NATIONAL SYNCHROTRON LIGHT SOURCE II (NSLS-II)

FINAL DESIGN PLAN

May 13, 2008

BROOKHAVEN NATIONAL LABORATORY

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1. Summary

The *National Synchrotron Light Source II (NSLS-II) Final Design Plan* defines the status of the NSLS-II design at the time of the construction readiness reviews scheduled for the fall of 2008 in support of DOE Critical Decision 3 (CD-3), Approve Start of Construction. The DOE Acquisition Executive milestone for CD-3 is January 2009 and the construction readiness reviews are scheduled to precede the approval decision. The BNL/NSLS-II Construction Readiness Review is scheduled for September 2–4, 2008, the DOE/SC IPR on September 30–October 3, 2008, and the DOE/EIR on October 20–24, 2008.

The *Final Design Plan* provides for a phased completion of the final designs for the NSLS-II facility, ensuring designs are sufficiently mature to start procurements and construction; enabling the most cost-effective schedule for constructing the facility; and maximizing the technical capabilities of the facility at CD-4. Completing all final design work before CD-3 is neither feasible nor desirable for three reasons: (1) design and construction plans must be consistent with the annual funding constraints; (2) for the facility to be a state-of-the-art research facility when it is completed in 2015, some design flexibility beyond CD-3 is required to incorporate advances in technology or to meet future user needs; and (3) completing all final design work by CD-3 might result in substantial design work that would not be used or would need to be substantially modified at a later date, incurring additional costs. .

At CD-3, the overall design will be 75% complete as a percentage of the value of scope requiring design effort.

- Conventional Facility (CF) design will be 90% complete (completing remainder of design after CD-3 enables optimization of LOB design – see Section 3)
- Accelerator Systems (AS) design will be 70% complete (completing remainder of design after CD-3 enables use of vendor developed designs for design/build turnkey procurements or design to an NSLS-II specification, to benefit from technology advances, and to ensure compatibility with the beamlines – see Section 4)
- Experimental Facilities (EF) design will be 25% complete (completing remainder of design after CD-3 enables installation of the best possible suite of instruments based on full participation of the user community – see Section 5).

2. Design Schedule

Milestones for the scheduled completion of design phases and the award of design–build contracts for elements of CF, Accelerator Systems AS, and EF are included in the NSLS-II integrated, resource-loaded schedule and the Performance Baseline. Table 1, NSLS-II Final Design Schedule, categorizes the design completion milestones into two categories for the purposes of identifying the facility design status at CD-3: final designs completed by NSLS-II staff, and designs completed by vendors under design–build contracts.

The scheduled submission of the NSLS-II CF Title II Design, including the CF drawings, technical specifications, and basis of design documents, is August 25, 2008. The physics design and performance parameters for the storage ring and injection system are already complete and subject to formal change control. The final design of subsystems and components will be completed on a schedule that meets the overall needs of the facility construction schedule.

Table 1. NSLS-II Final Design Schedule

	Level 2 System Value ($M)	Design or Specification % Complete at CD-3[1]	Final Design or Specification Completion Date
TOTAL LEVEL 2 SYSTEMS/FACILITIES	**560.3**	**75%**	
CONVENTIONAL FACILITIES (CF)[2]	**247.5**	**90%**	
Site Preparation		100%	09/08
Ring Building		100%	09/08
Injection System Buildings		100%	09/08
RF System Buildings		100%	09/08
Utilities		100%	09/08
Chilled Water Plant Expansion		100%	09/08
Lab Office Buildings (Beamline staff)		40%	01/11
ACCELERATOR SYSTEMS (AS)	**240.3**	**70%**	
Magnet and Support System		90%	09/08
RF Systems – Harmonic RF[3]		75%	06/09
RF Systems – Main RF[3]		65%	06/09
Injector Booster Synchrotron[3]		75%	07/09
Injector LINAC[3]		70%	10/09
Cryogenic Systems[3]		75%	10/09
Vacuum System		50%	03/10
Power Supply System		50%	04/10
Electrical/Mechanical Systems		50%	05/10
Photon Beam Front-Ends		50%	10/10
Control System		50%	04/11
Beam Transfer, Injection, & Extraction System		50%	08/11
Safety Systems (Final Subsystems)		50%	08/11
Insertion Devices		25%	05/11
EXPERIMENTAL FACILITIES (EF)	**72.5**	**25%**	
Powder Diffraction Beamline		30%	02/12
XAS Beamline		30%	02/12
Soft X-ray Coherent Beamline		25%	02/12
Hard X-ray Coherent Beamline		20%	02/12
Inelastic X-ray Scattering Beamline		20%	02/12
Nanoprobe Beamline		20%	02/12

[1] Weighted design completion percentage based on the subsystem value and design effort completed by NSLS-II staff.
[2] Interfaces between CF and Accelerator Systems and Experimental Facilities are completely defined by CD-3.
[3] This is a turnkey subsystem with subsystem definition completed by the NSLS-II staff and vendors completing final design.

