Hazard Analysis Report

for the

National Synchrotron Light Source II Experimental Tools (NEXT) Beamlines and Advanced Beamlines for Biological Investigation with X-rays (ABBIX)

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VERSION CONTROL SHEET

Version	Description of changes	Date	Preparer	Approved by
0	New	August 2011	Steven Hoey	Hoey, Hulbert, Dierker, Caradonna
1	Incorporates updates based on design evolution and incorporates information on the ABBIX beam lines. Changes document from a Preliminary Hazards Analysis Report to a Hazards Analysis Report to support CD-2. Includes BHSO comment resolution.	July 2012	Steven Hoey	Hoey, Hulbert, Dierker, Caradonna
2	Incorporates updates based on design evolution and minor editorial updates. Names new NEXT ES&H Manager (Stiegler)	June 2013	Lori Stiegler	Stiegler, Hulbert, Dierker, Caradonna
3	Minor edits to paragraph 1.4.1.	August 2013	Lori Stiegler	Stiegler, Hulbert, Dierker, Caradonna
4	Refined and updated hazards based on current analysis. Removed confined space and ozone hazards. Re-evaluated pre and post mitigation risks and determined all are low or routine. Added Experimental Equipment risk analysis.	December 2013	Lori Stiegler	Stiegler, Hulbert, Berman, Dierker,Caradonna

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ACRONYMS

ABBIX Advanced Beamline for Biological Investigations with X-rays

AHJ Authority Having Jurisdiction

AHU Air Handling Unit

ALARA As Low As Reasonably Achievable

ALI Annual Limit of Intake

ANSI American National Standards Institute

ASE Accelerator Safety Envelope

ASME American Society of Mechanical Engineers

ASTM American Society for Testing Materials

BCNY Building Code State of New York

BDP Beamline Development Proposal

BHL Baseline Hazards List

BNL Brookhaven National Laboratory

BPM Beam Position Monitor

BSL Biological Safety Level

CCWF Central Chilled Water Facility

CDR Conceptual Design Report

CFM Cubic Feet per Minute

CFN Center for Functional Nanomaterials

CFR Code of Federal Regulations

CMS Chemical Management System

CSA Canadian Standards Association

DOE Department of Energy

DOT Department of Transportation

EA Environmental Assessment

ECR Environnemental Compliance Representative

EEI Electrical Equipment Inspection

EESE Experimental End Station Enclosure

EMCS Emergency Management Control System

ERC Experimental Review Coordinator

ESM Electron Spectro Microscopy

ES&H Environment Safety and Health

ESR Experimental Safety Review

FACP Fire Alarm Control Panel

FDC Fire Department Connection

FHC Facility Hazard Categorization

FOE First Optics Enclosure

FSAD Final Safety Assessment Document

FUA Facility Use Agreement

FXI Full-field X-ray Imaging from Microns to Nanometers

HAR Hazard Analysis Report

HMTM Hazardous Material Transportation Manual

HSSD High Sensitivity Smoke Detection

HVAC Heating, Ventilation, and Air Conditioning

ID Insertion Device

ISM Integrated Safety Management

ISR Integrated In-Situ and Resonant X-ray Studies

ISS Inner Shell Spectroscopy

LCSC Labor Cryogenic Safety Committee

LEED Leadership in Energy and Environmental Design

LOB Lab–Office Building

LOTO Lockout/Tagout

MER Mechanical Equipment Room

MIC Microbially Induced Corrosion

MIE Major Item of Equipment

MPFL Maximum potential Fire Loss

MSDS Material Safety Data Sheet

NEPA National Environmental Protection Agency

NESHAPS National Emission Standards for Hazardous Air Pollutants

NEXT NSLS-II Experimental Tools (beamlines)

NFPA National Fire Protection Association

NRTL Nationally Recognized Testing Laboratory

NSLS National Synchrotron Light Source

NSLS-II National Synchrotron Light Source II

NYBC New York State Building Code

O Order, as in Executive Order, DOE Order, etc.

ODH Oxygen Deficiency Hazard

OSHA Occupational Safety and Health Administration

PC Performance Category

PCNY Plumbing Code New York State

PPE Personnel Protective Equipment

PHAR Preliminary Hazards Analysis Report

PSAD Preliminary Safety Assessment Document

PTS Permanent Threshold Shift (hearing loss term)

RSB Research Support Building

SAA Satellite Accumulation Area

SAD Safety Assessment Document

SBMS Standards Based Management System

SIX Soft Inelastic X-ray Scattering

SMI Soft Matter Interfaces

TLV Threshold Limit Values

TRU Trans-uranic

TXM Transmission X-ray Microscopy

UL Underwriters Laboratory

VUV Very UltraViolet

XAS X-ray Absorption Spectroscopy

XANES X-ray Absorption Near-Edge Spectroscopy

XES X-ray Emission Spectroscopy

Executive Summary

This Hazard Analysis Report (HAR) has been updated for the NSLS-II Experimental Tools (NEXT) beamlines project as part of the Critical Decision 2/3a (CD-2/3a) process in accordance with the requirements of the program and project management practices of DOE Order 413.3B, "Program and Project Management for the Acquisition of Capital Assets." This HAR is an extension of analysis completed for the NEXT beamlines for CD-1 and documented in the Preliminary Hazard Analysis Report (PHAR). The NEXT beamline project includes the development of five to six insertion device beamlines for NSLS-II, beyond the initial six NSLS-II project beamlines previously analyzed in the NSLS-II Preliminary Safety Assessment Document. This HAR was developed to predict hazards that may be encountered during the NEXT and ABBIX construction and operational phases. The HAR was also used to determine any impacts to the NSLS-II Ring Building Facility Hazard Categorization (FHC). This HAR also includes the scope of the Advanced Beamlines for Biological Investigations with X-rays (ABBIX) project. The ABBIX beamlines are a suite of three insertion device beamlines funded by the National Institutes of Health.

The findings of this HAR reflect the following:

The project is being developed following the Brookhaven National Laboratory Integrated Safety Management (ISM) principles and DOE O 420.2C "Safety of Accelerator Facilities."

BNL is committed to the success of the mission objectives of the National Synchrotron Light Source II and to the safety of its users, staff, the public and the environment.

The NSLS-II was determined to be an "Accelerator Facility" in accordance with DOE Order 420.2C. The NEXT and ABBIX beamlines do not change this designation.

All hazards identified for the NEXT and ABBIX beamlines are typical of those encountered with beamline operations at other accelerator facilities across the DOE complex. The design and operational criteria to mitigate these hazards, resulting from many years of operational experience and lessons learned, will be applied to these suites of beamlines.

These potential risks are discussed in section 3 of this HAR, and summarized on risk summary forms reproduced in section 6.

Table 1.1: Risk Assessment Summary.

HAR Hazard Identifier	Hazard	Pre-Mitigation Risk Category	Post Mitigation Risk Category
NEXT/ABBIX HAR-1	Natural Phenomena	Low	Routine
NEXT/ABBIX HAR-2	Environmental	Moderate	Low
NEXT/ABBIX HAR-3	Waste	Moderate	Low
NEXT/ABBIX HAR-4	Fire	High	Low
NEXT/ABBIX HAR-5	Electrical	High	Low
NEXT/ABBIX HAR-6	Vacuum	Moderate	Low
NEXT/ABBIX HAR-7	Noise	Moderate	Low
NEXT/ABBIX HAR-8	Cryogenic	Moderate	Low
NEXT/ABBIX HAR-9	Chemical/Biological/Hazmat	High	Low
NEXT/ABBIX HAR-10	Ionizing Radiation	High	Low
NEXT/ABBIX HAR-11	Non-Ionizing Radiation	Moderate	Low
NEXT/ABBIX HAR-12	Material Handling	High	Low
NEXT/ABBIX HAR-13	Experimental equipment	Moderate	Low

1 INTRODUCTION AND OVERVIEW OF RESULTS

1.1 NSLS-II Mission Need

Brookhaven National Laboratory is constructing National Synchrotron Light Source II (NSLS-II), a highly optimized, third-generation synchrotron facility that will enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. NSLS-II will provide world-leading brightness and flux as well as exceptional beam stability over a broad range of photon energies from infrared to hard x-rays. NSLS-II is designed to house at least 58 beamlines. Once operational, these experimental facilities will support a large user program that carries out research in such diverse fields as biology and medicine, chemistry and environmental sciences, physics, and materials science.

The NSLS-II project, which started construction in 2009 and will be complete in 2015, provides design, building, and installation of the accelerator hardware, civil construction, and facilities including offices and laboratories required to produce a new synchrotron light source. It includes a third-generation storage ring, full-energy injector, experimental areas, and appropriate support equipment, all housed in a new building. The NSLS-II project scope also provided an initial suite of six “best-in-class” beamlines. Additional beamlines and or suites of beamlines will be added over time to reach full build out.

Beyond that initial suite of six NSLS-II project beamlines, in May 2010 the Department of Energy approved “Critical Decision 0” (CD-0) for the NSLS-II Experimental Tools (NEXT) project. The purpose of the NEXT project is to design and construct five to six additional “best-in-class” insertion device (ID) beamlines. A Conceptual Design Report (2011) presented the scientific goals for the NEXT beamlines, describing them at the conceptual design level, and presenting evidence for the feasibility of designing, constructing, and installing them on the NSLS-II experimental floor. A Preliminary Design Report (2012) describes, at the preliminary design level of completion, the components of the photon delivery systems and endstations for the NEXT beamlines.

The scientific and programmatic selection of NEXT beamlines emanated from a multi-year series of workshops, culminating in a process of proposal submissions and reviews that was undertaken in the spring and summer of 2010. Under the auspices of the Photon Science Directorate Science Advisory Committee, this process approved a set of 34 beamline development proposals (BDPs) in August 2010. Selection of the NEXT beamlines from among those approved proposals was made based on scientific benefit and complementarily to the NSLS-II Project beamline scientific programs and to the DOE BES mission.

The ABBIX project is to design and construct a suite of three high-performance biological science beamlines funded by the National Institute of Health. All three beamlines will operate in the hard x-ray range, and one extends to lower photon energy, down to ~2.1 keV.

1.2 Overview of the HAR Results, Conclusions, and Comprehensiveness

Generally, all the hazards and their risks anticipated to be encountered at the NSLS-II NEXT and ABBIX beamlines as identified in this HAR are well known to the accelerator community. Years of experience with such facilities at BNL and within the DOE complex have generated well-defined design criteria and controls to eliminate and/or control these hazards, thus reducing the risks. The analysis is not intended to limit the beamlines to only hazards identified as it is recognized as advanced scientific techniques evolve these hazards may change and require additional analysis and or controls.

Table 1.1 summarizes the hazards as well as their pre-mitigation and post-mitigation risk categories. The design and operational factors listed in the HAR adequately address all risks, and ensures all hazards are brought to a Low or Routine level.

The hazard analysis process began concurrent with the NEXT conceptual design to ensure that all significant hazards were identified, so that they could be adequately incorporated into the design. Historical hazards analyses conducted for the NSLS-II Ring Building were utilized to assist in identifying the potential hazards for the beamlines. These analyses included a Baseline Hazards List (BHL), a Preliminary Hazards Analysis (PHA), a Preliminary Safety Assessment Document (PSAD), and documentation for the National Environmental Protection Agency (NEPA) and National Emission Standards for Hazardous Air Pollutants (NESHAPS) programs and finally a Preliminary Hazard Analysis Report for the NEXT beamlines. In this manner this HAR utilized the best available information from the NSLS-II conceptual design, existing NSLS and NSLS-II safety-basis documentation, subject matter expertise (from the Conventional Facilities, Accelerator Systems, and ES&H groups), and lessons learned from the DOE accelerator community covering design criteria, regulatory requirements, and related occurrences. The HAR process also included a preliminary (pre-mitigation) risk assessment at the subsystem level that identified a risk category before incorporating the ES&H related design and operational controls that are postulated to mitigate those risks. The identified hazards then were further developed when the proposed ES&H design enhancements were taken into consideration. This HAR reanalyzed the risks including those enhancements and, in certain cases, operational controls, in order to establish a post-mitigation risk category. This category affords a realistic assessment of the residual ES&H risks posed by the NSLS-II NEXT and ABBIX beamlines and is input to the design phase.

The potential hazards associated with the operation of the NSLS-II facility have been addressed in the Preliminary Safety Assessment Document (PSAD) for the NSLS-II project. That document will be superseded, at CD-4, by a Final Safety Assessment Document (FSAD) and an Accelerator Safety Envelope (ASE). Incremental commissioning SADs for the linac, booster, and storage ring are being (or have been, in the case of the linac and booster) developed; these SADs will be combined and incorporated into the Final SAD document for NSLS-II, along with any additional hazards and controls identified for the NEXT and ABBIX beamlines as identified by this HAR. Beamlines added after the development of the final SAD will be evaluated to determine if hazards would fall within the approved envelope.

1.3 Description of the NEXT Project

The NEXT project plans to build five to six high performance insertion device beamlines at NSLS-II over a period of four years (FY14 – FY17). Two of these beamlines operate in the soft x-ray range, two in the hard x-ray range, and two extend into the very hard x-ray range. In terms of techniques, two of the NEXT beamlines are dedicated to spectroscopy, two to imaging, two to elastic scattering, and one to inelastic scattering (this adds up to more than six, owing to technique overlap). These beamlines form a complementary set to the six NSLS-II Project beamlines, both in energy range and in scientific programs and techniques. The names and three-letter acronyms of the NEXT beamlines are:

- ESM Electron Spectro Microscopy
- FXI Full-field X-ray Imaging with Transmission X-ray Microscope
- ISR Integrated In-Situ and Resonant X-Ray Studies
- ISS Inner Shell Spectroscopy
- SIX Soft Inelastic X-ray Scattering
- SMI Soft Matter Interfaces

1.4 NEXT Project Scope

The scope of the NEXT project is to design six and install five insertion device beamlines for NSLS-II by specifying their source and front end requirements, design, engineering, fabrication/procurement, assembly, testing, and installation on the NSLS-II experimental floor. The sixth beamline design only (FXI) is included in this HAR for completeness. The beamlines contained in the NEXT Major Item of Equipment (MIE) project and their capabilities are described as follows.

1.4.1 ESM – Electron Spectro Microscopy Beamline

ESM is a high-resolution, high-flux, wide-energy range, micro-focused VUV/soft x-ray beamline designed to provide high-quality monochromatic radiation to three different electron microscopes for 1) in-situ growth and structural, electronic, and chemical characterization of material surfaces at the nanometer scale and 2) ultra-high energy- and angle-resolved physical studies of materials in ultra-high vacuum conditions.

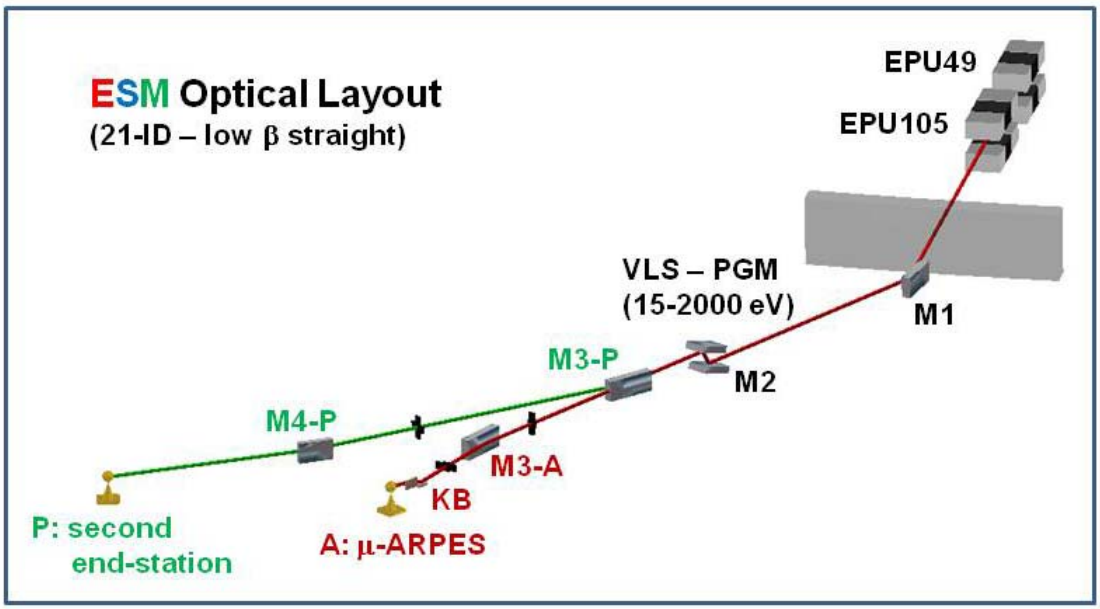


Figure1.1: Schematic of the Electron Spetro Microscopy (ESM) beamline.

1.4.2 FXI – Full-field X-ray Imaging with Transmission X-ray Microscope Beamline

FXI is a hard x-ray imaging and microscopy beamline that will provide state-of-the-art implementations of a 30 nanometer resolution, high speed transmission x-ray microscope (TXM) for samples demanding the highest resolution. The TXM, purposely designed for XANES (X-ray Absorption Near-Edge Spectroscopy) imaging, features precise metrology systems for automatic tomography and interior tomography.

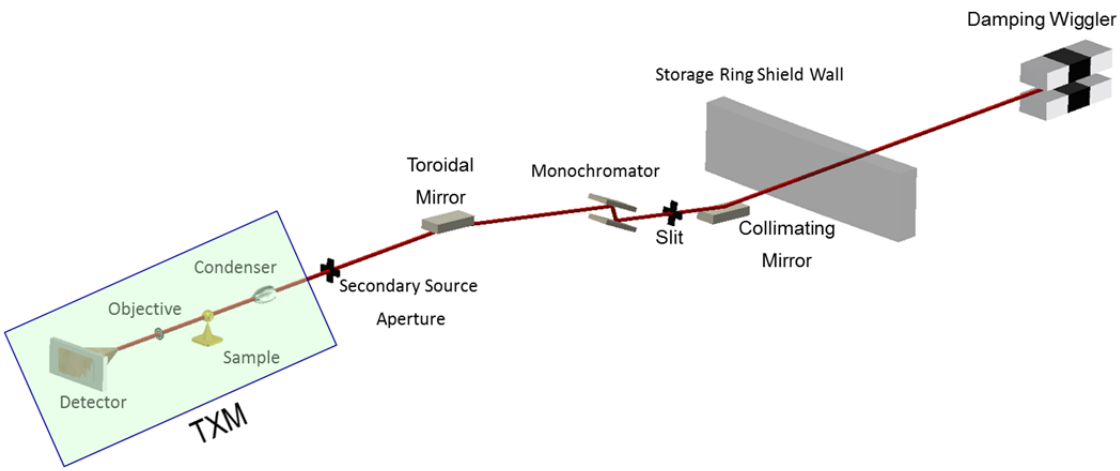


Figure1.2: Layout of the Full-field X-ray Imaging (FXI) Transmission X-ray Microscope (TXM) beamline.

