Department of Energy
Office of Science
Washington, DC 20585

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MEMORANDUM FOR: HARRIET KUNG
ASSOCIATE DIRECTOR
OF THE OFFICE OF SCIENCE
FOR BASIC ENERGY SCIENCES

FROM: STEPHEN W. MEADOR
DIRECTOR
OFFICE OF PROJECT ASSESSMENT

SUBJECT: Final Report on the DOE/SC Review of the NEXT Project, November 2015

Attached for your consideration and use is the final report on the Department of Energy/Office of Science review of the NSLS-II Experimental Tools (NEXT) project. The NEXT review was conducted on November 3-4, 2015, at the Brookhaven National Laboratory in Upton, New York.

If you have any questions or would like to discuss the report further, please contact me.

Attachment

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U.S. DEPARTMENT OF ENERGY | Office of Science

Office of Project Assessment
Review Report on the

NSLS-II Experimental Tools (NEXT) Project

at Brookhaven National Laboratory

November 2015

EXECUTIVE SUMMARY

A Department of Energy/Office of Science (DOE/SC) review of the NSLS-II Experimental Tools (NEXT) project was conducted at Brookhaven National Laboratory (BNL) on November 3-4, 2015. The review was conducted by the Office of Project Assessment (OPA) and chaired by Stephen W. Meador at the request of Dr. Harriet Kung, Associate Director of Science for the Office of Basic Energy Sciences (BES). The purpose of the review was to evaluate the project's status and progress.

The technical subcommittees were consistently positive in stating their assessment that the beamlines represent best-in-class, world-class or, in some cases, world-leading capabilities. Environmental, Safety, and Health and Quality Assurance (QA) requirements are being properly addressed with good safety experience to date. Cost growth and amount of contingency usage remains a concern. The remaining cost and schedule contingency appears to be just adequate to successfully complete the project.

Technical

There has been good progress in beamline component fabrication, delivery, and installation across all instruments. End-station/detector enhancements better position the project to achieve its goal of providing a suite of world-class beamlines. While there are no major technical issues, a concern was raised about the proposed installation of fire protection systems (water sprinkler systems) on beamlines with gas handling systems due to the potential for creating a safety hazard and for significant and expensive equipment damage.

Environment, Safety and Health

All aspects of ES&H are appropriate for the current phase of the project. Experienced and competent ES&H staff are integrated into the project. The Instrument Readiness Review (IRR) and QA processes are functioning well.

Cost and Schedule

The project team (including Control Account Managers or CAMs) is confident that the recently updated Estimate at Completion (EAC) is sufficient to complete the project scope. Processes are in place to resolve the issues associated with the erroneous reporting of accruals. While on-the-floor progress is visible and impressive across all beamlines, the remaining cost and schedule contingency reserves are tight. This limits the project's ability to respond to unanticipated issues in the future.

Management

As a response to the significant cost growth and process deficiencies that led to erroneous accrual reporting, BNL instituted a laboratory review of NEXT's EAC. Subsequently, a corrective action plan was put in place, intended to stabilize project cost growth. The remaining cost contingency is a concern, especially considering the small amount of scope contingency available.

Key Recommendations

- Re-evaluate the requirement for water discharging sprinkler systems in the ISR and ISS hutches.
- Incorporate the EAC presented at this review into the baseline.
- No further scope additions should be implemented until the project can assure the delivery of the Key Performance Parameters.
- Work with NSLS-II management, BNL management, and the program office to increase the contingency reserve.
- Ensure that sufficient controls personnel are available to NEXT so that beamline commissioning is not delayed.

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1. INTRODUCTION

The National Synchrotron Light Source II (NSLS-II) has been constructed as a highly optimized, third-generation synchrotron facility that enables the study of material properties and functions, particularly at the nanoscale, with a level of detail and precision never before possible. NSLS-II provides world-leading brightness and flux, as well as exceptional beam stability over a broad range of photon energies from infrared to hard x-rays. The NSLS-II Experimental Tools (NEXT) Major Item of Equipment (MIE) project is intended to provide up to six best-in-class beamlines with advanced experimental capabilities complementary to those provided by the six delivered NSLS-II project beamlines. These additional beamlines will support the urgent needs identified by the U.S. research community for responding to the Department of Energy (DOE) mission of achieving transformational energy solutions in the near-term while simultaneously expanding the knowledge of fundamental energy science. Overall, this project is expected to increase the number of users that NSLS-II can support by about 300 to 400 users per year.

Background

The mission for the Basic Energy Sciences (BES) within the DOE/Office of Science (SC) is to foster and support fundamental research to expand the scientific foundation for new and improved energy technologies, and for understanding and mitigating the environmental impacts of energy use. As part of this mission, the BES Scientific User Facilities (SUFD) program plans, constructs, upgrades, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories. The purpose of this upgrade fulfills goals and objectives in the Department's new strategic plan, which identifies the need of Facilities for Light Sources and Nanoscale Materials as one of the strategic initiatives.

Among the various BES user facilities, such as neutron sources, nanoscience centers, and electron microscopy centers, the synchrotron light sources have the highest user demand. Specifically, the four DOE-operated, storage-ring-based light sources—Advanced Photon Source (APS), Advanced Light Source (ALS), National Synchrotron Light Source-II (NSLS-II), and Stanford Synchrotron Radiation Light source (SSRL)—have provided research opportunities for an ever-expanding scientific user community of almost 10,000 scientists.

The NEXT project scope is to develop, fabricate, install, and test up to six insertion device beamlines for NSLS-II. The candidate beamlines and their capabilities are:

Electron Spectro-Microscopy (ESM) is an elliptically polarized undulator-based high-resolution, high-flux, wide-energy range, micro-focused VUV/soft X-ray beamline designed to provide high-quality monochromatic radiation to two electron microscopes for: 1) in-situ growth and structural, electronic, and chemical characterization of material surfaces at the nanometer scale (XPEEM) and 2) ultra-high energy and angle-resolved photoemission studies of materials in ultra-high vacuum conditions (μ-ARPES). The combination of full field (XPEEM) and scanning (μ-ARPES) microscopies is a unique feature of ESM that will advance our understanding of material properties, both physical and chemical, to unprecedented levels. The ESM scientific program directly addresses three of the five DOE/BES Grand Scientific Challenges: 1) controlling material processes at the electronic level; 2) designing synthesis of revolutionary new materials with

tailored properties; and 3) understanding and controlling the emerging phenomena and the non-equilibrium processes and mastering energy and information on the nanoscale.

Soft Inelastic X-ray Scattering (SIX) is an elliptically polarized undulator-based inelastic scattering beamline that will provide world-leading energy and wavevector (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 in the soft X-ray energy range that covers important elemental absorption edges that are particularly sensitive to magnetic and orbital excitations. It can potentially revolutionize studies in condensed matter excitations including correlated electron materials and superconductors, energy storage, environmental science, and catalysis at ambient pressures. This offers the prospect of major steps forward in addressing forefront energy-related questions pertaining to the DOE Mission Need. Specifically, the SIX beamline scientific program addresses questions related to technological improvements in energy sources (clean, renewable) and usage (storage, transmission), as well as in nuclear safety. In order for the emission spectrometer optics to achieve this ultimate resolution, the ultrahigh resolution end-station and its very large emission spectrometer must be located in a satellite building outside the NSLS-II experimental hall.

