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Report to the Committee on Science, House of Representatives

August 2000

NATIONAL IGNITION FACILITY

Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays

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Abbreviations

DOE	Department of Energy
ICF	Inertial confinement fusion
NIF	National Ignition Facility

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The Honorable F. James Sensenbrenner, Jr.
Chairman
The Honorable Ralph M. Hall
Ranking Minority Member
Committee on Science
House of Representatives

The University of California, under contract to the Department of Energy (DOE) to operate DOE's Lawrence Livermore National Laboratory in California, is building the National Ignition Facility (NIF) at the Laboratory. In this stadium-sized laser facility, DOE's goal is to produce intense pressures and temperatures that may, for the first time, simulate in a laboratory the thermonuclear conditions created in nuclear explosions. If successful, NIF would allow scientists to evaluate the behavior of nuclear weapons without explosive testing.

DOE considers NIF an essential component of its multibillion-dollar Stockpile Stewardship Program, which is responsible for ensuring the safety and reliability of nuclear weapons in the absence of nuclear testing.[1] Stockpile Stewardship entails building and operating science facilities in addition to NIF, replacing aging laboratory and production plant infrastructure, and refurbishing weapons in the stockpile. DOE has experimental facilities to support Stockpile Stewardship in all three of its defense laboratories: Lawrence Livermore, Los Alamos National Laboratory in New Mexico, and Sandia National Laboratories in New Mexico and California. In addition, NIF will be used to address basic and applied science issues in areas such as astrophysics, materials properties, and fusion research.[2]

[1]On July 3, 1993, President Clinton announced that the United States would no longer conduct nuclear tests, as a result of the Cold War's end and the desire to reduce the threat of nuclear weapons. As an alternative to such testing, DOE created the Stockpile Stewardship Program to certify that nuclear weapons are safe and reliable.

[2]Fusion results when light atoms, such as isotopes of hydrogen, are combined under very high temperatures and pressures to make heavier ones, such as helium. Fission is the opposite: It starts with very heavy atoms, such as uranium, and splits them into two or more pieces called fission products. Both fusion and fission release large quantities of energy as heat or radiation. Heat energy can be converted into steam to generate electricity.

NIF was originally expected to cost about $2.1 billion when completed in 2002. In 1997, DOE approved a $100 million increase and delayed completion until 2004. In September 1999, DOE announced that NIF would cost up to $350 million more and be completed in 2006. In the wake of these reports, you asked us to

- determine the magnitude of NIF's cost and schedule overruns,
- document the reasons for these cost and schedule problems,
- assess the effects of NIF's cost and schedule on other weapons and science programs, and
- evaluate DOE's and Lawrence Livermore's actions to correct these problems.

To address these objectives, we (1) examined the reviews of NIF conducted by DOE and its advisory board, the University of California, and by Lawrence Livermore Laboratory's advisers and (2) analyzed NIF cost data from DOE, Lawrence Livermore, and other DOE laboratories conducting research in support of the project. We also conducted extensive interviews with Lawrence Livermore and DOE officials responsible for NIF and with officials from other DOE laboratories and scientific institutions whose programs are affected by NIF. Appendix I describes our scope and methodology in more detail.

Results in Brief

DOE and Lawrence Livermore now estimate that NIF will eventually cost about $3.3 billion and will be completed in 2008. These new estimates mean NIF will cost over $1 billion more than originally planned and take 6 years longer to complete. However, on the basis of our analysis of figures from DOE and Lawrence Livermore, we estimate that NIF's cost is closer to $4 billion because DOE's estimate does not include all research and development costs from other program areas that are needed to support NIF. Furthermore, since significant research and development activities to support NIF remain to be completed and technical uncertainties persist, the cost of NIF could grow even higher and completion could take even longer.

Our estimates of NIF's costs are based on DOE's "interim" report to the Congress made on June 1, 2000. Last September, a congressional appropriations conference committee directed DOE to present a NIF cost and schedule plan with supporting details by June 1, 2000, or prepare to terminate the project. But DOE said that it was unable to present a "final"

plan until mid-September 2000. DOE's "interim" report did not contain details on NIF's costs and schedules.

NIF's cost increases and schedule delays were caused by a combination of poor Lawrence Livermore management and inadequate DOE oversight. Troubles began when Lawrence Livermore officials planned, and DOE approved, a NIF budget and a construction cost contingency that were inadequate, virtually ensuring that NIF would exceed cost and schedule estimates. The project manager put in charge of NIF had little experience directing large projects and had no control over separately funded laser research and development programs that were essential for NIF's success. This resulted in a poorly integrated management team. Furthermore, the Laboratory's former laser director, who oversaw NIF and all other laser activities, assured Laboratory managers, DOE, the university, and the Congress that the NIF project was adequately funded and staffed and was continuing on cost and schedule, even while he was briefed on clear and growing evidence that NIF had serious problems. DOE's inadequate oversight contributed to these problems by failing to uncover the increasing costs and delays in schedule until more than 6 months after they were first documented within the Laboratory. A number of key DOE program officials in headquarters and at the Laboratory told us that while they suspected NIF problems earlier, they did not take aggressive action to force the Laboratory to address these problems sooner. Since NIF's beginning, the absence of effective independent reviews has enabled the project's costs and schedules to grow undetected by DOE program officials at headquarters and at Lawrence Livermore. Furthermore, none of these reviews has examined both the construction project and its supporting research and development activities.

Paying for NIF's cost overruns has broad implications for DOE's nuclear weapons program. The Secretary of Energy has said he wants to complete NIF but will not ask the Congress for additional appropriations to pay for NIF's cost increases. Instead, he announced that the Department will pay for NIF's overruns by reallocating funds from within DOE's existing nuclear weapons budget. However, DOE has not fully disclosed which programs will be cut to pay for NIF, nor when or how this will be done. Nor has DOE evaluated how this reallocation will affect components of the nuclear weapons program that might be eliminated, reduced in scope, or extended in order to fund NIF. DOE tried but was unable to secure agreement among its three weapons laboratories that will use NIF—Lawrence Livermore, Los Alamos, and Sandia—about how, when, or at what cost NIF should be completed. Consequently, DOE's June "interim" cost and schedule plan was

not developed by taking into account the many potential impacts on DOE's nuclear weapons program. In addition, because DOE has not determined how it intends to pay for NIF's cost overruns, the potential impacts on other science programs are unknown.

While Lawrence Livermore and DOE have made changes to improve NIF management and strengthen oversight, concerns remain about NIF's cost and technical uncertainties, the absence of an independent review, and the impact of paying for NIF's cost overruns on the Department's nuclear weapons program. To ensure that DOE has an effective independent assessment of NIF, we recommend that the Secretary of Energy arrange for an outside scientific and technical review of the technical challenges remaining for NIF that could affect the project's cost and schedule risks. To ensure an appropriate balance between NIF and the rest of the nuclear weapons program, we further recommend that the Secretary of Energy not reallocate funds from the nuclear weapons program to pay for NIF until DOE (1) evaluates the impact of the current cost and schedule plan, as well as any other options for NIF, on the overall nuclear weapons program and (2) certifies that the selected NIF cost and schedule plan will not negatively affect the balance of the Stockpile Stewardship Program.

Background

NIF's primary mission is to support DOE's Stockpile Stewardship Program, which is intended to maintain the nation's nuclear arsenal indefinitely through scientific research and periodic weapon refurbishment. In 1990, the National Academy of Sciences recommended that DOE build a laser capable of simulating thermonuclear conditions, which would allow nuclear weapons scientists to evaluate nuclear weapons' behavior without testing. In 1993, DOE approved plans for the laser, now called the National Ignition Facility, and in 1996, chose to build it at Lawrence Livermore National Laboratory in Livermore, California. DOE has two other weapons laboratories that also perform essential research in support of maintaining the safety and reliability of the nuclear weapons stockpile: the Los Alamos National Laboratory in New Mexico and the Sandia National Laboratories in New Mexico and California.

The NIF project was originally approved in 1995 at a cost of $1.1 billion, excluding another $1 billion in related research and development costs and program funding, for completion in 2002.[3] Increases approved in 1997 brought the project cost to $1.2 billion, with completion in 2004, which is the current approved baseline. DOE now estimates that NIF project costs will be about $2.2 billion, with completion delayed until 2008.

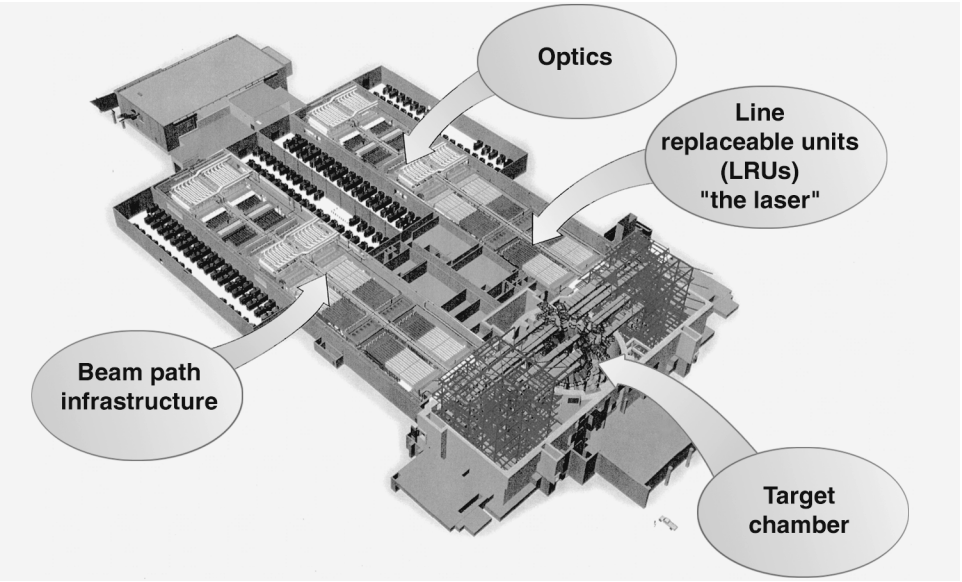
The stadium-sized NIF (85 by 200 meters) will focus 192 laser beams on a tiny capsule of nuclear fuel, compressing it by pressure. If NIF achieves its ultimate goal, the compressed nuclear fuel will "ignite" to release more energy than was added and simulate conditions during a thermonuclear explosion. Achieving ignition is an important goal in certain types of weapons physics experiments and is important for understanding basic fusion science. Achieving ignition is not expected until 2010, or about 2 years after NIF begins full operations. Originally, Lawrence Livermore estimated it would achieve ignition by 2003.[4]

NIF, when completed, will be nearly 60 times as powerful as any previous laser. As shown in figure 1, NIF has many different components. It is composed of a conventional facility, or building; the laser beam path infrastructure, which includes supporting structures, vessels, cabling, and utilities; the laser, which includes thousands of glass and optical components; and a target chamber surrounded by lenses known as "final optics."

