Interim Report of the National Ignition Facility Laser System Task Force

National Ignition Facility
Laser System Task Force
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INTERIM 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 series of initiatives 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 remaining 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. The SEAB National Ignition Facility Laser System Task Force (the Task Force) began its review in November 1999.

This report reflects the Task Force's initial work that included two open meetings in November 1999 and one open meeting in December 1999. Lawrence Livermore National Laboratory, working with the Department of Energy, is making major changes in the project organization and management, as well as carrying out a comprehensive review of budget and schedule (rebaselining). It is premature to evaluate the final product, particularly the budget, schedule, and final organization structure. In response to Secretary Richardson's charge, the Task Force submits this interim report documenting its initial findings and recommendations. A final report will be submitted after the rebaselining work can be reviewed (expected to be in late spring 2000).

The Task Force has not uncovered any technical or managerial obstacles that would, in principle, prevent the completion of the NIF laser system. Nevertheless, serious challenges and hurdles remain. The NIF Task Force believes, however, that with appropriate corrective actions, a strong management team, additional funds, an extension of the schedule and recognition that NIF is, at its core, a research and development project, the NIF laser system can be completed.

What follows is a synopsis of the Task Force's interim findings and recommendations.

I. Findings

The program and project management organizations of the NIF project failed to implement program and project management procedures and processes commensurate with a major research and development project. The program and project management systems employed by the Department of Energy's Office of Defense Programs, its Oakland Operations Office, the Lawrence Livermore lab and the University of California lacked clearly defined lines of authority and communications, independent oversight, and personnel skilled in large-scale project management. Despite their stated efforts to utilize best business practices in the development and construction of the project, from the beginning the NIF management team did not appreciate or implement private sector best practices or benefit from the project management review process used by the DOE Office of Science. Several recent management changes as well as the new focus on systems engineering are encouraging.

Recommendations

Office of Defense Programs should implement a project management review process similar to that long utilized by Office of Science for all major projects. This review procedure, which is commonly referred to as a "Lehman review," relies upon outside project management and technical experts to conduct in-depth reviews at regular intervals and to issue prompt and unambiguous recommendations to the head of the Program Office. As envisioned, this review process should be managed by a small expert team of project managers within the Office of Defense Programs, who have access to all levels of Office of Defense Programs management, and report to the head of the Office of Defense Programs. Implementation of a Lehman review process may streamline other dimensions of the ongoing review process, so that those investigations are more effective.

In order to utilize fully and effectively the guidance set out in this review process, the NIF team must place a greater emphasis on project management skills. Training in project management should also be implemented at both DOE headquarters and field offices and the University of California is encouraged to do the same at the laboratories it manages.

II. Findings

The role of the Lawrence Livermore lab director, C. Bruce Tarter, in the management of the NIF project is undefined. Responsibility and leadership for the NIF project is diffused, which undermines the lab's overall level of commitment to the project's success.

Recommendations

The lab director needs to take visible and unambiguous "ownership" of the NIF project. The success of NIF is vital to the future of the entire Lawrence Livermore laboratory, both programmatically and in the lab's ability to continue to attract and retain the best and brightest technical people. The director should forcefully articulate the importance of NIF to the laboratory as a whole, establish an appropriate project management structure, commit the appropriate resources, especially trained personnel, and create an environment that will not allow for "surprises." In its evaluation of the Lawrence Livermore lab director's job performance, the University of California should place a heavy emphasis on the success of the NIF project.

III. Findings

The Office of Defense Programs, DOE Oakland Operations Office, the lab and DOE lack clearly defined roles, responsibilities and lines of authority in the management of the NIF project. As a result of diverse and unclear roles of the management team, accountability has suffered. There is a real danger now that in addressing this issue, duplicative and paralyzing oversight mechanisms may be introduced.

Recommendations

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

As seen by this Task Force, the Department of Energy's role is to ensure that the laboratory supports DOE's missions effectively and efficiently. The University of California's role is to ensure that Lawrence Livermore lab has committed the appropriate management personnel to the NIF project and to assure the management team's technical, financial and administrative performance. The laboratory management is responsible for using its special expertise to propose and effectively and efficiently implement programs that support DOE missions, especially those of Office of Defense Programs. Lab management must also address the issue of institutional renewal to be able to address potential future DOE requirements.

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

IV. Findings

Former Assistant Secretary for Defense Programs Victor Reis should not have approved a budget based on a contingency factor of 15 percent. Such a contingency may be appropriate for an apartment building, but it is not appropriate for a technologically intensive project, such as NIF.

Recommendations

As a major research and development project, NIF faces many technical challenges. For such a complex project, a contingency of 30 to 35 percent is not out of line. Secretary Richardson should be prepared to increase the contingency accordingly. The Task Force recommends this issue be considered together with the rebaselining data.

V. Findings

The NIF laser system is the largest and most complex optical unit ever designed and constructed. With many of its design parameters representing an increase of 40 to 50 times over the parameters of previous systems, NIF may not be viewed as a linear extrapolation of previous systems. Under any circumstances, it would be a great challenge. Several early decisions have removed much robustness from the system design and may have increased its actual cost. These early decisions include the decision to limit the number of lasers to 192 instead of 240; to choose a minimal 16 disc (11-5) beamline architecture instead of the originally proposed, more robust 18 disc (11-7) one; and to adopt an overly confining building volume. A report on a new baseline is due in April 2000.

Despite management and design shortcomings, the project continues to make substantial technical progress. Sufficient challenges remain, especially the final optics adjacent to the target.

Recommendations

Increase the design robustness where feasible such as utilizing the 11-7 configuration in the new baseline. Increase research and development funding, especially for beamline optics damage reduction. Integrate the research and development activities into the total project management. Consider and respond appropriately to the thoughtful recommendations of the Technology Resource Group of Lawrence Livermore's NIF Council (the Emmet Group).