Integrated In-Situ and Resonant X-ray Studies (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 microfocusing with a greater than one meter working distance from the focusing optic. The broad range of capabilities will address DOE/BES mission priorities by enabling fundamental research in materials synthesis and processing, structure-property relationships in complex materials, and materials response to external stimuli such as high magnetic field.

Soft Matter Interfaces (SMI) is an in-vacuum undulator based X-ray scattering beamline operating from 2.05–24 keV, dedicated to structural studies of interfaces in soft and bio materials. It will provide micron-sized beams to address solid-vapor, solid-liquid, liquid-liquid, and liquid-vapor interfaces, using small- and wide-angle scattering and reflectivity geometries, to probe molecular self-assembly and shed new light on structure-function relationships from sub-nanometer to micron length scales. The beamline's world-class capabilities for fast reflectivity and time resolved scattering, mapping, and visualization will shed new light on the behaviors of polymers, gels, liquid crystals, granular materials, biomolecular materials, and micro/nano-fluidics systems. These capabilities are fundamental to the DOE/BES mission to design, model, assemble, and characterize new organic devices, biomimetic materials, and nanoscale composites, for applications in energy transfer and other functional materials.

Full-Field X-ray Imaging from Micrometer to nm (FXI) is a damping wiggler-based hard X-ray microscopy beamline that will provide a state-of-the-art implementation of a 30 nanometer resolution, high speed transmission X-ray microscope (TXM) for samples demanding the highest resolution. The TXM, purposely designed for X-ray Absorption Near Edge Spectroscopy (XANES) imaging, features a precise metrology system for automated tomography. This will allow nondestructive tracking of three-dimensional morphological and chemical state changes in a broad range of DOE/BES mission disciplines including energy, materials science, and the

environment. For example, FXI will enable the tracking of changes in: 1) energy storage devices in-operando; 2) materials under different environments in-situ, and 3) flow of fluids through porous media such as rocks.

Inner Shell Spectroscopy (ISS) is a damping-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 damping 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 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 will provide a complete picture of inner-shell electronic structure and will be applied to a broad, cross-disciplinary scientific mission, thereby supporting the DOE mission to enable transformative science and technology solutions in the energy and environmental area.

DOE approved the CD-0, Approve Mission Need, for the project on May 27, 2010. CD-1, Approve Alternate Selection and Cost Range, was received on December 19, 2011—the cost range was established to be $82.5-90 million, with a Total Project Cost of $90 million. The project received CD-2/3a, Approve Performance Baseline and Long Lead Procurements, on October 9, 2013 establishing the project's official baseline. CD-3, Approve Start of Construction, was received on July 7, 2014, and CD-4, Project Completion, is planned for fourth quarter FY 2017.

Charges to the DOE Review Committee

In a September 10, 2015 memorandum (Appendix A), Dr. Harriet Kung, Associate Director of Science for BES requested that Mr. Stephen W. Meador, Director, Office of Project Assessment (OPA), SC, organize, conduct and chair an Independent Project Review of the NEXT project at Brookhaven National Laboratory (BNL) on November 3-4, 2015. The purpose of this review was to determine the status of the NEXT project and to identify any concerns that could prevent the project from successfully completing within the approved baseline.

Membership of the Committee

OPA assembled a Review Committee composed of members (Appendix B) selected on the basis of their independence from the project, as well as for their technical and management expertise, and experience with building large and complex scientific research facilities. The Committee was organized into six subcommittees, each assigned to evaluate a particular aspect of the project corresponding to the subcommittee members' area of expertise. Stephen W. Meador, Director of OPA, chaired the review.

The Review Process

The review was conducted at BNL on November 3-4, 2015. NEXT project personnel provided information to the Committee in advance of and during the on-site review that was designed to assess the project's current status and identify any concerns that could prevent the project from successfully completing within the approved baseline. In addition, the Committee evaluated the performance, to date, on technical and cost and schedule progress since CD-3, including the use of contingency, and progress on ES&H and management effectiveness. Committee members submitted questions and received responses prior to the review. Representatives from the NEXT project team, DOE/Brookhaven Site Office (BHSO), and the DOE/OPA jointly developed the meeting agenda (Appendix C) with concurrence from BES/SUFD.

The first day of the review started with an Executive Session of the Committee in which the Federal Project Director presented an overview of the project's progress since the August 2014 DOE/SC review. The charge to the committee was reviewed along with the agenda. The BES program expressed the expectations for this review. Questions to be answered included: Are all five beamlines world class as currently designed? The project has experienced significant cost growth since the prior review. Did the Committee feel that the contingency had been appropriately used and was the remaining contingency adequate to complete the project? Did the project have a viable path to project completion defined within the baseline. The open session of the review began with a greeting by the NSLS-II Director, John Hill, to the Committee and observers. The plenary session of the review followed with presentations by the NEXT Project Manager, and key scientific, engineering and technical members of the project team covering the progress to date, the use of contingency and technical capabilities of each beamline. The afternoon started with the remaining plenary talks on technical systems. Following the plenary talks, the Committee broke into subcommittees for the afternoon breakout sessions. The breakouts started with committee-specific tours of the NEXT beamlines followed by one or more subcommittee specific talks. The first day ended with an Executive Session to review progress made throughout the day and discuss the initial findings.

The second morning continued with short breakout question and answer periods, as needed, for each subcommittee with project representatives. The Committee reconvened mid-morning at an Executive Session devoted to committee deliberations, and drafting the closeout presentation. The closeout was held prior to lunch with the Committee presenting their preliminary results to BNL, NSLS-II, and NEXT management. Final results are contained in this report, which Committee members individually authored and collectively reviewed.

2. TECHNICAL SYSTEMS EVALUATIONS

2.1 Electron Spectro-Microscopy (ESM)

2.1.1 Findings

The Electron Spectro-Microscopy (ESM) beamline uses one Quasi Periodic Elliptically Polarizing Undulator (QP-EPU) and one standard EPU serving complementary spectral regimes to cover 15 to 1500 eV. Both of these insertion devices (ID) deliver beams to a single plane grating monochromator (PGM) serving two complementary end stations:

- An Angle-Resolved and Spin-Resolved Photoemission Spectroscopy (ARPES and Spin-ARPES) with one micron focus at the sample, and
- A full-field PhotoElectron Emission Microscope (PEEM), which will be provided and supported by a partner user and is outside the project scope.

The cost increase of about $1.2 million resulted from the addition of a Scienta DA30 electron energy analyzer and an ultra-low temperature close cycle cryo (liquid helium) system. The latest generation DA30 electron analyzer allows an orthogonal momentum component to be varied electronically, a significant improvement over the previous generation. This enables Fermi surface mapping without rotating the sample, hence is a critical addition to the ARPES end station to take full advantage of the micron spatial resolution delivered by the state-of-the-art beamline. The addition of spin polarimeter further enhances its capability. The low temperature sample manipulator with one rotational degree of freedom, on the other hand, is a necessary investment to match the meV resolution of the beamline as the thermal broadening (~kT) needs to be reduced to a minimum.