[3]Completion occurs when the building, infrastructure, laser systems, and optical components are installed. At that point, experiments can begin.

[4] In commenting on a draft of this report, DOE said that 2004 would be the earliest year for gaining ignition.

Figure 1: The Completed National Ignition Facility



Source: DOE.

NIF is managed by DOE's Inertial Confinement Fusion Program, which is part of the agency's Office of Defense Programs.[5] This office conducts essential research for the NIF effort. According to DOE plans, about 85 percent of the facility's experiments will be for nuclear weapons physics. The remaining experiments will be for nuclear weapons effects and basic and applied sciences. DOE's Oakland Operations Office is responsible for day-to-day oversight of NIF and is expected to ensure that the Laboratory is meeting its contracting responsibilities. The Oakland office also prepares the Laboratory's annual performance appraisal. For the NIF project, Oakland staff also review monthly and quarterly Laboratory progress reports and transmit them to DOE headquarters for review. The University of California manages the Laboratory for DOE and reviews Laboratory performance annually as part of its oversight role.

[5]During our review, the National Nuclear Security Administration was created and assumed responsibility for DOE's Defense Programs (including the Stockpile Stewardship Program and NIF), effective March 1, 2000. The stockpile stewardship activity was reorganized and renamed. Since our work was performed before and after these administrative changes were occurring, for clarity we refer throughout this report to the organization and terminology in use before the changes took place.

NIF's Cost Overruns Could Grow

Using preliminary projections by DOE and Lawrence Livermore, we estimate that the total cost of building NIF is about $3.9 billion, when all supporting research and related program activity costs are included. Moreover, because significant research and development remains to be completed, the cost of completing NIF could grow even higher. DOE has not provided details on how much NIF will cost each year, how cost increases will be paid for, or what existing programs and activities will be cut to fund NIF in the future. DOE knew in June 1999 that a new NIF cost and schedule was needed, and a congressional appropriations conference committee directed DOE to present a new cost and schedule plan by June 1, 2000. However, DOE provided only "interim" estimates on June 1, 2000, and announced it will give the Congress a "final" cost and schedule plan by mid-September 2000.

NIF's Total Cost Is Likely to Reach $3.9 Billion, With Completion Delayed 6 Years

We estimate that, on the basis of DOE and Laboratory data, NIF's total cost could reach at least $3.9 billion. Although DOE's June 2000 "interim" NIF cost estimate is about $3.3 billion, we identified additional costs of over $600 million that directly support the completion of NIF and should be considered part of its total costs. As shown in table 1, DOE's latest estimate includes $2.12 billion for total project costs (funds for construction activities associated with the NIF building and its contents) and $1.14 billion for research and development and related program funds that directly support NIF (drawn from DOE's Inertial Confinement Fusion Program).

Although DOE officials included most of the supporting research and development and related program funds as part of the Department's June 2000 "interim" estimate, they did not include all supporting costs. Specifically, they excluded costs for designing and fabricating a NIF target and funds directly contributing to the NIF effort at other laboratories and contractors.[6] DOE officials told us that funds for developing a NIF target are more of a weapons research concern and therefore should be considered outside the program. Since these funds are necessary for NIF's success, we believe they should be included in any discussion of total NIF costs. The costs for designing and fabricating a NIF target ($491 million)

[6]Participating Internal Confinement Fusion contractors besides Lawrence Livermore National Laboratory are Los Alamos National Laboratory, Sandia National Laboratories, the University of Rochester, and General Atomics.

and NIF support costs from other laboratories and contractors ($136 million) should be added to DOE's estimate, according to our analysis of Laboratory costs and discussions with the individual laboratories contributing to the NIF effort. As shown in table 1, this would bring the total estimated cost of completing NIF to about $3.9 billion.

Table 1: NIF's Estimated Cost and Schedule Changes

Dollars in billions

Baseline change	Project costs	Supporting research and development and related program funds	Total costs	Fiscal year of completion
1995 Original baseline	$1.07	$1.00[a]	**$2.07**	2002
1997 Baseline change	1.20	1.04[a]	**$2.24**	2004[b]
2000 Estimates—DOE (6/1/00)	2.12	1.14	**$3.26**	2008
2000 Estimates—GAO (6/1/00)	2.12[c]	1.77[d]	**$3.89**	2008[e]

[a]1995 and 1997 costs are GAO estimates based on available Laboratory data.

[b] DOE defined completion in the 1997 baseline as occurring in fiscal year 2003, when half of NIF's beams become operational. This baseline assumed all 192 beams would be operational in fiscal year 2004.

[c]We did not assess the accuracy of DOE's estimates of project costs ($2.12 billion), supporting research and development (R&D) and related program funds ($1.14 billion).

[d]Includes the following additions to DOE's 6/1/00 estimate: $491 million for target physics and $136 million for direct support of NIF by other DOE laboratories and inertial confinement fusion contractors.

[e]We did not assess the accuracy of DOE's revised completion date.

Technical Uncertainties Could Drive NIF Costs Even Higher

Unresolved technical problems may further drive up the cost of NIF. A November 1999 review by a technical subgroup to Lawrence Livermore's advisory panel (the NIF Council[7]) highlighted several technical problems that must be solved for NIF to operate as planned.[8] The most challenging technical issue raised by the subgroup is the need to develop optical components that can withstand the laser's powerful beams as they reach the spherical target chamber. When operating, the laser beams focus on a system of glass lenses that surround the target chamber. These lenses must be able to withstand high levels of intense ultraviolet energy. Several Laboratory officials agree that lenses for the target chamber pose a major technical challenge and that there is currently no solution to this problem. So serious is this issue that the subgroup recommended that NIF scientists should be thinking "out of the box" for design alternatives. A May 2, 2000, technical review by another NIF Council subgroup also noted that the optical lenses remain an unresolved issue. Unless the Laboratory can fabricate lenses to withstand the enormous energy from the laser beams, the lenses will have to be replaced more often, making laser operation at high power levels much more expensive than planned.

Substantial technical and cost uncertainties also persist in the research and development needed to design and build a target for NIF's laser beams, according to the NIF Council and its subgroups. Still to be determined are physics and engineering issues for designing and fabricating a NIF target. The NIF Council's May subgroup report noted that fundamental work also remains on this technical issue.

The NIF Council and its subgroups have all concluded that the difficult technical issues facing NIF pose serious challenges but should not present insurmountable obstacles to completing the project. Laboratory officials said that they are confident that all these difficult technical challenges can be solved and noted the Laboratory has met other NIF technical challenges successfully.

[7]The NIF Council, which advises the Laboratory on NIF-related issues, is composed of leading experts on lasers from academia, government, and scientific institutions. It has recently been replaced by the NIF Programs Review Committee.

[8]*NIF Technology Review*, Technology Resource Group of the NIF Council (Nov. 4, 1999).

In its January 2000 interim report on NIF, the Secretary of Energy Advisory Board NIF Laser System Task Force also noted the technical issues cited by the NIF Council and acknowledged that technical issues still remain that will require significant attention. However, it stated that these issues should not prevent the completion of NIF.[9] Although both the NIF Council and the Advisory Board's task force expressed confidence in the Laboratory's ability to solve its remaining technical problems, neither group speculated on the risks posed by the many technical uncertainties, nor estimated their impact on future costs and schedules.

DOE's Cost and Schedule Plans for NIF Are Not Complete

The details of DOE's June 1, 2000, NIF cost estimates are sketchy, even though DOE senior officials learned in late June 1999 that NIF was over budget and behind schedule and that a new cost and schedule plan was needed. In its September 1999 report on energy and water development appropriations for fiscal year 2000, the conference committee directed DOE to submit a new cost and schedule by June 1, 2000, after declaring "disappointment" at learning of NIF's cost overruns and schedule delays.[10] The committee also directed that if DOE could not prepare a new cost and schedule by this date, it should develop a plan for terminating the NIF project. However, DOE's June 1, 2000, report provided only "interim" figures for a new NIF cost and schedule and no termination plan. DOE did not provide annual funding profiles for its cost and schedule plan, stating only that it will seek "up to" specific amounts in fiscal years 2002 to 2005 ($130 million to $150 million), and "additional funds as needed" to complete the project in later years. DOE officials also did not disclose the programs from which NIF increases will be funded or the impacts of these changes. DOE promised to submit a "final" plan to the Congress by mid-September 2000. This final plan, according to DOE, will include cost and schedule estimates with supporting details on annual funding requirements, funding sources, and deadlines, and an independent cost analysis. On June 27, 2000, DOE submitted a revised budget request for fiscal year 2001 that provides more cost information but does not give many details beyond fiscal year 2001.

[9]On October 6, 1999, Secretary Richardson requested that the Secretary of Energy Advisory Board form a task force to review the engineering and management aspects of the assembly and installation of the NIF laser system. The task force is composed of board members and individuals with expertise in systems engineering, laser science, and project management. It issued an interim report on January 10, 2000.

