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United States General Accounting Office
Washington, DC 20548

June 1, 2001

The Honorable John W. Warner
Chairman
The Honorable Carl Levin
Ranking Member
Armed Services Committee
United States Senate

The Honorable Bob Stump
Chairman
The Honorable Ike Skelton
Ranking Minority Member
Committee on Armed Services
House of Representatives

Subject: Department of Energy: Follow-Up Review of the National Ignition Facility

The Lawrence Livermore National Laboratory, operated by the University of California under contract with the Department of Energy (DOE), is constructing the National Ignition Facility (NIF) at Livermore, California. In this stadium-sized laser facility, DOE's goal is to simulate, in a laboratory setting, the thermonuclear conditions created in nuclear explosions. This will allow scientists to evaluate the behavior of nuclear weapons without explosive testing. DOE considers NIF an essential element of its multi-billion-dollar Stockpile Stewardship Program, which is responsible for ensuring the safety and reliability of nuclear weapons in the absence of nuclear testing.

On August 8, 2000, we issued identical reports on NIF to the Subcommittee on Military Procurement, House Committee on Armed Services, and to the House Committee on Science.¹ These reports highlighted the reasons for NIF's cost and schedule overruns, the effects of cost and schedule problems on other weapons and science programs, and the effectiveness of the Lawrence Livermore Laboratory's actions to correct its project management problems. In our reports, we recommended that the Secretary of Energy arrange for an independent outside scientific and technical review of NIF's remaining technical challenges as they relate

¹ See *National Ignition Facility: Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays* (GAO/RCED-00-141 Aug. 8, 2000) and *National Ignition Facility: Management and Oversight Failures Caused Major Cost Overruns and Schedule Delays* (GAO/RCED-00-271 Aug. 8, 2000).

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Abstract The Lawrence Livermore National Laboratory, operated by the University of California under contract with the Department of Energy (DOE), is constructing the National Ignition Facility (NIF) at Livermore, California. In this stadium-sized laser facility, DOE's goal is to simulate, in a laboratory setting, the thermonuclear conditions created in nuclear explosions. This will allow scientists to evaluate the behavior of nuclear weapons without explosive testing. DOE considers NIF an essential element of its multi-billion-dollar Stockpile Stewardship Program, which is responsible for ensuring the safety and reliability of nuclear weapons in the absence of nuclear testing. On August 8, 2000, we issued identical reports on NIF to the Subcommittee on Military Procurement, House Committee on Armed Services, and to the House Committee on Science. 1 These reports highlighted the reasons for NIF's cost and schedule overruns, the effects of cost and schedule problems on other weapons and science programs, and the effectiveness of the Lawrence Livermore Laboratory's actions to correct its project management problems. In our reports, we recommended that the Secretary of Energy arrange for an independent outside scientific and technical review of NIF's remaining technical challenges as they relate		Monitoring Agency Acronym
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to the project's cost and schedule risks. In addition, we recommended that the Secretary not reallocate funds from nuclear weapons programs to NIF until DOE evaluates the impact of NIF's cost and schedule plan on the overall weapons program and certifies that the selected NIF plan will not negatively affect the balance of the Stockpile Stewardship Program.

The National Defense Authorization Act for Fiscal Year 2001 directed the General Accounting Office to review the NIF and to report to the House and Senate Committees on Armed Services by March 31, 2001. The review was to include

the role of NIF in the Stockpile Stewardship Program,
the relationship of NIF to other Stockpile Stewardship Program elements,
the impact of delays in constructing NIF on the Stockpile Stewardship Program,
a description of funds spent to date on the project, and
an assessment of whether the new baseline has clear goals, adequate and sustainable funding, and achievable milestones.

In discussions with the staff of both committees, it was agreed that a formal briefing by March 31, 2001, would meet the congressional mandate. We provided a briefing for the staff on March 30, 2001, using the enclosed briefing slides. (See enc. I.) This letter summarizes the briefing.

