LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-TR-664196

National Ignition Campaign Program Completion Criteria and Primary Criteria and Functional Requirements Evidence of Completion

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November 12, 2014

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

LLNL-AR-592152
NIF-0135596

NIC

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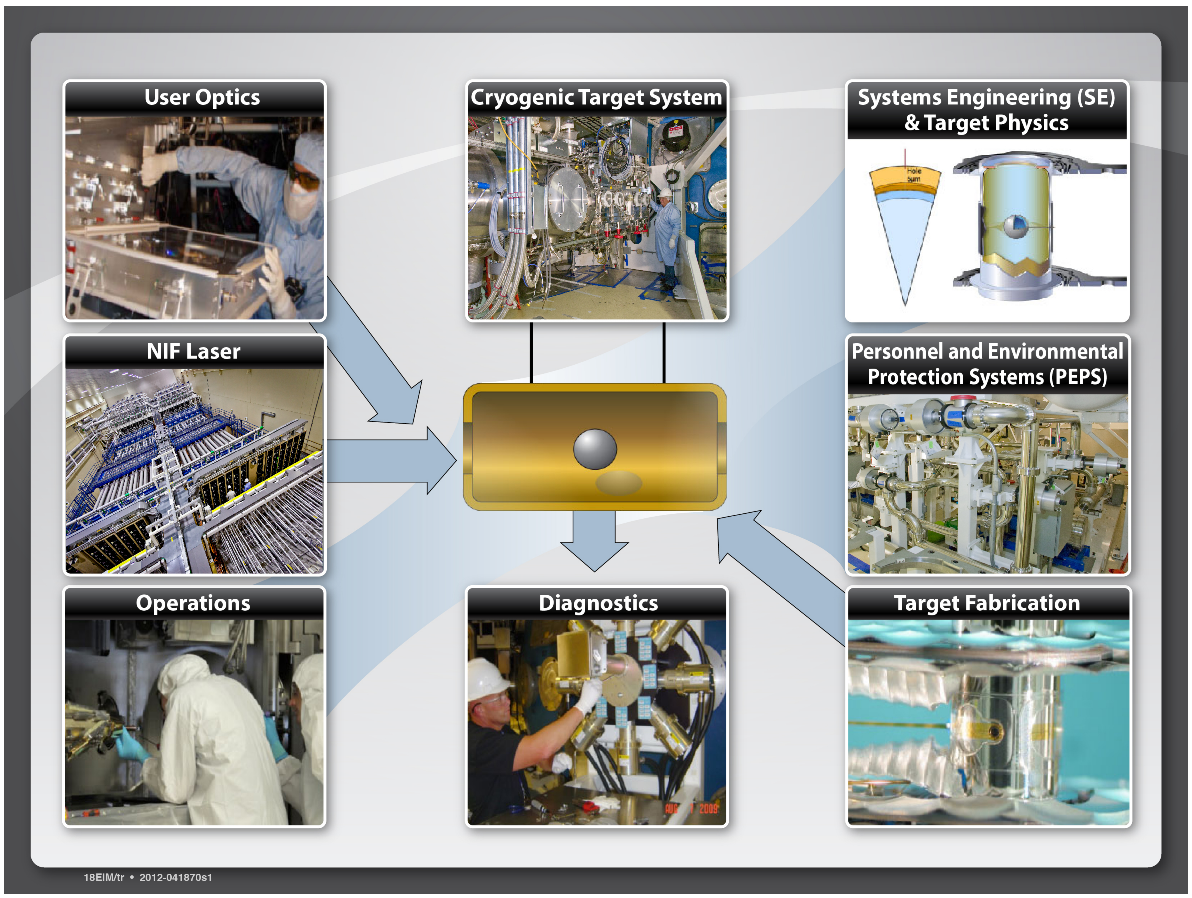

September 30, 2012

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This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion and the National Ignition Facility Project under Cooperative Agreement No. DE-FC52-08NA28302 and the University of Rochester. The support of DOE does not constitute an endorsement of the views expressed in this document.

Table of Contents

SUMMARY

All of the National Ignition Campaign Primary Criteria and Function Requirements (NIC PC&FRs) were accomplished prior to the completion of the NIC on September 30, 2012. In addition, the remaining subset of NIF Functional Requirements and Primary Criteria identified for demonstration during the NIC were completed[1]. All of the NIC Program Completion Criteria (NIC PCC) with the exception of "provide an initial ignition platform" were met. This document provides the evidence file for completion of the NIC PCC and the NIC PC& FRs.

INTRODUCTION AND REPORT STRUCTURE

The National Ignition Campaign (NIC) was formed in 2005 with the primary goals to perform integrated ignition experiments that would lead to fusion ignition and burn on NIF via inertial confinement fusion (ICF) – a goal that has long been recognized as a physics and technology grand challenge – and to transition NIF from project completion to routine facility operations at the end of the NIC in FY2013. During NIC, all of the capabilities necessary to perform integrated ignition experiments were developed and demonstrated. These included developing an integrated ignition point design with fusion energy output greater than or equal to laser energy to the target, delivering laser energy consistent with target illumination specifications, and providing diagnostics, user optics, a cryogenic target system, high quality targets, personnel and environmental protection systems, and NIF operational capabilities necessary to complete the NIC experimental objectives.

The NIC is an integrated national, multi-institutional effort that includes General Atomics, Lawrence Livermore National Laboratory (LLNL), Los Alamos and Sandia National Laboratories, the University of Rochester Laboratory for Laser Energetics, and a number of other collaborators including Lawrence Berkeley National Laboratory, the Massachusetts Institute of Technology, the U.K. Atomic Weapons Establishment (AWE), and the French Atomic Energy Commission (CEA).

Because of the importance of the NIC to the Stockpile Stewardship Program (SSP), it is managed as an "Enhanced Management" activity as defined by *NA-10 Defense Programs Program Management Manual.*[2] As such, the NIC was required to adhere to a rigorous set of project management standards that includes a formal execution plan. This plan described the multi-year (beginning-to-end) scope, schedule, and budget baseline. The NIC baseline was under formal change control, and progress was monitored using an earned value management reporting process. The first NIC Execution Plan (NIC EP Rev.0) was delivered to Congress in June 2005. The last revision of the execution plan, NIC EP Rev. 4.0 [0], was approved by NNSA at the beginning of the first quarter of FY 2011 and is the baseline from which NIC was operating at the conclusion of the program.

In the execution plan, a work breakdown structure (WBS) consisting of eight Level 1 elements was used to manage the scope of work defined in the NIC baseline plan. The NIC WBS is shown in Table 1 and the NIC Schedule Baseline by WBS[3] is shown in Figures 1a and 1b.

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[1] *National Ignition Facility Function Requirements & Primary Criteria – Evidence of Completion*, LLNL-AR-592152, NIF-0135506

[2] *NA-10 Defense Programs Program Management Manual,* U.S. Department of Energy, Washington, D.C., NA13-PMM-04-001 (December 30, 2004), later revised, NA14-PMM-08-0001, Revision 1 (January 12, 2010).

[3] Taken from Appendix C of the NIC Execution Plan, Rev. 4.0, (September 2010), UCRL-AR-213718, NIF-0111975-AE

Table 1. National Ignition Campaign Work Breakdown Structure (WBS)

- I. National Ignition Campaign
  - I.1 Management and Administration
  - I.2 Systems Engineering
  - I.3 Target Physics
  - I.4 Integrated Target Systems
    - I.4.1 Target Development and Manufacturing
    - I.4.2 Cryogenic Target System
  - I.5 Target Diagnostics and Experimental Systems
  - I.6 User Optics
  - I.7 Personnel and Environmental Protection Systems
  - I.8 Operational Capabilities

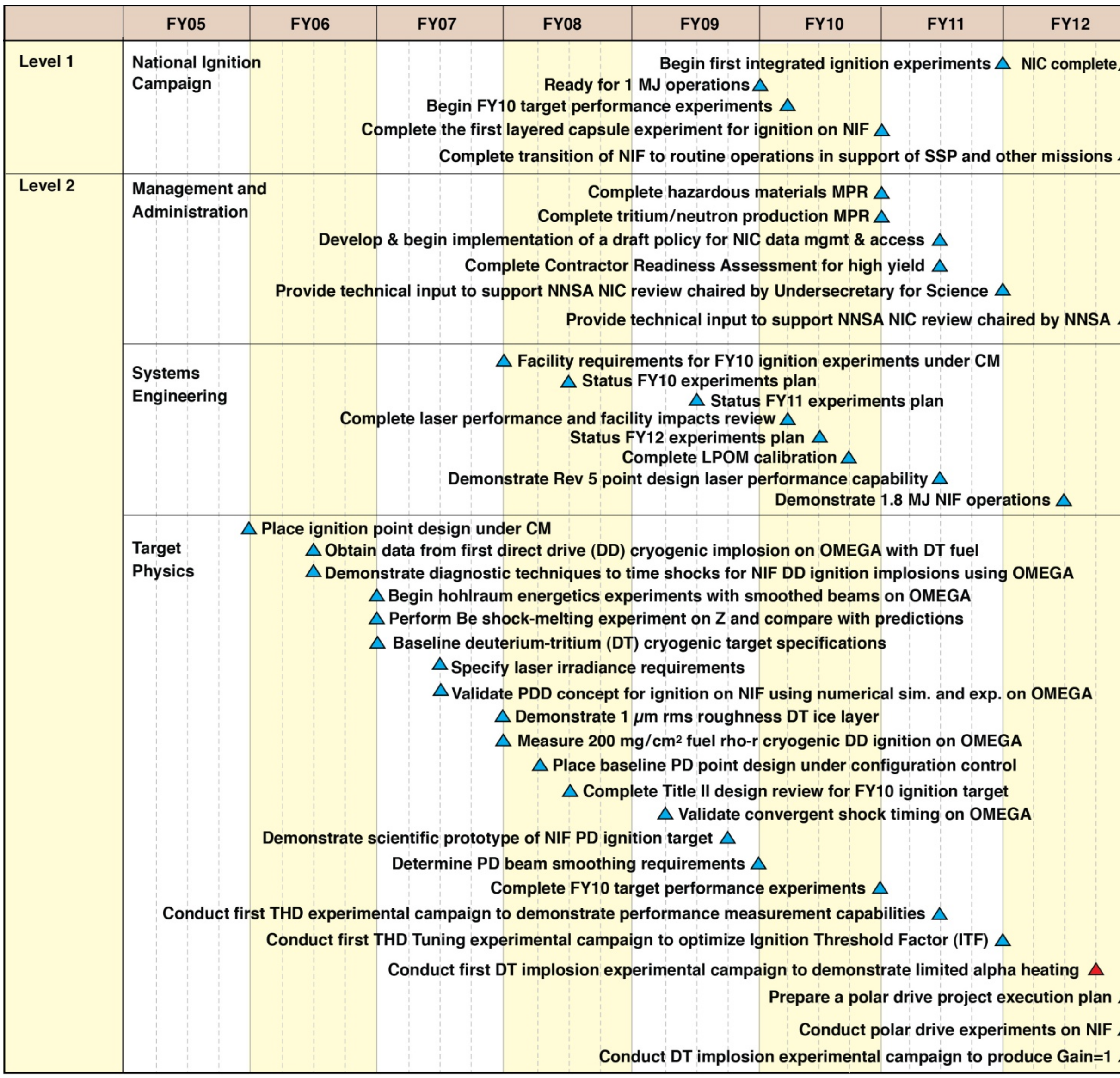

Figure 1a: The NIC Schedule Baseline from Appendix C of the NIC EP Rev. 4.0. for WBS elements I.1 Management and Administration through I.3. Target Physics

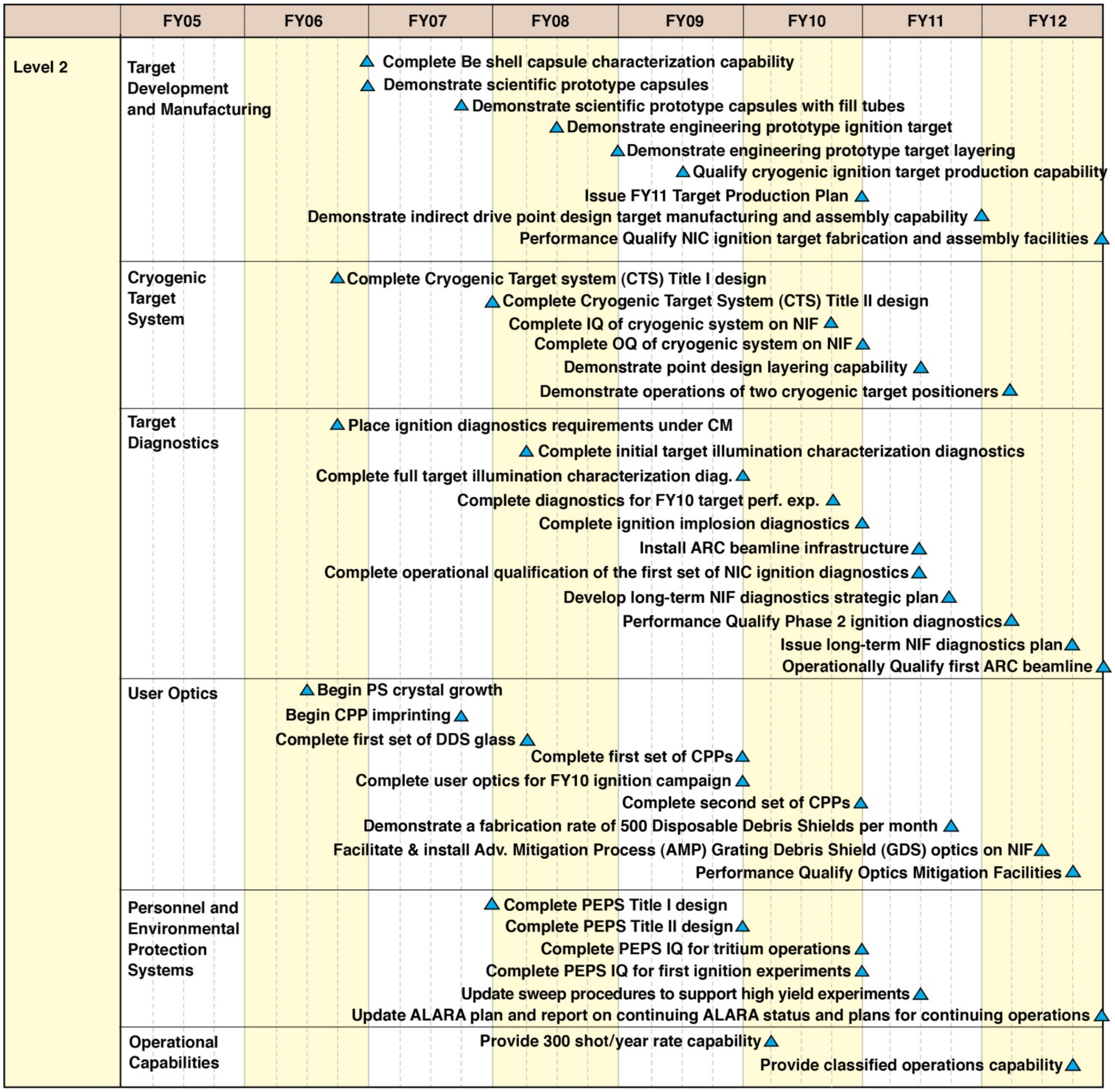

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Figure 1b: The NIC Schedule Baseline from Appendix C of the NIC EP Rev. 4.0. for WBS elements I.4 Integrated Target System through I.8. Operational Capabilities