[10]H.R. Rep. No. 106-336, at 96-97 (1999).

Management and Oversight Weaknesses Led to Cost Overruns and Schedule Delays

NIF's cost increases and schedule delays were caused by poor Laboratory management, which included weaknesses in planning, budgeting, and project 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. Standards we have developed require federal agencies to establish and maintain an effective system of internal controls over their operations.[11] Such a system is the first line of defense in safeguarding assets and preventing and detecting errors. Under our standards, managers should, among other things, ensure that their staff have the required skills to meet organizational objectives, that the organizational structure clearly defines key areas of authority and responsibility, that progress be effectively measured, and that operations be effectively monitored. These conditions were not present in the way NIF was managed by the Laboratory and overseen by DOE.

Planning and Budgeting Deficiencies

Laboratory managers told us that NIF will cost more and take longer because they (1) had not planned for the complexities associated with assembling and installing the highly intricate and tightly packed network of laser beams in a structure that requires high cleanliness standards and (2) underestimated the cost of building major laser components. These results occurred, according to Laboratory officials who examined the project, because the original NIF managers lacked adequate project management capabilities and, in particular, had no systems engineering focus within the NIF management hierarchy. As a result, these managers did not properly identify the full scope of the NIF effort and had greatly underestimated the project's engineering complexities. On the basis of our discussions with current and former DOE officials, Laboratory managers, and other experts, we believe several additional reasons contribute to NIF's cost overruns and schedule delays. For example:

- DOE and Laboratory officials initially developed a budget for the NIF project that was clearly inadequate, given its technical risks, complexity, and large size. DOE and Laboratory officials associated with NIF told us that they recognized it would cost more than planned but that they accepted this unrealistic budget in the belief that the Congress would not fund NIF at a higher cost and that the value of NIF to the future of

[11] *Standards for Internal Control in the Federal Government* (GAO/AIMD-00-21.3.1, Nov. 1999).

the Laboratory overshadowed potential cost concerns. Current and former DOE and Laboratory officials also told us that NIF would help the Laboratory maintain its nuclear weapons and science capabilities and attract new scientists.

- DOE and Lawrence Livermore used a construction budget contingency of 15 percent, which is now widely recognized by DOE and the Laboratory as being too low for such a complicated project. Contingencies are an essential planning factor in any construction project, allowing for unanticipated cost increases. The NIF Council and an independent engineering firm indicated that a 25- to 35-percent contingency in the beginning of the project would have been more realistic given the risks associated with NIF. DOE guidelines suggest a 20- to 40-percent contingency, depending on project complexity.
- After the project was approved, Laboratory officials began construction in tandem with essential research and development. While such a "fast-track" strategy is successful on projects with well-defined costs and designs and with little technical complexity, the NIF project does not meet these conditions. Starting construction early can save costs initially but is more costly if extensive changes are needed later. For NIF, the fast-track approach may have caused the Laboratory to focus too much attention on meeting construction goals at the expense of conducting and integrating necessary research and development solutions. DOE and Laboratory officials acknowledge that this approach affected basic construction decisions on the size and design of the facility and eventually led to cost increases and delays when changes had to be made to accommodate the results from subsequent research and development.
- According to Laboratory officials, to cut costs early in the project, they considered, but rejected, hiring outside industrial engineering firms to manage major parts of NIF construction. Such firms could have provided the experience to manage this large project, especially for assembling laser components with exacting cleanliness standards, such as those in the semiconductor assembly industry. The Laboratory is now contracting with such firms to help complete NIF.

Unrealistic budgets, a low contingency, and the fast-track construction strategy imposed substantial cost pressures that affected project management decisions. The NIF Council criticized Laboratory officials for failing to develop engineering prototypes that could have tested various NIF components and technologies before planning to assemble them—a strategy rejected, in part, because of cost pressures. For example, according to the Council, to save money, Laboratory managers dismantled

a laser scientific prototype—called the Beamlet—that would have been useful for conducting experiments on technical problems now affecting NIF.

Weak Laboratory Project Management

After DOE approved NIF in 1993, the Laboratory did not appoint project managers with the management and technical expertise needed for such a large and complex undertaking and failed to install an effective reporting structure that could have flagged emerging technical issues and project risks. For example:

- The NIF Project Manager originally selected had no previous experience managing large projects, and other managers had little or no expertise in lasers, hindering their ability to understand the significance of some problems as they arose. Furthermore, the project lacked a chief engineer, whose responsibilities could have focused on integrating the construction project with needed research and development efforts.
- The NIF Project Manager held a relatively low position in the Laboratory's organization. Despite the NIF project's high profile and its critical importance to the future of the Laboratory and to DOE's Stockpile Stewardship Program, the NIF Project Manager reported to a Deputy Associate Director who, in turn, reported to the Associate Director for Laser Programs, who then reported to the Director of the Laboratory. A separate manager was in charge of the inertial confinement fusion (ICF) research and development programs, which were crucial to the success of NIF. The NIF project manager and the ICF research manager each reported on different milestones. No one coordinated the two efforts or estimated how one program's missed milestones could affect the other program or the overall NIF effort. Both the project and research and development managers filed separate progress reports, and no one at the Laboratory or DOE assessed the impacts of problems and risks on projected budgets and schedules.
- Senior officials from Lawrence Livermore, the University of California, and DOE concluded that the NIF managers were overconfident about their own abilities to solve project problems. These officials now acknowledge that they should not have placed as much trust in the NIF managers and that the Laboratory's "can-do" culture prompted the NIF managers to convince themselves, then DOE and others, that they needed no outside help to successfully build NIF. The Laboratory's former top laser manager embodied this self-reliant attitude and was very persuasive in convincing others that NIF would be built within cost and schedule. In its review of NIF, the Secretary's Advisory Board task

force reported that DOE's weapons laboratories "have a tendency not to flag problems to the outside world, where they actually might find counsel and help, but rather prefer to go it alone for periods too long."

Inadequate DOE Oversight Allowed Problems to Worsen

DOE acknowledges that its managers in headquarters and at the Laboratory site office did not properly oversee NIF and, as a result, remained unaware of major cost and schedule problems until several months after Laboratory managers had first documented them. As a result, the Laboratory continued to present—unchallenged by DOE—an inaccurate picture of NIF's progress.

Several reasons help to explain DOE's oversight weaknesses. At the core of DOE's problems is its historical reliance on contractors to conduct the Department's missions in the absence of an effective oversight process and structure. For example, in response to the charge by outside reviewers of DOE's "micro-management," the Department, in the mid-1990s, shifted from a "compliance-based" to a "performance-based" management style. DOE's Oakland Operations Office, which is directly responsible for NIF, explained to us in 1997 that it had changed its "approach to oversight." The old approach "relied on DOE identifying problems and solutions" while the new approach "relies on [the] contractor identifying problems and solutions."

In addition, the Department lacked staff with sufficient management and technical skills to properly oversee NIF's managerial and technical complexities. Neither DOE headquarters staff nor field managers were skilled in managing large projects, nor did the field staff have technical proficiency in laser operations. Also, these staffs' oversight roles were diluted by other competing responsibilities—neither headquarters staff nor field managers were full-time NIF overseers. Only four DOE on-site technical staff worked on NIF oversight, along with one senior headquarters manager, and each had other duties.

To gauge NIF's progress, DOE relied heavily on Laboratory-prepared monthly and quarterly NIF reports. However, the reports did not reveal emerging cost and schedule problems, even though they required an assessment of project risk. These progress reports conveyed project status for senior DOE officials, based on criteria developed jointly by DOE and the Laboratory. The progress reports focused mainly on meeting construction and research milestones, not on linking specific successes and failures to impacts on future milestones, the budget, or the overall

project schedule. The reports also did not identify significant technical or managerial risks facing the project, even when these were recognized by senior project managers. Moreover, the Laboratory downplayed potential problems in its reports, hoping that as problems emerged they would be resolved quickly.

There was not a clear chain of command between DOE's headquarters and its on-site field office at Lawrence Livermore, thereby diffusing accountability for NIF. DOE's Defense Programs funded NIF and assigned a project director in headquarters, who provided Laboratory managers with programmatic direction. Day-to-day supervision of NIF, however, was assigned to a project manager from DOE's field office located on site at Lawrence Livermore. However, this field office manager reported to another part of DOE—the Office of Science—and not to the project director in Defense Programs.[12] While a 1997 memorandum of understanding defined the field project manager's responsibilities, it left unchanged the misdirected reporting to Science rather than Defense officials in Washington, D.C., who were responsible for the project. Laboratory officials said that they considered DOE's chain of command confusing and really did not know to whom they reported on a day-to-day basis. Because of this confusion, the DOE field manager had difficulty in taking active control of a project that fell outside of his chain of command. When suggesting revisions to the memorandum of understanding in 1998, DOE's field manager noted that the memorandum continues to serve a useful purpose in the "absence of consistently accepted understanding of the roles of HQ and the Field."

While DOE managers were hampered by their own technical, managerial, and organizational weaknesses, they missed opportunities to enforce Laboratory accountability. For example:

- DOE officials did not aggressively act on their own suspicions. DOE field and headquarters officials told us they started suspecting NIF cost and schedule problems early in 1999 but then allowed the Laboratory's monthly and quarterly reports, which were reviewed and approved by on-site DOE staff, to continue reporting satisfactory progress until June 1999. These DOE officials, including both headquarters and field staff,

[12]We previously highlighted weaknesses in DOE's chain of command. See *Department of Energy: Views on DOE's Plan to Establish the National Nuclear Security Administration* (GAO/T-RCED-00-113, Mar. 2, 2000).

did not aggressively pursue their suspicions by demanding more information in progress reports or by alerting senior DOE officials to potential problems. When the Secretary of Energy visited the Laboratory in early June to dedicate the NIF target chamber—and declared NIF to be within budget and on time—many DOE staff already knew that NIF had cost and schedule problems.