The following summarizes our findings:

The Role of NIF in the Stockpile Stewardship Program

NIF is expected to contribute to DOE's Stockpile Stewardship Program in three ways: by attracting new weapon scientists, supporting the stockpile's refurbishment,² and supporting research to improve the understanding of weapons science. Los Alamos, Sandia, and Lawrence Livermore laboratory officials have a general consensus that NIF, along with other scientific facilities, can attract new scientists to the stewardship program. However, because of the timing of planned stockpile refurbishments, NIF will not make any contribution to the refurbishment of W76 and W80 warheads or the B61-Mod 7 and 11 bombs in the stockpile. Although NIF is expected to support research efforts to develop the capabilities needed to certify the stockpile's safety and reliability, including the validation of computer codes for the Accelerated Strategic Computing Initiative,³ the three laboratories lack a complete consensus on NIF's research contribution. While all of the three weapons laboratories agree that NIF is one of several important facilities needed to successfully support weapons science research, Los Alamos National Laboratory officials believe that using plutonium in NIF and achieving robust (repeatable) thermonuclear ignition are key to NIF's value in the area of studying weapons primaries. However, NIF has not been approved for using plutonium, and the achievement of ignition is not guaranteed. Moreover, Sandia National Laboratories

² Refurbishment activities include extending the life of existing weapons through scientific study and replacing parts.

³ The Initiative aims to develop advanced computer models that will simulate nuclear explosions in three dimensions with higher resolution than previous models.

officials believe that NIF will not contribute to certifying whether weapons can survive hostile environments (those where radiation is present), and intend to rely instead on existing research facilities and computer simulations.

The Relationship of NIF to Other Stockpile Stewardship Program Elements

DOE has yet to certify that the completion of NIF will not negatively affect the balance of the Stockpile Stewardship Program. NIF is one of numerous facilities needed to successfully conduct the program. For example, other scientific research facilities will be needed to conduct weapons science research, and functioning production facilities will be needed to refurbish the stockpile. Although we recommended in our August reports that DOE evaluate and certify that NIF's cost and schedule would not negatively affect the balance of the program, the Department has not done so.

The Impact of Delays in Constructing the NIF on the Stockpile Stewardship Program

Future delays in constructing NIF may adversely affect DOE's ability to conduct weapons science research. DOE and laboratory officials agree that delays in constructing NIF to date will not affect meeting its current weapons science research milestones but that any additional delays may affect the ability to attract and retain scientists who desire to work on sophisticated science facilities such as the NIF. In addition, NIF delays would postpone certain weapons-related experiments, which would increase, to some extent, the uncertainties associated with understanding how weapons function.

A Description of Funds Spent to Date on the Project

Through fiscal year 2000, DOE had spent \$1.3 billion on the NIF project, plus another \$250 million in related costs (mostly those supporting research and development). NIF's completion is expected in 2008 at a cost of almost \$4.2 billion (\$3.5 billion in the NIF project's costs and about \$700 million more in related costs). This would result in a schedule that is 6 years longer than originally planned and a cost that is about \$1.4 billion higher than originally estimated. NIF's cost increases and delays were caused by a combination of poor Lawrence Livermore management and inadequate DOE oversight.

An Assessment of Whether the New Baseline Has Clear Goals, Adequate and Sustainable Funding, and Achievable Milestones

New baseline goals for NIF are clouded by a lack of consensus among the three laboratories about what size NIF should be and how it should be deployed. Proposals from DOE's Los Alamos and Sandia laboratories would limit NIF's size to 48, 96, or 120 laser beams until NIF's performance could be assured. Livermore states that building a smaller NIF would not be cost-effective, since most of the infrastructure supporting the full 192-beam design will soon be completed. Livermore estimates that pausing at 48, 96, or 120 beams, to assess NIF performance before restarting, could add up to nearly \$600 million in increased

project costs. Livermore's cost estimates for alternative deployment options have not been independently reviewed by DOE or others.

Optimistic assumptions about NIF's annual operating costs may compromise budget projections. Livermore's projected annual NIF operating cost of \$108 million is based on some optimistic assumptions. The major assumption is that a fourfold increase can be achieved in the performance of NIF's final optics laser glass. Replacing glass more often will significantly increase the cost of operating the laser. Although the laboratory states that it has a scientific solution to the technical problem of damage growth in the final optics when laser light strikes the glass surface, the concept has yet to be tested in an engineering and production environment. Other optimistic laboratory assumptions include NIF's obtaining reduced Livermore overhead rates and being excused from contributing project funds to support Livermore's Laboratory Directed Research and Development program--normally a 6-percent charge levied on all laboratory programs.

Although past internal reviewers concluded that NIF's milestones are challenging but doable, most major performance milestones will not occur until fiscal year 2004, when the first test of a laser beamline is to be made. Livermore has developed a detailed plan of NIF's milestones, including a revised comprehensive work breakdown structure. Past internal reviewers concluded that NIF could be built within the cost and schedule represented by these milestones. However, to better ensure tracking of progress, other laboratories and program reviewers recommended that more near-term milestones be added in order to assess NIF laser performance.