In addition to the objective of achieving ignition on NIF, the plan included performing the necessary technology development, procurement, engineering, and integration of hardware to perform ignition experimental campaigns on the NIF and transition the NIF from project completion to routine facility operations in support of SSP and other missions by the end of FY2012. The effort associated with meeting the NIC objectives called out in the execution plan included:

- Developing an integrated ignition point design, with fusion energy output greater than or equal to laser energy delivered to the target
- Providing the required quantity of targets consistent with the ignition point design

- Providing a cryogenic target system capable of supporting the ignition point design at a shot rate consistent with the NIC shot plan
- Operating the NIF facility consistent with the requirements of the NIC experimental plan as the highest priority
- Providing laser beam characteristics consistent with target illumination specifications in the ignition point design
- Providing diagnostic systems to characterize laser/target illumination, hohlraum energetics, symmetry, ablator performance, shock timing, and fusion ignition
- Providing personnel and environmental protection systems and storage capabilities consistent with the NIC experimental plan, the Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory[4] and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement (SW/SPEIS),[5] and the NIF Complex Tier 2 Safety Basis Document.[6]
- Planning and executing an integrated national effort, including experimental work at other facilities leading to experimental campaigns on NIF
- Conducting a direct-drive program to support the indirect-drive ignition effort and plan for a direct-drive program on NIF in the post-NIC period. This will include polar drive experiments in the current NIF configuration in the NIC program period.
- Facilitizing, preparing for, and implementing routine NIF operations in support of non-ignition experiments for SSP, fundamental science and other missions

Contained within Appendices D and F in the NIC EP Rev. 4 are the NIC Program Completion Criteria (PCC) and the Primary Criteria and Functional Requirements (PC&FRs), respectively. The NIC PCC and PC&FRs represent the top-level system requirements that must be achieved to support the NIC objectives and to ensure that operations meet applicable federal, state, and local requirements for the protection of workers, the public, and the environment.

This report provides evidence of completion of the NIC PCC and PC&FRs. In text that follows, each PCC and PC&FR is reproduced in order from the NIC EP Rev. 4.0 section by section by WBS, followed immediately by the evidence presented to justify completion. Although the accepted practice is to address only the "shall" requirements, we also provided evidence for "should" statements. In some cases where several requirements point to the same piece of evidence, the requirements have been grouped together. When the evidence cites specific reference material such as document, a report, or journal article, a number in square brackets will follow, which refers to a unique number of a file that contains the cited reference material. The reference material can be found at: https://lasers2.llnl.gov/reviews/[7], a password protect website. The numbers of the evidence files are not contiguous in some instances because some documents have been cited in multiple places.

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4 U.S. Department of Energy, *Final Site-Wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory*, DOE-EIS-0348.

5 *Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement*, DOE/EIS-0236-S3.

6 *Tier 2 Safety Basis Document for the Building 581-582 Complex*, NIF-5019666.

7 Select Ignition Review to find cited references.

I.1 MANAGEMENT AND ADMINISTRATION

1. Program Completion Criteria

Requirement*: Complete Conduct of Operations*

Evidence:
A Conduct of Operations Program is in place for B581 Operations. This program implements the requirements of DOE Order 422.1 [1], flowed down to LLNL organizations through ES&H Manual Document 3.5. The program was formally reviewed during the 2008 Contractor Readiness Assessment, prior to NIF Project completion. The Conduct of Operations matrix is reviewed at least triennially, or more frequently if conditions or requirements change. The current version of the B581 Conduct of Operations matrix was updated in June of 2011 to be consistent with the April 2011 update of ESH Manual Document 3.5.

Requirement*: Complete NIF User Facility Guide*

Evidence:
The NIC User Facility Guide (Release 00) has been completed and is posted on the NIF User/Visitor Office website (https://lasers.llnl.gov/) under the For Users tab. This is a living document that will be revised as new information becomes available. See Figure 2.

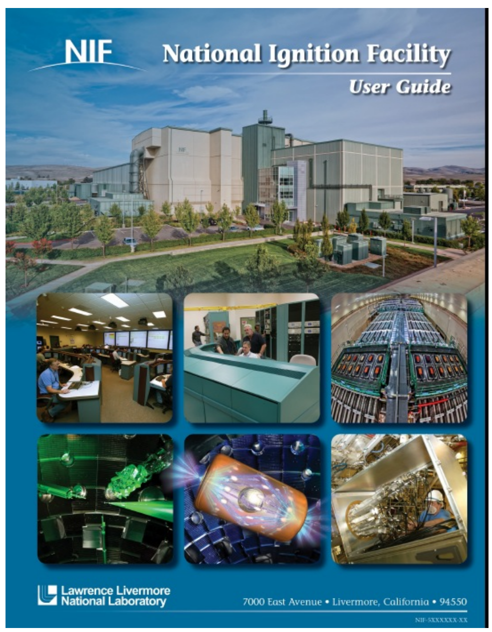

Figure 2. Cover of NIF User Guide.

I.2 SYSTEMS ENGINEERING

2. Program Completion Criteria

Requirement: ***Provide Laser Performance Operations Model (LPOM) for multi-bundle shot set-up***

Evidence:
A computational system, the Laser Performance Operations Model (LPOM) has been developed and deployed for the NIF Systems Engineering Group that automates the NIF laser setup process, and accurately predict laser energetics. LPOM determines the settings of the injection laser system required to achieve the desired main laser output, provides equipment protection, determines the diagnostic setup, and supplies post shot data analysis and reporting.

References:

1. Michael Shaw, Ronald House, Wade Williams, Christopher Haynam, Ronald White, Charles Orth, Richard Sacks, Laser Performance Operations Model (LPOM): A computational system that automates the setup and performance analysis of the National Ignition Facility, Fifth International Conference on Inertial Fusion Sciences and Applications (IFSA2007), Journal of Physics: Conference Series 112 (2008) 032022, IOP Publishing [2]

2. M. Shaw, W. Williams, R. House, C. Haynam, "Laser Performance Operations Model," Opt. Eng., 43, 2885-2895 (2004) [3].

3. M. Shaw, W. Williams, K. Jancaitis, C. Widmayer, and R. House, "Performance and Operational Modeling of the National Ignition Facility," at International Symposium on Optical Science and Technology (2003) [4].

4. Laser Performance Operations Model, LLNL-POST-566113, poster presentation at the Laser Performance Review Committee held on July 24-25, 2012 at LLNL [5]. This committee was chaired by Dr. Robert L. Byer, William R. Kenan, Jr. Professor of Applied Physics at Stanford University and the current (2012) President of the American Physical Society.

The journal publications, conference proceedings, and NIF memos identified above address and discuss in detail most aspects of the following NIC Completion Criteria and Primary Criteria and Functional Requirements (PC&FR), Section 2 System Engineering. Additional evidence is provided under specific PC&FRs.

Further Evidence:
In addition to the information provided on LPOM in the above reference, in March 2011, a test of a new release of the *Integrated Computer Controls System (ICCS)* was conducted in which a system shot [N110321-001-999] was taken to the RMDE (roving mirror diagnostic enclosure) calorimeters with four quads of beams. The test successfully demonstrated that the control software is capable of executing shots to the RMDE in rapid succession. This update enables NIF to calibrate the entire 1ω main Laser Performance Operations Model (LPOM) and all 192 1ω relay optics (RO) diodes in 1-2 shifts (part of a day) instead of 8-10 shifts (3-4 days). The ability to conduct multi-bundle shot set-up is part of the continuous improvement plan for NIF shot availability and rate**.** This capability is now used routinely for NIF shot set-up. (See March 2011 NIF Progress Report - Summary of NIF System Shots for March 2011) [6].

2.1 Primary Criteria

2.1.1 Analysis tools and validated operating models shall be implemented to support the ignition experimental campaigns beginning in FY2010 and routine facility operations in support of SSP by the end of FY2012

Evidence:
For its various missions, the NIF laser must generate pulses with a wide range of energies, pulse lengths, and temporal pulse shapes that must be balanced among the 192 beams. Since slight differences in amplifier gains, optical transmission losses, and converter configurations cause the output vs. input characteristics to differ among beams, a calibrated computational model of the facility is required to accurately determine the input conditions required for each beam and for each shot. That model must be part of the NIF controls system to provide real-time setup information within the NIF shot cycle. The laser performance operations model (LPOM) has been developed to provide this functionality. See references [2] through [5] for more detail.

2.2 Functional Requirements

2.2.1 A Laser Performance and Operations Model (LPOM) tool shall be available that is sufficiently accurate to meet ignition point design requirements

Evidence:

FY2010 DOE Level 2 Milestone MRT[8] 3417: *Complete Laser Performance Operations Model (LPOM) calibration*

Completion Criteria: "This milestone will be complete when Laser Performance Operations Model (LPOM) calibration for all 192 beams of the NIF laser is completed and documented." Title was: "Complete Laser Performance Operations Model (LPOM) calibration for power balance." Change approved on BSCR O07-002 3/7/07.

Completion has been documented in NIF-0115834, letter from Moses to Deeney, dated May 3, 2010 [7].

2.2.2 Tools shall be in place to perform laser shots at a rate consistent with the ignition experimental plan

Evidence:

LPOM is a fully automated system that has been designed, both in hardware and software, to scale to support full NIF operation within a time period consistent with shot rate goals. See references [2] through [5] for more detail.

2.2.3 Analysis tools shall be in place to review the data after a laser shot to support user requirements

Evidence:
One of the primary functions of LPOM is to provide shot analysis and reporting. One part of this functionality is data trending. LPOM has recently added its initial trending capabilities to its web-based browser. These trends are focused on shot metrics that LPOM is most interested (such as

[8] MRT = NNSA's Milestone Reporting Tool

PAM energy gain, main laser energetics, beam contrast) in order to verify the accuracy of its laser models.

2.2.4 Integrated demonstration [laser] experiments shall be performed to validate NIF performance for ignition experiments requirements

Evidence:

- FY2009 DOE Level 2 Milestone (not in MRT): *Ready for 1 MJ operations*
  Completion Criteria: "This milestone will be complete when the following are complete:
  - Completed the Readiness Assessment of 192-beam routine operations
  - Operationally qualified 24 laser bundles
  - Completed a 1-MJ non-target system shot to target chamber center
  - Confirmed 192-beam synchronization at target chamber center
  - Commissioned the target illumination characterization diagnostics
  - Installed and commissioned user optics
  - Demonstrated integrated cryogenic target operations."

  Completion has been documented in NIF- 0115820, letter from Moses to Deeney, dated September 14, 2009 [8].

- FY2010 DOE Level 2 Milestone MRT 3415: *Complete laser performance and facility impacts reviews*

  Completion Criteria: "This milestone will be complete when the laser performance and facility requirements necessary to conduct ignition implosion experiments are confirmed through review and approval by cognizant expert working groups and change control boards."

  Completion has been documented in NIF- 0117185, letter from Moses to Deeney, dated May 4, 2010 [9].

- FY2011 DOE Level 2 Milestone MRT 4071: *Demonstrate Rev 5 point design laser performance capability*

  Completion Criteria: "NIF operates at required laser specifications described in Rev 5 point design."

  Completion has been documented in NIF- 0117185, letter from Moses to Schneider dated March 1, 2011 [10].

- FY2012 DOE Level 2 Milestone MRT 4110: *Demonstrate routine 1.8 MJ NIF operations*

  Completion Criteria: "Demonstrate that NIF operates at 1.8 MJ as defined in the NIF the Primary Criteria and Functional Requirements, Section 2.1.1."

  Completion has been documented in NIF-0118050, letter from Moses to Quintenz, dated March 20, 2012 [11].

2.2.5 Capabilities needed to evaluate NIF performance for HED and other user applications shall be provided.

Evidence:
After a system shot is conducted, LPOM reads the shot data from the ICCS database and performs post-shot analyses. Within several minutes of the archiving of the raw shot data, LPOM

provides the NIF Shot Director and the experiment team with a web-based shot report that compares the laser performance metrics (including energetics, near-field beam contrast, and residual wavefront distortion) with the pre-shot predictions. It also displays the raw and processed near-field and far-field images, power sensor traces, and trends of selected laser metrics. These results are presented on the LPOM web browser and are available to all NIF users after a shot. The report is organized as a series of linked web pages that can be navigated to provide successive levels of detail, starting with a high-level status report for each participating quad, progressing to detailed reports from the underlying analyses. For more detail, see the references at the beginning of this section.

I.3 TARGET PHYSICS

3. Program Completion Criteria

Requirement 1 of 2: ***Design and execute NIC experimental campaigns***

Evidence: (Publications)
The NIC team has gained insights into the challenges of developing the scientific, technological, and engineering basis for indirect-drive ignition and has regularly communicated the technical progress to the broader communities through a number of reviews and refereed papers. Some of these include:

1. "Special Topic: Plans for the National Ignition Campaign (NIC) on the National Ignition Facility (NIF): On the threshold of initiating ignition experiments," PHYSICS OF PLASMAS 18, 050901 (2011) [12].
2. "Point design targets, specifications, and requirements for the 2010 ignition campaign on the National Ignition Facility," PHYSICS OF PLASMAS 18, 051001 (2011) [13].
3. "Capsule implosion optimization during the indirect-drive National Ignition Campaign," PHYSICS OF PLASMAS 18, 051002 (2011) [14]
4. "The experimental plan for cryogenic layered target implosions on the National Ignition Facility—The inertial confinement approach to fusion," PHYSICS OF PLASMAS 18, 051003 (2011) [15].

These Physics of Plasmas refereed journal publications address and discuss in detail most of the aspects of the NIC Completion Criteria and Primary Criteria and Functional Requirements.