- DOE's Office of Field Management, a headquarters office that was responsible for, among other things, preparing status reports for senior DOE managers on large construction projects, raised management issues regarding NIF that were largely ignored by NIF program managers in headquarters. In June 1999, as a result of growing concern with NIF, this office proposed a management action plan for NIF that recommended DOE track eight different elements, including status measures, risk assessments, pending actions, and completion dates. The office was abolished in June 1999 as part of a broader DOE reorganization. Its functions were transferred to other parts of DOE, but the recommendation was never acted upon.
- DOE negotiated a contract with the University of California that placed little emphasis on NIF performance, even though the project dominated the Laboratory's budget and mission. Also, DOE's evaluation of the Laboratory's performance did not reflect NIF cost and schedule problems. As late as August 1999, the Laboratory's self-evaluation claimed "outstanding" performance for the Laser Directorate, which included NIF. This score contributed to an overall DOE score for the Laboratory of "excellent." The Laboratory's performance fee is based on these scores.
- DOE did not enforce the requirement that the Laboratory update its estimates for the project's total cost and schedule in its monthly and quarterly reports. Enforcing this requirement could have revealed growing cost and schedule problems months earlier, giving DOE and Laboratory officials more time to prepare a new baseline.

Independent Review Mechanisms Did Not Work

The absence of effective independent reviews to ensure that project risks were recognized and addressed in a timely and effective manner was a major flaw in how DOE and the Laboratory managed NIF. Attempts to provide independent reviews all had limitations. For example:

- In 1996, the Laboratory established the NIF Council as an advisory group to provide Livermore staff with technical advice; however, this group was not independent. Members were chosen by the Laboratory's senior laser manager, who also prepared its charter, and received and

responded personally to its reports. Some NIF Council members described themselves to us as "friendly advisers" rather than as independent overseers. Although the Council provided valuable advice on wide-ranging technical issues, its members were unaware of the project's cost and schedule problems for many months. Also, the NIF Council was not aggressive in providing managerial advice, although this was one of its charter responsibilities.

- To fulfill a congressional request that DOE contract for independent reviews of its projects, a NIF review was conducted in early 1999, but the contractor performing the review did not report any significant cost, schedule, or technical issues for NIF.[13] At the time of this review, over two dozen senior NIF managers knew the project faced growing problems that threatened both its costs and schedules, but these concerns were not shared with the reviewers. The contractor's report concluded that NIF was "by far the best managed of any U.S. Government Project" that the contractor had reviewed. DOE's actions may have compromised the contractor's independence. For example, DOE imposed strict time limits on the contractor, which prevented a detailed review. DOE also instructed the contractor to not examine NIF supporting research and development, which was a vital part of the NIF program. We discovered that a DOE manager and the Laboratory's NIF Project Manager edited the contractor's draft report before it was submitted to the Congress. For example, they suggested changes to the final report that had the effect of downplaying the extent to which some research and development tasks remained unresolved and posed cost and schedule risks. Finally, DOE's on-site office at Livermore urged headquarters to discourage the contractor from making a second visit to the Laboratory.

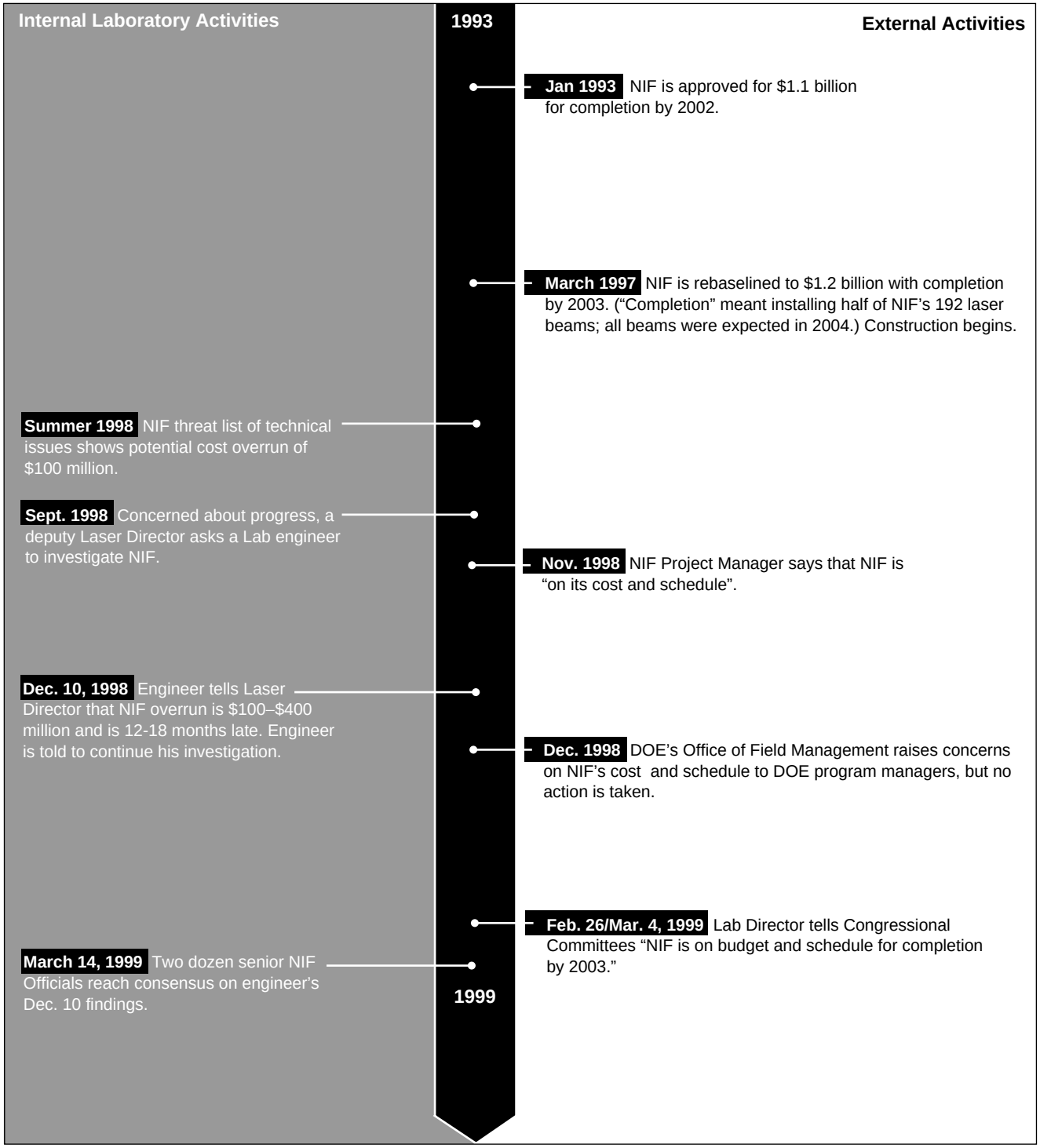
The Laboratory Withheld NIF's Problems From DOE and the University of California

The failure of senior Laboratory officials to disclose technical issues that threatened the NIF project's costs and schedules was a serious error in judgment, according to Laboratory and DOE officials we interviewed. Many Laboratory managers were aware of serious NIF problems months before these became public, yet they told us that they were not in a position of responsibility to report the problems outside the Laboratory. When asked why he did not disclose that a consensus of his senior managers believed

[13] *External Independent Review of the Department of Energy National Ignition Facility Project at the Lawrence Livermore National Laboratory Site, Detailed Review and Assessment Report*. Lockwood Greene Technologies (Mar. 29, 1999).

NIF could no longer be completed within current budgets and schedules, the Laboratory's highest ranking laser manager responded that he first wanted to "validate" the extent of the problems before reporting them to the Laboratory Director, the University of California, or DOE. Even after these problems were validated, the laser manager delayed disclosing NIF's cost and schedule problems. As figure 2 shows, technical issues affecting NIF's cost and schedule were first raised in the summer of 1998, were documented in early December, and were more completely documented and presented to the Laboratory's laser director in March 1999. Yet DOE was not formally told about the significance of these issues until late June 1999. The Secretary of Energy was not made aware of the cost and schedule problems until August 1999, 2 months after he and DOE's Chief Operating Officer had publicly praised NIF's budget and schedule successes.

Figure 2: Timeline of Laboratory's Disclosure of NIF Problems



Internal Laboratory Activities	1999 (continued)	External Activities
		Jan-May, 1999 DOE site officials suspect NIF cost and schedule problems but told by lab that it can solve problems.
		March 29, 1999 A team of Independent reviewers concludes NIF is "by far, the best managed" federal project they have seen.
March 30, 1999 Engineer warns Laser Director that NIF needs $300 million more and 18 months longer. He is told to validate results.		**March 30, 1999** DOE's NIF Project Director asks engineer if NIF has problems he should know about, but hears few details.
Mid April, 1999 Laser Director tells Lab Director that NIF is "getting harder" to keep within cost, but gives no details.		
May 24, 1999 Engineer validates cost and schedule warnings.		
		May, 1999 Quarterly lab review concludes satisfactory progress on all issues, including cost and schedule.
June 9, 1999 Lab Director told of NIF's large cost and schedule problems.		
June 10, 1999 Other senior lab officials briefed on cost and schedule problems.		
		June 11, 1999 Secretary Richardson proclaims NIF on cost and schedule in remarks that surprise Lab officials.
		June 23, 1999 DOE HQ officials briefed on cost and schedule problems.
		July 29, 1999 Lab quarterly review discloses for the first time minor schedule problem with NIF.
		Aug. 15, 1999 Lawrence Livermore sends it's annual self-assessment to the University of California, claiming NIF is on budget and schedule.
		Aug. 1999 Lab monthly report concludes both NIF cost and schedule are "major" problems.
Oct. 6-7, 1999 NIF Council concludes that meeting original NIF cost and schedule is "unrealistic" given technical and management problems.	2000	
		June 1, 2000 DOE submitted "Interim" report to the Congress on new cost and schedule baselines.
		Sept. 15, 2000 DOE's new date for "final" baseline report to Congress.

