Final Report of the National Ignition Facility Laser System Task Force

National Ignition Facility
Laser System Task Force

October 19, 2000

Secretary of Energy Advisory Board
U.S. Department of Energy

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FINAL REPORT OF THE
NATIONAL IGNITION FACILITY (NIF) LASER SYSTEM TASK FORCE

EXECUTIVE SUMMARY

In the late summer of 1999 it was revealed that, contrary to earlier reports, the National Ignition Facility (NIF) Laser System at the Lawrence Livermore National Laboratory would require more funds and time for completion than had been previously planned. In response to these revelations, Secretary Richardson announced a six-point series of initiatives (Appendix A) to get the project back on track, including the creation of an independent Task Force to review the project and provide recommendations for how to best tackle NIF's technical and managerial challenges.

On October 6, 1999, Secretary Richardson requested that the Secretary of Energy Advisory Board (SEAB) form a subcommittee to conduct an independent review of the engineering and management aspects of the assembly and installation of the NIF laser system. This SEAB subcommittee is comprised of board members and individuals with expertise in ultra-clean manufacturing, systems engineering, laser science, and large-scale project management (Appendix B). The Terms of Reference for the Secretary of Energy Advisory Board's National Ignition Facility Laser System Task Force are presented in Appendix C. The NIF Laser System Task Force (the Task Force) began its review in November 1999.

On January 10, 2000 the Task Force issued its interim findings based on three open meetings conducted in November and December 1999. The *Interim Report of the National Ignition Facility Laser System Task Force* did not uncover any technical or managerial obstacles that would, in principle, prevent the successful completion of the National Ignition Facility laser system, but made several recommendations to address major managerial and technical concerns.

Since the release of the Task Force's interim report, the NIF Project Management team has been restructured and has developed a revised project baseline cost and schedule for the NIF which reflects and incorporates the findings and recommendations of the NIF Laser System Task Force. The revised NIF project cost and schedule baselines were reviewed by the NIF Laser System Task Force. Following that review and the Department of Energy's Energy Systems Acquisition Advisory Board (ESAAB), the Secretary of Energy presented this plan to Congress on June 1, 2000 as an interim certification of the revised cost and schedule baseline for the National Ignition Facility Project.

The Secretary's interim report to Congress committed to a thorough and intrusive review and validation of the new NIF Project baseline cost and schedule prior to FY 2001 funding. In mid-August, as recommended by the interim report of the NIF Laser System Task Force, the NIF Project baseline cost and schedule were subjected to a ("Lehman" style) review chartered by the Office of Defense Programs. The Rebaseline Validation Review Committee, chaired by Ms.

Kathleen Carlson, Manager of the Nevada Operations Office, conducted the review. The Rebaseline Validation Review was followed by an Energy Systems Acquisition Advisory Board (ESAAB) meeting.

The ESAAB used these reports as the basis for the Secretary's final report on the status of the NIF Project to Congress, which was submitted on September 15, 2000.

This final report of the National Ignition Facility Laser System Task Force is the culmination of a review of the NIF Project which included six open meetings between November 1999 and May 2000.

What follows is a synopsis of the Task Force's findings and recommendations and pursuant actions taken by DOE and the NIF Project.

1. Program and Project Management Findings

The NIF Project Management Team failed to implement program and project management procedures and processes commensurate with a major research and development construction project, such as the National Ignition Facility.

The NIF Project Management Team did not assess or implement private sector best practices.

The Office of Defense Program's NIF project did not benefit from a successful project management review process such as routinely used by the Department of Energy's Office of Science.

Recommendations

The Office of Defense Program's should implement a NIF project management process similar to that employed by the Office of Science.

The NIF Project Management Team must place a greater emphasis on applying project management skills.

The Department of Energy should implement training in project management at DOE Headquarters, DOE Field Offices, and at the laboratories.

Subsequent Actions

Since the release of the Task Force's interim report, the NIF project has undergone a dramatic and fundamental restructuring of its project management, its procedures and processes. Since the Task Force's interim report the DOE and NIF Project Management Team have:

- Strengthened the connection between the DOE/NNSA headquarter and field elements responsible for NIF by creating an Office of NIF which reports to the Deputy Administrator;
- Established a NIF Project Mission Support Group to be responsive to user needs;

- Established an Office of Project Management Support within the Office of Defense Programs to assist in improving DP project management;
- Instituted a project management review process similar to that employed by the Office of Science;
- Reorganized the NIF Council into the NIF Programs Review Committee to focus on technical and management reviews;
- Solicited a wide variety of expertise from private industry to assist in the planning and implementation of NIF;
- Established or strengthened NIF Quality Assurance, Systems Engineering, Systems Engineering Risk Analysis organizations; and
- Established a Schedule and Budget Planning Group to manage and coordinate the integrated schedule and budget plans.

These and additional program and project management changes are described in greater detail in Chapter 2.

2. Laboratory Director's Role and Responsibility Findings

The role of the Laboratory Director in the management of the NIF project was undefined.

Responsibility for the NIF project was diffuse at LLNL.

Recommendations

The laboratory director must take visible and unambiguous ownership of the NIF project.

The laboratory director must establish an appropriate management structure for the NIF project.

The laboratory director must create an atmosphere that will not allow for "surprises."

Subsequent Actions

Since the release of the Task Force's interim report, the Director of the Lawrence Livermore National Laboratory has articulated his full commitment to the success of the NIF project. In addition, the Director has:

- Restructured the project management, its procedures and processes;
- Established a new NIF Program Directorate headed by an Associate Director for NIF Programs, who reports directly to the Laboratory Director; and
- Established a NIF Project Manager who serves as the Deputy Associate Director for the NIF Program Directorate.

3. Project Management Roles, Responsibilities and Lines of Authority Findings

The Department of Energy's Office of Defense Programs, Oakland Operations Office, and Lawrence Livermore National Laboratory, and the University of California lack clearly defined roles, responsibilities and lines of authority in the management of the NIF project.

In addressing this finding, there is a real danger that duplicative and paralyzing oversight mechanisms will be introduced.

Recommendations

The Office of Defense Programs, in conjunction with the DOE Oakland Operations Office, the University of California, and the Lawrence Livermore National Laboratory should clearly define and articulate the respective roles, responsibilities and lines of authority and accountability of all participants in the management of the NIF project.

Each of these major roles will require its special oversight responsibility.

Subsequent Actions

In response to the Task Force's interim report the NIF project, including the Office of Defense Programs, DOE Oakland Operations Office, University of California, and the Lawrence Livermore National Laboratory have:

- Revised the NIF Project Execution Plan to strengthen and clarify the lines of authority, accountability, and the respective roles of all participants in the management of the NIF project;
- Strengthened the connection between the DOE/NNSA Headquarters and field elements responsible for NIF by creating an Office of NIF which reports to the Deputy Administrator;
- Collocated the DOE Oakland Operations' NIF directorate at Lawrence Livermore National Laboratory site;
- Revised the NIF Project Execution Plan, Project Completion Criterion and other documents to reflect the new management structure, identify milestones associated with the completion of construction activities, management pre-start reviews, testing and operations;
- Established the "early warning system" necessary to prevent "surprises."

These and additional actions are described in greater detail in Chapter 2.

4. Contingency Factor Findings

The Assistant Secretary for Defense Programs should not have approved a budget based on a contingency factor of only fifteen percent. Given the planned increase in performance by a factor of fifty over that of existing facilities, as well as the need for concurrent research and development, a contingency of thirty to thirty-five percent would have been more appropriate.

Recommendations

An increase in the contingency factor should be considered in the NIF project rebaseline.

Subsequent Actions

In response to the Task Force's project planning and execution findings, the NIF Project Management Team has incorporated a more appropriate level of risk contingency in the project baseline. The newly established risk contingency (approximately 25 percent, distributed according to risk) was set after an in-depth review by a DOE-led team and seems reasonable. It has been incorporated into the new project baseline. In addition, the level of risk contingency was reviewed as an integral part of the "Lehman" style review process used to validate the NIF rebaseline as requested by the Task Force.

The NIF project contingency factor and project rebaseline are described in greater detail in Chapter 2.

5. System Design Robustness Findings

Several early decisions in the NIF project had removed robustness from the system design and may have increased the actual costs. Examples are the decisions to utilize 192 instead of 240 lasers, a 11-5 slab beamline architecture instead of a 11-7 beamline architecture, and use of an overly confining building volume.

Recommendations

Increase the design robustness where feasible, such as allowing for the 11-7 beamline architecture.

Increase research and development funding, especially for beamline optics damage reduction.

Integrate the research and development activities into the total project management.

Subsequent Actions

In response to the Task Force's technology findings, the NIF Project Management Team committed to revising the infrastructure baseline to provide for full 11/7-beamline architecture capability. NIF related research and development activities are now managed by the NIF Project Manager in an integrated manner with support and tracking by the NIF Systems Engineering organization. A new Integration Management and Installation contractor will now conduct manufacturer proof tests prior to the installation of the first beamline bundle and will allocate additional time for the installation of the first bundle.

The corrective actions taken by the NIF Project Management Team to address the NIF Laser System Task Force's technology findings are described in greater detail in Chapter 2.

6. Project Endpoint Findings

The NIF project needs a well-defined ending point.

Recommendations

Key project milestones should be established. These milestones should be an integral part of the project management and controls process.

The NIF project management system should clearly establish the point at which construction and testing end and NIF operations begin.

Subsequent Actions

In response to the Task Force's findings, the NIF Project Management Team revised the NIF Project Execution Plan, Project Completion Criterion and other documents to identify milestones associated with the completion of construction activities, management pre-start reviews, testing and operations. These milestones, their schedule, and costs were reviewed as an integral part of the "Lehman" style review used to validate the NIF rebaseline, as requested by the Task Force.

7. Performance Goal Findings

With appropriate research and development and appropriate project funding and management, the NIF Laser System Task Force expects that the original project technical goals for laser system performance will be met.

Both the state-of-the-art and user requirements point to the need for a phased implementation of NIF system capabilities.

Recommendations

The original NIF performance goals should be fully maintained, but reached in a phased manner.

Early operation of full symmetry should both satisfy user needs and provide useful information to optimize full system implementation.

Subsequent Actions

In response to the Task Force's findings, the NIF Project Management Team has:

- Provided the infrastructure baseline capability for a full 11/7 beamline architecture
- Established an Integration Management and Installation (IMI) contractor to conduct manufacturer proofing activities for the installation of the Beampath Infrastructure Systems prior to installation of the first bundle.
- Scheduled approximately 15 months for the commissioning of the first bundle, much longer than allowed for subsequent bundles, to permit the knowledge gained on the first bundle to

be utilized on subsequent bundles. The 1ω and 3ω laser diagnostics in the Precision Diagnostic Station will be used for the first bundle to understand and allow optimization of the laser performance. In addition, operation of early bundles and the performance bundle will provide the experience necessary for the laser to reach all performance goals. This early operation will also allow them to shake down the target area support systems and early target diagnostics.

- These activities provide a natural way of achieving the original NIF performance goals in a phased manner. To maintain a balanced stockpile stewardship program consistent with a constrained funding profile, the NIF Project added two years to the completion date for the project. This enabled the project to utilize 15 months in the schedule for the first bundle (8 beams) performance verification program. The stretched schedule and annual funding constraints also resulted in delaying the award of contracts for the laser hardware required for deployment of the additional laser beams. Any changes in the hardware design can be included in the procurement packages before they are released for bid and award.
- The final target optics, including the issue of 3ω optical damage, has demonstrated improvement. Further improvement is still required. As recommended, the NIF rebaseline budget requested additional funds for R&D for this purpose.

The NIF laser system performance goals, symmetry, and optics issues are described in greater detail in Chapters 3 and 4.

8. Cost and Schedule Baseline Findings

The NIF Laser System Task Force finds that the methodology used to arrive at the April, 2000 baseline was credible, but needs a bottom-up verification.

The "Lehman" style review process used by the Office of Science is the appropriate process to be used for conducting this review.

Recommendations

The Task Force recommended that the cost and schedule baselines be reviewed by an independent "Lehman" style review panel and recommends that such reviews should be conducted periodically throughout the life of the project.

Subsequent Actions

In response to the Task Force's interim findings and recommendations, the NIF project rebaseline underwent a thorough bottom-up validation review using the "Lehman" style review process used by the Office of Science. In mid-August, a weeklong forty person expert group reviewed the NIF rebaseline plan and assessed the project budget, cost, schedule, and management control systems. The Chairman of the NIF Laser System Task Force attended this review as an observer

Conclusions

The NIF Laser System Task Force has uncovered no technical or managerial obstacles that would, in principle, prevent the completion of the NIF laser system. The Task Force believes that the corrective actions undertaken by the NIF Project Management Team in response to the interim report, together with the revised cost and schedule rebaseline contained in the Secretary of Energy's report to Congress are sufficient to permit the NIF Project to be completed as planned.

The NIF Project is, at its core, a research and development project. Through the diligent, consistent and continued application of the changes adopted in response to the recommendations of the NIF Laser System Task Force the NIF Project can be completed.

The largest remaining issue to be addressed by the NIF Project Management Team is the restoration of public trust and confidence in the ultimate and successful completion of the NIF Project. The restoration of this trust and confidence will be necessary to retain and to hire the highly skilled scientists, engineers, and technicians essential to the achievement of the NIF project goals, the accomplishment of its mission, and the support of the public and its representatives.

FINAL REPORT OF THE
NATIONAL IGNITION FACILITY (NIF) LASER SYSTEM TASK FORCE

CHAPTER 1 - INTRODUCTION

Origins of the National Ignition Facility Laser System Task Force

In the late summer of 1999, projections indicated that, contrary to earlier reports, the development of the National Ignition Facility (NIF) Laser System at the Lawrence Livermore National Laboratory[1] would require more funds and time for completion than previously planned. In response to these revelations, Secretary Richardson announced a six-point series of initiatives to get the project back on track, including the creation of a high-level, independent Task Force to review the project[2].

On October 6, 1999, Secretary Richardson requested that the Secretary of Energy Advisory Board (SEAB) create such a subcommittee comprising SEAB members and independent experts to conduct a technical review of the project and provide recommendations for how to best address remaining technical challenges[3].

Secretary Richardson requested that the National Ignition Facility (NIF) Laser System Task Force review all components of NIF including its assembly and installation of the laser system and the ability within the proposed approach to achieve the cleanliness requirements necessary for the cost effective operation of the laser system. The Secretary asked that the Task Force pay particular attention to the engineering viability of the proposed assembly and activation method; the assembly and installation cleanliness protocols; the management structure; and the adequacy of the cost estimating methodology[4]. Issues such as weapons justification, details of the target system, including target instrumentation, and physics were beyond the scope of the Task Force. The Task Force was formed by the SEAB and commenced its work in November 1999.

Overview of the National Ignition Facility Laser System

The NIF laser system is part of DOE’s science-based Stockpile Stewardship and Management Program, which calls for a science-based approach for ensuring the reliability of the nation’s remaining nuclear weapons. Once completed, NIF will be the world's most powerful laser facility, with 50 times more energy than any existing laser system. Consisting of 192 laser beams, NIF was designed to produce, for the first time in a laboratory setting, conditions of matter close to those that exist at the center of stars and inside detonating nuclear weapons. DOE

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[1] Throughout this report, the National Ignition Facility Laser System may also be referred to by its acronym, NIF. In the same vein, the Lawrence Livermore National Laboratory may also be referred to as "Lawrence Livermore", "Lawrence Livermore lab", "LLNL", or "the laboratory." The Department of Energy’s Office of Defense Programs may be referred to as the "Office of Defense Programs." Finally, the University of California may be referred to as "the university" or "UC."
[2] See Appendix A for a summary of Secretary Richardson's initiatives.
[3] See Appendix B for brief biographies on the members of the Task Force.
[4] See Appendix C for a copy of the Task Force's Terms of Reference.

plans to use this facility for physics experiments to increase understanding of the performance of nuclear weapons without further need for underground nuclear testing.