Evidence: (Program Reviews, Audits, and Workshops)

1. JASON "NIF Ignition" Study (2005) - Study Leaders: David A. Hammer and Lars Bildsten– held at LLNL [16] [17].
2. External/internal optical material/damage review of laser-induced optics damage in ICF-class laser systems was held at LLNL, July 2007 – no document available
3. Target Fabrication Portfolio Review, external peer-review of target fabrication, held at LLNL, August 2008– held at LLNL – no report prepared
4. Nuclear Diagnostics Workshop for the NIC was held at LANL in March 2008 [20] [20a].
5. JASON Winter Study (2009) – Study Leader: Roy Schwitters – held at General Atomics, San Diego, CA [21] [21a].
6. Ignition Diagnostics Workshops were held at LLNL in February 2009 and again in July 2009 [22].
7. NIC Technical Review Committee (December 2009) – Chair, Alvin Trivelpiece (Committee established at the request of NNSA by B. Gen. Harencak) – held at LLNL [23] [23a].
8. General Accounting Office Audit (2010) Actions Needed to Address Scientific and Technical Challenges and Management Weaknesses at the National Ignition Facility [24] [24a]
9. NIC Independent Financial Review (June 2010) – chartered by NNSA– held at LLNL
10. LLNL Directorate Review Committee (DRC) for NIF and Photon Science (NIF&PS) (August 2010) - Chair reports to the Lab Director and serves on the LLNS (Lawrence Livermore National Security, LLC) Board of Governors – NIF&PS DRC chaired by General John Gordon, Former NNSA Administrator and member of the Livermore Laboratory National Security Board of Governors – held at LLNL [26]
11. NIC Quarterly Review (October 2010) – Conducted by Under Secretary of Science: Steven Koonin and chartered by NNSA – held at LLNL [27]

12. NIF Diagnostics Review (October 2010) - Chair, Jerry Wilhelmy (LANL retired) – held at LLNL [28].
13. NIC Quarterly Review (January 2011) – Conducted by Under Secretary of Science: Steven Koonin and chartered by NNSA – held at LLNL [29].
14. NIC Technical Review Committee (February 2011) – Chair, Alvin Trivelpiece (Committee established as the request of NNSA by B. Gen. Harencak– held at LLNL [30].
15. NIC Quarterly Review (June 2011) – Conducted by Under Secretary of Science: Steven Koonin and chartered by NNSA – held in Washington, DC [31].
16. NIC Quarterly Review (October 2011) – Conducted by Under Secretary of Science: Steven Koonin and chartered by NNSA – held at LLNL [32] [32a].
17. NIC Summer Study (July-August 2011) – Study group consisted of 17 experience scientists on the subject of ICF drawn from USA, Europe, and Israel – held at LLNL [33].
18. LLNL Directorate Review Committee (DRC) for NIF and Photon Science (NIF&PS) (August 2011) - Chair reports to the Lab Director and serves on the LLNS (Lawrence Livermore National Security, LLC) Board of Governors- NIF&PS DRC chaired by General John Gordon, Former NNSA Administrator and member of the Livermore Laboratory National Security Board of Governors– held at LLNL [34].
19. NIC Quarterly Review (January 2012) – NNSA Federal Program Manager's Program Update - chartered by NNSA and chair by Jeff Quintenz– held at LLNL [35].
20. NIC Quarterly Review (May 2012) – NNSA Federal Program Manager's Program Update - chartered by NNSA and chair by David Crandall– held at LLNL [36].
21. NIC Technical Review Committee (May 2012) – Chair, Alvin Trivelpiece (Committee established as the request of NNSA by B. Gen. Harencak– held at LLNL [37].
22. Ignition Science Workshop (May 2012)– Chaired by Bill Goldstein and Robert Rosner – held in San Ramon, CA - A total of 158 scientists and engineers from the US and abroad (about 1/3 from LLNL) attended the workshop, which was organized into the 6 topical subject areas related to ICF [38].
23. NIC Implosion and Hydrodynamics Workshop (August 2012) – held at LLNL [39] – no report prepared.

Evidence: (Milestone Completion)

- FY2008 DOE Level 2 Milestone MRT 2979: *Status FY10 experiments plan*

  Completion Criteria: "This milestone will be complete when a multi-site review of an updated detailed plan of all shots (primary and contingency) for 192 beam NIC tuning and ignition attempt shots is completed and results approved by the Systems Engineering / Physics Change Control Board."

  > Completion has been documented in NIF-0114723, letter from Moses to Donovan, dated March 31, 2008 [40].

- FY2009 DOE Level 2 Milestone MRT 2993: *Status FY11 experiments plan*

  Completion Criteria: "This milestone will be complete when a multi-site review of an updated detailed plan of all shots (primary and contingency) for FY11 is completed and results approved by the Systems Engineering / Physics Change Control Board."

  > Completion has been documented in NIF-0115434, letter from Moses to Deeney, dated April 8, 2009 [41].

- FY2010 DOE Level 1 Milestone MRT 3414: *Begin FY10 target performance experiments*

  Completion Criteria: "This milestone will be complete when the Hohlraum Energetics Shot Campaign is authorized and the first experiments have been conducted."

  > Completion has been documented in NIF-0115833, letter from Moses to Deeney, dated December 21, 2009 [42].

- FY2009 DOE Level 2 Milestone MRT 3416: *Status FY12 experiments plan*

  Completion Criteria: "This milestone will be complete when a multi-site review of an updated detailed plan of all shots (primary and contingency) for FY12 is completed and results approved by the Systems Engineering / Physics Change Control Board."

  > Completion has been documented in NIF-0115835, letter from Moses to Deeney, dated May 3, 2010 [43].

- FY2010 DOE Level 2 Milestone MRT 3418: *Complete FY10 target performance experiments*

  Completion Criteria: "This milestone will be complete when the Hohlraum Energetics, Capsule Tuning, and layered low-yield THD implosion Shot Campaigns are authorized and conducted, and experimental results reviewed by the Laser Performance, Energetics, Capsule, and Ignition IPTs."

  > Completion has been documented in NIF-0116829, letter from Moses to Schneider dated September 29, 2010 [44].

- FY2010 DOE Level 1 Milestone MRT 3745: *Complete first layered capsule experiment for ignition on NIF*

  Completion Criteria: "A cryo-layered THD capsule has been imploded on NIF. This experiment will demonstrate the complex integration of the sub-systems required for an ignition campaign including a target physics design, the laser, target fabrication, cryogenic fuel layering and target positioning, target diagnostics, control and data systems, and tritium handling and personnel environmental protection systems."

  > Completion has been documented in NIF-0116836, letter from Moses to Schneider, dated September 30, 2010 [45].

- FY2011 DOE Level 1 Milestone MRT 360: *Begin first integrated ignition experiments*
  Completion Criteria: *Attachment A: Completion Criteria for Level 1 Milestone 360; Attachment B: Completion Report for Level 1 Milestone 360;*

  > Completion has been documented in NIF-0117462, letter from Moses to Schneider, dated June 30, 2011 [46].

- FY2011 DOE Level 2 Milestone MRT 4072: *Conduct first THD experimental campaign to demonstrate performance measurement capabilities*

  Completion Criteria: "Demonstrate capability to measure laser, hohlraum, and capsule performance parameters in THD targets."

  > Completion has been documented in NIF-0117265, letter from Moses to Deeney, dated March 8, 2011 [47].

- FY2011 DOE Level 2 Milestone MRT 4073: *Conduct first THD Tuning experimental campaign to optimize Ignition Threshold Factor (ITF)*

  Completion Criteria: "Tune laser, hohlraum, and capsule performance parameters in context of ITF optimization in THD with goal of ITF of .25 or neutron yield of $2x10^{13}$."

  Completion has been documented in NIF-0117669, letter from Moses to Quintenz dated September 30, 2011 [48].

- FY2012 DOE Level 2 Milestone MRT 4111: *Conduct first DT implosion experimental campaign to demonstrate limited alpha heating*

  Completion Criteria: "Demonstrate cryogenic layered DT experiments producing a neutron yield of 10^{16} which corresponds to about 30 kJ of fusion yield."

  This milestone was not completed.

Requirement 2 of 2: ***Execute direct drive experiments and develop a plan for a polar drive program on NIF***

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4491 (formerly MRT 3419): *Prepare a Polar Drive Planning Document*

  Completion Criteria: "Prepare a Polar Drive Planning Document – Deliverable 1 – Q2; Deliverable 2- Q4."

  Completion has been documented in NIF-0118050, letter from Moses to Quintenz, April 16, 2012 [50], followed by a subsequent letter June 11, 2012 (NIF-0118223) [50a] [50b]. A response letter regarding completion of MRT 4491 was written by McCrory (LLE) to Quintenz on September 28, 2012 [50c] and a clarifying letter from Moses to Quintenz on October 26, 2012 [50d].

- FY2012 DOE Level 2 Milestone MRT 4114: *Conduct polar drive experiments on NIF*

  Completion Criteria: "Establish the baseline pointing and IDI phase plate defocus configuration for the Polar Ignition Campaign by measuring the symmetry of moderate compression implosions."

  Completion has been documented in NIF-0135555, letter from Moses to Quintenz, September 18, 2012 [50e].

3.1 Primary Criteria

3.1.1 The design of the ignition target shall use the indirect-drive geometry

3.1.2 The ignition target shall be designed to have a credible probability to ignite and burn using 2D and 3D radiation hydrodynamics codes

3.1.3 The design code used for ignition should be validated using experimental data from existing facilities to the extent possible

Evidence:
See Physics of Plasmas refereed journal publications [12]-[15] cited at the beginning of this section entitled "NIC Target Physics."

3.1.4 Research on direct drive shall support the indirect-drive ignition program and develop the technical basis for PD experiments on NIF

Evidence:

- FY2006 DOE Level 2 Milestone MRT 1817: *Place symmetric baseline direct drive deuterium-tritium (DT) cryogenic target specifications under configuration management*

  Completion Criteria: "This milestone will be considered complete when the baseline D-T cryogenic target specifications are placed under configuration management."

  Completion has been documented in NIF-0113574, letter from Moses to Hauer, dated October 25, 2006 [51].

- FY2007 DOE Level 2 Milestone MRT 2404: *Place symmetric baseline direct drive deuterium-tritium (DT) cryogenic target specifications under configuration management*

  Completion Criteria: "Validate polar direct-drive concept for ignition on NIF using numerical simulations and experiments on OMEGA."

  Completion has been documented in NIF-0114010, letter from Moses to Hauer, dated March 30, 2007 [52] [52a].

- FY2008 DOE Level 2 Milestone MRT 2907: *Place baseline PDD point design under configuration control*

  Completion Criteria: "This milestone will be complete when the polar direct drive baseline point design is reviewed, approved, and placed under configuration control."

  Completion has been documented in NIF-0114589, letter from Moses to Donovan, dated January 15, 2008 [53] [53a].

- FY2009 DOE Level 2 Milestone MRT 2994: *Determine polar drive (PD) beam smoothing requirements*

  Completion Criteria: "This milestone will be complete when a document containing the polar drive smoothing requirements is completed. The document will include specifications for phase plates, smoothing by spectral dispersion, and polarization rotation. It will also include the pointing locations and requirements for the NIF beams."

  Completion has been documented in NIF-0115831, letter from Moses to Deeney, dated October 9, 2009 [54] [54a].

3.1.5 Capabilities needed to develop optimized ignition designs for HED and other user applications shall be provided

Evidence:
A number of surrogate target physics platforms (Table 2) were developed and used during the NIC to optimize ignition designs. At the end of NIC, these and the associate diagnostic capabilities used to field these platforms are available for HED and other user applications.

Table 2. Target physics platforms.

Optimization Platform	Purpose
Symcap (gas-filled symmetry capsule)	Symcaps are used to establish that (a) the required peak radiation temperature can be achieved consistent with specifications on the radiation asymmetry, (b) the level and variability of scattered laser light is acceptable and (c) the hot electron production from laser–plasma interaction (LPI) effects as well as the level of hot electrons transported to the capsule are at acceptable levels.
Re-emit (Bi-re-emission sphere)	Reemit targets are used to optimize symmetry during the first 2 ns of the pulse by imaging soft x-ray reemission from the Bi coated sphere which replaces the standard CH capsule.
Keyhole (shock timing)	Keyhole targets are used to measure the timing and strength of shocks launched in the ablator and set the key parameters of the pulse shape. 1D and 2D platforms are available.
Convergent Ablator (ConA)	ConAs are used to radiograph the position of the imploding shell radius versus time and the optical depth of the mass remaining in the ablator as it implodes. The peak power and shell thickness, along with the dopant level in the ablator must be adjusted to optimize the tradeoff between implosion velocity and mix. Slit widths can be varied to vary the observation window.
2D Radiography	A variant of the ConA target which uses a 10-20 keV backlighter and a pinhole instead of a slit to obtain a sequence of 2D images of the optical depth of the imploding shell as a function of time.
MixCaps	A variant of symcap with engineered surface features whose optical depth can be imaged during the course of an implosion using a 5-10 keV x-ray backlighter. Ablator dopants can be used to measure mix via spectroscopy of radiochemistry.
Compton radiography	Areal density and shape of the dense cold fuel surrounding the hotspot can be obtained from high-energy x-ray images obtained using transmission Compton radiography where high energy Compton scattering is used rather than traditional photo-absorption to cast a shadow of the imploding capsule.
Crystal Ball	Crystal Ball is used to characterize the pressure at the surface of a spherical surface inside a hohlraum (e.g. a capsule).
ViewFactor	ViewFactor is used to directly measure the radiation drive as viewed by the capsule and compare it with the radiation drive deduced from the measurement through the laser entrance hole.
THD/DT Ignition	The integrated implosion performance of a layered target is measured to assess the results of optimization using the surrogate physics platform discussed above.

3.2 Functional Requirements

3.2.1 The ignition point design target should be designed using 1 MJ (nominal) of 3ω light in the NIF geometry, with alternative designs developed using up to 1.8 MJ of 3ω as well as polar drive.

Evidence:

- FY2005 DOE Level 2 Milestone MRT 1678: *Place ignition point design under configuration management*

  Completion Criteria: "This milestone will be considered complete when the ignition point design is documented, reviewed and validated by NIC stakeholders and placed under formal configuration management."

  > Completion has been documented in NIF-0112776, letter from Moses to Keane dated September 30, 2005 [55].

3.2.2 The ignition point design shall specify the laser pulse shape and energy consistent with the NIF energy, pulse length, and dynamic range limits at the time of NIF Project completion

Evidence:

- FY2008 DOE Level 2 Milestone MRT 2921: *Complete Title II design review for FY10 ignition target design*

  Completion Criteria: "This milestone will be complete when the Title II Design Review of the tabulated physics requirements for the FY10 NIC Point Design Target is completed and documented in a formal report."

  > Completion has been documented in NIF-0114722, letter from Moses to Donovan, dated 3/29/08 [56].

- FY2007 DOE Level 2 Milestone MRT 2295: *Place facility requirements for FY10 ignition experiments under configuration management*

  Completion Criteria: "This milestone will be complete when the Title II Design Review of the tabulated physics requirements for the FY10 NIC Point Design Target is completed and documented in a formal report."

  > Completion has been documented in NIF-0114365, letter from Moses to Hauer, dated 10/10/07 [57].

3.2.3 The ignition point design shall specify the beam spot, focusing, and pointing consistent with the NIF focusing and pointing specifications and user optics fabrication technology

Evidence:

- FY2007 DOE Level 2 Milestone MRT 2287: *Specify laser irradiance requirements*

  Completion Criteria: "This milestone will be considered complete when laser irradiance requirements in terms of phase plate, polarization smoothing, 2-Color wavelength, SSD, and Final Optics Assembly design configuration are identified, validated through stakeholder requirements reviews, documented, approved and placed under formal configuration management."