NIF's Cost and Schedule Delays Will Affect Weapons and Science Programs

NIF's primary mission is to support DOE's nuclear weapons program—also known as the Stockpile Stewardship Program. This program, which costs $4.5 billion annually, is intended to maintain the nation's nuclear arsenal indefinitely through scientific research and periodic refurbishing of weapons. Three different weapons laboratories—Livermore, Los Alamos, and Sandia—conduct significant weapons-related scientific research. Paying for NIF's cost overruns from within DOE's current nuclear weapons program accounts—as the Energy Secretary has pledged—could significantly affect portions of these laboratories' programs, as well as the Stockpile Stewardship Program as a whole. In developing its new cost and schedule estimate, DOE did not take into account which Stockpile Stewardship Program components might be eliminated, reduced in scope, or extended in order to fund NIF.

NIF's Relationship to the Stockpile Stewardship Program

DOE's Stockpile Stewardship Program is intended to maintain the nation's nuclear weapons in a safe and reliable state through a program of scientific study and periodic refurbishing of the weapons. Currently, the scientific study of nuclear weapons is organized around the concept of "campaigns." DOE describes campaigns as focused scientific and technical efforts to develop and maintain critical capabilities needed to certify that the nation's nuclear weapons are safe and reliable. Campaigns have definitive milestones, specific work plans, and specific end dates. All campaigns have milestones for completing scientific studies by 2005, although some will be completed later, up to 2010. NIF experiments would be useful for a number of campaigns, including the campaigns to (1) certify the yield (explosive energy) in a nuclear weapon's "primary," (2) determine what is needed to produce a militarily effective nuclear weapon's "secondary," and (3) certify that a nuclear weapon can withstand a hostile (i.e., wartime) environment during use.[14]

The other key feature of the Stockpile Stewardship Program is the effort to extend the lifetime of the nation's nuclear weapons through a series of planned refurbishments. These refurbishments will involve disassembling weapons and replacing selected components in order to extend each weapon's life for several more decades. Refurbishments for two weapons

[14]The "primary" is the fission stage of a thermonuclear weapon. Detonated first, the primary produces the extremely high temperatures and pressures required to produce fusion in the weapon's "secondary." The "secondary," or thermonuclear stage, of a nuclear weapon produces its energy through the fusion of deuterium and tritium nuclei.

in the stockpile—the W76 and the W80—are scheduled to begin later this decade. NIF could be useful to the refurbishment process by allowing weapons scientists to study the potential effect of proposed changes on a weapon's safety and reliability.

Stockpile stewardship is being carried out as an integrated program involving the three nuclear weapons laboratories, four production plants, and a test site. Integration can occur on several levels. For example, the three laboratories are expected to share experimental facilities, like NIF, in order to reduce the overall cost of the program. In addition to sharing facilities, the DOE laboratories work together to develop an annual certification to the President and the Congress that the nation's nuclear weapons remain safe and reliable without the use of underground testing.

DOE and its three weapons laboratories believe that NIF is a major component of the Stockpile Stewardship Program. Experiments conducted on NIF are expected to assist in the work of the campaigns as well as in the refurbishment of the stockpile. NIF is also expected to help attract and train new weapons scientists to replace the program's currently aging workforce.

NIF's Delays Will Affect the Timing of Some Experiments

In general, the delays NIF will experience will not affect meeting the campaigns' 2005 milestones since NIF was not expected to be ready in time for those. Some weapons scientists told us that, even before NIF's problems became public, they had already planned alternative experiments in case NIF was not ready on time. However, according to program documents, NIF's delays will in turn delay the achievement of some of the experiments needed for the 2010 milestones by as much as 3 years. With respect to weapons refurbishment, the expected delays in NIF will mean that it will not be available to help analyze the impact of any proposed changes in the W76 or W80 weapons.

Many important experiments can still be conducted on other facilities or on a partially completed NIF. For example, studies of the high-energy density properties of materials used in nuclear weapons can be conducted with only 48 to 96 beams installed in NIF (NIF is designed for 192 beams). This information is vital in modeling the performance of nuclear weapons. Livermore's Target Physics Review Committee, a NIF Council technical subgroup, recommended in May 2000, that while NIF should be completed to its full 192-beam configuration, a first cluster of 48 beams should be given a high priority and brought up for experiments as soon as practical,

both for weapons physics experiments and to attract and retain the best scientists. The former Associate Director for Defense and Nuclear Technologies at Lawrence Livermore told us that while he believes not having NIF available may introduce some risk into the stockpile, this increased risk does not approach any level that would indicate that the stockpile is unsafe and unreliable.

The Budgetary Impact of NIF Could Be Significant

In a September 1999 statement responding to the problems NIF was experiencing, the Secretary of Energy said,

> "I expect all cost issues to be handled within our DOE defense programs and Lawrence Livermore National Laboratory (LLNL) budget funding lines. We will reprioritize our national security program to reallocate dollars, people, and other resources—so the U.S. taxpayer does not foot additional bills because of these problems."

Assuming the Secretary enforces his pledge to fund NIF's cost overruns from the Stockpile Stewardship Program's current budget, significant portions of the nuclear weapons program could be affected. Currently, several DOE officials and veteran weapons experts believe the program is under significant stress as numerous activities compete for its limited budget. These activities include building and operating additional science facilities beyond NIF, replacing aging laboratory and production plant infrastructure, and refurbishing weapons in the stockpile. This stress is expected to increase as the result of increased security requirements, potential new problems with the stockpile, and the need to address the program's aging scientific and production workforce.

DOE has not revealed how it intends to pay for NIF's cost overruns, and Los Alamos and Sandia officials are concerned about how NIF's cost increases will affect the Stockpile Stewardship Program at their laboratories. DOE attempted to gain consensus among the weapons laboratories on a path forward for NIF. An April 2000 "White Paper" signed by DOE and its three weapons laboratories concluded that NIF was important to the Stockpile Stewardship Program, but no agreement was reached on how many beams NIF should have or how it should be funded. The paper's authors explicitly stated that the White Paper

> "does not address the appropriate revised scope for NIF, the schedule for deployment, the proper cost baseline, or the impact on the balance within the Stockpile Stewardship Program. Consequently, concurrence with the views stated here should not be construed as support for any specific path forward or for other yet to be resolved issues."

This lack of agreement regarding how NIF should be developed and funded was echoed in comments made to us by senior weapons scientists at the three laboratories. For example:

- The Associate Director for NIF Programs at Livermore believes that NIF is critical to certifying the nuclear weapons stockpile and supports completing a full 192-beam NIF. In discussions with us, he recognized that NIF is not the only essential facility in the Stockpile Stewardship Program and agreed that the rest of the program should not become unbalanced by funding NIF. He believed Livermore might accept a "pause" in completing NIF of about 3 years at the 120-beam level.
- The Deputy Director of the Nuclear Weapons Program at Los Alamos told us that he believes NIF should be stopped at 48 beams. This level of NIF would support about 80 percent of the experiments the program needs to perform. He believes that funding a larger NIF would seriously unbalance the stewardship program by taking funds away from needed research and production activities. Other Los Alamos weapons scientists also expressed the view that NIF had only a 50-percent chance of achieving ignition.
- The Senior Vice President for Nuclear Weapons Programs at Sandia National Laboratory told us he believes there is no clear role for NIF that requires it to be built to full power immediately. He believes that NIF should be built to a smaller scale—such as 48 or 96 beams—and operated for some period of time before additional investments are made. Taking this approach would allow the NIF program to demonstrate with certainty how much it costs to build and operate NIF.

Senior DOE officials told us that when such fundamental disagreements existed in the past, they would hold a "summit" to reconcile the views. However, according to our interviews with senior DOE officials, the Secretary did not reconcile these views before he made his decision regarding the "interim" cost estimate (rebaseline). The Secretary's rebaseline decision was not made in the context of which stewardship program components might be eliminated, reduced in scope, or extended in order to fund NIF. Rather, the Secretary relied on overall funding options. None of the various rebaselining options considered by the Secretary described what the specific effects would be on the overall stewardship program for fiscal year 2001 and in the future. DOE is still trying to determine how to adjust the Stockpile Stewardship Program for fiscal year 2001 and beyond to pay for NIF.

Potential Impact on Science Programs

The Secretary's pledge notwithstanding, some scientists believe that science programs are vulnerable to budget cuts. DOE sponsors a wide variety of science activities in such areas as high-energy physics, advanced computing, and fusion. Scientists at several universities told us that they believe funding for civilian research may be cut as a result of NIF cost overruns. Several scientists pointed out that each fusion energy experiment may take several years to plan, design, and conduct, requiring a long-term commitment for funding. Budget cuts would delay the development and implementation of these experiments—the very research that in 1990 the National Academy of Sciences recommended NIF be designed to conduct.

Scientists expressed mixed views about NIF's effect on science research schedules. While some scientists told us that schedule problems may delay needed experiments on NIF, others said that delays could actually be beneficial. Delays could provide additional time to observe the initial operations of NIF and to better design and modify planned experiments.

DOE and Laboratory Corrective Actions Are in Process

DOE, Laboratory, and University of California officials are taking several actions designed to strengthen the management and oversight of NIF. Some actions are complete, but most are still under way. Many of these actions address specific deficiencies in existing processes and organizational structures. These actions are encouraging, but implementation has only just begun in many areas, so an assessment of their ultimate value is premature.

