National Synchrotron Light Source II

Global Requirements Document LT-PRJ-0006

November 20, 2009 Revision 5

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NATIONAL SYNCHROTRON LIGHT SOURCE II GLOBAL PROJECT REQUIREMENTS

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BRIEF SUMMARY

The purpose of this document, the National Synchrotron Light Source II Project (NSLS-II) Global Requirements Document, is to specify the high level requirements to be satisfied by the NSLS-II facility.

KEY WBS ELEMENTS INFLUENCED

1.3 Accelerator Systems
1.4 Experimental Facilities
1.5 Conventional Facilities
1.6 Pre-Operations

REVISION HISTORY

2009 November 20 Revision 5

Update title page to include document number
Update Revision history
Correct section 1.2 (delete reference to operations center)
Update section 2.1 reference dates
Expand section 4.2 to provide more description of accelerator systems
Update section 4.3.1.1 to conform to current project beamline names
Update section 4.4.1.2 to reflect currently planned construction buildout
General edits to correct grammar and typographical errors

2008 September 12 Revision 4

Update of Signature page
Update section 4.3.1.1 to include SRX beamline
Update section 4.4 to include control room at NSLS

2008 June 5 Revision 3

Update and correct references
Sec 3.3.1 change availability from 90 to 95%

2007 December 7 Revision 2

General edits to improve clarity of document
Clarification of performance baseline
Update of key performance parameters

2007 October 12 Revision 1 Initial Release

1 SCOPE

1.1 IDENTIFICATION

The NSLS-II Global Requirements Document specifies the performance requirements for the NSLS-II synchrotron radiation facility, under construction at Brookhaven National Laboratory.

1.2 PROJECT DESCRIPTION

The NSLS-II project is being carried out to design and build a world-class user facility for scientific research using synchrotron radiation. The project scope includes the design, construction, and installation of the accelerator, experimental facilities, and civil construction required to produce a new synchrotron light source. It will be highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. These capabilities, when combined with advanced optics, will enable the study of material properties and functions down to a spatial resolution of 1 nm and an energy resolution of 0.1 meV, and with the ultra-high sensitivity necessary to perform spectroscopy on a single atom. Specifically the project scope includes:

- Electron gun and a linear accelerator (linac), where electron bunches are generated and accelerated to 200 MeV
- Beam transport system to the booster
- Booster storage ring, where the electron bunches from the linac are accelerated to 3 GeV beam energy for injection into the main storage ring
- Beam transport system to the main storage ring
- Main storage ring, where an electron beam can be stored at an energy of 3 GeV traversing through insertion devices and bending magnets to produce synchrotron radiation
- Procurement of 21 m of damping wigglers to provide the capability for operation at a horizontal electron beam emittance of 1.0 nm-rad
- RF systems capable of supporting a stored current of 300 mA with 21 m of installed damping wigglers
- Suite of six beamlines including their insertion devices and front-ends along with the supporting instrumentation required for their commissioning
- Injector (linac and booster ring) building, ring building including experimental floor, auxiliary lab office buildings, and mechanical equipment rooms, comprising the conventional facilities and supporting utility infrastructure

Comment [edj1]: As per Ferdinand, changed back to 300 mA 11/25/2009.

Comment [w2]: 300mA can be obtained if the RF cavities would be optimized for this mode of operation. We plan to optimize RF cavities (specifically the choice of the coupling of the resonator to the transmitter) for the full built-out and the full load of radiation loss. This will further limit what can be achieved with the initial configuration.

The baseline design shall not preclude the future installation of an additional 35 m of damping wigglers (for a total installed complement of 56 m of damping wigglers) and RF systems sufficient to support 500 mA of stored beam current with 56 m of installed damping wigglers. This configuration of the machine will permit operation with a horizontal electron beam emittance of 0.6 nm-rad.

The project will be executed by Brookhaven National Laboratory as described in the NSLS-II Acquisition Strategy and Project Execution Plan documents.

1.3 DOCUMENT OVERVIEW

The NSLS-II Global Requirements Document specifies, for NSLS-II and its subsystems:

- **Performance requirements**: key design parameters for NSLS-II including the baseline capabilities which can be achieved within the project scope, and the subset of parameters that must be achieved for recognition of project completion and Approval of Start of Operations (CD-4).