The beamline development project is on track and almost all of the hardware has been ordered. In total, 74% of the total $9.6 million EAC has been costed while 87% has been obligated. Most of the state-of-the-art optics have been received. All received optics meet the design specifications as verified by the metrology measurements. In particular, all four VLS (Variable Line Spacing) gratings have been demonstrated to have the designed efficiency. The installation of the beamline has already started and the end station assembly will start soon.

2.1.2 Comments

The scope additions to the ESM beamline and end station are essential to make this facility a world-class instrument that is capable of delivering world-class science. Addition of a Scienta DA30 analyzer with two spin detectors makes the micro ARPES end station state-of-the-art for measuring electronic structure of quantum material systems. This world-class facility will enable studying a myriad of complex systems including strongly correlated electron materials such as high temperature superconductors and materials with strong spin-orbit physics. These systems have technological importance for energy science and low-energy consumption spintronics. The other major scope addition of an ultralow temperature sample manipulator will allow taking full advantage of the meV resolution this beamline is capable of delivering.

Furthermore, the ESM team developed a sample puck and transfer mechanism that is compatible with both PEEM and OASIS (a combination of oxide Molecular Beam Epitaxy (MBE), ARPES, and Spectro Imaging STM system) developed by the Condensed Matter Physics Materials Science Department (CMPMSD) at BNL. This will help promote a synergy between NSLS-II; the Center for Functional Nanomaterials, which is developing the PEEM at the ESM beamline; and CMPMSD.

Some of the beamline optics are highly challenging having aspherical surfaces with slope errors of approximately 100 nrad and short radii (<10m), requiring cutting edge technology manufacturing and metrology. Many of these optics have already been received with metrology measurements done, demonstrating that these optics meet the challenging specifications. This is critical for a timely commissioning of the beamline as the cutting-edge optics can be the bottleneck. In addition to the challenging optics, the rest of ESM beamline development is making steady progress for early completion and should be ready for commissioning in July 2016.

There are three EPUs on the two soft X-ray beamlines under review: two of them (ESM EPU57 and ESM EPU105) serve the ESM beamline while the third (SIX EPU57) serves the SIX beamline. These EPUs are critical to achieve the full polarization control on these two state-of-the-art beamlines. The ID group has made outstanding progress in designing and procuring all three undulators from Kyma, which was very cost effective.

The shorter period ESM EPU57undulator has been manufactured and its initial magnetic measurements have shown that it has a good field quality even without shimming. With proper shimming it is expected to meet the requirement for the NSLS-II storage ring prior to installation. The longer period ESM EPU105 undulator is more challenging, as it is designed as quasi periodic—to help reduce the higher order component flux, as well as the power density in the low photon energy range. Its manufacturing is also on track with a target delivery in January 2016.

With the strong expertise and experience in optimizing the magnetic performance of an EPU, the ID team plans to perform shimming of both ESM EPU105 and SIX EPU57 undulators in-house. This is a good strategy to ensure full control of the shimming process and ultimate magnetic performance of these two more challenging EPUs. Related to the EPU development, a multilayer undulator diagnostic setup has been built, which will be extremely useful in characterizing the performance of the undulators, as well as optimizing the electron optics in the storage ring for better performance of the ID output.

2.1.1 Recommendations

None.

2.2 Soft Inelastic X-ray Scattering (SIX)

2.2.1 Findings

The Soft Inelastic X-ray (SIX) scattering beamline combines a high-resolution soft X-ray monochromator with a similarly high-resolution spectrograph to probe elementary excitations in

solids with elemental selectivity and momentum resolution. Experiments will provide important tests of existing theories for unraveling emergent properties arising due to many interacting degrees of freedom. Many important new applications to nanostructured materials will be developed around this sensitivity.

The optical design of the 15m spectrometer is further modified with the addition of a flat deflection mirror that will reduce the risk by eliminating the complexity of moving the detector arm in the vertical plane. The price of this addition is offset by the elimination of vertical motion, but it may increase the project cost a few hundred thousand dollars. By reducing the scope of sample manipulators from two units to one unit, and by reducing some installation and commissioning effort, will cover the additional cost.

The project is on track with 87% of cost obligated and 11 of the 14 state-of-the-art optics have been received.

2.2.2 Comments

The SIX beamline is pushing the frontier of Resonant Inelastic X-ray Scattering (RIXS) instrumentation to another level. If successfully completed, it will be the world best resolution RIXS facility in the world.

The Committee fully supported the idea of adding an additional deflecting mirror because it will reduce the high risk involving vertical motion of the detector and the operation of the spectrometer will become more users friendly and reliable. However, it will also reduce the detection sensitivity by a factor of about 50%, which is unfortunate but desirable to keep the project within a manageable risk.

The project is making steady progress as 87% of the funds have been obligated and most of the optics and the beamline monochromator have been received.

The experimental chamber with multiple rotating flanges is one of the high-risk items and thus special attention should be paid to keep track of its progress through regular update and physical inspection of the progress as appropriate.

It would be important to integrate various diagnostics in the beamline for commissioning the delivered photon beam as related to polarization measurement and focus optimization.

SIX is an extremely low-signal and very photon hungry experiment and all efforts need to be made to assure that the throughput of the combined beamline and associated spectrometer are maximized particularly for performance at highest resolution. This may be achieved as a future upgrade after CD-4 and completion of the project by incorporating the second undulator in the straight section, which should be preserved for this purpose.

The beamline and end-station will be ready for commissioning without beam during FY 2016.

2.2.3 Recommendations

None.

2.3 Integrated In Situ and Resonant X-ray Studies (ISR)

2.3.1 Findings

The In-situ and Resonant Scattering (ISR) beamline at NSLS-II is designed to become an important tool in the study of surfaces, interfaces, magnetic and electronic structure, and thin-film growth processes. The ISR beamline couples bright X-rays produced by widely tunable IDs with advanced polarization control and versatile focusing to achieve its goal. The beamline is capable of micro-focusing with large (> 1 m) working distance using KB mirrors. The design also ensures a highly flexible range of sample environments that can accommodate diffractometers with large UHV chambers, large magnets, and controlled temperature. The canted-frontend design leaves room for potential future growth by addition of a second ID and side stations. The scientific scope of the ISR beamline is well aligned with DOE's scientific mission. The addition of a pixel-array detector and a six-circle diffractometer to the baseline scope has a significant positive impact of the future world-class status of this beamline. The ISR team, under the commendable leadership of Christie Nelson, is executing its technical baseline in an exemplary manner and will provide a world-class beamline at project completion.

The manufacture of the photon delivery system is far advanced, and factory acceptance is expected in December 2015—a major goal of this beamline to meet the KPPs, and early completion of installation can provide final details regarding shielding dimensions and locations that are needed to finish the ray traces.