1.4.3 ISR – Integrated In-Situ and Resonant X-ray Studies Beamline

ISR is an x-ray scattering beamline covering the 2.4 – 23 keV energy range that will enable the in-situ study of materials in a flexible range of environment chambers. Specialized optics will provide polarization control and focusing to 1 μm vertically with a 1.5 m working distance from the focusing optic. This will allow the entire beam intensity to be placed at grazing incidence on millimeter size horizontal samples for surface and interface studies, providing a 1,000-fold increase over what is currently possible at the leading NSLS beamline, X21. The beamline will also enable coherent x-ray scattering techniques, such as x-ray photon correlation spectroscopy.

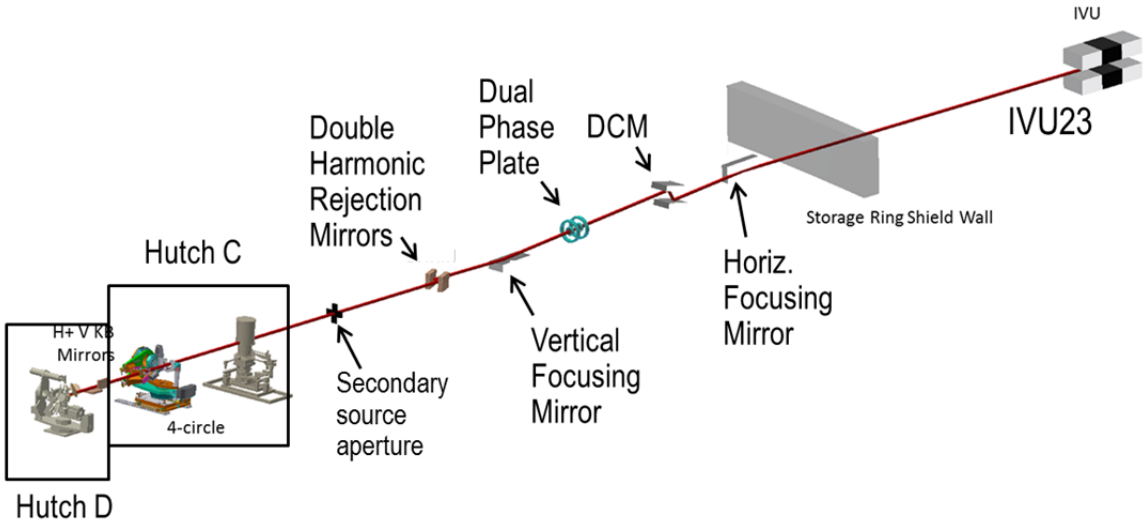


Figure1.3: Schematic of the Integrated In-Situ and Resonant Studies (ISR) Beamline.

1.4.4 ISS – Inner Shell Spectroscopy Beamline

ISS is a multipole-wiggler-based, hard x-ray beamline devoted to inner-shell spectroscopy and serving a very broad user community, including energy science, life and environmental science, materials science, industrial applications, and more. The exceptional flux provided by an NSLS-II multipole wiggler enables science which greatly expands upon capabilities at existing spectroscopy beamlines. This includes 1) measurement of X-ray Absorption Spectroscopy (XAS) at ultra-low absorber concentration or sample volume, including systems of environmental, technological or other relevance, 2) high-resolution fluorescence detection for all X-ray Absorption Near Edge Spectroscopy (XANES) measurements, and 3) X-ray Emission Spectroscopy (XES). All ISS detectors and spectrometers will be designed to accommodate various in-situ sample environments, thus allowing for real measurements of real materials under real conditions. Taken together, this suite of spectroscopies provides a complete picture of inner-shell electronic structure and applies them to a broad, cross-disciplinary scientific mission.

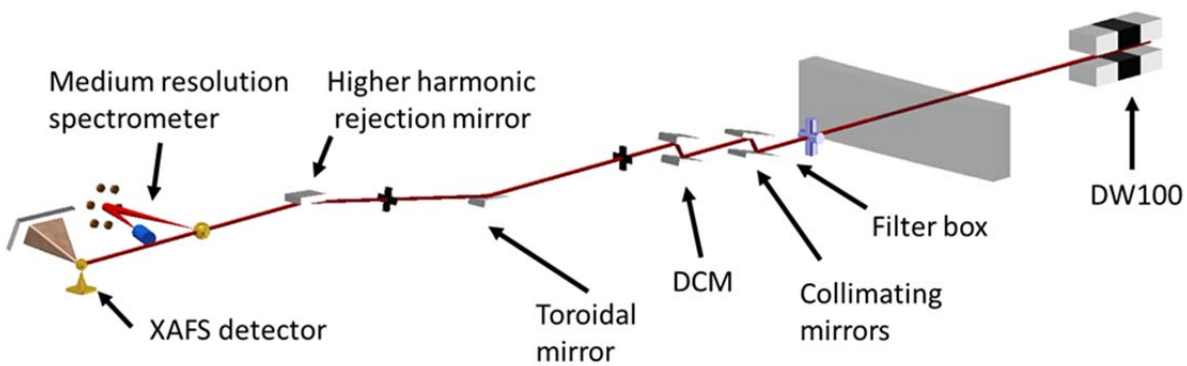


Figure1.4: Schematic of the Inner Shell Spectroscopy (ISS) beamline.

1.4.5 SIX – Soft Inelastic X-ray Scattering Beamline

SIX is an undulator-based inelastic scattering beamline that will provide world-leading energy and wave vector (q) resolution for research addressing key energy-related challenges and fundamental condensed matter physics. The beamline will deliver high-brightness polarized photons to an end station located on a long beamline equipped with an ultrahigh resolution spectrometer (10 meV) and continuously variable momentum transfer. This energy resolution is a factor of 10 better than anything in operation today and will revolutionize studies in condensed matter excitations, including correlated electron materials and superconductors, energy storage, environmental science, and catalysis at ambient pressures. The optics to achieve this ultimate resolution require that the ultrahigh resolution end station and its very large emission spectrometer.

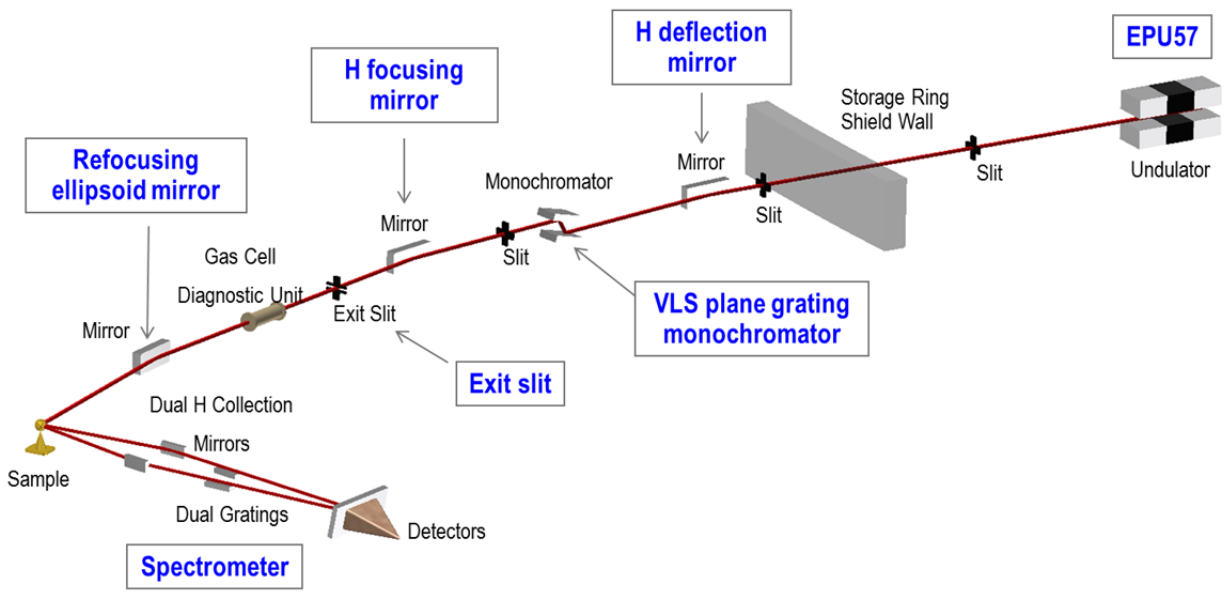


Figure1.5: Schematic of the Soft Inelastic X-ray Scattering (SIX) beamline.

1.4.6 SMI – Soft Matter Interfaces Beamline

SMI is an x-ray scattering beamline dedicated to interface scattering in the tender to hard x-ray (2–27 keV) region. It will provide micron-sized beams for liquid interface studies, and world-class capabilities for fast reflectivity and time resolved x-ray small- and wide-angle scattering measurements at solid/vapor, solid/liquid, liquid/liquid, and liquid/vapor interfaces.

Soft matter encompasses polymers, liquids, liquid crystals, granular materials, gels, and biomolecular materials, all of which lack the three-dimensional crystallinity characteristic of conventional hard-matter systems. These soft materials are increasingly called upon to address national needs in energy, health, and environment. High-resolution and time-resolved scattering measurements under a wide range of sample conditions are essential tools for understanding structural aspects of the interfacial properties and the self-assembly process leading thereto, which is a necessary step to developing improved materials.

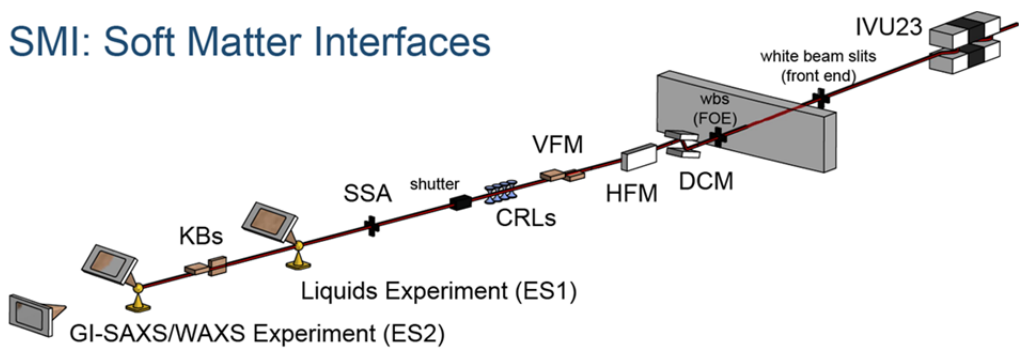


Figure 1.6: Layout of the Soft Matter Interfaces (SMI) beamline.

1.5 Description of the ABBIX Project

The National Institutes of Health, through its National Center for Research Resources (NCRR) and its National Institute of General Medical Science (NIGMS), has provided funding to NSLS-II to design and construct three "best-in class" insertion device beamlines by the end of 2015 in order to address NIH mission needs in the biological sciences arena. The project to perform this work at NSLS-II is identified as Advanced Beamlines for Biological Investigations with X-rays (ABBIX).

1.5.1 ABBIX Project Scope

The scope of the ABBIX Project is the development of three insertion devices, front ends, and beamlines for NSLS-II for life sciences research. Development of these sources and beamlines consists of the design, engineering, fabrication/procurement, assembly, testing, and installation on the NSLS-II experimental floor. Three undulator insertion devices, with parameters specified to meet the source requirements for these beamlines, and associated infrastructure including front end components will be designed, constructed and installed to serve as x-ray sources for the ABBIX Project. Common beamline components (funded through the NSLS-II Project) include utilities and safety systems, such as delivery

systems for power, air, cooling water, and liquid nitrogen and personnel and equipment protection systems.

All three beamlines will operate in the hard x-ray range, and one extends to lower photon energy, down to ~2.1 keV. Two of them are dedicated to macromolecular crystallography, and one (LIX) is dedicated to small-angle/wide-angle x-ray scattering (SAXS/WAXS). These beamlines represent the first set at NSLS-II to address biological science needs as their primary goal.

The names and three-letter acronyms of the ABBIX beamlines are:

- AMX Flexible Access and Highly Automated Beamline for Macromolecular Crystallography
- FMX Frontier Macromolecular Crystallography at an Undulator Beamline
- LIX High Brightness Beamline for X-ray Scattering for Life Sciences

The three beamlines contained in the ABBIX Project and their capabilities are briefly described below.

1.5.2 AMX, Highly Accessible and Automated Macromolecular Crystallography

AMX is a best-in-class undulator beamline for macromolecular crystallography (MX), delivering exceptionally intense beams of 5 to 18 keV x-rays focused at adjustable, small-convergence angles into spots measuring 4 to100 μm. AMX will provide investigators with a highly accessible facility, featuring both automated and remote participation modes of operation as well as rapid access. It will support both current and emerging styles of data collection and structure determination, and it will have the capacity and flexibility to accommodate new methods made possible by its speed and versatility. Small beams and tiered sample handling robots will offer the high throughput required for broad explorations of specimen conditions, and full size beams will be ideal for solving structures of very large multi-molecular assemblies.

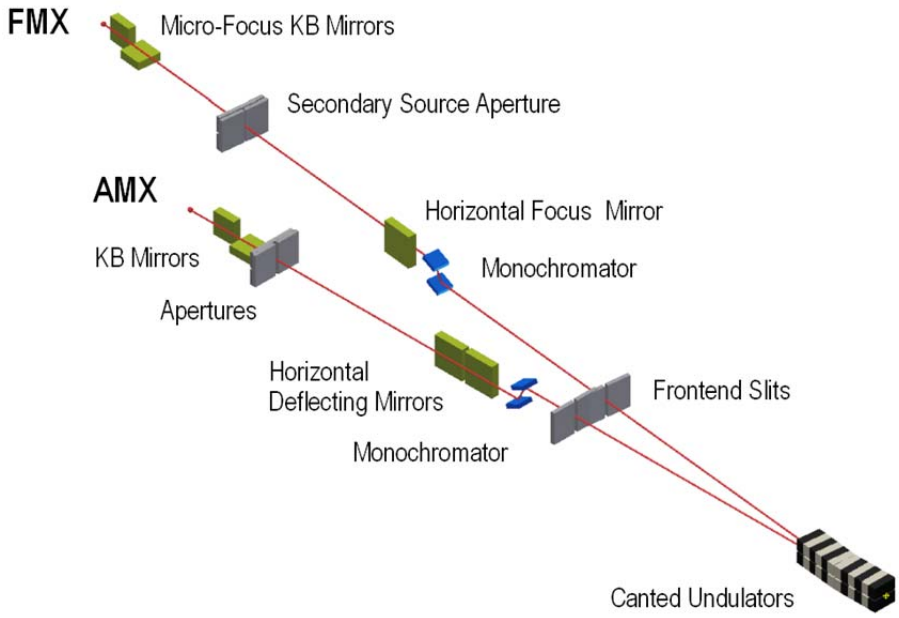


Figure1.7: Layout of the Flexible Access and Highly Automated Beamline for Macromolecular Crystallography (AMX) and Frontier Macromolecular Crystallography at an Undulator Beamline (FMX).

1.5.3 FMX, Frontier Macromolecular Crystallography

FMX is a tunable, micro-focus undulator beamline designed to produce the most intense possible 1 µm beam for macromolecular crystallography in the 5 to 30 keV range. The optics design will provide modest and controllable divergence, and will be readily adjustable to 20 µm. Instrumentation will provide stable specimen alignment to accommodate the small beam size, and will be fully automated for conventional high-throughput crystallography. The design of the experimental station will allow introduction of unusual crystal-delivery methods for serial crystallography.

1.5.4 LIX, High Brightness X-ray Scattering for Life Sciences

LIX is an x-ray scattering instrument specializing in the characterization of non-crystalline biological structures, within the energy range of 2.1 to 18 keV. The beamline will support the specific scientific areas of 1) time-resolved scattering from biomolecular solutions with time resolution down to 10 microseconds; 2) grazing incidence scattering from proteins associated with single-layered membranes; and 3) scanning probe imaging of biological tissues with spatial resolution of 1 micron.

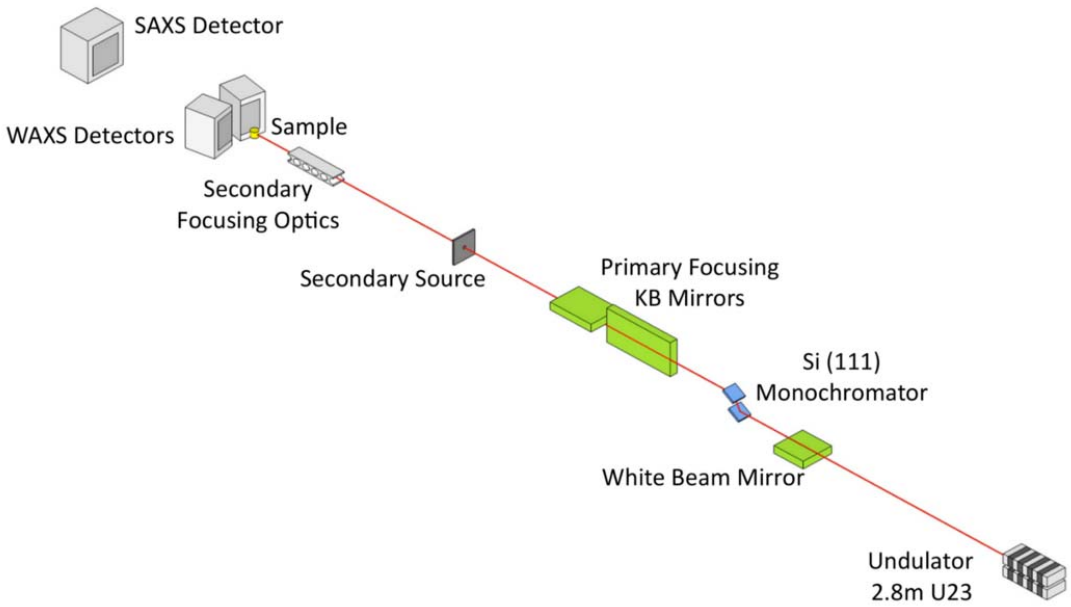


Figure1.8: Layout of the LIX (High Brightness Beamline for X-ray Scattering for Life Sciences) beamline.