- **Performance envelope**: parameters that provide guidance for the design of NSLS-II that are beyond its baseline scope capabilities, but that can be realistically anticipated to be required during the life of the facility. Typically these parameters are low cost impact to the project at construction, but would be extremely costly and disruptive to implement after project completion. An example would be the thermal capability of photon absorbers. Specifying them to be suitable for 500 mA capability is essentially a no cost consideration at design; retrofitting these absorbers later in the life of the facility would have major impact on facility operations.

- **Functional requirements**: other requirements to meet program objectives that must be satisfied by the NSLS-II complex within the baseline project scope. These requirements are in essence an expression of how the performance requirements work in concert to support the needs of the operating facility.

- **Functional envelope**: requirements arising from program objectives that are beyond the scope of the project, but are readily anticipated as needed during the life of the facility. The functional envelope represents one aspect of planning for the operation and development of NSLS-II.

The scope of this document is restricted to technical performance requirements imposed by the research mission envisioned for the facility. The NSLS-II Project must also satisfy requirements related to Integrated Safety Management, Project Management and Operations, as well as regulatory requirements. Section 2 (Reference Documents) lists some of the applicable documents.

Environment, Safety, and Health requirements which are specific to the NSLS-II project are described in the Final Hazards Analysis (FHA) for NSLS-II.

1.3.1 RELATION OF SYSTEM TO SUB-SYSTEM REQUIREMENTS

This document outlines the general requirements for the NSLS-II facility. Subsystem Requirements, Specifications and Interface definitions shall be consistent with the guidance provided by this document. Inconsistencies or non-compliances will be identified and corrected by NSLS-II management.

1.3.2 DOCUMENT UPDATES

The NSLS-II Global Requirements Document is a controlled document, which will be revised under change control. Revisions will be initiated as necessary to best communicate NSLS-II requirements to the NSLS-II project team.

2 REFERENCE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

CD-0 - Approval of Mission Need for NSLS-II (August 25, 2005)

CD-1 - Approval of Alternative Selection and Cost Range for NSLS-II (July 12, 2007)

CD-3 - Approval of Performance Baseline for NSLS-II (January 18, 2008)

DOE Policy 413.1 June 10, 2000: Program and Project Management Policy for the Planning, Programming, Budgeting, and Acquisition of Capital Assets.

DOE Order 413.3A Chg 1 November 17, 2008: Program and Project Management for the Acquisition of Capital Assets.

DOE Guide 413.3-1 September 23, 2008: Managing Design and Construction Using Systems Engineering.

DOE Guide 413.3-2 June 27, 2008: Quality Assurance Guide for Project management.

DOE Guide 413.3-3 September 15, 2007: Safeguards and Security for Program and Project Management.

DOE O 420.2B July 23, 2004 (Certified May 13, 2008): Safety of Accelerator Facilities

DOE Policy 450.4 October 15, 1996: Safety Management System Policy

DOE Manual 450.4-1 November 16, 2006: Integrated Safety Management System

2.2 BNL DOCUMENTS

Standards Based Management System (SBMS)

BSA/DOE Prime Contract (DE-AC02-98CH10886)

2.3 NSLS-II DOCUMENTS

NSLS- II Conceptual Design Report December 2006

NSLS-II Preliminary Design Report November 2007

2.4 OTHER DOCUMENTS

Reserved.

3 GLOBAL REQUIREMENTS

Changes to Global Requirements will be managed in accordance with the NSLS-II Configuration Management Plan.

3.1 PERFORMANCE REQUIREMENTS

3.1.1 BASELINE PERFORMANCE REQUIREMENTS

The performance requirements for the baseline design are to operate with an electron beam energy of 3 GeV and a stored current of 300 mA while maintaining an average current stability of better than 1%. When 21 m of damping wigglers are installed, the facility will be able to operate with a horizontal electron beam emittance of 1.0 nm-rad. Installed RF systems will be capable of supporting stored current of 300 mA with 21 m of installed damping wigglers.

3.1.2 PERFORMANCE REQUIREMENTS FOR PROJECT COMPLETION AND CD-4

As stated in the Project Execution Plan, the project completion milestone (CD-4) for NSLS-II will be accomplished when the Threshold Key Performance Parameters have been achieved. The project must demonstrate that the capital facilities, including at least 340,000 square feet of conventional facilities, have been installed and certified to operate properly and safely so as to provide stored electron beam at an energy of 3.0 GeV with a stored current of 25 mA, providing x-ray beam for 6 beam-lines which are installed and ready for commissioning.