Laboratory space has been allocated for NEXT beamlines providing about half of a laboratory room for each beamline. The availability of laboratory space that can be used and relied on is essential for assembly and test of beamline components before final installation on the floor.

The last station of the ISR beamline (Hutch D) will have a gas-handling system and an excimer laser installed. An interlock system will permit laser operation inside the station. The presence of flammable gases has prompted the need for a sprinkler system in Hutch D.

The current design of the beamline is mature and progress in fabrication and installation of components is appropriate at this stage. The established costs and schedules support the scientific scope, and the technical baseline is executed in exemplary manner.

2.3.2 Comments

Primary Bremsstrahlung ray traces and secondary Bremsstrahlung scattering calculations have been completed, but final details regarding shielding dimensions and locations are still needed before the ray traces can be submitted to the Radiation Safety Committee (RSC) for review and approval. Considering the progress in fabrication of the photon delivery system these final details should be available soon. However, RSC approval is critical to meet the KPPs, and therefore the Committee strongly encouraged the project to keep a keen eye on finishing the ray tracing approval as soon as possible.

In the later stages of mechanical assembly and floor placement of beamline components, the need for technical support will increase. The same can be said about the need for beamline controls support. NSLS-II has chosen motion control standards that require attention to each individual motor by specific (may be time consuming) tuning of the behavior of that motor and corresponding encoder.

A sprinkler system inside an experimental station at a synchrotron facility is a worldwide unique proposal. If activated, the water will destroy electrical equipment and severely damage high-precision mechanical equipment in the station. Also the use of water on high-voltage equipment is usually not considered a best practice. Considering these arguments, the cost of the sprinkler system, and potentially significant future costs, a more practical solution to the presence of flammable gases might be found.

The excimer laser in Hutch D is intense enough to require engineered safety including an interlock system to secure the laser-controlled area (LCA). For user operations at this station, it would be practical to design the laser-safety system such that one operation mode permits to remotely operate the fully enclosed laser. This type of safe operation has the advantage that most users would not be required to attend laser safety classes and undergo eye exams.

2.3.3 Recommendation

1. Re-design the gas handling and remove the sprinkler system to avoid cost and potential damage to equipment as soon as possible.

2.4 Soft Matter Interfaces (SMI)

2.4.1 Findings

The Soft Matter Interfaces (SMI) beamline at NSLS-II is designed to study the structure of liquid surfaces and soft matter using Liquid Surface Scattering (LSS), Grazing Incidence Small Angle X-ray Scattering (GISAXS), and Wide Angle X-ray Scattering (WAXS). The SMI beamline couples bright X-rays produced by widely tunable IDs with versatile focusing to achieve its goal. The asymmetrically canted front-end design avoids energy-tuning gaps and leaves room for potential future growth by the addition of a second ID to operate the LSS and GISAXS/WAXS instruments simultaneously. The scientific scope of the SMI beamline is well aligned with DOE's scientific mission. The addition of state-of-the-art detectors to the baseline scope has a significant positive impact of the future world-class status of this beamline. The SMI team, under the commendable leadership of Elaine DiMasi, is executing its technical baseline in an exemplary manner and will provide a world-class beamline at project completion.

The manufacture of the photon delivery system is far advanced, and white beam components have been received—a major goal of this beamline to meet the KPPs, and early completion of installation can provide final details regarding shielding dimensions and locations that are needed to finish the ray traces.

Laboratory space has been allocated for NEXT beamlines providing about half of a laboratory room for each beamline. The availability of laboratory space that can be used and relied upon is essential for assembly and test of beamline components before final installation on the floor.

The main components in the SMI end-station and the windowless design of the whole beamline, which is novel and unique in the hard X-ray regime, require intensive in-house design and fabrication. However, design and fabrication of the various components are on track.

The current design of the beamline is mature and progress in fabrication and installation of components is appropriate at this stage. The established costs and schedules support the scientific scope, and the technical baseline is executed in exemplary manner.

2.4.2 Comments

Primary Bremsstrahlung ray traces and secondary Bremsstrahlung scattering calculations have been completed, but final details regarding shielding dimensions and locations are still needed before the ray traces can be submitted to RSC for review and approval. Considering the progress in fabrication of the photon delivery system these final details should be available soon. However, RSC approval is critical for meeting the KPPs, and therefore the Committee strongly encouraged the project to keep a keen eye on finishing the ray tracing approval as soon as possible.

In the later stages of mechanical assembly and floor placement of beamline components, the need for technical support will increase. This is a particular concern for the SMI beamline because of the reliance on major in-house fabrication and assembly for the end-station components. The same can be said about the need for beamline controls support. NSLS-II has chosen motion control standards that require attention to each individual motor by specific (may be time consuming) tuning of the behavior of that motor and corresponding encoder.

The common-systems schedule presented by Chris Stebbins noted that SMI plans to receive the Personnel Protection System (PPS) installation between April and August 2016. On the other hand, the ID/front-end installation schedule presented by Gregory Fries noted that SMI front-end and ID Instrument Readiness Reviews (IRRs) are planned for February 2016. This implies that the beamline could receive X-rays only six months after the front-end would be able to deliver X-rays. The situation is reversed for the ESM beamline—here, the ID IRR is scheduled as much as five months after PPS installation. However, the PPS is not needed until the ID/front-end IRRs are complete. The project should consider switching the PPS installation schedules for the SMI and ESM beamlines to be aligned with the ID/front-end IRRs, and thereby avoid a delay in the ability of SMI to receive and use X-rays for alignment and commissioning of components.

2.4.3 Recommendations

None.

2.5 Full-Field X-ray Imaging from Micrometer to nm (FXI)

2.5.1 Findings

The scope of the NEXT project activities for the FXI beamline consists of the final design of the photon delivery system and the construction of the shielded enclosures for the FXI beamline. The design goals of the beamline are to deliver a photon energy range of 5–11 keV, an energy

resolution of 1.3×10^{-4}, and a photon flux of 5×10^{13} ph/s at 10 keV. The design goals of the TXM end-station instrument are to deliver 30 nm spatial resolution over a 40μm field of view. As of the August 2014 DOE/SC review the final design for FXI beamline optics and major components were complete. With the completion of the shielded enclosures, the FXI NEXT project scope is complete. The FXI beamline X-ray optical components, instrumentation, and construction have been transferred to be part of the NSLS-II operations beamline build-up effort.

2.5.2 Comments

While the FXI project will be completed with NSLS-II operations funds, these funds are always subject to competing demands and availability. It is important for NEXT project management and NSLS-II management to consider the importance of the FXI beamline given its close alignment with the laboratory's Energy Science mission and its capability to provide early, world-class science for NSLS-II.

The FXI beamline will provide world-class performance at first light. Its design is mature and very appropriate for NSLS-II. The project should consider the FXI scope beyond the shielded enclosures that could provide further enhanced capabilities, update the spectrometer, or provide a state-of-the-art detector at project completion.

