Report of the

Defense Science Board Task Force

on the

Employment of the National Ignition Facility

VOLUME I

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Office of the Under Secretary of Defense
For Acquisition, Technology, and Logistics
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OFFICE OF THE SECRETARY OF DEFENSE
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WASHINGTON, DC 20301-3140

DEFENSE SCIENCE
BOARD

17 NOV 2004

MEMORANDUM FOR ACTING UNDER SECRETARY OF DEFENSE (ACQUISITION, TECHNOLOGY & LOGISTICS)

SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on the Employment of the National Ignition Facility

I am pleased to forward the final report of the DSB Task Force on the Employment of the National Ignition Facility (NIF). This Task Force was begun in June 2004 to examine whether the proposed NIF activation and early use plan to achieve ignition by 2010 is executable. In addition, the Task Force was to assess the extent to which stakeholders are integrated into the plan and if the plan supports the near and long term goals of stockpile stewardship.

The Task Force concludes that the NIF program is well managed and on-track, and their report outlines eighteen specific recommendations to ensure the efficacy of the program and improve stakeholder integration. To reduce program risk, the Task Force states there is a need for a detailed risk mitigation plan with milestones and measures of merit. Some of the other recommendations include establishing an external national advisory committee and developing formal processes for stakeholder participation.

Achieving nuclear fusion ignition in a laboratory will be a key milestone and provide the capability to understand areas of astrophysics and weapons physics previously unobservable.

I endorse all of the Task Force's recommendations and encourage you to review the report.

William Schneider, Jr.
DSB Chairman

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DEFENSE SCIENCE BOARD

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Defense Science Board (DSB) Task Force on the Employment of the National Ignition Facility

The DSB Task Force on the Employment of the National Ignition Facility (NIF) was asked to make the following assessments and provide an interim report on 31 August.

- Assess the proposed ignition and "non-ignition" high energy density experimental physics programs at the NIF. Assess the program's executability, particularly with respect to the availability of NIF and supporting technologies.
- Assess the overall balance and priority of activities within the proposed plan and the degree to which the proposed program of NIF experiments supports the near- and long-term goals of stockpile stewardship.
- Assess the extent to which the major stakeholders in NIF are effectively integrated into the plan.

The Task Force found that the National Ignition Facility and planned programs of high energy density work build on a 30-year program expanding understanding of astrophysics, weapons physics, and other scientific areas of interest. The NIF adds new regimes in pressure, temperature, and density that will, given success in achieving ignition, provide visibility into the physical phenomena at the heart of nuclear explosions, astrophysics, and other very high energy density plasmas. Hence the NIF capability to produce thermodynamic burn will provide the much-needed understanding of the most important remaining question in weapons physics, and important questions in other sciences.

Overall, the project to develop, construct and commission the NIF is well managed and on-track. Still, at the time of the report, the technical risk associated with achieving ignition in 2010 remains high. A detailed risk reduction program defined in greater detail than the current plan is needed to further reduce the risk associated with the 2010 target and beyond 2010 should that date prove too ambitious.

Gen Larry D. Welch, General, USAF (Ret)
Task Force Chairman

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EXECUTIVE SUMMARY

The DSB Task Force was asked to:

- Assess the proposed ignition and "non-ignition" high energy density experimental physics programs at the National Ignition Facility (NIF).
- Assess the program's executability, particularly with respect to the availability of NIF and supporting technologies.
- Assess the overall balance and priority of activities within the proposed plan and the degree to which the proposed program of NIF experiments supports the near- and long-term goals of stockpile stewardship.
- Assess the extent to which the major stakeholders in NIF are effectively integrated into the plan

The National Ignition Facility and planned programs of high energy density work build on a 30-year program expanding understanding of astrophysics, weapons physics, and other scientific areas of interest. The NIF adds new regimes in pressure, temperature, and density that will, given success in achieving ignition, provide visibility into the physical phenomena at the heart of nuclear explosions, astrophysics, and other very high energy density plasmas. Hence the NIF capability to produce thermonuclear burn will provide the much-needed understanding of the most important remaining question in weapons physics.

Achieving ignition in 2010 is, appropriately, the highest priority goal for NIF. The plan to build, activate, and commission the laser — the NIF Activation Plan—is being competently executed. The plan for activation and growth of NIF experimental capabilities provides the highest probability for achieving ignition on the planned schedule. The overall program is a well-balanced set of activities that supports the Stockpile Stewardship Program. The program is technically challenging and would strongly benefit from continued, ongoing oversight by an external scientific group.

At the time of this report, the risk of achieving ignition in 2010 is high. A detailed risk mitigation program is needed to reduce that risk by 2010 and to further reduce the risk beyond 2010, should that date prove to be too ambitious. The risk mitigation plan, currently framed in general terms, needs to be further refined to provide a series of specific time-phased, measurable goals on the path to achieving ignition. The risk mitigation plan will need to reflect increased focus on ensuring that the high energy density physics (HEDP) community provides the diagnostics essential to success in experiments conducted in the

NIF. An integrated diagnostics plan should include a time-phased consideration of the full set of potential diagnostics, to include advanced diagnostic capabilities.

The current practice of subdividing high energy density goals into "ignition" and "high energy density physics" is neither valid nor useful. The distinction creates the impression that the ignition program should be separate from weapons physics when, in fact, the study of igniting plasmas is one of the most important areas in weapon science. Further, the high energy density physics (HEDP) regime of interest for *both* weapons physics and astrophysics includes: below ignition; ignition; and regimes well beyond initial ignition. Thus, ignition experiments in 2010 are continuing steps in an evolving program, not a "pass-fail" event. The Task Force strongly endorses a more unified, integrated approach to the experimental programs planned for NIF and other Inertial Confinement Fusion (ICF) facilities.