3.2 PERFORMANCE ENVELOPE

The baseline design shall not preclude the future installation of an additional 35 m of damping wigglers (for a total installed complement of 56 m of damping wigglers) and RF systems sufficient to support 500 mA stored current with 56 m of installed damping wigglers for operation with a horizontal electron beam emittance of 0.6 nm-rad. Up to 58 ports shall be available on the storage ring to provide synchrotron radiation for user beam-lines.

3.3 FUNCTIONAL REQUIREMENTS

3.3.1 NSLS-II OPERATIONAL EXPECTATIONS

NSLS-II will be scheduled to operate in such a manner as to provide for 5000 hours of user operations each year, with a minimum availability of 95%. The facility will be configured to allow for the installation or modification of beamlines without significant disruption of routine scheduled operations.

3.3.2 NSLS-II SAFETY EXPECTATIONS

The facility and equipment will be designed and operated in compliance with all applicable codes and standards as defined in 10 CFR Part 851. The radiation protection program will be conducted in compliance with the requirements of 10 CFR 835. Shielding will be designed to limit radiation exposure to personnel working within the NSLS-II facilities to less than 1000 mRem/year, assuming that personnel spend 2000 hours per year during normal operation at the immediate exterior of the shielded enclosure. Consistent with ALARA principles additional controls will be implemented to maintain all exposure as low as reasonably achievable; for example, no permanent work stations will be permitted within 1 meter of the outer storage ring wall to limit actual exposures to personnel.

3.4 FUNCTIONAL ENVELOPE

To the extent practical, the NSLS-II accelerator should be designed to provide the capability for stored current upgrades. This provides operating margin and enhanced reliability for the base configuration of the machine as well as performance upgrade potential. Consideration should also be given to configurations of the accelerator that would allow implementation of a few extra long straight sections.

Experimental facilities should be configured to allow rapid installation of beamlines including instruments recovered from the existing NSLS as well as new instruments funded outside of the NSLS-II Project. Configuration of the initial suite of instruments around the facility should be made with consideration for its impact on the NSLS-II user community. The configuration should foster the growth and intellectual strength of the community that utilizes the facility, as well as enhancing the impact of its scientific programs through the utilization of the unique capabilities of NSLS-II.

The conventional facilities should provide for upgrade opportunities that will facilitate the addition of future long beamlines that would extend beyond the boundary of the base conventional facility. Conventional facilities should be configured to provide for the future addition of laboratory/office space around the experimental floor. Conventional facilities should be situated to provide for the best utilization of the existing NSLS building as auxiliary staff and user space for NSLS-II, as well as enhancing the interaction of NSLS-II with the Center for Functional Nanomaterials and the future Joint Photon Sciences Institute.

The stability requirements of the cutting edge experimental portfolio of NSLS-II are in many cases quite stringent. Stability shall be a paramount consideration throughout the facility design to ensure that positional photon beam stability better than 10% of photon beam size can be achieved at experimental end stations. Aspects to be considered across the project include (but are not limited to) vibration in the 4 to 50 Hz range, floor settlement, electrical noise, mechanical and thermal stability of subsystems that have bearing on the goal of photon beam stability and overall facility performance.

4 SUB-SYSTEM REQUIREMENTS AND ENVELOPE

The NSLS-II project performance requirements and envelope can be met over a range of operating configurations of the facility. Requirements, Specifications and Interfaces for the subsystems are documented separately. An outline of the high level attributes of the subsystems is provided in the balance of this document.

4.1 WORK BREAKDOWN STRUCTURE

The NSLS-II project Work Breakdown Structure (WBS) outlines the major components of the project at level 2:

1.1 Project Management
1.2 R&D and Advanced Conceptual Design
1.3 Accelerator Systems
1.4 Experimental Facilities
1.5 Conventional Facilities
1.6 Pre-Operations

4.2 ACCELERATOR SYSTEMS [WBS 1.3]

The NSLS-II project accelerator systems include a Linear accelerator (Linac), Booster ring and Storage ring, with beam transport lines between the Linac and Booster and between the Booster and Storage Ring respectively. The Storage ring includes Beamline Front-ends up to the penetrations through the accelerator shield wall enclosure, Insertion Devices, and Radiation Safety and Equipment Safety Systems. In addition the accelerator systems element of the WBS provides all of the scientific facilities controls and process utilities infrastructure as well as a number of production and test facilities for Accelerator System components. This document provides only information on the integrated performance requirements and envelope for the accelerator systems. Details for each subsystem are provided in separate documents.