In addition to its role in the Stockpile Stewardship Program, the National Ignition Facility will also be used for scientific and technical experiments in such fields as fusion energy, laboratory astrophysics, optics, and materials. The Department of Energy further states that NIF will further the department's strategic missions in areas of national security, energy research and basic scientific and technological research. According to the Department's Stockpile Stewardship Program 30-Day Review,

> "The mission of the National Inertial Confinement Fusion [ICF] program is to execute high energy density physics experiments for the Stockpile Stewardship program, an important part of which is the demonstration of controlled thermonuclear fusion in the laboratory. Technical capabilities provided by the ICF program also contribute to other DOE missions including nuclear weapons effects testing and the development of inertial fusion power....NIF is one of the most vital facilities in the stockpile stewardship program. NIF will provide the capability to conduct laboratory experiments to address the high energy density and fusion aspects that are important to both primaries and secondaries in stockpile weapons."[5]

The NIF Laser System Task Force was not charged with the task of reviewing the Stockpile Stewardship Program or the National Ignition Facility's role in ensuring the reliability of the nation's nuclear weapons stockpile. The NIF Project and its role in the Stockpile Stewardship Program and its mission needs have been extensively reviewed and reaffirmed by both internal and external reviewers. The National Academy of Sciences conducted a review the NIF Project's contribution to stockpile stewardship in a report[6] released in 1997.

In January 1999, the NIF schedule called for the project to be completed at the end of Fiscal Year 2003 at a cost of $1.2 billion. At that time, the conventional facilities housing the lasers were about 70 percent complete. The NIF Project Management Team expected construction of the conventional facilities to be completed by the end of Fiscal Year 2001. By the summer of 1999, the NIF Project Management Team recognized that the approved budget and implementation plan were insufficient to cover the remaining work, including the acquisition of materials and the clean assembly and painstaking installation of the laser system.

Actions of the National Ignition Facility Laser System Task Force

Since its formation the Task Force has conducted seven open meetings, five meetings at Lawrence Livermore National Laboratory and two open teleconference meetings to finalize its two reports. Throughout this review process, the Task Force heard from DOE and Lawrence Livermore lab officials and project managers, private citizens and various organizations

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[5] US Department of Energy, "Stockpile Stewardship Program: 30-Day Review", November 23, 1999, Appendix E.
[6] National Academy of Sciences, "Review of the Department of Energy's Inertial Confinement Fusion Program -- The National Ignition Facility," Committee for the Review of the Department of Energy's Inertial Confinement Fusion Program, Commission on Physical Sciences, Mathematics and Applications, National Research Council, Washington, D.C., March 10, 1997 (Use Date: March 8, 2000)

concerned with the development of the NIF laser system[7]. The Task Force also considered the work of concurrent review panels and advisory boards[8], including, but not limited to, recent reports by the National Ignition Facility (NIF) Council[9], the University of California's President's Council[10] and the Department of Energy's Stockpile Stewardship Report[11].

Throughout this process, the Task Force members endeavored to bring the benefit of their collective experience and knowledge to the effort and to offer an objective assessment of the options to complete NIF. Members of the Task Force considered the project's engineering and management challenges and the proposed method for accomplishing the assembly and installation of the NIF laser system. The Task Force also sought to consider fairly and fully technical challenges still hindering NIF's progress, to review and assess the risks of completing the project and to develop recommendations for the best technical course of action to complete the project.

The dedication and commitment of the individuals who attended, participated in or otherwise offered information, guidance or support to help in this review was impressive. The Task Force appreciates the sincere efforts of everyone who offered their assistance to this review. The Task Force worked to fairly review, on their merits, the comments and opinions offered by everyone.

Interim Report of the National Ignition Facility Laser System Task Force

On January 10, 2000 the Task Force issued its interim findings based on reviews conducted by the Task Force during three open meetings conducted in November and December 1999. The *Interim Report of the National Ignition Facility Laser System Task Force*[12] did not uncover any technical or managerial obstacles that would, in principle, prevent the successful completion of the National Ignition Facility laser system. The report also documented the Task Force's interim findings and provided recommendations in seven key areas: The interim report recommended:

1. Improving NIF program and project management procedures and processes;
2. Increasing the Laboratory Director's project management roles and responsibilities;
3. Clarifying the roles, responsibilities and lines of authority of NIF Project Management;
4. Employing a more appropriate risk contingency budget factor;
5. Improving the design robustness of the NIF laser system;
6. Establishing a well-defined project end point; and

[7] See Appendix D for a more detailed summary of the Task Force's activities.
[8] See Appendix E for a listing of concurrent and historical NIF Reviews.
[9] The Technology Review Group of the NIF Council submitted its report, the "NIF Technology Review" on November 4, 1999. Dr. John L. Emmett chaired the review. Throughout the Task Force's report it may be referred to as the "Emmett Report".
[10] The "Report of the University of California President's Council: The National Ignition Facility (NIF) Review Committee" was submitted on November 18, 1999. It was chaired by Dr. Steven Koonin. Throughout the Task Force's report, it may be referred to as the "Koonin Report."
[11] The US Department of Energy, "Stockpile Stewardship Program: 30-Day Review" was submitted on November 23, 1999.
[12] The "Interim Report of the National Ignition Facility Laser System Task Force" was submitted by the Task Force on January 10, 2000 and submitted to the Secretary of Energy by the Secretary of Energy Advisory Board on February 11, 2000.

7. Accepting and implementing the Emmett Group's recommendations and the phased implementation of the NIF laser systems to full fluence.

An eighth area, the review of the detailed cost and schedule rebaselines, was independently reviewed by a "Lehman" style review panel.

NIF Project Management Team Response to the Interim Report Findings and Recommendations

The NIF Project Management Team's response to the findings and recommendations of the Task Force's interim report is presented in Appendix F - NIF Project Implementation Matrix[13]. The findings and recommendations presented in the Task Force's interim report may be grouped into the following broad categories of issues: Project Management; Project Planning and Execution; and Technology issues.

Project Management Issues --

Since the release of the Task Force's interim report, the NIF project has undergone dramatic and essential restructuring responsive to the Task Force's project management findings. The Department of Energy has clarified the project lines of authority, accountability and responsibility for the NIF project under the newly created National Nuclear Security Administration (NNSA). A separate Office of NIF has been created within the Office of Defense Programs to manage the NIF project, reporting directly to the Deputy Administrator. A revised NIF Project baseline cost and schedule has been developed which takes into account the previously unidentified or unrecognized scope and addresses the findings and recommendations of the NIF Laser System Task Force. Lastly, the detailed cost and schedule data contained in the NIF rebaseline plan was independently reviewed by a "Lehman" style review panel. The corrective actions taken by the NIF Project Management Team to address the NIF Laser System Task Force's project management findings are described in greater detail in Chapter 2.

Project Planning and Execution Issues --

In response to the Task Force's project planning and execution findings, the NIF Project Management Team has incorporated a more appropriate level of risk contingency in the project baseline at the DOE Level 0 Baseline Change Control level. Expertise has been solicited from private industry and has been incorporated into NIF Project planning and execution. An Integration Management and Installation subcontractor has been employed for project management, design management, commissioning, installation and assembly of the NIF beampath infrastructure. Additionally, Quality Assurance, Systems Engineering and Schedule and Budget Planning groups have been added to the NIF core management structure. The corrective actions taken by the NIF Project Management Team to address the NIF Laser System Task Force's project planning and execution findings are described in greater detail in Chapter 2.

[13] Appendix F provides the NIF Project's Implementation Matrix summarizing the NIF Project Management Team's response to the findings and recommendations presented in the NIF Laser System Task Force's interim report.

Technology Issues --

In response to the Task Force's technology findings, the NIF Project Management Team has committed to revising the infrastructure baseline to provide for full 11/7 beamline architecture capability. NIF related research and development activities are now managed by the NIF Project Manager in an integrated manner with support and tracking by the NIF Systems Engineering organization. Furthermore, the Integration Management and Installation contractor will conduct manufacturer proof tests prior to the installation of the first beamline bundle and will allocate additional time for the installation of the first bundle. The corrective actions taken by the NIF Project Management Team to address the NIF Laser System Task Force's technology findings are described in greater detail in Chapter 2.

Revised NIF Cost and Schedule Baselines

On June 1, 2000, the Secretary of Energy submitted to Congress an interim certification of the revised cost and schedule baseline for the National Ignition Facility (NIF) Project[14]. The interim revised baseline addressed the findings and recommendations of the NIF Laser System Task Force. The process for arriving at the revised baseline was endorsed by the Task Force.

The revised baseline submitted to Congress in June and endorsed by the Rebaseline Validation Review Committee provides the following budget profile for the NIF Project:

Year of Expenditure Funds in Millions of Dollars

$M	Prior Years	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	Total
TEC	899	209	245	187	150	130	130	130	15	2,095
OPC	145	6	1	1	0	0	0	0	0	153
TPC	1,044	215	246	188	150	130	130	130	15	2,248
O&M*	419	61	72	75	96	114	117	121	125	1,200
MOD**	0	12	12	11	8	3	0	0	0	46
Total	1,463	288	330	274	254	247	247	251	140	3,494

Notes:

TEC = Total Estimated Costs

OPC = Other Project Costs

TPC = Total Project Costs

O&M = Operations and Maintenance Costs

MOD = United Kingdom Ministry of Defence

*Project-related operating funds (prior years include NIF-related ICF program funding)

**Anticipated British funding for the Shot Rate Enhancement Program

[14] The Department of Energy's interim certification to Congress of revised cost and schedule baseline for the National Ignition Facility is available at http://www.dp.doe.gov/dp_web/doc/Interim_NIF_Cert.doc

The costs of designing and fabricating the NIF targets have historically been part of the Inertial Confinement Fusion (ICF) Program and are currently included in that program's budget request. The costs of designing and fabricating the NIF targets have never been identified with a line item project. 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.

The funding plan contained in the rebaseline forms the basis for the NIF Project to go forward with a final rebaselined cost and schedule plan, also referred to as the Balanced Program Plan. This plan is responsive to providing NIF as a tool for the Stockpile Stewardship Program (SSP) in a manner that is consistent with the overall cost and schedule of the Stockpile Stewardship Program. The revised baseline plan now calls for NIF to have first light in FY 04 and completion to the full 192 beams in FY 08. This corresponds to a delay of about 3 years for first light and 4 years for Project completion.

NIF Project Construction

The NIF building and facility construction, a $250M component of the NIF Project, is approximately 90% complete and on schedule and within budget. Of the two large laser bays, each housing 96 beams, one is now ready to accept the large steel structures that form the laser beampath enclosures and house the optical elements of the laser, called Line Replaceable Units (LRUs). The second laser bay is also nearing completion. The "switchyard" steel structures that hold the large turning mirrors and direct 96 beams from each laser bay into the center of the 10 meter diameter target chamber have been installed and the roof of one switchyard has been fully enclosed. NIF's central plant has been completed and turned over to LLNL and is ready to provide the required utilities to allow the start of environmental control in the Laser and Target Area Building. The adjacent optics assembly building has been completed and has been certified for clean room operations. A variety of specialized assembly, handling, and transport equipment is now being installed in order to support LRU assembly.

Installation of the beampath infrastructure has already started. The NIF Project Management Team will utilize an industrial contractor (the Integration Management and Installation, or IMI contractor) experienced in large, complex assembly projects to manage this activity throughout its phases of design, fabrication, assembly, installation, and commissioning. Companies with the appropriate expertise in high technology plant build-out will be sub-contracted as necessary to accomplish this complex task of clean assembly, alignment and integration of the beampath hardware.

The final design of the NIF LRUs is nearing completion. Recent successful laser glass pilot-production runs at one of the two vendors delivered 200 (or 5% of the required) glass slabs that meet all NIF specifications and with a better yield than in the planning assumptions. Full production at both vendors is scheduled to start next fiscal year. All the critical technologies required for the NIF have now been developed and integrated into final design, ready to begin procurement. Recent progress has been made on the issue of final-stage optics damage due to high fluence exposure to laser light. The NIF Project Management Team expects that their continued, aggressive optics R&D program will allow longer optics lifetimes and hence more economic operation by the time NIF is fully completed.

CHAPTER 2 - PROJECT MANAGEMENT, PLANNING & EXECUTION

Overview

A number of significant challenges to the successful completion of the NIF Project were identified in the *Interim Report of the National Ignition Facility Laser System Task Force.* Many of these challenges had their origins in project management. At the time, none were deemed obstacles that would, in principle, prevent the successful completion of the National Ignition Facility laser system if they were properly addressed.

The recommendations contained in the interim report are documented in Appendix F, together with the actions taken by the NIF Project Management Team consisting of DOE-Headquarters, the University of California, and Lawrence Livermore National Laboratory. The Task Force found that the kinds of problems that led to the NIF budget overrun and schedule delays were systemic and not particular to this project or this laboratory. Changes needed to be made in all three organizations in order to prevent future recurrences of situations of this nature. This call for changes was further underscored in other recent reviews. Many of the Task Force's conclusions were reached independently in the Department of Energy's "Stockpile Stewardship Program: 30-Day Review" (November 23, 1999), and the "Report of the University of California President's Council National Ignition Facility Review Committee" (November 18, 1999)[15].

Since the release of the Task Force's interim report, the NIF Project Management Team has been restructured. In addition, it has developed a revised Project baseline cost and schedule for the NIF that takes into account the previously unidentified or unrecognized scope and addresses the findings and recommendations of the NIF Laser System Task Force. Comments in this section reflect an appreciation that significant changes in project management and system engineering have taken place in response to reviews of the NIF Project and will continue to evolve with the project. The Task Force's relevant recommendations, both interim and final, should be taken as a reinforcement of the need for significant changes in these areas and elsewhere in the management organization overseeing the development of the NIF laser system.

Lawrence Livermore National Laboratory and Los Alamos National Laboratory, the two DOE laboratories with responsibility for the nation's nuclear stockpile, are strongly and properly focused on scientific research and development. These laboratories are ranked by many with the country's premier scientific institutions, and both conduct research on a par with the finest universities while meeting their nuclear mission responsibilities. The labs' capabilities, strongly nurtured by the managing contractor, the University of California, must be encouraged and preserved. This strong scientific culture, with its necessary emphasis on individuality and exploration, is not necessarily a good environment for the disciplined prosecution of a development and construction project for a major facility like NIF. A unique aspect of the culture of the laboratories is the fact that each is formally managed by the university as a GOCO (government-owned and contractor-operated) facility, but they also receive programmatic, management and business direction from the DOE's Office of Defense Programs' branch and

[15] References to other reports about NIF are made throughout this interim report of the NIF Task Force. See Appendix E, for information on how to obtain complete copies of these and other reviews of NIF.

field offices. As a result of multiple and frequently uncoordinated directives, and the largely classified environment in which they operate, the laboratories often act with greater de facto autonomy and self-reliance than advisable. The laboratories have too much of a tendency to not flag problems to the outside world, where they actually might find counsel and help. Rather they prefer to go it alone for periods too long, relying too much on their in-house scientific ingenuity and engineering skills.

A review by the University of California President's Council NIF Review Committee[16] similarly criticized this "do-it-yourself" mentality of the laboratory, which led to denial and delays in correcting problems with NIF and weakened the project management discipline. In addition, many outside observers believe that Lawrence Livermore's pride and distinction in science may be the cause of unwarranted complacency, if not disregard for time-tested management tools and project discipline. This complacency also contributed to a lack of well-identified, open and receptive channels within the laboratory for technical concerns that may be perceived by the NIF project staff.