2 THE SITE, NSLS-II CONVENTIONAL FACILITIES, AND OPERATIONS

2.1 Description of the Site

Brookhaven National Laboratory is a multidisciplinary scientific research institute located close to the geographical center of Suffolk County, New York, about 60 miles east of New York City. Figures 2.1 and 2.2 show regional and aerial views of BNL.

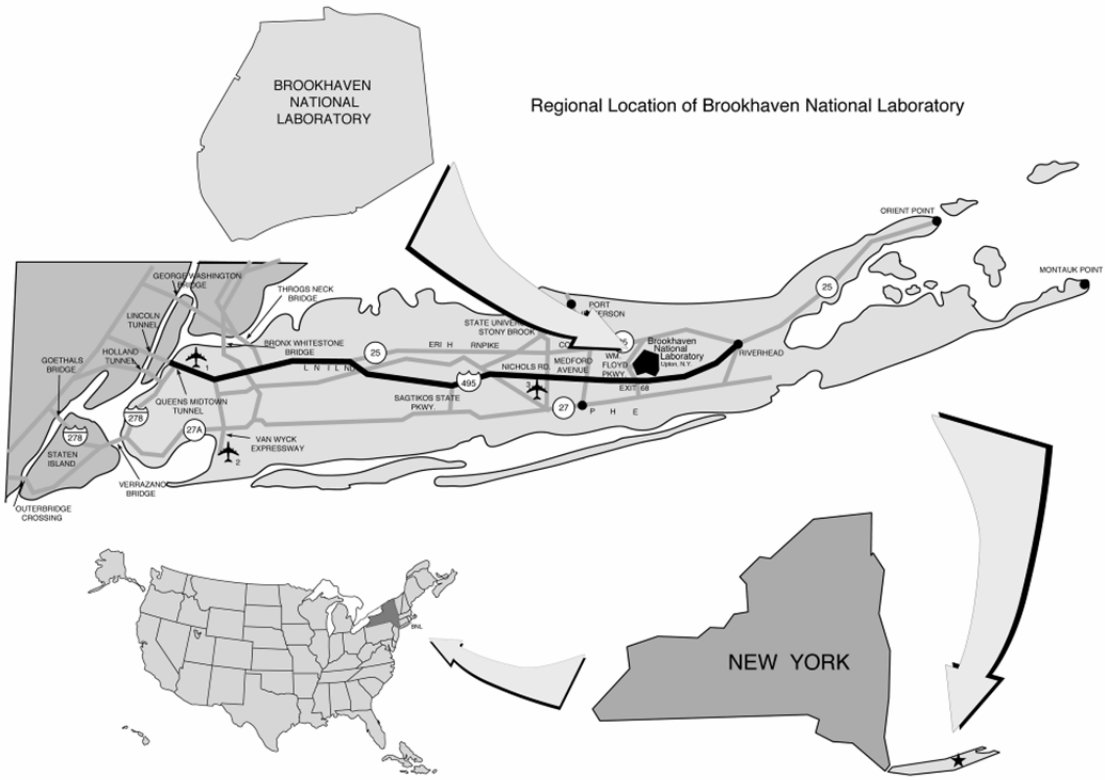


Figure 2.1: Regional view of the location of Brookhaven National Laboratory.

Figure 2.2: Photograph of BNL (October 2011) showing the existing National Synchrotron Light Source (NSLS), the Center for Functional Nanomaterials (CFN), and the NSLS-II construction site.

The approximately 47-acre area immediately south and east of the existing NSLS (Bldg. 725), east of the existing Center for Functional Nanomaterials (CFN; Bldg. 735) and south of Brookhaven Avenue, is the site for NSLS-II, Building 740 (Fig. 2.3). This location was chosen because 1) the area to the south and east is largely undeveloped and can accommodate long beamlines extending out from the NSLS-II building, if required; 2) the CFN is close by, directly across Grove Street to the west; 3) the existing NSLS building is diagonally across the intersection; and 4) the Physics, Chemistry, Materials Science, Biology and Medical Departments and Instrumentation Division are nearby.

The NSLS-II Ring Building property itself is bounded on the north by Brookhaven Avenue, on the west by an existing swale, on the south by an existing swale and landfill, and on the east by Fifth Street. Additional facilities are located north of Brookhaven Avenue on either side of Renaissance Street and include Building 725 (Control Room, offices, technical and laboratory spaces), Building 726-727 (mechanical, utility and magnet technical spaces), and Building 729 (Source Development Laboratory).

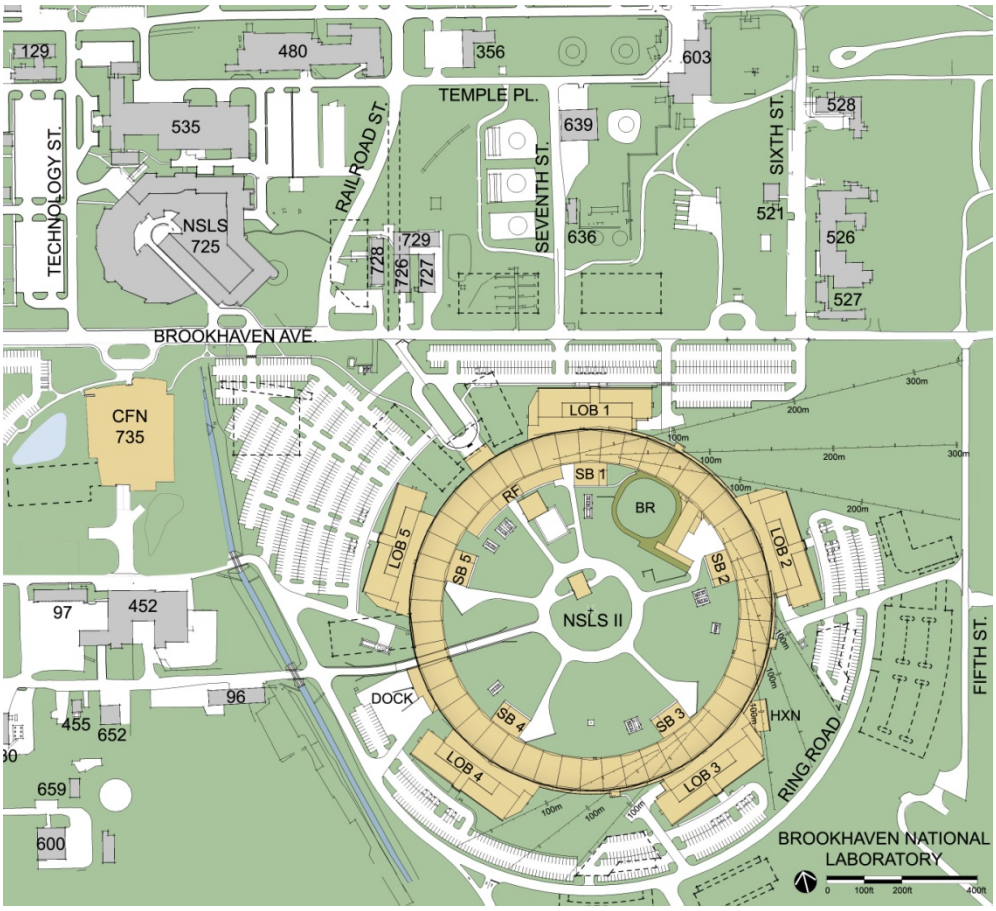


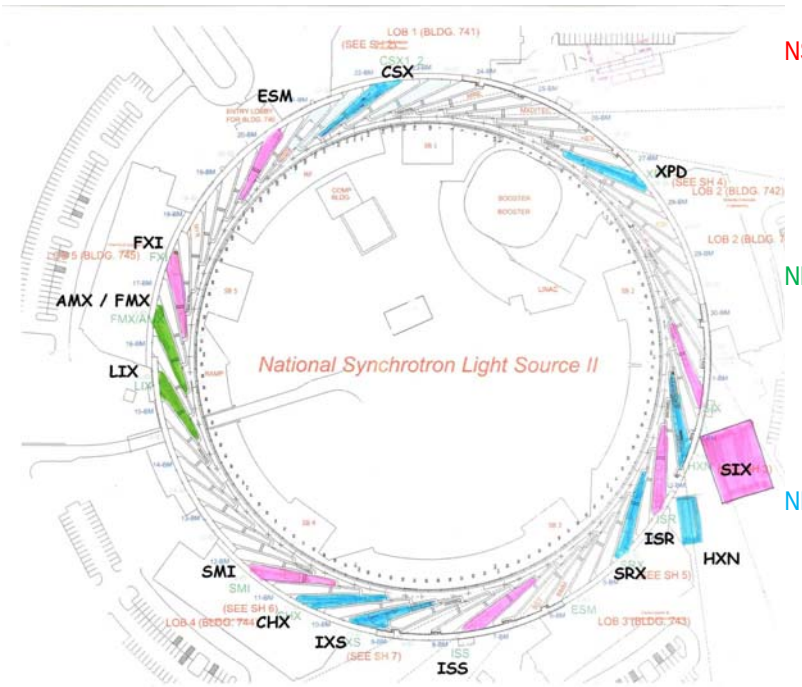
Figure 2.3: Siting of NSLS-II relative to NSLS and the Center for Functional Nanomaterials (CFN) and NSLS.

2.2 Conventional Facilities

2.2.1 Building Design

NSLS-II has distinct components that make up the building plan. At full build out, they consist of the Ring Building, five Laboratory–Office Buildings (LOBs), five service buildings, injection building, RF building and its associated compressor building, and cooling tower building (Fig. 2.4 shows a rendering of the completed facility). Each of these buildings has separate space and utility requirements. Additional buildings around the BNL campus are used to provide administrative/engineering office, workshop, and technical spaces that support the needs of the NSLS-II project. The NEXT and ABBIX beamlines will be contained within the Ring Building Experimental Floor (Fig. 2.5 shows the layout of the experimental floor).

Figure 2.4: Architectural rendering of NSLS-II.



NSLS-II Project Beamlines

- Inelastic X-ray Scattering (IXS)
- Hard X-ray Nanoprobe (HXN)
- Coherent Hard X-ray Scattering (CHX)
- Coherent Soft X-ray Scat & Pol (CSX)
- Sub-micron Res X-ray Spec (SRX)
- X-ray Powder Diffraction (XPD)

NEXT MIE Beamlines

- Photoemission-Microscopy Facility (ESM)
- Full-field X-ray Imaging (FXI)
- In-Situ and Resonant X-Ray Studies (ISR)
- Inner Shell Spectroscopy (ISS)
- Soft Inelastic X-ray Scattering (SIX)
- Soft Matter Interfaces (SMI)

NIH ABBIX Beamlines

- Frontier Macromolecular Cryst (FMX)
- Flexible Access Macromolecular Cryst (AMX)
- X-ray Scattering for Biology (LIX)

Figure 2.5: Site plan of NSLS-II building with projected locations for the NSLS-II Project beamlines (red) NEXT beamlines (green), and ABBIX beamlines (blue).

Figure 2.6 is a cross-sectional view of the NSLS-II Ring Building, showing, from right to left, the accelerator tunnel and experimental floor.

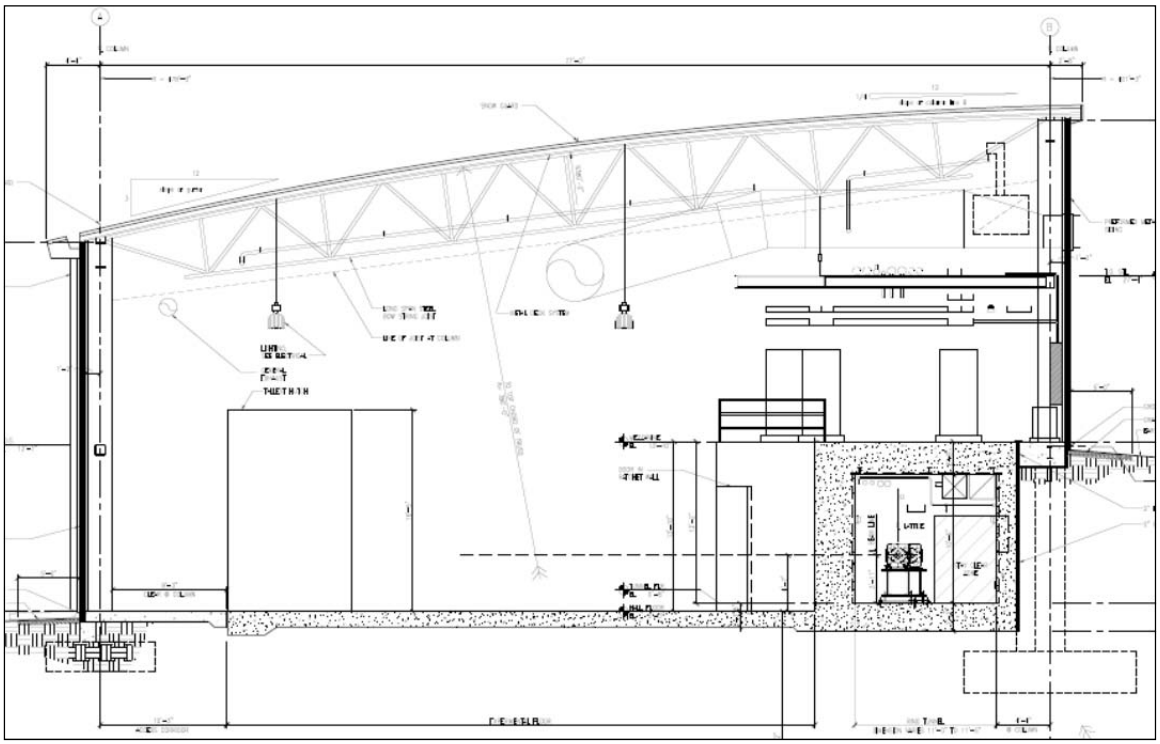


Figure 2.6: Cross-sectional view of the NSLS-II Ring Building.

2.2.2 Electrical Power

The existing 69 kV substation yard has been modified to provide the added power required for NSLS-II. A new 20.0/26.7/29.9 MVA, 66.0 to 13.8 kV main transformer is provided that is capable of supplying all NSLS-II loads, along with a new 13.8kV switchgear line-up to feed power to the site and to enable interconnecting to other BNL main transformers as back-up power sources for NSLS-II. The modification also includes the associated equipment of two new 69 kV potential transformers, a new 69 kV SF6 breaker, and a new fire separation wall between existing Transformer #3 and the new transformer. A fire-rated door and fireproofing have been added to the exterior of Building 603 to protect the building from the new main transformer.

2.2.3 Emergency Power

Two diesel emergency power generators are provided, one at Service Building #3 and one at the RF Building. The size of each generator is 700 kW. The emergency power requirements are distributed almost equally between the two units which have been located to minimize the cable runs between the emergency generators and the electrical components requiring emergency power. A sub-base fuel tank in compliance with 6NYCRR Parts 613 and 614 is provided with a 12-h full load operation capacity. To reduce noise and vibration, a weatherproof, sound attenuated reach-in enclosure is provided. Emergency

Generator #1 will be used to support the northern portion of the NSLS-II site, including the Cryogenic System Recovery Compressor and the Controls Computer System. Emergency Generator #2 will support the southern portion of the site.

The emergency power is provided for key safety systems, including the emergency address system (through the fire alarm panels), egress and exit lighting, the fire alarm system, fire suppression system, smoke exhaust fans; and important utility systems such as selected lab exhaust and make-up systems, sump pumps (sanitary and storm), and select HVAC control systems. The generators start upon loss of normal power. The loads are switched to the generators within 10 seconds. Power is transferred to the critical systems by Automatic Transfer Switches (ATS).

Loss of electrical power will result in the Storage Ring shutting down. The emergency generators will not provide power directly to the Storage Ring. Critical controls for the Storage Ring and RF will be connected to a UPS for orderly shutdown in the event of a prolonged power outage. Emergency power is not a requirement for the facilities Accelerator Safety Envelope credited controls. The emergency generators and transfer switches are tested monthly as per NFPA.

2.2.4 Heating, Ventilation and Cooling (HVAC) Systems

Heating, ventilation, and cooling systems are distributed in six mechanical equipment rooms (MERs) distributed around the inside of the ring. A combination of chilled water and tower water, cooling systems will meet the ambient HVAC requirements, as well as the process-induced cooling loads. The chilled water will come from the Central Chilled Water Facility (CCWF). NSLS-II will require a capacity of 2,500 tons. The CCWF capacity has been upgraded to meet this increased demand.

2.2.5 Compressed Air Systems

Compressed air is provided by the Central Compressed Air system that is part of the CCWF and will be available to all beamline locations

2.2.6 Gas and Cryogenic Gas Distribution Systems

NSLS-II will utilize a centralized liquid nitrogen source supplied by two storage tanks, one near the main loading area and the second on the east side of the facility. Liquid nitrogen will be distributed throughout the ring and experimental areas. Cryogenic systems will be designed in conformance with applicable ASME standards. Drops located throughout the experimental floor will provide cryogens for cooling systems. Dewar filling stations to support experimental operations will be provided at select locations.

2.2.7 Fire Protection

The NSLS-II fire protection system is described in detail in the *NSLS-II Fire Protection Assessment/Fire Hazard Analysis* (FPA/FHA). This HAR describes the salient design features of that system and focuses, where possible, on the ring building, which contains the NEXT and ABBIX beamline areas, and the structures that will house the extended HXN and SIX beamlines, adjacent to the ring building.

The ring building is classified as "Business" occupancy per the Building Code of New York State (BCNYS) and as "Industrial, General Purpose" occupancy per NFPA Standard 5000, *Building Construction and Safety Code*.

