Responses to Request for Information for the DOE-BES Triennial Review of NSLS-II

June 2017

Volume 2b: Beamlines

NSLS-II Operations Funded Beamline Capability Build-up: Plan and Execution Status

Volume 2b

June 20-21, 2017

Our responses to the questions for the 2017 review are presented in five volumes.

Volume 1 contains general responses to the questions about the facility including budget information, response to recommendations, the organizational structure, development milestones, R&D, and facility input.

Volume 2a contains detailed lists of beamline information (including specifications, funding, publications, and invited talks) as well as the BES surveys for FY15-16, and other supplementary material.

Volume 2b contains the NSLS-II Operations funded Beamline Capability Build-up: Plan and Execution Status.

Volume 3 contains all other requested information and documentation pertinent to this review including support facilities, the user program, and future plans.

Volume 4 is the NSLS-II 2017 5-year Strategic Plan.

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Acronyms and Definitions

3PW	Three-pole Wiggler
ABBIX	Advanced Beamlines for Biological Investigations with X-rays
ALD	Associate Laboratory Director
APS	Advanced Photon Source
AP-PES	Ambient Pressure Photoelectron Spectroscopy
ARO	Army Research Office
ARPES	Angle Resolved PhotoEmission Spectroscopy
BAD	Baseline Approval Decision
BDN	Beamlines Developed by NSLS-II project portfolio
BDP	Beamline Development Proposal
BES	Basic Energy Sciences
BMM	Beamline for Materials Measurements
BNL	Brookhaven National Laboratory
BORE	Beneficial Occupancy Review Evaluation
CES	Chemical and Energy Sciences
CDI	Coherent Diffraction Imaging
CDR	Conceptual Design Review
CMS	Complex Materials Scattering (beamline)
CSX	Coherent Soft X-ray (beamline 1&2)
CWRU	Case Western Reserve University
DAC	Diamond Anvil Cells
DAFS	Diffraction Anomalous Fine Structure
DAMA	Data Acquisition Management and Analysis
DoD	Department of Defense
DOE	Department of Energy
EPS	Equipment Protection System
ESRF	European Synchrotron Radiation Facility
EVMS	Earned Value Management System
EXAFS	Extended X-ray Absorption Fine Structure
FAT	Factory Acceptance Test
FCMT	Fluorescence Computed Microtomography
FDR	Final Design Review
FIS	Frontier Infrared Spectroscopy (beamline)
FOE	First Optical Enclosure
FXI	Full-field X-ray Imaging (beamline)
GU	General User
HAXPES	Hard X-ray Photoelectron Spectroscopy
HEX	High energy Engineering X-ray scattering (beamline)
IEPD	Instrument Execution Plan Development
INF	Infrared Near-Field Nanospectroscopy
IRR	Instrument Readiness Review
ISS	Inner-Shel Spectroscopy
IXS	Inelastic X-ray Scattering (beamline)
MET	Magneto, Ellipsometric and Time-Resolved IR (beamline)
MIE	Major Item of Equipment
NEXAFS	Near Edge X-ray Absorption Fine Structure
NEXT	NSLS-II Experimental Tools
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NPB	NSLS-II Partner Beamlines project portfolio
NSLS-II	National Synchrotron Light Source II
NYSERDA	New York State Energy Research and Development Authority
NYSBC	New York Structural Biology Center
NYSTAR	New York State Office of Science, Technology and Academic Research
NYX	NYSBC Microdiffraction Beamline
NxtGen	Next Generation NSLS-II Beamlines Project
OFW	Other Funded Work (changing to

	SPP)
PDF	Pair Distribution Function
PDR	Preliminary Design Report
PLS	Processing and Liquid Scattering
PMI	Project Management Institute
PMP	Project or Portfolio Management Plan
PPS	Personnel Protection System
QAS	Quick X-ray Absorption and Scattering (beamline)
QIX	Quick RIXS Beamline
RIXS	Resonant Inelastic Scattering
SAC	Science Advisory Committee
SAXS	Small Angle X-ray Scattering
SCW	Superconducting Wiggler
SMF/ARI	Soft X-ray Spectro-Microscopy Facility/ARPES and RIXS Nano-Imaging
SMI	Soft Matter Interfaces
SPP	Strategic Partnership Projects (new term for OFW)
SRC	Synchrotron Radiation Center (now closed)
SST	Spectroscopy Soft and Tender (beamline 1&2)
TES	Tender Energy X-ray Absorption Spectroscopy
TXM	Transmission X-ray Microscope
WAXS	Wide Angle X-ray Scattering
WBS	Work Breakdown Structure
XAFS	X-ray Absorption Fine Structure
XANES	X-ray Absorption Near Edge Spectroscopy
XAS	X-ray Absorption Spectroscopy
XFM	X-ray Fluorescence Microprobe (beamline)
XFP	X-ray Foot Printing (beamline)
XPD	X-ray Powder Diffraction (beamline)
XPS	X-ray Photoelectron Spectroscopy
XRD	X-ray Diffraction
XRF	X-ray Fluorescence

1. Executive Summary

This document addresses question 2 of the charge for the June 20-21, 2017 DOE review of the NSLS-II operations, Beamline Capability Build-up Plan. Specifically it asks for

iv. Provide a BES operations fund supported Beamline Capability Build-up plan including new world class beamlines with detail cost, schedule;
v. Execution status of the plan.

A similar document was prepared in April 2015 to support the DOE review of NSLS-II operations budgets. This document describes the progress over the last two years as well as the evolution of plans and proposals for new engagements. The scope is limited to the current plans for execution of beamlines that are funded in whole, or in part by NSLS-II operations funds. This includes the Beamlines Developed by NSLS-II (BDN) project portfolio in its entirety, and the NSLS-II Partner Beamlines (NPB) portfolio, where the BES funded scope is quite narrow, although essential to the success of these beamline projects. Additionally, NSLS-II has instituted a process for evaluating new engagements to develop plans and designs for world class instruments to be built utilizing NSLS-II operations funds at some level, up to and including complete beamlines. Once these instruments attain a 'baseline design' they would be executed as a component of the appropriate portfolio, or as standalone projects.

Since 2015 the BDN portfolio has brought the CMS and TES beamlines through their IRRs and completed modifications that allow for the independent operation of the two CSX branches by coordination of the installation and commissioning of the canting magnet systems. The EPU105 undulator for ESM has been installed and is expected to complete its IRR in June 2017, while the QAS and XFM beamlines are anticipated to complete their IRRs by the end of FY 17, followed by FXI and PDF (formerly XPD2) early in FY18 and FIS and MET to complete their IRRs by the fourth quarter of FY18.

In the same span of time within the partner portfolio the XFP (X-ray Foot Printing – Case Western) and the NYX (NYSBC Micro Diffraction Beamline – New York Structural Biology Consortium) completed their IRRs and started commissioning, supported by their respective home institutions. Three beamlines are under construction with NIST with BMM scheduled for its IRR in July 2017 and SST1 and SST2 planned to complete their IRR in January of 2018. In 2017 the HEX beamline is formally underway in a partnership with NYSERDA (New York State Energy Research and Development Authority) which is planned to complete in Q2FY22. The scope of the NEXT and ABBIX projects are specifically excluded from this document.

To address the charge question the document starts with a description of the portfolio management approach. The current component projects of the two portfolios are then described along with their cost, schedule and execution status. A summary of the recently completed Instrument Execution Plan Development (IEPD) evaluation of new BDPs is also provided, leading to the selection of the Bragg-CDI instrument for development to a Baseline design proposal.

2. Background

NSLS-II is designed to house at least 58 beamlines. The NSLS-II project scope provided for the design, construction and installation of six best in class beamlines. A significant challenge for the facility going forward is the construction and operation of additional beamlines that can exploit the exquisite capabilities of the facility.