2.5.3 Recommendation

2. NEXT project management should consider FXI as a high priority for future contingency spending with the goal of enhancing beamline performance in-line with the other world-class NEXT project beamlines.

2.6 Inner Shell Spectroscopy (ISS)

2.6.1 Findings

The design goal of the ISS beamline is to provide 4.9-36 keV operation, a flux of 2×10^{13} ph/s, and a 25 μm x 25 μm focused (1 mm x 1 mm unfocused) beam at the end-station. The beamline X-ray optics and instrumentation are well on the way to meeting (and exceeding) the project KPPs to deliver world-class performance to NSLS-II users. The beamline will be equipped with end-station experimental chambers that will provide variable temperatures over a large range and pressures from vacuum to 2 bar. Other special sample environments are planned, including a small-volume gas reactor and a sample heating system. The end-station also features a novel X-ray emission spectrometer that can accommodate multiple detectors and a hazardous gas handling system, which has been extensively reviewed.

The ISS team has completed all major procurement contracts for beamline optics (monochromator, mirrors, filter box, and beam transport), and most of the contracts for end-station instrumentation, and is approximately 90% obligated. ISS staff has fully addressed comments and recommendations from previous reviews. The design, safety analysis, and reviews of the hazardous gas handling system are in-line with previous review recommendations.

The project is three to four months ahead by virtue of the staff providing good planning, execution, and project tracking. The cost growth has been reasonable for ISS with the main growths in the design for the sample transfer system, a robust monochromator, increased radiation shielding, and the gas handling system ES&H. The latter includes provision of a sprinkler system for the ISS hutches that adds significant cost and raises concerns for equipment damage and high voltage safety.

2.6.2 Comments

The scope of ISS beamline as presently planned will provide world-class performance at project completion.

2.6.3 Recommendations

3. Requirements for hutch sprinklers in the ISS experimental stations raise concerns about damage to beamline instrumentation and equipment, as well as electrical safety. Requirements for sprinklers in experimental stations should be removed.

4. No changes to the ISS beamline scope are recommended. The technical design, risk, or other aspects of the ISS beamline project scope are appropriate. The remaining funding should be committed to the completion of the ISS beamline.

3. ENVIRONMENT, SAFETY and HEALTH

3.1 Findings

The Environment, Safety, and Health (ES&H) and Quality Assurance (QA) programs are appropriate and support the current phase of the project. The ES&H/QA staff appears to be competent and experienced with a good integration into the project. BNL recently transitioned to a centralized ES&H organization that integrated the Photon Sciences ES&H into the BNL ES&H Directorate. This appears to have been implemented without disruption to the project and has strengthened the already strong ES&H interfaces between the NEXT project, NSLS-II, and the centralized ES&H Directorate.

The complex gas handling systems for the ISS beamline has been installed and reviews have been completed. The ISR beamline gas handling system, which implemented many of the essential safety aspects of the ISS gas handling system, has completed the final design review.

3.2 Comments

The project has tracked and addressed all aspects of the recommendations from the August 2014 DOE/SC review.

The QA program appears to be strong and highly credible. The program is flowing-down pressure safety requirements to vendors to ensure proper implementation in products being manufactured in outside facilities. The beamline personnel are performing factory acceptance visits to ensure that products are manufactured and perform to specification so that they can be delivered ready for immediate installation. The use of an equipment traveler, discrepancy reporting, and assessment tracking systems has shown to be an effective tool in helping to maintain quality control over items awaiting installation.

The IRR process is well established, prescribing the activities required to determine that a beamline installation is complete and adequate. The NEXT ES&H staff has been well integrated into the IRR process.

The additional requirement related to the installation of smoke detection to each of the NEXT project beamlines hutches is seen as an acceptable best practice. This may prevent excess damage to beamline components and equipment by providing an early indication of a potential fire.

The additional requirement relating to the planned installation of water discharging sprinkler systems over electrical equipment for fire suppression in the ISS and ISR hutches with gas systems is not considered a best practice. A single point of failure may result is unnecessary exposure of the emergency response team to additional hazards and cause extensive damage to sensitive equipment within the hutches, which would not be considered a best practice. This addition may result in an extensive cost and time additions as components will be required to be manufactured and replaced after a sprinkler discharge.

3.3 Recommendation

5. Re-evaluate the requirement for water discharging sprinkler systems in the ISR and ISS hutches.

4. COST and SCHEDULE

4.1 Findings

PROJECT STATUS (Through September 2015)		
Project Type	Major Item of Equipment	
CD-0		Actual: 5/27/2010
CD-1	Planned: 9/30/2011	Actual: 12/19/2011
CD-2	Planned: 12/31/2013	Actual: 10/9/2013
CD-3	Planned: 3/31/2014	Actual: 7/7/2014
CD-4	Planned: 9/30/2017	
Percent Complete	Planned: 62.6% on BAC (59.9% on EAC)	Actual: 60.8% on BAC (58.2% on EAC)
TPC Cost to Date	$54.3M	
TPC Committed to Date	$71.4M	
TPC	$90 M	
TEC	$87 M	
Contingency Cost (w/Mgmt Reserve)	$7.4M on BAC ($3.8M on EAC)	23% on BAC (11.9% on EAC) work to go
Schedule contingency on CD-4	8 months	50% on work to go
CPI Cumulative	0.93	
SPI Cumulative	0.97	

The project presented an Estimate at Completion (EAC) of $86.2 million, leaving a contingency reserve, relative to the EAC, of $3.8 million. This reserve is marginal at best. It severely limits the project's capability to respond to the risks that will occur and compromises successful completion within the $90 million Total Project Cost (TPC).

As shown in Project Status Table (above), the project was 60.8% complete relative to the baseline, approximately 58% complete relative to their EAC at the end of September 2015.

In June 2015, the project changed their method of EAC estimation from BAC plus known/anticipated changes to the more customary method that adds cumulative actual costs (ACWP) to the estimated cost of the remaining work (ETC) where the ETC is updated monthly, as new information is available. This new process revealed a problem with the way accounting accruals were being processed and reported. This problem was corrected by including an "accrual gap correction", where applicable, in the EAC. This will enable a more accurate assessment of the project's cost performance.

The Control Account Managers (CAMs) developed the new bottom-up EAC, evaluating all remaining work at the activity level within the Primavera (P6) schedule. They understand how they got to where they are and are 100% confident that they can complete their scope within this updated estimate.

An internal BNL committee reviewed the project EAC and the project is implementing the corrective actions recommended. These actions include additional CAM training, improved reporting, particularly for labor and accruals, and enforcement of a zero cost growth state. Additionally, BNL has formed a Project Oversight Board subcommittee that will provide monthly oversight of the project's cost and schedule.

The project's funding profile (shown Appendix E) supports this revised Estimate to Complete (ETC). The funding profile always exceeds the current EAC by at least $3.3 million. The direct value of hardware commitments (materials, equipment) is approximately $17.2 million. The estimated cost of remaining uncommitted work, relative to the EAC, is $14.9 million. Contingency relative to remaining uncommitted EAC work is approximately 26%.