  > Completion has been documented in NIF-0114034, letter from Moses to Hauer, dated 4/19/07 [58].

- FY2008 DOE Level 2 Milestone MRT 2920: *Complete initial target illumination characterization diagnostics*

  Completion Criteria: "This milestone will be complete when diagnostics are available that will validate the target illumination symmetry (beam pointing, beam power and energy, focal spot shape) for the first quad of beam lines."

  > Completion has been documented in NIF-0114620, letter from Moses to Donovan, dated January 28, 2008 [59].

- FY2009 DOE Level 2 Milestone MRT 2998: *Complete full target illumination characterization diagnostics*

  Completion Criteria: "This milestone will be completed when diagnostics are available that will validate the target illumination symmetry (beam pointing, beam power and energy, focal spot shape) for all 192 beams. Specifically incident 3w laser energy shall be measurable on 192 beams, incident laser power shall be measurable on at least 48 quads (one beam per quad), laser beam pointing and focal spot shape shall be measurable through x-ray imaging on both upper and lower hemisphere beams."

  > Completion has been documented in NIF-0115752, letter from Moses to Deeney dated August 7, 2009 [60].

- FY2011 DOE Level 2 Milestone MRT 4071: *Demonstrate Rev 5 point design laser performance capability*

  Completion Criteria: "NIF operates at required laser specifications described in Rev 5 point design."

  > Completion has been documented in NIF-0117185, letter from Moses to Schneider dated March 1, 2011 [10].

3.2.4 The NIF experimental plan shall be consistent with the NIF capabilities at the end of project, and the operations costs shall be consistent with the NIF operations budget

Evidence:
In accordance with the NIF Governance Plan (LLNL-AR-416565 NIF-0115829-AA), the Experimental Facilities Committee (EFC) is charged with developing the multi-mission facility use plan for approval by the NIF Director and concurrence by the LLNL Director. This plan for FY2013 and beyond is being developed based on programmatic considerations (and later input from the Peer Review Panels for the mission areas as they are implemented), and then optimized to ensure the most efficient use of the facility resources and configurations. The NIF capabilities implemented during NIC are used as the basis for determining compatibility of proposed experiments for facility access regardless of mission area. Further, the operations costs used as the planning basis to execute the FY2013 Facility Use plan is consistent with the NIF operations budget and the SCAP[9] agreements going forward.

3.2.5 The experimental plan should use supporting facilities to determine the appropriate target configuration for NIC experimental campaigns

[9] SCAP = Self-Constructed Asset Pool

Evidence:

- FY2006 DOE Level 2 Milestone MRT 825: *Obtain data from first direct-drive cryogenic implosion on OMEGA with DT fuel*

  Completion Criteria: "This milestone will be considered complete when implosions of DT-filled cryogenic targets are performed on OMEGA, and existing, well-proven diagnostics are used to assess performance."

  > Completion has been documented in NIF-0112776, letter from Moses to Hauer, dated March 28, 2006 [61].

- FY2006 DOE Level 2 Milestone MRT 1815: *Begin hohlraum energetics experiments with smoothed beams at OMEGA*

  Completion Criteria: "This milestone will be considered complete when hohlraum energetics experiments with smoothed beams using phase plates begin at OMEGA facility."

  > Completion has been documented in NIF-0113499, letter from Moses to Hauer, dated June 7, 2006 [62].

3.2.6 The experimental techniques and diagnostics should be demonstrated to the required accuracy on supporting facilities to the extent possible

Evidence:

- FY2006 DOE Level 2 Milestone MRT 830: *Demonstrate diagnostic techniques to time shocks for NIF direct drive ignition implosions using OMEGA*

  Completion Criteria: "This milestone will be considered complete when: 1. Use the VISAR diagnostic to validate the hydrocode predications of single and dual shock propagation (shock propagation through shocked material) and coalescence in CH (determine velocity profiles, coalescence and shock breakout times); hydrocode predictions should be within +/- 50-ps of the experimentally determined values (well within the capabilities of VISAR). 2. Extend the multi-shock technique developed with CH to cryogenic D2 and validate the hydrocode predications. 3. Develop radiographic techniques (conventional and phase contrast imaging) for detecting shock trajectories applicable for both planar and spherical geometries. 4. Develop techniques to validate shock propagation and coalescence at the core in gas-filled cryogenic surrogate targets; validate hydrocode predications to within +/- 50-ps."

  > Completion has been documented in NIF-0113181, letter from Moses to Hauer, dated March 28, 2006 [63].

- FY2006 DOE Level 2 Milestone MRT 1819: *Perform Be shock-melting experiment on Z and compare with predictions*

  Completion Criteria: "This milestone will be considered complete when the Be shock melting experiments on Z are documented and released."

  > Completion has been documented in NIF-0113552, letter Moses to Hauer, dated October 9, 2006 [64].

- FY2009 DOE Level 2 Milestone MRT 3026: *Validate convergent shock timing on OMEGA*

Completion Criteria: “This milestone will be complete when experimental measurements of multiple shock timing in liquid deuterium are made in a converging geometry on OMEGA and the results compared with numerical simulations.”

Completion has been documented in NIF-0115277, letter from Moses to Deeney, dated January 14, 2009 [65] [65a].

- FY2007 DOE Level 2 Milestone MRT 2296: *Demonstrate 1 μm rms roughness DT ice layer*

Completion Criteria: “This milestone will be considered complete when a deuterium-tritium (DT) ice layer is measured that meets the uniformity specification.”

Completion has been documented in NIF-0113613, letter from Moses to Hauer, dated October 25, 2006 [66] [66a].

- FY2007 DOE Level 2 Milestone MRT 2304: *Measure 200 mg/cm^2 fuel rho-r cryogenic direct-drive implosion on OMEGA*

Completion Criteria: “This milestone will be considered complete when the existing OMEGA cryogenic target handling system is used to deliver high quality cryogenic targets to the center of the OMEGA target chamber which are subsequently imploded, and existing, well-proven diagnostics including charged particle spectroscopy are used to measure the area density.”

Completion has been documented in NIF-0113576, letter from Moses to Hauer, dated May 16, 2007 [67] [67a].

3.2.7 Experiments shall be performed on supporting facilities to determine the technical feasibility of polar drive

Evidence:
There were no DOE Level 2 Milestones associated with this task. LLE performed a significant number of experiments on the Omega Laser Facility to assess the technical feasibility of polar drive, with positive results. This work has been closely coupled to the design and initial performance of Polar Drive exploding pusher shots on the NIF and to the ongoing development of NIF polar drive ignition designs. While work is ongoing, some of the NIC research in this area has been published and/or presented at technical meetings:

1. Cok, A. M. (2007). Optimization of Polar-Direct-Drive Beam Profiles for Initial NIF Targets. 2006 Summer Research Program for High School Juniors at the University of Rochester’s Laboratory for Laser Energetics. Rochester, NY, University of Rochester.
2. Cok, A. M., R. S. Craxton, et al. (2008). "Polar-Drive Designs for Optimizing Neutron Yields on the National Ignition Facility." Phys. Plasmas **15**(8): 082705.
3. Collins, T. J. B., J. A. Marozas, et al. (2012). "A Polar-Drive–Ignition Design for the National Ignition Facility." Phys. Plasmas **19**(5): 056308.
4. Collins, T. J. B., J. A. Marozas, et al. (2011). Polar-Drive Hot-Spot Ignition on the NIF. presented at the International Workshop on ICF Shock Ignition, Rochester, NY, 8–10 March 2011.
5. Collins, T. J. B., J. A. Marozas, et al. (2010). "Preparing for Polar Drive at the National Ignition Facility." Bull. Am. Phys. Soc. **55**(15): 25.
6. Craxton, R. S. and D. W. Jacobs-Perkins (2005). "The Saturn Target for Polar Direct Drive on the National Ignition Facility." Phys. Rev. Lett. **94**(9): 095002.

7. Craxton, R. S., F. J. Marshall, et al. (2005). "Polar Direct Drive: Proof-of-Principle Experiments on OMEGA and Prospects for Ignition on the National Ignition Facility." Phys. Plasmas **12**: 056304.
8. Craxton, R. S., F. J. Marshall, et al. (2005). Polar-Direct-Drive Experiments on OMEGA Using Saturn Targets. presented at the 35th Annual Anomalous Absorption Conference, Fajardo, Puerto Rico, 26 June - 1 July 2005 (Paper TO9).
9. Craxton, R. S., F. J. Marshall, et al. (2005). "Radiation Transport in Saturn Targets Used for Polar Direct Drive." Bull. Am. Phys. Soc. **50**(8): 310.
10. Marozas, J. A., F. J. Marshall, et al. (2005). "Progress in Polar-Direct-Drive Simulations and Experiments." Bull. Am. Phys. Soc. **50**(8): 342 - 343.
11. Marozas, J. A., F. J. Marshall, et al. (2006). "Polar-Direct-Drive Simulations and Experiments." Phys. Plasmas **13**: 056311.
12. Marshall, F. J., R. S. Craxton, et al. (2006). "Optimized Polar-Direct-Drive Experiments on OMEGA." Bull. Am. Phys. Soc. **51**(7): 106.
13. Marshall, F. J., R. S. Craxton, et al. (2006). "Polar-Direct-Drive Experiments on OMEGA." J. Phys. IV France **133**: 153 - 157.
14. Marshall, F. J., V. Y. Glebov, et al. (2010). "NIF-Relevant, Polar-Drive Illumination Tests on OMEGA." Bull. Am. Phys. Soc. **55**(15): 26.
15. McKenty, P. W., T. J. B. Collins, et al. (2011). Preparing for Polar-Drive Ignition on the NIF. presented at the 7th International Conference on Inertial Fusion Sciences and Applications, Bordeaux, France, 12–16 September 2011.
16. McKenty, P. W., T. J. B. Collins, et al. (2007). Multidimensional Numerical Investigation of NIF Polar-Direct-Drive Designs with Full Beam Smoothing. submitted to the *Proceedings of the Fifth International Conference on Inertial Fusion Science and Applications (2007)* [to be published in the Journal of Physics: Conference Series (Institute of Physics), London, England].
17. McKenty, P. W., R. S. Craxton, et al. (2010). Results of Recent NIF Polar-Drive Diagnostic Activation Experiments. presented at 19th Target Fabrication Meeting, Orlando, FL, 21–26 February 2010.
18. McKenty, P. W., R. S. Craxton, et al. (2010). "Design of High-Neutron-Yield, Polar-Drive Targets for Diagnostic Activation Experiments on the NIF." J. Phys.: Conf. Ser. **244**: 032054
19. Radha, P. B., F. J. Marshall, et al. (2011). Polar Drive on OMEGA. presented at the 7th International Conference on Inertial Fusion Sciences and Applications, Bordeaux, France, 12–16 September 2011.
20. Radha, P. B., F. J. Marshall, et al. (2011). Results from Polar-Drive OMEGA Experiments. presented at the International Workshop on ICF Shock Ignition, Rochester, NY, 8–10 March 2011.
21. Radha, P. B., F. J. Marshall, et al. (2011). "OMEGA Polar-Drive Target Designs." Bull. Am. Phys. Soc. **56**(12): 242.
22. Skupsky, S., R. S. Craxton, et al. (2006). "Polar Direct Drive—Ignition at 1 MJ." J. Phys. IV France **133**: 233 - 235.
23. Wittman, M. D. and D. R. Harding (2010). Development of NIF-Scale Polar-Drive Cryogenic Targets, presented at the 19th Fabrication Meeting, Orlando, FL, 21–26 February 2010.
24. Zuegel, J. D., C. Dorrer, et al. (2011). Polar-Drive Beam Smoothing for Direct-Drive Ignition on the National Ignition Facility, presented at the 7th International Conference on Inertial Fusion Sciences and Applications, Bordeaux, France, 12–16 September 2011.

Copies of the above journal articles or presentations are available upon request from the University of Rochester, Laboratory for Laser Energetics.

I.4 .1 TARGET DEVELOPMENT AND MANUFACTURING

4.1 Program Completion Criteria

Requirement: ***Provide targets that meet NIC experimental plan requirements***

Evidence:

- FY2010 DOE Level 2 Milestone MRT 3420: *Issue FY11 Target Production Plan*

  Completion Criteria: "This milestone will be complete when an FY11 Target Production Plan is developed, reviewed by the NIC participating sites, and approved by the Target Development and Manufacturing CCB."

  Completion has been documented in NIF-0116834, letter from Moses to Schneider dated September 30, 2010 [68].

- FY2011 DOE Level 2 Milestone MRT 4074: *Demonstrate indirect drive point design target manufacturing and assembly capability*

  Completion Criteria: "Manufacture and assemble targets that meet ignition campaign requirements."

  Completion has been documented in NIF-0117671, letter from Moses to Schneider dated September 15, 2011 [69].

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  Completion has been documented in NIF- 0118323, letter from Moses to Quintenz, dated August 6, 2012 [70].

- E. T. Alger et al., "NIF Target Assembly Metrology Methodology and Results," *J. Fusion Science & Technology* 59 (2011) 269 [70a].

4.1.1 Primary Criteria

4.1.1.1 Targets shall be developed and manufactured to meet ignition point design specifications

Evidence:

- FY2009 DOE Level 2 Milestone MRT 2996: *Qualify cryogenic ignition target production capability*

  Completion Criteria: "This milestone will be complete when a cryogenic ignition target production capability is demonstrated and documented."

  Completion has been documented in NIF-0115433, letter from Moses to Deeney, dated April 8, 2009 [71].

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  > Completion has been documented in NIF- 0118323, letter from Moses to Quintenz, dated August 6, 2012 [70].

4.1.1.2 Capabilities needed to produce and deliver targets that contain deuterium-tritium cryogenic fuel shall be developed

Evidence:

- FY2007 DOE Level 2 Milestone MRT 2292: *Demonstrate scientific prototype ignition capsules with fill tubes (Be and/or plastic)*

  Completion Criteria: "This milestone will be considered complete when a scientific prototype ignition capsule with fill tubes, consistent with approved ignition point design, is fabricated and characterized for dimensionality, smoothness and density emphasizing effects due to drilling, mandrel removal, and fill tube attachment requirements."

  > Completion has been documented in NIF-0114159, letter from Moses to Hauer, dated July 5, 2007 [72].

- FY2008 DOE Level 2 Milestone MRT 2922: *Demonstrate engineering prototype ignition target*

  Completion Criteria: "This milestone will be complete when an engineering prototype ignition target, consistent with the approved ignition point design, is fabricated and characterized emphasizing precision assembly requirement"

  > Completion has been documented in NIF-0114742, letter from Moses to Donovan, dated April 14, 2008 [73].