Other Issues--Continuing Problems with DOE Oversight, Project Management, and the Lack of an Independent External Review Process Add to the NIF Project's Risks

Persistent DOE oversight problems continue to place the NIF project at risk. The NIF project office at DOE's headquarters is still not fully staffed, and the laboratory's monthly NIF reports to DOE do not summarize technical project risks.

The NIF project does not manage about \$700 million in research and development that directly supports NIF. This research primarily involves activities related to target physics and is considered crucial to NIF's success. This research is managed outside the NIF project and is not included in NIF's monthly reporting. DOE is currently studying how these activities might be brought under the NIF project's control so that the project and its supporting research are fully integrated under a single management structure.

NIF still lacks an independent external review process. Independent external reviews are valuable for measuring cost, schedule, and technical success in any large and ambitious science project. Yet, no such external independent reviews of NIF have been conducted or planned. DOE's own orders state that external independent reviews are beneficial; however, DOE plans to continue its own internal review program--allowing Defense Programs officials to manage the

process themselves. An external cost review conducted in August 2000 was not independent, according to both the contracted reviewer and a DOE official overseeing the review. The review was conducted in support of an internal review, not as a separate effort. While DOE's current internal reviews are valuable, an external independent review, as we recommended in our August 2000 reports, would provide the confidence that the NIF project is technically feasible and reasonable with respect to cost and schedule.

Agency Comments

We met with Department of Energy officials and provided them with a draft of our briefing slides for comment. The Department generally agreed with our findings and offered several clarifying changes, which we have incorporated as appropriate.

Scope and Methodology

To address our objectives, we interviewed Lawrence Livermore National Laboratory and DOE officials responsible for NIF and officials from other DOE laboratories and scientific institutions whose programs are affected by NIF. In addition, we obtained the latest cost and schedule data from DOE, Lawrence Livermore National Laboratory, and other laboratories conducting research in support of the NIF project. We conducted our review from October 2000 through March 2001 in accordance with generally accepted government audit standards.

This letter will also be available on GAO's home page at <http://www.gao.gov>.

If you have any questions about this letter or need additional information, please call me on (202)-512-3464 or Gary Boss on (202) 512-6964. Key contributors to this report were Gary Boss, James Noel, Thomas Kingham, and William Lanouette.



(Ms.) Gary Jones
Director
Natural Resources
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Enclosure

Briefing Charts on NIF



Status of GAO's Followup Review of the Department of Energy's National Ignition Facility

Prepared for the House and Senate Armed Service
Committees

March 30, 2001



GAO's Objectives

- The National Defense Authorization Act for 2001 required a GAO review of the following:
 - Role of NIF in the Stockpile Stewardship Program (SSP)
 - Relationship of NIF to other SSP elements
 - Impact of delays in NIF on SSP
 - Description of funds spent to date
 - Assessment of whether the new baseline has
 - clear goals
 - adequate and sustainable funding
 - achievable milestones
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Background

- NIF completion is expected in 2008 at a cost of \$3.5 billion, with another \$700-plus million in related research and program costs
 - NIF is taking 6 years longer and \$1.4 billion more to complete than was originally planned
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NIF's Role in the Stockpile Stewardship Program

- NIF is part of the Stockpile Stewardship Program--an integrated program to maintain the nation's nuclear weapons in a safe and reliable state
 - NIF is expected to contribute to stockpile stewardship by
 - Attracting and training new weapon scientists
 - Supporting and refurbishing the stockpile
 - Supporting research "campaigns" to improve understanding of weapons science
 - Although funded by the Energy Department's Defense Programs, NIF is also expected to make contributions to basic science
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NIF's Role--Attract Scientists

- NIF can contribute to attracting new scientists
 - By providing a scientific challenge, NIF, along with other facilities and activities, is an important factor in attracting and retaining scientists
 - Prior to the end of testing, a nuclear weapon test was the primary method for training weapons designers
 - Absent testing, multiple scientific facilities, like NIF, will be needed to train and evaluate new weapons designers
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NIF's Role--Refurbish Stockpile

- NIF will not make any contribution to planned stockpile refurbishments
 - DOE plans to rebuild the W76 and W80 warheads, and the B61-Mod 7 and 11 bombs, in order to extend their lifetimes
 - Because of the timing of these refurbishments and the approach being taken to refurbishment, NIF will have no role in meeting production deadlines
 - NIF also will not contribute to certifying the remanufactured W88 pit
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NIF's Role--Support Campaigns