- The overall building construction classification is IIB (BCNYS) and Type II – 000 (NFPA).
- The ring building is served by a constant volume air handling unit (AHU) capable of 22,000 CFM (cubic ft/min), located in the booster RF service building.
- Two 700 kW emergency generators are provided, one by Service Building #3 and one by the RF Building.
- Five Fire Service Rooms (FSR) are located on the exterior walls of the five service buildings, and another five FSRs are located along the exterior walls of the ring building. The latter FSRs also serve the LOBs. The RF Building is provided with a "hot box" located on the outside of the building wall.
- Fire Department Connections (FDC) are located on the Service Building exterior walls and on the outside exterior wall of the Storage Ring Building. The latter FDCs also serve the LOBs. The RF Building is provided with its own FDC located on the outside of the building wall.
- A smoke control management system has been provided in the experimental floor/mezzanine level of the ring building, the ring tunnel and the booster ring in the injection building. Hydrants are located between 40 feet and 300 feet from the FDCs.
- A dual water service fed wet pipe automatic sprinkler system with flow alarms serves the Storage Ring Building. The LOBs and the RF Building have an automatic, water-fed sprinkler system.
- Adequate water source to supply sprinkler protection for NSLS-II. The underground mains are provided with sectional control valves and provide a loop around the NSLS-II complex, as well as in the "infield" of the ring building.
- Automatic audio-visual alarm devices are provided throughout. Manual pull stations for fire alarms are installed at all building exits, at all exit stairs, and at 300-foot intervals in egress corridors.
- High Sensitivity Smoke Detection (HSSD) systems are installed in the storage ring tunnel, above the mezzanine, and in the experimental hall. The LOBs have smoke detectors in the laboratories. The RF Building has an HSSD system in the computer room and duct smoke detectors for the rest of the building.
- Fire extinguishers are installed throughout the NSLS-II facility in compliance with NFPA 10.
- Beamline hutches will have strobe alarms on or near their external walls and may have strobe alarms inside the hutches, depending on the hutch configuration. Requirements for smoke alarms inside the hutches will be determined based on the value of the installed equipment and combustible loading.

2.2.8 Fire Alarms and Detection

A fire alarm system will be installed, meeting the requirements of NFPA 72 "National Fire Alarm Code." The facility's fire alarm control panel (FACP) will be placed inside the main building's entrance lobby, giving the fire department easy access. The fire alarm system will monitor water flow in the sprinkler system and modulate the sprinkler valves and the installed fire detection systems. Audible/visual alarm-notification devices will be put in place to alert building occupants. At all the buildings' exits there will be manual fire alarm pull stations. Photoelectric area smoke detectors will be set up in the air handling systems, as required by NFPA 90A. Smoke detection systems may also be located in areas containing highly sensitive electronic equipment.. Combination audible/visual alarm and/or visual only annunciation devices to alert the occupants will be provided throughout the ring, the corridor system, in each laboratory, and in most rooms, other than single-person offices. Fire alarm and supervisory signals will be transmitted to the BNL Fire Rescue Group via the Site Fire Alarm System.

The Fire Rescue Group in Building 599 monitors all fire alarms and system supervisory signals. There is a secondary monitoring station at Security (Building 50). Typically, the Fire Rescue Group responds to the scene at a BNL facility within 5 minutes of an alarm annunciation. Fire Rescue is staffed and equipped for incipient-stage structural firefighting. BNL is a member of the Suffolk County Fire and Federal Mutual Aid System that provides assistance to 120 other fire departments in Suffolk County. Fire Rescue also provides emergency medical services via a NY State Certified Basic Life Support Ambulance. Additionally, Fire Rescue is the on-site hazardous materials response team, trained as Hazardous Materials Technicians as per NFPA.

2.2.9 Instrumentation and Control Systems

The environmental conditions in the NSLS-II accelerator tunnel and experimental spaces must be precisely controlled to ensure the optimal performance of the accelerator and the research instruments. Standard commercial HVAC controls typically utilized for office environments will be inadequate to meet these requirements. The NSLS-II tunnel and experimental spaces will be monitored and controlled by a combination of commercial HVAC controls and industrial grade process controls linked to a direct digital control system specially programmed to serve the precise requirements. The overall performance and monitoring of this system will be linked to, and continuously monitored by, the BNL sitewide Energy Management Control System (EMCS).

2.2.10 Communications

The communications systems distribute data and telephone communications. Generally, these provisions encompass the installation of cabling, equipment, and tie-in terminations by the BNL Communications Division.

The telephone service, with its fiber optic-based cable network and support equipment, will be connected to the facility's experimental, laboratory, office, and supporting mechanical/electrical rooms via an underground concrete-encased duct bank to the mechanical room.

A public address system is provided, for communication to staff in the various buildings and work areas. This system is integrated into the Fire Alarm Control Panels.

2.2.11 Facility Access Control

NSLS-II is equipped with an access control system in the form of card readers to restrict entry to authorized personnel (similar to NSLS). The card readers are located at each exterior entrance to the building.

2.3 Accelerator Systems

The following are the basic operational parameters of the NSLS-II Accelerator Systems.

2.3.1 Electron injection system

NSLS-II will incorporate a full energy injection system for the NSLS-II. It will utilize an electron source that feeds a linear accelerator (linac) to accelerate the electrons up to an energy of ~200 million electron volts. The linac will be housed in a shielded enclosure. The electrons from the linac, at 200 million electron volts, will be transported to a booster ring. Once the electrons are in the booster, they will be further accelerated to an energy of 3.0 billion electron volts, at which time they will be directed out of the booster and transported into the storage ring.

2.3.2 Electron Storage Ring

NSLS-II is based on a single electron storage ring creating synchrotron radiation that spans light wavelengths from the infrared to hard x-rays. The parameters of the ring are shown in Table 2.2.

Table 2.2: NSLS-II Electron Storage Ring Parameters.

PARAMETER	UNIT	VALUE
Beam Energy	GeV	3
Design Maximum Beam Current	mA	500
Circumference	m	792
Lattice Type		Double Bend Achromat (DBA)
Number DBA Cells		30
Lattice Periodicity		15
Bending Magnets		60
Bending Radius	m	25
Number Quadrupole Magnets		300
Maximum Quadrupole Gradient	T/m	22
Quadrupole Lengths	m	0.25, 0.275, 0.283, 0448
Number of quadrupole circuits/power supplies		300
Number of Sextupole magnets		270
Sextupole Strength	T/m^2	400
Number of sextupole families/power supplies		54
Short ID straight sections		15
Length of short ID straight sections	m	6.6
H/V Lattice functions in center of short ID straight	m	2/1
Long ID straight sections		15
Length of long ID straight sections	m	9.3
H/V Lattice functions in center of long ID straight sections	m	21/3
Maximum value of the dispersion function	m	0.46
Number of DC dipole correctors		180
Maximum corrector kick at 3 GeV	mrad	0.8
Number of AC dipole correctors		90
Horizontal beam emittance (bare lattice)	nm	2
Horizontal beam emittance (damping wiggler)	nm	1
Vertical beam emittance	nm	0.008
rms beam energy spread (with damping wiggler)		0.10%
H/V/L Radiation Damping times	ms	55/55/27 (without damping wigglers) 22/22/11 (with damping wigglers)
Damping wigglers (DW)		6
Damping wiggler period	mm	100
Damping wiggler length	m	3.4
Damping wiggler peak field	T	1.85
Power of radiation emitted by the Beam (w/ DWs)	kW	337
RF Frequency	MHz	499.68
Installed RF Power	MW	0.62(1.24*)
RF Voltage	MV	4.8(9.6*)
Number of superconducting cavities		2(4*)
3rd 1.5GHz-harmonic cavities		1(2*)

Harmonic Number		1320
Synchrotron Frequency	kHz	3-4
Total Peak Power Consumption	MW	~18

*At full build-out.

2.3.3 Magnet Insertion Devices

Various types of magnets will maintain the electrons in their proper orbital patterns around the storage ring. For the NEXT and ABBIX projects, magnetic insertion devices to be used to create the synchrotron radiation emitted by the circulating electrons will be In Vacuum Undulators (IVU), Dampling Wigglers (DW) and Elliptically Polarizing Undulators (EPU), . Insertion device parameters are identified in Table 2.3 (next page).

2.4 Operations

NSLS-II is anticipated to operate 24 hours a day, seven days a week. Periods of shutdown for routine maintenance and studies will be scheduled to maximize the beam time available for researchers.

The electron storage ring will serve multiple experiments at a given time, based on the number of operating beamlines. A staff of ~500 and an annual user population of ~3,500 are anticipated. Approximately 5,500 hours of beam time will be delivered per year to the users.

In addition to accelerator and beamline operations, many other support operations will be in place, including the safety system, mechanical, electrical, vacuum, accelerator and beamline research and development, instrumentation systems, and administrative support.

Detailed operational controls will be established and documented in the Safety Assessment Document (SAD) and Accelerator Safety Envelope (ASE) as required by DOE “Safety of Accelerator Facilities,” Order 420.2C. Operational controls will also be established in the Conduct of Operations manual as required by DOE Order 422.1 “Conduct of Operations.”

Table 2.3: NSLS-II Insertion device parameters.

Beamline	ID straight type	ID type, including period (mm)	Length	K_{max}*	FE type†	FE aperture (h x v, mrad)	No. of IDs (base scope)	No. of FEs	Project
ESM	lo-β	EPU105 (PPM)‡ EPU57 (PPM)	2.8 m 1.4 m	11.2 4.4	Standard	0.7 x 0.7	2	1	NEXT
SIX	hi-β L	EPU57 (PPM) x2	7.0 m (2 x 3.5 m)	4.4	standard	0.3 x 0.3	1	1	NEXT
ISR	hi-β H	IVU23 (H)	2.8 m	2.1	canted** (2.0)	0.5 x 0.3	1	1	NEXT
SMI	hi-β L	IVU23 (H)	2.8 m	2.1	canted** (2.0)	0.5 x 0.3	1	1	NEXT
ISS	hi-β H	DW100 (H)	6.8 m (2 x 3.4 m)	~16.5	damping wiggler	1.1 x 0.15	0	1	NEXT
FXI	hi-β H	DW100 (H)	6.8 m (2 x 3.4 m)	~16.5	damping wiggler	0.8 x 0.3	0	1	NEXT
FMX	lo-β	IVU21 (H)	1.5 m	1.79	canted (2.0)	0.5 x 0.3	1	1	ABBIX
AMX	lo-β	IVU21 (H)	1.5 m	1.79	canted (2.0)	0.5 x 0.3	1	0 (joint w/FMX)	ABBIX
LIX	hi-β L	IVU23	2.8 m	2.1	standard	0.5 x 0.3	1	1	ABBIX

* Depends on location within ID straight section

** Off-center canting magnet location in ID straight section

† For canted IDs/FEs, ( ) shows canting angle in mrad

‡ ESM long period undulator shall be a quasi-periodic device

3 HAZARD ANALYSIS

3.1 Identification Methodology for Hazards

Several completed NSLS-II hazards analyses were utilized to identify potential hazards for the NEXT and ABBIX Beamlines, including:

- Baseline Hazards List (BHL)
- Preliminary Hazards Analysis (PHA)
- Preliminary Safety Assessment Document (PSAD)
- NEXT Preliminary Hazard Analysis Report (PHAR)
- NEPA and NESHAP evaluations
- NSLS Safety Basis documentation
- Fire Hazards Analysis

Additional resources included beamline managers, subject matter expertise (with conventional facilities, accelerator systems, and ESH), and lessons learned from the DOE accelerator community, including design criteria, regulatory requirements, and occurrences. The HAR also includes a preliminary (pre-mitigation) risk assessment of the hazards at the sub-system level. This pre-mitigation assessment is to demonstrate the risk before incorporating sub-system design and operational controls. The identified hazards have been further developed in this HAR by considering the proposed ESH design enhancements and design evolution. Then, these risks in the HAR have been re-analyzed and, in certain cases, operational controls to develop a post-mitigation risk category have also been included (see section 3.2.2, Hazard Analysis and Risk Assessment). This post-mitigation risk category conveys a realistic assessment of the residual risks posed by the operations of the NEXT and ABBIX beamlines.

3.2 Hazard Analysis and Risk Assessment

The methodology of the HAR hazard and risk assessment is to qualitatively evaluate each hazard area by identifying the initiator of the hazard and its consequences, establishing a pre-mitigation risk category, recognizing design features to mitigate that risk, then establishing a post-mitigation risk category. Table 1.1 summarizes the pre- and post-risk categories. The risk consequences, probabilities, and categories are defined in Tables 5.1, 5.2, and 5.3. The HAR documents the residual risk after incorporating the proposed mitigations and serves as a checklist for the NEXT and ABBIX Beamlines design process. The proposed mitigating factors will be built in as required or as appropriate, as the design progresses.

The following hazards are specifically addressed in this assessment: natural phenomena, environmental, waste, fire, electrical, vacuum, noise, cryogenic/oxygen deficiency, chemical/nano-materials/biological materials, ionizing radiation, non-ionizing radiation, material handling, and experimental equipment.

3.2.1 Natural Phenomena Hazards (NEXT/ABBIX HAR-1)

3.2.1.1 Natural Phenomena Hazards

Natural Phenomena Hazards (NPH) include high winds/tornado, snow/ice, floods due to rain, lightning, and earthquakes. The NSLS-II design is governed by the Building Code of New York State (BCNYS), which specifies design criteria for wind loading, snow loading, lightning protection, and seismic events. The NSLS-II facility as a whole will contain small quantities of activated, radioactive, and hazardous chemical materials. If a NPH were to cause significant damage, the impact would be mission related (worker injury, equipment or building damage, local release of hazardous materials, or programmatic impact) and would not pose a hazard to the public or the environment. Based on the guidance in DOE Standard 1021-93 (Change 1), *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems and Components*, the NPH mitigation Performance Category for the NSLS-II facility is PC-1, based on the identified hazards and potential consequences. The Standard defines PC-1 as:

(i) It is a building/structure with potential human occupancy.

(ii) Failure of the structure, system, or component (SSC) may cause a fatality or serious injuries to in-facility workers.

(iii) Failure of the SSC may cause damage that can be prevented or reduced cost-effectively by designing it to withstand NPH effects.

Management and control of NPH follow the requirements in:

- DOE Order 420.2C, *Safety of Accelerator Facilities*
- DOE Guide 420.2-1, *Accelerator Facility Safety Implementation Guide*
- DOE Order 420.1C, *Facility Safety*
- DOE STD 1020-2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*
- DOE STD 1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems and Components*
- DOE STD 1022-94, *Natural Phenomena Hazards Site Characterization Criteria*
- DOE STD 1023-95, *Natural Phenomena Hazards Assessment Criteria*
- *Building Code of New York State*
- ANSI/UL-96A, *Installation Requirements for Lightning Protection Systems*
- NFPA-780, *Standard for the Installation of Lightning Protection Systems*
- BNL SBMS subject area *Engineering Design*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.1. The pre-mitigation risk is categorized as Low and the post-mitigation risk is categorized as Routine.

Natural phenomena that could lead to operational emergencies at BNL include hurricanes, tornadoes, thunderstorms, lightning, snowstorms, and ice storms. Hurricanes occasionally hit Long Island, and the associated high winds could potentially damage structures. Tornadoes and hailstorms are rare on Long Island. Thunder and rain storms, snowstorms, and ice storms occasionally occur and potentially could cause significant damage, entailing an operational emergency. However, operational emergencies do not involve loss of operational control or significant releases of hazardous or radiological material. In such an emergency, BNL management would decide whether to shut down operating facilities, shelter workers, or evacuate workers from the site.

Typical severe weather-related phenomena, either local or non-local, may affect the stability of electrical power supplied to the NSLS-II facility and so could impact the stability of the accelerator's magnet power supplies, resulting in the loss of stored electron beam. Radiological shielding protects personnel from such losses. If BNL were to declare a significant weather-related operational emergency and recommend that staff shelters or evacuates the site, the ring operators would take appropriate emergency procedures to secure/de-energize the NSLS-II and its beamlines. The Photon Sciences Directorate could also take action in advance of any BNL-wide direction. To date, the BNL site has experienced only minimal impacts from extreme weather, typically the incursion of rainwater (leaks in roofs and flooding under doors). Localized flooding could increase the potential for electrical hazards. Depending on the area and height of the floods, there is some possibility for minor chemical and lead (from shielding) contamination of flood water, but no possibility for its radiological contamination. The electrical hazards would be mitigated by 1) having properly grounded and bonded electrical equipment mounted on platforms or held in racks above floor level, 2) maintaining sumps (pumps powered by the emergency generator), 3) having adequate drainage that prevents water from accumulating. Chemical hazards would be mitigated by storing chemicals in cabinets and on shelving above the floor.

In recent years, the BNL site has been shut down for upwards of two days following rain or snow storms. The purpose for these shutdowns was to allow for power restoration or adequate snow removalfrom roads and walkways.

Earthquakes on Long Island are extremely rare. The probable occurrence of an earthquake sufficiently intense (>5.6 on the Richter scale) to damage buildings, accelerators, and reactor structures in the BNL area was investigated during planning before construction of the Brookhaven Graphite Research Reactor, High Flux Beam Reactor, and Relativistic Heavy Ion Collider. These investigations remain valid, and seismologists expect no significant earthquakes in the foreseeable future. No active earthquake-producing faults are known in the Long Island area.

3.2.1.2 Design Loads

To mitigate the effects of natural phenomena hazards, the following design loads have been incorporated into the design of the NSLS-II buildings.

Live Loads	*Design*
Injection building	250 psf
Booster ring	250 psf
Booster service building	150 psf
RF building	150 psf
Office mezzanine	100 psf
Equipment mezzanine	125 psf
Storage Ring tunnel	250 psf
Storage Ring mezzanine	250 psf
Experimental hall	250 psf
Ring building corridors	125 psf
Ring building Service Buildings	150 psf
Lab Office Buildings	100 psf
Laboratories	125 psf
Offices, corridors	100 psf
Mechanical rooms	150 psf
NEXT SIX Hutch	250 psf

Snow Loads	*Design*
Ground snow load Pg	30 psf
Snow importance factor I	1.0 (Category II)
Snow exposure factor Ce	0.9
Thermal Factor Ct	1.0
Design snow load	30 psf (minimum) + drift where applicable

Earthquake Loads	*Design*
Short period acceleration Ss	0.25 g
1-second period acceleration S1	0.08 g
Site Class	D
Seismic Use Group	I
Seismic Design Category	B
Seismic Importance Factor I_E	1.0 (Category II)

Wind Loads	*Design*
Basic wind speed (3-sec. gust)	120 mph
Wind load importance factor I_W	1.00 (Cat. II)
Wind exposure	B

3.2.2 Environmental Hazards (NEXT/ABBIX HAR-2)

A detailed environmental analysis is contained in the *Environmental Assessment* for NSLS-II (DOE/EA 1558), for which a *Finding of No Significant Impact* was issued on September 27, 2006. In June 2008, a comparison was made between the NSLS-II Title II design and the 2006 EA findings. The BNL NEPA Coordinator determined, with DOE concurrence, that no new adverse environmental impacts had been identified and design specifications are within the scope of the existing EA. An Environmental Evaluation Notification Form was developed for the NEXT beamlines, and a similar finding was made.