Beyond the initial suite of NSLS-II project beamlines, the Department of Energy (DOE) approved the NEXT Project to develop, fabricate and install five insertion device beamlines for NSLS-II. The project scope also includes the design and engineering of a sixth beamline. As of May 2017 all five of the NEXT scope beamlines are in service, with one (ISS) already in General User (GU) operations. Similarly, the NIH funded the ABBIX project to build out three beamlines in life sciences, all of which are now in General User operations.

While additional MIE projects may be funded in the future, an alternative approach for developing instruments for NSLS-II is utilizing a portion of its operations budget either for the direct construction of beamlines, or in partnership with other institutions to create new beamlines to enhance the scientific productivity of the facility. This strategy was established in 2015 and has successfully been employed to deliver four beamlines into service as of this writing.

The approach and benefits are described, as are the current portfolios of beamlines that utilize NSLS-II operations funds. One portfolio, called the Beamlines Developed by NSLS-II (BDN) portfolio utilizes funds from NSLS-II operations to execute the construction of entire beamlines, capitalizing on either equipment recovered from the original NSLS, utilizing affordances provided by prior projects, or complete instruments funded from NSLS-II operations. The second portfolio, the NSLS-II Partner Beamlines (NPB) portfolio leverages substantial investments by partner institutions for the construction of new beamlines and utilizes NSLS-II operations funding only for management and oversight of projects as well as construction of the critical safety systems.

Additionally, new beamline development is planned using operations funds as part of the NSLS-II construction practice. Once these instruments are developed to a baseline plan, they will be dispositioned to one of the portfolios for execution.

3. Introduction to Portfolio Management

Early in the life of the NSLS-II facility, beamline funding had been associated with large projects that were responsible for the construction of multiple beamlines under one funding source. The situation has evolved along with the business environment such that beamline funding and indeed the duration of the proposed beamline projects has become more variable with funding available asynchronously in smaller quantities. This has effectively always been the case for the partner beamlines which are funded by a variety of sponsors with differing fiscal calendars and tracking requirements. Earlier attempts to group these beamlines into MIE-like collections have proven difficult. For example the Next Generation NSLS-II Beamlines Project (NxtGen) brought

eight beamlines in parallel up through the Preliminary Design Review stage ready to baseline, but ultimately not all could be funded through to completion based on available resources.

An alternative management model has been developed for these beamlines where a shared management system is put in place for a portfolio of beamline projects. In this way a repeatable management process is encouraged and each of the component projects gains some benefits of economy of scale. Additionally, where the beamlines are similar in design or have common components, procurements can be grouped resulting in cost savings.

While we have adopted the title of 'Portfolio' to describe our management arrangement for beamline construction, it is an adaptation that most closely resembles the Project Management Institute (PMI) standard for a program, although it also has elements of the PMI Portfolio standard, as well as characteristics of the management systems BNL utilizes for tracking MIEs and DOE 413 projects.

In the present situation considering only NSLS-II Operations funded activities, a Portfolio is created by a charter approved by the NSLS-II facility director. This provides a minimum set of resources for the Portfolio manager to establish the necessary management documents for the operation of the portfolio. A typical minimum set of documents includes:

- Portfolio Management Plan
- Risk Management Plan and Risk Registry
- Quality Assurance Plan
- Configuration Management Plan

The need for a particular beamline project will be established outside the scope of the portfolio by the NSLS-II management through solicitation and evaluation through the Beamline Development Process. Those deemed by management to be worthy of further development, may be introduced into an appropriate portfolio. If minimal prior work has been done to establish a baseline cost and schedule for the beamline a document called a Preliminary Design Development Decision is created.
This document formally introduces the scope of a particular beamline into the portfolio. It will authorize development of beamline design documentation that will be sufficient in quality to describe a plan for the execution of a beamline that will largely meet the objectives defined in the beamline development proposal (BDP). Where exceptions to the BDP requirements are anticipated, they must be clearly identified by the documentation produced for this phase of the project. This decision will be authorized for a fixed duration and is to result in documentation and necessary reviews that will support the evaluation of the project by NSLS-II management for further execution. The documentation to be produced in the Preliminary Design Development phase will at a minimum include:

- WBS dictionary
- Resource loaded Schedule
- Detailed Cost Estimate

- Resource Plan
- Assumptions Document
- Baseline Design Review (PDR or equal)

As compared to a DOE O413 project, this phase of work is most similar to the span between a CD-1 decision and a combined CD2/CD3 decision. For the purpose of the portfolio this level of effort is required to establish reasonable confidence in the cost and schedule estimates such that contingency utilization in execution will be minimized.

Assuming the project reviews well and the documentation is in order a second decision is taken by NSLS-II management called the Baseline Approval Decision (BAD). The document for this decision is prepared by the Portfolio Manager and the Deputy Director for construction, reviewed by the senior leadership of the NSLS-II facility who may then recommend the decision to the NSLS-II facility director for approval. This document will formally authorize execution of the component project based on the documentation produced in the Preliminary Design Development phase of the project as well as NSLS-II strategic and business imperatives. At this decision point, Earned Value Management System (EVMS) tracking as well as change control, risk management and other standard project execution tools will be utilized to monitor the progress of the component project through to its completion. Each component project must compile lessons learned documentation to be available for the support of subsequent projects within NSLS-II.

4. Portfolio Descriptions

At this time two beamline project portfolios have been established. One portfolio, called the Beamlines Developed by NSLS-II (BDN) utilizes funds from NSLS-II operations to fund the construction of entire beamlines, capitalizing on either equipment recovered from the original NSLS, or utilizing affordances provided by prior projects. The second portfolio, NSLS-II Partner Beamlines (NPB) leverages substantial investments by partner institutions for the construction of new beamlines and utilizes NSLS-II operations funding only for management and oversight of projects as well as construction of the critical safety systems. What follows are descriptions of the portfolios and their beamlines, their schedule and cost estimates as well as their current execution status.

5. Beamlines Developed by NSLS-II (BDN) project portfolio

The BDN portfolio is managed by Julian Adams. Its scope is limited to beamline projects funded by NSLS-II operations. The portfolio is not constructed from whole cloth, and was in fact a successor to a previous plan to accomplish similar aims called the Next Generation NSLS-II Beamline Project (NxtGen).

Previously a set of eight beamlines was planned to be managed in a manner similar to a Major Item of Equipment (MIE) project, and work was to proceed for all of the beamlines in parallel. As the business environment has evolved, the decision was made to manage the construction of

these beamlines as component projects of the Beamlines Developed by NSLS-II (BDN) portfolio, to be executed on their own schedules as resources permit.

Building on the prior NxtGen project, a series five of the original eight beamline projects were selected for construction that would be executed out to roughly Fiscal year 2018. These include the following beamlines:

- FIS/MET – Frontier IR Spectroscopy/Magneto, Ellipsometric and Time-Resolved IR
- CMS – Complex Materials Scattering
- QAS – Quick X-ray Absorption and Scattering
- TES – Tender Energy X-ray Absorption Spectroscopy
- XFM – X-ray Fluorescence Microprobe

In addition, the NSLS-II project provided affordances for additional stations on the base scope beamlines that will provide independently operating beamlines including:

- PDF – Pair Distribution Function scattering (formerly XPD2)
- CSX2 – Coherent Soft X-ray scattering station 2

The NEXT MIE project also provided the detailed design for a beamline that will not be executed within the NEXT project scope:

- FXI – Full-field X-ray Imaging

Additional projects, including those from NxtGen which were suspended may be added to the portfolio as strategic needs and NSLS-II operations resources permit. It should be noted that the BNL Associate Laboratory Director (ALD) for Business Services has approved the use of an extraordinary construction rate overhead of 10.5% for the original NxtGen beamlines, which is a substantial support for the portfolio from the laboratory and a significant cost benefit for NSLS-II operations.

5.i Completed BDN Engagements

a. CMS – Complex Materials Scattering

The Complex Materials Scattering (CMS) beamline will serve the broad materials science community, providing them with critical tools to probe the structural order in next-generation hierarchical, multi-component assemblies. This community has a diverse set of scientific interests: soft materials, porous networks, nanomaterials, functional materials, and more. CMS targets particular emerging thrusts: rational materials design, which requires understanding of material assembly at multiple length-scales; and non-equilibrium physics, which is critically important to understand process-dependent structure formation as well as to engineer new complex materials.