VI. Findings

The project needs a well-defined ending point.

Recommendations

The Task Force proposes that key project milestones be established to clearly delineate the transition between the various phases of the project and that those milestones be an integral part of the project management and project controls process. The NIF project management and project controls system should clearly establish the point at which construction and testing ends and NIF operations begin.

VII. Findings

The Task Force agrees with the Emmet Group that today's state of the art "should permit reliable NIF operation at laser output fluence of 3 J/cm^2," and that "If...(the Emmet Group's) recommendations are pursued aggressively, operations at 4-5 J/cm^2 in Phase 1 could be projected." The user schedule presented to the Task Force ("Final Optics Performance and Operation," Nov. 29, 1999 (70-00-1199-2526)) indicates that this level of performance will satisfy users until mid Fiscal Year 2006.

The Emmet Group further states: "With continued work, operation at 8-9 J/cm^2 in phase 2 will become realistic." The proposed user schedule calls for full fluence in the Fiscal Year 2007 time frame. The Task Force agrees that, with the appropriate research and development, this is a reasonable projection. But, as in any forefront technology effort, it will be a challenging goal.

Recommendations

Both the state of the art and the user needs point to a phased system capability implementation. Such a phased implementation has precedent in the many successful high-energy accelerators built by DOE over the past several decades. Phasing allows cost-effective implementation of "lessons learned" in a forefront technological project.

The original NIF performance goals should be maintained, but reached in a phased manner. In the first phase, half the laser beamlines should be made operational and then utilized to obtain operational knowledge and to satisfy user needs. This knowledge should then lead to the commissioning of the full system, with the final optics performing robustly at full fluence.

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

INTRODUCTION

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 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 commenced its work in November 1999 and held three open meetings at the laboratory. During these public meetings and in follow-up submissions, the Task Force heard from DOE and Lawrence Livermore lab officials and project managers, private citizens and various organizations concerned with the development of the NIF laser system[5]. The Task Force also considered the work of previous review panels and advisory boards, including, but not limited to, recent reports by the National Ignition Facility (NIF) Council[6], the University of

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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" or "Lawrence Livermore lab" 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.

[5] See Appendix D for a more detailed explanation of the Task Force's activities.

[6] 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 interim report it may be referred to as the "Emmet Report".

California's President's Council[7] and the Department of Energy's Stockpile Stewardship Report[8].

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.

The Task Force members agree that at this time it is premature to make final recommendations on some of the recent changes adopted and those currently under consideration by the Department and the lab to address the problems facing the NIF project. Secretary Richardson has requested that the Task Force offer initial recommendations and assessments in this interim report.

The Task Force will continue to monitor the progress on the rebaselining of the NIF project and will offer an opinion on the rebaselining plan itself in early 2000. It is understood that the steps called for in both options in the rebaselining plan will lengthen the construction time and overall cost. While adequate information is not yet available to adopt a total cost figure for the upcoming project phase, the Task Force would advise Secretary Richardson to plan to spread out the cost and time for completion over a period of time longer than provided for in the original baseline.

A final report to be offered later in early 2000. The timing of such a report will be developed to meet Secretary Richardson's deadlines. This report documents the Task Force's interim findings and recommendations.

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[7] The "Report of the University of California President's Council: The National Ignition Facility (NIF)" 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."

[8] The US Department of Energy, "Stockpile Stewardship Program: 30-Day Review" was submitted on November 23, 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 plans to use this facility for physics experiments to increase understanding of the performance of nuclear weapons without further need for nuclear testing. The Task Force was not charged with the task of reviewing the department's stated missions for NIF. According to DOE's description of the facility, it could also be used for scientific and technical experiments in such fields as fusion energy, laboratory astrophysics, optics, and materials.

The department further states that NIF will further the department's strategic missions in areas of national security, energy research and basic scientific and technological scientific 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."[9]

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. The conventional facilities, which house the lasers, are currently about 70 percent complete. The NIF project team expects construction of the conventional facilities to be completed by the end of Fiscal Year 2001. Recent data and experience along with analysis of related engineering experience have demonstrated that the assembly and installation of the laser system must be done in a cleaner and a more painstaking and systematic manner than had been originally planned. The change in approach is considered essential for the NIF project to achieve its planned performance level, and the new assembly and installation process is expected to substantially increase the project's overall costs and delay the project's completion.

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[9] US Department of Energy, "Stockpile Stewardship Program: 30-Day Review", November 23, 1999, Appendix E-8.

CHALLENGES TO COMPLETION: PROJECT MANAGEMENT

No one gets a passing grade on NIF management: not the DOE's Office of Defense Programs, not the Lawrence Livermore National Laboratory and not the University of California. The kind of problems that have led to the NIF budget overrun and schedule delays are systemic and not particular to this project or this laboratory. Changes need to be made in all three of these places to prevent future recurrences of situations of this nature. This call for changes is 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)[10].

At the request of the Department of Energy, the National Research Council in 1999 conducted a study "to review the policies, procedures, and practices used by DOE to identify, plan, design, and manage its portfolio of projects." Coming out of this study was a series of findings and recommendations to improve DOE's oversight and management of projects. Many of the findings and recommendations contained in that study are pertinent to the NIF project.

In the past year, the laboratory has made significant changes in personnel involved with Project Management and Systems Engineering, and Secretary Richardson has ordered the lab to determine if additional changes are necessary. Although these changes are relatively recent and untested, the Task Force commends the Lab's recent efforts to confront quickly and directly the difficult but important issues of staffing and management changes.