There is a high degree of cooperation among key HEDP operations: Omega at Rochester, the Z Machine at Sandia, Nike at Naval Research Laboratory (NRL), Trident at LANL, and the developing NIF. Still, further work is needed to define and implement an integrated program across these high energy density operations. For the near-term, this program should support the ramp-up to realize the full potential of the NIF. For the longer term, an integrated program is needed to utilize the capabilities of this valuable set of HEDP capabilities after NIF becomes fully operational. The directors of the relevant laboratories need to agree to specific commitments to support the work to achieve ignition in the NIF.

There needs to be a much closer interface between the NIF program and the military departments that depend on the effectiveness of the Stockpile Stewardship Program to sustain an effective nuclear deterrent. The nuclear weapons Project Officer Groups need a full, up-to-date, understanding of the current capabilities and the future potential of the science tools available for increased confidence, over the long term, in the continuing process of certifying the safety, security, and reliability of the weapons in the stockpile. While the first production unit milestones for the early series of weapons to undergo the life extension programs do not currently depend on the capabilities of the NIF, these capabilities will add a new level of confidence to ongoing assessment activities.

Given that the NIF is a national capability that builds on and is part of a continuing community of HEDP activities, two users groups are needed. The first addresses priorities and activities at the NIF. This group needs to be from the community of users to negotiate with and advise the Director of the NIF. The second group needs to be composed of the directors of the relevant laboratories to better integrate the broader range of HEDP community activities to ensure that needed experiments and other activities are performed at the appropriate facility.

SUMMARY OF RECOMMENDATIONS

General Recommendation:

- Eliminate the artificial distinction between programs of experiments in HED for weapons physics and for ICF

- **<u>HIGH-ENERGY DENSITY PHYSICS EXPERIMENTS</u>**
  - Options for earlier availability (2009 timeframe) of increased energy operation for experiments at the NIF should be developed and considered.
  - A formal "Red Team" should be chartered for both ignition and weapon physics activities.
  - A detailed national plan for ignition should be produced; the plan should include milestones, measures of effectiveness, and accountability.
  - The program needs to provide a detailed risk mitigation plan with milestone dates and measures of merit that drive all areas to no worse than "moderate" and most to "low."
  - Enhanced effort should be applied to development of new diagnostic and target fabrication techniques.
  - The Program should be given sufficient flexibility to move resources between the ignition and weapon physics areas, as there are numerous examples where common activities benefit both.
  - It is essential that adequate contingency in NIF shot shifts and other key areas be maintained, as surprises will occur.
  - An external national advisory committee should be established.
  - Ensure facility time at all ICF Program facilities is adequate to support the milestones outlined in the NIF Activation and Early Use Plan.
- **<u>BALANCE AND PRIORITY OF ACTIVITIES</u>**
  - Demonstration of ignition on the current schedule should remain the highest priority for NIF experiments.
  - Ensure the POG's are routinely engaged in NIF progress and plans and their impact on assessment and certification activities.
- **<u>STAKEHOLDER INTEGRATION</u>**
  - A formal process is needed to ensure optimum use of HED facilities for the range of needs, e.g., weapons physics, astrophysics, and very high energy density laboratory plasmas.
  - A formal process is needed by which ICF program sites participate in the continuous updating of the NIF Activation and Early Use Plan.
  - National participation in NIF needs to be improved. An example is diagnostics, where a process to ensure broader participation should be implemented.
  - Scientists skilled in NIF technology should be readily available to the user community. This should be accounted for in personnel planning and recruiting.
  - Management of the national user program at NIF should rise to the same level of visibility and influence as that accorded to the NIF Project.
  - Two users groups need to be formed:

- To coordinate the most effective use of the national facility.
- A group composed of the directors of the relevant laboratories, to provide the needed coordination and commitment to the most effective path to ignition and use of HEDP facilities leading to and beyond ignition.

1. SCOPE, STUDY APPROACH, AND GENERAL FINDINGS

1.1 SCOPE

The Terms of Reference for the Defense Science Board Task Force on the Employment of the National Ignition Facility (NIF) are presented in Appendix A.

The Task Force is to:

- Assess the proposed ignition and "non-ignition" high energy density experimental physics programs at NIF. Assess the program's executability, particularly with respect to the availability of NIF and supporting technologies.
- Assess the overall balance and priority of activities within the proposed plan and the degree to which the proposed program of NIF experiments supports the near- and long-term goals of stockpile stewardship.
- Assess the extent to which the major stakeholders in NIF are effectively integrated into the plan.

The Task Force convened in June, 2004, and was tasked to deliver an interim report on its findings by the end of August, 2004. This document reports the Task Force findings and recommendations to date. The full cooperation of the HEDP community, including the commitment of the leadership of the community made it possible for the Task Force to do its work quickly and efficiently. In particular, the Task Force appreciates the valuable participation of the leadership of the NIF project at Lawrence Livermore National Laboratory, and the leadership of HEDP programs at Sandia National Laboratory, Los Alamos National Laboratory, the University of Rochester, Naval Research Laboratory, and General Atomics, Inc.

1.2 STUDY APPROACH

Presentations to the Task Force provided comprehensive discussions with the technical and administrative leadership of the NNSA Inertial Confinement Fusion (ICF) program. The discussions evolved as the Task Force continued to define the scope of its inquiry and assessments.

The first set of briefings provided introductions and overviews of the program, including an overview of the National Ignition Facility at the Lawrence Livermore National Laboratory (LLNL), the high energy density physics experiments in support of the Stockpile Stewardship Program (SSP), requirements for indirect drive ignition, the physics of direct drive ignition, the NIF Project and plans for commissioning the facility, and diagnostic, cryogenic, and other activities required to support the NIF Activation and Early Use Plan.