The CMS beamline construction was completed and ready for commissioning on August 10, 2016, and took first light on September 26, 2016. The cost performance was quite good, so funds were made available for scope enhancements, which included additional Data Acquisition, Management and Analysis (DAMA) work and the procurement of a Pilatus 2M detector. As of this report, only delivery of the detector remains incomplete (anticipated in August 2017).

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline	310					310
Baseline		1,219	3,738	611		5,568
BDN Management		175	175	200		550
CMS Baseline total		1,394	3,913	811		6,118
At Year Budget	310	1,394	3,913	811		6,428

Table 5.i.a.1: CMS Cost and Schedule at Completion

b. TES – Tender Energy X-ray Absorption Spectroscopy

The scientific mission of TES is the application of tender-energy spatially resolved EXAFS to studies of multi-scale heterogeneous and dynamic systems. It focuses on core DOE:BES research in energy and climate, with strong Partner User programs extending from this core into studies of geological and extraterrestrial materials, plus a broad-based and multidisciplinary user program. TES will be the only facility in the United States, and among only a few in the world, that will provide rapid, mm to µm beam X-ray absorption spectroscopy (XAS) capabilities over an energy range (1.2-8 keV) that covers unique edges of >25 elements critically important to human society and industry.

The TES beamline construction was completed and ready for commissioning on August 10, 2016, and took first light on September 28, 2016. The cost performance was quite good, so funds were made available for scope enhancements, which included additional DAMA work and the procurement of a new Canberra Germanium detector. As of this report, only delivery of the detector remains incomplete (anticipated in August 2017).

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline	310					310
Baseline		962	3,294	-67		4,189
BDN Management		175	175	200		550
TES Baseline total		1,864	1,984	133		4,739
At Year Budget	310	1,864	1,984	133		5,049

Table 5.i.a.2: TES Cost and Schedule at Completion

c. CSX-2 – Coherent Soft X-ray scattering station 2

The CSX-2 project added canting and phasing capabilities in the storage ring and an ambient pressure photoelectron spectroscopy endstation to the CSX-2 branch beamline. The Ambient Pressure Photoelectron Spectroscopy (AP-PES) endstation allows for surface chemical analysis via core-level photoelectron spectroscopy (including XPS and XAS) at gas pressures up to ~ 10 Torr and sample temperatures up to 500 °C. Applications include in-operando studies of surface chemistry, catalysis, and energy storage processes.

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline						
Baseline		53	175			228
BDN		175	175			350
CSX2		228	350			
At Year		228	350			578

Table 5.i.a.3: CSX-2 Cost and Schedule at Completion

Status

The AP-PES end station is installed and in General User Operations. The canting and phasing magnets were produced, installed, and commissioned. They have been in routine operation since mid FY2016 allowing independent simultaneous operation of the CSX1 and CSX2 beamlines.

5.ii Ongoing BDN Engagements

a. FIS/MET – Frontier IR Spectroscopy/Magneto, Ellipsometric and Time-Resolved IR

The Magnetospectroscopy, Ellipsomety & Time-Resolved Spectroscopy plus Frontier Infrared Spectroscopy (MET+FIS) beamlines will serve both the materials science and extreme conditions communities, providing them with the unique combination of high-brightness and pulsed THz, infrared & visible light for probing the electronic properties and dynamics in novel materials such as complex oxides and pnictides, nanomaterials, meta-materials and light harvesting systems (including photoconductivity spectroscopy), as well as the electronic and lattice dynamics in materials under conditions of extreme pressure, temperature and magnetic fields. The community spans condensed matter physics and materials science as well as geosciences.

MET+FIS complements other synchrotron-based techniques such as angle-resolved photoemission spectroscopy (ARPES) and inelastic x-ray scattering (IXS), providing bulk sensitivity to electronic structure with much higher energy resolution (potential for 1 meV) and to lower energies (to 250 meV).

MET+FIS will provide the following capabilities:

1) A wide energy range as required for extracting intrinsic optical response functions, reaching to from 250 meV to nearly 5 eV.
2) Optical systems for focusing the light into Diamond Anvil Cells (DACs) for reaching pressures of ~250 GPa as well as onto small samples.
3) Ellipsometry to directly extract optical constants with sensitivity to both electric and magnetic response (*e* and *m* independently).
4) Samples in magnetic fields to 10T and temperatures down to 1.5K.
5) Laser systems for photoexciting materials (pump-probe dynamics) and heating samples to extreme temperatures.
6) Photoconductivity capability from ~5 Hz up to 1 GHz

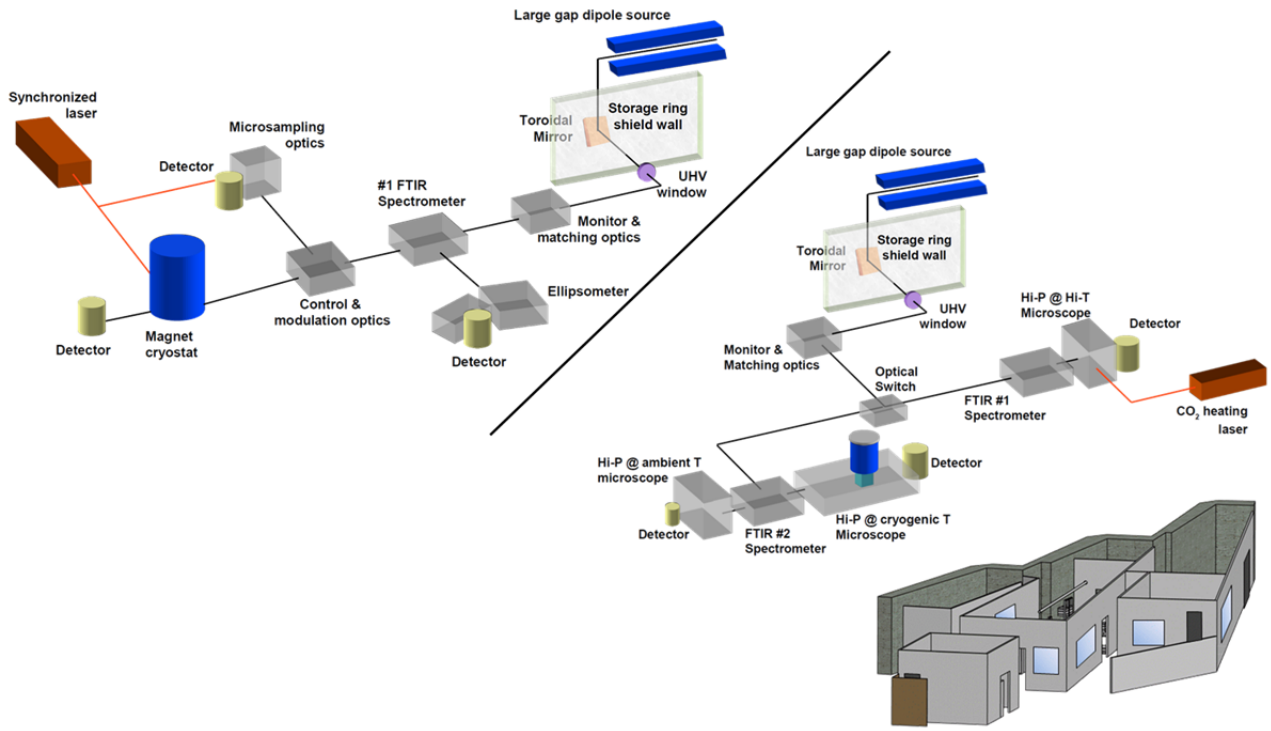

Figure 5.ii.a.1: FIS/MET Beamline Suite

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline	310					310
Baseline		433	461	2,376	1,302	4,572
BDN Management		175	175	228	200	778
FIS/MET Baseline		608	1,735	2,604	1502	5,305
At Year Budget	310	608	1,735	2,604	1.502	5,660

Table 5.ii.a.1: FIS/MET Cost Profile and Schedule

Status

FIS/MET Cabin construction is nearly complete as of this writing and beneficial occupancy of the cabins is expected in June 2017. The storage ring chamber and extraction system is under fabrication and is expected to be installed in December 2017. Completion of the beamline is anticipated for May 2018.

b. QAS – Quick X-ray Absorption and Scattering

The QAS beamline will be a flagship beamline for the Chemical and Energy Sciences (CES) community. The CES community includes scientists from academia, national laboratories and industry who work in catalysis, electrochemistry and energy conversion/storage fields. The key scientific drivers these groups share are: the atomistic real-time understanding of the mechanism of chemical reactions and catalyst deactivation, the design of new or more efficient chemical processes, the more efficient design of high-activity, high-selectivity, and low-cost catalysts, development of renewable energy conversion technologies, storage of energy products, and portable devices for energy delivery.