Comments in this section reflect an appreciation that changes in project management and system engineering are taking place. The Task Force's relevant recommendations should be taken as a reinforcement of the need to bring about significant changes in these areas and elsewhere in the management organization overseeing the development of the NIF laser system.

Lawrence Livermore and Los Alamos national laboratories, the two DOE labs with responsibility for the nation's nuclear stockpile, are strongly and properly focused on scientific research and development. These labs are ranked by many with the country's premier scientific institutions and both conduct research on par with the finest universities, while at the same time meeting their nuclear mission responsibilities. The labs' capabilities, strongly nurtured by the managing contractor, the University of California, must be encouraged and preserved. However, 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 they are formally managed by the university as a GOCO (government-owned, contractor-operated), but they receive programmatic, management and business direction from the DOE's Office of Defense Programs' branch and field offices. As a result of multiple and frequently not coordinated directives, the laboratories often act with greater de facto autonomy and self-reliance than advisable. The laboratories have a tendency not

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[10] 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.

to flag problems to the outside world, where they actually might find counsel and help, but rather prefer to go it alone for periods too long, relying too much on their in-house scientific ingenuity and engineering skills.

The recent review by a UC-chartered external committee (the Koonin Report) criticizes 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 complacency, if not disrespect for time-tested management tools and project discipline. Such complacency has led 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 REVIEWS

Independent reviews, especially those conducted by individuals who are external to the project, are excellent mechanisms for assessing the project’s status and management capability. The project team should redesign and actively manage the NIF project advisory process so that it includes a significant NIF-independent assessment function. This review function should not be a part of Lawrence Livermore or the University of California, but rather it should be independent and report to directly to the Office of Defense Programs. Accordingly, the charge, scope and membership of existing committees should be reexamined to streamline the entire process and assure the availability of competent, relevant and candid expert advice to NIF, particularly on the issues of cleanliness, beam alignment and tuning.

The Office of Defense Programs, in conjunction with NIF, should look to develop and use a Project Management oversight system analogous to the Office of Science Project Management System. Such a review mechanism would be advisory to the Secretary of Energy through the Assistant Secretary for Defense Programs. It would be tasked to advise the Secretary on budget and schedule as well as on significant technical risks of mission failure due to under performance of the various advanced technical systems involved.

The Office of Defense Programs does not effectively evaluate and monitor major projects. It does not have an appropriate process to track the management structure, progress, and technological risks of major projects. The delays and overruns at NIF are due in part to this failure. It does have a project program team generally good at the more conventional aspects of construction. However, the teams assembled for these reviews typically do not include or integrate outside experts from relevant technical areas. The Office of Defense Programs did have cost estimates made on the NIF project by outside contractors, but here, too, experience and expertise with the technology were lacking. No independent expert who understood NIF’s huge stretch in performance requirements beyond any previous experience with high power lasers would have accepted a 15% overall contingency on the project.

The DOE's Science Division (SC), formerly the Division of Energy Research, does have a project review and monitoring system that might be adopted by The Office of Defense Programs. The Office of Science has a group reporting to the Assistant Secretary-level Director of Science that follows major projects from the beginning of the "Conceptual Design" phase through construction. A group for each project is assembled consisting of appropriate DOE personnel plus technical experts in relevant areas. Budget, schedule, management plan, procurement practices, technology, and technological risk, are evaluated and progress tracked against agreed milestones. Commonly referred to as the "Lehman review" process, after Dr. Daniel Lehman who is the director of the Office of Science's construction management support division, this process has evolved over many years to the point where DOE's laboratories regard it as valuable to them as well as to the DOE. It has given early warning on management as well as budget and technical problems. The Office of Defense Programs should have a similar system adapted to its own needs.

OFFICE OF DEFENSE PROGRAMS

As the lead secretarial office overseeing the development of NIF, Office of Defense Programs is responsible for managing the NIF project, but must also guide and oversee the external review process. The Task Force questions whether, to date, the Office of Defense Programs has met that responsibility. As previously mentioned, the Assistant Secretary of Defense Programs, at the time Victor Reis, should never have approved a budget for such a technologically intensive project with such a low contingency.

On March 1, 2000, the new National Nuclear Security Administration will be formally established. As that date nears, the leadership of the Office of Defense Program becomes all the more important. The Task Force encourages Secretary Richardson as he prepares to select an Under Secretary to oversee the new semi-autonomous DOE agency, to insist that the new entity not take any steps to undermine existing efforts to improve the lines of authority and management throughout the NIF hierarchy. National security efforts need not conflict with the project management processes and open lines of communications that are vital to completing NIF. The Office of Defense Programs must recognize that many of NIF's problems are in part due to conflicting messages from various elements of the NIF power structure. The Task Force strongly encourages the Office of Defense Programs to take the lead in better coordinating and improving the lines of communications and overall management of the NIF project.

LAWRENCE LIVERMORE NATIONAL LABORATORY

The report of the University of California President's Council NIF Review Committee[11] identifies nine management deficiencies on the part of Lawrence Livermore lab:

1. The laboratory, (and in this case, the laser and engineering directorates) has a do-it-yourself mentality.
2. There was insufficient "technical definition" of the project at the baseline.
3. There was insufficient "implementation planning."
4. The organization structure separated the research and development and design functions.
5. The project suffered from a lack of effective system integration.
6. Management was inappropriate for the size and complexity of the undertaking.
7. NIF did not receive the management attention required of such a project at the most senior levels of the laboratory.
8. Performance measures or other formal means to judge project progress were inadequate.
9. The project review process was ineffective.

This Task Force agrees.