Presentations from representatives of the national inertial confinement fusion laboratory sites provided an overview of their respective inertial confinement fusion program, and outlined their views on issues that should be considered by the Task Force.

A second set of discussions probed in detail the plans for high energy density weapon physics. LLNL and Los Alamos National Laboratory (LANL) presented their views on the major weapon issues to be addressed by NIF and other ICF facilities. Scaling and other discussions on the relevance and importance of these experiments to the stockpile were presented. The Task Force examined plans for weapon physics experiments at NIF and other facilities including Z (Sandia National Laboratories (SNL)), OMEGA (University of Rochester), and Nike (Naval Research Laboratory). These briefings provided information about the process by which experiments are allocated to various facilities in the SSP, including the overall plan for high energy density experiments and the specific facility requirements for each. A proper evaluation of weapon physics experiments planned for NIF required an understanding of the integrated national plan that includes all other national facilities. In addition, at this meeting the Office of Science and Technology Policy discussed the importance of basic high energy density physics to the national scientific enterprise. The Navy Strategic Systems Program provided a view on the role of NIF in stockpile stewardship and weapon life extension programs.

A third set of discussions focused on the plan for achieving ignition on NIF. The presentations addressed the plans for completing and activating NIF (including a description of the facility characteristics available between now and 2010), the detailed experimental plans for achieving indirect drive ignition by 2010, and an integrated set of risks and the proposed strategy to mitigate them. The physics and facility modifications required for direct drive ignition were also described.

The indirect drive ignition program is primarily executed at LLNL and LANL. The other ICF Program sites (Sandia, Rochester, Naval Research Laboratory, and General Atomics) presented their views on risk and the role of their site in the indirect-drive ignition program. The Task Force was also briefed on the importance of university access to National Nuclear Security Administration (NNSA) facilities; university involvement in diagnostics and other activities was strongly recommended. LANL provided a senior management perspective on the role of NIF in stockpile stewardship.

1.3 GENERAL FINDINGS

- **NIF is to provide new vistas of discovery and understanding for weapons physics and astrophysics at the pre-ignition, ignition, and beyond initial ignition levels.**
- **NIF capabilities are a logical extension of at least 30 years of progress in understanding and exploiting high energy density physics.**
- **Ignition experiments in 2010 should be viewed as key steps in an evolving program, not a "final exam."**
- **The distinction between HED for weapons physics and for ICF is neither valid nor useful. In the early years of NIF operation, eighty percent of NIF activity is currently planned for the combination of achieving ignition and other activities directly supporting stockpile stewardship.**
- **The current overarching near-term goals are to:**
  - **Complete the machine**
  - **Support stockpile stewardship**
  - **Achieve ignition in 2010**
  - **Lay the foundation for continued advances in HEDP**
- **Users groups are needed to coordinate the most effective use of the NIF and to harmonize the contributions of the wider HEDP community to exploit high energy density physics capabilities.**

Figure 1: General Task Force Findings.

NIF builds on the 30-year program in high energy density physics described in Volume II. It will open up new regimes in pressure, temperature, and density— including ignition. NIF is both a logical continuation of the long-term HEDP program and a facility providing for breakthroughs in the science of high-energy density physics. The Task Force anticipates that, given the *breakthrough* nature of planned NIF capabilities, much of what will be done on NIF in the next 5-10 years cannot yet be defined.

Breakthrough technologies have already been developed in the HEDP program. As an example, a significant amount of time is currently spent on the Z Machine at SNL performing material properties experiments using a technique known as "isentropic compression," in which materials are smoothly compressed without shock heating. Z's ability to accomplish this was recognized only a few years ago. Isentropic compression experiments are now a major component of Z activities and are yielding important data for the stewardship program. In a similar manner, the Task Force anticipates that NIF will also open up new discoveries and new capabilities that are not yet anticipated.

Achieving ignition in 2010 is an important milestone, but not an end in itself. Nor is it a "pass-fail" event. 2010 is the earliest date to expect a reasonable chance of success from an attempt to achieve ignition. The NIF will provide unique understanding of key issues before ignition, and is expected to produce levels of performance well beyond initial ignition. This full spectrum of NIF performance will be important to both the Stockpile Stewardship Program and the Nation's basic sciences efforts. The first ignition experiments will be followed by systematic exploration of the phase space for ignition and improvements in ignition capsule performance. Scientists expect to eventually be able, for the first time, to understand and control the behavior of plasmas in the ignition regime. This advance in knowledge will have profound impacts on support for the weapons program, where ignition-related phenomena are of critical importance. In short, the purpose of the NIF ignition program is not simply to demonstrate ignition, but to provide a critically important "scientific tool."

The program of work on NIF and other ICF facilities has been characterized as subdivided into "ignition" and "high energy density physics." The latter is simple shorthand that refers to high energy density experiments in areas such as hydrodynamics, radiation, and materials properties that are driven by weapon issues explored at levels of energy density below ignition. This nomenclature is neither valid nor useful. It is not valid in the sense that there is a great deal of physics overlap between the ignition and high energy density physics programs; also, the field of high energy density physics, as formally defined, *includes* the ignition regime. It is "not useful" in the sense that making the distinction leaves the impression that the ignition program should be separate from weapons physics, when, in fact, the study of igniting plasmas is one of the most important areas in weapon science. The major benefit for the stewardship program of ignition will be the ability to control plasmas in the ignition regime. Hence, the ICF Program should lay out not just a program to demonstrate ignition, but also a program to apply it in the most expeditious manner to weapon issues associated with burning plasmas. The Ignition 2010 program should fit seamlessly into this longer-term program. As NIF matures, we can expect to see the advances supported by NIF proceed at an expanding pace. The Task Force strongly endorses a more unified, integrated approach to discussing the experimental programs planned for NIF and other ICF facilities.