The main mission of the QAS beamline is to provide tools required for the studies of multiple scales of spatial and temporal metrics *in situ* and *in operando*, and measure fast kinetics (with 10ms time resolution) of working catalysts. The QAS beamline will be used for studies of the large class of model and real systems undergoing real-time chemical and physical transformations, including those with characteristic times of the order of 100 ms or less. Research at the QAS beamline will include:

- *in situ*, time-resolved or potential-resolved studies of chemical transformations with coexistence of reactants, intermediates, and products. In catalysis science, such capability is needed for characterizing the structure of catalysts in heterogeneous reactor compartments. For the R&D of fuel cells, it will be used for studies of the mechanism of ionic conductivity
- *in situ* studies of the mechanisms of catalyst activation, de-activation, activity and selectivity.
- *In situ* and *operando* studies of size, shape, structure and morphology of metal nanocatalysts and their change in the course of catalytic reaction

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline	310					310
Baseline		1,829	907	2,750	110	5,596
BDN Management		175	175	228	200	778
QAS Baseline total		2,004	1,082	2,978	310	6,374
At Year Budget	310	2,004	1,082	2,978	310	6,684

Table 5.ii.b.1: QAS Cost Profile and Schedule

Status

QAS is nearing completion with the hutches and utilities in place. The 3PW source and frontend have now been installed and PDS installation is underway. This beamline is planned to undertake its Instrument Readiness Review in August of 2017.

c. XFM – X-ray Fluorescence Microprobe

XFM is an optimized three-pole wiggler beamline for the characterization of materials in an "as-is" state that are chemically heterogeneous at the micrometer scale via synchrotron induced X-ray fluorescence. XFM includes instrumentation for microbeam X-ray fluorescence (μXRF), diffraction (μXRD) and fluorescence computed microtomography (FCMT) . However, it is optimized to provide users state-of-the–art microfocused Extended X-ray Absorption Fine Structure (μEXAFS) spectroscopy between 4 to 20 keV. XFM will trade-off beam size and flux for sample configuration flexibility. This includes more readily achievable stability constraints for spectroscopies (μEXAFS), accommodating large sample sizes (up to meters), and provisions for customized environmental chambers.

The beamline optical system will include a monochromator and two independent sets of achromatic microfocusing optics (KB mirrors), capable of operation from 3.8 to 27 keV.

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline	310					310
Baseline		1,006	2,054	3,486	116	6,662
BDN Management		175	175	228	200	778
XFM Baseline total		1,181	2,229	3,714	316	7,440
At Year Budget	310	1,181	2,229	3,714	316	7,750

Table 5.ii.c.1: XFM Cost Profile and Schedule

Status

XFM, is nearing completion with the hutches and utilities in place. The 3PW source and frontend have now been installed. The monochromator Factory Acceptance Test (FAT) is scheduled for May 2017 and other elements of the PDS installation are underway. This beamline is planned to undertake it Instrument Readiness Review in August of 2017.

d. PDF – Pair Distribution Function (formerly XPD2)

Next generation complex materials lies at the heart of the solutions to many of society's most pressing problems such as sustainable energy, environmental remediation and health. Properties of most of these materials are governed by nanoscale structural fluctuations, which are believed to originate from the synergy of internal competing forces. The knowledge of structure-property relationship is essential to optimize and manipulate the properties of these materials. The atomic Pair Distribution Function (PDF) technique is a powerful technique, which can be used to study the crystal structure of complex materials on different length-scales.

The PDF beamline will be utilized for the studies of nanoscale structural fluctuations in complex materials, such as, superconductors, multiferroics, thermoelectrics, catalysts, and functional nanomaterials. The high flux and high-throughput data acquisition capabilities available will enable *in-operando* studies of materials under real working conditions. The beamline will also offer complementary small angle X-ray scattering (SAXS) and medium resolution wide angle X-ray scattering (WAXS) capabilities to its diverse user community. A variety of sample environments including low and high temperature equipment, electric and magnetic fields, and chemical reaction cells will be available at the beamline. In addition, the beamline will have provision to accommodate custom-made sample environments from the user community. It will operate at 4 different X-ray energies, 39 keV, 64 keV, 75 keV and 117 keV.

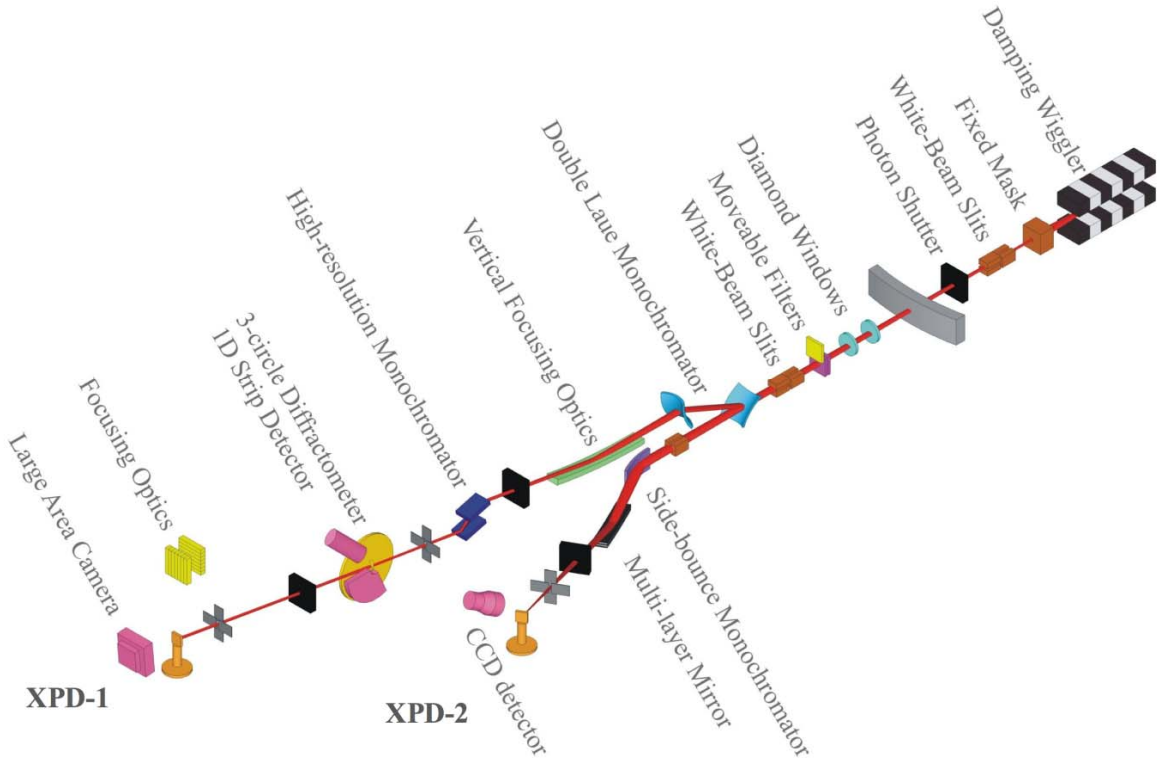

Figure 5.ii.d.1: Schematic beamline layout of section 28-1D. XPD-1 is presently in operation as the XPD beamline. XPD-2 is the PDF beamline presently under construction