DOE Actions

The Secretary of Energy has taken several actions to establish accountability for NIF's problems and to improve DOE's oversight. Stating that he was "deeply disturbed" to learn of NIF's cost and schedule problems and "gravely disappointed" with both the Laboratory and the University of California, he ordered DOE to withhold at least $2 million of the University's 1999 program performance fee in recognition of the "significant mission disruption caused by the project's problem." The Secretary also ordered a report, due later in the year, that can recommend disciplinary action against DOE officials responsible for NIF's mismanagement. Other actions announced by the Secretary include the following:

- creating a new headquarters NIF Project Office whose manager is dedicated to NIF,

- assigning six full-time employees to oversee NIF on site at Lawrence Livermore, and
- placing NIF on the Department's Chief Operating Officer's list of projects that require senior management attention (watch list), where it is subject to more stringent reporting requirements.

NIF has also been designated a pilot project for the new Project Management and Oversight function. DOE intends to hire an outside contractor who will give DOE project management expertise on-site at the Laboratory. This contractor will be paid from the $2 million fee that the University was required to return to DOE. Although not yet fully in place, other key features of this new function include the following:

- creating a headquarters Office of Engineering and Construction Management to provide guidance and expertise on project management,
- developing a career track for project managers, long a weak link in DOE's ability to attract and hire highly qualified project managers, and
- requiring and budgeting for more research and development before committing to major construction funding.

This new project management system will also attempt to establish clearer lines of responsibility from DOE headquarters to the field units that perform day-to-day contractor oversight at major construction projects. This is to be accomplished by requiring that DOE's on-site oversight managers report to the headquarters program offices responsible for the projects, as well as reporting through their field offices. DOE's headquarters chain of command is now more direct for the NIF project. DOE's on-site field manager for NIF will report directly to Defense Programs in headquarters, and DOE has advised us that his performance rating will be the responsibility of Defense Programs in headquarters, not the Oakland Operations Office.

The Secretary of Energy Advisory Board NIF Task Force also made recommendations in its January 2000 interim report. A main recommendation was to have DOE develop intensive internal review processes similar to those used successfully by its Office of Science to track projects for budget and schedule. DOE plans to start this new process in August 2000. The task force also called on DOE to clarify roles and responsibilities between headquarters and field offices and recommended that NIF be completed in phases. DOE is still studying these recommendations.

While improved processes and organizational fixes are helpful, DOE has difficulty implementing management reforms. For example, a 1991 DOE initiative, called the "Financial and Project Management Improvement Program," sought to give line managers early review authority over projects and outlined a plan to hire more well-qualified project managers. DOE acknowledged in 1999 that its project management suffers from "serious systemic issues needing correction." In addition, past DOE reorganizations have attempted to clarify chains of command and upgrade project management skills, also with little success.

Lawrence Livermore Actions

The Laboratory is taking a variety of corrective actions to improve its management of NIF. The original NIF project manager was reassigned to another laboratory, and the Laboratory's laser director resigned. In addition, the University of California did not give its Lawrence Livermore director a salary raise. Other Laboratory actions include the following:

- The Laboratory is reorganizing the NIF project to create clearer lines of responsibility and to better focus on major risk areas. The new structure promises to give the NIF project manager more authority and a more direct line to top management. This new structure could more closely integrate the NIF project with the laser research and development program that supports it. The new project manager has experience with large projects and has appointed a chief engineer.
- The reporting details and procedures for NIF progress reports are being changed to better reflect project risks and their potential impacts on future budgets and schedules. While reporting standards already exist, these new requirements are intended to make the reporting process more accurately reflect the NIF's project status.
- The Laboratory has replaced its NIF Council with a new NIF Programs Review Committee that will report to the Laboratory director, not just the laser director. In turn, the Laboratory director will forward each report to DOE. Laboratory officials told us that they will "invite" DOE to participate in selecting new committee members.

The University of California, as the contractor operating Lawrence Livermore for DOE, maintains its own oversight structure for the Laboratory. In its report on NIF's problems, the University called for clearer roles and responsibilities within the Laboratory, involving the Laboratory director more directly in NIF management, creating a new senior position of associate director for NIF, and improving the Laboratory's communications procedures.[15] The report also called on DOE to demand accountability from the Laboratory. The University has restructured its own advisory council to better oversee all of its national laboratories and has created a new panel on project management. The Laboratory is addressing these recommendations.

Conclusions

DOE, the Lawrence Livermore National Laboratory, and the University of California all share responsibility for NIF's cost and schedule problems. Each lacked the appropriate skills to manage and oversee the project and exercised oversight powers poorly. In addition, inadequate independent reviews enabled the Laboratory to withhold significant information from external reviewers and the Congress for months. The result is a billion-dollar overrun and multiyear schedule delay that could worsen because substantial research and development is still incomplete. Unfortunately, the Congress cannot know with assurance just how much NIF will cost, where in DOE's budget the money will come from, what impact NIF will have on the overall nuclear weapons program, or how long it will take to complete, even though 1-1/2 years have passed since the Laboratory first questioned whether it could meet its most recent cost and schedule.

These conditions have now spawned new reforms by the Laboratory and the University to improve their management and organizational shortcomings. NIF has also taught DOE to continue its efforts at streamlining chains of command between headquarters program offices and field management units. But the Department must work hard to hire—and retain—competent project managers. Also, since construction began, the NIF project has not been subject to a comprehensive and effective independent review that covers both the project and its supporting research and development activities. DOE must provide for effective independent review of its projects to ensure that it has the best possible

[15] *Report of the University of California President's Council National Ignition Facility (NIF) Review Committee,* University of California (Nov. 18, 1999).

advice on technical and managerial issues and that it is aware of the remaining risks to NIF's cost and schedule.

NIF was designed to be a national facility to support an integrated Stockpile Stewardship Program for maintaining the safety and reliability of the nation's nuclear arsenal. As such, we would have expected any decision about future NIF funding to be made in the context of what stewardship program components might be eliminated, reduced in scope, or extended in order to fund NIF's cost increases, as well as what impact any decision would have on the success of the overall program. The lack of agreement among NIF's users—the nuclear weapons laboratories—about the appropriate path forward indicates to us that considerably more work needs to be done before a final decision on NIF is made. Without such an agreement, the Secretary of Energy is unable to assure himself, and the Congress, that the appropriate cost/benefit trade-off has been made between funds for finishing NIF and funds for the other portions of the Stockpile Stewardship Program needed to maintain a safe and reliable nuclear weapons arsenal.

Recommendations

To ensure that DOE has an effective independent review of NIF, we recommend that the Secretary of Energy arrange for an outside scientific and technical review of NIF's remaining technical challenges as they relate to the project's cost and schedule risks.

To ensure an appropriate balance between NIF and the rest of the nuclear weapons program, we recommend that the Secretary of Energy not reallocate funds from the nuclear weapons program to NIF until DOE (1) evaluates the impact of its cost and schedule plan, as well as any other options for NIF, on the overall nuclear weapons program and (2) certifies that the selected NIF cost and schedule plan will not negatively affect the balance of the Stockpile Stewardship Program.

Agency Comments

In commenting on a draft of this report, DOE raised a number of issues concerning how NIF's costs should be counted and our characterization of the technical uncertainties facing the project. DOE also said that it is already implementing our recommendation for an external independent review and that it has met the "intent" of our recommendation to evaluate the impact of NIF's cost increases and schedule delays on the overall nuclear weapons program.

With respect to the first issue, DOE said that a substantial portion of the cost increases we cited is for developing a target for NIF and that this amount should be not included as part of NIF's construction costs. We are not suggesting that these costs be included as construction costs. But we are suggesting that all NIF costs be identified. Both our figures and DOE's show cost increases in related programs and research and development. To give the Congress a more accurate picture of the total costs associated with the NIF project, the cost of designing and building a target—without which the NIF cannot operate—is an essential component of the entire NIF effort, regardless of its budget account label. In addition, we included costs borne by other laboratories that directly contribute to the NIF effort that are not reflected in the NIF project figures that DOE has prepared.

Concerning our presentation of the project's technical uncertainties, DOE disagreed with our characterization of final stage optics as an unresolved technical risk, noting that problems associated with optics are only an issue of "economics" and that NIF's technical uncertainties are well understood. We disagree. As DOE's own expert reviewers have noted, final optics is NIF's most challenging technical area and remains an unresolved issue. As DOE noted in its letter, if optics cannot be made to withstand NIF's high-intensity lasers, they will suffer damage and will have to be replaced more often. This outcome has the effect not only of increasing NIF's operating costs but also of limiting its performance because fewer laser firings would result for a given operating budget. In addition, as we noted in our report, substantial technical and cost uncertainties persist in the research and development needed to design and build a target for NIF's laser beams.

DOE said that it is implementing our recommendation on the need for an independent scientific and technical review of NIF. DOE also cited a large number of past and ongoing technical and cost reviews of NIF, noting that it has been aggressive in obtaining expert reviews of NIF's technical challenges. DOE also said that it is planning an internal review of NIF in August 2000 that will include an independent cost estimate, and that this review is designed to give the Department "a higher level of confidence" that it can complete NIF as planned. We agree that the technical and cost components of NIF have been frequently reviewed in the past. However, past reviewers did not discover and report on the NIF's fundamental project and engineering problems, bringing into question their comprehensiveness and independence. Also, since cost and schedule problems were first identified in late 1998, there have been no effective independent reviews of NIF that have related technical challenges to its

cost and schedule risks. The internal review DOE is planning for August 2000 resembles the process DOE's Office of Science uses to evaluate its major science projects and has potential for providing valuable insights into technical and managerial issues. However, we believe internal review processes supplement—but cannot replace—the value of a separately conducted scientific and technical evaluation managed by experts outside DOE and its laboratory system.