1.4 General Recommendation

- **Eliminate the artificial distinction between programs of experiments in HED for weapons physics and for ICF.**

Figure 2: Task Force Findings and Assessment of Ignition/
HED Experiments: General Recommendation.

As discussed above it is important this distinction be eliminated. This change emphasizes the unity of the science pursued and the importance of ignition to stockpile stewardship. Many technical activities in areas such as diagnostic development are common to the ignition and HED experimental plans and thus this change should also result in a more integrated and efficient program.

2. ASSESSMENT OF PROPOSED EXPERIMENTAL PROGRAMS AT NIF

2.1 FINDINGS

The Task Force findings and assessment of ignition and high energy density physics experiments are summarized in Figure 3.

- **Laser performance is necessarily a current central focus of bringing the NIF on line**
  - **The first quad is running at better than the specified performance, and the major laser performance parameters, e.g., beam quality, beam pointing, diagnostic pointing, timing, etc., have been demonstrated**
  - **Completion of the first bundle (8 beams) in 2005 will validate that the laser performance obtained from the first quad utilizing "first article" hardware can be achieved with production hardware, virtually completing the laser development.**
  - **Bringing the remaining bundles up to the first cluster (48 beams) and the full complement of 192 beams is a complex matter of production and integration, rather than development.**
  - **Learning to operate this facility is also a major task – it is unique and complex and its effective use will require extensive operating experience.**
- **Optics durability and maintenance at full energy is an issue that impacts facility availability.**

Figure 3: Task Force Findings and Assessment of Ignition/ HED Experiments: Laser Performance.

The first four beams (quad) of the NIF facility have been performance-tested, including extensive single beam analysis. The NIF Project has demonstrated the performance specified in the Primary Criteria and Functional Requirements (on a per-beam basis), including the major laser performance parameters in the areas of beam quality, beam pointing, diagnostic pointing, and timing.

The first quad was constructed from "first-article" hardware as an engineering prototype. Based on testing the first quad and value engineering studies that reviewed the various components for both function and manufacturability, procurements are underway for the first "production" hardware for the system. These production components will be utilized throughout the facility, eventually replacing the currently installed first-article hardware. The first bundle (8 beams), scheduled for completion in FY2005, will be assembled entirely from production hardware. Testing of this bundle is to validate that the laser performance obtained from the production hardware also meets the established requirements. Once this is accomplished, the development phase of the laser system will be essentially completed. The laser elements of the remaining modules are replicas. Challenges during this period are more akin to those encountered in a complex manufacturing process than to a technology development effort. Procurement management, quality assurance, and process control will be key to completing the build-out of the required line replaceable units. The project recognizes this change in its nature, and is evolving its management structure to match the nature of the work.

Commissioning this major, new facility entails a remaining set of major challenges. Some of the challenges of most concern are associated with bringing the system to regular operation at full energy. The state of the NIF Project at project completion in 2008 as described in the NIF Activation and Early Use Plan is as follows:

- All 192 beams be installed and acceptance tested;
- 96 beams operated simultaneously at approximately half-energy;
- 8 beams (1 bundle) operated at full energy (1.8 MJ 192 beam equivalent).

As described in the NIF Activation and Early Use Plan, following project completion, commissioning and activation of the second set of 96 beams would be done as part of NIF operations. Ramp-up to full energy for all 192 beams is planned for FY2009-FY2010. Current planning calls for all 192 beams to be available for experiments starting in Q3FY2009. Initial ignition integration experiments at the 1MJ level are planned for FY2010. Full-energy (1.8MJ) ignition experiments are planned to commence in FY2011.

With respect to optics durability, the key component or "fuse" for the laser system is the final focusing optics that deliver third-harmonic laser light to the center of the target chamber. The durability of these optics determines the number of experiments that can be performed at full energy for a given operations budget.

- **Major risks for the ignition and weapon physics program have been identified. The risk for achieving ignition in 2010 is high, but is expected to decline thereafter.**
- **The national ICF community has performed effectively in generating an integrated national risk set for ignition. There is close agreement on the set of risks and general agreement on the mitigation approaches.**
- **The current community process for risk assessment is similar to that of a Red Team but does not have the power and focus of a formal chartered Red Team.**
- **There is a need for a detailed, documented national ignition plan that encompasses all program elements and facilities, and includes milestones, measures of effectiveness, and accountability. This plan needs to include a defined, time-phased set of milestones that drive risk areas to acceptable levels.**
- **Evolution of the NIF should not preclude direct drive ignition experiments in the future.**
- **Progress on weapon physics, including ignition, will be strongly dependent on advances in target fabrication and diagnostic technologies.**

Figure 4: Task Force Findings and Assessment of Ignition/ HED Experiments: Risks and Plans.

The Task Force is strongly in favor of sustaining the goal of achieving ignition by 2010. The proposed "fill-tube" approach, while high-risk, has the merit of allowing ignition experiments to be fielded as soon as possible. It is important that the program also maintain a variety of other options, such as diffusion fill targets, advanced target ablators, and direct drive. The risk for the 2010 ignition plan is currently high, but a properly designed and executed risk mitigation program can be expected to steadily reduce the risk.

There has been a national ignition plan since 1997–98. The national ICF community has had a long tradition of national discussion of risks in physics issues associated with ignition, and this has continued over the past few years. More recently, the community has evaluated the new NIF fill-tube approach to ignition, and developed an initial national risk set. Consensus has been reached on the key areas of risk and the general approaches. Details are currently being worked out regarding which elements of the ICF Program will undertake the various development activities in the risk mitigation program. Clearly, much work remains to be done, but a good start has been made. It is important that this national approach to risk assessment and mitigation be formalized to include commitments from the ICF community leadership.