The laboratory has begun to remedy these problems. This is a work in progress with much work still to be done. Lines of communication between the NIF project and Lawrence Livermore National Laboratory Director C. Bruce Tarter are still too long. The NIF project is as large as any of the Lawrence Livermore Divisions and must draw on other Divisions to accomplish its work. To settle priority and resource issues effectively, the laboratory should consider having the Project Manager sit at the same table as the other Associate Directors, rather than being once removed. This is particularly important in staffing the project. These issues must get sustained attention and priority from the lab director.

Lawrence Livermore is a large laboratory with a complex and diverse program. Associate Directors each of whom have broad authority and responsibility for the affairs of a division oversee its major divisions. In a corporate sense, it operates like a conglomerate. The Laboratory Director's supervision of the affairs of the lab's divisions appears to be too loose. As the NIF project is a cornerstone of the laboratory's long-term program, the lab director must pay particularly closer attention to NIF.

Laboratory management now recognizes that they lack enough qualified people in-house to carry out a project of this size and complexity on their own. Accordingly, they plan to bring in industrial contractors for the assembly of the lasers housing and the utilities, a very large and complicated job. Overseeing the work of these contractors is, in itself, a difficult task and they would do well to bring in an experienced construction management firm to do the job.

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

The new NIF Project Manager, Edwards Moses, has instituted major changes in the organization. Of particular importance is the recognition that Systems Engineering is central to NIF's success. The Systems Engineering group is now in place and working effectively, though still not fully staffed.

The NIF project needs a rigorous quality-control program. This has not yet been done. The Task Force concurs that a formal Quality Control function is needed for the beampath infrastructure and optics assembly. Current plans indicate that Quality Control will be one of the functions reporting to the head of Systems Engineering. The Task Force recommends that Quality Control be managed independently of Systems Engineering, and should report independently to the Project Manager, since possible conflicts exist between the systems design and Quality Control functions. The quality control acceptance rate should be an important independent measure of project value on an ongoing basis. Systems Engineering will continue to play an important role in the development of acceptance criteria and measurement/monitoring procedures for quality control.

A research and development program has been set up to address the materials issues relating to maximum fluence damage to the optics. This important program is necessary to understand and possibly mitigate the risk of final optics damage when NIF is operated at full fluence, which is essential for the ignition goal. According to present understanding, full fluence operation with today's technology may so damage the final optics that they would have to be replaced after 10 - 20 shots, sending operating costs up and delaying the part of the program aimed at ignition.

The project tracking, scheduling and financial analysis systems have been in place for some time, but have not been used effectively. The rebaselining and continuing construction program should better use these tools. If so they should provide early warnings of certain kinds of program problems.

The lab is considering how to implement an appropriate external review process, in addition to the Office of Defense Program's reviews. The NIF Council is a body with the breadth and expertise necessary to conduct such reviews. Until recently, the NIF Council has served as an advisory policy committee rather than as the laboratory's project review committee. Recently, a subcommittee of the NIF Council examined the technology issues[12] and quickly identified the major technical issues and risks. One of the significant benefits of periodic external reviews is the internal review that the laboratory must go through to prepare for the outside group. Either the NIF Council's role should be strengthened and expanded, or an alternate arrangement for external review must be created to periodically review the progress of the project. This external committee should report to the Laboratory Director.

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[12] NIF Technology Review of the National Ignition Facility Council (John Emmett, Chairperson), November 4, 1999.

UNIVERSITY OF CALIFORNIA

The University of California, through the NIF Review Committee that is referred to above, analyzed the Lawrence Livermore management problems but did not analyze its own. It needs to do this.

The University of California - President's Council on the National Laboratories was set up in January 1993, to improve the university's oversight of the programs at its three labs – Lawrence Berkeley National Laboratory and the two weapons labs, Lawrence Livermore National Laboratory and Los Alamos National Laboratory. The new President's Council represents a considerable improvement over the previous oversight system, but its primary functions of overseeing policy issues and science and technology quality does not include laboratory operations or project management.

The university is rethinking its oversight mechanism. The Task Force heard only the most preliminary plans and so cannot comment on the specifics. At a minimum, the University of California should mandate strong, external review committees for major programs at its laboratories. The reports of these review committees should be transmitted to the President's Office for action as necessary.

SYSTEM DESCRIPTION: POLICIES AND PROCEDURES

The NIF Project Management System Description[13] lists the project management requirements and approved documents that describe the project management system. The system contains many components needed for effective project management but it is noticeably thin in the early stage (pre-conceptual, conceptual, and preconstruction) planning, systems integration and review processes. It is particularly important to realize that this is a complex project and, as such, requires the processes, procedures and professional disciplines needed in complex construction projects and people skilled in the proper engineering disciplines.

It is not so much that the laboratory did not institute an appropriate project management structure and system. Rather, it was the inexperience of personnel in the proper use of procedures and planning tools, system integration, change control and performance metrics, to name a few, that led to many of the problems that NIF is experiencing today.

While it certainly is the laboratory’s role to be the “project manager” for NIF, the Task Force remains skeptical that Lawrence Livermore has sufficient project management skills in-house to execute the project alone. It is imperative that the people in key positions such as project management, project engineering, systems engineering and project controls are skilled in their respective disciplines. In constructing a one-of-a-kind laser facility, Lawrence Livermore should enlist key personnel with project management experience to work with the internal scientists and engineers.

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[13] NIF Project Management System Description, NIF Document Number NIF00002216.

PROJECT PLANNING AND REBASELINING

A billion-dollar project, by its very nature, requires full attention in the initial stages of the planning processes. It is in these early stages that costs and savings impacts are the greatest, where design reviews are critical and where designs need to be fixed or otherwise accommodated. The fact that NIF conducted extensive research and development even as the facility was being constructed was an invitation to escalation in the project's overall scope and cost and delay in its schedule.