Finally, DOE also said it has already met the "intent" of our recommendation to evaluate the impact of NIF's funding options on the Stockpile Stewardship Program. DOE stated that its June 1, 2000, "interim" report to the Congress and its fiscal year 2001 revised budget request of June 27, 2000, contain "an option that considers" the impacts of NIF on the overall Stockpile Stewardship Program. However, neither of these reports contains an analysis of the impacts of NIF's cost increases on the balance of the Stockpile Stewardship Program. DOE's June 1 report contained no details on how NIF cost increases will be funded. Its June 27 revised budget request only contains details for fiscal year 2001 on how the Department intends to reallocate funds to pay for NIF's cost increases. These reallocations included reductions in various Stockpile Stewardship Program components managed by Lawrence Livermore and other national laboratories but did not describe how its proposed reallocations and associated delays will affect the Stockpile Stewardship Program's campaigns and their objectives and milestones. In addition, the revised budget request did not describe how paying for NIF affects Stockpile Stewardship Program activities beyond fiscal year 2001. Because this is a long-term integrated program, we believe that the Secretary of Energy needs to present in more detail how planned cuts and delays caused by NIF affect the overall Stockpile Stewardship Program's objectives and milestones. The Laboratory's own technical advisers have recommended that better planning is needed to show how NIF is to be used within the Stockpile Stewardship Program and that such a plan should assess the impacts of delays on both NIF and other Stockpile Stewardship Program facilities.[16]

Appendix II includes the full text of DOE's comments and our response.

[16] *Report of the National Ignition Facility Target Physics Program Review Committee*, May 2, 2000.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Honorable Bill Richardson, Secretary of Energy, and the Honorable Jacob J. Lew, Director, Office of Management and Budget. We will also make copies available to others on request.

If you or your staff have any questions about this report, please call me at (202) 512-3841. Key contributors to this report are listed in appendix III.

Jim Wells,
Director, Energy, Resources,
and Science Issues

Scope and Methodology

To determine the magnitude of the National Ignition Facility's (NIF) cost and schedule overruns, we examined all Laboratory progress reports and quarterly documentation and interviewed Laboratory and Department of Energy (DOE) program officials. We worked closely with budget officials from each of the three defense laboratories to determine the amount of their funds that supported the NIF project. From these discussions, we constructed a detailed table of NIF's costs.

To document the reasons for the cost and schedule problems, we examined past reviews of NIF, including those conducted by the University of California and the Secretary of Energy Advisory Board Task Force on NIF. We also held extensive interviews with the authors of these reviews. We also interviewed all former and current project managers and past senior managers at DOE and the Office of Management and Budget. We also examined documents from the NIF Council and interviewed its members on several different occasions. We also interviewed senior budget officials from DOE and officials from the now defunct Office of Field Management. These individuals provided us with substantial documentation of past reviews of NIF's progress.

To assess the impacts from the problems, we interviewed a wide range of scientists from Lawrence Livermore, Los Alamos, and Sandia national laboratories. We also interviewed past and current officials and scientists from universities and from private interest groups.

To evaluate DOE and Laboratory actions to correct these problems, we examined the previously mentioned reviews and interviewed the authors of these reviews. This included interviewing officials from the University of California and Lawrence Livermore Laboratory. We also attended each of the four Secretary of Energy Advisory Board meetings on NIF and interviewed members of the board to ascertain their understanding of NIF's technical and managerial problems. We also interviewed the authors of the engineering firm that conducted a review of NIF.

Our review was performed from October 1999 through July 2000 in accordance with generally accepted government auditing standards.

Comments From the Department of Energy

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

July 28, 2000

U.S. General Accounting Office
ATTN: Mr. Jim Wells
Director, Energy Resources and Science Issues
Resources, Community, and Economic Development Division
441 G. Street, N.W.
Washington, D.C. 20548

Dear Mr. Wells:

The National Nuclear Security Administration (NNSA) appreciates the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled, "National Ignition Facility Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays" (GAO/RCED-00-141), dated July, 2000. The GAO team should be commended for its comprehensive fact finding; many of your findings and conclusions are similar to our own. However, NNSA is concerned that the manner in which the conclusions and recommendations are presented in the report gives the impression that the NNSA and the project have not taken appropriate action to resolve issues so as to ensure the success of the National Ignition Facility (NIF). It is our assessment that:

- The technical uncertainties and associated costs are well understood;
- The NNSA is well on its way to implementing the first recommendation for external independent reviews; and,
- The NNSA's path forward for NIF addresses the second recommendation and will ensure balance between NIF and the rest of the nuclear weapons program.

In addition, the report is inconsistent with DOE budget guidance by including Inertial Confinement Fusion (ICF) program costs in NIF construction costs and characterizing these costs as cost-growth in NIF.

Before addressing these issues and responding to the report's recommendations, a brief discussion is warranted about the National Ignition Facility and its relationship to our nation's Stockpile Stewardship Program for maintaining a safe, reliable and secure nuclear deterrent in the absence of underground testing.

Stockpile Stewardship Program

The maintenance of our nuclear deterrent in the absence of underground testing is a challenge for the Government, our national laboratories and industry. The last underground test was conducted in September 1992. The scientists and engineers who designed and tested our stockpile are aging; many will retire over the next several years. The Department of Energy, with our national laboratories and production facilities, will continue to maintain U.S. nuclear

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weapons through the Stockpile Stewardship Program (SSP). The program rests on developing an unprecedented set of scientific tools to better understand nuclear weapons, on significantly enhancing our surveillance capabilities, and on completing a new manufacturing program needed to extend the life of our nuclear weapons. Through Stockpile Stewardship, and consistent with Presidential direction, the Secretaries of Defense and Energy have successfully certified for the last four years that the nuclear stockpile remains safe and reliable and that nuclear testing is not needed at this time. The most recent certification was completed in 1999. The ability to continue to certify annually the safety and reliability of the stockpile without underground testing in the out years is dependent upon the availability of the scientific tools being developed and constructed as part of the stewardship program.

NIF Mission

The National Ignition Facility, under construction at Lawrence Livermore National Laboratory (LLNL), is one of these scientific tools and is an essential element in the Stockpile Stewardship Program. It is the only facility that will allow direct experimental study in the laboratory of issues that affect the aging stockpile in temperature and pressure regimes approaching those that occur in nuclear weapons. It will play a major role in providing the underlying science needed to validate state-of-the-art nuclear weapon simulation codes under development by the Accelerated Strategic Computing Initiative (ASCI). NIF's unique scientific challenges, including demonstration of ignition in the laboratory, will serve to attract, train, and retain the outstanding technical talent required for success of the stewardship program over time. The directors of the three weapons labs have reaffirmed the value of NIF to Stockpile Stewardship in unclassified and classified NIF White Papers dated April 24, 2000 and May 2, 2000 respectively.

ICF History

The demonstration of thermonuclear burn in an inertially confined target has been a major goal of the Inertial Confinement Fusion (ICF) Program since its inception in the early 1970's. Historically the ICF Program has pursued both direct and indirect drive paths to ignition. In the direct method, laser beams are focused directly on a capsule containing a mix of deuterium and tritium. In the indirect method, the capsule is placed in a cylindrical radiation case, known as hohlraum; the laser light is directed into the hohlraum and converted to X-rays that are used to drive the capsule.

By the end of the 1980's, the ICF program had built a series of successful laser facilities (Argus, Shiva, Nova, and Omega) and progressed to a point where the physics requirements for indirect drive ignition were understood. A major review of the program conducted by the National Academy of Sciences in 1990 concluded that the next major step should be demonstration of indirect-drive ignition in the laboratory. This guidance was important input in determining the size and plan for NIF. The NAS also indicated that direct drive should continue to be studied. Positive results from these efforts resulted in the 1997 decision to incorporate provisions for direct drive into the NIF design.

In addition to addressing the issue of ignition and thermonuclear burn, over time the ICF program has also developed the capability to execute weapons physics experiments not involving ignition in areas such as hydrodynamics, radiation transport, and material properties. The requirements for these experiments, as defined by the stewardship program, also played an important role in determining the final performance specifications for the NIF.

Statement of the Problem – It's project management; the underlying technology and science are sound

In June 1999, the NIF project was found to have significant cost and schedule problems. These problems are attributable to two causes: (1) the original cost contingency was too low; and (2) the scope associated with the complexity of the beampath infrastructure design and the necessity to assemble and install the laser system in a clean environment was inadequate. The problems with NIF were project management issues. They are not technological—the underlying science of NIF remains sound.

Status

In order to address the NIF management deficiencies, a new senior project management team was established at NNSA/Office of Defense Programs (DP) and at LLNL to provide clearer management oversight lines of authority. The choice was made to seek an integrating industrial contractor for construction and activation of the critical beam path infrastructure. Adding the industrial partner as the integrator, and conducting a bottom-up reassessment of costs and schedule to complete design and assembly of optical systems, provided the basis for a new baseline for the project. These actions defined possible paths forward for the project that added costs of about $1B and extended the NIF completion date by at least 2 years. A detailed rebaseline for NIF was initiated in early May. An interim baseline report to Congress was provided on June 1. A final baseline will be submitted to Congress in mid-September.

Response to the GAO Report

The GAO Report includes three major conclusions: concerns remain about NIF's cost and technical uncertainties; the absence of independent reviews; and, the impacts of paying for NIF's cost overruns on the NNSA's nuclear weapons program. These conclusions lead to two GAO recommendations: to conduct an outside review of NIF's remaining technical challenges, and to evaluate NIF's impacts on the overall nuclear weapons program.

The NNSA is concerned that the manner in which these conclusions and recommendations are presented gives the impression that the NNSA and the NIF project have not taken appropriate action to resolve issues so as to ensure the success of NIF. It is our assessment that:

- The technical uncertainties and associated costs are now well understood;
- The NNSA is well on its way to implementing the first recommendation for external independent reviews; and,
- The NNSA's path forward for NIF is designed to ensure balance between NIF and the rest of the nuclear weapons program.

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In addition, the report is inconsistent with DOE budget guidance by including ICF program costs in NIF construction costs and characterizing these costs as cost-growth in NIF.