While the internal review process within the ICF Program is similar to a Red Team, it does not have the full power and focus of a conventional Red Team. The fact that there is no formally chartered Red Team within this program has resulted in a less-than-fully focused process for risk assessment and mitigation. The Task Force applauds the current national efforts to generate a risk list. The panel believes that a formal Red Team activity would be highly beneficial.

The NIF Activation and Early Use Plan represents a major achievement in that, for the first time, the nation has a plan to bring the facility on line coupled with an ignition plan and a plan to develop and build diagnostics and cryogenics – all consistent with the NNSA 5-year budget plan. Now that this plan has been developed and reviewed, the next step is to develop the plan in detail. Of key importance is identifying the roles to be played by each NNSA site and each facility. It is essential that each participant in the program be given clearly defined tasks with milestones and clear measures of accountability.

The national ICF Program has pursued both direct drive fusion and indirect drive fusion since its inception (Volume II, Appendix E). The physics requirements for indirect drive were validated in the mid-late 1990s as part of the validation of NIF. Since that time, the physics requirements for direct drive have also been examined and are being finalized and validated.

NIF will be brought on line with the beams in the indirect drive position (Volume II, Appendix E). However, there are versions of direct drive ignition that might be implemented in this beam configuration. While the program should include alternatives to reposition the NIF beams to direct drive positions if necessary, the needed progress in direct drive technologies is being pursued at other ICF facilities.

Target fabrication advances will have a strong impact on the programmatic results obtainable on NIF. In certain cases, the quality and ability to characterize specified perturbations and other features of these targets will directly impact the degree to which NIF experiments can address specific weapon issues. In other cases, such as ignition, certain demanding specifications are essential to success in the planned experiment. Additional investment in this area is needed and is likely to have a significant payoff.

Additional effort in developing advanced diagnostics would provide significant benefit. Experience has shown that developing advanced diagnostic techniques is likely to lead to new insights. In this program, advanced diagnostics have been central to technical progress, and their continuing development is an area where the involvement of the broader community, including universities, should be particularly effective.

- **Surprises are to be expected, and the program should be prepared to make timely adjustments to priorities and schedules.**
- **Effective use of NIF's potential will demand high flexibility and the freedom to redirect resources so as to bring the facility to full power and fully exploit the outcomes of experiments.**
- **The technical program is highly challenging and would benefit from peer review.**
- **An extensive set of experiments on Nike, Trident, Omega, Z, and NIF are required to support the ignition goal. Currently planned facility time, particularly at OMEGA, is not sufficient to meet this need.**

Figure 5: Task Force Findings and Assessment of Ignition/
HED Experiments: Management Issues.

In a technically challenging program, such as the high energy density physics program, surprises are inevitable. Areas where surprises may be expected include laser performance and NIF reliability at full power, beam smoothing (including laser-plasma interaction phenomena), capsule physics (particularly achievable convergence ratios), and target fabrication. In fact, the Task Force believes the limited ability to address previously unforeseen problems is the greatest risk to the Ignition 2010 campaign. One of the strengths of the ICF Program has been its ability to deal with unforeseen issues. By focusing on a well planned and executed risk mitigation program and keeping alternatives open, the ICF Program should be able to overcome the challenges, both known and unknown, that lie on the path to ignition. This will take time and is consistent with the Task Force's belief that the risk for ignition in 2010 is high but declines with risk mitigation.

The Task Force believes that NNSA and the Congress must provide the ICF Program with the flexibility to manage through the remaining uncertainties that are inevitable with a first time endeavor of this magnitude. For example, artificially partitioning the program between "ignition" and "weapons physics" should be avoided, given the common activities shared by both.

The national ICF Program has made impressive progress but remains a technically challenging activity. Careful, ongoing peer-review of programs is of continuing great value. This program needs to institute a formal peer review process. Peer review by a standing external advisory committee would serve several goals: (i) it will provide needed peer review and external comment on key technical issues; (ii) it could offer innovative suggestions regarding experiments and diagnostics; (iii) it will help the program make key decisions, e.g., down selection of target type for indirect drive, indirect-versus-direct drive, priorities on certain weapon physics experiments; and (iv) it will provide an effective, motivating catalyst for helping the various partners in the program to work together.

The NIF ignition program includes a number of experiments to be carried out at OMEGA, Z, and other national facilities. Experimental time at NIF will be in high demand, and the Task Force thus applauds this approach and endorses the plan to perform risk reduction and other experiments on facilities besides NIF whenever possible. The Task Force notes that not all the machine time available on these other facilities is currently in the NNSA budget.

2.2 RECOMMENDATIONS

The Task Force recommendations on ignition and high energy density physics experiments are summarized in Figures 6-7.

- **Options for earlier availability (2009 timeframe) of increased energy for experiments at the NIF should be developed and considered.**

Figure 6: Task Force Recommendations on Ignition/ HED Experiments: Laser Performance.

The Task Force felt that full energy availability in the 2009–2010 timeframe would be important to mitigating risk for the weapon physics program at NIF, especially for experiments approaching, and at, the ignition level. As an example, initial ignition capsule physics experiments will be done with 80 percent-scale targets as a result of the limited initial available energy. The Task Force was presented with arguments that results from these experiments could be in the full-scale ignition target campaign. Earlier availability of full energy would reduce the need to go through this scaling process and, thus, decrease overall risk to the ignition program.

Further, fully stressing the optics will occur only with repeated exposures to full power. It would be highly desirable to mitigate the risks associated with optics durability earlier. However, achieving earlier full power operation would require a significant change in program directions and would likely require additional funding.