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline						
Baseline		438	584	3,307	367	4,697
BDN Management		175	175	228	200	778
XPD-2 Baseline		613	759	3,535	567	5,475
At Year Budget		613	759	3,535	567	5,475

Table 5.ii.d.1: PDF (formerly known as XPD-2) Cost Profile and Schedule

Status

The PDF Laue Monochromator mechanics have been installed. Installation of the crystals awaits completion of the rest of the beamline. The Vertical Focusing mirror has been delivered, the Beam Transport System FDR was recently completed and the PDR for the gas handling system has been completed. Various endstation components are also in fabrication. Presently the IRR for PDF is planned for January 2018. This is somewhat off of the technically limited schedule, but the delay allows for the least possible disruption of the very active PDF beamline which uses the same wiggler as its source.

e. FXI – Full field X-ray Imaging

The Full field X-ray Imaging (FXI) beam line will serve a wide range of scientific disciplines, providing them with world-class nano-imaging capabilities using the Transmission X-ray Microscope (TXM). At FXI, it will be possible to acquire a complete 3D data set with 30 nm spatial resolution in less than 1 minute. This opens the possibility of *in-situ* and *in-operando* studies such as real-time cycling of energy storage devices and materials processing. In addition, the nano-XANES capability will enable measurements of chemical states in 3D. FXI will operate in the 5-11 keV range.

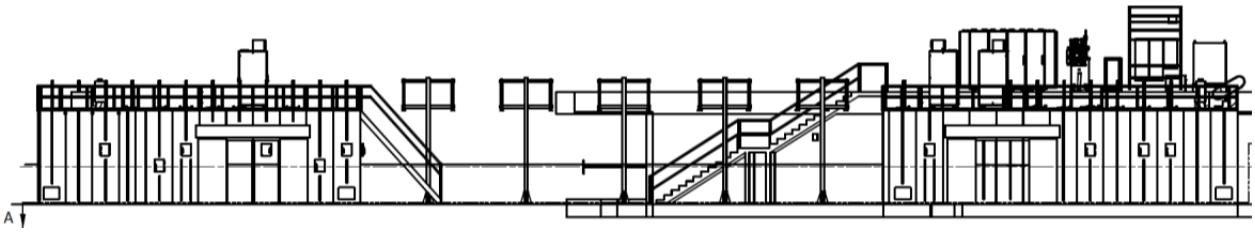

Figure 5.ii.e.1: FXI Beamline Elevation View

[$K]	FY14	FY15	FY16	FY17	FY18	Total
Pre-Baseline						
Baseline		293	1,134	5,915	298	7,642
BDN Management		175	175	228	200	778
FXI Baseline total		468	1,309	6,141	498	8,420
At Year Budget		468	1,309	6,141	498	8,420

Table 5.ii.e.1: FXI Cost Profile and Schedule

Status

The mechanics for the FXI PDS have been installed and the beamline is awaiting delivery of the mirrors. The FAT for the mirrors is anticipated in May 2017. New components for the TXM have been procured and installation is underway. A September 2017 IRR is currently planned for the beamline.

6. NSLS-II Partner Beamlines (NPB) project portfolio

The NPB portfolio is managed by Andy Broadbent. Its scope comprises beamline projects substantially funded by Partner organizations, with some smaller funding normally provided by NSLS-II operations. Each beamline is considered to be a separate project; these can start and finish asynchronously, and so each has its own Project Management Plan (PMP) which outlines the roles and responsibilities, as well as the funding obligations for the Partners. Generally, the NSLS-II contribution is limited to Portfolio Management oversight and activities "fundamental to NSLS-II" which includes provision of design and interface information, safety oversight and review, archiving of "as-built" drawings and other documentation, as well as the Personnel Protection System (PPS).
Cost planning is performed in conjunction with the Partner teams; three categories of funding exist, as follows:

- Activities funded and performed by BNL;
- Activities funded by the Partners, and performed by BNL (this typically includes the infrastructure);
- Activities funded and performed by the Partner team (this is flexible, and the Partners may procure significant hardware through BNL, or directly, at their discretion).

The coding for these categories is included in the P6 schedules, allowing easy sorting and filtering etc.

Currently a set of five beamlines is included in the NPB portfolio including;

- 7.01. XFP – X-ray Footprinting
- 7.02. SST1 – Spectroscopy, Soft and Tender 1

- 7.02. SST2 – Spectroscopy, Soft and Tender 2
- 7.03. BMM – Beamline for Materials Measurement
- 7.04. NYX – New York Structural Biology Center Crystallography Beamline.

In addition there is a separate WBS, 7.09 for the Portfolio Management.

It should be noted that the BNL Associate Laboratory Director for Business Services has approved the use of an extraordinary construction rate overhead of 10.5% for this activity, which is a substantial support for the portfolio.

6.i Completed NPB Engagements

a. XFP – X-ray Foot Printing

The beamline was built in Partnership with Case Western Reserve University's Case Center for Synchrotron Biosciences. The XFP beamline (X-ray Footprinting for *In Vitro* and *In Vivo* Structural Studies of Biological Macromolecules) is dedicated to solution state studies of biological macromolecular structure and dynamics.

The NSLS-II three-pole wiggler (3PW) source, focused onto the sample via a toroidal mirror inside the front end of the beamline provides unmatched "pink-beam" flux density for X-ray synchrotron footprinting samples. Vertical focusing of the mirror coupled with multiple sample locations available along the beam provides flexibility in beam size in the experimental endstation from 100s of microns to a few millimeters in each dimension to accommodate variable sample conditions. Temperature and humidity is controllable in the sample environment, and a preparation area for operations of critical timing to the experiment will be located proximal to the experimental endstation.

The unique capabilities of the XFP beamline will drive novel and challenging footprinting experiments including characterization of large macromolecular complexes in solution, membrane protein structural analysis, *in vivo* studies of macromolecular structure, and also enable time-resolved studies limited by mixing times rather than exposure times. The XFP beamline will represent a unique international resource for X-ray synchrotron footprinting, enabling powerful structural biology studies that are impossible with existing technology.

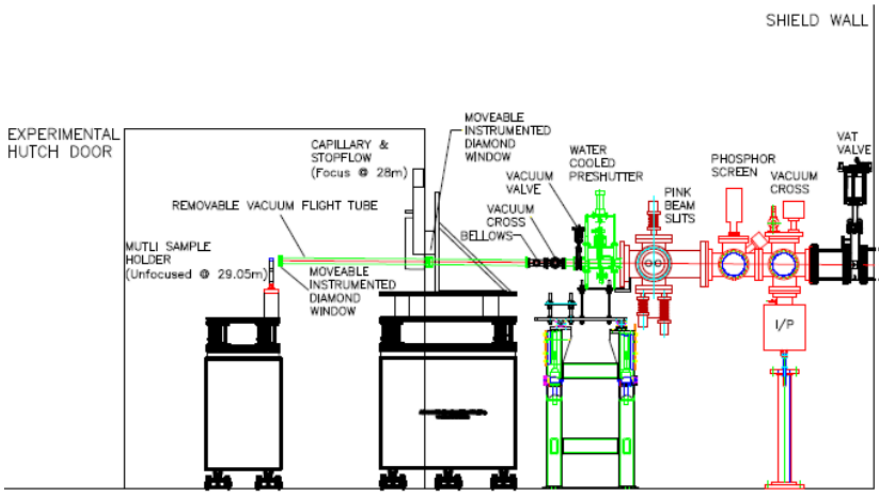

Figure 6.i.a.1: XFP End-Station Elevation

Figure 6.i.a.2: XFP Beamline Plan View

XFP Beamline Cost (excluding portion of Portfolio Management) and Schedule

Work Performed by:	Work Funded by:	FY14	FY15	FY16	FY17	Total
BNL	BNL		$192,819	$483,118	$15,601	$691,538
BNL	OFW		$708,350	$1,290,742	$374	$1,999,466
CWRU	CWRU	$74,197	$634,679	$151,805	$0	$860,680
Grand Total		**$74,197**	**$1,535,848**	**$1,925,665**	**$15,975**	**$3,551,684**

Table 6.i.a.1: XFP Cost and Schedule with costs broken out by origin of funds and which institution carries out the work. Costs for portfolio management are excluded from the table.