- NIF is expected to support four weapons science “campaigns”
 - “Campaigns” are research efforts to develop capabilities needed to certify stockpile safety and reliability
 - NIF is expected to support campaigns on:
 - Weapon secondaries (thermonuclear explosive) (including ignition)
 - Weapon primaries (nuclear explosive)
 - Dynamic properties of materials in weapons
 - Hostile (radiation) environments
 - NIF experiments also will help validate computer codes for the Accelerated Strategic Computing Initiative (ASCI)
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NIF's Role--Support Campaigns

- Complete consensus among laboratories is lacking on NIF's contribution to weapons science “campaigns”
 - All labs agree that NIF is important for supporting the weapon secondaries campaign
 - The labs do not fully agree on NIF's value to the primary and materials campaigns
 - Los Alamos believes that, while NIF can be useful, using plutonium in NIF and achieving robust (repeatable) ignition are key to NIF's value for supporting the primaries campaign
 - Livermore agrees ignition is key to NIF's value
 - However, NIF has not been approved for using plutonium, and achieving ignition is not guaranteed
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NIF's Role--Support Campaigns

- Los Alamos believes other facilities, such as the Z pulsed-power machine, are better for studying materials
 - Sandia believes NIF will not contribute to certifying that weapons can survive hostile environments
 - Sandia officials intend to rely on existing facilities, such as the Saturn pulsed power machine, and weapons simulation through computer modeling
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NIF's Relationship to other Elements of Stockpile Stewardship

- While NIF is important, other facilities are needed to successfully support weapons science campaigns
 - For example, the Dual-Axis Radiographic Hydrodynamic Test facility (Los Alamos) is needed to assess the condition and behavior of nuclear weapon primaries-- however, this facility is still under construction
 - In addition, operational weapons production facilities are needed to refurbish the stockpile
 - For example, a functioning Y-12 Plant (Oak Ridge) is needed to refurbish weapon secondaries—currently, portions of Y-12 are shut down for safety reasons
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NIF's Relationship to other Elements of Stockpile Stewardship

- Because all aspects of Stockpile Stewardship are important, we recommended, in August 2000, that DOE evaluate and certify that the NIF's cost and schedule problems would not negatively affect the balance of the Stockpile Stewardship Program
 - DOE has not evaluated the impact of NIF's cost and schedule problems on the balance of the SSP, especially the need to refurbish the stockpile and rebuild its infrastructure
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The Impact of NIF Delays On Stockpile Stewardship

- NIF's original delays will not affect meeting current weapons science campaign milestones
 - According to DOE officials, additional delays may affect their ability to attract and retain scientists
 - According to Los Alamos and Livermore weapons scientists, additional delays or NIF's termination will increase, to some degree, the uncertainties associated with their understanding about how weapons function
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Description of Funds Supporting NIF

<u>Cost Category</u>	<u>Prior Years</u>	<u>FY 2001</u>	<u>FY 2002-2008</u>	<u>Totals</u>
TPC	916.3	290.1	1041.7	2248.1
R&D (ICF)	402.7	75.9	721.4	1200.0
<u>REBASELINE</u>				
<u>TOTAL</u>	<u>1319.0</u>	<u>366.0</u>	<u>1763.1</u>	<u>3448.1</u>
Target Physics (LLNL)	173.0	30.0	291.0	494.0
<u>TOTAL LLNL</u>	<u>1492.0</u>	<u>396.0</u>	<u>2054.1</u>	<u>3942.1</u>
Other labs/ contractors	71.3	14.7	105.6	191.6
UK Contribution	0.0	9.2	36.8	46.0
<u>TOTAL</u>	<u>1563.3</u>	<u>419.9</u>	<u>2196.5</u>	<u>4179.7</u>



New NIF Baseline--Clarity of Goals

- New baseline goals are clouded by the lack of consensus among the weapons labs--the users of NIF--on what size NIF should be or how it should be deployed
- While agreement exists that NIF should be built, the three nuclear weapons labs provided alternative to DOE
 - Livermore advocated an accelerated schedule for completing NIF with all 192 beams
 - Los Alamos proposed limiting NIF to 120 beams until NIF performance could be successfully demonstrated
 - Sandia proposed a 48-96 beam NIF until specific milestones could be met
- DOE is attempting to reconcile these different views



New NIF Baseline--Clarity of Goals

- According to Livermore Lab
 - Building a smaller NIF is less costly, but this is not a cost effective strategy since the infrastructure for a full NIF is to be built early
 - Pausing the NIF for tests after 48 or 120 beams, and then restarting later, makes the NIF more costly to build and causes a multi-year delay
 - Accelerating the schedule for completing NIF would save \$219 million
- Importantly, Livermore Lab estimates have not been independently reviewed or carefully studied by DOE



New NIF Baseline--Clarity of Goals

Options

Savings/Added Cost

48 Beams only	Savings = \$540 M ¹
96 Beams only	Savings = \$442 M ¹
120 Beams only	Savings = \$388 M ¹
48 Beams (3 year pause) Full NIF	Added Cost = \$583M ²
96 Beams (3 year pause) Full NIF	Added Cost = \$379M ²
120 Beams (3 year pause) Full NIF	Added Cost = \$272M ²

¹ These represent theoretical savings in budget authority by terminating NIF. They do not include termination expenses.