- **A formal "Red Team" should be chartered for both ignition and weapon physics activities.**
- **A detailed national plan for ignition should be produced; the plan should include milestones, measures of effectiveness, and accountability.**
- **The program needs to provide a detailed risk mitigation plan with milestone dates and measures of merit that drive all areas to no worse than "moderate" and most to "low."**
- **Enhanced effort should be applied to development of new diagnostic and target fabrication techniques.**

Figure 7: Task Force Recommendations on Ignition/HED Experiments: Risks and Plans.

A formal Red Team process should be put in place. The Red Team should include members from both the ICF Program and experts outside the program to provide meaningful feedback. It is particularly important to seek university involvement in the Red Team. The Red Team process should be formalized and continue on an ongoing basis.

As noted, an ignition plan has existed in various forms since 1997–98. While the Task Force recognizes that the NIF Activation and Early Use Plan is still in its early stages — and applauds the effort so far — taking the *next* step is critical: to define, in detail, and reach agreement on all user responsibilities and roles. DOE should assure that all site responsibilities are made clear, and that a management approach that ensures each site is supported and held accountable for its assigned tasks is developed. Indirect drive provides the highest probability of achieving ignition at the earliest date. Still it is important that direct drive not be precluded as a future capability in the NIF.

A risk mitigation plan is essential to the success of this program. A particularly significant risk for the FY2010 ignition milestone is the lack of routine, full-energy operation until the end of CY2010. Enhanced attention and resources should be devoted to target fabrication. This encompasses both development of new materials and techniques, as well as devotion of resources to characterization of new and existing targets. Additional effort should also be devoted to new diagnostic development. All plans should have clear, identifiable sections devoted to target fabrication and diagnostics to ensure that progress in these areas may be closely tracked.

- **The Program should be given sufficient flexibility to move resources between the ignition and weapon physics areas, as there are numerous examples where common activities benefit both.**
- **It is essential that adequate contingency in NIF shot shifts and other key areas be maintained, as surprises will occur.**
- **An external national advisory committee should be established.**
- **Ensure facility time at all ICF Program facilities is adequate to support the milestones outlined in the NIF Activation and Early Use Plan.**

Figure 8: Task Force Recommendations on Ignition/ HED Experiments: Management Issues.

Currently the program has some flexibility to move resources between ignition and weapons physics activities. This flexibility needs to be maintained and enhanced.

The significant — and appropriate — contingency in the NIF shot budget in the NIF Activation and Early Use Plan should be maintained.

The Task Force recommends that NNSA look into various means for establishing a national advisory committee. Advisory committees for Inertial Fusion have existed in the past, and that they have been vital to validating program priorities and setting technical direction. NIF is a national facility, and, as such, the Task Force sees the need for outside guidance on experiments, and other matters related to the facility.

The experimental work required at major facilities, particularly OMEGA and Z, to support the NIF Activation and Early Use Plan was presented to the Task Force. There are resource shortfalls in funding experimental time, particularly at OMEGA, and the Task Force urges NNSA to remedy these shortfalls as soon as possible.

3. BALANCE AND PRIORITY OF ACTIVITIES

3.1 FINDINGS

- **Ignition on NIF is a "breakthrough" capability. With ignition, stockpile stewardship can begin to probe weapon phenomena associated with burn and thus address the most important question in weapon physics.**
- **There is extensive collaboration amongst the ICF laboratories on realizing the ignition milestone. There is less collaboration on weapon physics activities outside ignition.**
- **While NIF is not a part of current plans for meeting the first production unit milestone in the life extension programs, NIF will add a new level of confidence to ongoing assessment activities.**
- **The Weapon Project Officer Groups (POG's) have not been provided continuing education regarding NIF and its role in the SSP.**
- **A portion of the experimental facility time at NIF will be devoted to external users.**

Figure 9: Task Force Findings on ICF Program Balance and Priorities.

One of the most important questions in weapons physics is whether the phenomena involved in ignition and burn are properly modeled in the simulation codes. Ignition on NIF will provide a breakthrough capability, and it is almost certain that, once achieved, ignition will be used to perform weapons physics tests and experiments that have not yet been contemplated — in much the same way we now rely heavily on isentropic compression for materials work on Z.

There has been a long-standing and extensive collaboration between the ICF laboratories in the area of ignition, as evidenced by the integrated national list of risks to the NIF fill-tube ignition scheme presented to the Task Force. There is also collaboration in weapons physics, but to a lesser extent than in the area of ignition.

A methodology known as Quantification of Margins and Uncertainties (QMU) has been developed over the past several years at the national laboratories. A major goal of this methodology is to quantify the uncertainty and performance margin associated with specific weapon issues. QMU can and should be used to prioritize the ICF weapon physics program at the laboratories, with higher priority placed on issues having larger impacts on performance margin. The Task Force is aware that the JASONs are conducting a separate review of QMU. It is important that, as QMU and the analysis of weapon uncertainties are improved, this knowledge be fed back into the program of experiments at NIF and other facilities. The experiments on NIF, Z, and the other national facilities should be directed to address the issues having greatest impact on resolving uncertainties in weapons performance.

The Task Force heard from representatives from the W76 and W80 Project Officer Groups (POGs). The life extension activities are carefully focused and defined so as not to depend on NIF and other advanced capabilities within the SSP. However, history has shown that issues are likely to arise both during and after these refurbishments that require the application of advanced capabilities, such as NIF. It is not clear that current planning for W76 and W80 assessment and certification leverages all of the NIF capabilities that will be available.