Status

The XFP beamline construction was completed in 2016 with the IRR on June 28-29, 2016 and first light on July 10, 2016. A user program is under development, and an addition to the beamline, called XAS for performing X-ray Absorption Spectroscopy on samples of biological interests has now started, with modest support from the NPB portfolio.

b. NYX – New York Structural Biology Center Microdiffraction Beamline

The NYX Microdiffraction Beamline is being built in partnership with the New York Structural Biology Center (NYSBC) and aims to provide scientists from NYSBC and General Users with convenient access to x-rays from NSLS-II for macromolecular crystallography. This beamline has the scientific objective of providing a state-of-the-art source for a wide spectrum of crystallographic experiments and a cutting-edge source with exceptional energy resolution for optimized anomalous diffraction experiments.

Funding for NYX is in place from the National Science Foundation, including matching funds from NYSBC and the New York State Office of Science, Technology and Academic Research (NYSTAR), and from the Army Research Office (ARO) of the Department of Defense (DoD).

The beamline design features several innovations giving it best-in-class performance. These include a novel monochromator design for providing exceptional energy resolution in order to assure maximal anomalous scattering signals from sharp resonant features. NYX also includes a novel pixel array detector, co-developed by the Area Detector Systems Corporation and NYSBC, to match performance requirements for detector speed and dynamic range. The beamline is designed throughout to be a stable and versatile resource for macromolecular crystallography.

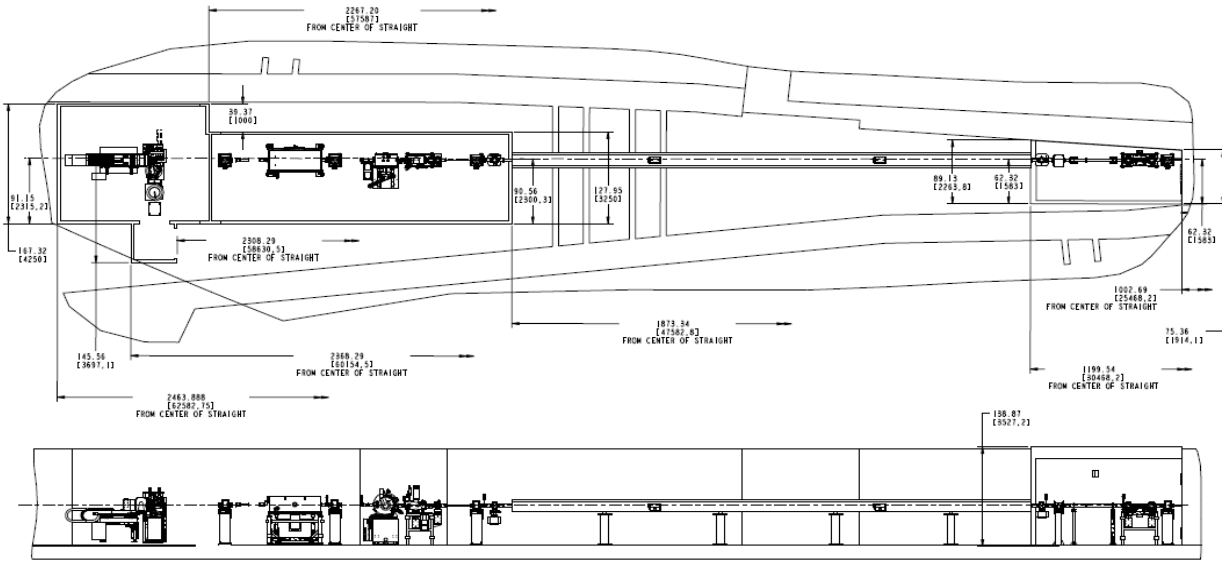

Figure 6.1.b.1: NYX Beamline Layout, plan view (top), side view (bottom)

NYX Beamline Cost (excluding portion of Portfolio Management) and Schedule

Work Performed by:	Work Funded by:	FY15	FY16	FY17	Total
BNL	BNL	$178,696	$1,435,573	$162,109	$1,776,378
BNL	OFW	$,50,527	$1,521,994	$408,198	$1,980,719
NYX	NYX	$10,727,562	$2,105,472	$118,424	$12951458
Grand Total		**$10,956,786**	**$5,063,038**	**$688,732**	**$16,708,555**

Table 6.1.b.1: NYX Cost and Schedule with costs broken out by origin of funds and which institution carries out the work. Costs for portfolio management are excluded from the table.

Status

Installation of the beamline was completed with a successful IRR on November 8 & 9 of 2016 and first light on November 2017, 2016. As of this writing, technical commissioning of the beamline sponsored by NYSBC is underway.

6.ii Ongoing NPB Engagements

a. SST1&2 – Spectroscopy Soft and Tender branches 1&2

The SST 1&2 beamlines are being built in partnership with the National Institute of Standards and Technology – Materials Measurement Laboratory. They make use of the fact that Synchrotron based X-ray Photoelectron Spectroscopy (XPS) and Near Edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy are complementary techniques, probing occupied and unoccupied density of states respectively. The ability to perform both measurements on the same sample achieves a complete, non-destructive, depth selective measurement of electronic structure, chemistry, and bond orientation.

NIST is building a pair of spectroscopy beamlines based on two canted undulator sources, one for soft x-rays (100 eV to 2.2 keV) and one for tender x-rays (1 keV to 7.5 keV). The beamlines will have a total of 6 unique world class NEXAFS/XPS experimental stations (2 full field microscopes, 2 automated high-throughput, and 2 insitu high pressure); three will be served by the soft x-ray undulator and three by the tender x-ray undulator, thus a variety of soft and tender spectroscopy experiments can be accomplished simultaneously in this beamline complex. Two of the experimental stations (high-throughput XPS/NEXAFS and the XPS microscope) can utilize the soft and tender X-ray undulators (sequentially or even simultaneously) enabling a continuous selection of X-rays from 100 eV to 7.5 keV (at a common focal point) in a single experiment (this is a unique capability, enhancing depth selectivity in XPS; i.e. in Hard X-ray Photoelectron Spectroscopy - HAXPES).

Enabled by the world class brightness of the NIST NSLS-II canted undulator beamline pair, NIST has pioneered two new and unique (large depth of field for practical materials) magnetic projection microscopes pushing the state-of-the-art in synchrotron XPS and NEXAFS spectroscopy full field imaging measurement science. (1) XPS microscope; combines nanometer scale spatial resolution with chemical and electronic state specificity and full three-dimensional mapping of the structure of nanomaterials and nanodevices at all points within their volume. (2) Large Area Imaging NEXAFS Microscope for high efficiency, highly parallel spectroscopic chemical and orientation maps of gradient samples, combinatorial arrays (e.g. 1000s of compositional samples at a time), and device arrays up to 4 cm^2 with simultaneous micron scale resolution.

SST 1&2 Beamline Cost (excluding portion of Portfolio Management) and Schedule

Work Performed by:	Work Funded by:	FY15	FY16	FY17	FY18	Total
BNL	BNL	$355,572	$437,331	$588,592	$28,818	$1,410,313
BNL	OFW	$2,132,820	$1,815279	$3,088,371	$36,453	$7,072,923
NIST	NIST	$18,529883	$5,868,316	$905,714	$993,311	26,297,225
Grand Total		**$21,018,275**	**$8,120,926**	**$,4,582,677**	**$1,058,582**	**$34,780,461**

Table 6.ii.a.1: SST 1&2 Cost and Schedule with costs broken out by origin of funds and which institution carries out the work. Costs for portfolio management are excluded from the table.