² These figures were developed by NIF managers at Lawrence Livermore and presented to DOE. They were not independently verified.



New NIF Baseline--Adequate
and Sustainable Funding

- NIF's internal reviewers concluded that Livermore's new baseline for NIF is challenging, but doable
 - None of NIF's reviewers reported on project risks in the context of future cost and schedule impacts
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New NIF Baseline--Adequate
and Sustainable Funding

- An important funding issue is the cost to operate NIF once it is completed
 - Livermore estimates NIF annual operating costs of \$108 million (FY 2001 dollars) when NIF is fully operational in FY 2011
 - Livermore says its estimate is a detailed, bottom-up review based on prior experience operating laser machines
 - Livermore's operating cost estimates have not been reviewed by us, DOE, program reviewers, outside peers, or by independent cost reviewers
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New NIF Baseline--Adequate and Sustainable Funding

- Livermore's operating cost estimate contains optimistic assumptions
 - A 4-fold improvement in the useful life of its most sensitive optics (final optics)--saving about \$50 million annually
 - Lab claims it has a plan for making optics last longer--internal program reviewers agreed but want more research to confirm success
 - Reduction from Livermore's normal overhead rates
 - Exclusion from the Laboratory Directed Research and Development tax (6 %), which is assessed on all laboratory programs for sponsoring independent research
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New NIF Baseline--Achievability of NIF's Milestones

- Livermore has a detailed plan of NIF's milestones, including a comprehensive work breakdown structure
 - Past internal reviewers concluded that NIF's milestones are challenging but doable and that NIF can be built on cost and schedule
 - While NIF's milestones are detailed and well developed
 - The first milestone that demonstrates machine performance isn't until FY 2004 when "first light" is expected
 - The first weapons experiments with beams aren't scheduled until FY 2006, when 48 beams are installed and commissioned
 - Other labs and reviewers suggested that more near-term milestones be added to assess laser performance
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Other Issues

- Continuing oversight concerns
 - Although DOE's federal staff in Livermore now report directly to the NIF Project Office in headquarters, the same people have performed oversight since 1999 when NIF's cost and schedule grew unnoticed
 - The NIF Project Office in DOE is not fully staffed, further limiting DOE's ability to oversee the NIF project
 - Livermore's monthly status reports on NIF do not summarize project risks, the absence of which prevents more effective oversight by DOE and others
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Other Issues

- Project management issues
 - Nearly \$700 million in NIF research and development work is still managed outside the control of the NIF Project
 - These activities are not part of monthly NIF reporting, even though it is crucial for NIF success
 - DOE is considering placing this research and development under the control of the NIF Project
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Other Issues

- Project management issues (continued)
 - DOE stated, in its September 2000 certification to Congress, that it will prepare a “report” on how it intends to address issues raised in two prior NIF reviews (the Carlson-Lehman Defense Program Review and a cost review by the Burns and Roe engineering firm)
 - DOE has not fully documented how it has responded to past review findings and recommendations
 - Without full documentation, it is unclear if the results from prior reviews have been fully addressed
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Other Issues

- Independent review issues
 - Independent NIF external review is still needed
 - Independent reviews are crucial to NIF cost, schedule, and technical success
 - Internal program reviews have been useful, but are no substitute for independent external review
 - DOE intends to continue its internal program review of NIF but will allow Defense Program officials to manage the process
 - Internal program reviews would have more credibility if managed by officials outside of Defense Programs, which sponsors NIF
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Other Issues

- Independent review issues (continued)
 - An external review conducted in August 2000, claimed by DOE to provide an independent review, was not independent according to both the reviewers and a DOE official
 - As we recommended in August 2000, an external independent review of NIF is still needed to provide confidence that the project is technically feasible and reasonable with respect to cost and schedule
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DOE Comments

- We asked DOE to review this briefing document
 - DOE provided clarifying comments which have been incorporated into this document
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