The U.S. nuclear stockpile will doubtless be transformed over the next 10-30 years. While U.S. policy in this area is still evolving, it is clear that leading-edge scientific capabilities, such as NIF, will be critical to address the technical issues that arise, validate our simulation codes in new areas, and recruit the top talent needed for the Stockpile Stewardship Program. Overall, a healthy Stockpile Stewardship Program is necessary for the maintenance of a safe, secure, and reliable stockpile.

It was clear that the POGs were not fully aware of the NIF Activation and Early Use Plan. In fact, in some cases they had not been briefed in several years, a situation that must be remedied. Action should be taken to ensure that the POGs are aware of the impact of NIF and other facilities on the assessment and certification process.

The execution of experiments at NIF by university and other external users will benefit the stewardship program, DoD, and the broader U.S. scientific community. The current plan calls for 15% of NIF experiments to be allocated to external users, and there is no need to modify this allocation at this time. The NIF Director will monitor this allocation on an ongoing basis.

3.2 RECOMMENDATIONS

- **Demonstration of ignition on the current schedule should remain the highest priority for NIF experiments.**
- **Ensure the POG's are routinely engaged in NIF progress and plans and their impact on assessment and certification activities.**

Figure 10: Task Force Recommendations on ICF Program Balance and Priorities.

Laboratory ignition experiments are essential to fully addressing weapons issues related to thermonuclear burn. Weapon questions related to thermonuclear burn are of overriding importance to the Stockpile Stewardship Program and, thus, ignition should be demonstrated as soon as feasible. Experiments supporting the 2010 goal should be held at the highest priority.

The POGs should be briefed regularly on the NIF Activation and Early Use Plan to ensure that the NIF weapons physics activities, which are geared toward quantifying margins, support the longer-term needs of the Life Extension Programs and Stockpile Stewardship.

4. STAKEHOLDER INTEGRATION

4.1 FINDINGS

- **The taxonomy of weapon physics needs as it relates to the various facilities should be further developed on a continuing basis, so the relevance of all HED facilities at any given time is clearly understood and optimized.**
- **The wider HED community needs to be more involved in NIF diagnostics.**
- **A cadre of machine scientists is needed to help experimentalists leverage NIF.**
- **There is a need to transition from the intense central management required to build the national facility to a collaborative approach appropriate for implementing an integrated national program.**

Figure 11: Task Force Findings on Stakeholder Integration.

LLNL and LANL have carefully considered the various facilities in the ICF Program as they have gone about choosing where experiments on specific weapon issues should be conducted. This analysis needs to be done on a continuing basis, since the relevance of the various facilities will change as new discoveries are made. While the current process is adequate, a more formal national process would ensure that the taxonomy is maintained in a complete and up-to-date state. This process should be extended to incorporate not only weapons science, but also astrophysics, geophysics, and ignition activities across all HED areas of endeavor to provide a truly integrated national experimental program at the major ICF Program facilities.

The Task Force heard from several laboratories that national participation in NIF could be improved. Diagnostics was cited as an example. Communication was observed to be sometimes lacking, i.e., the Task Force heard quite different accounts from different laboratories describing the same program activities. Communication among the sites needs to be improved.

It was pointed out that NIF is of such complexity that making effective use of the facility will require detailed attention to, for example, laser pulse shapes, energies, beam-to-beam balance, and other facility attributes required to field effective experiments. These must be factored into the experimental design from the outset. Experiments on NIF are so precious that every effort should be made to optimize the capability of the machine and the design of the experiment. It is important that the cadre of machine scientists be involved in the design of the experiments from inception. This has been accomplished on other large facilities such as particle accelerators around the U.S. and the world.

The NIF Project at LLNL is clearly being managed with high competency. It is a soundly executed project, where the entire scope is contained within the LLNL NIF Directorate. However, the program to use NIF will be substantially different, in that significant responsibilities will be held and key intellectual contributions should be made by talent across the HEDP community. As the project to stand-up the NIF is completed, a more collaborative and nationally based management structure needs to be installed to foster the necessary collaborations. This is a necessary step for the most effective execution of the NIF Activation and Early Use Plan.

A successful program of work on NIF — particularly on ignition — will require the talents of all the relevant national facilities and programs. This was proven in the past, as described in presentations to the Task Force, when a number of key issues that arose in the mid-1990s related to the proof-of-principle for indirect drive ignition were solved via collaborations between LLNL and LANL. Other problems will arise, the solutions to which will benefit from the insights of other program participants.

4.2 RECOMMENDATIONS

- **A formal process is needed to ensure optimum use of HED facilities for the range of needs, e.g., weapons physics, astrophysics, and very high energy density laboratory plasmas.**
- **A formal process is needed by which ICF program sites participate in the continuous updating of the NIF Activation and Early Use Plan.**
- **National participation in NIF needs to be improved. An example is diagnostics, where a process to ensure broader participation should be implemented.**
- **Scientists skilled in NIF technology should be readily available to the user community. This should be accounted for in personnel planning and recruiting.**
- **Management of the national user program at NIF should rise to the same level of visibility and influence as that accorded to the NIF Project.**
- **Two users groups need to be formed. One to coordinate the most effective use of the national facility. The other composed of the directors of the relevant laboratories, to provide the needed coordination and commitment to the most effective path to ignition and use of HEDP facilities leading to and beyond ignition.**

Figure 12: Task Force Recommendations on Stakeholder Integration.

With respect to the NIF Early Use Plan, the informal process by which LLNL and LANL allocated their experimental time to various facilities was workable. However, some of the other laboratories, which have highly relevant technical expertise, were not yet fully integrated into ongoing discussions. It is important that a formal process be instituted to ensure that experiments are integrated and optimally matched to the capabilities of the various facilities. It is especially important for HEDP community experiments that *could* be done at locations other than NIF be performed at those other locations. It is also important that HEDP community researchers be trained on other facilities, such as OMEGA, before they come to NIF since the scale and size of NIF make such experience an important prerequisite for work at the NIF.