Environmental hazards associated with the NEXT and ABBIX Beamlines include the potential discharge of the following materials to soil, surface water, groundwater, air, or the sanitary system: oils, solvents and inert gases (activated air products are described in section 3.2.14). The principal initiators would be the failure of equipment, impact from a natural phenomenon, fire, or a violation of procedures.

Management and control of environmental hazards follow the requirements in:

- DOE *National Environmental Policy Act* (10 CFR 1021)
- 6 NY CRR Parts 613 and 614 secondary containment criteria *National Emission Standards for Hazardous Air Pollutants* (NESHAP) (40 CFR 61 - Subpart A)
- NYSDEC *Prevention and Control of Air Contamination and Air Pollution* (6 NYCRR 200 – 234)
- Code of Federal Regulations, *National Pollutant Discharge Elimination System* (40 CFR 122-131, 133)
- NYSDEC *State Pollutant Discharge Elimination System (SPDES) Permits* (6 NYCRR 750)
- Code of Federal Regulations, *Hazardous Waste Management Regulations* (40 CFR 260-262, 264-265)
- NYSDEC *Hazardous Waste Management Regulations* (6 NYCRR 270-374-2)
- International Organization for Standardization - *Environmental Management System* – ISO 14001
- BNL SBMS subject area *Environmental Aspects and Impacts*
- BNL SBMS subject area *Environmental Assessments and ESH Management Review*
- BNL SBMS subject area *Environmental Monitoring*
- BNL SBMS subject area *Liquid Effluents*
- BNL SBMS subject area *Storage and Transfer of Hazardous and Non-Hazardous Materials*
- BNL SBMS subject area *Pollution Prevention/Waste Minimization*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.2. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

Oil from the facility is minimized, where possible, by the use of oil-free pumps. Oil-filled pumps are operated within secondary containment, where necessary, to protect against leaks and spills. Aerosolized oil is exhausted through filters to the exterior of the facility.

The NSLS-II environmental program is overseen by the Photon Sciences Directorate ISO 14001 Environmental Management System (EMS), as documented in the Photon Sciences Directorate EMS/OHSAS web site.

The NSLS-II facility established a goal of obtaining Leadership in Energy and Environmental Design (LEED) certification that contains requirements for sustainable design principles, pollution prevention, and waste minimization during construction and operations.

There will be some temporary rise in emissions due to construction (e.g., from vehicles and other equipment). Other increases will reflect the increased use of steam, chilled water, and electricity for constructing and operating the facility.

Oil from the facility and the experimental support equipment will be minimized where possible by using oil-less pumps and synthetic oils and by adequate secondary containment where necessary. The emission points for aerosolized oil will be identified and documented, and it will be vented to the exterior of the facility through filters as necessary.

Beamlines using radioisotopes and/or biological material will be controlled by specific facility procedures, rendering remote the likelihood of these materials entering the sanitary or groundwater systems. Any work with potentially airborne radioactive material, biological materials, or unbound engineered nanomaterials will be conducted within a laboratory exhaust hood or beamline enclosure equipped with HEPA filtration. Radioactive emissions will undergo a NESHAPS assessment by the Lab's Subject Matter Expert for Radiological Emissions in order to determine any applicable NESHAP permit requirements.

Exhaust hoods are installed in laboratories that utilize chemicals. Certain beamline hutches also will be connected to a general exhaust ventilation system if the experimental program warrants it. The products emitted to the ambient air from hoods or hutches typically will consist of trace emissions of evaporated solvents, acids, and other chemicals. Any need to exhaust toxic or highly toxic materials will necessitate the design and installation of dedicated exhaust ventilation systems. These emissions will be associated with research and development and, therefore, would be exempt from Federal and New York State permitting requirements. Experiments and work undertaken at NSLS-II will be reviewed, with input from the Experimental Review Coordinator (ERC) (and the Environmental Compliance Representative (ECR), as needed), to identify and manage the types and quantities of chemicals used. The ERC will ensure that

all safety reviews are undertaken for each activity and that any issues will be addressed. The ECR is knowledgeable in environmental compliance areas and will be responsible for identifying and assisting in resolving any environmental problems. The Instrument Readiness Review (IRR) and Experimental Safety Review (ESR) process will document these reviews and their controls. An active pollution prevention program at NSLS-II will consider alternatives to the chemicals used that might reduce the emissions released. The quantities of chemicals brought to NSLS-II will be kept to the minimum necessary to complete an experiment and to remain within the limits established for the building occupancy and ESR requirements (see Chemicals and Hazardous Materials, section 3.2.9).

3.2.3 Waste Hazards (NEXT/ABBIX HAR-3)

Waste-related hazards from the NEXT and ABBIX Beamlines include the potential for releasing waste materials (oils, solvents experimental samples (hazardous, biological, radiological) to the environment and injury of personnel. Typical initiators would be transportation accidents, improper storage of incompatible materials, insufficient packaging/labeling, failure of the packaging, a natural phenomenon, or a procedural violation.

The management and control of waste hazards will follow the requirements in:

- BNL SBMS subject area *Biosafety in Research*
- BNL SBMS subject areas *Hazardous Waste Management*
- BNL SBMS subject area *Industrial Waste Management*
- BNL SBMS subject area *Mixed Waste Management*
- BNL SBMS subject area *Radioactive Waste Management*
- BNL SBMS subject area *Regulated Medical Waste Management* (including references to nano-wastes)
- BNL SBMS subject area *Spill Response*
- BNL SBMS subject area *Nanoscale Particle ESH*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.3. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

The waste oil from mechanical pumps is reduced due to the use of oil-free pumps to back the turbomolecular pumps for roughing down vacuum systems and during system conditioning. Deionizing columns are recharged off site by a vendor, thus column recharge waste waters are not being created on site; follow-up with the vendor to ensure proper handling of wastes will also be done. Supply, use, waste, and disposal through these and other systems are documented by the Environmental Compliance Representative through the use of Process Assessment Forms (PAF). The Photon Sciences Directorate participates in the BNL pollution prevention program and uses the Environmental Management System to set goals for environmentally friendly design techniques and waste reduction, where practical.

90-day Waste Accumulation Areas and local Satellite Accumulation Areas are provided where required to help ensure compliance.

Safety inspections, periodic Chemical Management System (CMS) audits and internal inventory management, chemical limits specified by the NSLS-II Fire Protection Design Strategy, and Emergency Preparedness Hazard Assessments are major factors in maintaining the facility's chemical inventory at minimum levels needed to operate. Many processes do not generate any waste. Any need for exposure monitoring of waste operations would be assessed.

Every effort will be made to keep waste materials to a minimum. Experimenters work with the Experimental Review Coordinator during the review process to anticipate, report, and minimize waste materials. Wastes from the experimental program (hazardous, biological, radiological) that are considered hazardous are disposed through the BNL Hazardous Waste Management Facility.

3.2.4 Fire Hazards (NEXT/ABBIX HAR-4)

Extensive design criteria are established through NFPA, BCNYS, and DOE. Typical hazard initiators include equipment failure, accumulation of combustible/flammable materials, the use of pyrophoric or reactive materials, improper storage/use of flammable materials, inadequate or out of service fire detection and suppression, lightning storm, and electrical hazards due to static discharge. These could result in injury or death to workers, equipment damage or loss, release of hazardous materials to the environment, and programmatic impact.

The management and control of fire hazards follow the requirements in:

- *Building Code of New York State*
- BNL SBMS subject area *Fire Safety*
- BNL SBMS subject area *Lockout/Tagout (LOTO)*
- See the *NSLS-II Fire Protection Assessment/Fire Hazard Analysis* for a complete list of NFPA standards

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.4. The pre-mitigation risk is categorized as High and the post-mitigation risk is categorized as Low.

A detailed *NSLS-II Fire Protection Assessment/Fire Hazard Analysis* (FPA/FHA) has been prepared by the BNL Fire Protection Engineer. The level of fire protection in NSLS-II is classified as "improved risk," thereby meeting the objectives of DOE Order 420.1C. While NSLS-II is considered a high-value property (greater than $1 billion at full build-out), the noncombustible construction of the building and the accelerator is expected to keep the Maximum Potential Fire Loss (MPFL) of the facility-at-large to $5.5 million. The FPA/FHA outlines the MPFL calculations and assumptions, and provides as well the NSLS-II Fire Protection Design Strategy. Elements of this strategy have been summarized in section 2.2.7 above as applicable for the NEXT and ABBIX beamlines.

The experimental floor is 100% sprinklered with a hydraulically designed wet pipe system, and is equipped with High Sensitivity Smoke Detection (HSSD) system. While this action ensures excellent protection of the structure and contents, some concerns arise from the potential of water discharging on energized and high-value equipment, either during a fire event or from a false discharge. The false discharge risks are minimized by the qualified engineers' system designs, the high quality of installation materials, and pressure testing before placing the system into service. Further protection against leaks is afforded by incorporating any BNL-approved chemicals to control Microbial Induced Corrosion (MIC). Each beamline will have sprinkler system supply and return stubs available on the mezzanine above each beamline (in case sprinklers need to be brought into the hutches based on experimental needs).

A smoke control management system has been provided in the experimental floor/mezzanine level of the ring building, the ring tunnel and the booster ring in the injection building. The smoke control system can be manually activated at keyed smoke control panels adjacent to the fire alarm panels supporting the areas being protected. Smoke control systems can also be activated by two smoke detection zones, heat detectors, or water flow switches. The sequence of operation of the smoke control management system is to go in to 100% exhaust mode in the activated zone, while adjacent smoke control management system zones will go into 100% supply air.

The combustible loads and the use of flammable and/or reactive materials in the facility are controlled via the BCNYS building occupancy classification. The initial occupancy of the overall Injection Building has been determined to be Business (Group B) occupancy, based on the anticipated amount of hazardous materials and chemicals to be used. This occupancy classification sets the threshold for the maximum amount of hazardous material permitted in the facility. Evaluation of the existing NSLS chemical inventory and operations is a good indicator of the types and amounts of hazardous materials that are anticipated to be present in NSLS-II. The "controlled area" concept, allowed by BCNYS, is followed to provide the greatest amount of flexibility and control of materials by allowing inventory thresholds per controlled area ("controlled area" in this sense is a specified area, for instance a laboratory, that has a defined limit on the quantities and types of chemicals allowed to be within that area).

The NSLS-II facility complies with the design requirements in BCNYS for egress requirements; this also satisfies OSHA 1910 requirements. The BCNYS includes designing egress routes to ensure the safe exit of occupants from fires by imposing limitations on the maximum travel distance, maximum dead-end path lengths, protection of egress paths, emergency lighting of egress paths, and egress signage. NSLS-II will undergo annual evacuation drill exercises to ensure that building occupants respond adequately to such emergencies. All egress requirements in the BCNYS are met for the NSLS-II design.

3.2.5 Electrical Hazards (NEXT/ABBIX HAR-5)

Reflecting operational experience across the DOE complex and at BNL accelerators with electrical-related occurrences and injuries, the post-mitigation risk is deemed to be low due to the design and operational mitigations, especially due to strict adherence to codes. Typical initiators include electrical shock and arc flash from exposed conductors, potentially resulting in severe injury or death or damaged equipment as a result of unmitigated hazards, can be caused by exposed conductors, defective and substandard equipment, lack of adequate training, or improper procedures. Fire and smoke from defective overheated equipment/components has been experienced at other accelerators.

The management and control of electrical hazards follow the requirements in:

- BNL SBMS subject area *Electrical Safety*
- BNL SBMS subject area *Lockout/Tagout (LOTO)*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.5. The pre-mitigation risk is categorized as High and the post-mitigation risk is categorized as Low.

NSLS-II will have a large amount of high power and high voltage electrical equipment. Power distribution systems for NSLS-II facilities will be designed in strict compliance with NFPA 70. All systems will be grounded. Particular care will be provided for cable distribution to ensure code compliance with cable tray loading and content requirements. All electrical equipment and cables and cable trays will be protected against mechanical hazards.

All electrical equipment and installations must be approved by the Laboratory Authority Having Jurisdiction (AHJ). Approval is straightforward for equipment bearing the seal of a Nationally Recognized Testing Laboratory (NRTL), such as Underwriters Laboratories, Inc. (UL) or the Canadian Standards Association (CSA). OSHA requires that NRTL labeled equipment must be acquired whenever available, even if similar unlabeled equipment can be used. OSHA allows the approval of custom-made equipment or related installations, if, on the basis of test data, its manufacturer determines it to be safe for its intended use.

From prior experience, NSLS-II is anticipated to either use custom-made specialized equipment or foreign-made non-listed equipment for the experimental program. Such equipment will require review by the BNL Electrical Equipment Inspection (EEI) program which evaluates all equipment that does not have NRTL certification. Experimental equipment that is not NRTL-listed is required to be inspected and certified by a qualified person at BNL using established laboratory criteria to ensure that it affords the same level of protection as a NRTL-listed device. Attention will be needed during design and in installation to ensure adequate access and work clearance as defined by NFPA 70.

Particular attention is also needed to address NFPA 70E requirements to protect workers against electrical arc flash and shock hazards. Arc flash analyses will be required prior to operation to ensure the proper labeling of all electrical panels and switch boxes. High voltage switches, breakers, etc. will be evaluated during design to provide remote operation where possible to eliminate the need for workers to have direct contact with the devices while operating them. Attention will also be needed during design of electrical equipment to provide lock-out tag-out capability and to prevent the need to service energized components. Lessons learned in operating NSLS revealed that inadequate access to power at the beamline and hutch locations significantly contributes to electrical violations. Plug-powered equipment for experimental programs frequently is moved or replaced; adequate numbers and types of receptacles are needed to prevent excessive running of extension cords and overloading of circuits. The NSLS-II beamline layout will address the need for adequate power distribution.

3.2.6 Beamline Vacuum and Cooling Hazards (NEXT/ABBIX HAR-6)

The vacuum and cooling water are critical to properly operating the beamlines. Vacuum or cooling failure at NSLS-II could result in damage to equipment, programmatic impact, or injury to personnel. Initiators could be vacuum equipment failures, improper procedure, natural phenomena, fire, or operator error.

Management and control of vacuum hazards will follow the requirements in:

- ASME *Pressure Vessel Code*

- ASME B31.3 *Process Piping Design*
- 10 CFR 851, Appendix A, Part 4, *Pressure Safety*, section C
- BNL SBMS subject area *Pressure Safety*, section "*Vacuum Systems Consensus Guidelines for Department of Energy Accelerator Laboratories*"
- BNL SBMS subject area *Beryllium*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.6. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

Appropriate design of the vacuum systems and components plays an important role in providing effective machine operation and personnel safety. Proper accelerator vacuum ensures long stored electron beam lifetimes and minimizes the generation of bremsstrahlung radiation. Proper vacuum reduces corrosion to component surfaces. Systems must be designed to prevent personnel injury produced by vacuum system collapse or rupture, or by an over-pressurization of the system from an external pressure source.

The design of synchrotron radiation facilities must address several types of potential vacuum accidents: rupture of vacuum windows/view ports, breakage of the ceramic insulator of a feed-through, damage of a vacuum wall of a cooling channel by mis-steered beam, and failure of pneumatic devices. With the exception of vacuum window breakage, most of these failures are slow to develop in the absence of a pressure shock wave, and are handled by the vacuum interlock systems through dedicated vacuum programmable logic controllers in the Equipment Protection System (EPS).

Sudden collapse or failure of the vacuum vessel or windows could result in a loud pressure wave with the potential for hearing injury to personnel close to the point of failure. Such failures are minimized through the application of solid engineering principles and practices in the design and operation of all vacuum systems. All vacuum vessels are designed to ensure that allowable American Society of Mechanical Engineers (ASME) stresses for vacuum systems are not exceeded and to ensure that the vessel is stable (i.e., resistant to buckling). An independent design review has been performed to confirm appropriate design and engineering practice. In addition Beryllium windows are often used in beamline applications; rupture of these windows due to a vacuum failure could cause a beryllium contamination issue.

In addition, instrumentation is provided to quickly detect and isolate a vacuum failure. If an accelerator vacuum fault is detected, sector valves will close to limit contamination (from air) to as small an area as possible. This automatically dumps the stored electron beam. Rupture of any windows in or adjacent to the Storage Ring will cause significant programmatic down time. Radiological consequences of vacuum failure are discussed in section.

Cooling water flow for beamline systems will be interlocked to the beamline safety shutter through the personnel protection interlock system to protect cooled systems from illumination by the synchrotron beam, if the water flow is interrupted. The accelerator's flow of cooling water will be interlocked to the

appropriate power supplies for cooled accelerator components. Heat sensors will also be interlocked to system power supplies.

3.2.7 Noise Hazards (NEXT/ABBIX HAR-7)

Hazards from noise include overexposure of personnel to ACGIH and OSHA occupational exposure limits due to pumps, mechanical systems, HVAC systems and intermittent energy releases. These overexposures could induce permanent hearing loss, also known as Permanent Threshold Shift (PTS). The overall design goal for NSLS-II is to achieve Noise Criteria 60 dBA or better in the majority of spaces; mechanical spaces will have higher noise levels. Typical initiators include defective or improperly installed pumps, mechanical systems, HVAC.

Management and control of noise hazards will follow the requirements in:

- BNL SBMS subject area *Noise and Hearing*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.7. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Routine.

NSLS-II will incorporate a wide variety of equipment that will produce a range of noise and vibration. Support equipment, such as vacuum pumps, motors, fans, and general HVAC all contribute to point source and overall ambient noise levels. While noise will typically be below the OSHA 8 hr and ACGIH time weighted average, certain areas with mechanical equipment could exceed those criteria and will require periodic monitoring, posting, and the use of Personal Protective Equipment (PPE). Ambient background noise is a greater concern from the standpoint of users' comfort, stress level, and fatigue. Background noise in the accelerator and experimental areas at the existing NSLS is a common quality-of-life complaint and is distracting when trying to hear safety announcements and alarm systems.