4.1.1.3 There shall be sufficient capacity to manufacture targets consistent with the ignition experimental campaign, and the production infrastructure for routine facility operations that can support the SSP and other experimental programs by the end of FY2012

Evidence:

In FY2012, the NIC Target Development and Manufacturing teams have demonstrated the ability to sustain building 20 cryogenic targets per month (see Figure 3). This capacity meets requirements of the ignition experimental plan. At the end of FY2012, the infrastructure and capabilities develop under NIC will be available to support target fabrication needs of the SSP and other NIF missions.

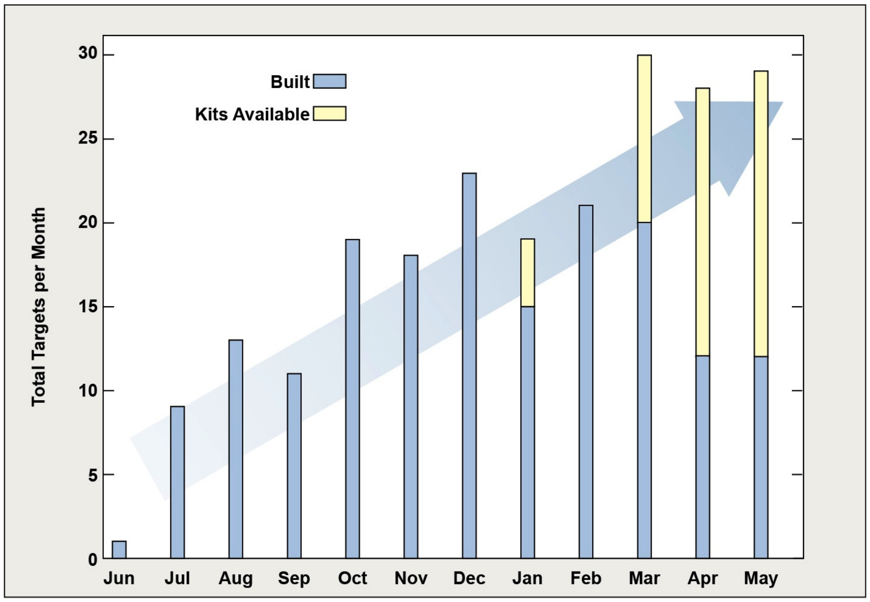

Figure 3. Targets built and kits available from June 2011 through May 2012.

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  Completion has been documented in NIF- 0118323, letter from Moses to Quintenz dated August 6, 2012 [70].

4.1.1.4 Capabilities needed to support the development and manufacture of targets for HED and other user applications shall be provided

Evidence:
To meet the demanding precision, schedule, and volume requirements for manufacturing the wide array of targets used during the NIC, numerous capabilities have been put into place both at GA and LLNL. Further, processes have been developed and documented to train the target production workforce, promote continuity and retention of expertise, and ensure high-quality component fabrication, characterization, and assembly on a consistent basis. The extraordinary target fabrication and manufacturing capabilities and infrastructure developed and implemented under NIC will broadly support all NIF missions in the future.

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  Completion has been documented in NIF- 0118323, letter from Moses to Quintenz, dated August 6, 2012 [70].

4.1.2 Functional Requirements

4.1.2.1 Capsules shall be manufactured using beryllium and/or CH (plastic) to the sphericity and surface roughness specified by the ignition point design requirements. Alternate ablator materials may be considered as they become available.

Evidence:

- FY2006 DOE Level 2 Milestone MRT 1816: *Demonstrate scientific prototype ignition capsules (Be and/or plastic)*

  Completion Criteria: "This milestone will be considered complete when a prototype ignition capsule (Be and/or plastic) is fabricated and characterized for dimensionality, smoothness, density, and dopant profile."

  Completion has been documented in NIF-0113571, letter from Moses to Hauer, dated October 9, 2006 [74].

- FY2006 DOE Level 2 Milestone MRT 1822: *Complete Be shell capsule characterization capability*

  Completion Criteria: "This milestone will be considered complete when radiography, interferometry, and atomic force microscope (AFM) methods for characterizing Be capsules are demonstrated."

  Completion has been documented in NIF-0113572, letter from Moses to Hauer, dated October 9, 2006 [75].

4.1.2.2 Capabilities needed for ignition capsules to be filled with deuterium-tritium fuel using a fill tube shall be developed

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  Completion has been documented in NIF- 0118323, letter from Moses to Quintenz dated August 6, 2012 [70].

4.1.2.3 Dopants and impurities in the capsule should be within the tolerances as specified in the ignition point design requirements

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

Completion has been documented in NIF- 0118323, letter from Moses to Quintenz dated August 6, 2012 [70].

4.1.2.4 The hohlraum shall be manufactured to the ignition point design requirements, including the dimensions and materials

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4115: *Performance Qualify NIC ignition target fabrication and assembly facilities*

  Completion Criteria: "GA, LLE and LLNL target facilities facilitized and ready to support point design target production for post-NIC ignition experiments."

  Completion has been documented in NIF- 0118323, letter from Moses to Quintenz dated August 6, 2012 [70].

4.1.2.5 The hohlraum shall provide the thermal environment to produce a deuterium-tritium cryogenic fuel layer to the ignition point design requirements

Evidence:
During the NIC, 9 cryogenic, layered THD and 28 cryogenic, layered DT experiments were conducted on NIF with targets that meet the experimental requirements. The thermal environment provided by the hohlraum is key for meeting the low mode (ℓ = 1-10) part of the power spectrum. Atomic force microscopy is used to provide low mode information. See Figure 4, Power spectral density vs model number AFM data from a layered DT shot [120411].

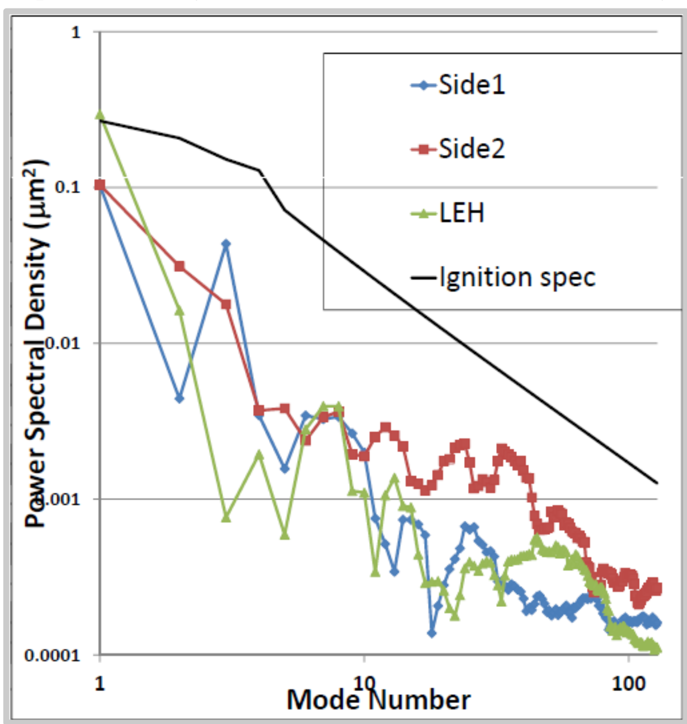

Figure 4. Power spectral density vs mode number Atomic Force Microscopy (AFM) data from a layered DT shot [N120214].

4.1.2.6 The cryogenic fuel layer quality shall be demonstrated to the accuracy specified by the ignition point design requirements.

Evidence:

- FY2009 DOE Level 2 Milestone MRT 2995: *Demonstrate scientific prototype of NIF polar drive ignition target*

  Completion Criteria: "This milestone will be complete when a prototype of a NIF polar drive target has been filled with liquid deuterium and an ice layer formed. Optical shadowgraphy and or x-ray phase contrast imaging will be used to determine that an ice layer was formed."

  Completion has been documented in NIF-0115628, letter from Moses to Deeney dated 7/10/2009 [76].

- FY2011 NIC EP Level 2 Milestone MRT 4075: *Demonstrate point design layering capability*

  Completion Criteria: "Demonstrate THD layering capability in the NIF layering-cryogenic target positioner."
  Completion has been documented in NIF-0117264, letter from Moses to Schneider dated 3/8/2011 [85].

- Since the first layered THD shot, September 29, 2010, eight additional layered THD fuel capsules and 29 DT layered fuel capsules have been imploded on the NIF using indirect drive. In addition to characterization for dimensionality (thickness), the layer quality is measured using three orthogonal x-ray views (at the equator for x and y and through the laser entrance hole for z) for low mode and high mode distortion. Low mode distortion results from a non-uniform thermal environment within the hohlraum, while high mode distortion is a consequence of beta layering. The power spectral density is the metric used to evaluate layer quality as a function of mode number. The other key layer specification is associated with local defects that are characterized in terms of groove areas and lengths. For example, shown in Figure 5 is the data acquired for the DT layer used in shot [120205]. These data demonstrate that this layer meets the point design requirements for layer quality. Layer quality is also addressed in Section I.4.2.

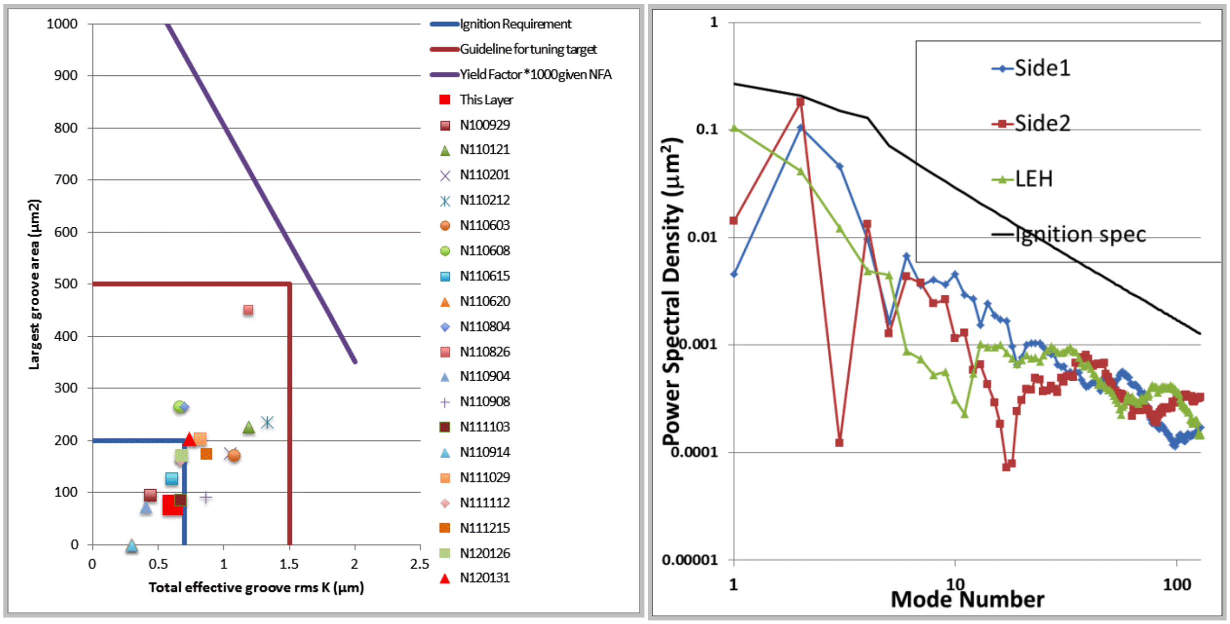

Figure 5. (Left) Power spectral density as a function of mode number data and (right) isolated defect characterization as groove area and length for layered DT shot [122005] show this layer meets NIF ignition specifications.

I.4.2 CRYOGENIC TARGET SYSTEM (CTS)

4.2 Program Completion Criteria

Requirement: ***Provide capability to field layered ignition targets***

Evidence:

During NIC, 37 cryogenic layered implosions were conducted. The shot numbers are listed in Table 3**.**

Table 3. Shot numbers for cryogenic layered implosions conducted during the NIC.

THD SHOTS				DT SHOTS			
#	**Shot ID**	**Campaign**	**Exp**	**#**	**Shot ID**	**Campaign**	**Exp**
THD1	N100929-003	IT_7_THD_PQ	S08d	DT1	N110608-002	IT_8_DT_CY11_C1	S07a
THD2	N110121-001	IT_7_THD_PQ	S11h	DT2	N110615-003	IT_8_DT_CY11_C1	S15a
THD3	N110201-002	IT_7_THD_PQ	S14k	DT3	N110620-002	IT_8_DT_CY11_C1	S16a
THD4	N110212-001	IT_7_THD_PQ_CY11	S01k	DT4	N110826-001	IT_8_DT_CY11_C2	S04a
THD5	N110603-001	IT_7_THD_PQ_CY11	S04a	DT5	N110904-003	IT_8_DT_CY11_C2	S05a
THD6	N110804-003	IT_7_THD_PQ_CY11	S07b	DT6	N110908-001	IT_8_DT_CY11_C2	S06a
THD7	N111029-001	IT_7_THD_CY11_C2	S01b	DT7	N110914-001	IT_8_DT_CY11_C2	S07b
THD8	N120114-005	IT_9_THDCR_PQ	S04b	DT8	N111103-001	IT_8_DT_CY11_C3	S01a
THD9	N120329-001	AP_1_THDConA	S01a	DT9	N111112-002	IT_8_DT_CY11_C3	S02a
				DT10	N111215-001	IT_8_DT_CY11_C3	S03a
				DT11	N120126-001	IT_8_DT_CY11_C3	S04a
				DT12	N120131-001	IT_8_DT_CY11_C3	S05a
				DT13	N120205-002	MX_8_DT_C1	S02a
				DT14	N120213-001	IT_8_DT_CY11_C3	S06a
				DT15	N120219-001	MX_8_DT_C1	S03a
				DT16	N120311-001	IT_8_DT_CY12_C1	S01a
				DT17	N120316-002	MX_8_DT_C1	S06a
				DT18	N120321-001	MX_8_DT_C1	S07a
				DT19	N120405-003	MX_8_DT_C1	S08a
				DT20	N120412-001	MX_8_DT_C1	S09a
				DT21	N120417-001	MX_8_DT_C2	S10a
				DT22	N120422-001	MX_8_DT_C1	S11a
				DT23	N120626-002	MX_8_DT_C2	S01a
				DT24	N120716-001	MX_8_DT_C2	S05a
				DT25	N120720-002	MX_8_DT_C2	S03a
				DT26	N120802-001	MXIT_8_DT	S01a
				DT27	N120808-001	MXIT_8_DT	S02a
				DT28	N120920-001	IT_8_DT_CY13_C1	S02a

- C.R. Gibson, D.P. Atkinson, J.A. Baltz, V.P. Brugman, F.E. Coffield, O.D. Edwards. B.J. Haid, S.F. Locke, T.N. Malsbury, S.J. Shiromizu, K.M. Skulina "Design of NIF Cryogenic Target System" Fusion Science and Technology 55, 233 (2009) [77].

- FY2006 DOE Level 2 Milestone MRT 1823: *Complete cryogenic target system (CTS) Title I design*

  Completion Criteria: "This milestone will be considered complete when the cryogenic target system Title I (preliminary) Design Review is completed and results are documented."