3 Conventional Facilities

Final design and engineering of Conventional Facilities (CF) are scheduled to be complete by September 2008. The CF scope includes the facility site, accelerator storage ring buildings, injection system buildings, radio-frequency system buildings, offices, utilities, and expansion of the BNL chilled water plant and main electrical substation to meet NSLS-II utility requirements. Construction for these CF scope elements will begin immediately following final design and DOE approvals, as described in the PEP approved by the Acquisition Executive.

Final design of the Laboratory Office Buildings (LOBs), less than 15 % of the planned value of the CF, will be completed after civil construction is well underway and the major accelerator contracts are in place. At that time a substantial fraction of the project cost risk will be retired and the requirements for the LOBs will be assessed to determine the optimum requirements and specifications prior to the start of final design. The timing for construction of the LOBs is determined by the necessity for the ring building to be constructed first and is also limited by the available funding profile. As a consequence, completing the LOB final design earlier would not allow the LOB construction to begin earlier. It is also important to note that the LOBs are not required for the Project to meet the NSLS-II Key Performance Parameters (KPPs) defined in the PEP.

4 Accelerator Systems

The final design of Accelerator Systems (AS) is implemented in a staged fashion in order to make effective use of the relatively long civil construction period and to enable resource leveling of NSLS-II design and engineering staff. The AS includes two major systems, the storage ring system and the injection system. The final layout of the storage ring and the injection system will be complete by September 2008, including the relevant Requirement, Specifications, and Interface (RSI) documents for both systems. The final design of the storage ring magnets and support systems will also be complete prior to the start of civil construction. These represent the most complex designs within the AS scope. The remaining AS design activities will be completed by industrial suppliers or by NSLS-II staff and are largely NSLS-II specific variations to well understood and mature systems widely used at similar facilities around the world. There is a very low probability that this remaining design work will pose any risk to the successful completion of the NSLS-II facility.

A number of AS systems will be procured as large design–build turnkey procurements. Additional components are purchased to NSLS-II performance specifications. In these cases, vendors, following the placement of contracts or purchase orders, complete the relevant design work when it is required. In many cases the NSLS-II requirements and specifications will be met by existing vendor designs. In other cases, the vendor will need to modify existing designs; in a small number of cases the vendor will need to develop new final designs. In all of these cases the design effort of the NSLS-II staff will be limited to conceptual and preliminary design. The scheduled contract award for these systems is provided in Table 1. For CD-3, design is considered final when the vendor specifications are complete for turnkey procurements.

AS turnkey procurements include:

- the injector LINAC,
- injector booster synchrotron,
- RF transmitters for the storage ring, and

- RF cavities for the storage ring.

Other systems will consist of major components that can be purchased based on NSLS-II performance specifications. The design work performed by NSLS-II staff includes the specifications, conceptual layouts, preliminary design of the systems, detailed and final design of connecting pipe work, calculations and analyses, and performance assessments and simulations. For these components, the detailed final designs will be developed by the vendors. Similar to turnkey procurements, design is considered final when the vendor specifications are complete for these procurements. These components include:

- cryogenics system needed for cooling of the storage ring RF cavities with liquid helium, and
- water pumps, heat exchangers, water-processing, and chillers needed in the water-cooling system.

The risk associated with outstanding design for all of these items is very small, as the items range from systems already constructed and operating at other facilities, to off-the-shelf components.

Another group of systems will only be needed after most components are already procured, assembled, installed, tested, and commissioned. The reason for the delaying design is to assure compatibility with the beamlines. In addition, for some of these systems the technology is developing very dynamically in industry. For these components, it is desirable to carry out the final design as late as possible in order to benefit from the technological progress or from cost reductions once a technology becomes mature and mass-producible. In many cases, vendors will complete preliminary and final design work. These components include:

Insertion Devices - The preliminary design of these components will be complete by CD-3. Final optimization of insertion devices will depend on input from the technical and scientific choices of the beamline layout. For this reason, the final technical design is scheduled to take place after CD-3. Insertion devices are planned to be installed after the accelerator has been commissioned with beam, which will provide the necessary window for the final design of those components. The design package consists of requirement documents, conceptual layouts, and preliminary design drawings. There is an option to procure turn-key systems for which designs exist with the vendor. Because these components involve small variations of existing, well understood and tested designs, there is only minimal design risk from this scope of work.