This makes it even more important to ensure that a strong project management team and clear, well-defined, processes and procedures are in place. One might say that part of the cost overrun was a consequence of the weak project management team initially in place. For example, the project baseline was set too early for a project as complex as NIF. The rebaselining activity must ensure that sufficient design documentation exists for a meaningful estimate. A rebaselining plan was recently submitted to the Department for review and approval. At this time, it would be premature for the Task Force to make final recommendations on the rebaselining plan in its entirety.

The Task Force will continue to monitor the progress on rebaselining and looks to offer an opinion on the rebaselining plan itself in early 2000. It is understood that the steps called for in both options in the rebaselining plan will lengthen the construction time and overall cost. Adequate information is not yet available to adopt a total cost figure for the upcoming project phase, but the Task Force would advise Secretary Richardson to plan to spread out the cost and time for completion over a period of time longer than provided for in the original baseline. Two points, however, are already clear.

While the original 15 percent contingency may be appropriate for the construction of an apartment building, it is too low for this challenging and unique project. A more adequate contingency must be included. The original contingency was woefully inadequate for a project as complex and undefined as it was (and still is). Members of the NIF project team have indicated that a more appropriate contingency range is 30 to 35 percent and the Task Force agrees that an increase in the contingency is appropriate for the technology challenges and complexity of the NIF project.

Second, the rebaselining schedule offers two possible schedules for the commissioning of the 192 laser beams. One option calls for 96 laser beams in 2004 and the final 96 laser beams, bringing the total to 192 laser beams in 2005. This second rebaselining option would commission the first 96 beams in 2004 and the second 96 beams by 2008. Both schedule options call for a full infrastructure to be completed in 2004 and to have 192 laser beams in the final NIF.

The decision remains to how quickly commission the second 96 laser beams after the first round is installed and operating. The Task Force members agree that a pause between the 96-beam phase and the 192-beam phase has some advantages. Although such a phased construction may increase the overall cost of the project and should be included in the rebaselining now underway, the Task Force believes that the benefits are worth the additional cost. NIF operations require more than the production of laser light. Other issues include stabilization, pointing, focusing, controls, synchronization, etc. It will take a few years of operation to bring NIF up to its performance specifications whatever the number of beams in use. The time spent commissioning the first 96 beams will certainly decrease the time necessary to commission the second 96 laser beams. One could argue that Lawrence Livermore can commission and install in parallel and so no real benefit comes from a pause, but the Task Force disagrees. A pause allows for the evaluation of and possible modifications to the first-round system and so any necessary modifications to the second-round systems could be made before they are installed. The second-round system could thus be integrated more rapidly into the facility. This is especially true if the NIF Council's Technology Resource Group's concerns about the need for advanced materials turns out to be justified.

SYSTEMS ENGINEERING

NIF is a very difficult engineering challenge and further technical problems should be expected. Changes implemented should be those that operate to identify potential problems at the earliest possible point and those that prioritize the existing resources. The changes in systems engineering staff and approach will be a major step in accomplishing this and thereby reducing risk. The systems engineering function should be a key part of the review of oversight management.

Small optics is an example where risk of not reaching full performance of the beamline quality is high and the probability of success can be greatly enhanced by diligent attention to detail. Cleanliness is another example and the efforts on that front have been described in detail. Installation of the beampath elements is a third example. The same installation process is repeated many times, raising the prospect for saving time in the schedule if the learning process is effective or losing time if a persistent problem occurs. The leverage is high, be it positive or negative.

The Systems Engineering group should be involved in addressing the now poorly-defined interface contracts. We believe it is the intent of the NIF project management staff to do so and encourages them to make this happen. Systems Engineering has taken on major responsibilities in risk detection and mitigation, but it is not clear from what the Task Force has seen if systems engineering has the necessary authority to direct resources to mitigate risk. (It is the Task Force’s understanding that the Configuration Manager, with an eight-person team, is the central point for risk detection. How this function interfaces with Systems Engineering is not clear.)

CONFIGURATION MANAGEMENT, COST/CHANGE CONTROL AND SCHEDULING CAPABILITIES

Although the NIF Project Management System Description explicitly describes the functions of configuration management, cost/change control and scheduling, it is clear that several of these functions have not been fully utilized because of inadequate or under-trained staffs. The proper utilization of the appropriate systems by knowledgeable people would have produced schedule and cost-forecasts for management in a more timely manner. Should Lawrence Livermore lab attempt to develop an in-house workforce component in these fields? Probably not. There are skilled project management organizations in the commercial sector, which can provide these skills.

The Task Force identified immediate and ongoing needs for greater staff capabilities in project management throughout the NIF organization. Inadequate project management both at NIF and DP was partly responsible for the delay in reporting to Secretary Richardson on the budget and schedule difficulties with NIF. At NIF, the inadequacy appears to be the result of an insufficient number of staff with the necessary training and experience, rather than ineffective deployment of, or ineffective work by, people with the right skills. The addition of the appropriate skills and experience should be a high-level management priority.

The need for project management capabilities can be met either through training the existing staff, hiring new staff, or contracting for needed skills. At the lab, where project management of this sort can be episodic, contracting would be a reasonable approach to supplementing existing skills. Also, supplemental training of NIF staff in project management could also be advantageous in getting the most from contracted help. The laboratory culture of relying heavily (and sometimes inappropriately) on existing internal expertise remains a hindrance in the acquisition of needed project management skills for NIF.

In the Office of Defense Programs, where project management is ongoing, training and hiring may be better approaches to acquiring needed skills.

The NIF staff also identified the specific need to train both the laboratory staff and contracted staff on the cleanliness protocols for the beampath installation. Because of the unique nature of NIF, these capabilities do not exist in the marketplace. At least some training will be required even for workers with experience in projects with strict cleanliness requirements. It is not possible for the Task Force to determine at this point whether the NIF team’s plans for this training, or for that matter, the protocols themselves, are adequate. This issue is appropriate for ongoing technical review as part of the overall cleanliness issue.