Project Management Issues

In response to the interim findings and recommendations of NIF Laser System Task Force, the NIF Project Management Team took the following actions to address the Project Management findings and recommendations:

- Revising the NIF Project Execution Plan to strengthen the lines of authority, accountability, roles and responsibilities for DOE Headquarters, NNSA, DOE Oakland Operations Office, University of California and LLNL.
- Strengthening the connection between DOE/NNSA HQ and field elements responsible for the NIF by creating a single Office of the NIF with HQ and field elements that report directly to the Deputy Administrator.
- Establishing the Office of Project Management Support (DP-6) to assist the Deputy Administrator in improving project management within the Office of Defense Programs. This office will be responsible for establishing policy and procedures for project management, including the ESAAB equivalent process; coordinating reviews and follow-up action tracking; and for providing non-advocate reviews of planned and on-going DP projects.
- Developing a NIF Project Mission Support Group that will be responsive to the needs of the Department's users of NIF in the areas of DOE Campaigns and Directed Stockpile Work.
- Instituting a project management review process similar to the "Lehman Review" process utilized by the Office of Science. These "Lehman" style reviews will be conducted with outside project management and technical experts. The first review was conducted in mid-August by the Rebaseline Validation Review Committee chaired the Manager of the Nevada Operations Office, Ms. Kathleen Carlson. The Rebaseline Validation Review represented a weeklong forty person review the NIF rebaseline plan and an assessed the project budget, cost, schedule, and management control systems. Other reviews by the Energy Systems

[16] The University of California President's Council's National Ignition Facility (NIF) Review Committee, November 18, 1999, Pages 6-8.

Acquisition Advisory Board (ESAAB) and the NIF Programs Review Committee will occur at regular intervals.

- Fully committing the Director of the Lawrence Livermore National Laboratory to the success of NIF. In response, the laboratory director established a new Directorate at LLNL, the NIF Programs Directorate, and a new senior position, Associate Director (AD) for NIF Programs, which reports directly to his Office. The NIF Project Manager also serves as the Deputy Associate Director for the NIF Programs Directorate.
- Reorganizing the NIF Council into the NIF Programs Review Committee (NPRC) to focus on thorough technical and management reviews of the NIF. This restructured group now reports directly to the LLNL Director and is chaired by Dr. H. Grunder, Director of Thomas Jefferson National Accelerator Laboratory. The NPRC and its subcommittees will consist of outside, independent technical and project management experts who will review all aspects of the project.
- Ensuring open channels of communication of NIF issues by requiring the Director to send NIF Program Review Committee (NPRC) reports directly to DOE without first having to share findings and meeting proceedings with his Office or the NIF Project.
- Providing weekly, monthly, and quarterly reports to NNSA and DOE on NIF project status.
- Establishing a Project Management Panel (PMP) on the University of California President's Council on the National Laboratories to assess and monitor the laboratories' project management systems. In addition the UC Office of the President has hired an expert in the management of large complex construction projects. To assist UC without imposing duplicative layers of review, UC now sends representatives to all reviews of the NPRC and receives all NPRC reports and LLNL responses.

The NIF Task Force believes that the corrective actions undertaken by the NIF Project Management Team in response to the project management findings and recommendations are both necessary and sufficient to permit the NIF Project to be completed within the revised NIF cost and schedule baselines. Continued diligence on the part of all NIF project participants will be required to assure that these project management improvements will function as envisioned and contribute to the successful completion of the NIF.

Project Planning and Execution Issues

A number of significant challenges to the successful completion of the NIF Project were associated with Project Planning and Execution Issues related to Project Planning & Rebaselining; Systems Engineering; Configuration Management, Cost/Change Control, and Scheduling; and Risk Management and Contingency.

In response to the Task Force's interim findings and recommendations, the NIF Project Management Team took the following actions to address the Task Force's Project Planning and Execution findings and recommendations:

- Incorporating a risk contingency (approximately 25 percent, developed according to risk) appropriate to the current status of the NIF into the new project baseline.
- Soliciting of a wide variety of expertises from private industry to assist in the planning and implementation of the NIF project. Individual expertise includes:

  Jacobs Engineering (Beampath Infrastructure System);

  Representatives from aerospace and the semiconductor communities (clean assembly);

  Senior managers from the aerospace and the semiconductor communities (acquisition strategy development and guidance on Project management and systems engineering); and

  Science Applications International Corporation (SAIC) (cost validation on NIF Line Replaceable Units).
- Using an Integration Management and Installation (IMI) subcontractor to provide for project management, design management, commissioning, and installation/assembly work for the Beampath Infrastructure System. The IMI contractor will also have a substantial QA/QC role in assembly of the beampath infrastructure.
- Elevating NIF Quality Assurance to report to the NIF's core management structure and providing an independent assessment of all NIF Project activities. The Quality Manager will manage the NIF audit program, and ensure sufficient qualified personnel are in place. This program will be evaluated by Quality Engineering and Design (QED), a consulting group with expertise in Quality Assurance and Quality Control (QA/QC) in large programs. A systematic recruiting effort is under way to appropriately staff the program.
- Establishing the NIF Systems Engineering Group, whose duties include: performance and risk analysis, configuration management, safety engineering, cleanliness and contamination control, alignment, commissioning, revalidation of requirements, and Functional System Description (FSD) systems integration/redesigns. Most of these areas are now fully staffed. The NIF Systems Engineering organization will coordinate all Risk Management activities.
- Establishing the System Engineering Risk Analysis Working Group to coordinate risk management. Their recommendations are to be prepared with FSD Managers as Engineering Change Requests that are presented to the Change Control Board. Systems Engineering will also continue to track the performance of the mitigation efforts that are currently underway, as well as search for and resolve new risks as they are identified.
- Creating a Schedule and Budget Planning Group to provide overall management and coordination of NIF current year and out-years integrated schedule and budget plans. The Schedule and Budget Planning Group plays a key role in the NIF rebaselining process. One of the key functions of this Group is to provide cost and schedule evaluations at the Baseline Change Control Board meetings. The NIF Project Management Team has extensively replanned and documented a project-optimized plan using design documentation as the basis for many of the cost estimates. The detail design drawings are now more than 85% complete. This drawing basis combined with vendor quotes and vendor estimates form the basis for a high percentage of the NIF procurement estimate.
- Revising the NIF Project Execution Plan, the Project Completion Criteria and other documents to reflect changes in the management structure of the Project, LLNL, UC and DOE. Authorities and responsibilities for each agency are defined in the Project Execution

Plan. The new NIF rebaselined plan identifies a set of milestones that are associated with completion of construction activities, management pre-start reviews, testing, and operations. Progress on these milestones will be reported regularly. LLNL and DOE will both track these performance milestones. The startup and commissioning phases will be part of this deployment strategy and will be incorporated into the new baseline with an appropriate set of project milestones. The final deployment option will be based on NNSA and Congressionally approved NIF rebaselining.

The NIF Task Force believes that the corrective actions undertaken by the NIF Project Management Team in response to the project planning and execution findings and recommendations are both necessary and sufficient to permit the NIF Project to be completed within the revised NIF cost and schedule baselines.

While the level of risk contingency included in the NIF rebaseline is lower that the value recommended in the Task Force's interim report, the Task Force concurs with the project's development of contingency based on overall risk. The Task Force recommended that the cost and schedule baselines be reviewed by an independent "Lehman" style review panel and recommends that such reviews should be conducted periodically throughout the life of the project.

CHAPTER 3 - BEAMPATH INTEGRATION AND CLEANLINESS

Overview

A number of significant challenges to the successful completion of the NIF laser system identified in the *Interim Report of the National Ignition Facility Laser System Task Force* were associated with Beampath Integration and Cleanliness Issues and were the result of either design requirements, budget or schedule pressures.

The Task Force recognized that the NIF beampath/optics systems represented a large and extremely complex system, housing leading-edge laser optics that must operate in a class-1 clean environment. More than a simple scale-up of previous large laser systems (such as the Nova and Shiva laser systems[17]), the NIF beampath/optics systems were forced by economics into extremely compressed, repetitious structure housing 192 laser beamlines. Assembling this laser infrastructure and installing the optics, while achieving the required level of cleanliness, was ultimately acknowledged to be a major challenge to a successful NIF construction.

Before the summer of 1999 when NIF cost overruns were revealed, the NIF Project Management Team had addressed the assembly plan and focused on developing protocols for the many phases of assembly. These phases included cleanup and installation of the infrastructure of the Laser and Target Area Building (LTAB) and the Optics Assembly Building (OAB), commissioning and optical component cleaning, and installing optics into the infrastructure. While the NIF Project Management Team had employed highly qualified industry consultants in clean-construction techniques, they were only beginning to engage experts in complex facility installation. Upon further study, achieving an adequate level of collaboration with industry experts in this area then became a critical element of the assembly path.

Beampath Integration & Cleanliness Issues

A number of challenges to the successful completion of the NIF laser system were identified in the *Interim Report of the National Ignition Facility Laser System Task Force* which were linked to Beampath Integration and Cleanliness Issues such as the needs for the following:

- Adequate prototyping and the need to provide sufficient resources to permit the installation of the first bundle as a NIF prototyping activity;
- More effective use of complementary (and possibly parallel) work taking place outside the present NIF Project Management Team and incorporation of that experience in the NIF development planning process; and
- A vigorous effort by the NIF Project Management Team to address beampath assembly/cleanliness issues.

In response to the interim findings and recommendations, the NIF Project Management Team took the following actions to address the Task Force's Beampath Integration and Cleanliness findings and recommendations:

[17] The Nova laser was the world's largest laser until the creation of NIF. Located at Lawrence Livermore, it fired more than 14,000 shots during its 15-year life. It fired its last shot in June of 1999. The Shiva 20-beam laser was completed in 1977. The Shiva laser delivered 10 kilojoules of energy in a billionth of a second.

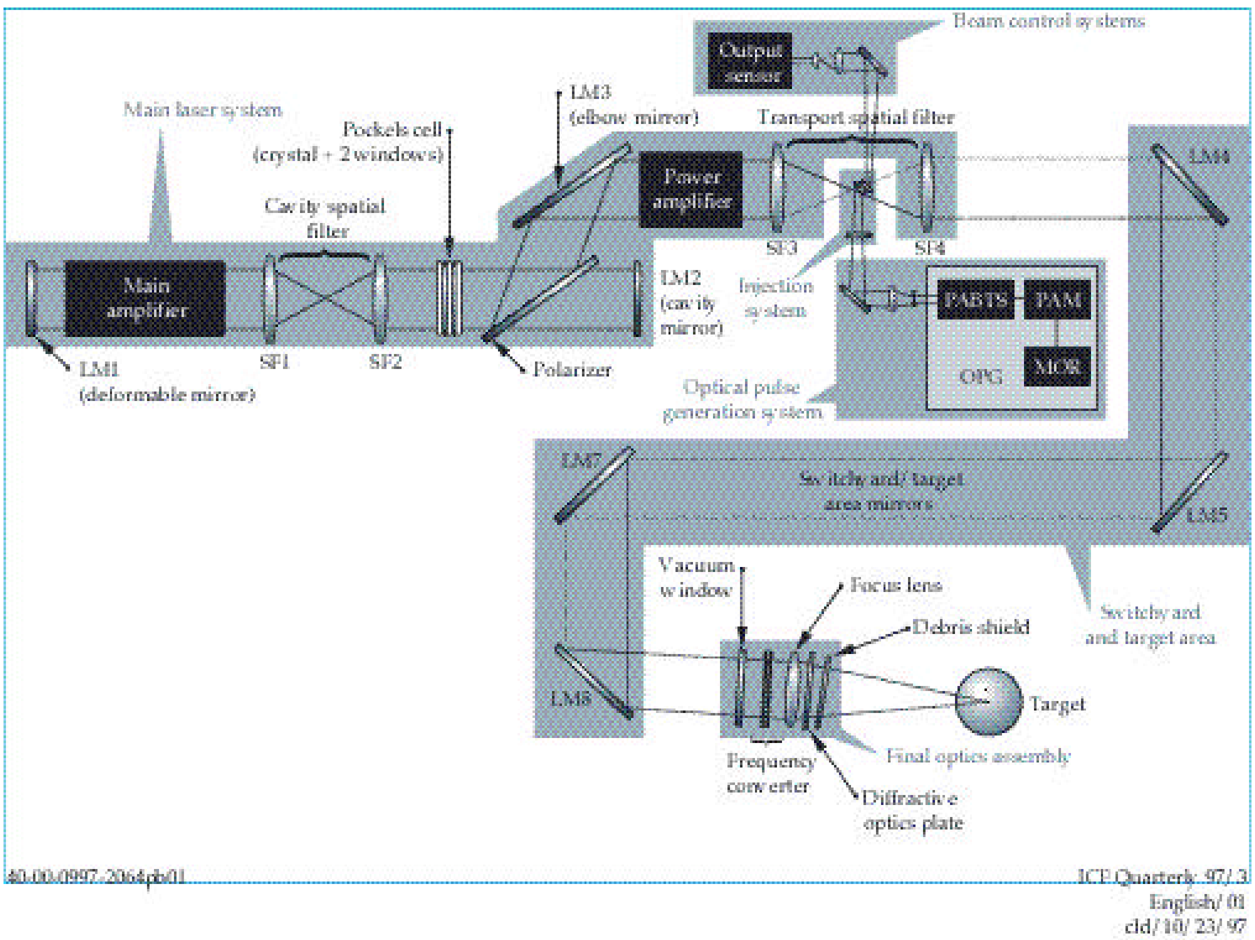
- Strengthening the NIF Systems Engineering group to better manage technical risks and optimize systems designs. During preparation of the rebaseline the Risk Analysis Working Group with the Functional System Description (FSD) Managers identified ~150 scope items to be included in the new NIF baseline.
- Providing an infrastructure baseline capability for a full 11/7 beamline architecture. While the NIF Project is currently committed to purchasing enough glass to populate 11/5, the final decision was postponed until data from the first bundle can be evaluated.
- Arranging for the NIF Project's new Integration Management and Installation (IMI) contractor to conduct beampath hardware assembly and installation prototyping on-line. The first set of beampath connections and validation that cleanliness requirements are achieved will use detailed assembly and installation procedures to verify each type of enclosure connection. These procedures are based on extensive installation sequence planning using the 3D model of the beampath hardware. Should issues with initial assembly and installation arises, they will be corrected and the procedures will be modified before proceeding with the balance of the beampath installation.
- Allowing approximately 15 months for commissioning of the first bundle, much longer than allowed for subsequent bundles. The experience gained on the first bundle will be utilized on subsequent bundles. The 1ω and 3ω laser diagnostics in the Precision Diagnostic Station will be used for the first bundle to understand and allow optimization of the laser performance. Operation of early bundles and the performance bundle will provide the experience necessary for the laser to reach all performance goals. This early operation will also allow the shake down of the target area support systems and early target diagnostics.

The NIF Task Force believes that the corrective actions undertaken by the NIF Project Management Team in response to the beampath integration and cleanliness findings and recommendations are both necessary and sufficient to permit the NIF Project to be completed within the revised NIF cost and schedule baselines.