Status

The SST beamline will utilize two undulators in a canted straight. The first of these undulators, an ESRF U42, has been installed in the storage ring. The second undulator is an EPU60 which was previously used at SRC is being refurbished and will be installed in the summer of 2017. Beamline PDS installation is continuing with modifications being performed in the field on equipment previously procured by NIST. The Beamlines are planned to have a split IRR with the ID/FE undergoing their IRR in October 2017, and the final beamline IRR in January.

b. BMM – Beamline for Materials Measurements

NIST is also constructing an X-ray absorption fine structure beamline at NSLS-II using a three-pole wiggler source. The beamline will take advantage of the superior beam characteristics of the NSLS-II source for high resolution X-ray absorption spectroscopy (XAS) measurements. The beamline will also add new X-ray diffraction (XRD) capabilities to complement NIST's existing and planned XAS program.

X-ray optics will be designed to provide either focused or collimated X-rays at the sample, for both high resolution XAS and diffraction experiments. The X-ray diffraction end station will be equipped to take advantage of the scanning capabilities of the beamline, adding glancing

incidence XAS and XAS at constant q (reflectivity XAS and diffraction anomalous fine structure (DAFS)) to NIST's many other spectroscopic tools for materials science study. Polarization dependent XAFS measurements will also benefit from the high precision eight-circle goniometer and its ability to accurately and quickly position samples relative to the X-ray beam.

This beamline will provide high-quality, high-throughput XAS for advanced sample characterization. XAS users will also have access to XRD for sample characterization. XAS and XRD are complimentary materials science probes. XAS measures local (short range) atomic structure while diffraction is more sensitive to a sample's long range order. By offering these combined and complementary measurement capabilities along with a variety of in situ sample environments, NIST's beamline will serve a broad range of structural characterization problems in materials science, ranging from the study of bulk mixed phases to epitaxy and strain state of thin films.

BMM Beamline Cost (excluding portion of Portfolio Management) and Schedule

Work Performed by:	Work Funded by:	FY15	FY16	FY17	Total
BNL	BNL	$40,989	$48,940	$340,614	$430,542
	OFW	$861	$1,528,111	$1,112,174	$2,641,147
NIST	NIST	$3,039,753	$1,470,093	$958,042	$5,467,889
Grand Total		**$3,081,603**	**$3,047,144**	**$2,410,830**	**$8,539,578**

Table 6.ii.b.1: BMM Cost and Schedule with costs broken out by origin of funds and which institution carries out the work. Costs for portfolio management are excluded from the table.

Status

The Frontend and 3PW source have now been installed and the ID/FE IRR is planned for June 1st, 2017. Final vendor installation of PDS equipment is underway and the beamline IRR is scheduled for July 2017.

c. Portfolio Management

The Portfolio Management costs are apportioned equally across the individual beamlines listed above, for the duration of each individual beamline project.

Work Performed by:	Work Funded by:	FY15	FY16	FY17	FY18	Total
BNL	BNL	$491,447	$967,088	$584,466	$105,785	$2,148,785
Grand Total		**$491,447**	**$967,088**	**$584,466**	**$105,785**	**$2,148,785**

Table 6.ii.c.1: Portfolio Management Costs by Fiscal Year

d. HEX –High energy Engineering X-ray scattering

Recently authorized by the New York State Energy Research and Development Authority (NYSERDA) board, the HEX beamline will be constructed as a partner engagement in the NPB portfolio. In this particular case, BNL is helping to guide the formation of the partner group.

Paid for by the $25 M contract with NYSERDA, BNL will design and construct a superconducting wiggler-based high energy x-ray beamline on the NSLS-II storage ring. The beamline will have capabilities which are unique in the United States, and world-leading for the *in-situ* and *in-operando* study of energy materials. The beamline is designed to be flexible and expandable, with affordances for up to 3 branch lines from the same SCW source. The core facility to be constructed adds high energy imaging and diffraction techniques to the NSLS-II suite of capabilities. It provides high x-ray energies up to 150 keV for phase contrast x-ray imaging in planar and CT modes. The resolution of about 1 microns combined with a field of view of 100 mm is suitable for most industrial batteries. The ability of phase contrast mechanisms, such as Diffraction Enhanced Imaging, to provide information on micro-structure using extinction contrast provides a new way for studying batteries.

As the community grows and requires more access to high energy light, the affordances built into the HEX project would allow simultaneous operation of multiple additional high energy x-ray techniques. These would however require additional funding which has not yet been identified.

The Key Performance Metrics for the engagement were established in the statement of work and are summarized in the table below:

Key Performance Metric	Objective	Objective Measure
Beamline Design	Flexible Hard X-ray beamline design for one functional branch line with affordances for a total of three branch lines	Fully documented in Final Design Review
SCW Source	Capable of producing photons of at least 150 keV	Analysis of measured parameters of the final SCW
Photon Delivery System	Capable of delivering monochromatic or white (non-monochromatic) x-ray beam	Successful completion of the IRR (Instrument Readiness Review)
Satellite End Station	At least 3000 GSF building housing integrated experimental end station enclosures (Hutches)	Evaluation of the completed structure and successful completion of the BORE (Beneficial Occupancy Review Evaluation)

Table 6.ii.d.1: Key Performance Metrics for the HEX Construction Project

HEX Beamline Cost Plan and Schedule

Work Performed by:	Work Funded by:	FY17	FY18	FY19	FY20	FY21	FY22	Total
BNL	BNL	$355,980	$841,360	$1,086,102	$1,142,455	$1,179,183	$388,129	$4,993,209
BNL	NYS	$346,430	$873,253	$5,835,200	$10,972,994	$5,382,762	$1,151,353	$24,562,029
Grand Total		**$702,410**	**$1,714,613**	**$6,921,302**	**$,12,115,449**	**$6,561,945**	**$1,539,482**	**$29,555,238**

Table 6.ii.d.2: HEX Cost and Schedule with costs broken out by origin of funds and which institution carries out the work. Costs for portfolio management are excluded from the table.

Status

The HEX Beamline was approved by the NYSERDA board at the end of April. The contract is currently being developed and the first funding is expected soon. A Conceptual Design Review (CDR) is anticipated for July 2017 with a Preliminary Design Review notionally scheduled for December 2017. A key make or buy decision for the superconducting wiggler is anticipated for April 2018. The project is anticipated as a 5 year engagement, with a target for the IRR in February of 2022.

7. Instrument Execution Plan Development (IEPD)

The Instrument Execution Plan Development (IEPD) Task Force was convened in May 2016 to develop preliminary plans for the delivery of five distinct instrument "engagements." These were derived from an extended, community-driven proposal process that included community workshops, pre-proposals, and a down-selection to solicited Beamline Development Proposals (BDPs) that were then externally reviewed and presented to our Science Advisory Committee. The beamlines were chosen based on their scientific merit, the extent to which they complemented and extended the existing capabilities at NSLS-II and utilized the unique properties of the NSLS-II source, and importantly, user community demand. This process resulted in six approved NSLS-II beamline development proposals. The taskforce was then charged to:

- clarify the scope of each instrument engagement that could be constructed
- evaluate an R&D program that might be needed to deliver the intended scope
- develop initial cost estimates (ranges) for the described scope (including R&D program)
- propose an initial technically limited schedule

The engagements were each evaluated in this context with a view to drawing high level conclusions to guide further work.

SMF/ARI: (Soft X-ray Spectro-Microscopy Facility/ARPES and RIXS Nano-Imaging)

These instruments represent several beyond state-of-the-art soft x-ray microscopy endstations, combined in a single sector to develop complementary toolsets for nano- and meso-scale imaging. Specifically, ARI will fill a key gap in our understanding of the nanoscale origin of macroscopic (electrical, magnetic, thermodynamic and optical) properties of matter by developing spatially-resolved experimental techniques that measure near-Fermi-edge single particle and collective electronic excitations – measuring nanoRIXS and nanoARPES spectra in a unique, combined endstation. SMF will develop beyond state-of-the-art STXM and CryoSTXM imaging techniques for chemical imaging in real space. Both ARI and SMF will take advantage of the world-leading soft x-ray coherent flux of NSLS-II.