The laboratory identified attrition of capabilities of trained and experienced weapons designers as a critical long-term issue for the role of NIF in the Stockpile Stewardship Program. The NIF organization is engaged in a number of activities to attract and retain the needed talent in the longer term. For example, NIF staff members appear to be well engaged with the scientific and research communities through the usual channels such as professional society meetings and laser users' groups, and specifically with the laser-based research at the University of Rochester. The lab practice, which may continue with NIF, of providing experimental facilities gratis for university research is another important contribution to creating needed capabilities among students and research faculty.

Given the amount of additional training and skill levels still necessary to complete and operate NIF, the Task Force would caution the Secretary to expect additional personnel costs. The project management and special skills training that are so vital to this project do not come cheap. As the Task Force continues to evaluate the rebaselining plan, it will continue to monitor the costs and efforts to address the issue of adequate training.

CONCLUSIONS ON MANAGERIAL ISSUES

The NIF project is badly over budget and one and half to two years behind schedule. The problem lies with all three entities involved – the Office of Defense Programs, Lawrence Livermore lab, and the University of California. If each can recognize its own shortcomings, a new system can be put together to properly manage and oversee NIF and other major projects. Lawrence Livermore and the university have recognized theirs; The Office of Defense Programs has not yet recognized its problems. The "30-Day Study" should focus The Office of Defense Programs' attention on this area for the next months.

The Task Force supports the need for independent reviews. The Office of Defense Programs needs to know that the project is proceeding according to agreed milestones, and would benefit from a high-level advisory committee fashioned after the Lehman review apparatus that exists in DOE's Office of Science. Lawrence Livermore needs an independent group that can monitor technical progress, raise flags when they see problems ahead, and advise on solutions to those problems. The University of California needs to assure itself that the project is being properly run. It should be possible to combine at least some parts of the necessary the Office of Defense Programs, Lawrence Livermore lab, and UC reviews.

Do the recently surfaced problems with NIF require a culture change for the laboratory, and can such a culture change be brought about in time for a successful completion of NIF? The existing culture has served the laboratory well and has brought about unparalleled excellence in the laboratory's prime mission and its scientific research and development programs. It does not need a major overhaul but must establish clear lines of authority. But a major construction project should not be run under the rules of this culture, they must be run in a distinct, well understood, and respected "project" mode, bought into by the laboratory, by the university, and by DOE. The respective authorities and responsibilities for each of these agencies must be clearly defined and adhered to, starting already with the initial definition, conceptual design, and budgeting efforts of a major construction project.

Major projects within the laboratory must also have clearly defined deliverables and goals, with adequate measurement tools for progress, unique visibility, and strong buy-in from senior management, including the lab director's office. In fact, the director's office has an ongoing "bully pulpit" responsibility for the unique requirements of a major project, including "project discipline," clear and prompt decision-making, and budget and schedule oversight. External review committees composed of experts who are not stakeholders of the project and have no other form of conflict of interest should report to the director. An important aspect of the director's responsibility is the establishment of open communication channels within the laboratory, and the laboratory's willingness to interact closely and openly with UC and DOE. The continuing health of such project policies will be greatly aided by the monitoring function of external review committees.

This unique project environment may require that the technical performance of the project be enhanced by bringing aboard contractor personnel with unique technical skills normally not available within the laboratory. These experts should not be used in a subservient "shadow" function, but should be fully integrated in the project's line structure.

These changes in a project can be implemented without perturbing the “science” culture of the rest of the laboratory. For its duration, a project simply operates under a unique set of rules, discipline, and management structure, strongly supported by all levels of laboratory management.

Program Management for the NIF program has been improved and there are plans for further improvements including:

- More detailed program tracking and stronger project controls capability
- Stronger systems engineering approach to risk assessment and management
- Added project management strength using outside commercial contractors.
- The Task Force believes that more needs to be done in these areas than is currently planned.

These changes will reduce the prospects for major surprises in the program and will improve the effectiveness of funds spent. However, they will not guarantee against future technical difficulties or overruns. Early detection would not have prevented the delay and cost overrun or the insufficiency in some baseline cost elements for beampath infrastructure, but better project management and design would have detected these problems much earlier.

CHALLENGES TO COMPLETION: BEAMPATH INTEGRATION AND CLEANLINESS

The NIF beampath/optics assembly is a large, extremely complex system, housing leading-edge laser optics that must operate in a class-1 clean environment. NIF is not a simple scale-up of previous large laser systems (such as the Nova and Shiva laser systems[14]). Instead, the goal of achieving ignition-level laser energy in an affordable facility has forced the design of an extremely compressed, repetitious structure to house 192 laser beams that will make up the NIF laser system. Assembling the laser infrastructure and installing the optics, while achieving the required level of cleanliness, is a major challenge to a successful NIF construction.

Over the past year, the NIF project team has vigorously addressed the assembly plan and it has diligently focused on developing protocols for the many phases of assembly. These phases include 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 team has employed highly qualified industry consultants in clean-construction techniques, they are only now beginning to engage experts in complex facility installation. Achieving an adequate level of collaboration in this area is now a critical element of the assembly path.

The clean assembly of NIF has many challenges. Some are inherent to such a large laser facility, while others are the result of either NIF design embodiment or budgetary/schedule pressures:

- Budgetary limits on the cost of the NIF building have resulted in very cramped assembly areas that preclude optimal clean air flow, thereby limiting the class 100,000 cleanliness level of the laser building. Such tight quarters also greatly limit the installation options. The initial budget greatly underestimated the difficulty of installing such an infrastructure. The additional cost and schedule delays that are now occurring are the result of such overly optimistic infrastructure planning and installation.