4.2.1 ACCELERATOR PERFORMANCE REQUIREMENTS

4.2.1.1 ACCELERATOR BASELINE PERFORMANCE REQUIREMENTS

The baseline scope shall include all components necessary to enable operation at the following parameters:

- Electron beam energy 3 GeV
- Stored current 300 mA
- Current Stability < 1%
- Electron beam lifetime > 3 hr
- Electron beam emittance < 1 nm-radian (horizontal)
- Source capability for up to:
  - 27 Insertion Devices (including up to 56 m of damping wigglers)
  - 31 'Bend Magnet' Sources (3-pole wigglers and dipoles including 4 far-IR capable ports)

4.2.1.2 ACCELERATOR PERFORMANCE REQUIREMENTS FOR PROJECT COMPLETION

- Electron beam energy 3 GeV
- Stored current 25 mA
- Sources ready for commissioning 6 (includes insertion devices, front-ends, and safety systems)

4.2.2 ACCELERATOR PERFORMANCE ENVELOPE

The baseline design shall not preclude operation at 500 mA with a horizontal electron beam emittance of 0.6 nm-rad. This is anticipated to require provision for the future installation of an additional 35 m of damping wigglers (for a total installed complement of 56 m of damping wigglers) and RF systems sufficient to support 500 mA stored current with 56 m of installed damping wigglers.

4.2.3 ACCELERATOR FUNCTIONAL REQUIREMENTS

Personnel Protection Systems to prohibit exposure of users, staff or the public to hazards associated with accelerator operations, and Equipment Protection Systems to limit damage to the facility from unusual operating configurations shall be implemented.

4.2.4 ACCELERATOR FUNCTIONAL ENVELOPE

The accelerator and its control system should be flexible enough to be reconfigured between standard operations modes and special modes to facilitate unique user needs and to facilitate a vigorous machine studies program. The objective is to make it possible to improve machine performance and develop new capabilities with minimum disruption to the ongoing user program.

4.3 EXPERIMENTAL FACILITIES [WBS 1.4]

The NSLS-II project experimental facilities include a suite of instruments to utilize the capabilities of the storage ring as well as equipment and infrastructure to support the experimental programs.

4.3.1 EXPERIMENTAL FACILITIES PERFORMANCE REQUIREMENTS

4.3.1.1 EXPERIMENTAL FACILITIES BASELINE PERFORMANCE REQUIREMENTS

The NSLS-II project will include the installation and integration of six beamlines within the project scope. The initial suite of experimental capabilities includes:

- Inelastic X-ray Scattering (IXS)
- Hard X-ray Nanoprobe (HXN)
- Coherent Hard X-ray scattering (CHX)
- Coherent Soft X-ray scattering and polarization (CSX)
- Sub-micron Resolution X-ray spectroscopy (SRX)
- X-ray Powder Diffraction (XPD)

4.3.1.2 EXPERIMENTAL FACILITIES PERFORMANCE REQUIREMENTS FOR PROJECT COMPLETION

As part of the project scope, 6 beamlines will be installed and ready for commissioning with x-ray beam at project completion. Interfaces between the beamlines and the facility (utilities, controls, safety systems) must be installed and qualified for operations at project completion.

4.3.2 EXPERIMENTAL FACILITIES PERFORMANCE ENVELOPE

The NSLS-II project must lay the foundation for a diverse experimental program which can utilize the full range of capabilities of the facility from the far Infra-Red to the hard x-ray. While the specifics of the programming of the facility will adjust to meet the prevailing needs of the scientific community, the following list provides a representative model for build out of the fully mature facility:

- 15 straights with ~5m available for user undulators
  - Could potentially drive up to 30 beamlines by canting two undulators
- 4 straights with ~ 7m available for user undulators
  - Could potentially drive up to 8 beamlines by canting two undulators
- 8 straights with ~ 7m available user damping wigglers
  - Could potentially drive up to 16 beamlines by canting two damping wigglers
- 27 BM ports for UV, soft X-rays and hard x-rays
  - Each of which could optionally accommodate a three-pole wiggler source
- 4 BM ports for far-IR

Hence the facility will be capable of supporting a program of at least 58 beamlines, with more possible if straight sections are configured with multiple insertion devices. Multiple hutches are also possible on some beamlines. Laboratory/Office space is included as part of the conventional facilities; experimental facilities will determine the programming of this space as well as provide special equipment in laboratories required to support the research program of NSLS-II.