The project estimated the expected value of remaining risks in July 2015 at $4.6 million and forecasts that this number will decrease to approximately $3.6 million at the next update.

Since CD-2, the project added approximately $5.1 million of additional instrument scope to increase capabilities, $1.3 million for IRR and closeout activities not included in baseline, approximately $2.1 million in scope for ID/front-end work, and eliminated approximately $500K of scope from SMI. The remaining $6.5 million in baseline changes was the result of estimate errors on baseline scope. EAC growth since CD-2 is shown in Figure 4-1.

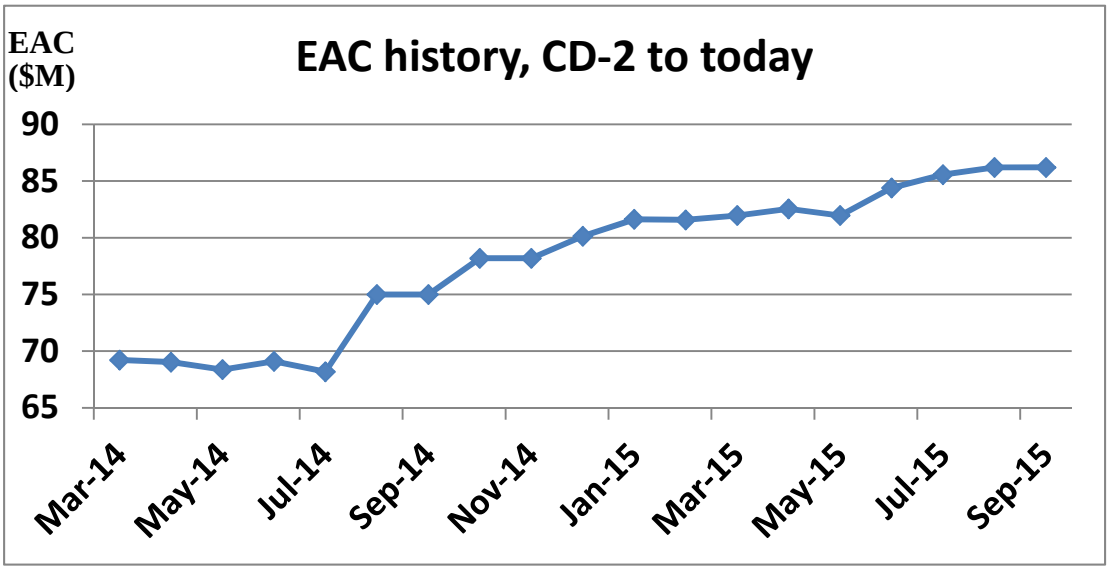


Figure 4-1. EAC Changes Since CD-2

The project identified approximately $1.5 million in potential scope contingency.

Since the August 2014 DOE/SC review, the project moved the early finish date from September 2016 to January 2017. The project's critical path runs through procurement, fabrication, assembly, installation and testing activities for the SIX instrument (see Appendix D).

4.2 Comments

The project has only two control accounts per beamline. Therefore, all actual costs related to the beamline construction are collected in a single account, with management in the other. This resulted in a lack of resolution and an inability to see that erroneous accruals were occurring.

The project is making very good progress with respect to installation tasks and hardware procurements. Installation of utilities is largely complete and electrical installation is proceeding on all instruments.

The review material, particularly with respect to the EAC, was presented in a consistent way that was easy to follow.

The CAMs are energetic, engaged, and displayed clear ownership of their instrument and their estimate to complete.

The NEXT schedule is aggressive with several maintenance outage dependencies. NEXT is only one of several projects installing beamlines at NSLS-II. Allocation of resources could be an issue. Several resource groups, such as beamline controls, data acquisition, data analysis, and PPS are critically needed at the end of installation and are in high demand by both operations and projects. Typically, these groups are small and do not have the capacity to support many customers at the same time.

The NEXT team has stated that they are the highest priority activity at this time. It is critical that the project retains this high priority if NEXT is to complete on the current schedule.

4.3 Recommendations

6. Incorporate the EAC presented at this review in the baseline. This should be done in a way that increases the resolution and helps in variance analysis for all remaining installation and testing activities.

7. Do not add any scope until the project can assure delivery of the KPPs.

8. Work with NSLS-II management, BNL management, and the program office to increase the contingency reserve.

9. Document the current EAC process (including the generation of a comprehensive EAC log) to ensure that it is followed consistently on a monthly basis.

5. PROJECT MANAGEMENT

5.1 Findings

The NEXT project experienced cost growth in the past 12 months, mostly due to underestimated labor with the additional complication of unaccounted-for accruals.

A comprehensive EAC was developed for the remaining project work scope in September. This EAC will be updated monthly by the project CAMs.

The NSLS-II director asked BNL to conduct a NEXT EAC review to better understand the reasons for EAC growth. A NEXT EAC corrective action plan was implemented to stabilize project cost growth. As part of the corrective action plan, a BNL Project Oversight Board subcommittee was formed to provide monthly oversight of NEXT cost and schedule.

The NEXT project will maintain the remaining contingency ($3.8 million) to address any Level 2 WBS elements that experience cost growth, with an additional $1.5 million in scope contingency available to offset cost growth.

Beamline motor controls need tuning prior to operation and data acquisition software must be available.

5.2 Comments

The NEXT project is now being effectively and efficiently managed, with the changes to cost estimation, accounting systems, and appropriate CAM retraining.

The utilization plan for the remaining contingency is well defined and appropriate, but the remaining contingency does not provide a sufficient safety margin for the current ETC.

The NEXT project has responded appropriately to previous review recommendations.

The use of recent examples of labor costs from other similar NSLS-II projects, financial tracking system changes, and CAM retraining are likely to minimize future inaccurate labor estimates in the ETC.

The present contingency of 12% of the ETC provides only a small safety margin for successful project completion, while the presented potential project scope deletions only add an additional 4.7% of the ETC to the contingency.

The beamline controls area has additional experts for motor tuning.

5.3 Recommendations

10. Explore potential project scope deletions that are not part of the Key Performance Parameters to gain contingency as an additional safety margin.

11. Work with NSLS-II management to ensure that sufficient controls personnel are available to NEXT so that beamline commissioning is not delayed.

Appendix A Charge Memo

United States Government **Department of Energy**

memorandum

DATE: September 10, 2015

REPLY TO ATTN OF: Office of Basic Energy Sciences, SC-22

SUBJECT: DEPARTMENT OF ENERGY INDEPENDENT PROJECT REVIEW FOR THE NATIONAL SYNCHROTRON LIGHT SOURCE II EXPERIMENTAL TOOLS (NEXT) PROJECT

TO: Stephen Meador, Director, Office of Project Assessment, SC-28

I request that you organize and conduct an Independent Project Review of the NEXT project at the Brookhaven National Laboratory on November 3-4, 2015 for the Office of Basic Energy Sciences. This review is to assess the current status of the NEXT project and identify any concerns that could prevent the project from successfully completing within the approved baseline.