CHAPTER 4 - OPTICS

Overview of NIF Optics

The NIF laser system is the largest and most complex optical system ever designed and constructed. It consists of approximately 7,500 large optical elements, 3,000 Neodymium (Nd) Phosphate glass slabs or 150 tons of optical grade Neodymium (Nd) doped glass, 1,600 mirrors and polarizers and 2,500 fused silica optics. These optics must be finished nearly defect-free and are coated. The optical system will be installed in a class-100 clean room environment. The primary laser oscillator/amplifier system consists of 192 laser beams. Each one of these beams contains 11 oscillator Neodymium glass slabs and 5 Nd:glass amplifier slabs followed by a spatial filter, beam steering optics and the final optics module that contains the Potassium Dihydrogen Phosphate (KDP) nonlinear crystals for conversion to the third harmonic at 355 nm. The final optics modules also contain a vacuum window interface to the target chamber, the fused silica final focus lens, and the glass debris shield.



Previous reviews have raised the issues of optical damage along the beam path, the availability and quality of the Neodymium phosphate laser glass, the antireflection coating technology, and the design of the spatial filters. Issues related to the laser architecture, laser gain, energy extraction, beam shaping, temporal pulse shaping and nonlinear frequency conversion were addressed by experiments and operating experience on the Nova and the Beamlet laser systems[18] at Lawrence Livermore lab.

The NIF laser system design originated from an optimization of minimizing the construction costs versus the operational costs of the laser system. The optimization was subject to the constraint that ignition could be achieved. The higher the laser fluence, which is the Joules of optical energy per square centimeter of optical area (J/cm^2), the smaller the physical size of the laser system and thus the lower the construction cost for the facility and for the lasers. However, the higher the operating optical fluence, the greater the risk that the optical components would suffer optical damage during a laser shot.

The optical damage fluence threshold has been raised in each successive laser system, from the Argus and Shiva lasers to Nova, by a combination of innovations. These innovations ranged from relay imaging and spatial filtering, to materials progress in laser glass and Potassium Dihydrogen Phosphate (KDP) nonlinear optical crystals, and dielectric coatings. However, optical damage is statistical in nature and there is no guarantee that continued improvements can be counted upon to increase the optical damage limit. Further, experience has shown that optical damage limits are wavelength dependent with damage expected at lower fluence levels in the ultraviolet frequency range than in the infrared range.

Early in the NIF design process, the designers decided to use a 192-beam architecture instead of the originally proposed 240-beam design. Although the decision to build a facility with 192 beams reduced the overall construction costs of the laser facility, it placed a higher degree of technical risk on the system due to the required increase in the optical fluence. The decision to use 192 beams instead of 240 beams also reduced the technical contingency margins for reaching ignition. For example, at the proposed NIF operating fluence of NIF of 8 J/cm^2, the output of NIF is limited to 2 million Joules (MJ) of energy while that of the 240-beam laser would be 25% greater at 2.5MJ. An alternative way of viewing this relationship is that, at an energy level of 2 MJ, NIF must operate at a fluence of 8 J/cm^2 while a 240-beam laser could operate at a lower fluence of $6.4 J/cm^2$. The increased technical risk resulting from NIF's decision to operate at the higher fluence was recognized in the 1994 technical reviews of the NIF laser design.

Experiments on the Beamlet laser at Lawrence Livermore lab provided experimental evidence that laser operation at a fluence of $8J/cm^2$ was possible. The Beamlet laser tested Potassium Dihydrogen Phosphate (KDP) crystals and fused silica optics for damage in air at fluence levels reaching slightly in excess of $8J/cm^2$. Given the history of improved optical damage fluence for each of the previous laser systems, the $8J/cm^2$ fluence level for NIF appeared to be justified. However, recent experiments have shown that optical damage at the ultraviolet wavelength remains a key technical challenge, especially in the final focus optics module. The damage of the SiO_2 final focus optics in the vacuum environment occurs at lower fluence levels than for the

[18] Beamlet is a 100-foot-long laser built at Lawrence Livermore in 1994 to serve as a proving ground for NIF. Beamlet was dismantled and shipped to Sandia Livermore to be used to create a bright source for taking images of plasmas.

optic in air. Work is underway to model the damage and to investigate methods to alleviate the lower damage level[19].

Extrapolation from the earlier Nova laser system at Lawrence Livermore lab to the larger and more powerful NIF laser required the development of a new process for the production of the laser glass. The smaller volumes of glass required for the Nova laser allowed for production by a pot melting and pouring method. The larger volume of laser glass required for NIF (3,000 laser glass slabs or 150 tons of laser glass) required the development of a continuous melt production method. In this method the glass is melted in a large refractory crucible. Laser glass feedstock is fed into the melter and molten glass extracted from a platinum-lined downpipe and fed onto a continuous belt for cool down and annealing. The continuous melt process leaves the glass in its high temperature molten state for less time than the older pot melting process. Thus steps must be taken to reduce any residual water vapor in the glass and to keep platinum inclusions from growing[20].

Early in the conceptual design of the NIF laser system it was recognized that the volume of Potassium Dihydrogen Phosphate (KDP) crystals required by NIF could not be met by traditional solution-growth techniques at an acceptable cost. Work was initiated on supersaturation solution rapid growth of KDP crystals at boule sizes adequate to meet the NIF optics dimensions. Concerns were raised about the optical quality of the crystals and about the antireflection coatings placed on the crystals[21].

The NIF laser system consists of approximately 1,600 mirrors and polarizers and more than 2,500 fused-silica optics. Further, there are some 30,000 elements of small optics in the NIF design needed in the preamplifier assemblies and in optical monitoring and alignment. The Task Force cautions the NIF laser program that the procurement of the small optics, quality control and subsystem specifications remains an issue of concern and merits ongoing review and monitoring.

The NIF optical components will need to be cleaned and mounted in portable holders prior to being installed into the NIF laser beamline. The cleanliness of these optical surfaces is critical to the operation of the laser and the success of NIF. Particles in the laser glass, or on the surface can be initiators for optical damage. A great deal of NIF Project Management Team effort will be required to plan for the acceptance of the glass elements; test the quality of the elements; provide the necessary antireflection coatings; mount the elements into the frames; and place the frames in the automated vehicles used to install the frames into the laser beamline. The issues raised include testing of optical quality in the clean room environment, exchanging optical elements in the beamline, and after a shot, confirming that the optical elements are of the quality required for the next shot. These issues of acceptance, coating, testing, assembly, cleanliness, and monitoring

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[19] Progress in the understanding of optical damage is addressed further on in this section of the Task Force's Final Report.

[20] Progress in the continuous melting process is addressed further on in this section of the Task Force's Final Report.

[21] The progress in the KDP crystal growth and coatings is an issue addressed in this section of the Task Force's Interim Report.

relate to NIF as an operational laser system as well as to the state of the optics as each beamline is installed and operated up to completion of the NIF laser.

Optical Damage

The NIF laser system was designed to operate at a maximum laser fluence of 8J/cm^2 in the ultraviolet wavelength range at the final optics. This operational level will require further advances in laser optics to increase the optical damage limit from what is now achievable on the fused silica final focusing lens in a vacuum environment. In short, the critical element of the NIF laser system is the ultraviolet optics. As the fluence is increased, dielectric breakdown, or optical damage will occur in all materials. The determination that the critical optical elements are in the ultraviolet frequency range is not a surprise. The determination that the fused silica lens is damaged at a lower fluence in a vacuum than in air is a surprise.

Optical damage can occur in any of the optical components that comprise the NIF beamline. Early in the history of glass lasers, optical damage was observed in the laser glass. This damage emanated from particles of platinum that precipitated in the glass as a result of parts of the platinum crucible lining dissolved during glass production. Progress has been made to keep the platinum dissolved in the glass to prevent its precipitation in the glass itself. To meet its specification NIF laser glass must contain less than four particles of platinum per laser glass disk. Each platinum particle may lead to a damage site, but in the phosphate glass the damage site does not grow in size and can thus be tolerated. The spatial filter with relay imaging protects the optics in the beamline from additional optical damage due to Fresnel fringing.

Optical antireflection coatings were also a concern for optical damage early in the NIF program. The combination of well-polished surfaces free from polishing compound particulates embedded into the surface, and low density solgel coatings have solved the optics damage problems associated with the antireflection-coated surfaces. The deuterated KDP crystals, or DKDP crystals, used in the polarization switch were also an early concern regarding optical damage. The combination of diamond turning and the addition of oxygen to the plasma switch has removed the formation of carbon films on the DKDP surfaces and thus eliminated the optical damage concern.

The formation of particles on the surfaces of the NIF beamline optics is a concern as particles are the initiation sites for optical damage. Careful inspection of the Nova optical system has shown that particles can be swept away from the surface of the glass by proper flow of the gas over the surface. Further, careful studies of the particulates in the flow show that some are formed by flashlamp decomposition of a monolayer of organic solvent used to provide the final cleaning to the optical surfaces. The decomposed organic is carbon and it can accumulate into low-density fuzzy dust particles of the size required to initiate damage. Steps have been taken to reduce the carbon formation by pre-illumination of the optical assemblies by 200 flashlamp pulses while providing gas flow. The second step taken was to increase the flow of gas over the optical surfaces to remove and filter carbon clusters that form during the NIF operation.

It is well known that surfaces facing upward suffer more from optical damage induced by initiator particles than surfaces facing downward. In NIF, some large optics in the final beam steering area must face upward. A recognized concern is the need to provide the cleanliness required to avoid particles on the surfaces of these optics.

The present tested optical damage threshold of the fused silica final focusing optics in a vacuum is an optical energy fluence of $5J/cm^2$. For NIF to operate at full energy these optics must operate at a fluence of $8J/cm^2$ in the ultraviolet. The NIF program has five years to improve the optical damage level on the fused silica surfaces so that NIF can operate 1,000 shots at a fluence level of $8J/cm^2$. Investigations underway to achieve this improvement include understanding the damage mechanisms of SiO_2 optics in a vacuum and low pressures of air; evaluating techniques to stop damage from growing to spot sizes that are a problem; reducing the required number of final optics; and smoothing the beam by better design of the optics. If the damage threshold level cannot be raised over the next five years, NIF can operate at full optical output energy for approximately 1/10 the number of planned shots before having to replace the fused silica optics, thus increasing the cost of operating NIF at full beam energy.

From the beginning, the risk of optical damage was recognized as critical to NIF's laser performance. Significant progress has been made but further progress will be necessary to improve the ultraviolet optical damage levels. The NIF program research and development efforts in this area should be supported at a level that is consistent with resolving the final focus optics damage issue.

Laser Glass

The NIF laser requires a Neodymium phosphate (Nd:phosphate) laser glass production rate that is twenty times that required to support the Nova laser. Thus, a new laser glass production method based on continuous melting had to be developed. The NIF program has worked with two vendors to develop a continuous melt laser glass production process. Each of the vendors has more than two decades of laser glass experience. Two facilities have been designed and constructed. Pilot runs were conducted at each of the two facilities.

The pilot runs showed that the continuous melt laser glass production process, used often for commercial silicate-based glass, is a possible candidate for use to produce the phosphate laser glass. The pilot runs also showed the platinum inclusions could be controlled, that the refractive index variations were slightly above specifications and that the glass had higher hydroxyl (OH) content than required by specifications.

As a result of that first pilot run, the glass melting process was modified in order to reduce the hydroxyl content of the glass and to improve its optical quality. The modifications to the process were tested in a second pilot run. Since the glass from this second run meets specifications, it then becomes the first production run of glass. Typically, production terminates when the hot molten glass melts a hole in the large refractory crucible that is then rebuilt for the next run. However, the turnaround time for each production run takes approximately a year. The required turn-around time, which combined with the desire to continue a run for as long as possible led the NIF Project Management Team to the decision to attempt a pilot/production run.

The higher hydroxyl concentration in the continuous melt glass should not be a surprise. Steps have been taken to reduce the hydroxyl concentration in the next pilot run. The steps include pre-drying the powdered glass starting materials; and bubbling oxygen and some chlorine through the melted glass prior to subsequent pouring of the continuous slab of glass on the conveyor belt. The pre-drying of the powder employs a standard technology that has been effective in the past. The bubbling of oxygen gas through the melt was tested in the second pilot run and testing of the resultant glass confirmed the lower hydroxyl concentration.

The continuous melt process proposed does not provide the same degree of mixing of the liquid glass as the pot melting process. Further, the cool conveyor belt used in the process may also lead to increased index of refraction variations in the glass. The glass from the first pilot run was polished and tested for optical quality to assess these factors. For those slabs that were not within specifications on optical wavefront quality, a second step was taken to repolish the glass in local areas. This step adds a modest cost increase to the polishing process but preserves the slab for use. This backup small-tool polishing step is a cost-effective way to meet the glass specifications on wavefront distortion and to improve the yield of the laser glass from the production runs.

The NIF glass procurement effort will proceed at a rate of approximately 15,000 liters per year until all of the glass has been procured. With the glass manufacturing facilities in place, the primary risk is a delay in the procurement due to budget or programmatic limitations. A delay is particularly costly to the glass procurement, as there is little that can be done to speed up the process of the glass pouring or the glass fabrication in the future. NIF glass fabrication includes the addition of the amplified spontaneous emission suppression cladding; cutting and polishing; final testing; and cleaning.

The glass procurement effort is well managed. The companies involved are competing for the business. The cost of NIF glass procurement is $400 million with a $50 million-cost contingency. This effort was on schedule prior to the second pilot/production run scheduled for 2000. Further, this effort may be indirectly supported by cooperation with the French MegaJoule laser project that may share some costs in the glass procurement effort.

KDP Crystals

NIF utilizes potassium dihydrogen phosphate (KDP) crystals in the oscillator for polarization switching and in the final focus optical module for conversion of the 1-micron laser wavelength to the ultraviolet output at the third harmonic wavelength at 355 nm. Early in the NIF project it was recognized that the traditional solution growth methods of growing KDP crystals was too slow and too costly to meet the NIF requirements. The laboratory imported knowledge from Russia on a technique for rapidly growing crystals from a supersaturated solution. The technical risks that were identified included the size of KDP crystals at the required optical quality, the surface finish of the crystals, the optical damage of the KDP crystals in both the polarization modulator and in the UV nonlinear optical converter. These issues have been resolved over the past five years through an aggressive research and development effort.

Today, the KDP crystals grown by the rapid growth process will meet the size and optical quality requirements of NIF. The deuterated KDP (DKDP or KD*P) crystals grown by the traditional method will also meet the requirements. The diamond turning method of surface preparation meets the surface quality and the damage threshold levels for NIF. The growth of the KDP crystals is about 25 percent complete although the boules have yet to be cut and processed into finished crystals. The yield of cut, oriented, and finished plates of ready for testing and coating is about 75 percent.

The remaining technical issue associated with the KPD crystals is the optical coating. The solgel coating has been tested and used in the Nova laser system. In that case, the solgel coating is preceded by a thin silicone undercoating. The NIF coating process initially proceeded without the silicone undercoating layer. The results were the formation of etched pits on the KPD crystal surface formed due to water vapor absorption into the porous solgel coating. A research and development effort is underway to investigate water vapor etching and to find avenues to eliminate the problem. Two approaches that appear to offer a solution are a return to the thin silicone underlayer or the modification of the solgel material. In brief, the growth of the KDP and DKDP crystals is proceeding on schedule. The issues with regard to orientation, diamond turning, and optical coating are resolved with the exception of finalizing the process for elimination of etching by water vapor absorption in the solgel coatings. Processes have been identified to eliminate the etching issue.

Small Optics

As noted in the overview, the procurement of the small optics, quality control and subsystem specifications is an issue of concern for the NIF laser program. The small optics support the preamplifier modules and the alignment and diagnostics for the NIF laser. There are approximately 10,000 small optics in the preamplifier modules and 20,000 small optics in the alignment and diagnostics modules. It is well known in the optics industry that the delivery of small optics is often late and that the quality of small optics is often less than required by the specifications. During the design of the NIF laser, the optics industry was in a slow economic period and the suppliers of small optics or subassemblies of optics were eager to participate in the NIF project. During the past five years the optics industry has seen economic times improve dramatically as optical telecommunications markets have grown rapidly. Today, NIF faces competition with the rapidly expanding telecommunications markets for procuring small optics. This competition may delay the delivery and raise the price for the small optics and the availability of integrators for assembling and testing small optics modules.