  > Completion has been documented in NIF-113376, letter from Moses to Hauer, dated June 28, 2006 [78].

- FY2007 DOE Level 2 Milestone MRT 2322: *Complete cryogenic target system Title II design*

  Completion Criteria: "This milestone will be considered complete when the cryogenic target system Title II Design Review is completed and results are documented in a formal report."

  > Completion has been documented in NIF-1143666, letter from Moses to Hauer, dated October 10, 2007 [79] [79a].

- FY2010 DOE Level 2 Milestone MRT 3421: *Complete installation qualification of cryogenic system on NIF*

  Completion Criteria: "This milestone will be complete when the cryogenic system equipment is installed in NIF and has completed required installation qualification (IQ) testing."

  > Completion has been documented in NIF-116687, letter from Moses to Schneider, dated August 9, 2010 [80].

- FY2010 NIC EP Level 2 Milestone (no MRT number assigned) *Complete operational qualification of cryogenic system on NIF*

  Completion Criteria: "This milestone will be complete when the vessel ventilation, positioner, x-ray imaging, and vacuum subsystems have completed operational qualification and the Cryogenic Target System (CTS) has completed system-level cryogenic shot commissioning testing."

  > Completion has been documented in NIF-0116824, letter from Moses to Schneider, dated September 30, 2010 [81].

- The Controls and Information Systems (CIS) have provided the capability to specify, track and control in real time a cryogenic layered ignition target customized to a particular physics experiment. The target shot setup specifications and associated design drawings contain all the necessary information in electronic form to specify an ignition target and are recorded prior to the shot at shot setup time. In addition, the history of the target is archived both during fuel layer growth and at shot time to support automated analysis and data visualization. The layered ignition targets are held by the control system at 18-20 degrees K, as proscribed by the specific DT triple point for the particular target, to the precise temperature and position stability requirements consistent with the ignition design requirements. In addition, the cryogenic deuterium-tritium "ice" layer on the interior annulus of the target capsule is grown with an automated scripted control system to within the specifications defined for an ignition experiment. The control system is capable of growing a target fuel layer outside the target chamber where it is characterized before it is inserted to the center of the target chamber for final alignment and the shot. The control system was designed to operate in within the bounds of the NIF radiological environment by utilizing compatible design techniques such as shielding and interchangeable components on kinematic mounts for rapid removal before yield shots.

4.2.1 Primary Criteria

4.2.1.1 The system shall be capable of fielding ignition target designs at up to 1.8 MJ at 3ω, maintaining the NIF target positioner stability and accuracy requirements

Evidence:

- FY2012 NIC EP Level 2 Milestone MRT 4116: *Demonstrate operations of two cryogenic target positioners*

  Completion Criteria: "Demonstrate the operation of two cryogenic target positioners, one with and one without layering capabilities."

  Completion has been documented in NIF-0117849, letter from Moses to Quintenz dated December 12, 2011 [82].

- C.R. Gibson, D.P. Atkinson, J.A. Baltz, V.P. Brugman, F.E. Coffield, O.D. Edwards. B.J. Haid, S.F. Locke, T.N. Malsbury, S.J. Shiromizu, K.M. Skulina "Design of NIF Cryogenic Target System" Fusion Science and Technology 55 (2009) [77].

4.2.1.2 The system shall be able to form and maintain a uniform cryogenic deuterium-tritium layer on the inside of a capsule in a hohlraum target

Evidence:

- As noted at the beginning of this section, 37 layered implosions were conducted during NIC.
- FY2008 DOE Level 2 Milestone MRT 2923: *Demonstrate engineering prototype target layering*

  Completion Criteria: "This milestone will be complete when creation of a cryogenic layer that meets NIC ignition requirements in an engineering prototype of an ignition target on a cryogenic platform with cryogenic target instrumentation identical to those of the cryogenic target system hardware is demonstrated."

  Completion has been documented in NIF-0115063, letter from Moses to Ross, dated September 24, 2008 [84].

- FY2011 NIC EP Level 2 Milestone MRT 4075: *Demonstrate point design layering capability*

  Completion Criteria: "Demonstrate THD layering capability in the NIF layering-cryogenic target positioner."

  Completion has been documented in NIF-0117264, letter from Moses to Schneider dated March 8, 2011 [85].

4.2.2 Functional Requirements

4.2.2.1 The system shall be able to cool the target to 18 K and maintain temperature stability as specified in the point design

Evidence:

- As noted at the beginning of this section, 37 layered implosions were conducted during NIC.

- C.R. Gibson, D.P. Atkinson, J.A. Baltz, V.P. Brugman, F.E. Coffield, O.D. Edwards. B.J. Haid, S.F. Locke, T.N. Malsbury, S.J. Shiromizu, K.M. Skulina "Design of NIF Cryogenic Target System" Fusion Science and Technology 55 (2009) [77].

4.2.2.2 The system shall be able to perform one shot every 24 hours for non-yield shots; the shot rate shall be limited by neutron effects for shots with appreciable neutron yield

Evidence:
A target postioner called TARPOS, capable of fielding warm and non-layered cryogenic targets at target chamber center, was delivered as part of the NIF Project. During NIC, a second target positioner called CryoTARPOS, capable of fielding warm, non-layered cryogenic, and layered cryogenic targets was added to NIF.

- FY2012 NIC EP Level 2 Milestone MRT 4116: *Demonstrate operations of two cryogenic target positioners*

  Completion Criteria: "Demonstrate the operation of two cryogenic target positioners, one with and one without layering capabilities."

  Completion has been documented in NIF-0117849, letter from Moses to Quintenz dated December 12, 2011 [82].

There are many examples when NIF has executed a non-yield shot within a 24-hour period. For example, from February 1 through March 20, 2011, 34 non-ignition target shots for the High Energy Density Stewardship Science program were successfully executed in 27 shot days**.** Usually, the time limiting factor related to executing a shot is not the laser turn-around time, but rather the time to load a target and align the target and the associated diagnostic systems or the time to reconfigure the facility (e.g., from no yield to a potentially high yield experiment or change out diagnostics for different classes of experiments). Another example is shown in Table 4.

Table 4. Shot sequence data.

Shot ID	Campaign	Exp	Shot Time
N111215-001-999	IT_8_DT_CY11_C3	S03a	12/15/2011 14:36
N111218-001-999	AP_1_ConA	S01a	12/18/2011 19:09
N111219-001-999	AP_1_ConA	S02b	12/19/2011 19:40
N111220-001-999	AP_1_ConA	S03a	12/20/2011 10:32
N111220-002-999	AP_1_ConA	S04a	12/21/2011 3:12
N111221-001-999	IT_0_Symcap_sc575_	S03a	12/22/2011 4:56

In this example, a layered DT shot, a potentially high yield experiment, was conducted on CryoTARPOS. After a short delay in re-entry due to radiation and time for facility reconfiguration, four convergent ablator and one symcap experiment were conducted on five consecutive days using the TARPOS. There is nothing to preclude using CryoTARPOS and TARPOS interchangeably for fielding warm and non-layered targets. However during NIC, CryoTARPOS was reserved for cryogenic layered fuel implosions.

For shots with appreciable neutron yield, the shot rate is limited by neutron effects (see below).

- NIF is authorized for Phase 4 Ignition Operations with High Yield (see PC&FR 7.2.5 — FY2011 DOE Level 2 Milestone MRT 4069: *Complete Contractor Readiness Assessment* *for High Yield*)[116]. The decay radiation environment in the target bay (TB) has been evaluated, and it has been determined that re-entry into the TB would be possible within 5 – 7 days after a 20-MJ shot (see OSP 581.11 *NIF Laser System Installation, Commissioning and Operation,* Appendix L, *Radiological and Beryllium Hazards and Controls*). This indicates that at least 50 – 20 MJ shots could occur each year, while allowing sufficient decay of induced radioactivity so that worker doses could be maintained as low as reasonably achievable (ALARA).

4.2.2.3 The system shall be designed to operate within the NIF radiological environment
Evidence:

- C.R. Gibson, D.P. Atkinson, J.A. Baltz, V.P. Brugman, F.E. Coffield, O.D. Edwards. B.J. Haid, S.F. Locke, T.N. Malsbury, S.J. Shiromizu, K.M. Skulina "Design of NIF Cryogenic Target System" Fusion Science and Technology 55 (2009) [77].
- In addition to design considerations enabling the system to operate within the NIF radiological environment, other changes were made to the CTS in response to operational experience gained during NIC. For example, to further harden the CTS against the hostile radiation environment in and around the NIF target chamber, the power supplies for the cryogenic layer x-ray characterization system were relocated from adjacent to the target chamber to outside the walls of the Target Bay in FY2011.

4.2.2.4 All target parameters set and controlled by the system shall be recorded at shot set-up time
Evidence:

- Sample data file for a DT layered experiment [N120213] showing target parameters set and controlled by the system that are recorded at shot time and later archived [86c].

4.2.2.5 The fuel layer shall be characterized before the target is moved from outside of the target chamber to target chamber center
Evidence:

- E. Mapoles, "THD fuel layering in NIF Targets" (NIC Technical Review Committee presentation, February 25 2011) [86].
- S. Haan et al., "NIF Ignition Campaign Target Performance and Requirements: Status October 2011," (October 2011) [86a].
- T. Parham "Cryogenic Layering in NIF" (NIC Technical Review Committee presentation, June 1, 2012) [86b].
- Sample data from the Summary Tab of an Excel workbook that is the Cryolayer Report for the DT layered experiment [N120214]. All of the characterization data for a layer is captured in this report, one for each layer, prior to positioning the target at target chamber center for an experiment [86d].
- As of the end of NIC, 37 cryogenic layered THD (9) and DT (28) shots were executed on NIF. For the DT shots, the highest measured yields in excess of ~ 9×10^{14} neutrons and the total accumulated neutron yield over all DT shots was ~8×10^{15}.

I.5 TARGET DIAGNOSTICS AND EXPERIMENTAL SYSTEMS

5. Program Completion Criteria

Requirement: ***Provide a core set of optical, x-ray, neutron, and radiographic diagnostics sufficient to support initial ignition, HED, and other user applications during routine facility operations***

Evidence:

A list of these diagnostics implemented during the NIC is given in the Tables 5-7.

Table 5. Diagnostics of laser absorption and hohlraum conditions.

Acronym	Diagnostic	Contributors	Observable
Dante1 Dante2	Broad-band, time-resolved x-ray spectrometer	LLNL	Hohlraum x-ray conditions
EHXI	Equatorial Hard X-ray Imager	LLNL	Beam pointing in the hohlraum
EMP	Electromagnetic Power	LLNL	Microwave generation
FABS31 FABS36	Full Aperture Backscatter Station	LLNL	Backscattered light into lenses
FFLEX FFLEX TR	Filter Fluorescer Diagnostic	LLNL/AWE	Hot electron fraction and temperature
NBI31 NBI36	Near Backscatter Imager	LLNL	Backscattered light near lenses
SXI-L SXI-U	Static x-ray imager	LLNL	Laser entrance hole size and beam pointing

Table 6. Diagnostics of the implosion phase.

Acronym	Diagnostic	Contributors	Observable
DISC, 3 of	DIM Insertable Streak Camera	LLNL/SNL	Implosion velocity and ablator thickness
GXD, 2 of	Time-Gated X-ray Detector	LLNL/LANL	Drive symmetry for low-yield shots
hGXI, 2 of	Hardened X-ray Imager	LLNL/LLE	Drive symmetry for yield $<10^{15}$ neutrons
nTOF 4.5 BT	Neutron Time-of-Flight	LLE/LLNL	Neutron bang time
pTOF	Particle Time-of-Flight Proton Detector	MIT/LLNL	Time of proton emission from the (D-^{3}He) reaction
SOP	VISAR in combination with a Streaked Optical Pyrometer	LLNL	Shock break out
SPBT	South Pole Bang Time	LLE/LLNL	Time of x-ray emission from the imploded capsule
SPIDER	Streaked Polar Instrumentation for Diagnosing Energetic Radiation	SNL/LLNL	X-ray burn history from implosion
VISAR	Velocity Interferometer System for Any Reflector	LLNL/LLE	Shock velocity vs. time

Table 7. Fuel assembly, stagnation and ignition diagnostics.

Acronym	Diagnostic	Contributors	Observable
Diagnostics of the Hot Spot			
NAD—Zr in well	Neutron Activation Detector (Well-mounted)	LLNL	Unscattered neutron yield from a DT-filled capsule
NAD—Cu	Neutron Activation Detector	SNL/LLNL	Unscattered neutron yield from a DT-filled capsule
NAD—DIM indium (In)	Neutron Activation Detector (DIM mounted)	LLNL	Unscattered neutron yield from a DD-filled capsule
ARIANE	Active Readout in a Neutron Environment (Gated x-ray imager)	LLNL	X-ray hot spot size and shape for yields $<10^{16}$ neutrons
DIXI	Dilation Imager for X-rays at Ignition	GA/LLNL	X-ray hot spot size and shape with an x-ray shutter time ~10 ps
NIS	Neutron Imager	LANL/LLNL	Hot spot size and fuel asymmetry
GRH	Time and spectrally-resolved Gamma Reaction History	LANL/LLNL	Gamma spectrum and time history
nTOF20 IgnHi	Neutron Time-of-Flight	LLE/LANL/LLNL	Ion temperature
nITOF	Neutron Imager Time-of-Flight	LLE/LANL/LLNL	Ion temperature
Diagnostics of Areal Density			
CR	Compton Radiography	LLNL	Areal density
MRS	Magnetic Recoil Spectrometer	MIT/LLE/LLNL	Areal density
nTOF20 SPEC-A nTOF20 SPEC-E	Neutron Time-of-Flight-Spectrum	LLNL/LLE	Areal density
NAD—Flange	Neutron Activation Detector (Flange Mounted)	LLNL	Areal density anisotropy
RAGS	Rapid Analysis of Gaseous Samples	LLNL	Areal density
SRC	Solid Radiochemical Collection Diagnostic	LLNL/LANL	Areal density
WRF	Wedge Range Filter	MIT/LLNL	Plastic areal density for deuterium and helium-3
Diagnostics of Mix			
Ross Filter Pair	Ross Filter Pair	LLNL	Mix
Super-snout II (multi-wavelength)	Multi-wavelength X-ray Spectrometer	LLE/LLNL	Mix

5.1 Primary Criteria

5.1.1 Target Diagnostics and Experimental Systems shall provide the diagnostic and experimental systems necessary to execute the NIC experimental plan

Evidence:

- FY2006 DOE Level 2 Milestone MRT 1824: *Place ignition diagnostics requirements under configuration management*

Completion Criteria: “This milestone will be considered complete when requirements for the ignition implosion diagnostic capabilities are defined, documented, approved and placed under configuration management.”

> Completion has been documented in NIF-0113377, letter from Moses to Hauer, dated June 27, 2006 [88].