Planning for diagnostics, cryogenics, and other experimental technologies at NIF is where decisions will be made regarding the priorities for the NIF experimental program. Thus, it is essential that there be a regular process by a users group so that stakeholders in NIF provide input regarding these activities. Still, the NIF Director must ultimately make the final decisions in this area.

National participation in NIF should be enhanced via the assignment of clearly defined responsibilities to those in the program. For the case of diagnostics, the process to ensure broader participation should include, where feasible, input from the university community, since important insights and novel ideas are very likely to be contributed.

LLNL needs to ensure that an appropriate core team of laser scientists remains associated with NIF during the operational phase. In soliciting university partnerships for the program, consideration should be given to the need to have laser scientists trained in operations of large-scale laser facilities.

NIF is fundamentally different from the other facilities in the ICF Program both in its scale and the fact that it was explicitly recognized as a major national scientific facility from the outset. The assembly of an integrated national plan to use NIF will be critical to its success. NNSA and the laboratories have committed to operating NIF in a manner truly befitting a national facility. It is now time to make this vision a reality.

A user group that coordinates NIF activities within the user community is an important step towards this goal. The success of the broader program in high energy density physics will require significant commitments from all partners in the ICF Program. A user group at the laboratory director level should be formed to ensure all participants are actively engaged in planning and meeting their commitments.

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APPENDIX A. TERMS OF REFERENCE

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THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

JUN 14 2004

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference -- Defense Science Board Task Force on the Employment of the National Ignition Facility

You are requested to form a Defense Science Board Task Force to evaluate the experimental program under development for the National Ignition Facility (NIF). NIF is a key component of the National Nuclear Security Administration's (NNSA's) Stockpile Stewardship Program to maintain the nuclear weapons stockpile without nuclear testing. The NIF is a 192-beam laser designed to achieve fusion ignition and produce high-energy-density conditions approaching those of nuclear weapons. In addition to the stockpile stewardship mission, the NIF has missions in support of basic science and inertial fusion energy. The NIF is scheduled for completion in 2008.

NNSA and the high-energy-density physics community have developed a plan for activation and early use of NIF. The plan includes a goal to demonstrate ignition by 2010, and also supports high priority, non-ignition experiments required for stockpile stewardship. The plan also provides facility availability for the basic science, inertial fusion energy, and DoD nuclear weapon effects missions. The plan is consistent with the current NNSA Future Years Nuclear Security Plan (FYNSP).

The Task Force is to review the plan and address the following:

- Assess the proposed ignition and "non-ignition" high-energy-density experimental programs at NIF. Are the programs executable, particularly with respect to the availability of NIF and supporting technologies?

- Assess the overall balance and priority of activities within the proposed plan and the degree to which the proposed program of NIF experiments supports the near and long term goals of stockpile stewardship.

- Assess the extent to which the major stakeholders in NIF are effectively integrated into the plan.

An interim report is requested by September 1, 2004. A final report is requested by December 15, 2004.

The Study will be co-sponsored by me as the Acting Under Secretary of Defense (Acquisition, Technology and Logistics), by the Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs, and by the Administrator, National Nuclear Security Administration. Gen Larry Welch, USAF (Ret.) will serve as chairman of the Task Force. Dr. Christopher J. Keane of NNSA will serve as Executive Secretary and Lt Col Dave Robertson, USAF, will serve as the Defense Science Board Secretariat representative.

The Task Force will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act," and DoD Directive 5105.4, the "DoD Federal Advisory Committee Management Program." It is not anticipated that this Task Force will need to go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code, nor will it cause any member to be placed in the position of acting as a procurement official.

Michael W. Wynne
Acting

APPENDIX B. TASK FORCE MEMBERSHIP

This is the report of the Defense Science Board Task Force on the Employment of the National Ignition Facility. Figure 13 lists the members of the Task Force and support personnel from the various organizations who participated on the Task Force. The Task Force received briefings from a broad variety of government organizations, including the National Nuclear Security Administration, all of the Department of Energy Weapons Laboratories, and all other elements of the Stockpile Stewardship Program.

Chairman:
Gen Larry Welch, USAF (Ret) ....Institute for Defense Analyses

Members:
Dr. John Foster......................................Technology Strategies and Alliances
Dr. Hermann Grunder..........................Argonne National Laboratory
Dr. David Hammer ....Cornell University
Dr. Ted Hardebeck...............................Science Applications International Corporation
Dr. Bill Press..Los Alamos National Laboratory
Dr. Rich Wagner...................................Los Alamos National Laboratory

Executive Secretary:
Dr. Christopher Keane ....National Nuclear Security Administration

Defense Science Board:
Lt Col Dave Robertson, USAF............Defense Science Board

Government Advisers:
Dr. Richard Bleach ....OUSD/AT&L
Dr. Jill Dahlburg....................................Naval Research Laboratory
Ms. Susan Stoner ....OSD/AT&L

Support Staff:
Ms. Julie Evans ....Strategic Analysis, Inc.
Mrs. Grace Johnson..............................Strategic Analysis, Inc.
Dr. Adrian Smith..................................Directed Technologies, Inc.

Figure 13: Task Force Membership

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APPENDIX C. ACRONYMS

HED	High Energy Density
HEDP	High-Energy-Density Physics
ICF	Inertial Confinement Fusion
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
MJ	Megajoules
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NRL	Naval Research Laboratory
POGs	Project Officer Groups
QMU	Quantification of Margins and Uncertainties
SNL	Sandia National Laboratories
SSP	Stockpile Stewardship Program

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