The problem becomes an issue because of the delay in preparing the specifications and bid packages for NIF's small optics purchases. This issue has been recognized by NIF and has received priority. What has not yet been decided is the approach to be used in making the purchases – as stand alone optics, mounted optics, or optics purchased as part of a subassembly optical system.

NIF as an Operating Laser System

Assembling, testing and operating the NIF laser system represents a five-year campaign. As noted in the optics section's overview, testing of optical components in the clean room environment, exchanging optical elements in the beamline, and after a shot, confirming that the optical elements are of the quality required for the next shot are challenges to NIF as an operating laser system. The state of the optics in the initial beamlines and in the completed 192 beamlines of the NIF laser system are process engineering issues of assembly, alignment and acceptance of the laser system. The acceptance, coating, testing, assembly, cleanliness, and monitoring issues relate to NIF as an operational laser system as well.

The NIF large optics will arrive at the Laboratory in a finished form, with the exception of precision cleaning and application of solgel antireflection coatings that will be applied on site. Acceptance of the finished optic requires inspection, confirmation that the component meets specification, and storage in a clean environment pending installation into the line-replaceable units (LRU) and into the laser beamline. The mounting of the optics into the appropriate frame will be done in a clean room environment. Optical wavefront testing in this environment will be made difficult by the flowing air required to maintain the required class of clean room. This is an issue that remains to be resolved. Mounting of large optics without stress-induced wavefront distortion is difficult. The task at the NIF site is made even more difficult by the lack of working space around the large optics, such as the final beam steering mirrors. Introduction of optical components into the NIF beamline must be done without compromising the air quality of the beamline. Procedures for optical element exchange into and out of the beamline under controlled clean room conditions must also be developed and tested.

Following a laser shot, the optical elements within the beamline need to be assessed for their readiness for the next shot. This is particularly the case for optical elements that form a vacuum barrier since they also must withstand the stress associated with the air to the vacuum interface. The diagnostics related to operating NIF as a laser system is the least mature element of the NIF program at this time. Sufficient support must be given to the planning, development of prototypes and to the testing of optical diagnostics such that they can be engineered and installed in a timely manner. Testing and evaluation of the optical diagnostics should be scheduled for the NIF laser as part of the testing and alignment of the first installed beamlines.

NIF Optics Issues

A number of challenges to the successful completion of the NIF laser system were identified in the *Interim Report of the National Ignition Facility Laser System Task Force* which were linked to NIF Optics Issues such as the needs to:

1. Identify and overcome the significant technical hurdles to meet the goal of an output energy of 1.8 MJ of energy on target with a shaped 20 nanosecond pulse duration; and

2. Address the remaining issues associated with optical damage, laser glass procurement, KDP crystal growth and fabrication, small optics, and use of the NIF as an operating laser system.

The actions undertaken by the NIF Project Management Team in response to the optics findings and recommendations of NIF Laser System Task include:

1. Extending, if necessary, the glass production runs by another 400 slabs. The NIF Project Team can also increase the number of capacitors in each of the 192 power supply modules to enhance pumping of the 11/5 configuration or to deploy the 11/7 configuration.

2. Managing NIF-related R&D activities at the NIF Project Manager level in an integrated manner. The NIF Systems Engineering organization now tracks and supports this activity. Increased funding has been dedicated to R&D efforts to reduce damage of amplifier slabs (~$2.5M) and UV optics (~$40M). Slab and UV optics damage R&D, modeling, and mitigation are currently underway. Other activities include the engineering redesign of the FOA to minimize beam modulation, studies to reduce the number of initiation sites, studies to mitigate damage growth, full qualification of the KDP rapid growth process and qualification of the KDP diamond finishing process.

3. The Technology Review Group of the NPRC reported on March 31, 2000 that "…the management has accepted, both in spirit and in fact, the majority of (its) recommendations. It is clear that the issues we had raised are high on their priority list for resolution."

4. On March 30-31, 2000, LLNL hosted a workshop on 3ω optical damage. Approximately 20 experts in the fields of materials, chemistry, and physics attended from universities, other national laboratories, and the private sector. Twenty additional experts from LLNL also participated. This was the NIF Project Management Team's first step to collaborate with the "best and brightest" on this issue.

The NIF Task Force believes that the corrective actions undertaken by the NIF Project Management Team in response to the optics findings and recommendations are both necessary and sufficient to permit the NIF laser system to be completed within the revised NIF cost and schedule baselines.

The NIF Task Force considers important the issues of optical damage, laser glass procurement, KDP crystal growth and fabrication, small optics, and NIF as an operating laser system. However, based on the Task Force's review these issues are capable of being resolved with adequate research and development effort. Accordingly, there are no technical issues related to optics that in principle will prevent the NIF laser from operating as a partial system initially and a 192-beam laser system in its completed configuration.

APPENDIX A

SECRETARY RICHARDSON'S INITIATIVES & CURRENT STATUS

In the late summer of 1999, projections indicated that, contrary to earlier reports, the development of the National Ignition Facility (NIF) Laser System at the laboratory would soon experience schedule delays and cost overruns. In response, Secretary Richardson ordered a six-point set of initiatives to get the project back on track and to address the schedule and cost problems. Listed below are Secretary Richardson's six-points and the current response status:

1. Change how Livermore executes its responsibility for the NIF project. Major assembly and integration is no longer be done in-house, but is to be contracted out to the best in industry with a proven record of constructing similarly complex facilities.

   Status: The NIF Project Management Team has implemented major management changes. An outside industrial contractor will now be responsible for the integration, management and installation (IMI) of the laser system infrastructure. LLNL will continue to provide the top-level design and requirements to industrial partners, who will then produce the detail drawings, fabricate the infrastructure components, and perform the installation of the hardware in the Laser and Target Area Building (LTAB). The IMI contractor will be responsible for completing all beamline structures, enclosures and utilities for the entire laser system.

2. Appointment of an independent expert panel to do an in-depth analysis of options and to recommend the best technical course of action. Proper, credible stewardship to maintain the safety, security and reliability of the Nation's nuclear deterrent should remain central to our solution.

   Status: The Secretary of Energy Advisory Board (SEAB) formed an independent external subcommittee, the National Ignition Facility Laser System Task Force to review plans for the completion of NIF. The NIF Laser System Task Force reviewed the NIF Rebaseline plan, and the criteria, guidelines and options used as the basis for the NIF Project cost estimate. The NIF Task Force was chaired by Dr. John McTague, former vice president of Ford R&D, and included other members of industry and academia. The NIF Laser System Task Force submitted an interim report to the Secretary of Energy on January 10 that, while critical of some aspects of the NIF Project, supported the completion of NIF. The final report of the NIF Laser System Task Force (this report) will, upon approval by the SEAB, complete the duties of the Task Force.

3. All cost issues are now to be handled within our DOE defense programs and Lawrence Livermore budget funding lines. Reprioritize our national security program to reallocate dollars, people, and other resources.

Status: The details of how costs are to be handled within DOE DP and LLNL have been presented in a letter to the Secretary of Energy from the NNSA Acting Deputy Administrator for Defense Programs in a memorandum dated May 31, 2000.

4. Contractors are to be held accountable. These funding issues with the NIF project are a significant disruption; therefore, in accordance with DOE's contract with the University of California, $2 million of the $5.6 million 'at risk' program performance fee was withheld. Based upon the final results of the independent review committee, that amount could increase. UC must assume a stronger role in the oversight of research and development projects at the laboratories they manage for DOE, such as NIF.

   Status: In addition to the NIF Task Force's review, the University of California held its own review into the issues surrounding the projected cost overruns on the NIF Project. The UC review committee supported the need for more formal reviews of large projects at LLNL, but felt confident that LLNL could successfully complete and operate NIF. The University of California also established a standing Project Management Panel of its President's Council and has added project management expertise to the Office of the President.

5. DOE management oversight will be strengthened. The Deputy Secretary will include this project on the Department's 'Project Management Watch List' forcing very stringent monthly DOE HQ review and compliance to other strict reporting structures. On June 25th, DOE announced an initiative to strengthen and improve the Department's project management. NIF is now center stage in that oversight program.

   Status: The NIF Project Management Team now holds weekly meetings with the Deputy Program Manager of the NNSA's Office of the NIF, who reports directly to the NNSA Program Manager of the Office of the NIF and to the Acting Deputy Administrator for Defense Programs within NNSA. A Transition Period Implementation Plan (TPIP) was developed to identify milestones from January through the end of Fiscal Year 2000. These milestones are discussed at the weekly meeting and serve as the focus for the monthly and quarterly reports.

6. Lawrence Livermore must initiate a management review to take action against any personnel who kept these issues from the Department as late as early June when DOE was informed that NIF was 'on cost and on schedule.' The Department will conduct a complete and thorough review of this very serious issue. Denial of these kinds of problems is unacceptable and we must ensure that when we learned about the problems the appropriate federal and contractor oversight roles were performed properly and in a timely manner. The Department will hear promptly from Lawrence Livermore on what further management actions they intend to take to insure the problems with NIF get resolved.

   Status: Lawrence Livermore National Laboratory reviewed the NIF Project and took steps to improve the management structure and communication flow to DOE. A new NIF Programs Directorate was established at LLNL to reorganize the NIF. A new NIF Project Manager, Dr. Edward Moses, and a new Associate Director for NIF Programs, Dr. George Miller, were appointed. Additional key personnel were hired into the Project, and it is felt that the new organization is better positioned to resolve the issues of concern.

APPENDIX B

SECRETARY OF ENERGY ADVISORY BOARD
NATIONAL IGNITION FACILITY TASK FORCE MEMBERS

John P. McTague,
Chairman of the SEAB National Ignition Facility Task Force

John McTague recently retired as the vice president for technical affairs of the Ford Motor Company. He is a member of the Secretary of Energy Advisory Board and also serves as Co-chair of the Department of Energy's Laboratory Operations Board. McTague was formerly vice president for research at Ford Motor Company. Prior to joining Ford, McTague served as Deputy Director of the Office of Science and Technology Policy, and as Acting Science Advisor to the President in the Executive Office of the President. He also was a professor of chemistry at the University of California at Los Angeles and an adjunct professor of chemistry at Columbia University. He was elected Alfred P. Sloan Research fellow, a NATO senior fellow, a John Simon Guggenheim Memorial fellow, a member of the National Academy of Engineering and a member of the President's Council of Advisors on Science and Technology (PCAST). He received a bachelor's degree from Georgetown University and his doctorate from Brown University.

Andrew Athy,
Chairman of the Secretary of Energy Advisory Board

Andrew Athy, Jr. is a partner in the Washington D.C. law firm of O'Neill, Athy and Casey. He previously served as counsel to the U.S. House of Representatives Energy and Commerce Subcommittee on Energy and Power (1978-1981). Prior to that he was an attorney in the Office of General Counsel at the Federal Election Commission (1976-1978), and Assistant Attorney General and Deputy Assistant Attorney General, Office of the Attorney General (Criminal Division) Commonwealth of Massachusetts (1973-1975). Athy received a bachelor's degree from the University of Pennsylvania, and his law degree from the Georgetown University Law Center.

Robert Byer

Dr. Robert Byer is the director of the center for Nonlinear Optical Materials and the director of the Hansen Experimental Physics Laboratory at Stanford University. In addition, he serves as a professor of physics at Stanford University. He served as Dean of Research at Stanford University from 1987 to 1993 when he stepped down to return to teaching and research. During his tenure as Dean of Research, Byer was responsible for the independent laboratories, centers and institutes that conducted multiple disciplinary research across departmental and school boundaries and represented approximately one-quarter of the $300 million research volume at Stanford University. From 1985 to 1987, Byer served as Associate Dean of Humanities and Sciences and from 1981 to 1984 he was Chair of the Department of Applied Physics. In addition to his academic experience, Byer has worked as a consultant in the field of lasers for major companies including Westinghouse, General Motors, Boeing and TRW. Byer also is a founding member of the California Council on Science and Technology which was established by the major public and private research universities in the State of California to assist the State with scientific, technical and engineering issues. He has served on the National Science Foundation Engineering Advisory Committee and is a member of the National Academy of Engineering and the Optical Society of America. Byer holds more than 35 patents in the field of lasers and nonlinear optics. He earned a bachelor's degree in physics from the University of California at Berkeley and a master's and doctorate in applied physics from Stanford University.

Gail Kendall

Dr. Gail Kendall is professor of the practice in the Department of Mechanical Engineering at Massachusetts Institute of Technology. Formerly, Dr. Kendall served as director for Strategic Science and Technology at the Electric Power Research Institute. In that position she has gained hands-on experience in the design and development of large-scale, multi-million dollar, cutting edge technology projects. In addition to her responsibilities directing the planning and implementing of new technologies, and coordinating government partnership for the institute, Kendall has overseen several panel evaluations of technical risk, progress, and achievements against planning milestones. Kendall earned her doctorate in mechanical engineering from the Massachusetts Institute of Technology; she also holds a master and bachelor's degree in mechanical engineering from the University of California at Berkeley.

Lawrence Papay

Dr. Lawrence Papay is the new sector vice president for the Integrated Solutions Sector of Science Applications International Corp. (SAIC). Prior to assuming his new post, Papay was the senior vice president and general manager of technology and consulting of Bechtel Group, Inc., a worldwide, high-technology systems engineering and construction firm. Prior to joining Bechtel, Dr. Papay served as senior vice president of Southern California Edison. He has a bachelor's degree in physics from Fordham University, a master's degree and doctorate in nuclear engineering from the Massachusetts Institute of Technology. Papay is a member of the National Academy of Engineering; the National Research Council Commission on Engineering and Technical Systems and its Board on Energy and Environmental Systems; the President's Council of Advisors on Science and Technology Task Force on Energy Research and Development; the National Science Foundation Industrial Panel; the American Nuclear Society; the Industrial Research Institute; and the Center for Resource Management. He is a registered professional engineer (nuclear) in California.

Burton Richter

Dr. Burton Richter is the Paul Pigott Professor of Physical Sciences, Stanford University and the Director Emeritus of the Stanford Linear Accelerator Center and is one of the world's leaders in the construction of large-scale science facilities. In 1976, Richter shared the Nobel Prize in Physics with MIT Professor Samuel Ting for independently discovering of a new elementary particle. Richter led the group that designed and built the Stanford Positron Electron Asymmetric Ring. Experiments conducted at SPEAR in 1973 - 1974 led to the discovery of a new kind of quark, a fundamental particle that is a constituent of neutrons and photons and other hadrons. As the author of more than 300 publications in high-energy physics, accelerators, and colliding beam systems, Richter is a leader in the physics community. Richter is also a member of the National Academy of Sciences; the American Academy of Arts and Sciences; the past president of American Physical Society; the Mitre Corp.'s JASON Group; and President of the International Union of Pure and Applied Physics (IUPAP). He received his bachelor's and doctorate degrees from the Massachusetts Institute of Technology. Finally, Secretary Richardson recently appointed Richter to the Secretary of Energy Advisory Board.

Rochus Vogt

Dr. Rochus Vogt is R. Stanton Avery Distinguished Service Professor and Professor of Physics at the California Institute of Technology (Caltech). From 1987 to 1994, he was the director of the Laser Interferometer Gravitational-Wave Observatory (LIGO) Project. Prior to leading the development and construction of that large laser project, Vogt was a Chief Scientist, Jet Propulsion Laboratory, 1977-78; Chairman, Division of Physics, Mathematics and Astronomy, 1978-83; Acting Director, Owens Valley Radio Observatory, 1980-81; Vice President and Provost, 1983-87 at Caltech. He received a master's degree and a doctorate in Physics from the University of Chicago.