4.3.3 EXPERIMENTAL FACILITIES FUNCTIONAL REQUIREMENTS

The NSLS-II project experimental facilities, including beamlines, instruments and laboratories, will be configured to provide protection for the users, staff or the public from the hazards associated with their installation, operation, and maintenance.

4.3.4 EXPERIMENTAL FACILITIES FUNCTIONAL ENVELOPE

Experimental facilities should be configured to allow rapid installation of beamlines including instruments recovered from the existing NSLS as well as new instruments funded outside of the NSLS-II Project. Configuration of the initial suite of instruments around the facility should be made with consideration for its impact on the NSLS-II user community. The configuration should foster the growth and intellectual strength of the community that utilizes the facility, as well as enhancing the impact of its scientific programs through the utilization of the unique capabilities of NSLS-II.

4.4 CONVENTIONAL FACILITIES [WBS 1.5]

The NSLS-II project conventional facilities include development of the project site, construction of the buildings and provision of utility services that encompass the NSLS-II facility. The buildings include the Injector (linac and booster ring) building, Ring building including experimental floor, Lab-Office buildings, and Service buildings for mechanical equipment. Space will also be refurbished in the existing NSLS to provide the control room for NSLS-II. Utility services provided by conventional facilities include the interfaces to campus utilities (electrical power, chilled water, steam, potable water, sanitary, storm water communication and data systems) that support NSLS-II operations.

4.4.1 CONVENTIONAL FACILITIES PERFORMANCE REQUIREMENTS

4.4.1.1 CONVENTIONAL FACILITIES BASELINE PERFORMANCE REQUIREMENTS

The NSLS-II conventional facilities must be completed and their functional performance tested and documented. Conventional facilities systems will undergo a commissioning process in advance of accelerator and beamline systems commissioning to assure that all systems meet their stated performance requirements. A minimum of 20 MVA of electric power and 2500 tons of Central Chilled Water facility capacity shall be available. Three LOB's will be constructed as part of the project scope.

4.4.1.2 CONVENTIONAL FACILITIES PERFORMANCE REQUIREMENTS FOR PROJECT COMPLETION

The 340,000 gross square feet of NSLS-II conventional facilities required to support commissioning of the accelerator and installation of the beamlines must be completed and their functional performance tested and documented.

4.4.2 CONVENTIONAL FACILITIES PERFORMANCE ENVELOPE

To the extent practical, provision will be made in the initial construction to support accelerator operations at power levels above the baseline to allow for potential stored current upgrades.

4.4.3 CONVENTIONAL FACILITIES FUNCTIONAL REQUIREMENTS

The NSLS-II project conventional facilities must be constructed to satisfy all applicable life-safety codes. NSLS-II will be integrated into BNL campus operations and the BNL site infrastructure must be operated and maintained at a level commensurate with the support of the operational requirements of NSLS-II. The conventional facilities shall meet the vibration and thermal stability requirements deemed necessary to achieve the scientific objectives outlined in the CD-0, mission need statement. The facility will be designed to meet the sustainability goals of the USGBC LEED (Leadership in Energy and Environmental Design standard) as a certified facility. Conventional facilities should be situated to provide for the best utilization of the existing NSLS building as auxiliary staff and user space for NSLS-II, as well as enhancing the interaction of NSLS-II with the Center for Functional Nanomaterials and the future Joint Photon Sciences Institute.

4.4.4 CONVENTIONAL FACILITIES FUNCTIONAL ENVELOPE

The NSLS-II project will provide conventional facilities that support the research operations of the initial suite of beamlines at project completion. Further, provision will be made in the design to enable the evolution of the facility as the program matures to support a full compliment of instruments utilizing all available beamports. It will also allow for the installation of additional laboratory space with minimal interruption of scheduled operations, and facilitate the construction of future long beamlines that reach beyond the envelope of the storage ring building constructed as part of the project scope.