- FY2009 DOE Level 2 Milestone MRT 2998: *Complete full target illumination characterization diagnostics*

  Completion Criteria: “This milestone will be completed when diagnostics are available that will validate the target illumination symmetry (beam pointing, beam power and energy, focal spot shape) for all 192 beams. Specifically incident 3ω laser energy shall be measurable on 192 beams, incident laser power shall be measurable on at least 48 quads (one beam per quad), laser beam pointing and focal spot shape shall be measurable through x-ray imaging on both upper and lower hemisphere beams.”

  > Completion has been documented in NIF-0115752, letter from Moses to Deeney, dated August 7, 2009 [60].

- FY2010 DOE Level 2 Milestone MRT 3422: *Complete diagnostics for FY10 target performance experiments diagnostics*

  Completion Criteria: “This milestone will be complete when diagnostics are commissioned that meet the needs of the first pre-ignition experiments including laser backscatter measurable on at least one quad, hohlraum temperature measurable by viewing through the laser entrance hole, time resolved x-ray imaging available on at least two lines of sight, and a VISAR interferometer available for shock timing.”

  > Completion has been documented in NIF-0115836, letter from Moses to Schneider, dated July 6, 2010 [89].

- FY2011 DOE Level 2 Milestone MRT 4077: *Install ARC beampath infrastructure*

  Completion Criteria: “This milestone will be complete when the following ARC vessels are installed in the target area: calorimeter spool, parabola vessel, compressor vessel #1, compressor vessel #2.”

  > Completion has been documented in NIF-0117352, letter from Moses to Schneider dated March 24, 2012 [90] [90a]

- FY2012 DOE Level 2 Milestone MRT 4118: *Operationally Qualify first ARC beam line per BCP 12-003*

  Completion Criteria 1: “Advanced Radiographic Capability (ARC) Full Aperture Compressor Test (AFACT), the off-line testbed for ARC, will be commissioned and available to develop and verify the alignment procedures for the ARC compressor gratings.” Completion has been documented in NIF-0118048, letter from Moses to Quintenz, dated March 22, 2012 [91].

  Completion Criteria 2: Prepare a document detailing the status of ARC at the end of FY2012 and the remaining scope of work and budget required to provide the first ARC beam line.

  > Completion has been documented in NIF-0135588, letter from Moses to Quintenz, dated September 26, 2012 [91a].

5.1.2 Capabilities needed to support the design and development of advanced diagnostics for HED and other user applications shall be provided

Evidence:

- FY2011 DOE Level 2 Milestone MRT 4078: *Develop long-term NIF diagnostics strategic plan*

  Completion Criteria: "Using continuing diagnostic workshops develop long-term NIF diagnostic strategy for evolving HED science missions including plasma diagnostics, nuclear diagnostics, and material property diagnostics appropriate for NIF experimental conditions."

  Completion has been documented in NIF-0117551, letter from Moses to Schneider, dated June 30, 2011 [92].

- FY2012 DOE Level 2 Milestone MRT 4119: *Issue long-term NIF diagnostics plan*
  Completion Criteria: "Using results of continuing diagnostic workshops, issue long-term NIF target diagnostic plan for evolving HED science missions such as optical, x-ray, plasma diagnostics, nuclear diagnostics, materials property diagnostics appropriate for NIF experimental conditions."

  Completion has been documented in NIF-0118246, letter from Moses to Quintenz, dated June 25, 2012 [93] [93a].

- DIM-based Diagnostic Design Guidance for the NIF, NIF5041482, issued June 29, 2012 [94].

5.2 Functional Requirements

5.2.1 Diagnostics for experiments on energetics, symmetry, ablator characterization, radiography, and shock timing and for the characterization of ignition implosions shall be available
Evidence:

- FY2010 DOE Level 2 Milestone MRT 3424: *Complete ignition implosion diagnostics*

  Completion Criteria: "This milestone will be completed when diagnostics are available that meet the requirements of the first ignition implosion tests including measurement of DT yield, core x-ray imaging, implosion stagnation time, and ion temperature."

  Completion has been documented in NIF-0116835, letter from Moses to Schneider, dated September 29, 2010 [95].

- FY2011 DOE Level 2 Milestone MRT 4076 and Multi-Site Target 3.1.2: *Complete operational qualification of the first set of NIC ignition diagnostics*

  Completion Criteria: "This milestone will be completed when the first set of ignition diagnostics are operationally qualified to perform measurements of neutron yield, neutron spectrum, neutron image, and capsule bang time."

  Completion has been documented in NIF-0117156, letter from Moses to Schneider, dated March 1, 2011 [96].

- FY2012 DOE Level 2 Milestone MRT 4117: *Performance Qualify Phase 2 ignition diagnostics*

Completion Criteria: "The following diagnostics will be performance qualified on NIF: Neutron Imager (NI), Active Readout in a Neutron Environment-Light (ARIANE-L,) South Pole Bang Time (SPBT)."

Completion has been documented in NIF-0117850, letter from Moses to Quintenz, dated 12/12/2011 [97].

5.2.2 The support systems necessary to utilize the diagnostics including controls, timing, procedures, staff training, alignment capability, diagnostic manipulators, data acquisition, and analysis tools shall be available, as required, for each experimental campaign

Evidence:

- The Controls and Information Systems (CIS) have provided the capability to specify, track and control in real time a core set of target diagnostics customizable to a suite of physics experiments to support the NIC experimental plan. The target diagnostic shot setup specifications and associated design drawings contain all the necessary information in electronic form to specify an ignition target and are recorded prior to the shot at shot setup time. In addition to core diagnostic controls, support systems have been fielded to utilize the diagnostics including precision timing triggers, alignment capability with position manipulators, data archive and analysis tools, as required for planned experimental campaigns.
- Shot analysis and data visualization tools for target diagnostics have been developed to review data after a laser shot. These include automatic transfer of data to long-term data archive, automated analysis of key target diagnostic systems, tools for downloading data from desktop analysis environments and tools for viewing data and downloading data from the data archive.

5.2.3 Core facility diagnostics required for routine facility operations that can support the SSP and other experimental programs shall be developed and fielded by the end of FY2012

Evidence:

- A core set of facility diagnostics needed to support SSP and other experimental programs as part of routine facility operations was installed and commissioned on NIF during the NIC. See Tables 5-7 at the beginning of I.5 Target Diagnostics and Experimental System.
- The Controls and Information Systems area supports a core set of optical, x-ray, neutron, and radiographic diagnostics sufficient to conduct initial ignition, HED, and other user applications during routine facility operations.
    - R. T. Shelton, J. H. Kamperschroer, L. J. Lagin, J. R. Nelson, and D. W. O'Brien "Target diagnostic control system implementation for the National Ignition Facility," Rev. Sci. Instrum. 81, 10E101 (2010) [97a].

I.6 USER OPTICS

6. Program Completion Criteria

Requirement: ***Provide continuous phase plates (CCPs) that are required for the ignition experiments and the manufacturing capability to develop and fabricate additional CCPs***

Evidence:

- FY2009 DOE Level 2 Milestone MRT 3000: *Complete User Optics for FY10 Ignition Campaign*

  Completion Criteria: "This milestone will be complete when 192 beams worth of user optics (192 DDSs, 48 inclusion-free TCVWs, 96 polarization rotators, 96 scale 1.0 CPPs and 96 scale 1.07 CPPs) are available."

  Completion has been documented in NIF-0115754, letter from Moses to Deeney, dated August 13, 2009 [98].

6.1 Primary Criteria

6.1.1 An initial set of continuous phase plates (CPPs), disposable debris shields (DDSs), polarization rotation crystals, and sufficient operating inventory to support the FY2010-12 ignition experimental campaign as specified in the ignition point design requirements shall be provided

Evidence:

- FY2007 DOE Level 2 Milestone MRT 2323: *Begin continuous phase plate (CPP) imprinting*

  Completion Criteria: "This milestone will be considered complete when a contract to begin imprinting CPP's for the 2010 Ignition Campaign is awarded."

  Completion has been documented in NIF-0114035, letter from Moses to Hauer, dated April 19, 2007 [99].

- FY2009 DOE Level 2 Milestone MRT 2999: *Complete first set of CPPs*

  Completion Criteria: "This milestone will be complete when 96 scale 1.0 and 96 scale 1.07 CPPs are available for installation."

  Completion has been documented in NIF-0115753, letter from Moses to Deeney, dated August 12, 2009 [99a].

- FY2010 DOE Level 2 Milestone MRT 3426: *Complete second set of CPPs*

  Completion Criteria: "This milestone will be complete when 96 scale 1.175 CPPs are available for installation."

  Completion has been documented in NIF-0116612, letter from Moses to Deeney, dated July 6, 2010 [100].

6.1.2 Capabilities needed to support the design and development of new optics for HED and other user applications shall be provided

Evidence:

- The primary user-defined optics on NIF are continuous phase plates (CCPs). Several of the experimental campaigns planned for NIF call for specific target plane laser beam characteristics incorporating well-defined beam pulse shapes, energy distributions, and wavefront profiles that can be produced using CPPs. Capabilities have been developed within the Systems Engineering group to design CCPs to meet user specifications applicable to NIF.

- S.N. Dixit, M.D. Feit, M.D. Perry, and H.T. Powell, "Designing fully continuous phase screens for tailoring focal-plane irradiance profiles," Optics Letters, vol. 21, 1 Nov. 1996, pp. 1715- 1717 [101].

CPP optics use a free-form diffractive grating prescription that must imprinted into the surface of a transmissive fused silica optic with one CCP is required for each NIF beam line to achieve the desired result. The NIF Optics Manufacturing and Technology group has now developed techniques to transform the CCP designs into a process that utilizes magneto-rheological finishing (MRF) technology to manufacture CCPs to the desired physical size and specifications needed for NIF.

- Joseph A. Menapace, Sham N. Dixit, Francois Y. Genin, and Wayne F. Brocious, "Magnetorheological Finishing for Imprinting Continuous Phase Plate Structure onto Optical Surfaces," Boulder Damage Symposium XXXV, Boulder, Colorado, September 21 -24, 2003 (Updated January 5, 2004.) [102].
- J.A. Menapace, "Developing Magnetorheological Finishing (MRF) Technology for the Manufacture of Large-Aperture Optics in Megajoule Class Laser Systems," *Laser Induced Damage in Optical Materials: SPIE Proc*. 7842, 1W-1-14 (2010) [102a].

6.2 Functional Requirements

6.2.1 Sufficient DDS cassettes shall be provided to support the initial ignition experimental campaigns in FY2010-FY2012, and manufacturing capability for long-term operations shall be developed

Evidence:

- FY2008 DOE Level 2 Milestone MRT 2918: *Complete first set of DDS glass*

  Completion Criteria: "This milestone will be complete when the initial set (200) of DDSs are fabricated, inspected, accepted, and placed into inventory."

  Completion has been documented in NIF-0114035, letter from Moses to Donovan, dated December 17, 2007 [103].

- FY2011 DOE Level 2 Milestone MRT 4079: *Demonstrate a fabrication rate of 500 Disposable Debris Shields per month*

  Completion Criteria: "This milestone will be complete when the DDS manufacturer can demonstrate a fabrication rate of 500 DDSs per month."

  Completion has been documented in NIF-0117177, letter from Moses to Schneider dated February 3, 2011 [104].

6.2.2 Optics manufacturing and refurbishment capabilities should be facilitated to support ignition experimental campaigns after FY2010- FY2012, and manufacturing capability for long-term operations should be developed

Evidence:

- FY2006 DOE Level 2 Milestone MRT 1825: *Begin polarization smoothing (PS) crystal growth*

  Completion Criteria: “This milestone will be considered complete when crystal growth production for the purpose of polarization smoothing begins.”

  Completion has been documented in NIF-0113182, letter from Moses to Hauer, dated March 28, 2006 [105].

- FY2012 DOE Level 2 Milestone MRT 4121: *Performance Qualify optics mitigation facilities*

  Completion Criteria: “B391 Optics Mitigation Factory is facilitized with 3 fused silica stations and 2 crystal stations, qualified and in production, with procedures in place, and teams trained to support ignition and non-ignition HED experimental campaigns on NIF.”

  Completion has been documented in NIF-0118247, letter from Moses to Quintenz, dated June 25, 2012 [107].

- The Controls and Information Systems have designed and deployed the support necessary for the optics manufacturing and refurbishment capabilities to support ignition experimental campaigns. This includes optics manufacturing and refurbishment metrology and damage initiation site measurement, archiving, and analysis. In addition the control and information systems to support manufacturing capability for long-term operations have been deployed.

6.2.3 Sufficient optics manufacturing and processing capabilities needed for routine facility operations to support SSP and other experimental programs by the end of FY2012 shall be developed

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4120: *Fabricate and install Advanced Mitigation Process (AMP) Grating Debris Shield (GDS) optics on NIF*

  Completion Criteria: “Fabricate and install Advanced Mitigation Process (AMP) Grating Debris Shield (GDS) optics on NIF.”

  Completion has been documented in NIF-0118049, letter from Moses to Quintenz, dated March 21, 2012 [106].

- FY2012 DOE Level 2 Milestone MRT 4121: *Performance Qualify optics mitigation facilities*

  Completion Criteria: “B391 Optics Mitigation Factory is facilitized with 3 fused silica stations and 2 crystal stations, qualified and in production, with procedures in place, and teams trained to support ignition and non-ignition HED experimental campaigns on NIF.”

  Completion has been documented in NIF- 0118247, letter from Moses to Quintenz, dated June 25, 2012 [107].

- Control and Information Systems have been developed and deployed to support optics manufacturing and processing capabilities that are needed for routine facility operations to enable SSP and other experimental program shots.

I.7 PERSONNEL AND ENVIRONMENTAL PROTECTION SYSTEMS

7. Program Completion Criteria

Requirement: ***Provide the personnel and environmental protection systems necessary for routine operations including yield (Tritium Processing System, shield doors, Hazardous Material Management Area, and radiation monitoring system)***

Evidence:

- FY2007 DOE Level 2 Milestone MRT 2324: *Complete Personnel and Environmental Protection Systems (PEPS) Title I design*

  Completion Criteria: "This milestone will be considered complete when the Title I Design for the PEPS, including the general decontamination work station, the waste handling system, monitoring systems, and the shield doors is completed and documented."

  Completion has been documented in NIF-0114367, letter from Moses to Donovan, dated October 10, 2007 [108].

- FY2009 DOE Level 2 Milestone MRT 2919: *Complete Personnel and Environmental Protection Systems (PEPS) Title II design*

  Completion Criteria: "This milestone will be considered complete when the Title II Design for the PEPS, including the initial tritium processing system, the general decontamination work station, the waste handling system, monitoring systems, and the shield doors is completed and documented."

  Completion has been documented in NIF-0115830, letter from Moses to Deeney, dated September 29, 2009 [109].

- FY2010 DOE Level 2 Milestone MRT 3001: *Complete installation qualification (IQ) of PEPS for tritium operations*

  Completion Criteria: "This milestone will be considered complete when the systems required for operations with up to 500 Ci of tritium (maximum facility inventory), including the stack tritium monitor, area tritium monitors, tritium processing system, and decontamination enclosures, are installation qualified (IQ)."