- The requirement that, in the end, all 24 bundles must operate at full power implies a near-100 percent bundle assembly final yield. The need to make approximately 6,000 clean connections, compatible with a class-1 beampath environment but made in a nominal class-100,000 building remains a significant challenge that must continue to be monitored.

- The NIF assembly schedule plans that the entire infrastructure for all 24 bundles will be completed before the optics for the first bundle is installed. Such a plan greatly increases the difficulty of incorporating operational learning experience from the first bundle into the infrastructure design. The assembly plan relies on process control without direct measurement of final assembly cleanliness, thereby precluding a guarantee of satisfactory final assembly. This challenge is exacerbated by the absence of a NIF bundle prototype which adequately addressed assembly and cleanliness issues.

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[14] 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.

- The cleanliness level demanded by NIF is comparable to that required in leading-edge semiconductor fabrication. Additionally, the size of the NIF building is of a comparable scale to that of a large, high-volume semiconductor manufacturing facility. The NIF team is wisely taking advantage of techniques developed by the semiconductor industry to achieve the required cleanliness. These techniques include using SMIF-like enclosures for installing optics in the beampath; adopting standard industry particle contamination control methodology, especially the use of particulate and nonvolatile residue standards to plan effective protocols; and incorporating standard cleanliness characterization techniques and instrumentation for measuring cleanliness levels.

However, there are significant differences between the NIF laser system and a semiconductor facility. First, the NIF building has a ceiling height several times that of a conventional clean room. This, when combined with the restricted airflow available once the infrastructure is in place, precludes making the NIF laser bay a true clean room. Second, the commissioning of the NIF bundles does not allow the typical cleanliness improvement period seen in semiconductor facilities. A bundle simply cannot operate with a poor initial level of particulate contamination. Third, the NIF beampath has a much more stringent requirement for nonvolatile organic residues. But there are also some advantages that NIF has over semiconductor facilities. There are essentially no moving parts inside the beampath and once the bundle assembly is completed, the beampath will not be regularly opened.

The NIF team has made considerable progress in developing cleaning/assembly protocols, and it has achieved leading-edge solutions in many cases. Key solutions include the introduction of laminar air flow across the amplifier slabs during operation, and the development of cleaning protocols to remove nonvolatile residues, especially the procedures in place at NIF's large component cleaning vendor.

CONCLUSIONS ON BEAMPATH INTEGRATION AND CLEANLINESS ISSUES

There is still considerable protocol development to be done, especially for target-bay and switchyard-bay installations, and the NIF project team must address the remaining critical issues.

NIF is being constructed without adequate prototyping but it is not appropriate to halt further work to construct a prototype. Instead, the assembly and satisfactory operation of the first bundle should be considered a prototyping activity. It is imperative to allow adequate prototyping-level resources and to reserve adequate time in the project schedule for the first bundle to be used as a learning vehicle for the remaining bundle installations.

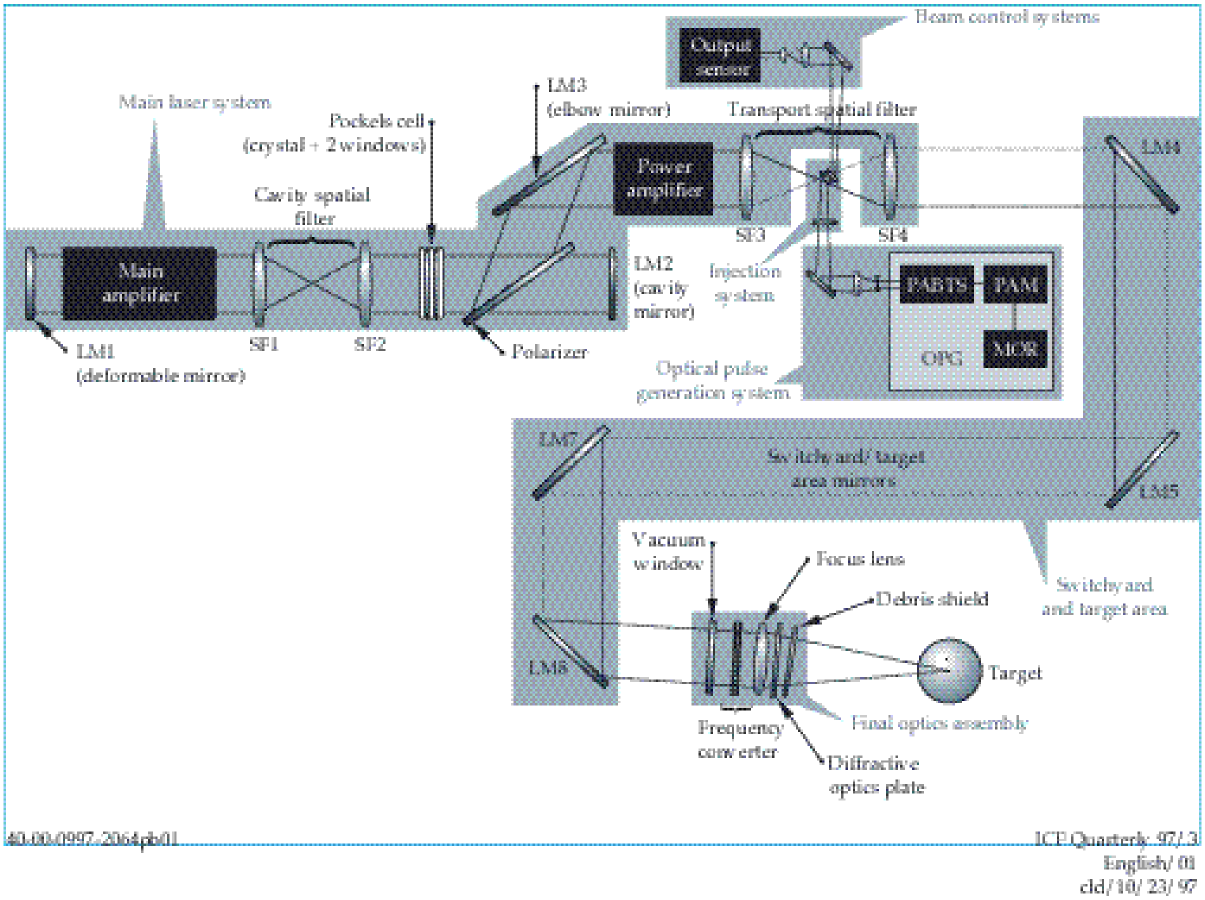
The construction of NIF is in many ways pioneering clean assembly methods. It is reasonable to expect that things will not always go as planned and mistakes in assembling the full set of bundles are likely so sufficient budget, schedule, and replacement part contingencies need to be in place. The NIF team needs to take better advantage of complementary (and possibly parallel) work taking place outside the present NIF team. In particular, the lessons now being learned about contamination in extreme ultra-violet (EUV) lithography at Lawrence Livermore and DOE's Sandia Livermore National Laboratory, and the work at Lincoln Laboratory of the