The performance baseline for NEXT (CD-2) was approved October 9, 2013 with a Total Project Cost of $90M and a CD-4 date of September 30, 2017 along with authorization for Long Lead Procurements (CD-3A) in the amount of $16M. CD-3, Start of Construction, was approved on July 7, 2014. In the two years since the baseline was established, over 60 project change requests (PCRs) have been submitted by the project, and approved by the Federal Project Director. The net result, including estimated cost variances, is a growth in the estimated cost at completion of the project from $68.1M to nearly $85.6M, leaving only $4.4M in unencumbered contingency (July 2015 data). With the project only 54% complete, and two years until CD-4, contingency usage needs a critical examination.

The objective of NEXT is to provide NSLS-II with a minimum of five "best-in-class" beamlines. This will enable exploration of the unique scientific opportunities offered by the new NSLS-II facility beyond those provided by its initial beamlines.

In carrying out its charge, the review committee should respond to the following questions:

1. Project Scope: Is the project executing its technical baseline in a manner to provide world-class beamlines at project completion? Is the cost of the scope additions in line with the technical performance enhancements expected?

2. Cost and Schedule: Are the cost and schedule performance, including contingency utilization, adequately understood, controlled and reasonable based on project performance to date? Is contingency usage appropriate for this stage of the project and adequate to complete the project successfully?

3. Management: Is the project being effectively and efficiently managed? Is the utilization plan for the remaining contingency well-defined and appropriate?

4. Environment, Safety & Health and Quality Assurance (ES&H/QA): Are the ES&H/QA requirements being properly addressed given the project's current stage of development?

5. Recommendations: Has the project responded appropriately to previous review recommendations?

Philip F. Kraushaar, the NEXT Program Manager, will serve as the Office of Basic Energy Sciences point of contact for this review. I would appreciate receiving your committee's report within **60 days** of the review's conclusion.

Harriet Kung
Associate Director of Science
for Basic Energy Sciences

cc: F. Crescenzo, BSO/BNL
R. Caradonna, BSO/BNL
E. Johnson, BNL
S. Hulbert, BNL
D. Gibbs, BNL
B. Huizenga, APM
K. Chao, SC-28
C. Clark, SC-28
J. B. Murphy, SC-22.3
P. Kraushaar, SC-22.3
P. Lee, SC-22.3
E. Stevens, SC-22.3
L. Cerrone, SC-22.3
R. Meneses, SC-22.3

Appendix B Review Committee

DOE/SC Status Review of the
NSLS-II Experimental Tools (NEXT) Project
November 3-4, 2015

Stephen W. Meador, DOE/SC, Chairperson

SC1
ESM and SIX

* Zahid Hussain, LBNL
Donghui Lu, SLAC

SC2
ISR and SMI

* Wolfgang Sturhahn, NASA
Jin Wang, ANL

SC3
FXI and ISS

* Mark Beno, ANL
Ian McNulty, ANL
Sam Webb, SLAC

SC4
Environment, Safety and Health

* Paul Rossi, ANL
Mike Andrews, FNAL

SC5
Cost and Schedule

* Barbara Thibadeau, ORNL
Elmie Peoples-Evans, ANL

SC6
Management

* Ben Feinberg
Kin Chao, DOE/SC
Tony Indelicato, DOE/PSO

Observers

Harriet Kung, DOE/SC
Jim Murphy, DOE/SC
Phil Kraushaar, DOE/SC
Peter Lee, DOE/SC
Ed Stevens, DOE/SC
Robert Caradonna, DOE/BHSO
Frank Crescenzo, DOE/BHSO

LEGEND

SC Subcommittee
* Chairperson

COUNT: 15 (excluding observers)

Appendix C Review Agenda

DOE/SC Review of the
NSLS-II Experimental Tools (NEXT)
Project November 3-4, 2015

AGENDA

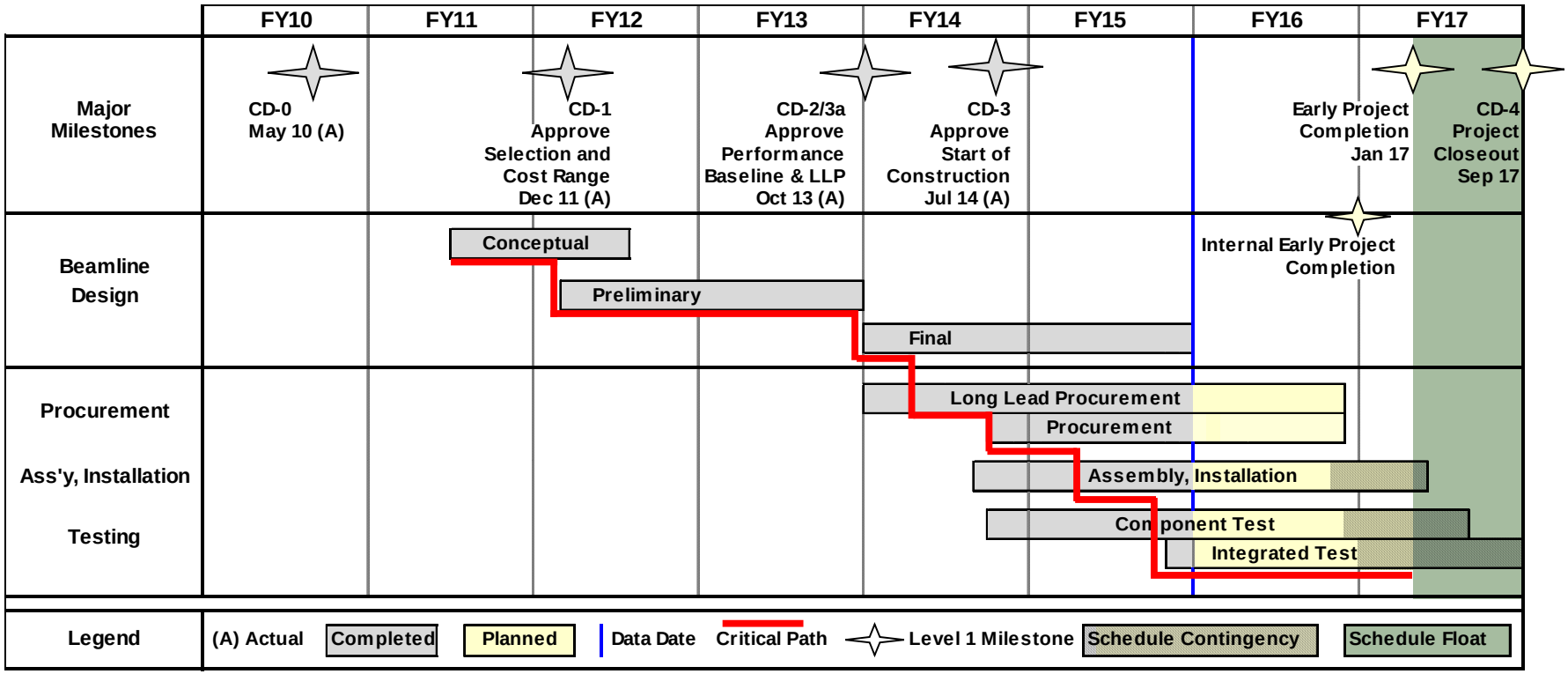
Tuesday, November 3, 2015 —Building 703, Large Conference Room