  Completion has been documented in NIF-0116690, letter from Moses to Schneider, dated August 23, 2010 [110].

- The Controls and Information Systems have designed and deployed the personnel and environmental protection systems necessary for routine operations including yield. These systems include tritium processing systems, shield door control and interlocks, Hazardous Material Management Area access controls and alarms, as well as radiological tracking systems, and radiation monitoring systems as specified by DOE and laboratory safety requirements.

7.1 Primary Criteria

7.1.1 Equipment and practices shall be in place to ensure that NIF is in compliance with the *NIF Complex Tier 2 Safety Basis Document*[4] and the *Final Site-Wide Environmental Impact Statement (SW/SPEIS)*[3]

Evidence:

- FY2011 DOE Level 2 Milestone MRT 4069: *Complete Contractor Readiness Assessment for High Yield*

- Completion Criteria: "Complete Contractor Readiness Assessment (RA) for Phase 4 operations as defined in the Safety Evaluation Report for the Safety Basis Document."

  Completion documented in NIF-0117295, letter from Moses to Schneider dated March 8, 2011 [111]. The review team agreed with the one LLNL self-identified pre-start finding and NNSA concurrence on the RA report was received from Scott Samuelson. The one-pre-start finding "Complete training for Ignition Operations" was closed. Approval was given to enter Phase 4 of the Safety Basis Document and authorize ignition operations in B581. See PC&FR 7.2.5 ─ FY2011 DOE Level 2 Milestone MRT 4069: *Complete Contractor Readiness Assessment for High Yield* for more detail.

7.2 Functional Requirements

7.2.1 Equipment and practices shall be in place to use beryllium and depleted uranium

Evidence:

- FY2010 DOE Level 2 Milestone MRT 2992: *Complete hazardous materials management prestart review (MPR)*

  Completion Criteria: "This milestone will be complete when the Management Prestart Review (MPR) of the readiness for operations involving targets containing beryllium and/or depleted uranium is completed."

  Completion has been documented in NIF-0116727, letter from Moses to Schneider dated August 20, 2010 [112].

7.2.2 Equipment and practices shall be in place to limit the annual release of tritium to be consistent with the *SW/SPEIS*[3] while meeting the requirements of the ignition experimental campaign plan

Evidence:

- FY2010 DOE Level 2 Milestone MRT 3001: *Complete installation qualification of Personnel and Environmental Protection Systems (PEPS) for tritium operations MPR*

  Completion Criteria: "This milestone is complete when the systems required for operations with up to 500 Ci of tritium (maximum facility inventory), including the stack tritium monitor, area tritium monitors, tritium processing system, and decontamination enclosures, are installation qualified."

  Completion has been documented in NIF-0116690, letter from Moses to Schneider dated August 23, 2010 [110].

7.2.3 Equipment and practices shall be in place to monitor radiation in sub-ignition experiments at the beginning of neutron-producing experiments

Evidence:

- FY2010 DOE Level 2 Milestone MRT 2991: *Complete tritium/neutron production MPR*

  Completion Criteria: "This milestone will be complete when the Management Prestart Review (MPR) of the readiness to begin operations using up to 500 Ci of tritium (maximum facility inventory) and producing up to 30 kJ of thermonuclear yield (low yield) per shot is completed."

Completion has been documented in NIF-0116683, letter from Moses to Schneider dated August 20, 2010 [114].

7.2.4 Equipment and practices shall be in place to allow one 20-MJ yield shot in FY2012

Evidence:

- FY2010 DOE Level 2 Milestone MRT 3436: *Complete installation qualification of Personnel and Environmental Protection Systems (PEPS) for first ignition experiments*

  Completion Criteria: "This milestone will be considered complete when systems required for experiments that produce up to 20 MJ of thermonuclear yield per shot, including shield doors and area neutron and gamma monitors, are installation qualified (IQ)."

  Completion has been documented in NIF-0116773, letter from Moses to Schneider dated September 30, 2010 [115].

7.2.5 Equipment and practices should be in place for routine yield experiments by the end of FY2012 as specified in the *NIF Complex Tier 2 Safety Basis Document*[4] and the *Site-Wide Environmental Impact Statement (SW/SPEIS)*[3]

Evidence:

- FY2011 DOE Level 2 Milestone MRT 4069: *Complete Contractor Readiness Assessment for High Yield*

  Completion Criteria: "Complete Contractor Readiness Assessment (RA) for Phase 4 operations as defined in the Safety Evaluation Report for the Safety Basis Document."

  Completion documented in NIF-0117295, letter from Moses to Schneider dated March 8, 2011 [116]. The review team agreed with the one LLNL self-identified pre-start finding and NNSA concurrence on the RA report was received from Scott Samuelson [117]. The one-pre-start finding "Complete training for Ignition Operations" has been closed. Approval has been given to enter Phase 4 of the Safety Basis Document and authorize ignition operations in B581.

- FY2012 DOE Level 2 Milestone MRT 4487: *Update ALARA plan and report on continuing ALARA status and plans for continuing operations*

  Completion Criteria: "Prepare the FY2012 ALARA plan describing the estimated dose rate to NIF facility workers including dose reduction measures and controls to ensure achieving the lowest reasonable exposure."

  Completion has been documented in NIF-0118045, letter from Moses to Quintenz, dated March 13, 2012 [118].

I.8 OPERATIONAL CAPABILITIES

8. Program Completion Criteria

Requirement 1 of 2: ***Provide the capability to demonstrate the NIF Functional Requirements & Primary Criteria (FR&PC)***

Evidence:

Completion evidence of the NIF PC&FRs is provided as a separate document, National Igntion Facility Functional Requirements and Primary Criteria – Evidence of Completion, LLNL-AR-592152, NIF-0135506.

Requirement 2 of 2: ***Provide an initial ignition platform and operational capabilities to support post-NIC SSP experiments, including ignition application experiments***

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4113: *Conduct DT implosion experimental campaign to produce Gain=1*

  Completion Criteria: "Demonstrate cryogenic layered DT experiments producing a neutron yield consistent with a Gain = 1. The definition of ignition, Gain = 1, is that used in the 1997 National Academy of Sciences review of the ICF Program, i.e., fusion energy output is greater than or equal to laser energy delivered to the target"

  This milestone was not completed.

- The Controls and Information Systems have provided the support necessary to demonstrate the NIF Functional Requirements and Primary Criteria (FR&PC). These include laser setup, automated laser alignment, pulsed power control for the injection laser, main laser and PEPC switches, precision timing, and laser and target diagnostic capabilities. In addition all of the data was electronically archived with data analysis, visualization and extraction capabilities provided. This has provided an initial ignition platform and operational capability capable of supporting post-NIC SSP experiments, including ignition application experiments.

8.1 Primary Criteria

8.1.1 Equipment, procedures, and operational capabilities shall be in place to conduct ignition experimental campaigns beginning in FY2010 and routine facility operations by the end of FY2012

Evidence:

The National Ignition Facility ***Transition to Operations Plan*** [129] prepared by the NIF Project Division (NA-123.2) Staff in June 2008 described the process by which the National Ignition Facility (NIF) transitioned from a construction project (Total Project Cost+ NIF Demonstration Program/Assembly and Installation Program) to a fully operational facility. This plan covered the transition of the facility from completion of the construction project (CD-4) described in the NIF Project Execution Plan (UCRL-AR-212539) through the transition to operations as described in the NIC Execution Plan (UCRL-AR-213718, rev2). Highlight and important documents from that plan are cited below:

- The ***National Ignition Facility Operations Management Plan*** (NIF-5020544) [119] provides a roadmap of how the NIF Operations organization functions. It also provides a listing of roles and responsibilities, core processes, procedures, authority matrices, change control boards, and other information necessary for successfully functioning in the NIF Operations organization and is further discussed below. The *NIF Operations Management Plan,* the *NIF Shot Operations Manual,* and the *NIF Maintenance Plan* together represent the primary documents satisfying NIP's Conduct of Operations compliance requirement.
- The ***NIF Shot Operations Manual*** (NIF-5018506) [120] implements Conduct of Operations requirements and identifies the policies and general procedures necessary to perform and support shot operations in the NIF Facility. Shot Operations are defined as those activities directly related to or supporting the operation of the NIF Main Laser System, Precision Diagnostic System (PDS), Target Chamber (TC), and associated systems located on the NIF Site. Operations include delivery of low-power laser light through to the firing of the main laser amplifiers, operation of the beampath and associated utilities, target positioners and diagnostics, and the various computer control systems. Duties, responsibilities, and reporting requirements of the various positions associated with shot operations are detailed in the NIF Shot Operations Manual.

  General policies governing administrative and operational practices related to shot operations are also included. This includes general responses for major facility off- normal conditions such as fire, earthquake, oxygen deficiency, and crash button actuation. Operational Safety Procedures (OSPs) and operating procedures may include additional detailed steps, as required. Guidelines for control room activities are included in the *NIF Shot Operations Manual* as well. Additional information concerning protocols for working in the control room is covered in the Control Room Protocol web-based training class (NP0131). Processes for managing and using system operating procedures, OSPs, shot setup sheets, and shot checklists are also contained in the Manual. The detailed procedures should be used for the operation of the facility and equipment, where appropriate.

  The ***NIF Maintenance Plan*** (NIF-5018526) [121] implements Conduct of Operations requirements for maintenance activities and identifies the policies and procedures necessary to perform and support the maintenance of the NIF Complex's support systems infrastructure and is applicable to Buildings 581, 681, 582, 682, 683,684, and the associated utility pads. The support systems are designated as either Conventional Facility (CF) or Beampath Utility Systems (BUS). These systems support the operation of the beampath, Line Replaceable Units (LRUs), and diagnostics and create environments within the beampath consisting of vacuum, argon, or clean dry air. Policies governing administrative and operational practices related to maintenance are described in the *NIF Maintenance Plan*. Also, processes and procedures for managing, tracking, and documenting the work are referenced in the *NIF Maintenance Plan*.

  System level maintenance plans describe the system's equipment and assets, boundaries, interfaces to other systems, and the maintenance approach including failure modes and general responses for major system off-normal conditions. These plans are regularly updated as they describe the technical basis for maintenance work on the systems. The system level plans also contain the detailed technical procedures and checklists for maintenance used when performing work, which are then incorporated into NIF's computerized maintenance management system commonly known as the System Maintenance and Reliability Tracking (SMaRT) system.

  Preventative Maintenance (PM) procedures are written based on industry standard maintenance tasks. The SMaRT system has embedded in it an auto-generated workflow process that generates PM Work Orders that can be automatically triggered by meter readings or start dates. Work Orders are prioritized as being either low, routine, medium, high, or urgent, and the priority system have been in effect since April 2007. In addition, the SMaRT tracks & trends maintenance activities, provides documentation archiving and retrieval, and maintains equipment histories.

- The ***Facility Safety Plan for Buildings 581, 582, 682, 683, and 684*** (NIF-0113578) [122] describes training required for site access. Additional training is required for special access areas (e.g., Control Room, Capacitor Bay, VISAR), as listed in Section 3.3.1.1 of the NIF Facility Safety Plan (FSP), and to be qualified as a site worker. Record of training completion shall be tracked by the Livermore Training Records and Information Network (LTRAIN) (alternate methods of tracking may be used for subcontractors).

  Service personnel or other personnel not normally assigned to work in B581 may receive an appropriate alternate briefing from the B581 Facility Point of Contact or designee to understand facility specific hazards and controls related to their specific activity. Fire Department responders receive facility specific training on the Capacitor Bay hazards.

  Qualification to perform certain roles at the NIF site is through Qualification Cards and is described in the ***NIF Training Plan*** (NIF-5018705) [123]. In addition to assignment-specific training, further training is required for work in the NIF and in certain areas within the NIF. Access control systems with administrative procedures are utilized to ensure workers have completed their required training prior to entering these areas. The NIF Operations Manager establishes these training requirements when workers need to be familiar with special technical or ES&H-related conditions. These training requirements are identified in the FSP.

- The ***NIF & Photon Science Directorate Safety Manual*** [124] covers the Core Safety management processes that are the essential management activities that shall be used to control work safety and reliability. These processes include: setting expectations and monitoring work, work planning, work authorization, and providing feedback (incident investigation, lessons learned, etc.)

  The NIF&PS Safety Manual sections also cover specific activities and hazards associated with working on the NIF Project Site and augments the LLNL ES&H Manual to provide compliance with the most stringent of DOE, LLNL, Federal Occupational Safety and Health Administration (OSHA), California (Cal)/OSHA, and federal and state environmental requirements. These sections of the NIF&PS Safety Manual apply to the NIF Project Site as described in the NIF Project Site Safety Program (or to NIF Programs facilities if specifically stated.) Individual areas may augment these sections and its processes with additional procedures or requirements to meet the current hazards and activities of the area.

8.2 Functional Requirements

8.2.1 The NIF shall be configured to operate at performance levels required for the initial ignition experimental campaign in FY2010, follow-on ignition experimental campaign in FY2011 and FY2012, and routine facility operations by the end of FY2012

Evidence:

- FY2011 DOE Level 2 Milestone MRT 4080: *Update sweep procedures to support operation of secondary shield doors for high yield experiments*

Completion Criteria: “Update sweep procedures to support secondary shield door operation for high yield experiments.”

Completion has been documented in NIF-0117171, letter from Moses to Schneider, dated February 9, 2011 [125].

8.2.2 Sufficient inventories shall be in place to perform laser shots at a rate consistent with the ignition experimental plan

AND

8.2.3 The facility shall be operated at a rate consistent with the ignition experimental plan

Evidence:

- FY2010 DOE Level 2 Milestone MRT 3002: *Provide 300 shot/year rate capability*

  Completion Criteria: “This milestone will be considered complete when NIF provides a shot rate capability equivalent to 300 shot attempts per year.”

  Completion has been documented in NIF-0115833, letter from Moses to Deeney, dated May 3, 2010 [126].

8.2.4 Sufficient staffing, procedures, and tools shall be developed to support routine facility operations by the end of FY2012 consistent with the NIF shot rate and availability requirements.

Evidence:

- FY2012 DOE Level 2 Milestone MRT 4487: *Update ALARA plan and report on continuing ALARA status and plans for continuing operations*

  Completion Criteria: “Prepare the FY2012 ALARA plan describing the estimated dose rate to NIF facility workers including dose reduction measures and controls to ensure achieving the lowest reasonable exposure.”

  Completion has been documented in NIF-0118045, letter from Moses to Quintenz, dated March 13, 2012 [127].

- FY2012 DOE Level 2 Milestone MRT 4122: *Provide classified operations capability*

  Completion Criteria: “A Classified Control Room is operational in NIF and is supported by infrastructure that allows Classified Data Acquisition.”

  Completion has been documented in NIF-0117851, letter from Moses to Quintenz, dated December 12, 2011 [128].

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