A suitable layout was needed that would accomplish the objectives of the separately-proposed SMF and ARI beamlines in a single sector. This was achieved by merging the proposed properties of the ARI beamline with those of the low energy branch of the SMF beamline, such that the same branch would meet the objectives of both. The design utilizes switchable white beam mirrors keyed to the requirements of each instrument. The proposed RIXS instrument will require R&D to establish performance limits.

CDI: (Bragg Coherent Diffraction Imaging)

The Bragg Coherent Diffraction Imaging (CDI) beamline will be a state-of-the-art beamline that takes full advantage of the world-leading coherent photon flux in the 6-15 keV energy range at

NSLS-II, and will enable cutting-edge research on structural evolution in a wide-range of materials systems under *in-situ* conditions. By taking advantage of the largely empty reciprocal space at large momentum transfers, CDI has the unique capability to single out materials of interest in highly complex systems, leading to imaging of defects, dislocations, and strain fields in single grains of heterogeneous materials with relatively high signal-to-noise ratios. Additional capabilities include Bragg ptychography to allow mapping single grains in polycrystalline and extended specimens, and time-resolved measurements for both reversible and naturally occurring processes.

To realize this beamline, the Task Force team developed and evaluated an implementation that could fit inside the experimental hall and meet the CDI objectives. This was achieved through a careful layout of the required optical elements, which simulations showed could deliver the required coherent beam properties. However, the Task Force pointed out that a longer version of the CDI beamline, placing the experimental station in a satellite building outside the experimental hall, could also deliver the required beam properties, perhaps more easily but at greater cost. This issue needs further study.

PLS: (Processing and Liquid Scattering)

The Processing and Liquid Scattering beamline will be a versatile x-ray scattering facility sharing a canted straight section at 12-ID. Its science mission is to support a world-class scientific program for *operando* studies of soft matter interfaces, especially polymer thin films during processing and liquid surfaces. This facility will operate independently in parallel with the Soft Matter Interfaces (SMI) beamline at 12-ID through the use of a canted undulator. The high flux and tight focus of the NSLS-II source will enable unprecedented time-resolved studies of soft matter specimens undergoing industrially-relevant formation, processing, additive manufacturing, as well as structural transformation, weathering, degradation, and aging. These studies will encompass polymers, liquids, liquid crystals, granular materials, gels, and biomolecular materials, all of which lack the three-dimensional crystallinity characteristic of conventional hard materials. The PLS beamline will play an important role in our strategic directions in emergent behavior from complexity and in *in-situ* and operando science.

The principal challenge for this engagement was to develop a sufficiently modular endstation design to address the range of proposed experimental techniques. This was achieved through separation of the elements of the endstation into distinct, independent units in which the components could be repositioned to suit particular experimental needs.

QIX: (Quick RIXS Beamline)

The quick resonant inelastic X-ray scattering (QIX) beamline will be a soft X-ray RIXS/XES beamline with best-in-class photon flux and throughput for investigation of static and dynamic behaviors of advanced energy materials in realistic conditions. This new instrument will have a resolving power of ~10,000 at 1000 eV in an energy range of 200 – 2000 eV, with a focused beam spot of 1 μm x 10 μm. Taking advantage of the NSLS-II spectral brightness in this energy range, this soft X-ray capability will enable very fast RIXS data acquisition on the level ~1 sec

for a 2D RIXS map over a few eV energy window, providing time-dependent (sec. to min.) snapshots of chemical, orbital, charge, & site-resolved electronic structures relevant to catalysis and chemical sciences and meeting the research needs of a strong and active spectroscopy user community.

For QIX, a layout was developed that would allow merging the instrument with the existing CSX-2 beamline. This was achieved by utilizing the upstream optical elements of the CSX-2 beamline for use by QIX and devising a means to pass the monochromatic beam through the existing CSX-2 endstations on to the QIX-specific optics and endstation farther downstream.

INF: (Infrared Near-Field Nanospectroscopy)

The infrared near-field nanospectroscopy (INF) beamline will be a new infrared beamline for nanospectroscopy and vibrational spectroscopy of materials central to current problems in condensed matter physics and chemical catalysis. Aperture-less near-field nanospectroscopy, based on synchrotron infrared light scattered from an atomic force microscope (AFM) tip, offers broadband spectroscopy of materials with better than 10 nm spatial resolution across the important range of wavelengths from 2 μm to 100 μm. This is the wavelength range that probes many intrinsic electronic and vibrational excitations. Applications of this novel method will include a wide range of studies in such areas as phase transitions and intrinsic inhomogeneities in Mott insulators, high T_c superconductors, magnetic and multiferroic domains in complex oxides and heterostructures, elementary excitations in low dimensional and plasmonic materials, spectroscopic and chemical catalysis of nanoparticle catalysts, and phonon vibrations in oxide nanoparticles or organic thin films.

For this beamline, a suitable layout of the INF endstations was needed that could meet the requirements of proximity to the CSX-2 beamline (one of whose endstations would also make use of a beam from INF) while satisfying ESH requirements for access and egress. This was achieved through careful placement of the INF endstations within the neighboring bending magnet sector floor space to CSX-2.

Cost and Schedule Estimates:

A common methodology was employed for developing cost and schedule estimates for each of these engagements. A shared basic WBS structure and dictionary was used to capture the work anticipated for development of the engagements. Some project management and support costs were excluded from the estimates since it was assumed that they would be captured separately within the portfolio which manages the execution of the engagements. This reflects the economies of scale that come from managing engagements in groups, but is an additional cost to be factored into the completion cost of an instrument. Common resource burdens and overheads were assumed across the engagements including the application of the extraordinary project overhead rate, which has yet to be granted. Indeed, it has become clear that it will be increasingly difficult going forward to obtain such exceptions to the conventional overhead rate structure. Technically limited schedules (i.e. executed as fast as possible) were planned in the estimates.

Other resource constraints, including staff levels and access to the storage ring for installation, as well as integration with ongoing work of the facility will likely extend these schedules.

The following table below summarizes the burdened cost and technically limited schedule estimates:

Engagement	**Cost [$K]**	**Duration [Yrs]**	**Notes**
SMF/ARI	30,896	4.3	Two beamlines merged in one sector. Includes R&D for the ARI spectrometers.
CDI	22,406	4.3	Costed based on endstation inside NSLS-II experimental hall. A satellite end station configuration will require separate evaluation.
PLS	10,485	3.5	Substantial infrastructure exists already at 12-ID.
QIX	9,191	3.5	Upstream portion of this beamline exists already at 23-ID-2.
INF	6,461	2.5	Two required new endstations are not commercially available yet with the necessary features.

Table 7.1: Burdened estimated cost for the 5 engagements discussed in the table above with technically limited duration for the schedules. There are several key assumptions in these estimates that may not be appropriate and these estimates should be regarded as very preliminary. Nevertheless, they serve as a basis for comparison between the engagements.

These estimates are very preliminary and should be regarded as an order of magnitude estimate, as well as a direct 'apples to apples' comparison of the possible construction costs for the proposed instruments. Full details, including an executive summary and background for the engagements, as well as the details behind the estimates are available in the full report of the task force, which is available on the review web site..

Status

Evaluation of the IEPD report and consultation with the SAC led to the decision by NSLS-II management to start the development of a baseline design for the B-CDI beamline. A position has been opened for the lead beamline scientist and interviews are under way as of this writing. The main task facing the lead scientist will be determining the proper optical configuration for the beamline. This will be factored into a revised cost and schedule estimate, with a target of preparing a baseline scope, cost and technically limited schedule which can be reviewed by the close of FY18.

Efforts are also underway for the other engagements both to refine open questions and to seek alternative means to fund them. At this time NSLS-II management believes that only one new state of the art insertion device beamline can be constructed entirely from the funds which can be provided by the NSLS-II facility operations budget.