8:00 am	DOE Executive Session	S. Meador
8:30 am	Welcome	J. Hill
8:40 am	NEXT Project Status and Plan for Completion	S. Hulbert
9:20 am	ISR Beamline Status and Plan for Completion	C. Nelson
9:40 am	SMI Beamline Status and Plan for Completion	E. DiMasi
10:00 am	Break	
10:15 am	ESM Beamline Status and Plan for Completion	E. Vescovo
10:35 am	SIX Beamline Status and Plan for Completion	I. Jarrige
10:55 am	ISS Beamline Status and Plan for Completion	K. Attenkofer
11:15 am	Common Beamline Systems Status and Plan for Completion	C. Stebbins
11:35 am	EPUs Status and Plan for Completion	C. Kitegi
12:00 pm	Lunch	
1:00 pm	Beamline Controls Status and Plan for Completion	Z. Yin
1:20 pm	ID & FE Installation Status and Plan for Completion	G. Fries
1:40 pm	Break	
2:00 pm	Subcommittee Breakout Sessions—**See attached Breakout Agenda—Bldgs. 743, 744 & 745)**	
5:00 pm	DOE Full Committee Executive Session—**Bldg. 745, Rm. 156**	S. Meador
6:00 pm	Adjourn	

Wednesday, November 4, 2015

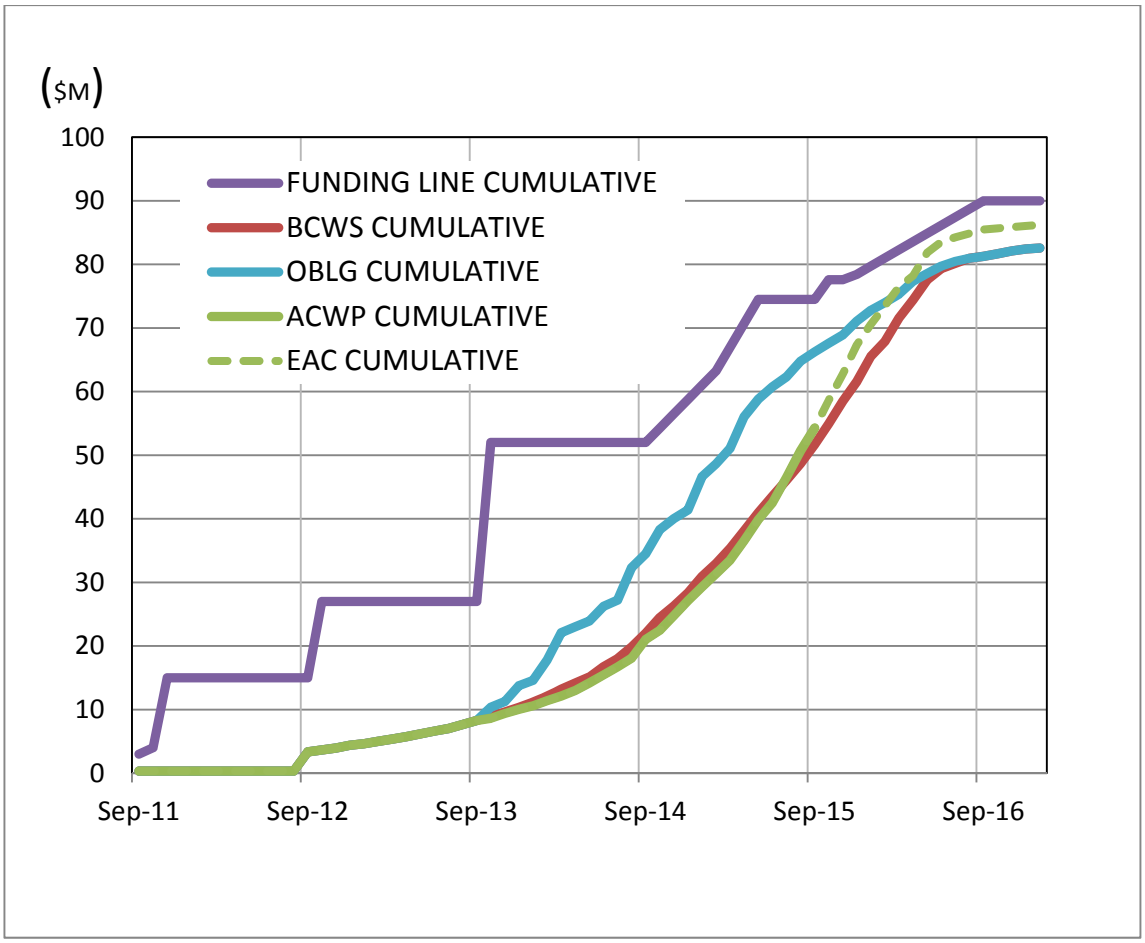
8:00 am	Subcommittee Breakout Sessions **(Bldgs. 743, 744 & 745)**	
10:00 am	Full Committee Working Session—**Building 703**	S. Meador
11:00 am	DOE Full Committee Executive Session	S. Meador
12:00 pm	Lunch	
1:00 pm	Closeout Presentation to NEXT Project Management	
2:00 pm	Adjourn	

Appendix D NEXT Schedule Chart



Appendix E NEXT Funding Table

	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	Total ($M)
OPC	3.0							**3.0**
TEC Design		3.0	2.0					**5.0**
TEC Fabrication		9.0	10.0	25.0	22.5	15.5		**82.0**
Total ($M)	**3.0**	**12.0**	**12.0**	**25.0**	**22.5**	**15.5**	**0.0**	**90.0**



NEXT Level 2,3 WBS Managers

WBS 2.0
NEXT Project
S. Hulbert
J. Keister

NEXT Beamline Advisory Teams

2.01
NEXT Project Management
S. Hulbert – Manager
J. Keister – Deputy

ES&H – L. Stiegler
QA – J. Zipper
Project Controls – J. O'Connor
Admin – E. Morello

2.02
Conceptual Design
(complete)

2.03
Common Beamline Systems
C. Stebbins

2.04
Control Systems
Z. Yin

2.05
ESM: Electron Spectro-Microscopy beamline
E. Vescovo

2.06
FXI: Full-field X-ray Imaging beamline
W.-K. Lee

2.07
ISR: Integrated In-Situ and Resonant X-ray Studies beamline
C. Nelson

2.08
ISS: Inner Shell Spectroscopy beamline
K. Attenkofer

2.09
SIX: Soft Inelastic X-ray Scattering beamline
I. Jarrige

2.10
SMI: Soft Matter Interfaces beamline
E. DiMasi

2.11
Insertion Devices
C. Kitegi

Utilities
M. Bromfield

PPS, EPS
G. Fries

WBS 2.12 added Dec. 2014

2.12
ID/FE Installation
G. Fries