This letter will address the report's conclusions and their associated recommendations. But first, we will clarify the differences between the GAO and the NNSA related to the how the ICF Program costs are accounted.

See comment 1.

The report is inconsistent with DOE budget guidelines by including ICF Program costs in NIF construction costs and characterizing these costs as cost-growth in NIF

The GAO report states that $627 M of ICF program target-physics costs should be included in the cost of NIF. These funds are not a cost increase, but are funds that have always been included in the ICF budget as operating funds and have been reported annually to Congress. These funds cover the costs of scientists who conduct experiments in the facilities. The construction costs of NIF should be characterized separately, requested by DOE, and appropriated by Congress.

The ICF program is not part of NIF; on the contrary, NIF is part of the ICF program. The ICF program, with its goal of achieving fusion ignition, burn, and high yield, has been an ongoing research program in the Office of Defense Programs for over three decades. The ICF Program has built several facilities over the past 30-years and currently operates three major research facilities: the Omega laser at the University of Rochester, the Z machine at Sandia Albuquerque, and the Nike laser at the Naval Research Laboratory. None of the ICF research program funds have been included in the construction costs of any of these facilities.

See comment 2.

The technical uncertainties and their associated costs are well understood

We believe the costs due to the technical uncertainties of NIF are well understood and planned for in the NIF rebaseline. NIF has made significant progress in conventional construction and in major laser technologies that are required for NIF. In fact, the NIF building – representing an investment of approximately $250 million – is about 90 percent complete, and continues to meet established cost and schedule goals. In addition, the NIF Project method of execution has been changed to address the increased complexity of the laser beampath infrastructure and associated problems in assembling and installing the laser and target system infrastructure in a "clean" environment. For example, assembly and installation of the beampath infrastructure system will be managed and performed by an industrial partner, and industrial subcontractors, with proven records of constructing similarly complex facilities.

NIF will deliver 60 times more energy than its state-of-the-art predecessor laser systems, Nova and Omega, but at a fraction of the cost per energy delivered. This advancement in capability has required six major breakthroughs in technology that benefits the scientific and industrial community as a whole. These breakthroughs include: faster and less expensive laser glass production; large-aperture optical switches; stable high-gain preamplifiers; servo-controlled large-aperture deformable mirrors; large rapid-growth frequency-conversion crystals; and,

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demonstration of long-life final-stage optics. The first five technologies have been successfully developed due in large part to DOE's thirty-year investment in the ICF community and a long-term partnership with the optics industry. This is the same spirit of creativity and dedication that has been part of DOE's laboratories since the Manhattan project.

Only one technical challenge remains to be completed, with good progress to date. This is the demonstration of long-life final-stage optics that can withstand exposure to the high energy levels associated with operating the laser at the required ultraviolet wavelength. The GAO report highlights this technical area as a project risk not adequately addressed. Supported by the findings of our technical reviewers, this issue is one of economics. The frequency at which the final-stage optics in the system need to be refurbished or replaced directly affects the cost of operations, not the cost of the construction project or the maximum power of the NIF. Nonetheless, development of longer-lived optics is progressing well to meet this challenge. We expect the planned development will be completed in time to fulfill the needs of the Stockpile Stewardship Program.

The recommendations of the GAO report are being implemented

Recommendation 1 - To ensure that DOE has an effective independent review of NIF, we recommend that the Secretary of Energy arrange for an outside scientific and technical review of NIF's remaining technical challenges as they relate to the project's cost and schedule risks.

See comment 3.

We believe we are implementing this recommendation. There were several independent reviews conducted before the NIF cost and schedule problems were identified. These reviews included: an Independent Project Assessment conducted by Lockwood-Greene in 1999; a GAO Review of the NIF Project/ICF Program conducted in 1998; a NIF Project/ICF Program Assessment conducted by the Department of Defense also in 1998; an independent cost estimate (Title-I design) conducted by Foster Wheeler, USA in 1997; an extensive National Academy of Science review in 1997; an independent ICF Program and NIF Project review conducted by the JASON Group in 1996; an independent cost estimate (NIF Conceptual Design) also conducted by Foster Wheeler, USA in 1994; and, several ICF Advisory Committee reviews between 1992 - 1995. Additional reviews have been conducted since identification of the management and technical challenges. The program has been aggressive in obtaining expert external/independent reviews of its technical development for NIF.

At Secretary Richardson's direction, an independent Task Force, chaired by Dr. John McTague, former Vice President of Technical Affairs for the Ford Motor Company, was formed in October 1999 by the Secretary of Energy Advisory Board. The Task Force was chartered to review options to complete the project, and to recommend the best technical course of action. The overall conclusion in the Interim Report to the SEAB stated:

> "The Task Force has not uncovered any technical or managerial obstacles that would, in principle, prevent the completion of the NIF laser system. Nevertheless, serious challenges and hurdles remain. The NIF Task Force believes, however, that with appropriate corrective actions, a strong management

team, additional funds, an extension of the schedule and recognition that NIF is, at its core, a research and development project, the NIF laser system can be completed."

The Task Force has concluded its evaluation and will submit its final report to the Secretary in early August. This report will be part of the final rebaseline submission.

In August, Defense Programs will conduct a detailed cost, schedule and scope review of the Rebaseline Plan as recommended by the SEAB Task Force. Ms. Kathy Carlson, Manager, Nevada Operations Office, will chair this review, and the deputy chair will be Mr. Daniel Lehman, Office of Science. Burns and Roe will also conduct an Independent Cost Review as part of this process. These combined reviews are designed to give the NNSA/DP a higher level of confidence that the proposed baseline can be successfully executed as planned. It will be completed in time to support presenting the final cost and schedule baseline plan for NNSA approval and prior to delivering the certified baseline to Congress in mid-September.

Recommendation 2 - To ensure that there is an appropriate balance between NIF and the rest of the nuclear weapons program, we recommend that the Secretary of Energy not allocate funds from the nuclear weapons program to NIF until DOE (1) evaluates the impact of its cost and schedule plan, as well as any other options for NIF, on the overall nuclear weapons program and (2) certifies that the selected NIF cost and schedule plan will not negatively impact the balance of the Stockpile Stewardship Program.

See comment 4.

We believe we have already met the intent of this recommendation for FY 2001. The Secretary's June 1 NIF Interim Baseline report and the DOE June 27 FY 2001budget amendment contain an option that considers the impacts of NIF on the overall SSP. This option delays the completion of NIF until 2008 and increases the overall NIF cost in order to reduce near-term impacts on other SSP projects and assure an overall balanced SSP. We are in the process of developing the NNSA FY 2002 budget request that continues to maintain a balanced program. The revised baseline currently under review represents our best estimate as to what is affordable and in fact is close to the slowest pace consistent with maintaining a coherent and technically viable project. The NNSA's ability to fund this baseline profile will obviously be contingent upon the total funding envelope for the stewardship program, which is decided on an annual basis.

The DOE reaffirmed the need for a 192-beam NIF thus maintaining the objective of ignition in NIF as critical to the stewardship program and recognized that other requirements within the SSP are essential in order to maintain a balanced program. This is consistent with the Department's "30-Day Study" that reviewed "the balance of activities at the production facilities and at the national laboratories to ensure that the priority given to these important tasks are commensurate with the needs of the program." This principle is being used in balancing the go-forward plan for NIF.

NIF is an ongoing project with a large industrial base that has mobilized to complete the facility and its specialized equipment. To avoid additional cost increases, it is imperative that the project execute activities consistent with its rebaseline plan.

Path Forward

The NIF project team will complete and submit a detailed Rebaseline Report by August 1, 2000. At that time, an independent, detailed cost, schedule, and scope review of the entire rebaseline plan will be conducted as recommended by the SEAB Task Force. In parallel, the Office of Engineering and Construction Management has contracted an independent firm (Burns & Roe Engineering, Inc.) to conduct an independent cost review.

The information gained from these reviews will be used as part of the Department's approval process and as support for the Secretary's certification of the NIF revised baseline to Congress by mid-September.

In summary, and as amplified throughout this response, the NNSA firmly believes that the technical uncertainties of NIF are understood and are being addressed. NIF go-forward costs are identified and well understood. We have conducted independent/external reviews and implemented numerous recommendations, and most important, we have considered related budgetary impacts of the NIF on the overall Stockpile Stewardship Program in detail for FY 2001 and are currently validating requirements as part of the FY 2002 budget formulation process.

In addition to this response, we also have a set of detailed points of clarification that we want to discuss informally. We will arrange to do this shortly with Mr. Gary Boss of your office. If you have any questions regarding these comments or would like to discuss them further, please contact me at 202-586-2181 or Mr. Scott Samuelson, Acting Director, Office of the NIF, at 925-423-0593.

Sincerely,

Madelyn R. Creedon
Deputy Administrator
for Defense Programs

cc:
Steven M. Younger, Los Alamos National Laboratory
George Miller, Lawrence Livermore National Laboratory
Michael Anastasio, Lawrence Livermore National Laboratory
Thomas O. Hunter, Sandia National Laboratories

The following are GAO's comments on the Department of Energy's letter dated July 28, 2000.

GAO's Comments

1. Our response is included in the body of the report.

2. Our response is included in the body of the report.

3. Our response is included in the body of the report. In addition, DOE's listing of a GAO review of the NIF Project/ICF Program in 1998 is misleading because we have not previously analyzed the NIF Project or ICF Program. We did receive a one-day briefing in 1998 on NIF and ICF program issues that was part of another assignment. Also, DOE stated that the Lockwood-Greene review was conducted before the NIF cost and schedule problems were identified. However, as we noted in our report, Lawrence Livermore's NIF managers were aware of cost and schedule problems before Lockwood-Greene conducted its visits in early 1999.

4. Our response is included in the body of the report.

GAO Contacts and Staff Acknowledgements

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Acknowledgements

In addition to those named above, James Noel, Thomas Kingham, William Lanouette, and Robert Sanchez made key contributions to this report.

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