⁸⁵ Nevertheless, if these improvements are possible, then the margin at 192 beams should be substantial. Furthermore, it is possible that higher fusion energy yields (gain)⁸⁶ than were envisioned in the original NIF design would be possible, leading to the ability to study physical phenomena still closer to actual conditions in nuclear weapons.

While confidence is high that ignition will be achieved, it is still not certain, however, and confirmation probably will have to await until NIF is operational. If NIF cannot achieve ignition for any reason, its value to the SSP would be reduced significantly as noted above. It would still be able to perform physics useful for the program, although it is not clear whether its contribution in that case would be commensurate with its cost. Because of the uncertainty and the importance of ignition to the program, the lab director's and the Target Physics Program Review Committee recommend the full 192 beams.

NIF and Nonproliferation. Because NIF would explore certain physical regimes (temperature and density) similar to that of a thermonuclear weapon, some concern has been expressed that results from NIF studies could contribute to nuclear proliferation.⁸⁷ Accessibility to NIF for investigations of civilian applications of inertial confinement fusion would likely enhance the expertise of individuals who are or could become weapons designers. Such knowledge likely is not sufficient by itself for proliferation, however, and is irrelevant for the design of *fission* weapons likely to be the objective of first-time nuclear weapons states or organizations. It should be noted that the basic scientific principles of operation of thermonuclear weapons are widely known. Also, a DOE study, coordinated with the Arms Control and Disarmament Agency, found that potential proliferation concern can be managed.⁸⁸

⁸³ JASON, *Science Based Stockpile Stewardship*; Target Physics Review Committee, 11.

⁸⁴ Stephen E. Bodner, "Time-Dependent Asymmetries in Laser-Fusion Hohlräume," *Comments on Plasma Physics and Controlled Fusion*, v. 16, 1995, pp. 351-374.

⁸⁵ Target Physics Review Committee, 10.

⁸⁶ Fusion yield or gain is the ratio of energy produced by nuclear fusion reactions to the energy required to drive those reactions. Ignition occurs when gain just exceeds one.

⁸⁷ Jacqueline Cabasso and John Burroughs, "End Run Around the NPT," *The Bulletin of the Atomic Scientists*, September/October 1995, pp. 27-29.

⁸⁸ U.S. Department of Energy, Office of Arms Control and Nonproliferation, *The National Ignition Facility (NIF) and the Issue of Nonproliferation*, NN-40, December 19, 1995.

NIF and Inertial Fusion Energy. While NIF is being designed to achieve ignition, an important milestone for inertial fusion energy (IFE) research, the specific type of laser used by NIF is unlikely to be a candidate for a practical fusion power plant driver, the device that supplies energy to initiate the fusion reaction. Although DOE is currently funding research to develop alternate driver technology, there is no certainty one will emerge that can meet conditions of a practical power plant. Without such assurance, therefore, even successful demonstration of ignition on NIF, prior to alternate driver development, may be for naught as far as development of inertial fusion energy is concerned. On the other hand, proceeding with driver development before demonstration of ignition could also result in misallocated resources. If ignition cannot be achieved at conditions that would allow a practical fusion reactor, then a feasible driver candidate could be of little value.

A potential added complication is the emergence of the National Nuclear Security Administration (NNSA). This organization, which was mandated by Congress in the FY2000 defense authorization act (P.L. 106-65, H.Rept. 106-301), might create added organizational barriers between the defense and civilian activities within DOE.⁸⁹ If so, coordination between the civilian and defense inertial confinement fusion research efforts might be made more difficult. Recently, however, DOE announced the formation of a “Heavy Ion Fusion Virtual National Laboratory (VNL)” involving three of the DOE labs including LLNL.⁹⁰ The purpose of the collaboration is to conduct research on heavy-ion drivers for inertial fusion energy applications. Such an agreement might serve as a means to smooth the passage for future inertial fusion energy research involving NIF.

Outlook for the 107th Congress. The limitations on spending for the NIF project imposed by the FY2001 DOE appropriations and Defense authorization acts (see above) ensure that Congress will continue to monitor this project closely during the 107th Congress. The primary focus will probably be how DOE is performing in meeting the changes in the project baseline announced on September 15, 2000. In addition, there is likely to be close oversight of DOE’s efforts to resolve the remaining technical problems with the project. Of particular interest are the consequences of any actions on the eventual cost and effectiveness of NIF. Besides the management and technical issues, the role of NIF in the stockpile stewardship program may be raised in the 107th Congress. As noted above, questions to this effect were raised during the 106th Congresses review of the difficulties encountered by the NIF project.

Any assessment of the stockpile stewardship program as a whole is also likely to consider the need for NIF.

Conclusions

The importance of NIF to the Stockpile Stewardship and Management Program makes it difficult to separate decisions about NIF from decisions about the entire program. If one agrees that the SSP as defined by DOE is both feasible and

⁸⁹Congressional Research Service, *Department of Energy: programs and reorganization proposals*, by Carl Behrens and Richard Rowberg, RL30307, Oct. 28, 1999.

⁹⁰Fusion Power Associates, “Heavy Ion Fusion VNL,” FPN00-20, April 5, 2000, [<http://aries.ucsd.edu/fpa/fpn00-20.shtml>].

necessary, then NIF now appears necessary to achieve the program's goals, particularly if it achieves ignition. Without NIF or nuclear testing, there currently does not appear to be any way to examine important aspects of nuclear weapon physics critical for the computer codes designed to simulate nuclear weapons or to carry out complete validation of those codes. If one believes that the SSP is either not feasible or not needed, however, then NIF could be called into question.⁹¹ If NIF were not needed to assure a credible nuclear weapons stockpile, then it would have to be evaluated on the merits of its civilian scientific applications. While those areas appear to be important, the project's high cost would make it difficult to justify solely as a civilian scientific research instrument.

The recent problems with NIF have added considerably to the controversy surrounding the project. With a cost overrun of nearly 60%, it is difficult to see how completion of NIF could be funded from existing stockpile stewardship funds. Indeed, actions by Congress for FY2001 are providing additional funds although not the entire increase requested, however, do not suggest that additional funds will be easily forthcoming. While the current sentiment is to build NIF to its original design specifications, it is possible that the laser will be scaled back. If the cost overruns are even greater than now estimated, if the technical challenges with the laser optics are more daunting than now appears, and/or confidence in ignition with a lower number of beams grows, pressure could mount to reduce the scope of the project.

At this point, it is unclear how extensive any action on NIF by the 107th Congress will be. The 106th Congress did agree that the project was necessary and approved most of the adjustments requested by DOE. There has been no indication thus far that the 107th Congress may have a different view of NIF. If the new project management demonstrates that it has control of the project and meets the revised schedule, and if good progress is made in resolving the technical issues, then it is likely that oversight will be confined to the review of the budget request. If new problems emerge, however, it is likely that the entire project will be subject to extensive review and possible modification.

⁹¹ For a description of other options for stockpile stewardship see Congressional Research Service, *Nuclear Weapons Stockpile Stewardship: Alternatives for Congress*, by Jonathan Medalia, CRS Report 96-11 F, December 14, 1995.