John Warlaumont

Dr. John Warlaumont is the director of Silicon Technology and Advance Semiconductor Technology Laboratory for IBM's Research and Microelectronics Divisions. He is an expert in microcontamination technologies who has orchestrated the construction of several clean room projects. Warlaumont also led various IBM projects in silicon innovation and modeling and X-ray lithography and optical lithography enhancement techniques. Warlaumont started his career researching high power bombardment and soft x-ray sources and the application of x-ray lithography. He received his degree in physics from Cornell University.

APPENDIX C

NATIONAL IGNITION FACILITY (NIF) LASER SYSTEM TASK FORCE TERMS OF REFERENCE

Objectives and Scope of Activities:
The Task Force will focus on the engineering and management aspects of the proposed revised method for accomplishing the assembly and installation of the National Ignition Facility (NIF) laser system. The review will provide independent external advice and recommendations to the Secretary of Energy Advisory Board on the options to complete the National Ignition Facility (NIF) Project and recommend the best technical course of action. The Task Force will also review and assess the risks of successfully completing the NIF Project.

Background:
The National Ignition Facility, under construction at the Lawrence Livermore National Laboratory, is the cornerstone of the science-based Stockpile Stewardship program and is required for U.S. support of the Comprehensive Test Ban Treaty. When completed, NIF will be the world's most powerful laser, with 50 times more energy than any existing laser. Consisting of up to 192 laser beams, the NIF will produce, for the first time in a laboratory setting, conditions of matter close to those that exist at the center of stars and inside detonating nuclear weapons. This ability can be used directly for physics experiments to increase understanding of the performance of nuclear weapons without further need for nuclear testing. NIF experiments are also essential to demonstrating the feasibility of fusion energy. An additional benefit of NIF is that it would provide substantial opportunities for advances in science and technology including laboratory astrophysics, optics, and materials.

The current NIF schedule calls for the project to be completed at the end of FY 2003 at a cost of $1.2 B. The conventional facilities are about 70% complete now and should be completed by the end of FY 2001. Recent data and experience along with analysis of related engineering experience has demonstrated that the assembly and installation of the laser system must be done in a cleaner and more rigorous and detailed manner than had been originally planned. This change in approach is considered essential for achieving the required laser performance. This change will add costs in the range of several hundred million dollars. It is essential to have confidence that the revised engineering and management approach will provide a complete and functional laser facility at the requirements set for the NIF for a known cost.

Description of the Task Force's Duties:
The Task Force should conduct a thorough in-depth review and assessment the risks of successfully completing the NIF Project. The focus should be the engineering and management aspects of the proposed method for accomplishing the assembly and installation of the NIF laser system. The review should cover the full scope of assembly and installation and the ability within the proposed approach to achieve the cleanliness requirements established for the operation of the laser. To ensure that the options being considered by the Department are credible, the analysis should review, as a minimum: (1) the engineering viability of the proposed assembly and activation method; (2) the assembly and installation cleanliness protocols; (3) the management structure; and (4) the adequacy of the cost estimating methodology.

APPENDIX D

NIF TASK FORCE ACTIVITIES

The National Ignition Facility (NIF) Laser System Task Force held seven open meetings. Five meetings were held at the Lawrence Livermore National Laboratory, one open teleconference meeting was held to finalize the Task Force's interim report, and one open teleconference meeting was held to finalize the Task Force's final report. During the open meetings and in follow-up materials, the Task Force also heard from private citizens and various organizations following the development of the NIF laser system. Several members of the Task Force also spoke individually with senior Departmental, laboratory officials, and persons currently or previously affiliated with the NIF project on particular areas of interest.

The first meeting was held at the Lawrence Livermore National Laboratory on November 13 and 14, 1999. The meeting sought to provide an overview of the project, including a history of the program, its mission and the challenges that contributed to cost overruns and scheduling delays.

The second meeting, which was held November 29 and 30, 1999, focused on specific hurdles still facing the NIF Project Management Team. Specifically, the Task Force reviewed problems with the NIF optics, cleanliness protocols, project construction and development schedule and system integration.

At the third meeting, which was held December 13 and 14, 1999, the Task Force considered the rebaselining plan developed by the Lawrence Livermore National Laboratory and the Department of Energy’s Office of Defense Program's NIF project teams.

In addition, the Task Force focused on the relationship and flow of information between the principal management teams involved with the NIF project development. Representatives from the Department of Energy, its Office of Defense Programs, the Lawrence Livermore National Laboratory and the University of California answered questions about daily management and communication and offered opinions on the current project management and oversight and proposed changes offered to improve that process. The Task Force also was briefed on the project oversight review process currently used in the Department of Energy’s Office of Science (formerly known as the Office of Energy Research).

The Task Force also considered the work of previous Task Forces and advisory panels, including, but not limited to, recent reports by the National Ignition Facility (NIF) Council and the University of California President's Council. The members of the Task Force were impressed by the dedication and commitment of the individuals who attended, participated, and provided supported the Task Force's efforts. The Task Force appreciates the sincere efforts of everyone who offered information and guidance to the Task Force. The group worked to fairly review the comments and opinions offered by everyone, regardless of their affiliation or technical background.

The fourth meeting was an open teleconference meeting held on January 5, 2000 discuss the interim findings and recommendations of the National Ignition Facility Laser System Task Force in advance of its release on January 10, 2000. The meeting included public comment period where stakeholder comments on the draft report were presented.

On January 10, 2000 the Task Force issued its interim findings based on reviews conducted by the Task Force during three open meetings conducted in November and December 1999. The *Interim Report of the National Ignition Facility Laser System Task Force*[22] did not uncover any technical or managerial obstacles that would, in principle, prevent the successful completion of the National Ignition Facility laser system.

At the fifth meeting, which was held at Lawrence Livermore National Laboratory on April 26, 2000, the Task Force reviewed an implementation matrix summarizing the NIF Project Management Team's response to the findings and recommendations contained in the Task Force's interim report. In addition, the Task Force reviewed two "white papers" outlining progress made since December 1999 in the NIF final optics system and the integration, management and installation of the beampath infrastructure system. The Task Force also reviewed and commented upon early plans for the NIF rebaseline.

At the sixth meeting, which was held at Lawrence Livermore National Laboratory on May 17, 2000, the Task Force reviewed the revised NIF Rebaseline plan approved by the Department of Energy's Energy Systems Acquisition Advisory Board (ESAAB). In addition, they reviewed NIF Project plans for validation and submittal of the revised cost and schedule baseline to Congress; project integration plans for the assembly, installation and commissioning of the beamlines; risk management efforts undertaken by the NIF Project Management Team; and contingency levels. The Task Force also discussed plans for the final report and the NIF Project plans for the independent validation of the revised project baseline cost and before their submittal to Congress in mid-September.

The seventh meeting was an open teleconference meeting held on October 19, 2000 to discuss the draft final report of the National Ignition Facility Laser System Task Force in advance of its release. The meeting included public comment period where stakeholder comments on the draft report were presented for consideration.

Finally, the Task Force wishes to thank the staff at the Lawrence Livermore Protocol Office who provided organizational support to the Task Force. Their work on a very tight schedule helped to ensure that the Task Force meetings ran smoothly.

[22] The "Interim Report of the National Ignition Facility Laser System Task Force" was submitted by the Task Force on January 10, 2000 and submitted to the Secretary of Energy by the Secretary of Energy Advisory Board on February 11, 2000.

APPENDIX E

PREVIOUS NIF REVIEWS

DOE

Secretary of Energy Advisory Board Laser System Task Force (1999-2000)

Chair/Committee: J. McTague
Oversight Agency: Department of Energy
Focus: Scope
Interim Report of the National Ignition Facility Laser System Task Force, Secretary of Energy Advisory Board (2000)
URL: http://www.hr.doe.gov/seab/NIF_rpt.pdf

Energy Systems Acquisition Advisory Board (1999-present)

Chair/Committee: T. J. Glauthier
Oversight Agency: Department of Energy
Focus: Cost, Schedule, Mission, Scope

NIF Program Review Committee (Formerly NIF Council) (1999-present)

Chair/Committee: H. Grunder
Oversight Agency: Lawrence Livermore National Laboratory
Focus: Cost, Schedule, Scope

Fire Protection Surveillance (on going)

Chair/Committee: Field Office Safety Team
Oversight Agency: DOE -- Oakland Field Office
Focus: Environment, Safety and Health

Fire Protection Surveillance (on going)

Chair/Committee: Institutional Safety Team
Oversight Agency: Lawrence Livermore National Laboratory Hazards Control
Focus: Environment, Safety and Health

Independent Project Assessment (1999)

Chair/Committee: Lockwood-Greene
Oversight Agency: Congress/DOE - FM
Focus: Cost, Schedule, Mission, and Scope
Contact Information: 303-231-9475

Annual Safety Assessment, Radiation Protection (1998)

Chair/Committee: Radiation Specialist
Oversight Agency: DOE - HQ
Focus: Environment, Safety and Health, Scope

ICF Quarterly Reports (1997-present)

Chair/Committee: Field Office Team
Oversight Agency: DOE – Oakland Field Office
Focus: Mission, Scope
URL: *http://lasers.llnl.gov/lasers/pubs/icfq.html*

Weekly Safety Walk-through of the NIF Site (1997-present)

Chair/Committee: Field Office Safety Team
Oversight Agency: DOE – Field Office
Focus: Environment, Safety and Health

Annual Management System Review (1997-present)

Chair/Committee: Field Office Team
Oversight Agency: DOE -- Oakland Field Office
Focus: Cost, Schedule and Scope

Independent Cost Estimate (Title I Design) (1997)

Chair/Committee: Foster Wheeler, USA
Oversight Agency: DOE-FM
Focus: Cost
Contact Information: 303-988-2202

Integrated Safety Management (1997)

Chair/Committee: FM Safety Team
Oversight Agency: DOE-FM
Focus: Environment, Safety and Health

Quarterly Safety Evaluation (1996-1997)

Chair/Committee: Field Office Safety Team
Oversight Agency: DOE -- Oakland Field Office
Focus: Environment, Safety and Health

ICF Program and NIF Project, JASON Committee (1996)

Chair/Committee: D. Hammer (Cornell)
Oversight Agency: DOE - DP
Focus: Mission
URL: http://www.llnl.gov/PAO/NIF

NIF Quarterly Reviews (1995-present)

Chair/Committee: HQ Team
Oversight Agency: DOE - HQ
Focus: Environment, Safety and Health, Cost, Schedule, Scope
URL: *http://lasers.llnl.gov/lasers/pubs/*

The NIF and the Issue of Nonproliferation (1995-1996)

Chair/Committee: Arms Control and Nonproliferation Team
Oversight Agency: DOE - NN
Focus: Mission
URL: http://www.doe.gov/news/docs/nif/front.htm

ICF Program Science, JASON Committee (1994-1995)

Chair/Committee: S. Drell (Stanford)
Oversight Agency: DOE - OFFICE OF DEFENSE PROGRAMS
Focus: Mission
URL: http://www.llnl.gov/PAO/NIF/Nonproliferation.html

ICF Program Science, Inertial Confinement Fusion Advisory Committee (1992-1995)

Chair/Committee: V. Narayanamurti (U.C. Santa Barbara)
Oversight Agency: DOE - OFFICE OF DEFENSE PROGRAMS
Focus: Mission
Contact:

Independent Cost Estimate (NIF Conceptual Design) (1994)

Chair/Committee: Foster Wheeler USA
Oversight Agency: DOE-FM
Focus: Cost
Contact Information: 303-988-2202

OTHER GOVERNMENT AFFILIATED and LABORATORY REPORTS

General Accounting Office, (2000)

Chair/Committee: J. Wells (GAO)
Oversight Agency: General Accounting Office
Focus: Management and Oversight
Report Number: GAO/RCED-00-141, August 2000
URL: http://gao.gov/cgi-bin/getrpt?rced-00-141

University of California President's Council (1999-present)

Chair/Committee: W. Friend
Oversight Agency: University of California
Focus: Cost, Schedule, Scope, Environment, Safety, Health and Management

Report of the University of California President's Council: The National Ignition Facility (NIF) 1999

Chair/Committee: University of California President's Council NIF Review Committee
Oversight Agency: University of California
Focus: Cost, Schedule, Mission, Scope
URL: http://labs.ucop.edu/nr/nr112399.html

Review of Materials Management (1998)

Chair/Committee: Lawrence Livermore National Laboratory Plant Engineering Team
Oversight Agency: Lawrence Livermore National Laboratory
Focus: Environment, Safety and Health
Contact Information:

NIF Project/ICF Program Assessment, Defense Research and Engineering (1998)

Chair/Committee: Dr. Hans Mark
Oversight Agency: Department of Defense
Focus: Cost, Schedule and Scope
Contact Information:

Environment, Safety and Health Assessment (1998)

Chair/Committee: Program Safety Team
Oversight Agency: ICF Program
Focus: Environment, Safety and Health
Contact Information:

NIF Conventional Facility 100% Title II Reviews (1997-1998)

Chair/Committee: Project Team
Oversight Agency: NIF Project
Focus: Environment, Safety and Health, Schedule, Scope

NIF Special Equipment and Optics 100% Title II Reviews (1997-present)

Chair/Committee: Project Team
Oversight Agency: NIF Project
Focus: Environment, Safety and Health, Cost, Schedule, Scope

NIF Technology Readiness, NIF Council (1996-present)

Chair/Committee: J. Birely (LANL Retired)
Oversight Agency: Laser Programs
Focus: Cost, Schedule and Scope
URL: http://lasers.llnl.gov/

ICF Target Physics, Target Physics Program (TPP) Advisory Committee (1995-1997)

Chair/Committee: R. Ripin (NRL/APS)
Oversight Agency: Laser Programs
Focus: Scope
URL: http://lasers.llnl.gov

Laser Science and Technology (1995-1997)

Chair/Committee: Laser Science and Technology Program Advisory Committee
Oversight Agency: Laser Programs
Focus: Scope
URL: http://lasers.llnl.gov

Advance Conceptual Design Review (1996)

Chair/Committee: Project Team
Oversight Agency: NIF Project
Focus: Environment, Safety and Health, Cost, Schedule, Scope
Contact Information:

Title I Design Review (1996)

Chair/Committee: Project Team
Oversight Agency: NIF Project
Focus: Environment, Safety and Health, Cost, Schedule, Scope
Contact Information:

NON-GOVERNMENT REPORTS

The National Ignition Facility: Flawed Rationale, High Cost, and Security Risks, Tri-Valley CAREs (1998)

Chair/Committee: Paul Carrol
Focus: Environment, Safety and Health, Cost, Schedule, Mission, Scope
Oversight Agency: N/A
URL: http://www.igc.org/tvc/cwaug98.htm

APPENDIX F

NIF PROJECT'S IMPLEMENTATION MATRIX OF THE SEAB NIF TASK FORCE'S INTERIM REPORT FINDINGS AND RECOMMENDATIONS

Management Actions:

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendations: Roles and responsibilities should be clearly defined, including lines of authority and accountability for HQ, OAK, UC and LLNL. UC should ensure LLNL has committed appropriate management personnel to project and assure the team's performance. LLNL should use its expertise to effectively and efficiently support DOE missions. Must also address issue of institutional renewal to be able to address future DOE requirements. NNSA should not take any steps to undermine existing efforts to improve the lines of authority and management throughout the NIF hierarchy. The Office of Defense Programs should take the lead in better coordinating and improving the lines of communication and overall management of NIF. Office of Defense Programs should implement a project management review process similar to that long utilized in the Office of Science, with outside project management and technical experts conducting reviews at regular intervals. Process should be managed by small team of project managers within the Office of Defense Programs. LLNL Director needs to take "ownership" of the NIF Project He should establish an appropriate project management structure and commit trained personnel. Evaluation of the LLNL Director's performance should place heavy emphasis on the success of NIF.	• The NIF Project Execution Plan is currently being rewritten to update the lines of authority, accountability, roles and responsibilities for HQ, DOE/OAK, UC and LLNL. • The NIF Project has developed a Mission Support Group responsive to the needs of the DOE users of NIF in the areas of DOE Campaigns and Directed Stockpile work. • Implementation of the NNSA has not had a negative impact on the management improvements envisioned for the NIF. Current organizational concepts tighten the connection between the (DOE/NNSA) HQ and field elements responsible for the NIF, creating a single Office of the NIF with HQ and field elements that reports directly to the Deputy Administrator. • DOE/DP has established the Office of Project Management Support (DP-6) to assist the Deputy Administrator in the continuous improvement of project management within Defense Programs; this office establishes DP policy and procedures for project management, including the DP ESAAB equivalent process; coordinates reviews and follow-up action tracking; it also provides non-advocate reviews of planned and on-going DP projects. • In response to the recommendation that a project management review process be implemented similar to that long utilized in the Office of Science, with outside project management and technical experts, DOE has arranged for a "Lehman" style review (chaired by the Manager of the Nevada Operations Office, Ms. Kathleen Carlson) of the NIF Project to be carried out on August 7, 2000. Other reviews by the Energy Secretary Acquisition Advisory Board (ESAAB) and the NIF Programs Review Committee are occurring regularly . - The LLNL Director is fully committed to the success of NIF. He has established a new Directorate at LLNL, the NIF Programs Directorate, and a new senior position, Associate Director (AD) for NIF Programs, which reports directly to his Office. The NIF Project Manager also serves as the Deputy Associate Director for the NIF Programs Directorate.	Office of Project Management Support (DP-6). Dr. Bruce Tarter, LLNL Director; Dr. George Miller, LLNL Associate Director for NIF Programs Dr. Edward Moses, NIF Project Manager Dr. Hermann Grunder, Chair, NIF Programs Review Committee University of California Presidents Office (C. Judson King, Vice-Provost for Academic Affairs) UC President's Council on the National Laboratories (William Friend, Chairperson) NNSA Office of Defense Programs (DP-1), NNSA Office of the NIF (Jim Anderson), NNSA NIF Project Office (Scott Samuelson)	• PEP re-write is in final draft stage. • NPRC membership is complete. • First meeting of the NPRC was held on April 18, 19, 2000. • NPRC Target Physics Review Sub-committee met at LLNL on April 3-5, 2000. • Lehman review scheduled for August 7-11, 2000.

Management Actions (cont.):

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
Lines of communication between the NIF Project and the LLNL Director are too long. The laboratory should consider having the Project Manager sit at the same table as the other Associate Directors rather than being once removed. The Laboratory Director must pay closer attention to NIF. The Laboratory Director must ensure open communication channels within the laboratory and the Laboratory must be willing to interact closely and openly with UC and DOE. The project team should redesign and actively manage the NIF project advisory process so that it includes a significant NIF-independent assessment function. The charge, scope and membership of existing committees should be re-examined to streamline the entire process and assure the availability of expert advice to NIF, particularly on issues of cleanliness, beam alignment and tuning. Either the NIF Council's role should be strengthened and expanded, or an alternate arrangement for external review must be created to periodically review project progress. This external committee should report to the Laboratory Director. The University of California needs to analyze its own management problems. The President's Council is an improvement but should add oversight of Laboratory operations and project management to its primary functions. The University of California should mandate strong external review committees for major programs at its laboratories. Reports should be transmitted to the President's Office for action. UC Recommendations: The Laboratory Director must take ownership and devote greater attention to the project The Director should appoint an Associate Director for the NIF. The roles and responsibilities of the various parties should be clearly defined.	• The NIF Council has been reorganized into the NIF Programs Review Committee (NPRC) which now reports directly to the LLNL Director. Dr. H. Grunder, Director of Thomas Jefferson National Accelerator Laboratory, chairs the NPRC. Composition of the membership has been changed and the charters for the NPRC and its subcommittees have been written to focus on thorough technical and management review. Charters will be signed by the Director with concurrence from DOE and UC. The NPRC and its subcommittees consist of outside, independent technical and project management experts who will review all aspects of the project. • The Director will send the NIF Program Review Committee (NPRC) reports directly to DOE without first having to share findings and meeting proceedings with his Office or the NIF Project. This ensures open channels for communicating issues associated with NIF. UC and DOE have been invited to attend all NPRC activities so that they can observe first-hand the issues and concerns that the outside experts raise and the manner in which the laboratory project teams respond to them. Reports of the NPRC are also directly forwarded to UC along with point-by-point responses from the Director. DOE and UC will track all proposed LLNL actions. • The NIF Project Office provides weekly, monthly, and quarterly reports to NNSA and DOE on NIF project status. • NIF has solicited advice and partnered with industry since its inception to assist in planning and implementation of the NIF. Areas of partnering include clean assembly, precision survey and alignment,, systems engineering, scheduling, cost estimating, construction management, parts manufacturing, facility architecture and engineering, and project management. A list of over 30 major NIF vendors and their expertise can be found in Fiscal Year 1999 4th Quarterly Review (NIF-0039151). • The University of California President's Council on the National Laboratories has added a Project Management Panel (PMP) to assess the laboratories' project management systems. In addition the UC Office of the President has hired an expert in the management of large complex construction projects. To assist UC without imposing duplicative layers of review, UC sends representatives to sit in on all reviews of the NPRC and receives all NPRC reports and LLNL responses.	Office of Project Management Support (DP-6). Dr. Bruce Tarter, LLNL Director; Dr. George Miller, LLNL Associate Director for NIF Programs Dr. Edward Moses, NIF Project Manager Dr. Hermann Grunder, Chair, NIF Programs Review Committee University of California Presidents Office (C. Judson King, Vice-Provost for Academic Affairs) UC President's Council on the National Laboratories (William Friend, Chairperson) NNSA Office of Defense Programs (DP-1), NNSA Office of the NIF (Jim Anderson) NNSA NIF Project Office (Scott Samuelson)	• NPRC membership is complete. • First meeting of the NPRC was held on April 18, 19, 2000. • NPRC Target Physics Review Sub-committee met at LLNL on April 3-5, 2000. • Major contract awarded for industrial partner to manage the installation and integration of the beampath infrastructure hardware system. • UC project management system expert hired. • UC ES&H Panel meeting held to review NIF, March 2000.

Project Actions:

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: Consider increasing project contingency from 15% to 30-35% in development of the new baseline.	• A contingency appropriate to the current status of the NIF Project is being established in the development of the new project baseline; it will be incorporated into the DOE Level 0 Baseline Change Control Proposal.	NIF Project Office, NIF Project Manager (Ed Moses) NNSA Office of the NIF, Level 1 Baseline Change Control Board Chairman (Jim Anderson)	Completed. BCCB-1&2 review committee met on 4/17/00 to review contingency prior to BCCB-0 (ESAAB) Meeting. ESAAB Meeting took place on May 9, 2000 with recommendation for Project funding.
SEAB Recommendation: The Lab should bring in an experienced construction management firm to oversee the industrial contractors assembling the laser housing and utilities. A formal QA function is needed for the beampath infrastructure and optics assembly. Quality Control should be managed independently of Systems Engineering, and should report independently to the Project Manager since possible conflicts exist between systems design and QA functions. QA acceptance rate should be an independent measure of project value on an ongoing basis.	• Planning for completion of NIF beampath infrastructure includes a strong role by the Integration Management and Installation (IMI) subcontractor. This acquisition strategy was developed and endorsed by senior executives from industry and recommends that a single subcontract provide for project management, design management, commissioning, and installation/assembly work. • NIF Quality Assurance is placed within the NIF's core management structure and provides independent assessment of all NIF Project activities. The Quality Manager manages the quality of the NIF audit program, and ensures sufficient qualified personnel are in place to conduct day-to-day quality control. This program is being evaluated by Quality Engineering and Design (QED), a consulting group with expertise in Quality Assurance and Quality Control (QA/QC) in large programs. A systematic recruiting effort is under way to appropriately staff the program. • The IMI contractor will also have a substantial QA/QC role in assembly of the beampath infrastructure.	NNSA Office of the NIF (Jim Anderson) NIF Project Manager (Ed Moses) Beampath Infrastructure Manager (Valerie Roberts) NIF Systems Engineer (Mary Spaeth) NIF Deputy LEOT Manager (Paul Weber)	In progress. DOE HQ approval of the request for proposal was provided in late April. Final contract negotiations are being completed and will require DOE approval prior to full implementation.
SEAB Recommendation: Systems Engineering is now in place and working effectively, but needs to be fully staffed.	• Responsibilities for the NIF Systems Engineering Group includes: performance and risk analysis, configuration management, safety engineering, cleanliness and contamination control, alignment, commissioning, requirements revalidation, and FSD systems integration/redesigns. Most of these areas are fully staffed. Significant staffing is still needed for FSD integration and documentation support. Recruiting is underway.	NIF Systems Engineer (Mary Spaeth)	Completed. Staffing levels are being increased over the next 6 months.
SEAB Recommendation: The NIF Project Management System Description is noticeably thin in the early stage (pre-conceptual, conceptual, and pre-construction) planning, systems integration and review processes.	• This is a recognition of historical deficiencies in the program that are currently being addressed in the project. The next finding includes actions being taken to address perceptions of management skills, knowledge and abilities.	N/A	N/A

Project Actions (cont.):

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: The rebaselining and continuing construction program should better use the tools of project tracking, scheduling and financial analysis systems. The rebaselining activity must ensure that sufficient design documentation exists for a meaningful estimate. UC Recommendation: The project must follow sound project management principles	• A Schedule and Budget Planning Group has been created within the NIF management structure to provide overall management and coordination of NIF current year and out years integrated schedule and budget plans. • A rigorous framework that encompasses the Functional System Description and the phases of project execution has been implemented to enhance visibility and fidelity of the cost and schedule plans • The NIF Schedule and Budget Manager regularly performs cost and schedule analysis, and provides analysis to the NIF Project Manager. • The Schedule and Budget Planning Group is playing a key role in the NIF rebaselining process. One of the key functions of this Group is to provide cost and schedule evaluations at the Baseline Change Control Board meetings. • We have extensively replanned and documented Option 1 rebaselining using design documentation as the basis for many of the cost estimates. The detail design drawings are now 85% complete. • This drawing basis, combined with vendor quotes and vendor estimates forms the basis for a high percentage of the NIF procurement estimate.	NIF Project Manager (Ed Moses) NIF Project Manager (Ed Moses) NNSA NIF Project Office (Scott Samuelson) NNSA Office of the NIF (Jim Anderson) NIF Schedule and Budget Planning Group (Ralph Patterson, Sarita May, Dave Rardin, Rick Sawicki, Felix Fernandez, John Post)	Completed for Option 1 (the project-optimized option). Additional work is in progress to fully document the Balanced Program Option recommended by ESAAB by September 2000.
SEAB Recommendation: LLNL may not have sufficient project management skills in-house to execute the NIF alone. Contract skilled project management organizations to supplement inadequate or under-trained staffs. Make this a top-level management priority. Also, provide supplemental training to NIF staff in project management.	• The laboratory concurs with this finding and has adopted this recommendation. The NIF Project Office has recently hired several additional senior level managers and is recruiting others. • An orderly effort to train NIF staff in Project Management skills and in specific tools is in development. This activity is being referred to as NIF College. • The NIF Project Office will take advantage of UC's recent hiring of a project management specialist to evaluate and recommend ways to strengthen the NIF Project Office.	NIF Project Manager (Ed Moses)	Completed
SEAB Recommendation: Major construction projects must be run in a distinct, well-understood and respected "project" mode, bought into by LLNL, UC, and DOE. Authorities and responsibilities for each agency must be clearly defined and adhered to.	• We are currently revising the NIF Project Execution Plan, the Project Completion Criteria and other documents to reflect changes in the management structure of the Project, LLNL, UC and DOE. Authorities and responsibilities for each agency are defined in the PEP. • A Transition Project Implementation Plan has been developed and approved by DOE to move the Project towards and through rebaselining.	LLNL Director (Bruce Tarter) Associate Director for NIF Programs (George Miller) NNSA Office of the NIF (Jim Anderson) UC Presidents Council on National Laboratories (William Friend)	PEP is in final draft. TPIP-I was completed on June 1, 2000. TPIP-II continues project milestone tracking from June 1 through the end of FY00.

Project Actions (cont.):

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: The unique project environment may require bringing aboard contractor personnel with unique technical skills normally not available within the laboratory who are fully integrated in the project's line structure.	• NIF has solicited a wide variety of expertise from private industry to assist in planning and implementation of NIF. Examples include: Jacobs Engineering for the Beampath Infrastructure System, personnel from aerospace and the semiconductor communities for clean assembly, senior managers from the aerospace and the semiconductor communities for acquisition strategy development and guidance on Project management and systems engineering, and SAIC for support in cost validation on NIF LRUs. A list of over 30 technical vendors that have provided expertise to NIF is provided in Fiscal Year 1999 4th Quarterly Review (NIF-0039151).	NIF Project Manager (Ed Moses)	Completed
SEAB Recommendation: The changes in Systems Engineering staff and approach will be a major step in identifying potential problems at the earliest possible point and thereby reducing risk. The systems engineering function should be a key part of the review of oversight management.	• The NIF Systems Engineering organization will continue to be an important part of the NIF management team. They will coordinate Risk Management activities. Systems Engineering will also continue to track the performance of the mitigation efforts that are currently underway, as well as search for and resolve new risks as they are identified. One of the responsibilities of the FSD Integration element of Systems Engineering will be to search out interference and interface issues between FSD elements, allowing resolution of these issues to begin before they have critical impacts of the schedule.	NIF Systems Engineer (Mary Spaeth)	Completed
SEAB Recommendation: The Systems Engineering group should be involved in addressing the now poorly defined interface contracts. Ensure Systems Engineering has the necessary authority to direct resources to mitigate risk.	• Interface management is a significant aspect of the Systems Engineering role. Our FSD Integration team supports redefinition of interfaces and revalidation of requirements. They will be a continuing force in completion of the interface contracts, as exhibited this past year in their close work with the . Beampath Infrastructure Team to define both performance and interface utility requirements. • The System Engineering Risk Analysis Working Group is responsible for coordinating risk management.. Their recommendations are prepared with FSD Managers as Engineering Change Requests that are presented to the Change Control Board.	NIF Systems Engineer (Mary Spaeth)	Risk Mitigation Team in place and actively reviewing all aspects of the NIF Project
SEAB Recommendation: Train both the laboratory staff and contracted staff on the cleanliness protocols for the beampath installation. These capabilities do not exist in the marketplace.	• We are in the process of developing a training curriculum based on the procedures and practices important for NIF. Aerospace and semiconductor experience is supporting definition of this work. The curriculum will involve course-work, qualification testing and hands-on training in a simulation area. Qualification will be required.	NIF Project Manager (Ed Moses) NIF Deputy Project Manager for Assurance (Jon Yatabe)	In progress

Project Actions (cont.):

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: Establish well-defined ending point where construction and testing are completed and operations begin. Key project milestones must be established to clearly delineate transition between various phases of the project. Milestones must be an integral part of the Project Management Control process.	• The new NIF rebaselined plan identifies a set of milestones that are associated with completion of construction activities, management prestart reviews, testing, and operations. Progress on these milestones will be reported in regular reports and meetings. LLNL and DOE will both track these performance milestones. Construction, testing and operation of bundles in NIF are phased in a manner that is consistent with the Mission First Strategy. • The NIF Project has developed a Project Completion Criteria document that details the necessary conditions for completion of the Project.	NNSA Office of the NIF (Jim Anderson) NIF Project Manager (Ed Moses) NNSA NIF Project Office (Scott Samuelson)	Project Completion Criteria Document is updated and was submitted for approval to BCCB 1/2 on 4/17/00. Awaiting decision from NNSA and Congress on rebaselining options prior to completion.
SEAB Recommendation: NIF performance goals should be maintained but reached in a phased manner. For first phase, half of the laser beamlines should be made operational and then utilized to obtain knowledge and to satisfy user needs. Knowledge should then lead to commissioning of the full system.	• Deployment options under consideration for NIF have been evaluated in terms of their impact on the Stockpile Stewardship Program. The bundle deployment strategy for Option 1, designated as the Mission First Strategy, accommodates the needs of the user community as well as can be accomplished while at the same time satisfying the need for commissioning of the laser system in an orderly and safe manner. Decisions on the deployment schedule also considered expected rates of learning for both lab personnel and our equipment suppliers. • The startup and commissioning phases will be part of this deployment strategy and will be incorporated into the new baseline with an appropriate set of project milestones.	NIF Project Manager (Ed Moses) NIF Mission Support Group (Brian MacGowan) NIF Project Manager for Commissioning (Jack Campbell)	DOE Mission-oriented deployment options have been developed and discussed in detail with NIF users. Impacts of deployment options on user milestones have been assessed and a consensus reached on deployment that maximizes utility of NIF during startup and commissioning. Final deployment option will be based on NNSA and Congressionally approved NIF rebaselining.