Methodologies to reduce noise and vibration have been incorporated into the NSLS-II design. These techniques include using low noise/vibration producing equipment, especially for fans in the HVAC equipment, isolating the noise producing equipment by segregating or enclosing it, and using sound deadening materials on the walls and ceilings of areas. This methodology will be carried forward for beamline design.

Baseline and periodic area surveys of noise will be conducted in accord with OSHA requirements. Based on dosimetry results in certain areas of high noise, employees working there may be put on a medical hearing protocol and be required to wear hearing protection.

3.2.8 Cryogenic, Oxygen Deficiency, and Pressure Hazards (NEXT/ABBIX HAR-8)

Cryogenic hazards at NSLS-II will include the potential for oxygen deficient atmospheres due to catastrophic failure of the cryogenic systems, thermal (cold burn) hazards from cryogenic components, and pressure hazards. Initiators could include the failure/rupture of cryogenic systems from overpressure, failure of insulating vacuum jackets, mechanical damage/failure, deficient maintenance, or improper procedures.

Management and control of cryogenic and pressure hazards will follow the requirements in:

- BNL SBMS subject area *Cryogenics Safety*
- BNL SBMS subject area *Compressed Gas Cylinders and Related Systems*
- BNL SBMS subject area *Pressure Safety*
- BNL SBMS subject area *Oxygen Deficiency Hazards, System Classification and Controls*
- American Society of Mechanical Engineers (ASME) *Boilers and Pressure Vessel Code*, sections I through XII, including applicable Code Cases, (2004) ASME B31 (ASME Code for Pressure Piping) as follows:
  - (i) B31.1–2001, *Power Piping*, and B31.1a–2002, *Addenda to ASME B31.1–2001*
  - (ii) B31.2–1968, *Fuel Gas Piping*
  - (iii) B31.3–2002, *Process Piping*
  - (iv) B31.4–2002, *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*
  - (v) B31.5–2001, *Refrigeration Piping and Heat Transfer Components*, and B31.5a - 2004, *Addenda to ASME B31.5–2001*
- 29 CFR 1910.134, *OSHA Respiratory Protection Standard*
- 10 CFR Part 851, Appendix A, Functional Area 4, *Pressure Safety*
- Chapter 32, 2007 *Fire Code of NYS*
- CGA Pamphlet P-18

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.8. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

Large volumes of inert cryogen liquid (nitrogen) will be piped into and around the NSLS-II facility and to the beamlines from a centralized distribution point. In addition, Dewar vessels (typically up to 500 liters) will be used locally in experiments.

Liquid nitrogen and liquid helium will be used for keeping experimental samples cold, such as protein crystals. They also will be used to cool beamline equipment, such as monochromators and detectors. ODH analyses will be conducted in areas at risk for releasing significant amounts of inert gases (an example would be the use of cryogens to cool monochromator crystals in the beamline First Optical Enclosures). ODH mitigation could include employing oxygen deficiency sensors that alarm locally, or read back into the Control Room at times when oxygen levels fall below preset levels (OSHA 29CFR 1910.146 considers atmospheres containing less than 19.5% oxygen by volume to be oxygen deficient); and piping to direct gasses from pressure relief valves or burst disks to the exterior of the building. Emergency response procedures will be developed for responding to these alarm systems.

Dewar vessel filling stations and piping systems will be evaluated for ODH risk and handled as described above. Usage of these systems will be limited to trained personnel. PPE (gloves, goggles, face shields) will be supplied at the station and their use required. A written operator aid will be posted at the fill station and used when training users.

All piping systems and storage systems will be designed and installed to comply with applicable ASME and ANSI standards. The BNL Laboratory Cryogenic Safety Committee (LCSC) is the Authority Having Jurisdiction for reviewing cryogenic systems.

With any cryogenic system there is a potential for thermal burns. The facility's distribution systems will be adequately marked and insulated from inadvertent contact. Small systems to support the experimental programs will be evaluated through the Experimental Safety Review program to ensure that they are properly designed, and that operators are trained and qualified. All staff, visitors, and users of NSLS-II, as with all accelerator complexes, will undergo general hazard awareness training that will cover the potential hazards of cryogenic material.

The accelerator vacuum systems have the potential for pressurization under certain failure scenarios associated with the back-fill nitrogen system. The probability of such failure in these systems will be minimized by design in accordance with ASME *Pressure Vessel Code* and B31.3, *Process Piping Code*. However, because of this potential, design of the accelerator vacuum systems must address 10 CFR 851, Appendix A requirements for pressure systems. ASME *Pressure Vessel Code* requirements apply to any vacuum system that can be over-pressured to ≥15 psig. A standard has been developed: *Consensus Standard for the Design, Construction, Operation, Inspection, and Maintenance of Vacuum Vessels and Associated Components at DOE Accelerator Laboratories.*" This standard identifies design features that satisfy the requirements of 10 CFR 851 and has been incorporated into the BNL SBMS *Pressure Safety* subject area. A key feature in this standard is the use of pressure relief devices to prevent over-pressurization by back-fill. These devices must keep pressure in the vacuum space from exceeding 15 psig during a failure in the nitrogen gas or cryogenic systems. The design of the NSLS-II accelerator and beamline vacuum systems includes pressure relief devices that satisfy the requirements of this consensus standard and are installed to discharge away from occupied spaces. Pressure relief devices are reviewed by BNL Safety and Health Services personnel. The vacuum system underwent an ESH Design Review in 2008 by a committee with broad BNL representation. The attachment, piping, and labeling of compressed gas systems will comply with BNL requirements

3.2.9 Chemicals and Hazardous Materials, Including Nano-materials and Biological Materials (NEXT/ABBIX HAR-9)

Chemical, biological and nano- materials used at NSLS-II could result in injury, death, or exposures that exceed regulatory limits. Initiators could be experimental operations, transfer of material, failure of packaging, improper marking/labeling, failure of fume hood/glovebox, reactive or explosive event, improper selection of or lack of personal protective equipment (PPE), improper procedure or a natural phenomenon.

Management and control of chemical hazards will follow the requirements in:

- BNL SBMS subject area *Chemical Safety*
- BNL SBMS subject area *Biosafety in Research*
- BNL SBMS subject area *Beryllium*
- BNL SBMS subject area *Nanoscale Particle ESH*
- BNL SBMS subject area *Work Planning and Control for Experiments and Operations*
- BNL SBMS subject area *Bloodborne Pathogens*
- BNL SBMS subject area *Compressed Gas Cylinders and Related Systems*
- BNL SBMS subject area *Electrical Safety*
- BNL SBMS subject area *Exhaust Ventilation*
- BNL SBMS subject area *Pressure Safety*
- BNL SBMS subject area *Piping Systems, Identification of*
- BNL SBMS subject area *Lead*
- BNL SBMS subject area *Explosives Safety*
- BNL Radcon Manual
- Biosafety in Microbiological and Biomedical Laboratories fifth edition - USDHHS
- 49 CFR, Department of Transportation
- ANSI Z358.1-2004, *Emergency Eyewash and Shower Equipment*
- 29 CFR 1910 Subpart H, *Hazardous Materials*
- 10 CFR Part 851, Appendix A, functional areas 2, *Fire Protection*; 3, *Explosives Safety;* 4, *Pressure Safety*; 6, *Industrial Hygiene*; 7, *Biological Safety*; 8, *Occupational Medicine*; *and* 10, *Electrical Safety*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.9. The pre-mitigation risk is categorized as High and the post-mitigation risk is categorized as Low.

Due to the wide variety of chemicals that will be utilized and the potential to introduce new hazardous materials at NSLS-II for the experimental programs, rigorous programs to control chemical inventory and usage are in place. While a detailed chemical/hazardous material inventory has not yet been completed, quantities can be estimated based on the type of experimental programs anticipated, number of beamlines, and an evaluation of the types and quantities of materials used at the existing NSLS to support the facility and similar experimental programs. The BNL Chemical Management System will be utilized to inventory and track chemicals.

Experimental activity undertaken at NSLS-II will be fully reviewed under the Experimental Safety Review (ESR) process, input and approval from the Experimental Review Coordinator (ERC) and other Subject Matter Experts as needed (e.g., representatives from Environmental Compliance, Industrial Hygiene, and Industrial Safety), to identify and manage the hazards of each experimental operation. The Principal Investigators will ensure that all safety reviews take place for each activity and that any issues are appropriately addressed. The Experimental Safety Review (ESR) process will document these reviews, covering the necessary controls and management approval to proceed.

The experimental program is expected to require small quantities of corrosive, reactive, pyrophoric, flammable, explosive, toxic, and highly toxic materials. The program also will involve the study and use of nano-particles, biological and radioactive materials. The use of all hazardous materials will be strictly controlled as required by OSHA, DOE and BNL requirements. It is noted that safety requirements are continually evolving for nano-materials, and that design and handling requirements may continue to evolve. Conservative features will be provided during design to take these potential changes into account and to ensure that nano-materials can be handled as required at the time of operation. This includes the installation of HEPA filtered lab hoods or glove boxes in the LOB laboratories, and may include HEPA filtration on hutch exhaust. Close contact will be maintained with the BNL nano-material community to ensure awareness of changing requirements that may have impact on the NSLS-II design and operations.

The use of biological materials in NSLS-II has also been reviewed at the conceptual stage and no use beyond Bio-safety Level 2 is anticipated at this time. Laboratory design will accommodate Bio-safety Level 2 requirements. The use of Bio-safety Level 2 materials has been successfully addressed at NSLS without problem. Biological hazards are addressed by a Brookhaven National Laboratory subject area entitled “Biosafety in Research”. The BNL subject area describes the procedures users of biological materials must follow to perform research at BNL, and covers biological materials, including microorganisms such as bacteria, protozoa, mycoplasma, and viruses, and other potentially infectious materials such as recombinant DNA. Currently, no Biosafety Level 4 (BSL-4) work is allowed at BNL, and there are no BNL facilities that currently conduct Biosafety Level 3 (BSL-3). Future work at the beamlines that may involve BSL-3 work will require approval from the Laboratory Director, the Institutional Biosafety Committee and DOE. In addition the Environmental Assessment for NSLS-II would need to be updated and approved prior to moving to a BSL-3. A comprehensive program of work planning and experimental review is in place for the Photon Sciences Directorate that will evaluate all experiments involving biological materials. Detailed procedures will be developed to cover specific protocols for transport, testing, treatment and disposal of these materials. The total inventory of chemical

and hazardous material utilized on the experimental floor is governed by the number of active beamlines and the number of users. The quantity utilized in an experiment is small, typically in the milligram or milliliter range, as only the amount required for experimental operations will be allowed in the facility and storage will be restricted to short-term periods.

The use of radiological materials including trans-uranic radionuclides can be expected at NSLS-II. All radioactive materials will be strictly controlled via procedure that will be based on material, quantity, and form of the materials and include specific review processes by the Experimental Safety Review Committee. Trans-uranics (TRUs) such as Np-237, Pu-239, and Am-241 are all long radiological half-life alpha emitters which, if inhaled or ingested, selectively deposit in bone with long biological half-life. As a result, the permissible intake for humans for these materials is extremely low. These materials are also considered very dangerous and must be handled in a manner that prevents release to the environment or uptake by humans.

Work with radioactive materials involves some risk. For the purpose of establishing risk-based containment requirements, a policy for NSLS-II will be developed that will include the best practices of facilities conducting similar research. This policy will be along the lines of:

> "The maximum a person should inhale from a breach or leak in sample containment should not exceed 2% of the annual limit of intake (ALI) for a given dispersible radionuclide. This would result in a committed effective dosed equivalent of 100 mrem. This is 2% of 5 rem, the US-DOE whole-body stochastic limit for annual total effective dose equivalent (10CFR835). In cases of potential inhalation of multiple radionuclides, the total committed effective dose equivalent from all inhaled radionuclides should not exceed 100 mrem."

Two factors will limit material inventories; building occupancy fire limitations and the Experiment Safety Review process (ESR). The former (See Fire Hazard Analysis section 3.2.4) will cover chemicals for both facility support and experimental support. The quantities for the individual fire control zones will be strictly controlled via the BNL Chemical Management System to ensure that inventories do not exceed the building occupancy limits. Experimental chemicals and materials will be controlled via the ESR process that evaluates all hazardous materials for the experimental programs to ensure that the least hazardous material is used, quantities are minimized, and proper handling and storage requirements are applied.

There will be no bulk storage of flammable or combustible liquids; corrosive, reactive, or toxic chemicals; nano-materials or biological materials within the facility. All liquid and solid chemicals for experimental use will either be stored in the main designated chemical storage location close to the loading dock area or at satellite locations. Chemicals in use will be stored in designated cabinets at the beamlines, or at the beamline support laboratories.

All locations where chemicals are used or stored will be evaluated and equipped as needed with combination safety shower/eyewashes compliant with ANSI. These areas also may have automatic sprinklers.

Small quantities (milliliters) of toxic or highly toxic gasses may be used for experiments. Provision for ventilation and exhaust will be evaluated and determined during beamline design. Exhausted and sprinklered gas cabinets may be required; and depending on the type of toxic material, gas leakage detection and automatic shutdown may be necessary. The small quantities of toxic or highly toxic gases that will be used will follow BNL guidelines for handling and using toxic materials.

Flammable and non-flammable gases that will be used for the research program, including instrumentation support, will be kept in DOT cylinders in quantities limited to the minimum required for that particular process. Gas segregation and the use of flash arrestors will be evaluated as needed.

Exterior storage areas for gas cylinders are provided close to the main and LOB delivery docks. They will allow the segregation of flammable gasses from oxidizers. The storage areas are protected from the weather and vehicular traffic.

Emergency planning and procedures will be established and used if needed to evacuate/shelter in place in the event of a chemical or hazardous material release.

Beryllium windows are often used in beamline applications; failure of these windows could cause a beryllium contamination issue.

3.2.10 Ionizing Radiation Hazards Associated with Beamline Operations (NEXT/ABBIX HAR-10)

Consequences resulting from ionizing radiation include potential for excessive radiation dose and possible injury or death. Radiation related hazards can be initiated by accelerator or beamline component failure, interlock failure, insufficient shielding, inadequate configuration control and/or procedural violation/ inadequacy.

The management and control of ionizing radiation hazards will follow the requirements in the:

- BNL SBMS subject area *Radioactive Airborne Emissions*
- BNL SBMS subject area *Radiological Dose Limits*
- BNL SBMS subject area *Radioactive Waste Management*
- BNL SBMS subject area *Radiation Generating Devices*
- BNL SBMS subject area *Transport of Haz/Rad Materials On and Off Site*
- BNL SBMS subject area *ALARA*
- BNL SBMS subject area *Accelerator Safety*
- BNL SBMS subject area *Entry and Egress for Areas Controlled for Radiological Purposes*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.10. The pre-mitigation risk is categorized as High and the post-mitigation risk is categorized as Low.

There are two types of beamline radiation hazards: synchrotron radiation and bremsstrahlung radiation from loss of high energy electrons within the ring. Both sources will produce scattered x-ray, neutron and secondary bremsstrahlung radiation along the beamline from interactions with apertures, monochromators, mirrors, windows, beam pipes or samples. Lead or tungsten shielding is required to reduce radiation to design levels (<0.05 mrem/hr) outside the experimental enclosures. Bremsstrahlung radiation is analyzed through a ray tracing process to ensure that it is confined to the beamline vacuum chamber by lead or tungsten collimators.

The synchrotron radiation beamlines on the experimental floor are positioned in such a manner that their centerlines are tangential to the electron orbit in the insertion devices or dipole magnets within the storage ring. Thus, synchrotron radiation, generated when the high-energy electrons are bent by the magnetic fields of dipole or insertion devices, emerges through the beam port of the storage ring and into one or more individual beamlines where the radiation is used for experimental purposes. Redundant interlocked (lead) safety shutters (30 cm each) in the front end are required to provide access to the beamline enclosures.

The front end of each beamline at NSLS-II typically consists of photon shutter, slow gate valve, fixed aperture photon mask (which defines the dimensions of the synchrotron radiation), first photon beam position monitor (BPM), lead collimators, fast gate valve, second photon BPM, water cooled photon shutter, redundant lead safety shutters, and lead ratchet wall collimator. The water-cooled photon shutter is interlocked with the safety shutters and is used to protect them from overheating by the synchrotron radiation when closed. The critical components are protected by the Equipment or Personnel Protection System (EPS). The safety shutters are designed to render the beamline downstream experimental end station enclosures (EESE) safe for access and must be closed whenever there is access to the first optics enclosure (FOE) located immediately downstream of the forward ratchet wall. One or more EESE housing the experimental equipment are normally located downstream of the FOE. A separate shutter located in the FOE must be closed for access into the EESE.

The principal radiological hazards during beamline operations are associated with:

1. Electron beam injection into the storage ring with front end safety shutters open
2. Bremsstrahlung radiation produced from electron interactions with residual gas molecules in the ring vacuum chamber or interactions with the storage ring components themselves
3. Synchrotron radiation produced by the wigglers/undulators or the bending magnets

Each hazard will be considered separately.

3.2.10.1 Injection

Because of the relatively short life time of the stored electron beam (~2 h), NSLS-II will be operated with frequent electron injections to maintain stored beam current within 1% of the planned 500 mA. In order to maintain a constant heat load on beamline optics, it is important to conduct these injections with frontend safety shutters open. This method of operation is referred to as “top-off” and has become increasingly common in recent years at other light sources around the world.

An analysis has been carried out to determine if there are failure modes possible in the magnet lattice that would permit the injected electron beam to accidentally enter into the front end and pass on into the FOE during top-off injection with safety shutters open. Radiological simulations have shown that such an event would create hazardous radiation levels in areas around the hutch and cannot be tolerated under any circumstances. The lattice failure mode analysis has been conducted by physicists within the NSLS-II Accelerator Division using analytical codes developed at SLAC and Lawrence Berkeley Lab. These codes are used to determine potential particle trajectories that are possible under a variety of fault conditions ranging from improper injection (e.g., wrong energy, wrong orbit), to incorrect magnet settings. The purpose of the analysis is to determine what conditions (if any) permit electrons to enter beamline front end. Based on this analysis, engineering controls in the form of fixed apertures and PPS interlocks have been developed which would prohibit the conditions from occurring during a top-off injection.