Massachusetts Institute of Technology in 157 nm lithography, should be incorporated in the NIF development plan.

The NIF team is now vigorously addressing the assembly/cleanliness issues. This diligence needs to be combined with the recognition that there is likely to be a significant assembly learning curve. With this effort, beampath integration and the achievement of adequate cleanliness are not predicted to be factors in preventing NIF from meeting its performance objectives.

CHALLENGES TO COMPLETION: 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 lenses. The optics must be finished nearly defect-free and coated. The optical system will be installed in a class-1 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 the fused silica final focus lens and the glass blast shield at the interface to the vacuum of the target chamber.



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[15] 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 $6.4J/cm^2$. 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 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 optic in air. Work is underway to model the damage and to investigate methods to alleviate the lower damage level[16].

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[15] 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.

[16] Progress in the understanding of optical damage is addressed further on in this section of the Task Force’s Interim Report.

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[17].

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[18].

The NIF laser system consists of approximately 1,600 mirrors and polarizers and more than 2,500 fused silica focusing optics. Further, there are some 25,000 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 effort will be required by the NIF team 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 that will 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 relate to NIF as an operational laser system as well as to the state of the optics in each of the 96 initial beamlines and in the 192 total beamlines upon completion of the NIF laser.

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

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

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 formed particles of platinum in the glass that resulted when parts of 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 e-beam hard oxide 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 surface chemistry of SiO_2 optics in a vacuum, modifying the vacuum to a low pressure gas with oxygen present, and investigating the possibility of 2π phase step spatial beam smoother optics from the final optics module. If the damage 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. The first pilot run has been conducted at each of the two facilities.

The pilot run 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 run 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 are to be tested in a second pilot run. If the glass from this second run meets specifications, it could become 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 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 will be tested early in the second pilot run. If testing of the resultant glass confirms the lower hydroxyl concentration, then the pilot run will continue as a production run.

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 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; cleaning; and mounting.

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 MagaJoule 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 and oriented plates of KDP from the boules is about 80 percent. The yield of finished KDP plates ready for testing and coating is about 50 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 densification of the solgel coating after it has been applied to the KDP surface. 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 rapid 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 each of the initial 96 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 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 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 of the 92 installed beamlines.

CONCLUSIONS ON OPTICS ISSUES

NIF is a research and development project aimed at achieving ignition of a deuterium-tritium (DT) fueled sphere by laser induced inertial confinement. The project as a major step in the evolution of the Neodymium glass (Nd:Glass) laser technology. As expected, the NIF laser has had to identify and overcome significant technical hurdles to meet its goal of an output energy of 1.8 MJ of energy on target within a 3 nanosecond pulse duration. In particular, optical damage became a key technical issue at the outset with the decision to proceed with the 192 beam configuration laser system. This step reduced the construction cost of the laser but put a higher degree of technical risk on the operation of the laser system due to the increased optical fluence to 8J/cm2. The selection of 192 beams rather than 240 beams also reduced the technical contingency margins for reaching ignition.

The issues of optical damage, laser glass procurement, KDP crystal growth and fabrication, small optics, and NIF as an operating laser system have been identified and are important but are also capable of being resolved with adequate research and development effort. There are no technical issues related to optics that in principle will prevent the NIF laser from operating as a 96-beam system initially and a 192-beam laser system in its completed configuration.

APPENDIX A

SECRETARY RICHARDSON'S INITIATIVES

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 the following actions to get the project back on track and to address the schedule and cost problems:

- 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.

- 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.

- 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.

- 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.

- 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.

- 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.

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 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 Representative 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 in the Criminal Division of the 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 the 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's 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 of Physics 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 three open meetings at the Lawrence Livermore National Laboratory. 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 project 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 level of dedication and commitment impressed the members by the individuals who attended, participated and provided support to 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.

Finally, the Task Force would like 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 ensure that the Task Force meetings ran smoothly.

APPENDIX E

PREVIOUS NIF REVIEWS

DOE

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

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

NIF Project/ICF Program, (1998)
Chair/Committee: GAO
Oversight Agency: General Accounting Office
Focus: Cost, Schedule
URL: http://gao.gov

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

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.

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 $1/\text{ft}^3$.

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 $100{,}000/\text{ft}^3$.

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.

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.

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.