Photon Beam Front-Ends - These systems will consist of masks, shutters, vacuum components, and absorber blocks, for which detailed designs exist at other facilities. Only small modifications are necessary to adapt Advanced Photon Source designs to the NSLS-II requirements. The design package will consist of preliminary designs (which will be 50% complete at CD-3), and final design drawings that will require only small modifications depending on the actual beamline choices. Because these components involve small variations of existing, well understood and tested designs, there is only minimal design risk from this scope of work.

Safety Systems - Final design of the personal safety systems depends on details of the beamline layouts that will only be available after the layouts are complete. The design package will include requirements, analysis of safety logics, preliminary design of the

system and electrical circuit boards of design components. These will be 50% complete at CD-3. There is no risk that the safety systems for the beamlines cannot meet the facility requirements, as these types of systems are used extensively at light sources throughout the world.

Control System - The technology on which the control system is based is expected to develop rapidly. The design effort is foreseen to extend over a longer period of time to take advantage of these expected technology developments. It concentrates, for this reason, on control system architecture, preliminary layout of hardware and software components, information systems, and interface with high-level modeling systems. The critical system is the timing system, which will be 50% complete at CD-3. Design packages will consist of control system requirements, control system architecture layouts, and preliminary design drawing packages for the timing system. There is no risk that the control system will not meet the facility requirements. There is positive risk (opportunity) associated with delay of this design to take advantage of technology advancement.

Finally, there is a group of systems for which, because of the low risk, design was delayed to allow resource leveling. These include:

Vacuum System - Detailed design and manufacturing drawings will make up the design package for the cell vacuum chambers. This part of the design will be 100% complete at CD-3. A prototype chamber based on this design will be produced by CD-3, which is expected to retire any technical risk associated with the chamber. Vacuum valves, vacuum pumps with power supplies, and controls will be vendor-supplied items where design resides with the vendor.

The design of the sliding pieces with shielded bellows will be made up of a drawing package, impedance calculations, a thermal analysis, and an assessment of mechanical fatigue. This will be 50% complete at CD-3. The technical risk is totally contained within the vacuum system; the challenge is to produce a reliable vacuum system at the lowest possible cost. Because these components involve small variations of existing, well understood and tested designs, there is only minimal design risk from this scope of work.

Power Supply System - Power supplies are a combination of vendor-supplied base systems and additions produced in house. The vendor-supplied components will be specified at 100% by CD-3. The design of the in-house additions will be at the 25% design level at CD-3, resulting in an overall weighted design completion value of 50%. The design package consists of drawings of mechanical layouts; drawings of electrical circuit boards; analyses and specification of the control loops; and the complete layout of the cable system. There are minimal risks associated with the storage ring main power supply and the multipole power supplies as these are standard systems. The modest design risk for the corrector magnet power supplies will be addressed by CD-3 by the fabrication and testing of a prototype. Detailed drawing packages will be based on the result of the tests with this component.

Beam Transfer, Injection, and Extraction System - The beam transfer systems are planned to be turn-key, vendor-supplied systems. Preliminary design is complete and the design package consisting of specifications for the vendor-supplied systems will be 100%

complete at CD-3. The injection and extraction system of the booster will be part of the vendor-supplied turnkey system.

The storage ring injection system preliminary design will be complete at CD-3. The final design for the baseline system with the major components will be 50% complete by CD-3. The completed final design will include refinements that will be based on tests of design prototypes for key magnets (particularly the pulsed septum). The design package consists of drawing packages for the baseline system. There are minimal risks associated with this system, as it is a standard system.

5. Experimental Facilities

The NSLS-II Experimental Facilities consists of six beamlines that are selected to meet the needs of the NSLS-II scientific user community and to exploit the capabilities of the facility. The process for determining the beamlines will be completed in 2008, with Beamline Advisory Teams (BATs) established to provide input from the user community. Once the BATs are established and preliminary designs are completed, the NSLS-II project will establish technical, cost, and schedule baselines for each project beamline and authorize the use of funding for the completion of detailed design and component fabrication.

The project beamlines are scheduled to be installed and ready late in the construction project. They are similar to the AS insertion devices, in that the beamlines are commissioned only after the accelerator storage ring is successfully commissioned with beam. **The general strategy is to construct the six project beamlines within a fixed budget for EF; therefore, it is not likely that cost risk will transfer to the overall project.** The approach is to build the best possible suite of scientific instruments within the fixed budget and at the latest possible time prior to CD-4, Approve Start of Operations.

Completing final design of the beamlines by CD-3 would incur several risks to the project in either committing the project to building experimental facilities that do not meet the needs of the scientific user community, or being forced to make changes at a late stage in final design, thus incurring additional costs.