3.2.10.2 Bremsstrahlung

Bremsstrahlung represents a significant radiological source term and is produced from the interaction of the circulating electrons with gas molecules in the vacuum pipe or with the storage ring accelerator structures. Bremsstrahlung radiation is highly peaked in the forward direction, and for a given electron beam energy is directly proportional to the stored current and the gas pressure in the ring section that electrons pass through. Bremsstrahlung is more important for undulator and wiggler beamlines, which are tangential to the straight sections in the ring, thereby providing longer flight paths for bremsstrahlung production by the circulating electrons.

Bremsstrahlung in the forward direction must be shielded with thick lead blocks (or with other high Z materials such as tungsten) to control personnel exposure in occupied areas during normal or abnormal operation. To ensure the adequacy of shielding, each beamline is examined as described inLT-C-ESH-STD-001 and 002 (Revised Guidelines for the NSLS-II Beamline Shielding Design, Shielding Guidelines for Secondary Bremsstrahlung at NSLS-II Beamlines with Mirror as the First Optical Element). In these analyses, the bremsstrahlung shielding is evaluated by conducting ray traces down the length of the beamline to confirm that the bremsstrahlung is stopped before emerging to the experimental floor. A bremsstrahlung ray is considered stopped after it has passed through the full shield thickness specified for the bremsstrahlung stop. The stopped primary bremsstrahlung ray should not be closer than 3 Moliére Radii (3R) from the lateral edge of the collimator or stop (the Moliére Radius for lead is 12.5 mm and that for tungsten of density ~18 g/cm^3 is 8 mm).

3.2.10.3 Synchrotron Radiation

The synchrotron radiation created in the storage ring represents an intense, broad band radiation source; scattered radiation from beam interactions with windows and other beamline components can produce significant radiation fields that must be considered.

The full unattenuated spectrum of photons emitted from an insertion device or bending magnet is commonly called the “white” beam. White beams constitute the greatest radiological hazards and require the greatest shielding and cooling because they contain the total power of the emitted synchrotron radiation. In some beamlines, the white beam will be deflected through the use of cooled mirrors. This results in the loss of the higher and lower energy components of the white beam. This type of beam is typically called a “pink” beam. Such beams require additional shielding at beam scatter points, but typically less than that found for white beams.

Commonly the research conducted at a beamline requires single energy synchrotron beam produced by the diffraction of the white or pink beam off one or more monochromator crystals. Monochromators will appear in practically all beamlines at NSLS-II. The characteristics and magnitude of scatter hazards for these synchrotron radiation sources differ and analysis is done on a case by case basis.

3.2.10.4 Shielding Requirements for Bremsstrahlung and Synchrotron Radiation

The synchrotron radiation and bremsstrahlung can be scattered from any potential component in the beamlines and front ends. Such components include windows, slits, monochromators, mirrors and so forth. These components differ from beamline to beamline. Therefore calculations are performed with a worst case potential scatterer, located at the upstream end of the experimental enclosure.

Table 3.2.10.1 gives the shielding thickness for the First Optics Enclosures based on available information on source parameters for NEXT and ABBIX beamlines.

Table 3.2.10.1: Shielding requirements for NEXT and ABBIX First Optics Enclosures (FOE)

Beamline Source	Pb to shield < 0.05 mrem/hr (mm)		
	Lateral panels	Roof panels	Downstream panels
EPU105/DW100	18	10	50
EPU 57	18	5	50
IVU 21/23	18	6	50

3.2.10.5 Abnormal Operating Conditions for Beamlines

Pressure Surges in the Storage Ring

The beamline shielding described in the above sections is typically based on worst-case conditions, with the exception of vacuum operating pressures. Higher vacuum pressure will produce greater dose rates of bremsstrahlung, which will result in higher scattering dose rates around the FOE. Bremsstrahlung production increases in direct proportion to increases in vacuum pressure. The primary bremsstrahlung source term for NSLS-II beamlines is calculated for a vacuum chamber pressure of 1 ntorr. However, it is possible to have higher vacuum pressure, >10 ntorr, in the storage ring straight sections for brief periods of time during the initial conditioning of the vacuum chamber or insertion devices. Typically, this may last for a conditioning time period of ~50 Amp-hours. During this conditioning period, higher dose rates of >0.05 mrem/hr may be possible around the first optics enclosure shield walls at 500 mA of beam current. Vacuum pressures will be monitored in the Control Room and radiation detectors located at each FOE wall will alarm and automatically close the frontend safety shutters if radiation levels exceed >5 mrem/hr.

3.2.11 Lasers and other Non-Ionizing Radiation Hazards (NEXT/ABBIX HAR-11)

Non-ionizing radiation at NSLS-II consists of laser, radiofrequency (RF), microwave, static magnetic, visible light, infrared (IR), and ultraviolet (UV) hazards. The consequences of hazards associated with non-ionizing radiation include exposures exceeding regulatory limits, which could result in personal injury. These hazards could be initiated by equipment failure, interlock failure or override, or inadequate or removed shielding.

The management and control of non-ionizing radiation hazards will follow the requirements in (the relevant ANSI, ACGIH and OSHA standards are included in these subject areas):

- BNL SBMS subject area *Laser Safety*
- BNL SBMS subject area *Static Magnetic Fields*
- BNL SBMS subject area *Non-ionizing Radiation Safety* (includes radio frequency, microwave, infrared, visible light, ultraviolet)

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.11. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

The NSLS-II operations and experimental programs will use Class 1, 2, 3A(R), 3B, and 4 lasers. Some lasers will occupy permanent locations, while others will be part of short-term beamline experiments and in place for just days to weeks at a time. All uses of lasers will be reviewed and controlled as required in national consensus standards and BNL subject areas. Locations for long-term use of Class 3B and Class 4 lasers will be identified during design and appropriate safety features (e.g. control of exposed beams) will be incorporated into the design of the facility. Lasers, particularly those in Class 3B and 4, will require written procedures for each device to control eye or skin exposure and associated electrical and industrial hygiene hazards e.g. exposure to solvents, dyes, and halogen gasses. As per BNL laser safety procedures, Class 4 laser control areas are required to be interlocked with a failsafe system. Laser systems requiring toxic cover gas (e.g., fluorine) necessitate using exhausted gas cabinets.;

The NSLS-II devices that generate magnetic fields will have numerous and diverse uses.. Magnetic insertion devices will be used on the storage ring. Ion pumps used on all evacuated accelerator and beamline pipes and chambers contain magnets of ~1000 gauss at contact. Some experiments employ superconducting magnets with cores rated up to 16 Tesla. The concern with all these devices is the strength and extent of the fringe fields and how they may affect persons and equipment in their vicinity. Fringe fields in excess of 5 gauss are of particular concern because they could affect medical electronic devices (pacemakers), while fields over 600 gauss could impact ferromagnetic implants (artificial joints) and cause injury by unexpected magnetic pull on adjacent materialsand tools. Stray static magnetic fields will be measured and mapped, and appropriate warning signs will be posted.

Storage ring beamlines may use the visible portion of the synchrotron radiation spectrum to align and focus optical components. To do this, light is focused through a glass window that transmits wavelengths from 280 to 3,000 nm, i.e., mostly in the visible spectrum, but including infrared and ultraviolet wavelengths. Remote camera viewing and administrative controls, including Experiment Safety Reviews, will be implemented during normal beamline operation and alignment. View ports that can transmit the direct or reflected visible portion of the synchrotron beam normally will be covered and the cover will bear a caution sign. When the visible beam is required for alignments, the area it traverses will be roped off, preventing inadvertent access and it will be backstopped within the roped off area. Caution signs will be placed along the barriers.

3.2.12 Material Handling Hazards (NEXT/ABBIX HAR-12)

The consequences of hazards encountered in material handling include serious injury or death to equipment operators and bystanders, damage to equipment, and interruption of the program. These hazards could be initiated by a dropped or shifted load, equipment failure, suspect or counterfeit hardware, improper procedures, or insufficient training/qualification of operators. Operational experience across the DOE complex and with BNL accelerators with material handling related occurrences and injuries suggests that the post-mitigation risk will remain relatively high even though the probability of occurrence will be reduced through strict operational controls.

The management and control of material handling hazards will follow the requirements in:

- BNL SBMS subject area *Lifting Safety*
- BNL SBMS subject area *Forklift Safety*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.12. The pre-mitigation risk is categorized as High and the post-mitigation risk is categorized as Low.

The nature of accelerator operations demands a significant amount of manual and mechanical material handling. The material/equipment being moved is typically one of a kind, potentially of high dollar or programmatic value, and may not have dedicated lifting points or an obvious center of gravity. A review has been made of material handling requirements for NSLS-II and it has been determined that rigging needs can be met without requiring an overhead crane system extending throughout the Ring Building. Most beamline hutches will have an interior overhead crane to facilitate movement of beamline equipment for installation or servicing. Other material handling can be done by employing A-frame cranes and fork lifts, wheeled carts or simple mechanical hoists serving a particular limited application. Procurements for high value or unique equipment include the requirement for the vendor to supply an installation plan which details rigging needs.

To facilitate material handling throughout the facility, wide aisles will be incorporated behind beamlines to allow the passage of at least a fork truck with palletized equipment. Tight radiuses and blind corners will be kept to a minimum. Aisles will be designated and marked to prevent the storage of materials/equipment and to ensure that gas cylinders, hazardous storage areas, flammable material lockers, electrical equipment, etc., are adequately protected.

Material handling operations throughout the DOE complex have resulted in numerous incidents of injury and equipment damage to which improper equipment, inadequate rigging, or insufficient training/ qualification have contributed. BNL instituted extensive training and qualification requirements and significantly limited the number of personnel who have access to mechanical material handling equipment. Personnel requiring authorization to use material handling devices unsupervised must complete laboratory specified training and pass a qualification practical exam conducted by a skilled operator; only then are they deemed “responsible” and given access to the equipment.

In addition, the NSLS-II design reduces the amount of manual material handling. For example, a major source of potential injury at research facilities is moving cylinders of compressed gas. NSLS-II will pipe in nitrogen gas, thereby reducing the number of cylinders that must be handled manually. Material receiving and storage is located close to the facility loading/delivery dock. A staging area is available to break material down into manageable quantities for distribution throughout the experimental areas.

3.2.13 Other Experimental Hazards (NEXT/ABBIX HAR-13)

Other hazards that may be encountered in beamline operations include physical hazards such as sample robots, furnaces or high temperature ovens, pressure cells, or machine shop or portable hand tool use. The consequences from other experimental operation hazards range from minor to severe injuries, possible death, and danger to the experimental or facility equipment, as well as a programmatic impact. Initiators would include: mechanical malfunction of sample robots, furnaces, ovens or pressure cells; failure of protective systems; operator error, lack of training, exhaustion; poorly designed/installed equipment; equipment failure; and undefined hazard/risks from material not considered in experimental safety reviews.

The management and control of Other Experimental Hazards will follow the requirements in:

- BNL SBMS subject area *Work Planning and Control*
- BNL SBMS subject area *Beryllium*
- BNL SBMS subject area *Compressed Gas Cylinders and Related Systems*
- BNL SBMS subject area *Interlock Safety*BNL SBMS subject area *Pressure Safety*
- BNL SBMS subject area *Piping Systems, Identification of*
- BNL SBMS subject area *Machine Shop Safety*

Design criteria and operational controls incorporated to mitigate these risks are given in Table 6.13. The pre-mitigation risk is categorized as Moderate and the post-mitigation risk is categorized as Low.

Equipment purchased for use at experimental stations will be commercially available, with incorporated safety controls where required. Robot systems are reviewed for compatibility with the Personnel Protection System (PPS). Machine shop equipment complies with SBMS requirements, and personnel are trained on the use of each machine. Portable hand tool training is available. Furnaces and ovens may be used for reaction chambers or sample preparation. Careful control of combustible loading and hot surfaces will be required. Pressure cells may need to be enclosed, and will comply with SBMS Pressure Safety.

4 FACILITY HAZARD CATEGORIZATION

The NSLS-II Facility was classified as an accelerator facility, subject to the requirements of the DOE Accelerator Safety Order, DOE O 420.2C. The NSLS-II facility will have the potential for no more than minor on-site and negligible off-site impacts to people and the environment. A Final Safety Assessment Document (SAD) and an Accelerator Safety Envelope (ASE) will be established before routine operations begin, in accordance with DOE Order 420.2C.

5 RISK CATEGORIZATION TABLES

The Risk consequence Classifications and Risk Probability Classifications below provide the methodologies used to categorize the consequence and the probability, respectively, of the risk for potential hazards at the NEXT/ABBIX beamlines. The hazards are assigned a Risk Category based on consideration of their potential consequence and probability, as summarized in the third table below. These tables are adapted from the Risk Screening Matrix Questions table in the SBMS Facility Hazard Analysis Subject Area. The focus of the HAR hazard and risk assessment is to qualitatively evaluate each hazard area by identifying the initiator of the hazard and its consequences, establish a pre-mitigation risk category, recognize design features to mitigate that risk, and then establish a post-mitigation risk category.

Table 5.1: Risk consequence classification.

Consequence (Hazard Severity)		
Category	Descriptor	Potential Consequence
I	High	Can a radiological or chemical hazard cause multiple deaths or serious injury, off-site evacuation, >100 Rem to an individual, >$1,000,000 damage, >4 mos. Facility downtime, total loss of mission data, or have a public impact that closes the DOE buildings or a User Facility?
II	Moderate	Can a radiological or chemical hazard cause a death or serious injury, >25 Rem to an individual, >$250,000 damage, 3 weeks to 4 months program downtime, severe loss of experimental data, or have a public impact that closes down an experiment or program?
III	Low	Can a radiological or chemical hazard cause multiple moderate injuries, local evacuation, > 5 Rem to an individual, >$50,000 damage , 4 days to 3 weeks program downtime, major loss of experimental data, or have a public impact that brings the experiment to the attention of the community and activist groups?
IV	Routine	Can a radiological or chemical hazard cause minor injuries, no onsite or offsite evacuation, <2 Rem to an individual, < $50,000 damage, <4 days program downtime, minor loss of experimental data, or have a public impact that is below public perception?

Table 5.2: Risk probability classification.

Hazard Probability		
Category	Descriptor	Frequency
A	Frequent	Likely to occur repeatedly during the life cycle of the system
B	Probable	Likely to occur several times in the life cycle of the system
C	Occasional	Likely to occur sometime in the lifecycle of the system
D	Remote	Not likely to occur in the life cycle of the system, but possible
E	Extremely Remote	Probability of occurrence cannot be distinguished from zero.
F	Impossible	Physically impossible to occur

Table 5.3: Risk category classification.

Risk Category (= Consequence x Probability)						
Hazard Consequence	A Frequent	B Probable	C Occasional	D Remote	E Extremely Remote	F Impossible
I High	High	High	High	Moderate	Low	Routine
II Moderate	High	High	Moderate	Low	Low	Routine
III Low	Moderate	Moderate	Low	Low	Routine	Routine
IV Remote	Routine	Routine	Routine	Routine	Routine	Routine

6 RISK ASSESSMENT SUMMARY TABLES

The following tables provide a summary of the hazards, design criteria and operational controls incorporated to mitigate these risks, and pre- and post-mitigation risk categorizations for the hazard categories identified in this HAR.

Table 6.1: Risk Assessment Summary for Natural Phenomena Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-1**

SUBSYSTEM: NEXT Beamlines

HAZARD: Natural Phenomena

HAZARD INITIATOR(S): Earthquake, hurricane, tornado, snow, rain, ice, surface flooding, lightning

HAZARD CONSEQUENCE: Personnel injury/death, equipment and building damage or loss, release of hazardous materials, or programmatic impact

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☒ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Performance Classification designation PC-1
- Strict conformance to New York State Building Codes
- Design snow load: 30 psf (minimum) + drift where applicable
- Wind design 120 mph (with 3-second gust)
- Seismic design to 0.25g short period acceleration velocity
- Lateral load building design
- Lightning protection system as per NFPA 780
- Pitched roofs on structures to preclude localized flooding.
- Site drainage designed to shed water away from the structure

MITIGATING FACTORS (OPERATIONAL)

- Limited and controlled quantities of hazardous materials
- BNL Site Emergency Plan
- Building Emergency Plan
- Emergency drills
- All NEXT and ABBIX Beamlines with exception of the HXN and SIX hutches, respectively, will be within NSLS-II Ring Building structure

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☒ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☐ III Low	☒ IV Routine

Table 6.2: Risk Assessment Summary for Environmental Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-2**

SUBSYSTEM: NEXT Beamlines

HAZARD: Environmental

HAZARD INITIATOR(S): Equipment failure, procedural violation, NPH, fire

HAZARD CONSEQUENCE: Release of oils, solvents, chemicals to the soil, surface water, groundwater, air, or sanitary system

RISK ASSESSMENT PRIOR TO MITIGATION:

CONSEQUENCE	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☒ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Handling and storage facility for control of waste water
- Design to Suffolk County Article 12 (secondary containment) where required
- Radiation loss points evaluated to determine shielding requirements to protect environment from soil activation
- Facility includes sustainable design principles and has obtainedLeadership in Energy and Environmental Design (LEED) Silver certification.
- Minimizing the number of floor drains; prevents impact to Peconic river and groundwater
- Fire protection/detection systems

MITIGATING FACTORS (OPERATIONAL)

- Implementation of the environmental management program (ISO 14001) where chemical usage is minimized through review; less hazardous chemicals and processes are substituted where possible. Controls are based on:
- Environmental Management System
- Significant Environmental Aspects matrix
- Chemical management system
- Process Assessments
- ESH Committee, Instrument Readiness Reviews, design reviews
- Work Planning, Experimental Safety Reviews, Tier I inspections, postings
- Training/qualification
- NSLS-II Environmental Assessment
- NESHAPS evaluation
- Soil and water sampling
- Use of oil-less pumps and synthetic oils
- NEXT NESHAPS evaluation and Finding of No Significant Impact

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☒ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.3: Risk Assessment Summary for Waste Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-3**

SUBSYSTEM: NEXT Beamlines – Maintenance and Beamline operations

HAZARD: Waste

HAZARD INITIATOR(S): Transportation accident, improper storage of incompatible materials, insufficient packing/labeling of materials, package failure, NPH, procedural violation

HAZARD CONSEQUENCE: Loss of material (oils, solvents, chemicals) to environment, personnel injury, possible reactive or explosive event