Technical Actions:

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: A number of design recommendations are paraphrased in the next four items: a. Increase Design Robustness (e.g. Use 18 Disk (11-7) Beaming Architecture).	• The NIF Systems Engineering group has been formed to manage technical risks and optimize systems design. • During the rebaseline effort the Risk Analysis Working Group with the Functional System Description (FSD) Managers identified ~150 scope items to be included in the baseline. • The infrastructure baseline provides for full 11/7 beamline architecture capability. At present, we are committed to purchasing enough glass to populate 11/5, but the final decision is being postponed until data for the first bundle can be evaluated. • If necessary, the glass production runs could be extended by another 400 slabs. We can also increase the number of capacitors in each of the 192 power supply modules to enhance pumping of the 11/5 configuration or to deploy the 11/7 configuration.	NIF Systems Engineer (Mary Spaeth)	Completed
SEAB Recommendation: b. Increase R&D funding, especially in the area of beamline optics damage reduction.	• Increased R&D funding has been applied to reduce damage of amplifier slabs (~$2.5M) and UV optics (~$40M). Slab and UV optics damage R&D, modeling, and mitigation are currently underway.	NIF Systems Engineer (Mary Spaeth)	Funding in place. R&D in progress. Recent tests to full NIF design fluence (8J/cm^2) completed.
SEAB Recommendation: c. Integrate R&D activities into total project management.	• NIF-related R&D activities are now managed by the NIF Project Manager in an integrated manner. The NIF Systems Engineering organization proactively tracks and supports this activity.	NIF Project Manager (Ed Moses)	Completed
SEAB Recommendation: d. Consider and respond to recommendations of the LLNL NIF Council Technology Resource Group	• On February 24, 2000 the NIF Project team met with the Technology Review Group (TRG) of the NPRC to explain its responses to the recommendations of the NIF Council Technology Resource Group. In a March 31, 2000 report the TRG states, "…the management has accepted, both in spirit and in fact, the majority of the recommendations. It is clear that the issues we had raised are high on their priority list for resolution."	NIF Project Manager (Ed Moses)	Completed
SEAB Recommendation: Further progress will be necessary to improve the ultraviolet optical damage levels. The NIF program R&D efforts in this area should be supported at a level that is consistent with resolving the final focus optics damage issue.	• A well funded (~$40M) 3 damage reduction program has been planned. This program includes: an engineering redesign of the FOA to minimize beam modulation, studies to reduce the number of initiation sites, studies to mitigate damage growth, full qualification of the KDP rapid growth process and qualification of the KDP diamond finishing process • LLNL hosted a workshop March 30-31 on ultraviolet optics 3 damage with approximately 20 materials, chemistry, and physics experts from universities, other national laboratories, and companies in the field. An additional 20 experts from within LLNL also attended. This is a first step in an aggressive effort by LLNL/NIF to collaborate with the "best and brightest" on this issue.	NIF Project Manager (Ed Moses) NIF Systems Engineer (Mary Spaeth)	

Technical Actions (cont.):

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: The assembly and satisfactory operation of the first bundle should be considered a prototyping activity. Allow adequate prototype-level resources and reserve adequate time in the project schedule for the first bundle to be used as a learning vehicle for the remaining bundle installations.	• Prior to installation of the first bundle the Integration Management and Installation (IMI) contractor will conduct manufacturer proofing activities for installation of the Beampath Infrastructure System. • The time allowed for commissioning of the first bundle is ~12 months, much longer than allowed for subsequent bundles. This time period is consistent with our experience on Novette and Nova. Experiences gained on the first bundle will be utilized on subsequent bundles. The 1 and 3 laser diagnostics in the Precision Diagnostic Station will be used for the first bundle to understand and allow optimization of the laser performance. • Operation of early bundles and the performance bundle will provide the experience necessary for the laser to reach all performance goals. This early operation will also allow us to shake down the target area support systems and early target diagnostics.	NIF Project Manager (Ed Moses) NIF Project Manager for Commissioning (Jack Campbell) NIF Mission Support Group (Brian MacGowan)	Completed

Other Actions:

Recommendation	LLNL Response	Responsible Person(s)/Office(s)	Completion Status
SEAB Recommendation: The Laboratories have a tendency not to flag problems to the outside world, where they actually might find counsel and help, but prefer to go it alone for periods too long, relying too much on their in-house scientific ingenuity and engineering skill. UC Recommendation: The project must establish a “surprise-free” environment.	• The laboratory recognizes the need to flag potential project concerns to both DOE and project stakeholders; reviews are now being held as appropriate to address project risks,. These include: the NPRC Council on technology, DuPont on safety, SAIC for LRU cost validation, BCCB-1 on Cost and Schedule, Beampath Infrastructure System Acquisition Strategy Review Group, LRU Acquisition Strategy Review Group, Quality Engineering and Design review of Quality Assurance/Control in the NIF Project. • Issues and major findings are presented to the NIF Project Office and LLNL management. Communications between the Project and the DOE/NNSA project line managers have been improved. The DOE field staff has been co-located with the project and is better-integrated into daily project operations. These moves provide for more direct interaction, improving the Field Manager’s ability to obtain “raw” data and formulate an independent assessment of project status for further discussion with the Project Manager. • The NIF Field Manager holds weekly status meetings with the LLNL Project Manager. The NIF Field Office staff participates in the daily “Morning Meetings” with the NIF Functional System Description Managers. • The revised FY00 NNSA NIF Project Performance Objective for LLNL now includes specific provisions for measuring timely communications, openness, quality of the reporting and project execution.	Associate Director for NIF Programs (George Miller) NNSA NIF Project Office (Scott Samuelson) NIF Project Office (Ed Moses)	Completed
SEAB Recommendation: LLNL’s pride and distinction in science may be the cause of complacency, if not disrespect for the time-tested management tools and project discipline. Such complacency has led to a lack of well-defined, open and receptive channels within the Laboratory for technical concerns that may be perceived by the NIF project staff.	• The rebaselining process has resulted in the creation of strong communication channels between the Director, the AD for NIF, the NIF Project Manager, and the NIF Program in general. These will be continuously fostered by a series of management and risk mitigation reviews, and the regular tracking of project milestones. • Significant changes in the NIF Project Office and throughout the NIF organization have resulted in free discussion of concerns and paths that might be followed for their resolution.	NIF Project Manager (Ed Moses) NIF Systems Engineer (Mary Spaeth)	Completed

APPENDIX G

GLOSSARY

Amplifier: As used in NIF, an enclosure containing neodymium-doped phosphate glass slabs that are set in the beam at an angle and pumped with xenon-filled flashlamps. The light from these flashlamps excites the neodymium ions to a higher energy state that leads to amplification of light beams at a small range of wavelengths around 1053nm.

Amplifier slab: The slabs of neodymium-doped phosphate glass contained in the amplifiers.

Annealing: In laser glass fabrication, a baking process typically used to incorporate doping atoms into the silicon crystal lattice.

Argus: Laser completed in 1976 consisting of two laser chains, 5.0 trillion watts of power at one-micron wavelength, reduced power at 1/2 and 1/3 micron wavelengths.

Beamlet: The 100-foot-long laser built at LLNL in 1994 to serve as a proving ground for the NIF laser. Beamlet was dismantled and shipped to Sandia to be used to create a bright X-ray source for taking X-ray images of the plasmas produced on Sandia's Z machine.

Beam-line: The overall physical infrastructure required for the functioning of an individual laser beam.

Boule: An artificially grown crystal in its raw state, after generation but prior to cutting or polishing.

Bundle: A bundle consists of 8 lasers (2 quads) and is the smallest unit of the 24-bundle laser system that can be fired independently.

Class 1 (beampath): Classification for a “safe laser”. A Class 1 laser is considered to be incapable of causing personal injury for its intended use and is therefore exempt from most control measures or other forms of surveillance.

Class 1 clean room: Airborne particulate cleanliness class based on the maximum number of particulates allowable per cubic foot of air according to Federal Standards 209E. For a clean room class 1 the number of allowable particles is $1/ft^3$.

Class 100,000 clean room: A level of cleanliness where the number of particles, 0.5 microns in diameter or larger, per cubic foot of air is 100,000. Measurements are made according to Federal Standard 209E. A class 100,000 clean room is a facility with air filtered to maintain the number of particles in this size range $100{,}000/ft^3$.

DKDP or KD*P: Large deuterated potassium dihydrogen phosphate (DKDP) crystal plates that will be used in the NIF laser oscillator as a polarization electro-optic switch. The first ever NIF-sized boule of DKDP, measuring 55 cm in each direction, was recently grown.

DT: deuterium-tritium, isotopes of hydrogen that compose the fusion fuel that will be the source of ignition for the NIF.

E-beam: Electron Beam.

"Emmett Group" or Technology Resource Group: A subcommittee of the NIF Council. The Technology Resource Group is chaired by Dr. John L. Emmett and is responsible for the independent review of the NIF laser and technology program.

EUV (Extreme Ultraviolet) Lithography: Process where integrated circuits are fabricated by projecting patterns of extreme ultraviolet radiation onto a resist coated wafer. This process, using radiation near 13 nm wavelength, is a very high resolution process that enables features as small as 50 nm.

Flashlamp: Source of powerful light formed by an electrical discharge used to excite photon emission in a solid-state laser.

Fluence: The energy per unit of area (generally J/cm^2) in a beam of light.

Fresnel fringe: A single band in a group of light and dark bands that can be viewed in the periphery of a Fresnel diffraction shadow.

FSD: Functional System Description (document).

GOCO: Government owned and Contractor operated. The contracting method employed by the Department of Energy in contracting for the management of several laboratories.

Fused Silica (glass): A glassy, noncrystalline form of quartz (SiO_2) used to make lenses and windows for ultraviolet light at NIF. The fused silica used in NIF is usually high-purity form that is manufactured by chemical vapor deposition (CVD).

ICF (Inertial Confinement Fusion): A fusion process in which the fuel is confined by its own inertia for a long enough time (several trillionths of a second) at high enough density and temperature that fusion reactions take place.

Ignition: The ICF process in which there is more nuclear energy produced from fusion reactions than laser energy.

Joule: Unit of energy equivalent to 1 Watt for one second.

KDP: Potassium dihydrogen phosphate used in crystal plates to convert infrared laser light to green laser light or to mix infrared and green laser light to the ultraviolet light needed for optimum capsule implosions.

Laser: An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser gain: Amplification factor by which the radiation intensity is multiplied after traversing a certain distance of the active laser medium. If the gain is positive, the intensity increases exponentially as a function of distance. Gain is often quoted as the factor in the exponent or e (gain X distance) in units of inverse distance. The increase of intensity in a laser is much greater than can be obtained by spontaneous emission mechanisms.

LTAB: Laser and Target Area Building at LLNL.

MJ: Mega joules: One million **joules**.

Nanosecond (ns): One billionth of a second.

Nanometer (nm): One billionth of a meter.

Nd:Glass Laser: A solid-state laser of neodymium: glass offering high power in short pulses. A Nd doped glass rod or slab used as a laser medium to produce 1064 nm laser light.

Neodymium phosphate (NdP) (glass), or Neodymium doped (glass): Material used in the NIF amplifier disk. A phosphate-based glass that has neodymium ions added. After being excited by flashlamps, the neodymium ions emit the light necessary for the NIF laser.

NIF Council: An independent advisory group composed of senior technical managers who report to the Laser Programs Associate Director of the Lawrence Livermore National Laboratory on issues concerning the National Ignition Facility project.

Nova: The world's largest laser until the creation of National Ignition Facility. Located at the U.S. Department of Energy's Lawrence Livermore National Laboratory, it has fired more than 14,000 times during its fifteen year life. It fired its last shot in June of 1999.

OAB: Optics Assembly Building

OPDL: Optics Processing Development Laboratory.

Oscillator: In lasers, a device that generates coherent optical energy. Generally, it consists of a laser medium placed between two mirrors. The optical energy bounces back and between mirrors as the laser continues to add more optical energy, so that the energy intensity grows with time.

Polarizer: An optical element that separates the two polarization states of a light beam. The polarizers used on NIF are thin-film polarizers consisting of a specially designed multi-layer coating applied to an optical glass substrate.

Potassium Dihydrogen Phosphate (crystal): See **KDP** above.

Pulse shaping: The use of variations in the power supplied to a laser to change the shape of the output pulse. The technique is used in laser welding to condition a surface by preheating it at a low power or to anneal a surface at low power after the high-power weld is completed.

Relay imaging: or image relay; An arrangement of optical components that forms a real image of a beam-defining aperture at several points ("relay image points") through an optical system, creating less beam modulation from diffraction than unrelayed systems.

RTBF: Research Technology Base Facility.

Shiva: 20-beam laser, completed in 1977, provided more power, better control over conditions, higher temperature, and greater fuel compression than previous lasers, including delivering 10 kilojoules of energy in a billionth of a second.

SMIF: Standard Mechanical Interface, an industrial design standard for clean handling semiconductors.

Solgel: As used in NIF, a technique for applying anti-reflection coatings to optical elements. The coating is composed of ~50-nm particles of silica (SiO_2) deposited from an alcohol solution.

Spatial filter: A device used to smooth the aperture of the laser beam. It uses two lenses, separated by the sum of their focal lengths, and a pinhole aperture at the common focus. On-axis light is focused through the pinhole in a vacuum, off-axis light is blocked.

Technology Resource Group or "Emmett Group": A subcommittee of the NIF Council. The Technology Resource Group is chaired by Dr. John L. Emmett and is responsible for the independent review of the NIF laser and technology program.

UC Presidents Council NIF Review Committee: A subcommittee of the University of California's President's Council which was formed in October 1999 to advise the Council on "the causes leading to any overruns that may be projected for the NIF project." Dr. Steven Koonin, California Institute of Technology chairs the NIF Review Committee.