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☒ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Beamlines will use 90-day waste accumulation area in Ring Building
- 90-day area designed with 2-hr fire rating, independent exhaust ventilation, fire detection, alarm pull box, communications (phone) system, access control (card reader), secondary containment

MITIGATING FACTORS (OPERATIONAL)

- NSLS-II chemical usage and waste production will be minimized through review; less hazardous chemical and processes substituted where possible.
- Local Satellite Accumulation Areas (SAA) in laboratories or at beamlines

- Assess need for exposure monitoring
- 90-day weekly inspections
- Periodic NYSDEC inspections of the 90-day areas and SAAs
- Hazardous waste generator training
- Experimental Safety Review
- Work Planning and control
- Beamline and Facility-Specific Safety Orientation
- Tier I inspections
- Training/qualification
- Process Assessment Forms
- Waste reduction, pollution prevention and recycling.
- Hazmat transportation as per DOT

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☒ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.4: Risk Assessment Summary for Fire Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-4**

SUBSYSTEM: NEXT Beamlines

HAZARD: Fire

HAZARD INITIATOR(S): Equipment failure, accumulation of combustible/flammable material, use of pyrophoric or reactive materials, improper storage use of flammable materials, lightning storm, static discharge, inadequate or out of service fire detection or suppression

HAZARD CONSEQUENCE: Personnel injury/death, equipment damage/loss, release of hazardous material to environment, programmatic impact

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☒ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Design to NYSBC and appropriate NFPA 70 (Business Occupancy) and other appropriate NFPA standards
- Fire Protection Assessment /Fire Hazards Analysis
- Non-combustible construction throughout facility
- Automatic early warning fire detection systems, e.g., smoke detectors, rate of rise detectors
- High Sensitivity Smoke detection in Ring Building experimental floor
- Fully sprinklered, including a fire department standpipe service (available for hutches)

- Smoke curtains and manually activated exhausts around ring to limit spread of heat and smoke on experimental floor
- Redundant water supplies
  - Two feeds to Ring Building
  - Well gridded water supply system
- Emergency power system for essential systems
- Hazardous material storage areas, rated, vented, alarmed as required by contents
- Lightning protection system for facilities
- Adequate grounding systems

MITIGATING FACTORS (OPERATIONAL)

- Manual fire suppression provided by ample portable fire extinguishers
- Alarm systems to alert occupants and summon fire department, e.g., fire alarm bells/strobes, manual pull stations, connected to onsite fire dept.
- Full time, BNL Fire/Rescue Group with mutual aid arrangements with local fire departments
- Tier I inspecting program to minimize combustibles and ignition sources
- Ignition source control programs (cutting/welding permits, no smoking policy)
- Beamline safety reviews to ensure proper installation of components and code compliance
- Experimental Safety Review to minimize fire hazards of experiments by design features
- Fire evacuation drills
- Training/qualification

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☒ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☐ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.5: Risk Assessment Summary for Electrical Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-5**

SUBSYSTEM: NEXT Beamlines

HAZARD: Electrical

HAZARD INITIATOR(S): Electrical shock/arc flash from exposed conductors, defective equipment, substandard equipment or installation of equipment, lack of training or improper procedure

HAZARD CONSEQUENCE: Death, permanent injury, equipment damage

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☒ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Design to NFPA 70 National Electric Code and 70 E Standard for Electrical Safety in the Workplace
- Provide adequate power distribution (beamlines and labs) to reduce need for extension cords and temporary wiring
- Provide segregated power and utility distribution; no over-loading (cable/utility trays)
- Electrical and mechanical equipment rooms adequately sized and accessible from outside of ring
- Electrical distribution/disconnect equipment located in unobstructed areas (physically marked where necessary to provide clear access/maintain clearances)
- Protect equipment and cables from mechanical and other hazards
- NRTL certified equipment if available, all non-NRTL certified by BNL EEI program
- Conduct arc flash calculations, determining PPE requirements, and label all electrical panels and switches
- Assess need and feasibility for remote operation of high voltage switches and breakers to prevent human contact during opening and closing
- Implement Lockout/Tagout capability into design of energized equipment

MITIGATING FACTORS (OPERATIONAL)

- Non-NRTL equipment inspected and certified by a qualified person per BNL's EEI program
- Beamline design reviews
- Operation of equipment at <50 volts where feasible
- SBMS procedures for electrical safety
- Electrical safety/LOTO training
- Operational procedures to keep electrical equipment unobstructed
- Tier 1 inspection program
- Compliance with NFPA 70E

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV
PROBABILITY	☐ **A** Frequent	☒ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☐ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.6: Risk Assessment Summary for Vacuum and Cooling Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-6**

SUBSYSTEM: NEXT Beamlines

HAZARD: Catastrophic Loss of vacuum or cooling water., causing loss of control of stored electron or synchrotron beam and possible radiation exposure

HAZARD INITIATOR(S): Vacuum or cooling equipment failure, improper procedure, natural phenomena, fire, operator error

HAZARD CONSEQUENCE: Damage to equipment, injury to personnel, programmatic impact

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☒ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Engineered safety systems in place to protect ring and beamlines from vacuum, cooling water, faults
- Vacuum faults cause accelerator interlock systems to close sector and front end valves thus dumping beam; beamline interlocks would close a beamline valve and/or a front end valve; insertion device beamline interlocks would close the fast valve and dump RF.
- Reduced cooling water flow is sensed causing accelerator interlocks to dump RF and causes beamline interlocks to close safety shutters.
- Elevated magnet temperature would turn off the magnet power supply; if sensed on ring components, would dump RF; if sensed in pump room water, would dump RF and magnet power supplies.
- Loss of primary compressed air supply from the Central Chilled Water Facility alerts control room.

- Loss of backup compressed air supply (affecting operation of front end components, safety shutters and fast valves) alerts control room.
- Valves fail safe on loss of compressed air
- Fire protection/detection systems
- Bulk and supplemental shielding

MITIGATING FACTORS (OPERATIONAL)

- Safety Analysis Document and Accelerator Safety Envelope for routine operations
- Operational procedures
- Systems design review
- Exclusion zones (i.e., posted radiation areas)
- Training/qualification
- Beamline safety reviews
- Tier 1 inspections

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☒ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.7: Risk Assessment Summary for Noise Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-7**

SUBSYSTEM: NEXT beamlines

HAZARD: Noise,

HAZARD INITIATOR(S): Defective or improperly installed pumps, mechanical systems, HVAC

HAZARD CONSEQUENCE: Personnel over exposure to OSHA limits, threshold shift and permanent hearing loss

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☒ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Separate mechanical/utility areas from work areas; isolation of operations/experimental process equipment (pumps), hutches or individual equipment enclosures
- Use low-noise equipment (fans) in HVAC and electronic systems
- Incorporate sound absorbing materials into structure (wall and ceiling panels, baffles)
- Hutches lead lined
- Hutch mechanical equipment on roof of hutch

MITIGATING FACTORS (OPERATIONAL)

- Baseline and periodic area noise surveys

- Personnel noise dosimetry
- Noise exposure medical protocol where required
- New equipment reviewed for noise as part of procurement process
- Personal protective equipment
- Training/qualifications

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☐ II Moderate	☒ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☒ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☐ III Low	☒ IV Routine

Table 6.8: Risk Assessment Summary for Cryogenic Hazards Including ODH and Pressure.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-8**

SUBSYSTEM: NEXT Beamlines Experimental Systems

HAZARD: Cryogenic, Oxygen Deficiency, and Pressure

HAZARD INITIATOR(S): Failure/rupture of cryogenic system from overpressure, failure of insulating vacuum jackets, mechanical damage/failure, insufficient or improper maintenance, improper procedure

HAZARD CONSEQUENCE: Release of cryogenic material into locations where injury or death could occur due to oxygen deficiency, overpressure or thermal burns, injury from fragments or missiles, startle hazard from pressure relief

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☒ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Cryogenic and other pressure systems per ASME , ANSI and all other applicable codes
- Design and provide relief/burst disk mechanisms for all pressurized systems as defined by 10CFR 851 and SBMS guidelines
- Perform ODH analyses for all predictable failure scenarios
- Define ODH classifications, and provide ODH sensors and alarms as required in hutches
- Conduct design and safety reviews of the cryogenic systems, ODH analyses and pressurized components by the BNL LESHC subcommittees as required by SBMS
- Provide interlocks and automatic exhaust system/quench installed where required
- Provide relief mechanisms in all piping and dewar systems
- Pipe labeling
- Define procedures and perform initial and final pressure testing of all pressurized systems

MITIGATING FACTORS (OPERATIONAL)

- Design review process
- Initial system pressure testing
- Major systems reviewed by Cryo Safety Committee and testing completed as required by SBMS
- NSLS-II facility specific access training
- Compressed gas safety training
- Cryogen Safety Awareness training
- Oxygen Deficiency Hazard training
- ODH classification, monitoring, and controls
- System specific training
- Personal protective equipment (i.e., portable O2 monitors)
- Emergency escape packs if warranted

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☒ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6. 9: Risk Assessment Summary for Chemical/Hazardous Material Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-9**

SUBSYSTEM: NEXT Beamlines

HAZARD: Chemical/Hazardous Material/Nano-materials/Biological Materials/Radioactive materials

HAZARD INITIATOR(S): Experimental operations, transfer of material, packaging failure, improper labeling/marking, failure of fume hood/glove box, reactive or explosive event, improper or lack of PPE, improper procedure, NPH

HAZARD CONSEQUENCE: Exposure to hazardous material leading to injury/death or exposures greater than regulatory limits

RISK ASSESSMENT PRIOR TO MITIGATION:

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☒ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Dedicated Chemical Storage Area with segregation, ventilation, fire protection system, flammable and O2 monitors and access control
- Chemical delivery located adjacent to loading dock
- Each lab designed based on anticipated use and future use (user input in design process, historical inventories/hazards considered)
- Labs designed for Bio-safety level 2 materials
- Vented chemical storage cabinets in laboratories and at beamlines as determined
- Gas cabinets for toxic and highly toxic gasses, individual venting and purging capacity and exterior access
- Dedicated storage for biological and infectious materials

- Bulk gas piped in, (Liquid Nitrogen, Gaseous Nitrogen, Air) ; limit individual bottles
- Exhausted fume hoods in labs meeting industry consensus standards, (specialized hoods including HEPA filters for nanomaterials and radioactive materials where necessary)
- Covered centralized location for storing gas, satellite locations due to size of ring
- Safety showers and eyewashes in each lab (tepid water) and at beamlines where required
- Loading dock and bypass corridors with leveling systems to reduce material handling
- All lead material encapsulated/painted
- Hutches with exhaust ventilation capability to exterior of bldg

MITIGATING FACTORS (OPERATIONAL)

- Experimental safety review to determine type and use of all chemicals, nanomaterials, radioactive and biological, minimize quantities in use and in storage, and compatibility
- Compliance with BNL Subject Areas and Part 851 requirements for handling chemicals, including nano and biological materials
- Chemical Inventory control system (barcode), Chemical Management System (CMS) (periodic inventory review)
- Lab Standard/Hazcom and other required training
- Transport of materials per DOT and BNL Hazardous Materials Transportation Manual (HMTM)
- Exposure monitoring
- Safety protocols for workers using or machining lead
- Medical surveillance as required
- Training/qualification
- Tier 1 inspections

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☒ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.10: Risk Assessment Summary for Ionizing Radiation Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-10**

SUBSYSTEM: NEXT beamlines

HAZARD: Ionizing Radiation

HAZARD INITIATOR(S): Accelerator or beamline component failure, interlock failure, insufficient shielding, inadequate configuration control, procedural violation or inadequacy

HAZARD CONSEQUENCE: Potential for excessive radiation dose and possible injury or death

RISK ASSESSMENT PRIOR TO MITIGATION:

CONSEQUENCE Routine	☒ I High	☐ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☒ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Well designed shielding for accelerators, beamlines and hutches to reduce dose to administrative levels.
- Interlock systems (e.g., beam dumps if interlock broken, emergency stop capability, audible/visual alarms)
- Redundant interlock systems for accelerator enclosures and beamline hutches
- Redundant monitored radiation safety critical devices (e.g., transfer line dipole magnets , beamline safety shutters) which reach back to upstream devices like RF and dipole power supply if there is a failure
- Real-time beam loss monitoring system for injection and storage ring operation
- Real-time interlocked area radiation monitors on experimental floor
- Shielding around plug doors and beamline penetrations to minimize leakage; e.g., single-block concrete construction wherever possible, tongue-and-groove to eliminate line-of-sight
- Office areas/staff lounges and other public areas (e.g., walkways) will not be exposed to radiation fields produced by machine operations or by equipment, including magnetic or RF fields
- Enclose first optical elements in shielded enclosures.

MITIGATING FACTORS (OPERATIONAL)

- Radiological protection program incorporating requirements of 10 CFR 830 and 835, and BNL SBMS Radiological Control Manual
- Strict configuration control of shield and interlock systems
- Routine area monitoring of dose levels by passive dosimeters for neutrons and gammas on the experimental floor (and other occupied areas)
- Radiological safety training, e.g., GERT, Radiation Worker I, etc.
- Facility Specific Safety Orientation and ESH Orientations
- Training/Qualifications
- Tier 1 insepections
- Work planning and control procedures for work in radiation areas or with radioactive materials
- ALARA designs and committee reviews

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☒ **E** Extremely Remote		
	☐ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.11: Risk Assessment Summary for Non-ionizing Radiation Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-11**

SUBSYSTEM: NEXT Beamlines

HAZARD: Laser and other non-ionizing radiation (RF, microwave, static magnetic, infrared, visible, ultraviolet)

HAZARD INITIATOR(S): Equipment failure, interlock failure/over ride, inadequate/removed shielding

HAZARD CONSEQUENCE: Exposure to non-ionizing radiation could result in personnel injury and/or overexposure to regulatory limits

RISK ASSESSMENT PRIOR TO MITIGATION:

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☐ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☒ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Commercial equipment designed with integral enclosure shielding (interlock systems if required by intensity or wavelength)
- Laser labs must address ANSI design requirements, including control of exposed beams and interlock systems
- Use of gas cabinets for lasers using halogens (fluorine gas) vented exterior to bldg

MITIGATING FACTORS (OPERATIONAL)

- Baseline and routine surveys for stray magnetic fields, RF, and microwave
- Training for static magnetic fields, RF, and microwave hazards

- Laser safety training
- Equipment ESH review during procurement, installation and use
- Subject Matter Expert reviews, written procedures as required
- PPE
- Tier 1 inspections

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☒ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☐ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.12: Risk Assessment Summary for Material Handling Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-12**

SUBSYSTEM: NEXT Beamlines

HAZARD: Material Handling

HAZARD INITIATOR(S): Dropped or shifted load, equipment failure, suspect or counterfeit hardware, improper procedure, insufficient training/qualification

HAZARD CONSEQUENCE: Severe injury or death to equipment operator and bystanders, equipment damage, program interruption

RISK ASSESSMENT PRIOR TO MITIGATION:

CONSEQUENCE Routine	☒ I High	☐ II Moderate	☐ III Low	☐ IV
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☒ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☒ I High	☐ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Hoists and attach points designed to ASTM/ANSI standards
- Gasses piped in to reduce cylinder handling
- Adequate aisle space for maneuvering loads (aisles marked where necessary)
- Heavy beamline components designed with lift points
- Bypass corridors with material lifts installed to allow equipment movement around long beamlines

MITIGATING FACTORS (OPERATIONAL)

- Hoists proof-tested after installation and any modification

- Routine inspection and maintenance of all hoists and rigging equipment
- Only trained and qualified personnel allowed to use hoists and fork trucks
- Critical lift evaluations
- Hoists are locked to prevent unauthorized use.
- Daily inspection as required by SBMS to ensure proper operating conditions
- Ensure areas are adequately protected from the forklifts and other traffic
- Good rigging practices (i.e., tag lines, secure material during transport etc.)
- Proper personal protective equipment
- Tier 1 inspections

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☒ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☐ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine

Table 6.13: Risk Assessment Summary for Other Experimental Hazards.

Beamlines Hazard Analysis

SYSTEM: NSLS-II **HAZARD ID:** NEXT/ABBIX **HAR-13**

SUBSYSTEM: NEXT beamlines

HAZARD: Experimental Equipment Operations

HAZARD INITIATOR(S): Failure of protective system(s),interlocks, , operator error, lack of training, exhaustion, poorly designed/installed equipment, equipment failure, undefined hazards/risks from material not considered in design reviews

HAZARD CONSEQUENCE: Minor to severe injury to personnel and possible death, damage to experimental, accelerator or facility equipment, programmatic impact

RISK ASSESSMENT PRIOR TO MITIGATION

CONSEQUENCE	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine
PROBABILITY	☐ **A** Frequent	☐ **D** Remote		
	☐ **B** Probable	☐ **E** Extremely Remote		
	☒ **C** Occasional	☐ **F** Impossible		
RISK CATEGORY	☐ I High	☒ II Moderate	☐ III Low	☐ IV Routine

MITIGATING FACTORS (DESIGN)

- Each lab designed based on anticipated use and future use (user input in design process, historical inventories/hazards considered)
- Experimental Equipment design evaluation
- Protective systems/interlocks/guards
- Design to ASME B31.3
- Adequate power designed into lab to support equipment/future growth. (GFCI protected, if needed)
- Equipment bonding system installed
- Labs designed for easy access/egress, process flow, ease of cleaning etc.
- Labs located in proximity to beamlines reducing travel with experimental materials
- Facility and labs designed to meet OSHA 1910 (walkways, stairs, egress etc.)

MITIGATING FACTORS (OPERATIONAL)

- Experimental safety review program
- Periodic testing of interlock systems
- Control of hazardous materials (inventory, storage)
- Control combustible loading near heat sources, furnaces
- Warning signs
- ESH support staff
- Principle Investigators R2A2 and training in hazard recognition
- Personal Protective Equipment
- Adequate Beamline staffing
- Tier 1 inspections

RISK ASSESSMENT FOLLOWING MITIGATION

CONSEQUENCE Routine	☐ I High	☒ II Moderate	☐ III Low	☐ IV

PROBABILITY	☐ **A** Frequent	☒ **D** Remote
	☐ **B** Probable	☐ **E** Extremely Remote
	☐ **C** Occasional	☐ **F** Impossible

RISK CATEGORY	☐ I High	☐ II Moderate	☒ III Low	☐ IV Routine